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TO E. S. [illegible] FROM [illegible] DATE [illegible] 9-64

EXT 2882, 583

SUBJECT Thermionic and Thermoelectric Energy Conversion

This search was made as an updating of AI/LS 294, AI/LS 392, and LS 489.

The references of this search are arranged as follows:

I. GENERAL

A. Bibliographies
B. General articles, reviews, books
C. Conferences, etc.
D. Theory
E. Apparatus and measurement techniques

II. MATERIALS

A. Thermoelectric properties
B. Thermionic properties

III. POWER GENERATION

A. Thermoelectric converters
B. Thermionic converters
C. Miscellaneous thermal energy conversion devices

IV. THERMOELECTRIC COOLING

The references are arranged chronologically within each subject heading.

The following sources have been searched:

ASTIA TABS - October 1962 through December 1963

Astronautics Information Abstracts and Surveys - January through August, 1963

Applied Science and Technology Index (AS&TI) - 1962 through December 1963

Engineering Index (EI) - 1962 through January, 1964

Electrical Engineering Abstracts (EEA) - November 1962 through December 1963

Nuclear Science Abstracts (NSA) - January 1963 through January 30, 1964

Physics Abstracts (PA) - July 1962 through December 1963

JPL Library Additions Subject Printout - January through December 1963

References of a classified nature and references otherwise restricted in distribution and availability have been included in Supplement 1 to this search.

The following topics were searched in the aforementioned references:

ASTIA

auxiliary power systems
batteries
bibliographies
electric power production
generators
semiconductors
thermionics
thermoelectricity

AIA and AIS

SNAP
solar energy
solar power systems
nuclear energy
power supplies
thermionic converters
thermionic power systems
thermoelectric power systems
thermoelectric converters

ASTI

electric power
electrons,
  thermionic emission
isotopes
Peltier effect
Seebeck effect
solar batteries
solar power
space vehicles,
  auxiliary power
thermionics
thermocouples
thermoelectricity

EI

electricity, direct conversion
electric batteries, radioactive isotopes
magnetohydrodynamics
metals and alloys
nuclear energy
refrigeration, thermoelectric
rockets and missiles,
  auxiliary power systems
power generation, solar
satellites, power supplies
semiconductors, thermoelectric
space vehicles, power supplies
thermocouples
thermoelectricity

NSA

auxiliary power systems
bibliographies
electrical conversion
nuclear batteries
solar batteries
thermoelectric conversion
thermoelectric effect
semiconductors, thermoelectric
SNAP
radioisotopic power generators
thermionic cells
thermionic converters
power supply
plasma, thermionic converter
materials, thermoelectric
solar power

PA (sections scanned)

current electricity
nuclear power studies
nuclear radioactivity
solid state physics:
  electrical properties of solids
  thermoelectric properties
ion emission
plasma, electron emission

A. Bibliographies

1833 (AD-249100) POWER SUPPLIES. An ASTIA Report Bibliography. (Armed Services Technical Information Agency, Arlington, Va.). Jan. 1961. 313p.

References (about 1800) are included to unclassified reports in ASTIA's AD collection (1953 to present) on power supplies. Most of the references are related to power supplies for space research, but entries pertaining to more conventional applications and related topics such as space radiation are included. Information on requisition of the reports is also given. (D.C.W.) NSA 64

UNCLASSIFIED

110652 POWER SUPPLIES; an ASTIA Report Bibliography (U)
(Period covered: 1953-1960)
January 1961
Armed Services Technical
Information Agency
Report Bibliography

Secret
(ASTIA AD-321 100)

Fuel cells
Power systems, solar
Batteries
Power systems, nuclear
Power sources, electrochemical
Power systems, chemical
Generators, thermoelectric
Engines, gas generator
Bibliographies (power devices)

UNCLASSIFIED

93498 DIRECT ENERGY CONVERSION LITERATURE ABSTRACTS
September 1961
Navy Dept.
Naval Research Laboratory
Abstracts

Unclassified
(Bibliography-Issue 2)

This is the second in a series of bibliographies covering the literature on direct energy conversion. The material is divided into the following subjects: energy conversion, thermoelectricity, thermionic emission, photoelectric processes, magnetohydrodynamics, electrochemical processes, energy storage, energy sources, and regulation and control.

Bibliography -- Converters
Thermoelectric converters -- Bibliography
Thermionic converters -- Bibliography
Photoelectric cells -- Converters
Magnetohydrodynamic converters -- Bibliography
Converters -- Bibliography

UNCLASSIFIED

96468 DIRECT ENERGY CONVERSION LITERATURE ABSTRACTS
April 1962 Unclassified
Navy Dept. (Bibliography-Issue 3)
Naval Research Laboratory
Abstracts

This is the third in a series of bibliographies covering unclassified literature related to the direct conversion of energy. Subject coverage includes thermoelectricity, thermionic emission, photoelectric processes, magnetohydrodynamics, electrochemical processes, energy storage, and energy sources.

Bibliography
Energy
Thermionics

37004 (IITRI-1194-13) LITERATURE SURVEY ON WORLD ISOTOPE AND RADIATION TECHNOLOGY. Final Report, June 15, 1961 to June 14, 1962. J. W. Haffner (Illinois Inst. of Tech., Chicago. IIT Research Inst.). Contract AT(11-1)-578. 66p.

In order to study the uses and technology of radioisotopes in the countries of the world, with particular reference to the USA and USSR, a survey of the open literature appearing since 1955 was made. Papers or abstracts of papers were classified by country, year of publication, and subject matter. The subject material was divided into the following eight categories: industrial applications of radioisotopes; metallurgy research; geology, mining, and meteorology; radiochemistry research; physics research; radioisotope apparatus and techniques; food, botany, and agriculture; zoology and medicine. The survey was planned to include two phases. Phase I involved the direct comparison of radioisotope work in all fields in various countries as demonstrated at international conferences. Phase II was devoted to a more detailed study of work in the above fields using such literature sources as Nuclear Science Abstracts. In Phase II, the work of most countries in each category was analyzed by chronological growth rate, subcategory region of interest, and quality of the research being published. The main results of Phase II are presented in graphical and tabular form. The results and conclusions presented were based upon the literature examined in the course of this investigation. (auth) NSA '63

UNCLASSIFIED

110372 AUXILIARY POWER SOURCES IN SPACE: TECHNICAL DOCUMENTATION, VOLUME II OF III
July 30, 1962 Unclassified
North American Aviation, Inc. (Projects: SNAP)
Space and Information Systems Division
SID 62-708

This bibliographic search surveys the literature on Systems for Nuclear Auxiliary Power - SNAP - from 1957 to date, with special emphasis on space applications of these devices.

SNAP (Project)
Power systems, nuclear
Space power systems
Bibliographies (power systems)

Electron levels, electrochemical effects, and thermoelectricity. W. T. Scott. bibliog Am J Phys 30:727-37 O '62

Background and future of energy conversion. C. C. Furnas. bibliog Elec Eng 81:845-9 N '62

2

AS&TI '63

AD-293 856 Div. 7, 25
(TISTM/EJH) OTS price $3.50

Naval Research Lab., Washington, D. C.
DIRECT ENERGY CONVERSION LITERATURE ABSTRACTS.
Dec 62, 121p.
Unclassified report

DESCRIPTORS: *Thermoelectricity, *Thermionic emission, *Magnetohydrodynamics, *Power supplies, *Fuel cells, *Solar cells, *Bibliography, Photoelectric cells, Primary batteries, Nuclear power plants, Storage batteries, Auxiliary power plants, Biochemistry, Energy, Electrochemistry, Abstracting.

Contents:
Energy conversion (general information, bibliographies, patents)
Thermoelectricity (general information, theory, related phenomena, materials, design, applications)
Thermionic emission (general information, theory, electrode properties, plasma properties, design parameters, devices, systems)
Photoelectric process (photovoltaic, photoemissive, high energy processes)
Magnetohydrodynamics (general information, principles, plasma properties, devices)
Electrochemical processes (fuel cells, primary batteries)
Energy storage (general information, chemical)
Energy sources (chemical fuels, nuclear, solar collection and concentration)
Regulation and control

'63

UNCLASSIFIED

112751 DIRECT ENERGY CONVERSION LITERATURE ABSTRACTS
December 1962 Unclassified
Navy Dept.
Naval Research Laboratory
Abstracts

A collection of references from various sources is presented covering the current literature on thermoelectricity, thermionic emission, photoelectric processes, magnetohydrodynamics, electrochemical processes, energy storage, and energy sources.

Bibliographies (power devices)
Solar cells
Converters, thermionic
Converters, thermoelectric
Solar collectors
Power sources, nuclear
Energy conversion

11322 (NP-12429) DIRECT ENERGY CONVERSION LITERATURE ABSTRACTS. (Naval Research Lab., Washington, D. C.). Dec. 1962. 121p.

A collection of 735 references from various sources is presented covering the current literature on thermoelectricity, thermionic emission, photoelectric processes, magnetohydrodynamics, electrochemical processes, energy storage, and energy sources. (auth) NSA 63

21394 (ORNL-3300(vol. 3)) PUBLICATIONS, REPORTS, AND PAPERS FOR 1962 FROM OAK RIDGE NATIONAL LABORATORY. K. O. Johnsson and Ann S. Klein, eds. (Oak Ridge National Lab., Tenn.). Contract W-7405-eng-26. 248p.

The titles of written and oral scientific information originating at ORNL during 1962 are listed. The publications are listed by division with each list divided into 5 categories: books, journal articles, papers at professional meetings, reports, and theses. A key-word index and an author index are included. (M.C.G.) NSA '63

15413 (TID-3561(Rev. 3)) DIRECT ENERGY CONVERSION DEVICES AND SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP). A Literature Search. Sidney F. Lanier and Henry D. Raleigh (Division of Technical Information Extension, AEC). Jan. 1963. 63p.

A total of 553 references are listed on the SNAP program and related topics. The references were taken from Nuclear Science Abstracts to Dec. 31, 1962. The contents are arranged in sections on radioisotope-fueled units, reactor-fueled units, direct energy conversion, and general topics on nuclear auxiliary power. (J.R.D.) NSA '63

21392 (NP-12749) LIST OF PUBLICATIONS AVAILABLE TO THE PUBLIC. CUMULATION NO. 7, JANUARY–DECEMBER 1962. (United Kingdom Atomic Energy Authority. Research Group. Atomic Energy Research Establishment, Harwell, Berks, England). Mar. 1963. 108p.

References (1464) are given to reports, journals, books, and translations listed during 1962 on subjects of interest to nuclear science. Separate author and report number indexes are included. (P.C.H.) NSA '63

AD-409 902 Div. 7, 12, 1
(TISTA/PCR) OTS price $10.10

Aerospace Corp., Los Angeles, Calif.
APPLIED RESEARCH PROGRAMS ABSTRACT BULLETIN. FLIGHT VEHICLE POWER AND MATERIALS. ABSTRACTS 2-399 THROUGH 2-518, JAN-MAR 63, by K. B. Andrews, N. B. Crow, R. C. Evans, M. S. Hicks, E. Moore and others. Mar 63, 1v. Rept. no. TDR930 2701 01 TN1, v2, pt. I, no. 5
Contracts AF04 647 930 and AF04 695 169
DCAS TN61 3, vol. 2, pt. 1, no. 5
Unclassified report

Descriptors: (*Power supplies, Spaceborne), (*Auxiliary power plants, Spaceborne), Airborne, Indexes, Abstracts, Chemicals, Magnetohydrodynamics, Nuclear industrial applications, Solar cells, Solar panels, Thermionic converters, Thermoelectricity, Materials, Metallurgy, Refractory materials, Polymers, Composite materials, Magnetic materials, Fluids, Lubricants, Manufacturing methods, Processing, Batteries and components, Fuel cells, Nuclear power plants, Electric power production, Electric propulsion, Satellites (Artificial), Launch vehicles (Aerospace), Nuclear propulsion.

This Bulletin contains abstracts of the unclassified literature on the subject of Flight Vehicle Power. The following categories are: (1) Chemical Sources of Energy; (2) Magnetohydrodynamic Systems; (3) Mechanical Devices; (4) Nuclear Sources of Energy; (5) Solar Sources of Energy; (6) Thermionic Devices; (7) Thermoelectric Devices. Abstracts of selected references in the field of materials are also included. All abstracts are prepared from the original reports and are limited to those available within Aerospace Corporation. References '63

26946 (LAMS-2895) SELECTED BIBLIOGRAPHY OF PUBLICATIONS OF LASL RESEARCH 1957-1962. Barbara Hendry and Marjorie Johnson (Los Alamos Scientific Lab., N. Mex.). Apr. 17, 1963. Contract W-7405-eng-36. 368p.

All publications other than LA and LAMS reports that appeared during the years 1957-62 and that covered work done at the Los Alamos Scientific Laboratory are included in 2062 references. Entries are arranged first by year and then alphabetically by first author. Abstracts are separated from full papers and are arranged in a separate alphabet at the end of each year's listing. Entries are designated by numbers beginning with the last two figures of the year of publication; numbers for abstracts carry the letter A at the end. An addendum listing publications discovered after the main body of the bibliography had been prepared has entries designated with numbers beginning with Add-. They are arranged alphabetically by first author regardless of year of publication. An author index and listing by LADC number is given for all entries, including those in the addendum. A tabulation of the number of papers published in each journal appears in Appendix I. (N.W.R.) NSA '63

UNCLASSIFIED

113400 ELECTROCHEMICAL CONVERSION DEVICES: A REPORT BIBLIOGRAPHY
(Supplement to ASTIA AD-249 100)
Rice, Randall G. (Compiler)
April 1963
Armed Services Technical
Information Agency
Bibliography

Unclassified
(ASTIA AD-299 415)

In updating the ASTIA Power Supplies bibliography of January, 1961, the listed reports have been restricted to electrochemical conversion devices, as nearly as possible, with the emphasis on the arrangement of the references for display being on class of device rather than its applications. Because of its related interest, a section on thermoelectrics and thermoelectricity has been added to this bibliography. The entries in this bibliography represent reports in the ASTIA collection for the period of approximately January 1961 through 1962.

Bibliographies (power devices)
Batteries
Solar cells
Fuel cells
Thermoelectricity

UNCLASSIFIED

UNCLASSIFIED

117554 AUXILIARY POWER SYSTEMS FOR SPACECRAFT: AN ANNOTATED
BIBLIOGRAPHY (135 refs.)
(Period covered: 1962-1963)
Stromer, Peter R. (Compiler)
May 1963
Lockheed Aircraft Corp.
Missiles & Space Division
AF 04(695)-136
Bibliography

Unclassified
(R-8-55-63-4)
(SB-63-46)

Bibliographies (power divices)
Spacecraft power systems
Power sources, nuclear
Power sources, solar

26948 (TID-3717) INFORMAL LISTING OF BIBLIOGRAPHIES OF ATOMIC ENERGY LITERATURE. Bibliographies Issued or in Progress During the Period, April–May 1963. (Division of Technical Information Extension, AEC). 28p.

Bibliographies issued or in progress during the period April and May 1963 are listed. A list of 74 bibliographies issued and 73 bibliographies in preparation is given. A combined subject and author index is presented along with a report number index. The bibliographies are listed alphabetically according to AEC contractors or other agencies. Information covers all fields of atomic energy. (N.W.R.)

NSA '63

32482 (AD-408618) COMPOSITE MATERIALS: AN ANNOTATED BIBLIOGRAPHY. SUPPLEMENT I. Helen M. Abbott, comp. (Lockheed Missiles & Space Co., Sunnyvale, Calif.). June 1963. 53p. (SB-63-49)

Supplement to Lockheed Missiles & Space Co. Report SB-62-58.

An annotated bibliography containing 90 selected references pertaining to composite materials is presented. These references were selected as supplement material to a previous report; COMPOSITE MATERIALS: AN ANNOTATED BIBLIOGRAPHY, Helen M. Abbott, Lockheed Missiles & Space Company SB-62-58, February 1963. This search covered the period from September 1962 to June 1963. (auth)

NSA 63

819 (NP-13277) DIRECT ENERGY CONVERSION LITERATURE ABSTRACTS. (Naval Research Lab., Washington, D. C.). July 1963. 178p.

References and abstracts (1076) to U. S. and foreign unclassified literature on thermoelectricity, thermionic emission, photoelectric processes, magnetohydrodynamics, electrochemical processes, energy storage, and energy sources are compiled. Availability of the documents is indicated, and an author index is included. (D.C.W.)
NSA '64

UNCLASSIFIED

117229 DIRECT ENERGY CONVERSION LITERATURE ABSTRACTS (1,076 refs.)
July 1963 Unclassified
Navy Dept.
Office of Naval Research
Naval Research Laboratory
Abstracts-5

Energy conversion
Bibliographies (power devices)
Thermoelectricity
Thermionic emitters
Patents
Materials, thermoelectric
Converters, thermoelectric
Generators, thermoelectric
Thermocouples
Refrigeration
Temperature control systems
Electrodes
Photovoltaic devices
Semiconductor devices
Photoelectricity
Magnetohydrodynamics
Generators, MHD
Fuel cells, electrochemical
Fuel cells, biochemical
Electrochemistry
Power sources, electrochemical
Power sources, nuclear
Power sources, solar

UNCLASSIFIED

2572 (JUL-Bibl-1) THERMIONIK. EINE LITERATURZUSAMMENSTELLUNG. (Thermionics. A Literature Search). D. Wickmann (Kernforschungsanlage, Julich, Germany). Aug. 1963. 21p.

A collection of 239 references covering the period 1958 to July 1963 on thermionic cells is presented. The references are arranged in categories by subject and subcategories by year. (M.C.G.) NSA '64

38627 (TID-3719) BIBLIOGRAPHIES OF ATOMIC ENERGY LITERATURE. Issued or in Progress During the Period, August-September 1963. (Division of Technical Information Extension, AEC). 16p.

A total of 99 bibliographies are listed. A subject and author index is included. (D.L.C.) NSA '63

70,504 ENERGY CONVERSION SYSTEMS REFERENCE HANDBOOK
September 1960
Wright Air Development Division, Flight Accessories Lab., Wright-Patterson AFB, Ohio
WADD TR 60-699, Vol. I-XI

This document consists of eleven volumes pertaining to energy conversion systems. The authors, all from Electro-Optical Systems in Pasadena, are W. R. Menetrey, J. H. Fisher, D. H. McClelland, C. W. Stephens, R. Spies, J. Blair, J. D. Burns, W. Evans, J. Chrisney, A. Haire, L. Hays, R. Wall, D. Erway, and D. McDowell.

Volume I, General Systems Considerations, serves as an introduction to subsequent volumes dealing with specific areas of power system technology. Solar-Thermal Energy Sources discusses basic problems in the development of lightweight, highly efficient, solar concentrating mirrors for space power systems. Concentrator structural design classifications are presented and related to fabrication techniques, materials, and reflective surfacing methods. Volume III, Dynamic Thermal Converters, incorporates a detailed discussion of the two dynamic thermal converters which appear most useful in future power systems. Two static thermal converters, the thermoelectric generator and the thermionic emitter, are analyzed in Volume IV. The volume on Direct Solar Conversion describes in detail the performance characteristics of the photovoltaic converter when used to convert solar radiation directly to dc electrical energy. Volume VI deals with power systems which use chemical fuel as the energy source. Empirical and analytical equations are presented in Volume VII, and the performance of several types of heat exchangers is described.

Volumes are also devoted to each of the following subjects: Other Devices, Solar System Design, Reactor System Design, and Radioisotope System Design.

A complete detailed Table of Contents for the entire Energy Conversion Systems Reference Handbook is included in Volume I.

7756 THE DIRECT CONVERSION OF THERMAL ENERGY TO ELECTRICAL ENERGY. P.J.Nowacki and Z.Celiński.
Przeglad elektrotech. (Poland), Vol. 37, No. 3, 97-105 (March, 1961). In Polish.

A general review of recent research and development in the direct conversion of heat to electricity. The paper discusses the basic theory, problems and technology of: (1) thermoelectric generators with semiconductor thermal elements and radioactive isotopes as sources of heat; (2) thermionic convertors including vacuum diodes, Cs plasma diodes and magnetic triodes; (3) magnetohydrodynamic generators of open cycle and close cycle type and also plasma reactors. Whilst application of the low power thermoelectric generators maybe economically justified, the most promising concept is a combination of the classical system of generation with a direct conversion system which in the case of a nuclear power station may result in the increase of efficiency to about 0·5 - 0·6. The development of direct conversion generators of large outputs is hindered by lack of sources for producing heat of high enough temperature and lack of materials with the required electrical characteristics capable of withstanding these high temperatures. W.J.Grek

Survey of Power Sources, N.WHEELER Gen Elec Co—Light Military Electronics Dept—Advanced Electronics Center. Ithaca, NY, 1961 57 p. Survey of available "battery" power sources for selection of optimum power source for sonobuoys, missiles, or other similar devices; power sources described include wind driven impellers, wave boosted battery, weight driven systems, electrochemical cells, solar cells, thermoelectric power generation, thermionic cells, nuclear cells, primary and secondary cells, reserve or delayed action batteries, fuel cells, etc. EI '63

Progress and prospects in thermoelectricity. K. H. Spring. Chem & Ind p 1994-7 D 9 '61

AS&TI '62

1723 SOLAR DIRECT-CONVERSION POWER SYSTEMS. William C. Cooley (Exotech, Inc., Alexandria, Va.). IRE (Inst. Radio Engrs.), Trans. Military Electron., MIL-6: 91-8(Jan. 1962).

A survey is made of the present status of technology of solar photovoltaic, photoemissive, thermoelectric, and thermionic power systems for spacecraft. The subjects of radiation damage to solar cells, power-system design, and solar simulation are reviewed. Various types of solar power systems are discussed and compared with respect to weight, availability, environmental tolerance, and cost. It is concluded that solar photovoltaic and solar thermionic systems are most desirable for power levels up to 3 kw. However, the life capability of thermionic converters has not yet been established. Solar thermoelectric and photoemissive systems will be less desirable because of their lower efficiency and, therefore, larger area per unit power output, except for missions where radiation resistance or economy are paramount considerations. (auth) NSA '63

Engineering Evaluation of Energy Conversion Devices, F.LAUCK, O.A.UYEHARA, P.S.MYERS. SAE—Paper 463A for meeting Jan 8-12 1962 12 p. Comparison of energy converting devices on basis of ultimate efficiency, weight, size, and cost; compared are engines whose operation requires that internal energy of fuel be converted to heat and transferred to working fluid which goes through cycle (steam engines, nuclear boilers, thermoelectric and thermionic generators, etc), and those engines whose operation does not require that internal energy of fuel be first converted to heat; conclusions made. EI 62

New thermoelectric developments in research and engineering show promise. Il Elec Eng 81:32-3 Ja '62

AS&TI '62

11604 PROGRESS IN THERMOELECTRICITY. P.H.Egli.
IRE Trans Military Electronics (USA), Vol. MIL-6, No. 1, 27-32 (Jan., 1962).

Discusses its application to the direct conversion of heat to electric power. PA 62

Isotopic power. C. E. Crompton. Am Soc Naval Eng J 74:99-103 F '62

AS&TI '62

9518 NEW METHODS OF DIRECTLY CONVERTING HEAT INTO ELECTRICAL ENERGY. K.G.Günther.
Nukleonik (Germany), Vol. 4, No. 1, 58-64 (Feb., 1962).
In German.

In this review article the thermoelectric, thermionic and magnetohydrodynamic methods are discussed. Twenty four references are provided. A.J.Salmon

PA '62

Electricity from Heat, LEE[illegible]. Int Science & Technology n 3 Mar 1962 p 15-27. Analysis of principles, operation, and advantages and disadvantages of 3 methods for obtaining electricity directly from heat; these are magnetohydrodynamics, thermoelectric generation and thermionic generation.
ET62

5616 PRODUCTION OF ELECTRICAL ENERGY FROM RADIOACTIVE ISOTOPES. P.Wenzel.
Isotopentechnik (Germany), Vol. 2, No. 3, 85-92 (March, 1962). In German.

Discusses the production of electrical energy from radioactive sources directly to produce high-voltage, low-current supplies; and indirectly by the use of secondary emission, contact potential, semiconductor, photoelectric and thermoelectric devices to produce energy at low voltages.
A.O.Stanesby
PA 63

4886 (AD-275610) RESEARCH ON MATERIALS, PROCESSES, AND DEVICES RELATED TO ENERGY CONVERSION. Semiannual Technical Summary Report No. 2. (Massachusetts Inst. of Tech., Cambridge. School of Engineering). Mar. 30, 1962. Contract Nonr-1841(78). 180p.

Research progress is reported on high-temperature thermoelectric and thermionic materials, thermal electric energy conversion, thermionic energy conversion, superconducting materials, superconducting systems, and electrochemical energy conversion. (M.C.G.) NSA '63

Proposed system for the direct conversion of re-entry thermal energy into electric energy. R. W. Truitt. diag J Aerospace Sci 29:478-9 Ap '62
AS & TI '62

Energy Sources of Future, J.B.CLAMPETT, J.R.NORMAN. Australian Chem Eng v 3 n 3 Mar 1962 p 19-28. Survey and review include solar radiation, geothermal energy, ocean temperature differences, salt concentration differences, vortex tube, fuel cells, high energy batteries, thermoelectric generators, thermionic generators, magnetohydrodynamic generators, and unconventional power sources. 22 refs.
ET 62

New power sources aren't apt to put old standbys on shelf. F. Lauck and others. S A E J 70:27-33 Ap '62

New power sources and energy converters. D. Linden. il diags Electronics 35:35-42 Ap 6 '62

AS & TI '62

Generation of Electricity by Unconventional Methods. H.BILLETT. P.D.DUNN. H.C.WHITBY. Combustion v 33 n 11, 12 May 1962 p 29-39. June p 41-6. Theoretical considerations of methods and fields for application of unconventional energy conversion devices; thermoelectric and thermionic generators; fuel cells; possible applications in large-scale power generation, medium power installations and in nuclear power plants. 25 refs.
ET63

Slow progress is seen for unconventional power sources. diags Eng & Min J 163:207 Je '62

AS & TI '62

9522 THE DIRECT CONVERSION OF CALORIC ENERGY TO ELECTRICAL ENERGY. J.J.Martin Artajo.
An. Mecan. Elect. (Spain), Vol. 39, No. 3, 123-33 (May-June, 1962). In Spanish.

The author gives a general discussion of the various methods of energy conversion: fuel cells; thermo-electronic generators; thermo-ionic generators; and magnetic dynamos. The operational principles, the present state of development, comparative difficulties and economics of each of the types of generators is discussed with a view toward economical industrial installations.
J.T.Burridge
EEA '63

13991 PHOTOELECTRIC, THERMOELECTRIC AND THERMIONIC CONVERSION OF SOLAR ENERGY INTO ELECTRICAL ENERGY. C Tingwaldt and F.W.Seemann. Brennstoff-Wärme-Kraft (BWK) (Germany), Vol. 14, No. 7, 329-33 (July, 1962). In German.

Gives a review of the papers of the United Nations Conference on New Sources of Energy, August 1961 in Rome. Various types of solar generator are illustrated and described including solar batteries for satellites. E.H.Dock

EEA '62

Materials for Use in New Methods of Power Conversion, K.H. SPRING. Eng Matls & Design v 5 n 7, 8 July 1962 p 482-5, Aug p 584-6. Environmental conditions and problems in approach to material selection considering new methods of power generation for future; fuel cell, magnetohydrodynamic and thermionic generation; photovoltaic cell.

EI 63

V13987 DIRECT CONVERSION AND FUSION REACTORS. J.W.Gardner.
Brit. Power Engng, Vol. 5, No. 2, 24-31 (July, 1962).

A number of unconventional energy sources and conversion techniques are briefly discussed, viz., magnetohydrodynamic conversion, fuel cells, thermocouples, and thermionic conversion with some brief notes on solar energy, possible fusion reactions with deuterium and tritium fuels, with particular reference to energy balance considerations, containment and stability. Obstacles to the construction of practical thermonuclear reactors, rocket-borne or earthbound, lie in the field of plasma diagnostics (containment, control, and measurement of plasma). There are numerous literature references. J.Smuts

EEA '62

12751 (ARF-1214-1) A NUCLEAR-PHOTON ENERGY CONVERSION STUDY. Quarterly Technical Report No. 1, April 1, 1962 – July 1, 1962. H. V. Watts and C. W. Terrell (Illinois Inst. of Tech., Chicago. Armour Research Foundation). July 13, 1962. Contract AF33(657)-8527. 34p. (AD-278364)

Capabilities of materials that could possibly be used in the components of a nuclear radiation powered electrical energy source that consists of a radioisotope, a luminescent material, and a photovoltaic device are discussed. Considerations affecting the efficiencies of the components are examined. A silicon junction solar cell is selected as the photon-to-electrical energy converter, and a cadmium sulfide phosphor activated with silver or copper is chosen for nuclear radiation-to-photon conversion. Beta-emitting radioisotopes, particularly strontium-90, are presently used as emitters. (D.C.W.)

NSA '63

1461 THERMIONIC TOPPING UNIT FOR NUCLEAR PLANT SEEN. R.C.Howard.
Elect. World (USA), Vol. 158, No. 4, 38-40 (July 23, 1962).

Discusses possibilities of the application of direct conversion devices in central station power plants. Both the thermionic (TI) device, in which an ionized gas or vacuum is used between a hot electron emitter and a cold collector surface as well as the thermoelectric (TE) device, in which a temperature gradient across a semiconducting material produces current, are examined. The scheme of a combination thermionic cell and fuel element is illustrated. The possibility of coupling the in-pile TI concept with the out-of-pile TE concept is envisaged. S.Chakrawarti

EEA '63

Present state of energy converters. H. Billett and P. D. Dunn. bibliog flow diag diag Engineering 194:254-6 Ag 24 '62

Exotic power sources. Electronics 35:26-7 Ag 31 '62

AS & TI '62

Potential of Solar Thermionics for Space Vehicle Power, D.L. DRESSER. SAE—Paper 741B for meeting Sept 23-27 1963 12 p. Paper summarizes theoretical and experimental results obtained during past 4 yr on solar thermionic system considering following components—thermionic generator, power conditioning equipment; cavity absorber, energy storage; and solar concentrator, orientation and temperature control; results provide basis for estimating future competitive position of thermionic system vs solar cells in space power; basic characteristics of system are outlined and recent developments reviewed; comparison of thermionic and solar cell as power sources. 35 refs.

ET 64

41607 RADIONUCLIDE POWER FOR SPACE. PART 3. GENERATOR PERFORMANCE AND MISSION PROSPECTS. Fred Schulman (National Aeronautics and Space Administration, Washington, D. C.). Nucleonics, 21: No. 9, 54-8(Sept. 1963).

Future prospects for isotope power in space and the status of the technology upon which these prospects are based are pointed out. Generator needs and performance in space are discussed with examples of present missions cited. (R.E.U.)

NSA '63

UNCLASSIFIED

104214 STATUS REPORT ON THERMOELECTRICITY
104215 Davisson, J. W. & Pasternak, Joseph
October 1962 Unclassified
Navy Dept.
Office of Naval Research
Naval Research Laboratory
NRL MR-1361

In this report there is an effort to review a number of topics in some detail. Materials progress is presented in Part I and includes sections on reliability and on radiation effects. Part II is devoted to devices. In order to improve coherence, some of the data presented is relatively old. Evaluating the data presented in this report together with information presented at recent meetings and from various organizations, indicates that progress in power generating materials for intermediate temperature ranges continues to move slowly. An interesting development has been in liquid thermoelectrics. Attempts to utilize liquids would pose formidable engineering problems. Another development is work on the Ettingshausen effects. In the area of devices, large refrigeration equipment for submarine applications continues to make progress.

Thermoelectricity UNCLASSIFIED

3548 SPACE DEMANDS NUCLEAR POWER SYSTEMS. B.C.Lindley.
Engineering (GB), Vol. 194, 457-8 (Oct. 5, 1962).

A space vehicle power system consists of a source of chemical, solar or nuclear energy, together with a device for converting the energy into electricity. Reliability and output per unit weight take precedence over efficiency and low cost. The use of chemical energy is limited by the fuel storage capacity available, and solar energy is of low power incidence. Nuclear power systems, however, are attractive for large powers and long durations, and the feasibility of both fast and thermal reactor heat sources is discussed. Five types of energy conversion device are reviewed; thermoelectric and thermionic elements, the regenerative fuel cell, the turbogenerator and the magnetoplasmadynamic generator. Short-term and long-term data are derived for the various possible nuclear reactor–energy convertor combinations, and show that at the present the thermionic and turbogenerator systems are the most attractive.

D.J.Bailey
EEA '63

Direct Conversion—Present Stage of Development, J.W.GARDNER English Elec J v 17 n 8 Sept-Oct 1962 p 35-43. Recent developments in magnetohydrodynamic conversion, fuel cells, thermoelectrics and thermionics; none of these methods of power generation is held likely to replace conventional ones in foreseeable future, but some of them, on development, might be used in conjunction with turbogenerators to give worthwhile increase in overall system efficiency. 28 refs.

EI 63

70,181 POWER SOURCES FOR NUCLEAR SPACE INSTRUMENTS
Corliss, W. R.
Nucleonics, v. 20, no. 10, pp. 61–63, October 1962

The ultimate energy source for satellite and interplanetary missions will unquestionably be nuclear. Both nuclear and non-nuclear power sources available and under development are tabulated. It is predicted that within ten years the space experimenter will have an assortment of standard power supplies with which to work and will not have to rely on tailored power supplies.

AIA '63

70,282 DYNAMIC ENGINES FOR SPACE POWER SYSTEMS
Kovacik, V. P.
ARS Journal, v. 32, no. 10, pp. 1511–1522, October 1962

An over-all perspective of the current state of the art in dynamic energy conversion systems is presented. Dynamic engines are catalogued into open- and closed-cycle systems. The open-cycle engines invariably use chemical fuels and the closed power systems use solar or nuclear energy as the energy source. Promising dynamic engine concepts, their current development status, future areas of research and development, performance, and their estimated availability are reviewed.

10203 POWER SYSTEMS. Nathan W. Snyder (Kaiser Aircraft and Electronics, Oakland, Calif.). Astronautics, 7: No. 11, 110-14(Nov. 1962).

Low power output of other devices at this time dictates the use of nuclear-reactor systems for manned space explorations. Work up to the present is briefly reviewed, and progress and utilization of other power supplies are discussed. Pros and cons of solar cells, fuel cells, and thermoelectric and thermionic devices are included as well as consideration of energy storage, solar energy collector technology, and heat transfer and rejection for space power. (D.C.W.)

NSA '63

20681 METHODS FOR DIRECT CONVERSION OF NUCLEAR FUSION ENERGY INTO ELECTRICAL ENERGY. K. Meyer. Energietechnik, 12: 496-503(Nov. 1962). (In German)

A review of methods that according to the present state of knowledge have prospects, in combination with nuclear reactors, for direct production of electric energy is presented. These methods depend on the principles of thermoelectronic, thermoelectric, and magnetohydrodynamic generators as well as fuel cells. The chief mode of action of conceivable instruments based on these methods is explained, the state of research is explained by exa[illegible] from the literature, and the prospects for applic[illegible] are discussed. (tr-auth)

N[illegible] 63

Background and future of energy conversion. C. C. Furnas. bibliog Elec Eng 81:845-9 N '62

ASSTI '63

20282 THE WINNING OF ELECTRICAL ENERGY FROM RADIOACTIVE ISOTOPES. P. Wenzel. Energietecknik, 12: 504-7(Nov. 1962). (In German)

After detailed statements of general viewpoints, such as the selection of suitable isotopes, the various well-known nuclear batteries are described. (tr-auth) NSA 63

Power Systems. N.W.SNYDER. Astronautics v 7 n 11 Nov 1962 p 110-14. Summary of present state of art; it is found that use of germanium silicon alloy thermoelectric element will advance Snap 10A nuclear reactor system closer to flight test; hydrogen oxygen fuel cells reached point of development to be used in short term manned flights of Gemini and Apollo; magnetohydrodynamics appears to be of little or no value; review of energy conversion schemes. E 163

13158 DEVELOPMENTS IN THE FIELD OF THERMO-ELECTRICITY. G.Gramberg and H.G.Plast. Brown Boveri Rev. (Switzerland), Vol.49, No.11-12, 501-14 (Nov.-Dec., 1962).

In recent years thermo-electricity has become increasingly interesting in the fields of refrigeration and for the direct conversion of heat into electrical energy. General considerations show that the efficiency of this method is governed by the Carnot cycle and by a material factor known as the "figure of merit". The efficient utilization of thermo-electricity requires materials with a high figure of merit: the discovery of such materials is the task of the physicist. Since the thermo-electric production of energy and electro-thermal refrigeration are based on the same physical phenomena, both can be devolved from the same first principles. These basic principles are described in the article which also includes some salient points concerning development work into electro-thermal refrigeration. The applications are particularly interesting because the equipment operates silently, contains no moving parts and has a long working life. EEA 63

AD-401 931 Div. 8, 14
(TISTM/PCR) OTS price $6.60

Energy Conversion and Semiconductor Lab., Mass. Inst. of Tech., Cambridge.
RESEARCH ON MATERIALS, PROCESSES, AND DEVICES RELATED TO ENERGY CONVERSION.
Semiannual technical summary rept. 31 Dec 62, 65p. incl. illus. tables (Rept. no. 6)
(Contract Nonr-184178, Proj. 9800)
Unclassified report

DESCRIPTORS: *Superconductors, *Electrochemistry, *Thermoelectricity, *Thermionic converters, *Thermionic emission, *Energy conversion, Superconductivity, Alloys, Microstructure, Niobium, Thorium, Eutectics, Phase studies, Deformation, Fracture (Mechanics), Semiconductor devices, Semiconductors, Radiation damage, Photoelectric effect, Zinc, Antimony alloys, Molybdenum, Oxides, Materials, Fuel cells.

Research reports are presented on: (1) Superconducting materials and systems, (2) Electrochemical energy conversion research, (3) Thermoelectric and thermionic materials research, (4) Solid state energy converters, and (5) The development of thermionic emitter materials. (Author) '63

6551 HISTORY AND RECENT DEVELOPMENTS IN DIRECT ENERGY CONVERSION SYSTEMS. Paul H. Egli (U. S. Naval Research Lab., Washington, D. C.). p.371-407 of "Materials Science and Technology for Advanced Applications." Englewood Cliffs, N. J., Prentice-Hall, Inc., 1962.

Improved power sources and energy conversion systems are an important long range national problem and of immediate military importance. Various direct conversion processes appear promising for the solution of some of these problems. In thermoelectricity, progress in materials has been good, but much remains to be done. Even at this stage a number of valuable thermoelectric devices can be constructed, particularly cooling devices ranging from small modules for temperature control of electronic parts to submarine air conditioning, and small size power generators for various remote locations including long lived satellite missions. Thermionic emission offers light weight power generators for large power supplies for relatively short missions. Magnetohydrodynamics is confronted with imposing problems associated with the high temperature requirements for operation of more than a few minutes duration. Important improvements are in sight, and continued progress is imperative to provide high density power sources for advanced weapon systems. Photoelectric processes show good improvements toward the goals of lower costs and performance in severe environments. Fuel cells offer exciting possibilities for uses ranging from the main power source for submarines to the auxiliary power on short time space missions. (auth) NSA '63

Y0213 THE NASA NUCLEAR ELECTRIC POWER PROGRAM. Fred Schulman (National Aeronautics and Space Administration, Washington, D. C.). ARS Preprint No. 2522-62. New York, American Rocket Society, 1962. Prepublication Copy. 11p. $1.00.

The projected requirements and capabilities for space electric power in the ranges below 0.5 kw, on the order of 10 kw, and on the order of 10 Mw are discussed. The uses of radioisotope, reactor, and advanced systems to fulfill the requirements are outlined. (T.F.H.) NSA '63

9525 GENERATION OF ELECTRICITY BY UNCONVENTIONAL METHODS. H.Billett, P.D.Dunn and H.C.Whitby. Proc. Instn Mech. Engrs (GB), Vol. 176, No. 18, 421-48 (1962).

This paper, presented at a Thermodynamics and Fluid Mechanics Group meeting, describes the basic theory, construction and operation of four types of energy conversion device namely - thermoelectric conversion, thermionic conversion, magnetohydrodynamic generation and fuel cells, having no moving parts and potentially capable of greater efficiencies than present methods of power generation. Although individual units have been built, the main field of application would seem to lie in using these devices to extend conventional plant not fully utilizing the available temperature range of 0 to 2400°C. EEA '63 W.Lord

105250 UNCLASSIFIED
ENERGY CONVERSION SYSTEMS REFERENCE HANDBOOK, VOLUMES I-V
Rec'd JPL: January 10, 1963 Unclassified
Electro-Optical Systems, Inc. (Air Force Dept.
AF 33(616)-6791 WADD-TR-60-699, Vol. I-V)
EOS R-390, Vol. I-V Final

This document consists of eleven volumes pertaining to energy conversion systems. These volumes include: general system considerations; solar-thermal energy sources, dynamic thermal converters; static thermal converters; and direct solar conversion.

Solar energy conversion
Stirling engines
Spacecraft power systems

105251 UNCLASSIFIED
ENERGY CONVERSION SYSTEMS REFERENCE HANDBOOK, VOLUMES VI-XI
Received JPL: January 10, 1963 Unclassified
Electro-Optical Systems, Inc. (Air Force Dept.
AF 33(616)-6791 WADD TR-60-699, Vol.VI-XI)
EOS R-390, Vol. VI-XI Final

This handbook contains chapters on chemical, solar, reactor and radioisotope systems. Also has chapters on heat exchangers, orientation mechanisms and MHD generators.

8019 SOLID-STATE CONVERSION CONCEPTS.
J.F.Wise.
IEEE Trans Aerospace (USA), Vol. AS-1, No. 1, 24-9 (Feb., 1963).
Outlines the present state of development and future prospects of a number of devices for providing electrical power in aerospace vehicles. The emphasis is chiefly on photo- and thermo-electric cells using solar or nuclear sources of energy, but piezoelectrics, pyroelectrics, ferroelectrics, the Nernst effect and nuclear photon conversion are also mentioned.
L.M.Roberts
EEA '63

Radionuclide power for space: isotope costs and availability. H. L. Davis. Nucleonics 21:61-5 Mr '63

AS & TI '63

Dynamic Energy Conversion, V.P.KOVACIK. Astronautics & Aerospace Eng v 1 n 4 May 1963 p 84-8. Paper is concerned with closed cycle systems used with solar and nuclear energy sources; development efforts on dynamic engines involved mercury Rankine cycle, at 1000-1200 F; power systems in 0.5-3-kw range are characterized by one-pass boiler, hermetically sealed turboalternator unit, impulse turbine, solid rotor permanent magnet alternator with ceramic bore seal, mercury journal bearings, and direct condenser-radiator; operating temperature and efficiency dictate different criteria for selecting energy-conversion components for solar and nuclear power systems; table shows representative component choices.
EF '63

35226 SPACE ELECTRICAL POWER. Walter C. Scott and Fred Schulman (National Aeronautics and Space Administration, Washington, D. C.). Astronaut. Aerospace Eng., 1: No. 4, 48-53(May 1963).
The objectives and achievements of the development program for space electrical power systems are discussed. Power requirements for various space projects and products of power development research are considered. Research on the radiation-resistant n-p solar cell, thin-film solar cells, and rechargeable batteries is outlined. The development of Snap-8 is also discussed. (C.E.S.) NSA '63

Thermo-electrical engineering. A. G. Heaton. bibliog diags Inst E E Proc 109 pt B: 223-32 My '62; Discussion. 110:998 My '63

AS & TI '63

34073 STATIC POWER CONVERSION FOR SPACECRAFT. Terry W. Koerner (California Inst. of Tech., Pasadena). Astronaut. Aerospace Eng., 1: No. 4, 89-92 (May 1963).

Characteristics of static power conversion systems for medium power levels and problems of matching power sources to the load are discussed. Solar panels, storage batteries, thermoelectric couples, and the thermionic diode are discussed. Current-voltage diagrams are compared and several types of regulators that can be used to achieve the desired load regulation are described. (C.E.S.) NSA '63

34072 SPACE POWERPLANT NEEDS AND SELECTION. D. T. Bernatowicz, D. C. Guentert, and J. L. Klann (Lewis Research Center, Cleveland). Astronaut. Aerospace Eng., 1: No. 4, 22-6(May 1963).

The anticipated maximum requirements for nonpropulsive and propulsive electric power for the period through 1975 is discussed. Criteria for evaluating and selecting space power systems are outlined. Chemical, nuclear, and solar power systems are considered. (C.E.S.) NSA '63

80,606 DYNAMIC ENERGY CONVERSION
Kovacik, V. P.
Astronautics and Aerospace Engineering, v. 1, no. 4, pp. 84–88, May 1963

Closed-cycle dynamic energy conversion systems expected to be used with solar and nuclear energy sources are discussed. Aspects of dynamic power important to future applications are emphasized.

80,603 SPACE ISOTOPIC POWER SYSTEMS
Carpenter, R. T.
Astronautics and Aerospace Engineering, v. 1, no. 4, pp. 68–72, May 1963

The status of today's space isotopic power program is evaluated. The technology has developed to the point where the designer can plan appropriate space application of isotopic systems. Various systems are described and evaluated.

31768 THE APPLICATION OF NUCLEAR ENERGY FOR LARGE-SCALE SPACE POWER. B. C. Lindley (C. A. Parsons and Co. Ltd., Newcastle upon Tyne, Eng.). J. Brit. Interplanet. Soc., 19: 92-9(May-June 1963).

Possible types of nuclear reactors and energy convertors suitable for the generation of power in space are surveyed. Estimates of probable performance are given. (auth) NSA '63

AD-409 915 Div. 25, 7
(TISTA PCR) OTS price $8.10

Monsanto Research Corp., Dayton, Ohio.
HIGH TEMPERATURE THERMOELECTRIC RESEARCH.
Quarterly progress rept. no. 6, 29 Mar-28 June 63,
by C. M. Henderson. 28 June 63, 74p.
Contract AF33 657 7387, Proj. 8173, Task 817302 9
Unclassified report

14 '63

Small Non-Conventional Electrical Power Sources, G.W.WILSON. Brit Interplanetary Soc—J v 19 n 3 May-June 1963 p 81-6. Present status of each of 3 methods of conversion of heat or light into electrical power without use of rotating machinery is surveyed; thermoelectricity, thermionic conversion, and photovoltaic converters; comparison of practical devices indicates that for some time each method will find specialized applications for space vehicles, etc. '63

25391 DEVELOPING ELECTRIC-PROPULSION POWERPLANTS. David G. Elliott (California Inst. of Tech., Pasadena). Astronaut. Aerospace Eng., 1: No. 5, 82-8(June 1963).

Auxiliary power supplies available now or in the future are discussed, and considerations involved in designing propulsion systems are examined. Basic problems in powerplant design are pointed out; and design and development of turboelectric, thermionic, and magnetohydrodynamic systems for converting heat to electrical energy are reviewed. (D.C.W.) NSA '63

28576 NUCLEAR REACTORS IN SPACE. Bernard L. Spinrad (Argonne National Lab., Ill.). News-Bull. Intern. (Argonne Natl. Lab.), 4: No. 3, 5-10(June 1963).

Advantages of using nuclear reactors in space flight are given, and systems now under development are described. These include heat transfer rockets in which fuel is heated to high temperatures by reactors, electrical propulsion systems (ion and plasma drives) in which the electricity is provided by reactor-driven generators, and electric power generators that convert nuclear power to electric power. Feasibility of the systems is discussed along with problems in their design. (D.C.W.) NSA '63

AD-405 957 Div. 7, 20, 25, 21, 12, 17
(TISTM/PCR) OTS price $4.60

Defense Documentation Center, Cameron Station, Alexandria, Va.
POWER GENERATION.
June 63, 42p.
Unclassified report

Descriptors: *Power equipment, *Nuclear power plants, *Solar cells, *Thermoelectricity, *Piezoelectric effect, *Energy, *Bibliographies, *Abstracts, Aircraft nuclear propulsion, Nuclear propulsion, Electric power production, Submarines, Rocket propulsion, Thermonuclear reactions, Underwater propulsion, Naval vessels (Combatant), Spacecraft, Space flight, Ion engines, Icebreakers, Solar furnaces, Plasma physics, Fuel cells, Magnetohydrodynamics, Boiling water reactors, Reactor operation, Nuclear weapons, Alloys, Satellites (Artificial), Power equipment.

'63

26239 COURSE WORK AND EXPERIMENTS IN DIRECT RADIATION-TO-ELECTRICAL ENERGY CONVERSION. G. H. Miley (Univ. of Illinois, Urbana). Trans. Am. Nucl. Soc., 6: 207-8(June 1963). NSA '63

Thermo-electricity powers radio repeater. il Elec World 159:101 Je 17 '63

AS & TI '63

Progress on—Advanced Methods of Power Generation, H.A. WAGNER. Edison Elec Inst—Bul v 31 n 6 June-July 1963 p 222-9. Principles of thermoelectric, thermionic and magnetohydrodynamic generation, fuel cells, and fusion reactors are reviewed; their future possibilities in large scale power production are assessed and evaluated.

EI '63

35079 (ANL-6749) REACTOR DEVELOPMENT PROGRAM PROGRESS REPORT, JUNE 1963. (Argonne National Lab., Ill.). July 15, 1963. Contract W-31-109-eng-38. 67p.

Research and development activities are reported on Borax-V, ZPR-III, EBR-I, EBR-II, Faret, EBWR, and Treat. Reactor technology and investigations are reported in reactor physics, fuels and materials development, component development, heat transfer, and chemical separations. Nuclear safety development in thermal and fast reactors is discussed. Development of thermionic cells, magnetohydrodynamic generators, and the plutonium recycle program is also reported. (N.W.R.)

NSA '63

37749 REVIEW OF ENERGY CONVERSION METHODS USING RADIOISOTOPES. J. L. Craston (Atomic Energy Research Establishment, Harwell, Berks, Eng.). J. Brit. Interplanet. Soc., 19: 105-9(July-Aug. 1963).

The characteristics of radioisotopes are outlined and their potential hazards are indicated. Methods of converting the disintegration energy of radioisotopes into electrical power can be classified into two main groups, which can be subdivided into a total of five classes. Progress in each class is reviewed. (auth)

NSA '63

Liquid Metals for Aerospace Electric-Power Systems, L. ROSENBLUM. J of Metals v 15 n 9 Sept 1963 p 637-41. Liquid metals and their properties are evaluated for their tested or potential usefulness as high temperature fluids in such light weight, long-lived electric supply systems as Rankine-cycle nuclear turbogenerator and nuclear thermionic systems; Li, Na, K, Pb, Bi, and NaK-78 are compared in schematic form; Hg and Rb are discussed. 23 refs.

EI '64

827 PRODUCTION OF ELECTRIC ENERGY BY MEANS OF NUCLEAR BATTERIES. J. Euler and A. Scharmann (Universität, Giessen, Ger. and Varta AG, Frankfurt am Main). Kerntechnik, 5: 385-7(Sept. 1963). (In German)

The methods of electrical energy production in nuclear batteries are described. Some uses are discussed. Thermoelectric, thermionic, and photoelectric nuclear batteries are described. (R.E.U.)

NSA '64

Space Demands Nuclear Power Systems, B.C. LINDLEY. Engineering v 194 n 5033 Oct 5 1962 p 457-8. As missions become more ambitious in concept, high power requirements are envisaged for electrical propulsion and for manned vehicle power systems; any power system based on closed cycle heat engine must reject heat into space, which can only be achieved by radiation, and fast and thermal reactors may be considered; of presently known energy conversion techniques, thermoelectric, thermionic, regenerative fuel cell, turbogenerators and magnetoplasmadynamic generator offer possibilities; these components and integrated systems are assessed; table shows approximate performance details derived for various combinations.

EI '63

Brayton Cycle for Space Power, W.L. STEWART, A.J. GLASSMAN, R.P. KREBS. SAE—Paper 741A for meeting Sept 23-27 1963 9 p. Paper reviews basic features of Brayton cycle and selection of such cycle parameters as working fluid, pressure, and temperature; system performance, weight, and reliability characteristics are considered to determine suitability of system for space applications; Brayton cycle can be considered suitable for low-power solar and intermediate-power nuclear applications where low specific weight is not critical requirement; to achieve low specific weights required for electrical propulsion missions, turbine-inlet temperatures in 3000 R region at power levels in 500-1000 kw range appear to be necessary.

EI '64

Unconventional Methods of Electricity Generation, P.D. DUNN, J. K. WRIGHT. Instn Elec Engrs—Proc v 110 n 10 Oct 1963 p 1837-54. Physical principles are discussed on which magnetohydrodynamic, thermoelectric, and thermionic generators, and fuel cell are based; limitation of conventional steam turboalternator for large scale power generation is pointed out, and desirability of developing higher temperature plant to be used in conjunction with conventional generation plant is shown; other methods of generation, including solar cell, are mentioned, as is applicability of other generation methods discussed, in space vehicles. 91 refs. Paper 4274S.

EI '64

2564 (DL-55) A PERSPECTIVE ON DIRECT CONVERSION. W. B. Lewis (Atomic Energy of Canada Ltd. Chalk River, Ont.). Oct. 1963. 12p. (AECL-1852; CONF-307-1)

From Canadian Electronics Conference, Toronto, Sept.-Oct. 1963.

The objective of direct conversion is high electrical output for minimum total cost, and not always high conversion efficiency. The wide range of techniques embracing cryogenics and hot plasma derives from the special requirements of source, environment, and application. Sources include solar and other radiation, nuclear fission and fusion, chemical energy, and heat. Environments and applications range from space vehicles to submarines and from giant power networks to isolated buoys and pocket devices. (auth)

NSA '64

Background and Future of Energy Conversion, C.C. FURNAS. Elec Eng v 81 n 11 Nov 1962 p 845-9. Survey of probable future use and relative value of various energy conversion systems and devices; possibilities of space heating, process heating, fuel cell, thermoelectric devices, magnetohydrodynamics and special purpose devices; basic research. EI '63

2576 ELECTRIC PROPULSION AND POWER.
John M. Teem (Electro-Optical Systems, Inc., Pasadena, Calif.), and George C. Szego. Astronaut. Aerospace Eng., 1: 98-103(Nov. 1963).

Progress in electric propulsion systems, thrustor research and development, applications, and mission analysis are discussed. Some types of electric power systems and their applications are presented. These include solar cells and collectors, the SNAP program, radioisotope systems, thermoelectric and thermionic technology, MHD power, batteries and fuel cells, and power conditioning. (R.E.U.) NSA '64

2569 (ANL-6687(p.188-203)) ENERGY CONVERSION. (Argonne National Lab., Ill.).

Progress is reported on the development of regenerative emf cells and thermoelectric cells for the direct conversion of nuclear energy into electricity. (D.L.C.) NSA '64

Thermoelectric systems of cooling and heating A. B. Newton. diags Heating-Piping 35:123-7 O; 152-4 N '63

AS & T I '63

14120 (ANL-6596(p.201-10)) ENERGY CONVERSION.
C. E. Crouthamel, M. Foster, et al. (Argonne National Lab., Ill.).

Research concerning the conversion of nuclear energy to electricity by use of regenerative emf cells and by thermoelectricity is reported. (J.R.D.) NSA 63

UNCLASSIFIED

110705 SUNFLOWER I POWER CONVERSION SYSTEM (U)

Confidential

Thompson Ramo Wooldridge, Inc. (Projects: Sunflower I)
Tapco Division
ER-4003B

Several power conversion concepts capable of meeting the requirements of the Sunflower system exist in varying states of development. These include the Sterling cycle system, the thermoelectric system, the thermionic system and the mercury Rankine cycle system. Each of these systems has been evaluated to determine ability to meet the detailed requirements of the Sunflower I power system. Also included in this report is a technical discussion on various components of the Sunflower system. (U)

Sunflower (Project)
Space power systems
Solar energy devices
Power systems, solar

Book:

ENERGY CONVERSION
SS.L. Chang, Prentice-Hall, 1963.

I. GENERAL

C. Conferences, etc.

AD-410 476 Div. 25, 8
(TISTP/FEM) OTS price $21.00

Office of Naval Research, Washington, D. C.
PROCEEDINGS OF THE FIFTH NAVY SCIENCE
SYMPOSIUM. NAVAL RESEARCH SPONSORED BY THE

OFFICE OF NAVAL RESEARCH, APRIL 18, 19, 20,
1961 U.S. NAVAL ACADEMY, ANNAPOLIS, MARYLAND.
1961, 367p.
ONR 9 V.1 Unclassified report

Descriptors: (*Symposia, Research program administration), (*Queuing theory, Analysis), (*Thermoelectricity, Thermal conductivity), Distribution, Probability, Rockets, Interception probabilities, Rocket trajectories, Digital computers, Ship models, Hydrodynamics, Aeroelasticity, Reentry vehicles, Heating, Radiation effects, Guided missiles, Solid state physics, Particles, Chemical analysis, Niobium, Oxidation, Dosimeters.

9238 THERMOELECTRIC GENERATING AND COOLING DEVICES. J.D.Richards.
Proc. Amer. Power Conf., Vol.23, 446-57 (1961).

The thermoelectric cycle may be used to generate electricity from heat, or to transfer heat from one point to another by means of an electric current. Although there are many applications where thermoelectric generators and coolers appear to offer the best solution these devices cannot yet complete on a large scale with conventional generation and refrigeration equipment on cost performance. Problems arise due to brittleness of materials, destructive thermal stresses within thermocouple arms and at the junctions, resistance which produces heat losses, degradation of thermoelectric properties, oxidation and the effect of high temperatures. Efficiencies as high as 18% are predicted for the case where several materials are segmented in series to utilize each material only over the temperature interval where ZT is highest. Optimum current density is necessary in all segments and provision must be made for matching coefficients of expansion. Thermoelectric generators can compete with batteries and small engine generators in the range 100 mW to 100 W capacity. Units at present undergoing evaluation tests are enumerated and described as more efficient materials become available applications will increase.

G.V.Hargreaves
E CALL

UNCLASSIFIED

111031
111032 MATERIALS SCIENCE AND TECHNOLOGY FOR ADVANCED APPLICATIONS
(Advance papers of the ASM 1962 Golden Gate Metals Conference, San Francisco, California)
(Period covered: February 15-17, 1962)

American Society for Metals
Meetings
Preprints

Unclassified

Conferences (materials research)
Materials (research)
Spacecraft (design)
Materials, high-strength
Materials, semiconductor
Energy conversion

Session on Thermal Energy Conversion. 16th Annual Power Sources Conference—Proc. U S Army Signal Research & Development Laboratory, Fort Monmouth, NJ, May 1962 p 49-70. 250 Watt Propane-Fired Thermoelectric Generators, P.A.O'RIORDAN, 49-51; 45 Watt Thermoelectric Generator for Field Use, M.BARMAT, 52-5; Design Consideration for Gasoline-Powered Thermionic Generators, W.R.MARTINI, 55-60; Progress in Cesium Thermionic Converter, G.N.HATSOPOULOS, S.KITRILAKIS, F.LYCZKO, 60-4; Radioisotope Power Sources, W.L.KERSHAW, 64-7; Nuclear Reactor Power Sources, C.K.SMITH, 68-70. E I '63

Space Vehicle Electrical Design. IEEE—Special Publ S-145 Feb 1963 272 p. Sixteen papers presented at AIEE Summer General Meeting June 17-22 1962, Denver, Colo, on various types of equipment for spacecraft power supply and related problems; papers are indexed separately. E I '63

Wind-, Sonnen- und Geothermische Energie. Brennstoff-Waerme-Kraft v 14 n 7 July 1962 p 309-53. Solar energy, wind power and geothermal energy; 9 articles presented at United Nations Conference Aug 1961, Rome; Economical and social points of view concerning power supply of underdeveloped countries, H.KRAUCH, 310-12; Geothermal energy, N.GASPAROVIC, 313-20; Wind power, G.CLAUSNIZER, 321-6; Available solar energy and instruments for measuring radiation, K.GRAEFE, 326-9; Photoelectric, thermoelectric and thermionic conversion into electric power, C.TINGWALDT, F.W.SEEMANN, 329-33; Solar power plants, H.KRAUCH, 334-6; Direct use of heat load, K.JECHT, A.Th.GROSS, 337-47; Energy storage, 347-8; New materials for solar energy utilization, H.KRAUCH, K.JECHT, 349-53. EI '62

70,186 NUCLEAR FUELS FROM POWER REACTORS TO SPACE POWER

Whitman, M. J. (U.S. Atomic Energy Commission, Washington, D.C.)

American Rocket Society, Inc., New York, N.Y.

2542-62

(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25–28, 1962)

During the past twelve years, the Reactor Fuel Development Program of the Division of Reactor Development of the AEC has been concerned with the development of new materials which would increase operating temperature capabilities and allowable fuel burnup, ensure fission product retention, and solve the compatability problems which occur when temperatures are increased. In order to provide specific examples of the contributions made by civilian power to the space program, those nuclear fuels which show real potential for space power applications are discussed in some detail. The five fuels of interest are UC, UN, UO_2, a UO_2-refactory metal cermet, and a niobium-base alloy.

70,184 SPACE PROBE LIMITATIONS ON NUCLEAR-ELECTRIC POWER SUPPLIES
Welles, O. W. (Space General Corp., El Monte, Calif.)
American Rocket Society, Inc., New York, N.Y.
2527-62
(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25–28, 1962)

The various interfaces between a deep space probe and its nuclear-electric power supply are reviewed in order to predict the constraints of the probe on the supply. The interfaces include the magnitude and type of power consumed by the probe, the relative weights of probe and power supply, and the mission duration. The environment created by the power supply constitutes another class of interface. Physical interfaces are associated primarily with the large radiators required for the power supply. It is shown that certain of the constraints will considerably influence the power supply design features. These features include control of scatter radiation, cancellation of rotating inertias, design for failure life much longer than wearout, and provision for folding the radiators in most probes.

70,183 THE NASA NUCLEAR ELECTRIC POWER PROGRAM
Schulman, F. (National Aeronautics and Space Administration, Washington, D.C.)
American Rocket Society, Inc., New York, N.Y.
2522-62
(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25–28, 1962)

An outline is presented of the NASA nuclear power program ranging from the very lowest power range which can possibly be met by radioisotopes to advanced systems technology which may ultimately provide the long-life low specific weight power in the multimegawatt range needed for future missions to distant planets.

20603 SYMPOSIUM ON THERMIONIC POWER CONVERSION, MAY 1962, COLORADO SPRINGS, COLORADO.
John Blair, J. J. Connelly, G. M. Grover, et al., eds.
Advan. Energy Conversion, 2: 1-643(July-Sept. 1962).
Twenty-eight papers presented at the symposium are included. Separate abstracts were prepared for twenty-six; two have been previously abstracted in NSA. (A.G.W.) NSA 6

13855 POWER FOR SPACECRAFT. Newell D. Sanders, Charles A. Barrett, Daniel I. Bernatowicz, Thomas P. Moffitt, Andrew E. Potter Jr., and Harvey J. Schwartz (National Aeronautics and Space Administration, Cleveland). p.125-50 of "Proceedings of the NASA-University Conference on the Science and Technology of Space Exploration. Vol. 2." Washington, D. C., National Aeronautics and Space Administration, 1962.

The power requirements for present and future space missions are described. Solar photovoltaic cells are used in satellites that require power for more than a few months. Some of the problems of solar cells, including radiation damage and the complexity and weight of solar-cell power systems, are discussed. The use of batteries and radioisotope power supplies is also mentioned. Fuel cells are good power systems where moderate power is required for periods up to several weeks. Two H-O fuel-cell systems, the modified Bacon cell designed for the Apollo mission and the ion exchange membrane cells designed for the Gemini mission, are compared, and other types of fuel cells are briefly described. Other sources of power include chemically fueled engines, solar heat collectors, and nuclear reactors. Brayton cycle systems, thermionic converters, and low- and high-power Rankine cycle systems can be used to convert power from reactors or solar heat sources. The advantages and disadvantages of utilizing these power sources and conversion systems in spacecraft are discussed. The problems of obtaining suitable materials for the reactor, boiler, and radiator in Rankine cycle systems are described. (M.P.G.) NSA '63

27954 SYMPOSIUM ON THERMIONIC POWER CONVERSION, COLORADO SPRINGS, COLORADO, 1962. Sessions IV-VII. Paul H. Egli, ed. Advanced Energy Conversion, 3: 1-405 (Jan.-Mar. 1963).

Separate abstracts were prepared for thirty-four of the forty papers on thermionic-cell design and performance, phenomena associated with thermionic cells, and studies of materials for thermionic cells. Three of the remaining papers were previously abstracted for NSA. (D.C.W.) NSA '63

UNCLASSIFIED

113264
113265 TRANSCRIPT OF THE PHOTOVOLTAIC SPECIALISTS CONFERENCE, VOLUME II: REPORT ON SYSTEMS EXPERIENCE, APPLICATIONS, AND DESIGN (Held at Statler-Hilton Hotel, Washington, D.C.) (Period covered: April 10-11, 1963)
July 1963
Pennsylvania, Univ. of
Institute for Cooperative Research
Power Information Center
DA 36-039-SC-90831
Publication

Unclassified
(PIC-SOL 209/3.1)

Conferences (power sources)
Photovoltaic devices
Photovoltaic cells
Power systems, solar
Conversion systems, solar energy
Generators, thermoelectric
Solar panels
Solar cells

UNCLASSIFIED

UNCLASSIFIED

115591 PROCEEDINGS OF THE 17th ANNUAL POWER SOURCES CONFERENCE (May 21-23, 1963)

Unclassified

Army Dept.
Signal Corps
Research & Development Laboratory
Power Sources Division
Meetings, 17th Power Sources

Conferences (power sources)
Solar cells
Solar energy devices
Energy conversion
Generators, thermionic
Converters, thermionic
Batteries
Fuel cells
Space power systems
Converters

UNCLASSIFIED

Facts about solid state devices; symposium.
il Metal Prog 83:138+ My '63

As ET I '63

UNCLASSIFIED

117425 SPACE POWER SYSTEMS: 1963 STATE OF THE ART (XIVth Congress of the International Astronuatical Federation, Paris, September 1963)
Szego, G.C.

Unclassified

Institute for Defense Analyses Paper (International Astronautical Congress Meetings, XIVth)

Space power systems
Solar cells
Power systems, nuclear
Radioisotopes
Energy conversion
Batteries
Converters, thermionic
Generators, thermionic

UNCLASSIFIED

I. GENERAL

D. Theory

23483 UNRESOLVED PROBLEMS OF THERMOELECTRICITY
A.F.Joffe, B.Ya.Moyžes and L.S.Stilbans.
"Semiconductor Physics" Conference Prague. 1960 (see Abstr. 21113 of 1962) p.619 26. In Russian.

Some problems related to the study of thermoelectricity are discussed, especially those, which are closely concerned with the scattering of heat transfer in semiconductors.

PA '62

AD-282 718 Div. 7
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General Electric Co., West Lynn, Mass.
VOLTAGE REGULATION AND POWER STABILITY IN UNCONVENTIONAL ELECTRICAL GENERATOR SYSTEMS.
Quarterly technical progress rept. no. 3, 31 Dec 60-31 Mar 61.
31 Mar 61, 139p. incl. illus. tables.
(Contract Now 60-0824-c)

Unclassified report

DESCRIPTORS: *Voltage regulators, *Electric power production, *Power supplies, *Fuel cells, *Generators, *Thermoelectricity, *Thermionic emission, Switching circuits, Control systems, Transistors, Direct current, Inverted rectifiers, Solid state physics, Inverter circuits, Electronic circuits, Sources, Voltage, Impedance, Design, Tests.

Research continued on voltage regulation and power stability in unconventional electrical generator systems. Test data on the internal impedance characteristics of a fuel cell are presented. Steady state volt-ampere characteristics of both thermoelectric and thermionic generators are given. An analysis of series-parallel switching methods of voltage control is included. The results to date of a survey of applicable power conversion circuits using power transistors and silicon controlled rectifiers is given. Progress to date in the experimental investigation of efficient power conversion circuits using an input voltage of one volt is presented. (Author)

'62

Calculations of the thermoelectric parameters and the maximum figure of merit for acoustical scattering. L. R. Testardi. biblio J Ap Phys 32:1978-81 O '61

AS 7II '62

14588 THERMOELECTRIC EFFECTS IN NONLINEAR JUNCTIONS. R.W.Ure,Jr.
J. appl. Phys. (USA), Vol. 33, No. 5, 1902-3 (May, 1962).

Discusses the definition of the Peltier effect in p–n junctions, with reference to the inclusion of the Joule heating term.

N.H.Saunders

PA '62

Rendement theorique maximum des convertisseurs d'énergie a émission thermoélectronique, B.DEVIN, M.VANDEVYVER J de Physique et Radium (Physique Appliquée) v 23 n 6 June 1962 p 73A-90A. Maximum efficiency of energy converters with electron thermal emission; general equation for efficiency of thermionic converter in optimized conditions derived in terms of 2 fundamental parameters which are anode work function and cathode quality factor; maximum efficiency is calculated; relative magnitude of conduction and radiation losses is pointed out; sets of curves for various anode work functions presented. 32 refs. ET '62

14594 THEORY OF MINORITY CARRIER THERMOELECTRIC COOLING. M.A.Melehy.

J. appl. Phys (USA), Vol. 33, No. 6, 2100-6 (June, 1962).

The possibility of backward injection of minority carriers in p--n junctions is shown. It is predicted that in a forward-biased p--n junction where this type of injection occurs, heat energy is pumped out of the junction causing it to cool off. Some conditions which lead to backward injection of minority carriers are described. Theory is presented for a particular p—n junction model in which this new cooling effect takes place. It is shown that a given d.c. electrical energy may be used to pump nearly an equal amount of heat energy from one of the junctions to the neighbouring ones provided that the junction temperatures are sufficiently close to each other.

PA '62

Definition of figure of merit for energy-conversion processes. R. Monti. J Aerospace Sci 29:881 Jl '62

Dependence of the thermoelectric figure of merit on energy bandwidth. R. C. Miller and others. bibliog J Ap Phys 33:1928-32 Je '62

AS 7 II '62

AD-287 833 Div. 25
(TISTP/WH) OTS price $1.60

Northeastern U., Boston, Mass.
CONVENTIONAL AND PLASMA THERMOCOUPLES,
by Jack Davis and Giovanni Lanza. 5 June 62,
17p. incl. illus. 9 refs. (Scientific rept. no. 1)
(Contracts AF 19(604)7358, AF 19(604)8462 and AF 49(638)555, Proj. 6694)
(AFCRL 62-630) Unclassified report

DESCRIPTORS: *Thermocouples, *Thermoelectricity, *Irreversible processes, *Differential equations, *Plasma physics, *Electrons, *Thermal conductivity, *Electrical conductance, Theory.

Existing theory on conventional thermocouples is summarized and revised. Utilizing the concepts and ideas of irreversible thermodynamics we are able to obtain the Seebeck, Peltier and Thomson coefficients by making use of the relations between the phenomenological coefficients. Since we are mainly interested in developing a general theory for a plasma thermocouple employing these methods we consider a simple case as an example of how one uses the techniques of irreversible thermodynamics. To this end we assume the collision term in the Boltzmann equation can be replaced by a relaxation type of phenomena. We then consider an electron gas in a solid conductor using Fermi Dirac statistics and a plasma using Maxwell Boltzmann statistics. With these simplified assumptions we obtain the usual expressions for the electrical and thermal conductivities. (Author)

'63

23484 THEORETICAL CONSIDERATIONS WITH RESPECT TO THE DEFINITION OF THE ELECTROLYTIC PELTIER EFFECT. Y.Thouvenin.

C.R. Acad. Sci. (France), Vol. 255, No. 4, 674 6 (July 23, 1962). In French.

After consideration of the historical definition of the Peltier effect, an up-to-date version is given as the amount of heat involved at an isothermal junction of two phases traversed by an electric current when the irreversibility of the phenomenon is negligible. In the particular case of an electrochemical system, it is the quantity of heat liberated by the reversible passage of a mole of the electroactive ion from one phase to the other [cf. ibid., Vol. 251, No. 7, 956 (Aug. 17, 1960)]. H.H.Hodgson

PA '62

19891 COMMENTS ON THE THEORETICAL BOUND ON THE THERMOELECTRIC FIGURE OF MERIT FROM IRREVERSIBLE THERMODYNAMICS. E.S.Rittner.
J. appl. Phys. (USA), Vol. 33, No. 8, 2654-5 (Aug., 1962).

See Abstr. 5032 of 1961. By irreversible thermodynamics (and otherwise) one can show that the maximum efficiency of an infinitesimal thermoelectric generator is given by Joffe's formula: $\eta(\max) = (\Delta T/T)\{(1+z)^{1/2}-1\}/\{(1+z)^{1/2}+1\}$ where $z = \alpha^2\sigma T/K > 0$ (α is the Seebeck coefficient, σ and K the electrical and thermal conductivities). While "in principle" the efficiency tends to the Carnot efficiency, $\Delta T/T$, for large z it is emphasized here that this is a misleading formulation, since the properties of actual materials place rather drastic limits on z.

R.O.Davies

PA'62

Theoretical bound on the thermoelectric figure of merit from irreversible thermodynamics. H. Littman and B. Davidson. bibliog J Ap Phys 32:217-19; 33:2655-6 F '62. Ag '62: Discussion (pt 1). E. S. Rittner. 33:2654-5 Ag '62

AS&TI'62

19892 A CLARIFICATION OF THE THEORETICAL UPPER BOUND ON THE THERMOELECTRIC "FIGURE OF MERIT" DERIVED FROM IRREVERSIBLE THERMODYNAMICS. H.Littman.
J. appl. Phys. (USA), Vol. 33, No. 8, 2655-6 (Aug., 1962).

The point made in the paper of the preceding abstract is accepted. It is then remarked that an apparent paradox remains since in the limit of large z the entropy production does not vanish, although the Carnot efficiency is reached. In explanation it is urged that the Joffe formula is approximate and that in any case the infinite load resistance required in the limiting case to realize maximum efficiency leads to zero fluxes.

R.O.Davies

PA62

423 ZERO-FIELD EMISSION FROM THERMIONIC HOLLOW CATHODES. I.Brodie and A.Niewold.
J. appl. Phys. (USA), Vol.33, No.11, 3328-34 (Nov., 1962).

An examination of the theory of the thermionic hollow cathode shows that several distinct modes of zero-field emission are possible. The mode that exists in any given case depends on the relationship between a certain parameter d, which characterizes the nature of the electron cloud within the cavity, and the size of the effusion hole and the cavity dimensions. A quantitative expression is given for the conditions under which the hollow cathode can be used for a precise determination of the thermionic constants by the method of Jain and Krishnan. Under other conditions a quasi-hollow beam is obtained and a theoretical prediction of the total zero-field current from the hole was found to be in order of magnitude agreement with experimental observations. An explanation of the similarity of emissions between 'L' cathodes of different porosity is also given.

PA63

Solid-state conversion concepts for space needs. J. F. Wise. bibliog Elec Eng 81:864-8 N '62

AS&TI'63

27998 DEVELOPMENTS IN THE FIELD OF THERMOELECTRICITY. G. Gramberg and H. G. Plust. Brown Boveri Rev., 49: 501-14(Nov.-Dec. 1962).

In recent years thermoelectricity has become increasingly interesting in the fields of refrigeration and for the direct conversion of heat into electrical energy. General considerations show that the efficiency of this method is governed by the Carnot cycle and by a material factor known as the "figure of merit." The efficient utilization of thermoelectricity requires materials with a high figure of merit: the discovery of such materials is the task of the physicist. Since the thermoelectric production of energy and electrothermal refrigeration are based on the same physical phenomena, both can be devolved from the same first principles. These basic principles are described along with some salient points concerning development work into electrothermal refrigeration. (auth)

NSA'63

25423 THERMODYNAMICS OF THE THERMOELECTRICITY IN THE CHANGE OF PHASE. C.J.Claro.

Bol. Acad. Nac. Cienc. Cordoba (Argentina), Vol. 43, No. 1, 26 pp. (1962).

Considering the reversible thermoelectric phenomena in the production of melting by the Peltier effect in a metal, an extension of the laws of the thermodynamics is made: (1) The Gibbs–Helmholtz equation connects the thermoelectric coefficients with the calorimetric parameters. (2) The free energy variation of the conduction electrons is identified with the Peltier effect. (3) The specific heat variation between solid and liquid is equal to the Thomson heat variation. (4) There is a law of proportionality between the latent heat evolved and the electric charge and between the mass of metal that changes phase and the electric charge. (5) The Peltier coefficient can be obtained from the velocity of the interphase movement. (6) The velocity of the interphase is compared with the drift electronic velocity. PA '63

10892 A THEORY OF THERMOELECTRIC AND THERMO-MAGNETIC EFFECTS. J.Kołodziejczak, L.Sosnowski and W.Zawadzki.

"Semiconductor" Conference, Exeter, 1962 (see Abstr. 6566 of 1963) p. 94-8.

A method of solving the Boltzmann–Lorentz equation is found which enables the general expression for the heat and charge transport in the presence of a magnetic field to be obtained. The method applies to the case of spherically symmetric bands, non-parabolic dispersion law and an arbitrary degree of degeneracy. The formulae for the heat conductivity, the Thomson coefficient, the thermoelectric power, Nernst–Ettingshausen, Righi–Leduc and related effects for the isothermal and the adiabatic case are given. It is shown that the deviation from the parabolic band structure can cause even the reversal of sign of some of the effects. PA '63

23025 ON THE RELATIONSHIP BETWEEN RESISTIVITY AND THERMO-e.m.f. D.Smart and E.Smart.

Phil. Mag. (GB), Vol. 8, 643-50 (April, 1963).

Qualitative indications are given that for a number of thermocouples the relationship between resistivity and thermo-e.m.f. is fairly simple. It is also shown that under certain conditions Mott's equation for thermo-power is directly integrable and leads to an equation for a couple of metals A and B, with junctions at T_1, T_2:

$$ {}_AV_B = \left[\frac{2c\zeta_0}{e}\log\frac{\rho_2 F(T_1)}{\rho_1 F(T_2)}\right]_B^A, $$

where ${}_AV_B$ is the e.m.f., c is a constant, ζ_0 is Fermi energy at 0°K, e is electronic charge and ρ is resistivity. F(T) gives the effect of ionic vibrations in the lattice, being $T(1 + 2\alpha\gamma T)$ at high temperatures, where α is thermal expansion coefficient and γ relates change in volume to change in Debye point. Data for platinum and copper are shown to be consistent with this equation and data for some other non-transition metals are not inconsistent. Since the equation relates thermo-e.m.f. to deviations from the 'standard' form for resistivity, extreme accuracy is required and thermo-e.m.f. and resistivity should preferably be measured on the same specimen. PA 63

24208 POTENTIAL AND CONCENTRATION DISTRIBUTIONS IN A LOW-PRESSURE THERMIONIC ENERGY CONVERTOR. A.A.Ostroukhov.
Radiotekhnika i Elektronika (USSR), Vol. 8, No. 4, 619-21 (April, 1963). In Russian.

Essentially a continuation of the author's article (see Abstr. 9718 of 1963). The theoretical expression for the distribution agrees fairly well with the experimental data; the agreement is not so good as regards the absolute values of the concentration.

PA'63 D.E.Brown

Conversion of thermal to electrical energy with ferroelectric materials. S. R. Hoh. bibliog diags IEEE Proc 51:835-45 My '63

AS&TI '63

25425 THEORY OF THERMOELECTRIC POWER IN LOW-MOPILITY SEMICONDUCTORS.
M.M.Chadda and A.P.B.Sinha.
Indian J. pure appl. Phys., Vol. 1, No. 5, 161-3 (May, 1963).

Investigates the thermoelectric properties of low-mobility semiconductors, in which the charge carriers are localized and the electrical conduction takes place through their hopping motion. The heat of transport (Q^*) and the energy lowering (ϕ) due to the polarization of the lattice are shown to be related by the expression $Q^* = \phi_h - \phi_c$ where ϕ_h and ϕ_c are respectively the components due to polarizations associated with the ions in the hot and cold parts of the semiconductor. It is shown that the contribution of Q^* to the thermoelectric power can be appreciable in some cases. The values of Q^*/ϕ are theoretically evaluated for a face-centred cubic crystal for certain select directions of temperature gradient.

PA'63

Theoretical bound on the thermoelectric figure of merit of two-band semiconductors. E. S. Rittner and G. F. Neumark. bibliog diags J Ap Phys 34:2071-7 Jl '63

AS&TI '63

25424 PHONON-DRAG SEEBECK EFFECT IN A STRONG MAGNETIC FIELD. I. LONGITUDINAL CASE. T.Ohta.
J. Phys. Soc. Japan, Vol. 18, No. 8, 1166-73 (Aug., 1963).

A quantum theory is developed for the phonon-drag thermoelectric power of semiconductors in a longitudinal strong magnetic field with the use of the quantum-limit approximation. Thermoelectric power in the pure crystal is first calculated to give

$$\Delta Q(B)/Q(0) = k_{(ijk)} (\hbar\omega_c/kT)^{1/2}$$

where $\Delta Q(B)$ is the incremental thermoelectric power due to magnetic field, $Q(0)$ is the thermoelectric power without the field, $k_{(ijk)}$ is a constant dependent on the crystal direction $|ijk|$, and ω_c is the cyclotron frequency. This can explain an experiment approximately. Saturation effect, impurity scattering effect, and Herring's hydraulic analogue (1954) are also discussed taking the magnetic field into account.

PA'63

10030 THE PHYSICS OF THERMOELECTRICITY.
R.Wolfe.
Semiconductor Prod. (USA), Vol. 6, No. 4, 23-8 (April, 1963).

The technology of thermoelectric refrigeration and power generation is based on the physics of thermoelectricity. The choice of optimum thermoelectric materials requires an understanding of such basic properties of semiconductors as the electrical and thermal conductivities as well as the various thermoelectric effects. These properties, along with the thermoelectric "figure of merit" which they determine, are defined and discussed, first from a phenomenological point of view and then in terms of the electron theory of semiconductors.

EEA '63

Thermoelectric transients. J. B. Horvay. 11 diags IEEE Trans Applications & Ind p 111-15 My '63

AS 2TI '63

15639 EXPERIMENTS WITH PELTIER JUNCTIONS PULSED WITH HIGH TRANSIENT CURRENTS.
M.Idnurm and K.Landecker.
J. appl. Phys. (USA), Vol. 34, No. 6, 1806-10 (June, 1963).

Landecker and Findlay (Abstr. 16762 of 1962) showed that when transient currents are passed through a cooling Peltier junction the resulting transient temperature depends strongly on the current waveform. In particular, an extremal of the current as a function of time exists for which the resulting transient temperature is much lower than for any other current waveform. With the aid of an experimental method developed for the purpose, temperatures well below 100° K were in fact observed with bismuth telluride junctions. Since the occurrence of temperature transients producing such low junction temperatures is rather difficult to reconcile with some notions of solid-state theory, these results have been re-examined for current densities of up to ~4000 A/cm² using a modified technique that eliminates possible sources of systematic errors in the previous method. The results may be summarized as follows. Up to the highest current densities that could be produced a monotonic increase of the temperature drop with final current density was observed. The final temperature drops ranged from 205° to 120° measured from a reference temperature of ~20°C (room temperature) depending on the efficiencies of the junctions. These efficiencies were difficult to predict from the performance of the junctions with stationary currents. For the highest currents and the very low transient temperatures an error of up to 150° may arise from imperfect heat transfer from the hot junctions to the water-cooled heat sinks unless special probes are provided to measure the Seebeck voltage. It is very likely that the accuracy of the measurements cannot be expected to be improved much further as long as grown crystalline n and p branches are used. It is hoped to produce sintered junctions of more suitable shape and greater mechanical strength for further experiments.

PA 63

32832 ON THE BOUNDEDNESS OF THE DIMENSIONLESS INDEX OF PERFORMANCE OF A NERNST EFFECT GENERATOR. S. W. Angrist (Carnegie Inst. of Tech., Pittsburgh). New York, American Society of Mechanical Engineers, 1963, Preprint 63-APM-4, 4p. (CONF-6-5).
From Conference, Ithaca, N. Y., June 1963.

In an earlier paper, a Nernst effect generator was analyzed by the usual thermodynamic methods and it was found that a bound of unity arises on the dimensionless quantity θT where θ is given as the square of the product of the Nernst coefficient and magnetic field divided by the thermal conductivity and electrical resistivity. By application of the appropriate equations of semiconductor theory, this bound is shown to be justified for four limiting cases: weak magnetic fields considering both extrinsic and intrinsic materials, and strong magnetic fields considering both extrinsic and intrinsic materials. (auth)

NSA '63

E. Apparatus and measurement

19893 A SIMPLE METHOD OF RECORDING THE PELTIER EFFECT AT THE BOUNDARY BETWEEN SOLID AND LIQUID PHASES. G.V.Komarov and A.R.Regel'.
Pribory i Tekh. Eksper. (USSR), No. 2, 160-1 (March-April, 1961). In Russian.

The Peltier effect at a solid-liquid boundary can be studied by observing the movement of the interface during the growth of a crystal. One of the problems involved is the accurate measurement of the position of this interface and this is overcome in the system described. The crystal is grown in a glass tube so that a beam of light can be reflected from the growing crystal. By suitable optics it is possible to obtain an image of the interface on a moving film and to record its position (± 5μ) as a function of time (± 0.1 sec). [English translation in: Instrum. exper. Tech. (USA), No. 2, 369-70 (March-April, 1961; publ. Dec., 1961)]. C.H.Gooch

PA62

11316 (NAA-SR-Memo-6741) HIGH TEMPERATURE SEEBECK COEFFICIENT APPARATUS. E. G. Forster, Jr., and A. J. Saur (Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.). Sept. 14, 1961. Contract [AT-11-1-GEN-8]. 33p.

An apparatus for measuring the Seebeck Coefficient of pellets of "N" and "P" types of lead tellurides was built and operated. The apparatus will measure the Seebeck Coefficient as a function of temperature in the range extending from 350°F up to the melting point of lead telluride. With proper operating technique and applying corrections for known systematic errors, the probable error in the results is less than 20%. (auth)

NSA 63

Measurement of the figure of merit of a thermoelectric material. A. E. Bowley and others. diags J Sci Instr 38:433-5 N '61

Hot probe measures semiconductor thermoelectric power. N. Bobson. il diags Electronics 34:61-3 D 8 '61

Determination of thermal diffusivity by utilization of the thermoelectric effect. D. A. Pinnow and others. bibliog diag R Sci Instr 32:1417-18 D '61

ASTI '62

Study of Fast Transient Behaviour of Peltier Junctions, K. LANDECKER, A.W.FINDLAY. Solid-State Electronics v 3 n 3-4 Nov-Dec 1961 p 239-60. Method developed for measuring temperature of thermojunction after passage of fast transient current pulses, 30 msec to several seconds duration; results obtained are applicable to Peltier heating, but main interest of study is in cooling effect.

EI '62

Apparatus for the rapid scanning of the Seebeck coefficient of semiconductors. L. E. J. Cowles and L. A. Dauncey. diags J Sci Instr 39:16-18 Ja '62

Measurement of the thermal diffusivity of thermoelectric materials. D. J. McNeill. diag J Ap Phys 33:597-600 F '62

ASTI '62

7601 APPARATUS FOR THE RAPID MEASUREMENT OF SEEBECK COEFFICIENT. M.Fraser.
J. sci. Instrum. (GB), Vol. 39, No. 5, 227-8 (May, 1962).

Describes an apparatus which was designed for the rapid but accurate measurement of Seebeck coefficient at several points along the length of a sample. By a simple modification the measuring technique can be extended to cover a range of temperatures. The sample is clamped between steel blocks which are maintained at different temperatures. The temperature gradient and the resulting thermoelectric voltage are measured between two thermocouples which are mounted on the tips of triangular probes. These are constructed of thermal insulation and so do not result in extraneous heat flow. The reproducibility of the results obtained with this apparatus was estimated to be better than 3%. The absolute values are compared with those obtained by a Harman technique and agree to within 5%.

EEA'63

23490 RAPID METHOD FOR MEASURING SEEBECK COEFFICIENT AS ΔT APPROACHES ZERO. J.E.Ivory.
Rev. sci. Instrum. (USA), Vol. 33, No. 9, 992-3 (Sept., 1962).

A rapid method for obtaining the Seebeck coefficient is described. A Seebeck voltage obtained across a sample with respect to one material of a thermocouple is plotted against that obtained across the sample with respect to the second thermocouple material on an X-Y recorder as the temperature gradient across the sample is slowly varied. The slope of this curve, which is not dependent upon accurately matched thermocouples, yields the Seebeck coefficient of the sample. This slope can be measured at a point corresponding to zero ΔT.

PA 62

9864 SURFACE TEMPERATURE MEASUREMENT. ERRORS IN MEASUREMENTS WITH THERMOCOUPLES.
F.Moeler and H.Meyer.
Arch. tech. Messen (Germany), No. 323, (Ref. V 2162-4), 269-72 (Dec.); No. 324, (Ref. V-2162-5). 1-2 (Jan., 1963).
In German.

A thermocouple is embedded in the surface and fixed in position by suitable insulating varnish. The leads run parallel to the surface for a short distance and emerge perpendicular to the surface. Temperature distribution along the leads is estimated by calculating the thermal resistances involved and results for a particular set up are considered. The effect of embedded length and wire diameter are considered.

E.H.Dock

EEA'63

14963 MEASUREMENT OF THERMOELECTRIC MATERIALS AND DEVICES. T.C.Harman.
Semiconductor Prod. (USA), Vol. 6, No. 9, 13-21 (Sept., 1963).

The measurements of electrical resistivity, Seebeck coefficient, thermal conductivity and the thermoelectric figure of merit are discussed in detail. Emphasis is placed on the underlying principles rather than on a comprehensive discussion of the many experimental arrangements which are presently in use. Various experimental factors which may lead to significant measurement errors are mentioned in connection with some experimental methods which have been found useful.

EEA'63

II. MATERIALS

A. Thermoelectric properties

23161 EFFECTS OF IMPURITIES IN BISMUTH TELLURIDE.
H.J.Goldsmid.
"Semiconductor Physics" Conference, Prague, 1960 (see Abstr. 21113 of 1962) p. 1015-17.

Experiments on Bi_2Te_3 containing different impurities are reported. Density measurements suggest that iodine atoms enter the lattice substitutionally. Studies on tin-doped Bi_2Te_3 indicate an unusual temperature-variation of carrier density. Thermoelectric measurements in the intrinsic range, on solid solutions of Bi_2Te_3 with Sb_2Te_3, show that the mobility of electrons can exceed that of holes over a wide range of compositions.

PA62

23084 THE THERMAL AND ELECTRICAL PROPERTIES OF CADMIUM AND MERCURY TELLURIDES.
R.P.Chasmar, E.W.Durham and A.D.Stuckes.
"Semiconductor Physics" Conference Prague, 1960 (see Abstr. 21113 of 1962) p. 1018-22.

The thermal and electrical properties of cadmium telluride, doped with indium and with iodine to give carrier concentrations up to 2×10^{18} electrons cm^{-3} were determined from 25° to 250°C. A value of 0.14 for the effective electron mass ratio at 25°C was obtained and results indicated a rise in this value with temperature. CdTe specimens doped with iodine show a substantial, temperature-independent, increase in thermal resistance while the thermal conductivity of the CdTe –HgTe system is a minimum near the centre of the alloying range. Some thermoelectric figures of merit for CdTe are calculated.

PA62

860 THE INFLUENCE OF THE OXYGEN CONTENT ON ELECTRICAL AND THERMOELECTRIC PROPERTIES OF THE TERNARY SYSTEM $Bi_2Te_{3-x}Se_x$. K.Šmirous and L Štourač.
"Semiconductor Physics" Conference, Prague, 1960 (see Abstr. 21113 of 1962) p. 1017-18.

The influence of oxygen contained in the semiconducting system $Bi_2Te_{2-x}Se_x$ on its electrical and thermoelectric properties was studied. It was shown that the admixture of Bi_2O_3 in a concentration lower than 0·01% to the solid solution of $Bi_2Te_{2,4}Se_{0,6}$ of n-type conductivity causes a decrease of the electrical conductivity, while the thermoelectric power remains unchanged.

PA163

23487 THE THERMOELECTRIC BEHAVIOUR OF $Zn_xCd_{1-x}Sb$. E.Justi.

"Semiconductor Physics" Conference, Prague, 1960 (see Abstr. 21113 of 1962) p. 1074-9. In German.

Until recently measurements by different authors of the Seebeck coefficient α of pure stoichiometric ZnSb showed great discrepancies ranging from α = +90 to α = +455 μ V deg^{-1} C, or even negative values. In the first part of this lecture it is shown how to obtain homogeneous reproducible specimens of ZnSb or $Zn_xCd_{1-x}Sb$ by proper annealing. Within 12% the e.m.f. of such ZnSb can be represented by α = 629 - 200.log σ, of $Zn_{0.9}Cd_{0.1}Sb$ by α = 669 - 200.log σ; the coefficient 200 corresponds exactly to the theoretical value Mk/e according to Schottky and Pissarenko. Doping experiments with impurities as Na, Cr, Ni, Cu, Ge, Pd, In, Sn, Te, Pt, Hg, Bi in different concentrations are described. Cu is the best acceptor in so far as increasing the amount of $\alpha_{\sigma=1}$ by 19 μ V deg^{-1} C. Of all additions only In is able to diminish α and σ acting as donor. In the third part the author describes measurements of α or pure ZnSb, pure $Zn_{0.9}Cd_{0.1}Sb$ and Cu doped $Zn_{0.9}Cd_{0.1}Sb$ down to 4°K, showing a continuous decrease of α; the problem is discussed from the point of view of theory of Seebeck effect and Nernst's theorem, generalized by Kohler.

PA '62

14630 ELECTRIC CONDUCTIVITY OF $BaTiO_3$ BASE SOLID SOLUTIONS OF MANGANESE, COBALT AND NICKEL NIOBATES AND TANTALATES. E.A.Stafiichuk and E.V.Sinyakov. Izv. Akad. Nauk SSSR, Ser. fiz., Vol. 24, No. 11, 1380-3 (1960). In Russian.

"Ferroelectricity" Conference Paper, Moscow, April, 1960 (see Abstr. 12561 of 1962). The resistivity, thermo-e.m.f. and activation energy were measured for solid solutions of barium titanate with manganese, cobalt and nickel niobates and tantalates. X-ray diffraction studies showed that the composition containing AB_2O_6 where A stands for Mn, Co and Ni and B stands for Nb and Ta is a compound. The detailed differences between the many compositions are discussed at length as is the character of the conductivity. [English translation in: Bull. Acad. Sci. USSR, phys. Ser. (USA), Vol. 24, No. 11, 1376-9 (1960)].

P.E.Seiden

PA '62

/843 NEW WAYS FOR THE STUDY OF SEMICONDUCTORS. A.F.Joffe.

"Semiconductor Physics" Conference, Prague, 1960 (see Abstr. 21113 of 1962), p. 9-12.

A survey of outstanding problems and possible lines of development of work on semiconductors, with particular reference to thermoelectricity.

J.B.Birks

PA '63

23303 A NOTE ON THE MECHANISM OF CONDUCTIVITY IN FERROMAGNETIC AND ANTIFERROMAGNETIC SEMICONDUCTORS. Ya.M.Ksendzov and V.A.Stogova.

"Semiconductor Physics" Conference, Prague, 1960 (see Abstr. 21113 of 1962) p. 92-6. In Russian.

A connection of the magnetic arrangement with the electrical properties of transition metals compounds of the 3d group is studied. A supposition is stated that the electrical conductivity is connected with exchange interactions of ions and electrons in the 3d-shell. On the basis of this model a study of electrical conductivity of compounds with ferro- and antiferromagnetic properties, and the properties of these compounds in the paramagnetic region is also made. The work shows that the results of the temperature dependence of electrical conductivity and thermoelectric force in some ferro- and antiferromagnetic semiconductors can be explained by the presented model.

PA 62-

23374 ELECTRICAL PROPERTIES OF Cd_3As_2.
W.Żdanowicz.
"Semiconductor Physics" Conference, Prague, 1960 (see Abstr. 21113 of 1962) p. 1095-9.

Resistivity, Hall coefficient, magnetoresistivity and thermoelectric power were measured for Cd_3As_2 monocrystals (n-type conductor) between 95° and 700°K. The Hall constant amounted to $R = -3.6\ cm^3\ C^{-1}$ ($n = 2 \times 10^{18}\ cm^{-3}$), resistivity $\rho = 3.86 \times 10^{-4}\ \Omega\ cm$. The activation energy of electron $\Delta E_0 = 0.14$ eV was calculated from the Hall slope. The Hall mobility of electrons at 290°K, $\mu_H = 8/3\pi(R\sigma) = 9500\ cm^2\ V^{-1}\ sec^{-1}$, while at 95°K, $\mu_H = 27\,000\ cm^2\ V^{-1}\ sec^{-1}$. Between 95° and ~350°K the Hall mobility changed according to the law $\mu_H \sim T^{-1}$, from ~350° to 475°K — according to $\mu_H \sim T^{-1.5}$, while above 475°K according to $\mu_H \sim T^{-2.5}$. The thermoelectric power at 300°K was $\alpha = -60\ \mu V\ deg^{-1} K$. The Fermi level expressed in terms of $\eta = \zeta/kT$ was always larger than two. The effective mass of electron increased with temperature from $m_n^* = 0.046\ m_0$ to $m_n^* = 0.066\ m_0$ at 290° and 700°K respectively.

PA62

23399 ELECTRICAL AND THERMAL PROPERTIES OF In_2Te_3 SEMICONDUCTOR WITH DEFECT STRUCTURE.
V.P.Žuze, A.I.Zaslavskiĭ, V.A.Petrusevič, V.M.Sergeleva, I.A.Smirnov and A.I.Šelykh.
"Semiconductor Physics" Conference, Prague, 1960 (see Abstr. 21113 of 1962) p. 871-81. In Russian.

Electrical conductivity, Hall effect, thermoelectric power, thermoconductivity and absorption spectrum of In_2Te_3 (semiconductor with defect structure) was studied. A polymorphic $\alpha \rightleftharpoons \beta$ change which can be attributed to the process of ordering cation vacancies or the reverse process was found and studied. The defect of the lattice and the degree of order of the vacancies determines the size and temperature dependence of electron and phonon scattering.

PA62

23401 SCATTERING AND EFFECTIVE MASS OF CURRENT CARRIERS IN LEAD SELENIDE.
I.A.Smirnov, B.Ya.Moižes, E.D.Devyatkova, E.D.Nensberg and A.A.Averkin.
"Semiconductor Physics" Conference, Prague 1960 (see Abstr. 21113 of 1962) p.645-8. In Russian.

Thermal and electrical conductivity, thermoelectric force and the Hall coefficient were measured on samples of PbSe with different concentrations of impurity electrons and holes in the temperature range from 90° to 430°K. It is shown that current carriers scatter on acoustical modes and their effective mass changes with temperature. This change can be connected with the anomalous temperature dependence of mobility. An analogous dependence of mobility on m* can be obtained from electrical conductivity and thermoelectric force measurements during hydrostatic pressure. Some suppositions are quoted on the band structure of PbSe. According to these suppositions the change m* must be of the same order as the change in width of the forbidden band experimentally found as $\Delta\rho/\rho$.

PA62

23413 ELECTRONIC CONDUCTION IN RUTILE (TiO_2).
H.P.R.Frederikse, W.R.Hosler and J.H.Becker.
"Semiconductor Physics" Conference, Prague, 1960 (see Abstr. 21113 of 1962) p. 868-70.

Measurements of conductivity, Hall effect and thermoelectric power performed on slightly reduced crystals of rutile can be explained with a model involving two conduction mechanisms: one of free electrons in a narrow 3d-band of titanium (above 5°K), and the other of self-trapped electrons or polarons in a polaron band (below 5°K). The ionization energy of the polaron increases from ~0.01 to 0.07 eV with increasing temperature.

PA62

V 23415 ELECTRICAL AND OPTICAL PROPERTIES OF $Zn_xCd_{1-x}Sb$ SOLID SOLUTIONS.
L.Štourač, J.Tauc and M.Závětová.
"Semiconductor Physics" Conference, Prague, 1960 (see Abstr. 21113 of 1962) p. 1091-4.

Measurements of electrical conductivity, Hall constant, thermoelectric power and infrared absorption studied with polarized radiation on single crystals CdSb and $Zn_xCd_{1-x}Sb$ solid solutions are reported and discussed.

PA 62.

AD-294 688 Div. 14
(TISTM/ODN) OTS price $1.60

Union Carbide Corp., Parma, Ohio.
THERMOELECTRIC MATERIALS.
Final rept., 28 Jan 59-28 July 60,
comp. by R. G. Breckenridge. 15 Aug 60, 17p.
incl. illus. tables.
(Contract NObs-77066, Proj. NS 058-001)
Unclassified report

DESCRIPTORS: *Thermoelectricity, *Crystals, Nitrides, *Rare earth compounds, *Semiconductors, Generators, Carbon, Graphite, Thermal conductivity, Theory, Halides, Alkali metal compounds, Chemical impurities, Boron, Density, Physical properties, Resistance, Temperature, Electrical conductance, High temperature research, Materials.

Contents:
Carbon and graphite materials
Refractory nitrides
Alkali metals in their fused halides
Crystal chemistry
Thermal conductivity
Theoretical studies
Development of prototype generators

63

874 THE PREPARATION AND PROPERTIES OF AgTlTe: A NEW SEMICONDUCTOR. J. Black and E. Banks.
"Semiconductor Physics" Conference, Prague, 1960 (see Abstr. 21113 of 1962) p. 1007-9.

Melting point data, metallographic examination and X-ray powder patterns of sections of zone-refined ingots of composition AgTlTe indicated that this material was a ternary compound. Electrical measurements showed that AgTlTe was a p-type semiconductor with a high resistivity and a high thermoelectric power. The temperature variation of resistivity for a purified sample suggested a forbidden energy gap of about 0·65 eV.

PA 63

V 23378 THE ELECTRICAL PROPERTIES OF CHROMIUM CARBIDES.
S.N.L'vov, V.F.Nemchenko, T.Ya.Kosolapov and G.V.Samsonov.
Fiz. Metallov i Metallovedenie (USSR), Vol. 11, No. 1, 143-5 (Jan., 1961). In Russian.

The electrical resistivity, Hall coefficient, thermoelectric power, and temperature coefficient of resistivity of chromium and three of its carbides were measured at room temperature. With increasing carbon content, the conduction mechanism changed from being predominantly hole to electronic in origin. [English translation in: Physics of Metals and Metallography (GB), Vol. 11, No. 1, 138-40 (1961; publ. Oct., 1961)].

P.A.Walker
PA 62

AD-294 668 Div. 25, 17
(TISTM/SJR) OTS price $1.60

Merck and Co., Rahway, N. J.
STRUCTURAL INVESTIGATIONS IN THERMOELECTRIC MATERIALS.
Progress rept. no. 4, 1 Dec 60-31 Jan 61, by P. I. Pollak, J. B. Conn and others. 31 Jan 61, 15p. incl. illus. tables. (Contract NObs-78503, Proj. SR 010024)
Unclassified report

DESCRIPTORS: *Semiconductors, *Antimony alloys, *Bismuth alloys, *Tellurium alloys, *Electrical properties, Thermal conductivity, Thermal diffusion, Mercury alloys, Selenium alloys, Vanadium alloys, Metallurgy, Processing, Crystal structure, Lattices, X-ray diffraction analysis, Resistance, Thermoelectricity.

Two further alloys in the system BiSbTe were investigated in order to complete our evaluation bracketing Alloy 68 compositions. The systems selected were $Bi_{28}Sb_{48+x}Te_{134-x}$ and $Bi_{12}Sb_{70+x}Te_{158-x}$. In general, the two alloys seem to fall in line chemically with Alloy 68 in that effects of compositional changes on the electrical properties become minimized as the antimony content of the alloy increases. This is in line with our concepts of poising. Introduction of selenium into the antimony-rich alloy leads to an overall degradation of the figure of merit. Investigations were continued in the analogous vanadium alloy system of Alloy 68. The compositions turned out to be nearly degenerate and further work was discontinued. Substitution of arsenic for antimony was carried out in an alloy system patterned after Alloy 68, but experimental difficulties have to date precluded any reasonable results. Elimination of bismuth from this system leads to alloys in the series SbAsTe which have proven to be p-type materials with low Seebeck coefficients. (Author)

'63

23234 VARIATIONS IN ELECTRICAL RESISTIVITY AND THERMO-ELECTROMOTIVE FORCE IN THE PROCESS OF $\alpha \rightleftharpoons \gamma$ TRANSFORMATION IN ALLOYED IRON.
M.E.Blanter and A.K.Mashkov.
Fiz. Metallov i Metallovedenie (USSR), Vol. 11, No. 2, 194-202 (Feb., 1961). In Russian.

The Fe–Cr system was studied in the composition range 4.32-12.63 at.% Cr, from room temperature to 1000°C. [English translation in: Physics of Metals and Metallography (GB), Vol. 11, No. 2, 41-8 (1961; publ. Nov., 1961)].

PA62

23485 INVESTIGATION OF THE KINETICS OF RECOVERY OF THE THERMO-ELECTROMOTIVE FORCE IN COLD-DEFORMED IRON. V.I.Ivanov and K.A.Osipov.
Fiz. Metallov i Metallovedenie (USSR), Vol. 11, No. 3, 360-7 (March, 1961). In Russian.

An investigation was made of cold-deformed specimens of various degrees of purity. Activation energies were obtained for the process of recovery as a function of degree of deformation and recovery. A maximum activation energy was found. [English translation in: Physics of Metals and Metallography (GB), Vol. 11, No. 3, 41-6 (1961; publ. Nov. 1961)].

PA '62

AD-286 098 Div. 30, 14
(TISTM/EJH) OTS price $2.75

Stanford Research Inst., Menlo Park, Calif.
SURFACE TEMPERATURE MEASUREMENTS WITH THERMOELECTRIC MATERIALS.
Final rept., 1 June 60-31 May 61.
Aug 62, 109p. incl. illus. tables, refs.
(Contract AF 33(616)7377, Proj. 1347)
(ASD TR 61-373)

Unclassified report

DESCRIPTORS: *Thermocouples, *High temperature research, Reliability, Instrumentation, Aerodynamic heating, Simulation, Surfaces, Temperature, Heat transfer, Thermal conductivity, Noise, Vibration, Calibration, Stability, Materials, Wire, Copper alloys, Nickel alloys, Platinum alloys, Rhodium alloys, Chromium alloys, Aluminum alloys, Bibliography, Coatings.

A study was made of the errors in surface-temperature measurements made with a thermocouple (TC), when both TC wires and surface are exposed to radiant energy. The errors arise from the net heat transfer at the TC junction, and the quality and stability (change in calibration) of the TC materials. The response of surface TC's to transient heating was studied. For a single specimen thickness, transient response is greater for large TC wire diameter during the initial transient heating period but becomes independent of TC wire diameter when the heat flux rate reaches steady state. The magnitude of errors arising from instability, which is independent of the quality of TC materials, depends upon the exposure condition and duration. The calibration of commercial thermocouples, whether noble metal or base metal, will probably change less than 1 F after exposure at less than 1000 F in air for 1000 hours. Failure of TC's due to vibration at 40 cps and 2 to 3g acceleration for up to 4 hours is unlikely up to temperatures of about 1300 F. (Author)

'63

21155 INVESTIGATION OF THE TERNARY SEMICONDUCTOR COMPOUND $PbBiSe_2$.
L.S.Palatnik, O.M.Konovalov, N.T.Gladkikh and V.N.Kolesnikov.
Fiz. Metallov i Metallovedenie (USSR), Vol. 11, No. 5, 677-80 (May, 1961). In Russian.

Reports, inter alia, the composition dependence of the thermo-e.m.f., the temperature dependence of the electrical resistivity, the V-I characteristic of a point contact, and X-ray structure data. [English translation in: Physics of Metals and Metallography (GB), Vol. 11, No. 4, 36-9 (1961; publ. Jan., 1962)].

12391 EXTENSION OF THE RANGE FOR MEASURING VACUUM BY THE THERMOELECTRICAL METHOD.
M.I.Korsunskii, R.I.Zaichik and L.N.Lembik.
Pribory i Tekh. Eksper. (USSR), 1961, No. 3, 114-18 (May-June). In Russian.

The thermoelectrical method of measuring vacuum is based on the dependence of the thermal conductivity of the gas on pressure. By reducing the thermal conductivity of the manometer and its radiation losses, the relative importance of the main working processes of the method—the heat transfer through the gaseous medium—can be increased. The thermal conductivity of the manometer was reduced by the use of a thin-layer heater and thermopiles. The radiation is reduced by spraying the heater with two metals and cooling it by using the Peltier effect. The work shows that the application of thin-layer manometers and the utilization of the Peltier effect make possible an increase of the range of the thermoelectrical method into the high-vacuum region, i.e. to about 5 to 6×10^{-6} mm Hg. [English translation in: Instrum. exper. Tech. (USA), No. 3, 527-30 (May-June, 1961; publ. Dec., 1961)].

EEA '62

24058 (WCAP 18[illegible]0) THERMOELECTRIC NUCLEAR FUEL ELEMENT QUARTERLY PROGRESS REPORT, APRIL-JUNE 1961. (Westinghouse Electric Corp. Atomic Power Dept., Pittsburgh). July 10, 1961. Contract AT (30-3)-500. 47p.

Uranium-bearing thermoelectric compounds are now being prepared by tantalum bomb melting and by the hydride process. Tests of devices made up from these compounds indicate that the main fabrication problems are densification and contact bonding. Data from a hot-swaged pellet and a swaged device of US_2 indicate some promise for that compound. Improvements in techniques of thermoelectric parameter measurements include programming of automatic test data recording at desired intervals around the clock; increased accuracy and versatility of measurements through use of a newly-constructed adjustable precision resistor; and a method for measuring which should lead to an experimental means for determining the thermoelectric figure of merit, Z. Potential profile studies on PbTe pellets are yielding important information on contact resistance parameters. A fission-fired thermoelectric generator is being prepared for the next in-pile test. (auth) NSA 63

24064 (WCAP 1865) THERMOELECTRIC NUCLEAR FUEL ELEMENT QUARTERLY PROGRESS REPORT, JULY-SEPTEMBER 1961. (Westinghouse Electric Corp. Atomic Power Dept., Pittsburgh). Oct. 10, 1961. Contract AT(30-3)-500. 38p.

Samples of makeup compositions U_2S_3, U_2Se_3, U_3Se_5, U_3Te_4, and UTe_2 were prepared by solid-vapor reaction process. In addition, the following samples were melted in sealed tantalum bombs at the indicated temperatures: U_3Se_4, 1800°C; UTe_2, 1480°C; U_3Te_4, 1430°C; and UTe, 1490°C. A U_3S_5 sample was run to 1800°C in the 2500°C high vacuum furnace, at which point the bomb failed, resulting in severe damage to the tantalum furnace parts. Thermoelectric properties of the above compounds indicate their uses for thermoelectric fuel elements. The theory and development of the Z-meter were described by thermoelectric measurements. Thermoelectric measurements were indicated for PbTe, Bi_2Te, and USeTe. Radiation effects studies on lead telluride elements were completed and reported. Design and fabrication of nine PbTe elements were evaluated. (N.W.R.) NSA 63

AD-288 455 Div. 7, 14
(TISIM/ODN) OTS price $1.10

Electro-Optical Systems, Inc., Pasadena, Calif.
HIGH TEMPERATURE SEMICONDUCTING COMPOUNDS FOR THERMOELECTRIC POWER GENERATION.
Bi-monthly progress rept. no. 4, 15 June-15 Aug 61,
by C. B. Jordan. 30 Aug 61, 9p. (EOS rept. no. 1592-2M-4)
(Contract NObs-84327)
Unclassified report

DESCRIPTORS: *Semiconductors, *Power supplies, Resistance, Intermetallic compounds, Thorium compounds, Sulfides, Selenides, Uranium compounds, Tellurides, Thermoelectricity.

63

11294 (AD-277223) THERMOELECTRICITY QUARTERLY PROGRESS REPORT NO. 2, JULY 1, 1961-OCTOBER 1, 1961. (Westinghouse Electric Corp. Research Labs., Pittsburgh). Contract NObs-84687. 61p.

An evaluation was made of the proposal that narrow band semiconductors offer good possibilities as thermoelectric elements. It is shown that Tz goes to zero as the band width goes to zero. Results of recent studies on the thermal conductivity of the Ge-Si alloys are discussed. Present theory of lattice thermal resistance is seen to be in reasonable agreement with the experiment. Schroeder criticized the paper of Cosgrove, McHugh, and Tiller in which they explained the variation of thermoelectric properties with growth rate of Bi_2Te_3. It is pointed out that the criticism is invalid. A discussion of the definitions of thermoelectric effects in non-linear junctions is given. (auth) NSA 63

6633 (AD-274831) THERMOELECTRIC MATERIALS. Report No. 6. Final Report, January 1, 1960-September 30, 1961. T. S. Shevlin, Henry E. Wenden, and S. R. Ali Zaidi (Ohio State Univ. Research Foundation, Columbus). Sept. 1961. Contract NObs-78254. 32p.

Difficulty was experienced in containing molten $Na_2O \cdot V_2O_4 \cdot 5V_2O_5$, a highly corrosive fluid. The precision and reproducibility of all results were very low. $Na_2O \cdot V_2O_4 \cdot 5V_2O_5$ has a potential difference of 2500 μv/°C as referred to platinum when oxygen is circulated over the hot junction and the cold junction is sealed. When air is circulated over the hot junction and the cold junction is sealed, a maximum potential difference of 700 μv/°C may be attained. As the difference in temperature between hot and cold junctions is decreased, the potential difference increases, rising to a maximum near a temperature difference of 40°C. A reducing atmosphere over the hot junction reduces the thermal emf, and, if sufficiently reducing, reverses the polarity; an oxidizing atmosphere raises the emf, as compared with a neutral (He) atmosphere. (auth) NSA 63

14924 (AD-278451) THERMOELECTRIC MATERIALS. Bi-Monthly Progress Report No. 11, September 1-October 31, 1961. Merton H. Brooks (Titanium Alloy Mfg. Div., National Lead Co., Niagara Falls, N. Y.). Contract NObs-78326. 10p.

Preparation of CeO_2 ceramic materials with additions of Y_2O_3, La_2O_3, and Nb_2O_5 is reported. Data on composition and properties of these materials are tabulated. It was found that although these bodies are not well sintered at 2900°F, they are badly over-fired at 3000°F. Standard ceramic bodies were also fabricated from $PbNb_2O_6$ and $Pb_2Nb_2O_7$ with additions of CdO, Bi_2O_3, Sb_2O_5, MoO_3, and WO_3. Data on these materials are included. Results obtained in electric conductivity and Seebeck coefficient measurements on forty-two CeO_2-base compositions are also included. (J.R.D.) NSA 63

10[illegible]3 SINTERING THEORY AND EFFECTS IN THE POWDER METALLURGY OF THERMOELECTRIC MATERIALS.
H.Schreiner and F.Wendler.
UK Atomic Energy Authority AERE Transl.899, 26 pp. (Oct., 1961; publ. 1962). English translation of article in. Z. Metallk. (Germany), Vol.52, No.4, 218-28 (1961).

The production of thermoelectrical materials by powder metallurgical methods depends mainly on the fabrication process. Thermoelectrical properties are not only influenced by the material and its composition but mostly by its structure. Different powder metallurgical fabrication methods for the production of sintered semiconductors are described. It is desirable to obtain the highest possible sinter or final density together with the optimum thermoelectrical properties. The influence of compacting pressure and sintering temperature on sintering density was studied. Data are presented which show possibilities of cold compacting the compound Bi_2Te_3. The drop of density under certain working conditions is discussed. EEA'63

Poluchenie i issledovanie termoelektricheskikh materialov na osnove Bi-Sb-Te, A.D.GOLETSKAYA, V.A.KUTASOV, E.A.POPOVA. Fisika Tverdogo Tela v 3 n 10 Oct 1961 p 3002-8; see also English translation in Soviet Physics, Solid State v 3 n 10 Apr 1962 p 2189-93. Production and investigation of thermoelectric materials based on Bi-Sb-Te; specimens were prepared by controlled crystallization and investigated as thermocouple material; maximum temperature difference of 70 C was obtained with hot junction at 30 C. EI 62

23880 INVESTIGATION OF PLATINUM–MOLYBDENUM ALLOYS. H.Nishimura.
UK Atomic Energy Authority AERE Transl.T884 6pp. (Nov., 1961). English translation of article in: J.Japan Metals Assoc., Vol. 22, No. 8, 425-8 (1958).

Pt–Mo alloys were arc-melted in argon atmosphere. Their melting temperatures were measured, and X-ray analyses and microscopical study were carried out. From these results the equilibrium diagram was constructed. This alloy system consists of three kinds of solid phases, i.e. the Pt-rich solid solution α, an intermediate β corresponding to a Pt–Mo compound, and the Mo-rich solid solution γ. The liquidus of β phase shows a maximum and on the Pt-side a peritectic reaction liquid $+ \beta \rightleftharpoons \alpha$ occurs; on the Mo-side there exists a eutectic reaction liquid $\rightleftharpoons \beta + \gamma$. The electric resistance of Pt-rich alloys and the thermo-electromotive forces of Pt–(Pt–Mo) alloys were measured. The thermo-electromotive force shows a maximum value at about 3.5% Mo. PA 62

11293 (AD-277122) THERMOELECTRICITY QUARTERLY PROGRESS REPORT NO. 4, SEPTEMBER 11, 1961–NOVEMBER 11, 1961. (Westinghouse Electric Corp. Research Labs., Pittsburgh). Contract NObs-84317. 228p.

Eight papers having a direct bearing on the thermoelectric project are included. The role of Se vapor pressure in the formation of Ag-doped MnSe was studied. The effects of doping on the vapor pressure of a thermoelectric material were investigated toward the solution of practical problems of thermocouple encapsulation. Preparations and properties of some rare earth semiconductors and certain mixed hydride–chalcogenide rare earth compounds were investigated. Directions are given for the preparation of the optimumly doped thermoelectric material CeS 1.38 and for many other rare earth compounds which were investigated as possible thermoelectric elements. Solid solution studies were made on some post-transition metal tellurides of the rock-salt structural type and on electrical properties of T_lSbTe_2–T_lBiTe_2 solid solutions. A technique for pulling single crystals of volatile materials, a rotating sample method for measuring the Hall mobility, and a steady-state comparative apparatus for measuring thermal conductivity between 100 and 800°C are described. (auth) NSA '63

Leitfaehigkeit und Hallkonstante--15. W.KOESTER, W.GMOEHLING. Zeit fuer Metallkunde v 52 n 11 Nov 1961 p 713-20. Electric conductivity, thermoelectric power, and Hall effect of solid solutions of nickel with its neighbor elements in Periodic System; measurements determining effects of temperature and alloy concentration on these properties in Ni-rich solid solutions with titanium, vanadium, chromium, and manganese; interpretation of results and of literature data for other nickel alloy systems according to band model. 31 refs. EI '62

Interrelation of Electronic Properties and Defect Equilibria in PbTe. E.MILLER, K.KOMAREK, I.CADOFF. J Applied Physics v 32 n 11 Nov 1961 p 2457-65. Resistivity, Hall coefficient, and Seebeck coefficient of interest for use in thermoelectric generators were investigated in range from 77 to 900 K; low temperature properties obtained agree with data reported in literature; for understanding thermal energy gap obtained from high temperature measurements it is necessary to include carriers generated by defect formation at elevated temperatures, both Schottky-Wagner and Frenkel defects being present. EI 62

Summarized Proceedings of Conference on Thermoelectricity Durham, July 1961. B.R.PAMPLIN. Brit J Applied Physics v 12 n 11 Nov 1961 p 592-4. Main features of presented papers; potential application of suitable materials to thermoelectric energy conversion and thermoelectric refrigeration; detailed works on semiconductors, individual compounds and alloys presented. EI 62

Measurement of Figure of Merit of Thermoelectric Material. A. E.BOWLEY, L.E.J.COWLES, G.J.WILLIAMS, H.J.GOLDSMID. J Sci Instruments v 38 n 11 Nov 1961 p 433-5. Apparatus described uses only direct current and is based on Harman's technique, in which temperature gradient is established by means of Peltier effect; corrections for radiative heat transfer take relatively simple form at room temperature; figure of merit of thermoelectric material can also be obtained by measuring maximum lowering of temperature using Peltier effect in junction between sample under test and metal. EI 62

7751 AN INVESTIGATION OF $Li_xNi_{1-x}O$ AS MIXED-VALENCE THERMOELECTRIC MATERIAL.

J.C.Danko, G.R.Kilp and H.M.Ferrari.

Solid-State Electronics (GB), Vol.3, No.3-4, 233-8 (Nov.-Dec., 1961).

The mixed valence material, $Li_xNi_{1-x}O$, was investigated as a potential thermoelectric material. Measurements of the Seebeck coefficient, α(μ V/deg C), electrical resistivity, p(Ω-cm), and thermal conductivity, k(W/cm deg C) were made as a function of temperature and lithium concentration. The thermoelectric figure of merit, Z (α^2/pk), reaches a value of approximately $1{\cdot}4 \times 10^{-4}$ at 1100°C for the composition $Li_{0.04}Ni_{0.96}O$. EEB '62

23927 (WCAP-1703) FABRICATION OF THERMOELECTRIC MATERIALS BY ROTARY SWAGING J. C. Danko, R. C. Goodspeed, G. R. Kilp, and P. V. Mitchell (Westinghouse Electric Corp. Atomic Power Dept., Pittsburgh). Dec. 1961. Contract AT(30-3)-500. 32p.

A powder metallurgy process for fabricating thermoelectric materials into tubular elements by rotary swaging is described. Results of swaging studies on n- and p-type PbTe and $Bi_xGe_{1-x}Te$ are reported. Results are reported on the measurements of electrical resistivity, Seebeck coefficient, and thermal conductivity of n- and p-type PbTe swaged annular elements. The compatibility of lead telluride and bismuth germanium telluride with a variety of cladding materials is reported. Data are presented for several combinations of thermoelectric and cladding materials as follows: representative photomicrographs of the thermoelectric material–clad interface of swaged and heat treated specimens, and reaction zone thickness values plotted versus time at constant temperature. (auth) NSA'63

Low-Temperature Thermoelectric Power of Rare-Earth Metals, H.J.BORN, S.LEGVOLD, F.H.SPEDDING. J Applied Physics v 32 n 12 Dec 1961 p 2543-9. Seebeck coefficients (thermoelectric powers) of yttrium, lanthanum, and 11 of rare earths have been measured for temperature range 7 to 300 K; with exception of samarium and ytterbium, TEP of metals are negative throughout most of temperature range covered, and, with same exception TEP curves have about same slope near room temperature. 47 refs. EI 62

Low-temperature thermoelectric power of the rare-earth metals. H. J. Born and others. biblog diag J Ap Phys 32:2543-9 D '61

ASTTI '62

14500 ELECTRIC PROPERTIES OF AMORPHOUS TELLURIUM FILMS AND THE EFFECT OF IMPURITIES ON THE CONDITIONS OF THEIR CRYSTALLIZATION.
In' Shi-duan' [Yin Shih-tuan] and A.R.Regel'.
Fiz. tverdogo Tela (USSR), Vol. 3, No. 12, 3614-20 (Dec., 1961).
In Russian. English translation in: Soviet Physics–Solid State (USA), Vol. 3, No. 12, 2627-31 (June, 1962).
For abstract see Abstr. 8284 of 1962. PA'62

14593 THERMOELECTRIC PROPERTIES OF Mg_2Si–Mg_2Sn SOLID SOLUTIONS.
E.N.Nikitin, V.G.Bazanov and V.I.Tarasov.
Fiz. tverdogo Tela (USSR), Vol. 3, No. 12, 3645-9 (Dec., 1961).
In Russian. English translation in: Soviet Physics–Solid State (USA), Vol. 3, No. 12, 2648-51 (June, 1962).
For abstract see Abstr. 8453 of 1962. PA'62

New alloy generates more power; thermoelectric generators. Il Iron Age 188:121 D 7 '61

ASTTI '62

Hot Probe Measures Semiconductor Thermoelectric Power, N. BOBSON. Electronics v 34 n 49 Dec 8 1961 p 61-3. Temperature stabilized probe determines thermoelectric power of semiconductor samples without sample preparation or shaping; device permits point measurement of Seebeck coefficient. EI 62

Continuous Casting of Thermoelectric Materials, R.J.HACH, M. J.BRAU, T.S.BURKHALTER. Rev Sci Instruments v 32 n 12 Dec 1961 p 1341-3. Casting apparatus for producing thermoelectric material rapidly, reliably, and in large quantities with minimum amount of labor; bismuth telluride and alloys of Bi_2Te_3, Sb_2Te_3, and Bi_2Se_3 were cast in rods up to 70 in. in length; deviation of thermoelectric properties throughout length of rods was less than 5%. EI 62

14748 (AERE-Trans-899) SINTERING THEORY AND EFFECTS IN THE POWDER METALLURGY OF THERMOELECTRIC MATERIALS. H. Schreiner and F. Wendler. Translated by D. P. Donnelly (U.K.A.E.A. Atomic Energy Research Establishment, Harwell, Berks, Eng.) from Z. Metallk., 52: 218-28(1961). 29p.

Sintering force theories and the mechanisms responsible for substance transport during sintering processes are discussed. The vacancy diffusion mechanism must be considered when sintering theories are applied to semiconductors. The production of thermoelectric materials by powder metallurgical methods depends mainly on the fabrication process. Thermoelectric properties are not only influenced by the material and its composition but mostly by its structure. Different powder metallurgical fabrication methods for the production of sintered semiconductors are described. It is desirable to obtain the highest possible sinter or final density together with the optimum thermoelectric properties. The influence of compacting pressure and sintering temperature on sintering density has been studied. Data are presented which show possibilities of cold compacting the compound Bi_2Te_3. The drop of density under certain working conditions is discussed. (auth) NSA 63

15539 ELECTRICAL AND THERMOELECTRIC PROPERTIES OF THIN COBALT LAYERS. F.Savornin.
"Thin Layers" Conference, Liège, 1961 (see Abstr. 13029 of 1963). p. 69-76. In French.

The study was carried out in vacuum and in a proper enclosure where the films had been preparated by thermal evaporation. The spontaneous evolution showed a reduction of the electrical resistance on certain rather thick films, but the phenomenon was inversed for thinner films; the passage from one type of evolution to the other took place for films about 100 Å thick. The first heating irreversible curve R = f(T) looks like the one established for iron by other authors. For a film of given "thickness" this curve makes it possible to determine the value of the resistance of a film having the same thickness, if it was condensed on a support at a known temperature T. The thermoelectric power of the couple constituted by an Ag thread and the thin Co film changes with temperature and, when temperature is known, with the thickness of the film. It increases with thickness and approaches the value obtained for the silver-massive cobalt couple. The results agree with the theory of Justi et al. (1951) on the thermoelectric power of thin films.

PA '63

Neu bestimmte Grundwerte fuer die Thermopaerkombination Pt 30%Rh-Pt6%Rh, W.OBROWSKI, W.PRINZ. Archiv fuer das Eisenhuettenwesen v 33 n 1 Jan 1962 p 1-4. Redetermination of calibration values of thermoelectric voltage for thermocouple combinations Pt30%Rh-Pt6%Rh, called PtRh18, between 0 and 1800 C; corrections were made on basis of more than 2500 measurements at fixed point temperatures; greatest changes in old values had to be made at below 250, between 1250 and 1500, and above 1650 C.

41665 SEMI-CONDUCTING DEVICE FOR THE PRODUCTION OF ELECTRICAL ENERGY. (to Telefunken GmbH). French Patent 1,286,969. Jan. 29, 1962. Priority date Mar. 9, 1960, Germany.

A device designed for the production of electrical energy consists of a semiconductor, in which a beta-emitter, such as Ni^{63} or Pd^{107}, is incorporated in the p-n junction. (NPO)

NSA '63

9236 HIGH TEMPERATURE THERMOCOUPLES IN THE ROVER PROGRAM.
A.R.Driesner, C.P.Kempter, C.E.Landahl, C.A.Linder and T.E.Springer.
IRE Trans nuclear Sci. (USA), Vol. NS-9, No. 1, 247-52 (Jan., 1962). [Proceedings of the International Symposium on Aerospace Nuclear Propulsion, Las Vegas, Nevada (Oct., 1961)].

Tungsten/tungsten-rhenium thermocouples have been successfully used for various hydrogen gas temperature measurements in the Kiwi-A reactors of the Rover nuclear propulsion programme. The most useful combination has been tungsten coupled with a tungsten-rhenium alloy containing 25% rhenium. This alloy exhibits a solidus temperature over 3100°C, has considerably more ductibility than tungsten, and gives an e.m.f. of about 40 mV against tungsten at 2300°C. Four thermocouples were used to measure the temperature of exit gases in the Kiwi-A3 test. All four survived the test and gave similar readings, three of them within 0·5%. Bare wire thermocouples will probably be used in an automatic control system of exit gas temperatures in some subsequent Rover tests.

R.A.Bones

EEA '62

9237 A NOTE ON PLATINUM/PLATINUM RHODIUM THERMOCOUPLE UNCERTAINTY. W.E Bostwick. IRE Trans. nuclear Sci. (USA), Vol. NS-9, No. 1, 253-9 (Jan., 1962). [Proceedings of the International Symposium on Aerospace Nuclear Propulsion, Las Vegas, Nevada (Oct., 1961)].

During the Tory II-A nuclear rocket programme tests were made on eight samples selected at random from platinum/platinum-rhodium thermocouples purchased for test use. Tests between 2000° and 2400°F extended over a 12-week period during which the error spread for all samples was about ± 10° F and was fairly constant. As a result, extensive tests were carried out on thermocouples manufactured in different ways from different diameter wires. It is concluded that the platinum/platinum-rhodium thermocouple is not a satisfactory standard for this temperature range. It is hoped to extend the use of platinum resistance thermometers up to 2000°F.

R.A.Bones

EE 7 '62

Thermo-Electric Properties of Metals and Alloys as Functions of Mechanical and Thermal Treatments. G.P.CHATTERJEE. J Mines, Metals & Fuels v 10 n 1 Jan 1962 p 14-18. Wires of aluminum, copper, nickel, brass and nichrome were given stress relieving anneal in vacuum and then cold drawn; their thermoelectromotive forces against constantan were then measured and plotted as function of cold deformation; wires were then heated in vacuum at different temperatures for different times and their thermoelectromotive forces measured; some investigations have been made on effects of quenching and annealing on high carbon steel wires.

E.7.63

2984 THE PROBLEM OF BINDING FORCES IN THE CRYSTAL LATTICE OF α-IRON, Fe–Cr AND Fe–Mn SOLID SOLUTIONS. I.Kh.Varivoda. Fiz. Metallov i Metallovedenie (USSR), Vol. 13, No. 1, 144-6 (Jan., 1962). In Russian. English translation in: Physics of Metals and Metallography (GB), Vol. 13, No. 1, 129-31 (1962; publ. Sept., 1962).

Fe–Cr and Fe–Mn alloys with up to 8·5 at. % of the second constituent were prepared and the thermoelectric power of iron-alloy couples and of annealed-alloy–cold deformed-alloy couples were measured. The results are discussed in terms of the lattice binding forces.

H.Mykura

PA '63

36280 (AD-291456) THERMOELECTRIC MATERIALS FOR POWER CONVERSION. Quarterly Progress Report No. 4 (Final), February 1, 1961–January 31, 1962. F. D. Rosi and E. F. Hockins, eds. (David Sarnoff Research Center, Princeton, N. J.). Feb. 15, 1962. Contract NOBS-84660. 32p.

The thermal conductivity of heavily doped Ge–Si alloys was found to be low enough that the thermoelectric figure of merit was raised to usefully high values at elevated temperatures. Methods were developed for producing and analyzing the alloys; their thermoelectric properties were measured; and a power generating thermocouple was made using Ge–Si alloys as the n- and p-type thermoelements. The highest efficiency measured was 7.0%. Preliminary tests on segmented power generating thermocouples constructed from tellurides were also encouraging. Materials research on metal trisilicides, rare earth sulfides, and ternary compounds and alloys is also reported. Phase diagrams, thermoelectric properties, and electric conductivity are among the data included. (D.C.W.)

NSA '63

14801 (AD-278452) THERMOELECTRIC MATERIALS. Bi-Monthly Progress Report No. 12, November 1 to December 31, 1961. (Titanium Alloy Mfg. Div., National Lead Co., Niagara Falls, N. Y.). Jan. 15, 1962. Contract NObs 78326. 14p.

Standard ceramic bodies of UO_2 additions to CeO_2 were formed; Standard ceramic bodies of $YCrO_3$ with standard series addition of TiO_2 CeO_2, ZrO_2 were fabricated and their pertinent ceramic properties tabulated. Standard ceramic bodies with additions of SnO_2 to $YCrO_3$ were formed as well as those of $LaCrO_3$ with additions of TiO_2, CrO_3, ZrO_2, and SnO_2. Temperature, Seebeck coefficient, and resistivity values are tabulated for 47 compositions. $PbNb_2O_6$ with 0.5 mole % Bi_2O_3 had the largest negative Seebeck coefficient, of moderate consistency with temperature, of any material thus far measured. Following this and of the same general characteristic are: $PbNb_2O_6$ plus 0.1 mole/% Sb_2O_5; $PbNb_2O_6$ plus 5.0 mole/% CdO; and $Pb_2Nb_2O_7$ plus 5.0 mole/% CdO. (auth)

NSA '63

14590 THERMOELECTROMOTIVE FORCE OF BISMUTH AND BISMUTH–TELLURIUM ALLOYS. D.V.Gitsu, G.A.Ivanov and A.M.Popov. Fiz. tverdogo Tela (USSR), Vol. 4, No. 1, 22-8 (Jan., 1962). In Russian.

It is shown that the thermoelectric force in pure, monocrystalline bismuth is highly anisotropic. However, the anisotropy decreases rapidly with the addition of tellurium and practically vanishes in Bi–Te alloys with a tellurium content as large as 0.1 at.%. Absolute values of the thermoelectric coefficients also decrease rapidly with the addition of tellurium. The observed experimental results agree with theory. For anisotropic semiconductors, one can expect a large anisotropy of thermoelectric force in the intrinsic conductivity range, whereas anisotropy can be absent in general in the extrinsic conductivity range. [English translation in: Soviet Physics–Solid State (USA)].

R.L.Powell

PA '63

16753 THERMOELECTRIC PROPERTIES OF Bi_2Te_3 Bi_2Se_3 IN THE TEMPERATURE RANGE 77-600°K
É.K. Iordanishvili and B.M. Trakhbrot.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 1, 122-31 (Jan. 1962).
In Russian.

The temperature dependences of the electrical conductivity, thermoelectric power and the efficiency (for direct conversion of heat into electricity) were investigated on polycrystals of the $Bi_2Te_3-Bi_2Se_3$ solid solution system. Three carrier scattering mechanisms are considered and it is found that for scattering on impurity ions the mean free path of carriers is proportional to the square root of their energy. The 80% Bi_2Te_3–20% Bi_2Se_3 solid solution, suitably doped, is considered to be a promising material for the negative branches of thermocouples used in direct conversion of heat into electrical energy. [English translation in: Soviet Physics–Solid State (USA)].

S.Chomet
PA '62

Thermoelectricity and Electrical Resistivity of Dilute Copper Alloys of Chromium, Manganese, Iron, and Cobalt at Low Temperatures. A.K.JEKSHUS, W.B.PEARSON. Can J Physics v 40 n 1 Jan 1962 p 98-112. Results are compared to similar measurements on gold alloys; both thermoelectric and resistivity measurements have been made for first time on same alloys. 53 refs. EI 62

Thermoelectric Materials Today, R.D.CARLTON. Matls in Design Eng v 55 n 1 Jan 1962 p 79-82. Properties of lead telluride alloys which appear to be best material now used for generators; how they compare with other thermoelectric materials; cost factor; effect of temperature on properties; how performance is measured; 3 processing methods described; current uses. EI 62

Measurement of Thermal Diffusivity of Thermoelectric Materials, D.J.McNEILL. J Applied Physics v 33 n 2 Feb 1962 p 597-600. Simple modification of Angstrom's classical method for determination of thermal diffusivity of thermoelectric materials is described; results of measurements at room temperature on lead telluride are presented. EI 62

18703 THE MOBILITY AND EFFECTIVE MASS OF HOLES IN GALLIUM ANTIMONIDE.
V.I.Ivanov-Omskii, B.T.Kolomiets and Chzhou-Khuan [Chou-Huang].
Fiz. tverdogo Tela (USSR), Vol. 4, No. 2, 383-7 (Feb., 1962).
In Russian.

The electrical conductivity, Hall effect, and thermoelectric power of p-type gallium antimonide, with hole density of 1.4×10^{17} - 2.7×10^{19} cm^{-3}, were measured near room temperature. The hole mobility due to thermal lattice vibrations and the effective mass of holes were found. [English translation in: Soviet Physics–Solid State (USA). Vol. 4, No. 2, 276-9 (Aug., 1962)

S.Chomet
PA 62

18668 ANTIFERROMAGNETIC SEMICONDUCTORS WITH SMALL MOBILITY. É.L.Nagaev.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 2, 413-23 (Feb., 1962).
In Russian.

In many antiferromagnetic semiconductors it has been shown experimentally that the mobility of the carriers of current is small (less than 0.1 $cm^2 V^{-1} sec^{-1}$), and that it grows exponentially with rising temperature. The present paper contains a theoretical (mathematical) investigation of the question of the production of the activation energy of the mobility in such semiconductors. An expression for their thermo-e.m.f. is obtained. [English translation in: Soviet Physics–Solid State (USA), Vol. 4, No. 2, 300-6 (Aug., 1962)].

N.Davy
PA 62

Inadequate materials hinder wider use of thermoelectric devices. A. B. Neild, jr. Il S A E J 70:41-5 F '62

New thermoelectric material. J. Hillier. Franklin Inst J 273:172-4 F '62

MS+TE '62

4957 PROBLEM OF THE THERMO-E.M.F. OF ALLOYS.
L.N.Petrova.
Fiz. Metallov i Metallovedenie (USSR), Vol. 13, No. 2, 173-9 (Feb., 1962). In Russian. English translation in: Physics of Metals and Metallography (GB), Vol. 13, No. 2, 16-21 (1962; publ. Nov., 1962).

The temperature dependence of the thermo-e.m.f. of ordering alloys and the dependence of thermo-e.m.f. on composition for disordered alloys are considered. A formula is obtained which relates thermo-e.m.f. to the temperature and concentration coefficients of electrical resistivity. There is an anomaly in the temperature course of thermo-e.m.f. close to ordering point. Comparison with experiment is made for the alloys CuPt and Cu_3Au. 171 63

Halbleitermaterialien fuer die thermoelektrische Kuehlung und Stromerzeugung. K.SAGEL. Metall v 16 n 2 Feb 1962 p 87-96.

Semiconductor materials for thermoelectric cooling, heating, and current generation at 20-1000 C; literature review under main headings of—basic principles; production of materials used; types of thermoelectric materials; prospect of further developments. 30 refs.

E I 62.

12550 THE INFLUENCE OF HALOGEN DOPING ON THE THERMOELECTRIC PROPERTIES OF THE SYSTEM $Bi_2Te_{3-x}Se_x$. U.Birkholz and G.Haacke

Z Naturforsch. (Germany), Vol. 17a, No. 2, 161-5 (Feb., 1962). In German.

The thermoelectric properties of the above system were investigated in the range $0 \leq x \leq 1.2$ with Cl, Br and I doped specimens prepared from materials of 99.999% purity. In the composition range considered the scattering parameter $r = 0$. From measurements of thermoelectric power and conductivity the quantity $(m/m_0)^{3/2}\ \mu_{kl}$ was determined. m is the effective mass of the carriers and μ_{kl} the mobility in the non-degenerate case. $(m/m_0)^{3/2} \times \mu_{kl}$ falls with increasing x. For $x > 0$ it is smallest with iodine doped materials. From the temperature dependence of conductivity it can be deduced that the charge carriers are scattered by the thermal lattice vibrations for $x = 0$. For $x > 0$ there is additional scattering at neutral dislocations.

R.Parker

PA 62

21202 THE THEORY OF EXCITATION OF ELECTRONS BY PHONONS IN RHOMBOHEDRAL SEMICONDUCTORS. V.L.Gurevich and Yu.A.Firsov.

Fiz. tverdogo Tela (USSR), Vol. 4, No. 2, 530-7 (Feb. 19, 1962). In Russian.

The excitation of electrons by phonons in rhombohedral semiconductors is investigated and the temperature dependence of the resultant thermoelectric power is determined. It is shown that if there is an accidental (i.e. not connected with crystal symmetry) intersection of two branches of the phonon spectrum the thermoelectric power is proportional to $T^{-7/2}$. If there is no such intersection then the thermoelectric power is proportional to T^{-3} perpendicular to the crystal axis and T^{-3} in T parallel to the axis. [English translation in: Soviet Physics—Solid State (USA), Vol. 4, No. 2, 385-90 (Aug., 1962)].

D.J.Huntley

PA62

6617 SAMPLE HOLDER FOR USE IN THE MEASUREMENT OF THERMOELECTRIC POWER OF THERMOELECTRIC MATERIALS. J.F.Turco, J.Hickey and I.Bar-Gadda.

Rev. sci. Instrum. (USA), Vol. 33, No. 3, 384-5 (March, 1962).

When a thermoelectric material is heated at one end and the other end kept at constant temperature, an EMF is developed across the ends of the material. This is the Seebeck voltage 'E', and the relation between this voltage, the thermoelectric power 'α' and the temperature difference across the sample '$\Delta\tau$' is given by the equation $E = \alpha\Delta\tau$. Therefore 'α' may be found from E and $\Delta\tau$ measurements. In the sample holder, one end of the material is heated and the temperature measured with a thermocouple whilst the temperature of the other end is kept constant in a Dewar flask. The voltage drop across the sample is measured with a potentiometer. The accuracy of the method is ± 5 microvolts/degree C. A dimensioned drawing is given.

B.B.Austin

E I A '63

Nekotorye elektricheskie svoistva intermetallicheskogo poluprovodnikovogo soedineniya Cd_4Sb_3, legirovannogo razlichnymi primesyami, Ya.A.UGAI, F.M.AVERBAKH, T.A MARSHAKOVA, O.V. MATVEEV. Fizika Tverdogo Tela v 4 n 3 Mar 1962 p 615-17; see also English translation in Soviet Physics, Solid State v 4 n 3 Sept 1962 p 448-50. Some electrical properties of intermetallic semiconducting compound Cd_4Sb_3 doped with various impurities; effect of various impurities on electrical conductivity, Hall coefficient, and thermal emf.

E/63

Studies on Thermo-Electric Phenomena in Relation to Structural [illegible] Metals and Alloys, G.P.CHATTERJEE. J Mines, Metals & Fuels v 10 n 3 Mar 1962 p 15-18. Experimental thermal-emf studies of Al, Cu and Ni revealed that changes in thermo-emf force dE with different amounts of cold reduction dR is either linear or parabolic function and, only in some cases, logarithmic function; rate of change of emf force with cold reduction (dE/dR) is greater for alloys than for pure metals; dE/dR for Al, Cu and Ni are in increasing order.

EJ'63

6891 THERMOELECTRIC PROPERTIES OF BISMUTH–ANTIMONY ALLOYS. G.E.Smith and R.Wolfe.
J. appl. Phys. (USA), Vol. 33, No. 3, 841-6 (March, 1962).

The thermoelectric figure of merit (z), resistivity, and Seebeck coefficient were measured between 20° and 300°K on single crystals of several alloys in the range from 1 to 40% antimony in bismuth. These materials are semimetals (0 to 5% antimony) or small-energy-gap intrinsic semiconductors (5 to 40% antimony) and all are n-type. The Seebeck coefficients and figures of merit are anisotropic, the larger values being those measured parallel to the threefold symmetry axis. In the 12% antimony alloy the larger z rises from $1{\cdot}0 \times 10^{-3}$/°K at 300°K to a maximum of $5{\cdot}2 \times 10^{-3}$/°K at 80°K and falls rapidly at lower temperatures. All of the alloys between 3 and 16% antimony have a maximum z near 5×10^{-3}/°K at a temperature between 70° and 100°K. The 5% antimony alloy has the highest z at room temperature ($z = 1{\cdot}8 \times 10^{-3}$/°K). In this material, the Seebeck coefficient is practically constant ($S = 110 \pm 10\ \mu$ V°/K) between 77° and 300°K and the ratio of the thermal to electrical conductivities is close to the theoretical Wiedemann–Franz ratio above 100°K. As a result, z is inversely proportional to the absolute temperature ($zT = 0{\cdot}52 \pm 0{\cdot}05$) between 100° and 300°K. In the 12% antimony alloy, S rises from $-110\ \mu$ V/°K at 300°K to $-220\ \mu$V/°K at 20°K. A specimen of this material, doped with 0·01% lead, is p-type below 42°K. A qualitative explanation of these results is given in terms of mixed conduction by electrons and holes having properties similar to those in pure bismuth. The use of these alloys (and semimetals in general) in thermoelectric refrigeration at low temperatures is discussed.

EEA'62

7753 REFERENCE TABLES FOR 40 PER CENT IRIDIUM-60 PER CENT RHODIUM VERSUS IRIDIUM THERMOCOUPLES. G.F.Blackburn and F.R.Caldwell.
J. Res. Nat. Bur. Stand. (USA), Vol. 66C, No. 1, 1-12 (Jan.-March, 1962).

Initially various combinations of Ir-Rh were used before the main tests on the 40/60 alloy over a temperature range of 0 - 2100°C. The e.m.f. is 11·6 mV at 2100°C. The test apparatus is described, including a wirewound furnace and an In block heated by induction and measured under black-body conditions. Upper temperatures were measured with an optical pyrometer. Many tables of detailed results are given as well as graphs.

E.H.W.Banner

EEA62

√ 18707 GALVANOMAGNETIC AND THERMOMAGNETIC PROPERTIES OF P-TYPE INDIUM ARSENIDE.
N.V.Zotova and D.N.Nasledov.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 3, 681-4 (March, 1962).
In Russian. English translation in: Soviet Physics–Solid State (USA), Vol. 4, No. 3, 496-8 (Sept., 1962).
For abstract see Abstr. 16724 of 1962.

PA62

16693 A NON-STATIONARY METHOD FOR MEASUREMENT OF THERMOELECTRIC AND THERMAL PROPERTIES OF SEMICONDUCTORS. I.S.Lisker.
Inzhen.-fiz. Zh (USSR), Vol. 5, No. 3, 58-64 (March, 1962).
In Russian.

The non-stationary method of simultaneous measurement of thermoelectric and thermophysical characteristics of semiconductor materials is considered. The experimental set-up and certain results of the investigation are described.

PA '62

12552 THE THERMOELECTRIC POWER OF THE ACTINIDE METALS AT LOW TEMPERATURES.
G.T.Meaden and J.A.Lee.
Cryogenics (GB), Vol. 2, No. 3, 182 (March, 1962).

A preliminary report of thermoelectric power measurements on the actinide metals thorium, uranium, neptunium and plutonium. between room temperature and 20°K. Large variations of thermoelectric power with temperature were observed, in particular, a peak was observed in the results for plutonium at 80°K and changes of sign were observed for neptunium and thorium. P.A.Walker

PA '62

16724 GALVANOMAGNETIC AND THERMOMAGNETIC PROPERTIES OF P-TYPE INDIUM ARSENIDE.
N.V.Zotova and D.N.Nasledov.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 3, 681-4 (March, 1962).
In Russian.

The temperature dependences of the transverse Nernst–Ettingshausen coefficient, of the hole mobility of and the Hall coefficient of p-type indium arsenide indicated that between 95 and 350°K scattering of carriers on impurity ions is replaced by scattering on phonons. This transition to phonon scattering occurred at lower temperatures in a sample with degenerate hole gas than in purer samples. This is the first time such behaviour has been observed in p-type material of $A^{III}B^{V}$ composition. Measurements of the thermoelectric power were used to calculate the effective masses of holes and their temperature dependence. [English translation in: Soviet Physics–Solid State (USA)].

PA '62 S.Chomet

16764 EFFECT OF PHONON DRAG IN α-SiC CRYSTALS.
G.A.Lomakina and Yu.A.Vodakov.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 3, 820-2 (March, 1962).
In Russian.

Measurements at 20-600°K showed that phonon drag contributes to the thermoelectric power of p- and n-type α-SiC. [English translation in: Soviet Physics-Solid State (USA)]. S.Chomet

PA '62

Thermo-Electricity at Low Temperatures—9. Transition Metals as Solute and Solvent, D.K.C.MacDONALD, W.B.PEARSON, I.M. TEMPLETON. Roy Soc—Proc Ser A v 266 n 1325 Mar 6 1962 p 161-4. Transition metals (in particular Cr, Mn, Fe, Co and Ni) present as solutes give rise to highly anomalous thermoelectric powers and unusual resistive behavior at very low temperatures; experimental data on alloys of gold as parent metal; results compared with theory; experimental data are also presented on alloys of Pd and Pt. 37 refs.

E1 62

Thermoelectric Properties of Some Cerium Sulfide Semiconductors from 4° to 1300° K. F.M.RYAN, I.N.GREENBERG, F.I. CARTER R.C.MILLER. J Applied Physics v 33 n 3 Mar 1962 p 864-8. Thermal conductivity, Seebeck coefficient, and resistivity were measured for series of sintered cerium sulfide compounds of thorium phosphide structure; thermoelectric "figure of merit" is given for one of samples and some remarks are made on conduction mechanism in system. EI 162

18699 SOME ELECTRICAL PROPERTIES OF THE INTERMETALLIC SEMICONDUCTING COMPOUND Cd_4Sb_3 ALLOYED WITH VARIOUS IMPURITIES.
Ya.A.Ugai, E.M Averbakh, T.A.Marshakova and O.V.Matveev.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 3, 615-17 (March, 1962).
In Russian. English translation in: Soviet Physics—Solid State (USA), Vol. 4, No. 3, 448-50 (Sept., 1962).
For abstract see Abstr. 16719 of 1962. PA 62

2985 THE CHOICE OF THE OPTIMAL MODE OF OPERATION OF A CASCADE THERMOELECTRIC ELEMENT.
B.Ya.Moizhes, A.V.Petrov, Yu.P.Shishkin and L.A.Kolomoets.
Zh. tekh. Fiz. (USSR), Vol.32, No.4, 461-72 (April, 1962).
In Russian. English translation in: Soviet Physics - Technical Physics (USA), Vol.7, No.4, 336-44 (Oct., 1962).
A method is given for calculating the efficiency of a thermoelectric element whose branches are composed of various substances which have high thermoelectric powers over particular temperature ranges. As an example, the complete design is given of a thermoelectric element composed of semiconducting compounds. For low temperatures, one uses alloys based on Bi_2Te_3, and for higher temperatures alloys based on PbSe, with varying concentrations of current carriers. When matching losses are taken into account, the efficiency of the thermocouple turns out to be 12·7% for a temperature range of 20°-700°C. PA 63

21204 DETERMINATION OF THE EFFECTIVE MASS OF ELECTRONS IN InSb FROM THE MEASUREMENT OF THERMOELECTRIC POWER IN STRONG MAGNETIC FIELDS
I.V.Mochan, Yu.N.Obraztsov and T.V.Smirnova.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 4, 1021-8 (April, 1962).
In Russian. English translation in: Soviet Physics—Solid State (USA), Vol. 4, No. 4, 754-8 (Oct., 1962).
For abstract see Abstr. 18757 of 1962. PA 62

14509 ELECTRONIC PROPERTIES OF POLYSULFUR NITRIDE.
P.L.Kronick, H.Kaye, E.F.Chapman, S.B.Mainthia and M.B.Labes.
J. chem. Phys. (USA), Vol. 36, No. 8, 2235-7 (April 15, 1962).
This polymer consists of alternating sulphur and nitrogen atoms with conjugated double bonds and has a very low electrical resistance. Some results on electrical and thermal conductivities and on the Seebeck coefficient are reported and discussed.
PA 62 H.N.V.Temperley

AD-404 062 Div. 7, 8, 17
(TISTE/OHD) OTS price $10.10

Westinghouse Electric Corp., Pittsburgh, Pa.
THERMOELECTRICITY.
Quarterly progress rept. no. 1, Jan-Apr 62.
Apr 62, 1v.
Contract NObs86595

Unclassified report

Descriptors: *Thermoelectricity, Mechanical properties, Electrical properties, Germanium compounds, Tellurides, Tellurium alloys, Silver compounds, Antimony compounds, Antimony alloys, Cobalt alloys, Selenides, Indium alloys, Indium compounds, Bismuth alloys, Powder alloys, Electric terminals, Lead compounds, Tin, Temperature, Deformation, Alloys.

Contents:
Materials development
Ge-Ag-Sb-Te alloys
CoSb(3-x-y)Te(x)Se(y) alloys
Sb-In-Te alloys
Contacting
A processing technique for bismuth doped lead-telluride thermoelectric alloys
The effects of heavy deformation and annealing on the electrical properties of Bi(2)Te(3)
The thermoelectric properties of CoSb(3)
Non-stoichiometry in some group IV tellurides

'63

14591 EXPERIMENTAL INVESTIGATION OF THE INFLUENCE OF CHEMISORPTION ON THE THERMOELECTRIC POWER OF EVAPORATED METAL FILMS.
K.Blänsdorf and G.Lautz.
Z. Naturforsch. (Germany), Vol. 17a, No. 4, 339-45 (April, 1962).
In German.

The thermoelectric power and electrical resistance of thin evaporated Cu films were measured during the chemisorption of oxygen on the films. The results are consistent with a model assuming electron transfer from the metal to the chemisorbed oxygen. The increase in resistance and decrease in thermoelectric power can be accounted for by a reduction in free electron density, and no change in electron scattering mechanism is necessary. PA'62

H.Mykura

18760 THERMOELECTRIC PROPERTIES OF TELLURIUM AT LOW TEMPERATURES. I.N.Timchenko and S.S.Shalyt.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 4, 934-45 (April, 1962).
In Russian. English translation in: Soviet Physics-Solid State (USA), Vol. 4, No. 4, 685-92 (Oct., 1962).
For abstract see Abstr. 16765 of 1962.

PA'62

16765 THERMOELECTRIC PROPERTIES OF TELLURIUM AT LOW TEMPERATURES. I.N.Timchenko and S.S.Shalyt.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 4, 934-45 (April, 1962).
In Russian.

Thermoelectric properties of samples with various carrier densities were studied with heat flowing along and at right angles to the principal crystal axis. The experimental results agree with the theory of thermoelectric power in a semiconductor with an allowance for phonon drag. [English translation in : Soviet Physics-Solid State (USA)].

S.Chomet

PA'62

New Uses for Lead, S.W.TURNER, B.A.FADER Indus & Eng Chem v 54 n 4 Apr 1962 p 52-5. Survey of uses includes sound and vibration, thermoelectricity, piezoelectricity, corrosion, ceramics, pigments and paints; 3 general areas of usefulness have been found for lead in field of sound and vibration—antivibration mountings, sound barriers, and sound- and vibration-damping materials. EI62

18757 DETERMINATION OF THE EFFECTIVE MASS OF ELECTRONS IN InSb FROM THE MEASUREMENT OF THERMOELECTRIC POWER IN STRONG MAGNETIC FIELDS.
I.V.Mochan, Yu.N.Obraztsov and T.V.Smirnova.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 4, 1021-8 (April, 1962).
In Russian.

A formula for thermoelectric power in high magnetic fields is derived, allowing for arbitrary dependence of energy on momentum for spherical zones. It is shown that from thermoelectric power measurements one can obtain the dependence of energy on quasimomentum. Measurements were made on n-InSb in the temperature range 90°-150°K and fields up to 9 kG. From these an effective mass $m^* = (0.0143 \pm 0.007)\,m$, constant between 100° and 145°K is deduced, in good agreement with values derived from measurements of cyclotron resonance, Faraday effect, and optical constants. [English translation in: Soviet Physics—Solid State (USA)].

D.J.Huntley
PA62

Thermoelectric Power of Ionic Crystals—2. Results for Potassium Chloride. A.R.ALLNATT, P.W.M.JACOBS Roy Soc—Proc Ser A v 267 n 1328 Apr 24 1962 p 31-44. Thermoelectric power of single crystals of pure KCl and of KCl containing 107×10^{-5} mole fraction of strontium chloride has been measured in temperature range 561 to 693 C, platinum electrodes being used; results for pure KCl differ substantially from value reported by Nikitinskaya and Murin (1955) and show much less experimental scatter. 22 refs.
EI62

23410 ELECTRICAL AND THERMOELECTRIC PROPERTIES OF TlSe SINGLE CRYSTALS.
G.D.Guseinov, G.A.Akhundov and G.B.Abdullaev.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 5, 1206-12 (May, 1962).
In Russian. English translation in: Soviet Physics—Solid State (USA), Vol. 4, No. 5, 885-9 (Nov., 1962).
For abstract see Abstr. 18712 of 1962.
PA62.

18712 ELECTRICAL AND THERMOELECTRIC PROPERTIES OF TlSe SINGLE CRYSTALS.
G.D.Guseinov, G.A.Akhundov and G.B.Abdullaev.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 5, 1206-12 (May, 1962).
In Russian.

The electrical conductivity, the Hall coefficient and the thermoelectric power were measured at 80-570°K. The forbidden band width, its temperature coefficient, the effective carrier masses and the ratio of mobilities were determined. In high-resistivity samples carrier drag by phonons was detected below 170°K. [English translation in: Soviet Physics—Solid State (USA)].

S.Chomet
PA62 1E

Inversion der Thermokraft bei gesinterten thermoelektrischen Werkstoffen. H.SCHREINER, F.W. [illegible] Metall v 16 n 5, 9 May 1962 p 399-402, Sept p 855-8. Inversion of thermal power in sintered thermoelectric materials. Series of investigations dealing with possible advantages of producing thermoelectric semiconductors by powder metallurgy methods rather than melting. May. Effect of lattice defects in powder metal processes. Sept. Experimental results obtained with compacted and sintered bismuth tellurides in which either pure Bi_2Te_3 was used or telluride doped with 0.15% AgI; in former, repeated inversion of thermal power was observed with increasing sintering temperature. 27 refs. E.I '63

Theory of Electrical Properties of Liquid Metals—2. Polyvalent Metals. C.C.BRADLEY, T.E.FABER, E.G.WILSON, J.M.ZIMAN. Philosophical Mag v 7 n 77 May 1962 p 865-87. Electronic properties of liquid polyvalent metals investigated in relation to nearly-free-electron model; thermoelectric power has been measured for Zn, Cd, Hg, In, Sn, Pb, Bi, and can be made to fit theory if it is assumed that in few metals (especially Hg) scattering cross section of each atom depends on energy of electron; temperature-dependence of resistivity can also be explained by model. 35 refs. E.I '62

1729 THERMOELECTRIC EMISSION OF IONIC SEMICONDUCTORS IN STRONG FIELDS.
K.B.Tolpygo and G.V.Chaika.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 5, 1146-53 (May, 1962). In Russian. English translation in: Soviet Physic – Solid State (USA), Vol. 4, No. 5, 845-9 (Nov., 1962).
For abstract see Abstr. 12227 of 1962. EEA '63

J14495 THE ELECTRICAL RESISTANCE OF THIN FILMS OF SILVER AND THE THERMOELECTRIC POWER OF A COUPLE BULK SILVER/SILVER FILM.
F.Savornin, J.Savornin and A.Donnadieu.
C.R. Acad. Sci. (France), Vol. 254, No. 19, 3348-50 (May 7, 1962). In French.

A note on the results of deposition on glass, silica and mica. It is shown that the thermoelectric power of a couple between the bulk metal and the same thin metal must always be negative.

T.C.Toye
PA '62

14592 MEASUREMENTS OF THE ROOM TEMPERATURE THERMOELECTRIC PARAMETERS OF LEAD TELLURIDE. G.W.Johnson.
J. Electronics and Control (GB), Vol. 12, No. 5, 421-32 (May, 1962).

A modification of the technique suggested by Hérinckx and Monfils was used to measure the room temperature thermoelectric parameters of single crystal n and p-type lead telluride over a range of carrier concentrations. The Seebeck coefficient α, electrical conductivity σ ($ohm^{-1}\ cm^{-1}$), and thermal conductivity K are related by the empirical equations:

$$\alpha_n = 717 - 181 \log \sigma_n\ \mu V/deg, \quad 500 < \sigma_n < 6000,$$

$$\alpha_p = 702 - 187 \log \sigma_p\ \mu V/deg, \quad 200 < \sigma_p < 1700,$$

$$K = 0.020 + 5 \times 10^{-6} \sigma \text{ watt cm}^{-1} \text{ deg}^{-1}.$$

N-type material has a maximum figure of merit at room temperature of $1.1 \times 10^{-3}\ deg^{-1}$ when $\sigma_n = 750$ and p-type of $1 \times 10^{-3}\ deg^{-1}$ when $\sigma_p = 550$. Comparison of the results with theory suggests that the charge carriers are scattered by the acoustical modes of vibration of the lattice and that the effective mass ratio is 0.25 for electrons and 0.35 for holes. Consistency between the theoretical calculations of Seebeck coefficient and thermal conductivity can be obtained if it is assumed that the lattice thermal conductivity is reduced by the addition of doping elements. A typical reduction is 20% for an addition of 0.2 at.% of iodine atoms. PA '62

12551 THE EFFECT OF THE MARTENSITIC TRANSFORMATION IN SODIUM ON THE THERMOELECTRIC POWER.

J. Adler and S.B.Woods.

Canad. J. Phys., Vol. 40, No. 5, 550-6 (May, 1962).

When sodium is cooled, its crystal structure partially changes by martensitic transformation from b.c.c. to close-packed hexagonal below about 40°K. Reversion does not begin until the temperature is raised above about 45°K, so there is a small temperature range in which sodium may consists of either pure b.c.c. or mixed phases. Using results obtained by Dugdale and Gugan, it is possible to estimate the amount of hexagonal phase present in the mixed samples from electrical resistance measurements. The thermoelectric power was measured at 43°K for specimens of b.c.c. sodium and for partially transformed sodium whose composition was thus known. From these measurements the thermoelectric power of pure hexagonal sodium is estimated to be 10% smaller than that of cubic sodium at 43°K. The distribution of the phases in the partially transformed material is represented by two different models and this result is found to be insensitive to which is used. A brief description of the experimental apparatus is given and some theoretical implications of the results are considered.

PA62

12549 THERMOELECTRIC FIGURE OF MERIT OF TWO-BAND SEMICONDUCTORS. R.Simon.

J. appl. Phys. (USA), Vol. 33, No. 5, 1830-41 (May, 1962).

The locus of points on the $(\alpha, \kappa/\sigma T)$ plane for a two-band (electrons and holes) semiconductor as the concentration of doping agent is changed, is a curve that forms a closed loop, where α is the Seebeck coefficient, κ the thermal conductivity, σ the electrical conductivity, and T the absolute temperature. The value of the dimensionless thermoelectric figure of merit $ZT = \alpha^2/(\kappa/\sigma T)$ has, in general two maxima on this loop, either or both of whose values are determinable, in principle, from measurements of α, κ, and σ on a few specimens with different amounts of doping. The shape and size of the loop and its position on the $(\alpha, \kappa/\sigma T)$ plane depend upon the values of two dimensionless material parameters of the Chasmar and Stratton (Abstr. 4374 of 1960) type, one for each band, the scattering parameters for the charge carriers in each band, and the value of the band gap in kT units. The effects of these parameters on the values of the ZT maxima are considered and approximate empirical relationships for Z(max)T as a function of these parameters are developed to aid in the quantitative evaluation of these effects. The relationships between these parameters and the pertinent physical properties of the material are discussed from the viewpoints of the requirements for improved thermoelectric materials and of the possible existence of an upper limit to the thermoelectric figure of merit.

PA 162

14589 DEPENDENCE OF THE THERMOELECTRIC FIGURE OF MERIT ON ENERGY BANDWIDTH.

R.C.Miller, R.R.Heikes and A.E.Fein.

J. appl. Phys. (USA), Vol. 33, No. 6, 1928-32 (June, 1962).

The thermoelectric figure of merit Tz of a semiconductor is calculated as a function of the width of the conduction band. It is found that Tz approaches zero as the bandwidth goes to zero. The existence of an optimum bandwidth is established; however, the magnitude cannot be ascertained on the basis of the simple model used here.

PA'62

14447 THERMOELECTRIC EFFECTS AND THEIR APPLICATIONS. M.Rodot.

Onde elect. (France), Vol.42, 507-16 (June, 1962). In French.

The use of semiconductors for thermoelectric generators and refrigerators is discussed. The general principles are outlined and expressions are derived for optimum output and efficiency, with numerical examples. Constructional problems are considered briefly and the choice of suitable semiconductors is discussed in relation to the ideal physical properties.

L.M.Roberts

ELA '62

AD-290 728 Div. 25, 7
(TISTP/WH) OTS price $5.60

DuPont de Nemours, E. I., and Co., Inc,
Wilmington, Del.
THERMOELECTRIC PROPERTIES OF SELENIDES AND TELLURIDES OF GROUPS VB AND VIB METALS AND THEIR SOLID SOLUTIONS.
Quarterly rept. no. 4, 1 Apr-30 June 62,
by W. T. Hicks and H. Valdsaar. 30 July 62,
32p. illus.
(Contract NObs-84824, Proj. SR-007-12-01)
Unclassified report

DESCRIPTORS: *Thermoelectricity, *Resistance, *Thermal conductivity, *Tungsten, *Antimony, *Selenium alloys, *Tellurium alloys, *Intermetallic compounds.

Seebeck coefficient, resistivity and thermal conductivity measurements were performed on tantalum-doped WSe2-type compositions containing mixed anions and/or cations; for example, W0.47Mo0.47Ta0.06SeTe. Such compositions had much lower thermal conductivities at room temperature than their less complex counterparts, but this advantage did not result in improved Figures of Merit, partly because electrical properties were inferior and partly because their high-temperature thermal conductivities approached that of WSe2. The tungsten-selenium-antimony phase diagram was found to contain no ternary phases of thermoelectric interest. Tantalum-doped tungsten diselenide thermoelements sealed in standard ceramic capsules were exposed to hot-end temperatures of 950 C for several hours without deterioration. Measurement of the thermoelectric parameters of NbSiGe in the 1000-1500 C range is in progress. (Author)

'63

23400 SEMICONDUCTING PROPERTIES OF LANTHANO-COBALTITE. P.Gerthsen and K.H.Härdtl.
Z. Naturforsch. (Germany), Vol. 17a, No. 6, 514-21 (June, 1962).
In German.

Reports measurements of thermoelectric power, conductivity and Hall effect on samples of $LaCoO_3$, doped with either Sr or Th, from 77° to 500°K. Results are interpreted on the basis of the model of the "small polaron"; that is, the transport properties are determined by hopping of the carriers between neighbouring localized levels, in this case 3d-levels.

L.Pincherle
PA62

23370 SOME PROPERTIES OF SEMICONDUCTING COMPOUNDS OF $A^I_2B^{IV}X^{VI}_3$ TYPE.
L.S.Palatnik, V.M.Koshkin, L.P.Gal'chinetskii, V.I.Kolesnikov and Yu.F.Komnik.
Fiz. tverdogo Tela (USSR), Vol 4, No. 6, 1430-1 (June, 1962).
In Russian.

The electrical conductivity and the thermoelectric power were studied for compounds of $A^I_2B^{IV}X^{VI}_3$ type, where A^I is Cu, B^{IV} is Ge or Sn, and X^{VI} is S, Se or Te. For some of these compounds the Hall coefficients, hole mobilities and carrier densities at room temperature were found, and estimates of the energy gap were obtained. The electrical properties are related to some details of chemical structure. [English translation in: Soviet Physics—Solid State (USA)].

S.Chomet
PA62

20949 THERMAL CONDUCTIVITY OF CADMIUM ANTIMONIDE.
I.M.Pilat, L.I.Anatychuk and A.V.Lyubchenko
Fiz. tverdogo Tela (USSR), Vol. 4, No. 6, 1649-54 (June, 1962)
In Russian.

The temperature dependences of the thermal conductivity, electrical conductivity, thermoelectric power and the Hall coefficient of polycrystalline and monocrystalline CdSb samples were studied at 77-420°K. The temperature dependence of the thermal conductivity of monocrystals at high temperatures indicated transport of heat by electromagnetic radiation. [English translation in: Soviet Physics—Solid State (USA)].

S.Chomet
PA '62

Thermoelectricity and resistivity of pyrite from Renison Bell and Mt Bischoff, Tasmania. P. A. Hill and R. Green. bibliog map diag Econ Geol 57:579-86 Je '62

ASTI '62

41550 (MND-2739) METALLIC THERMOELECTRIC ELEMENTS. Final Report. William E. Kortier (Martin Co. Nuclear Div., Baltimore). June 1962. Contract AT(30-1)-2839. 65p.

Work on metallic-alloy thermoelements is described. The electrical and thermal characteristics of metallic thermoelements with thermal barriers were compared with the characteristics of elements without thermal barriers. The use of the thermal barrier configuration in these metallic thermoelectric elements apparently resulted in a marked improvement in the performance of the generator subassembly. The reason for this apparent improvement was that the ratio of element length to element area in the elements without thermal barriers was far from optimum. Adoption of the barrier principle permitted the length-to-area ratio to approach, but not reach, an optimum. The diminution of the thermal conductance of a strip of thermoelectric alloy caused by the imposition of a thermal barrier was of the same order of magnitude as the decrease in its electrical conductance. Thermal barriers had no effect on Seebeck voltages. It was concluded that introducing the thermal barrier cannot result in higher conversion efficiency. No mechanism was found to lead to an increase in the figure of merit of thermoelectric materials as a result of the imposition of thermal barriers. (M.C.G.)

NSA '63

16628 STUDY OF THE BAND STRUCTURE OF TELLURIUM BY TRANSPORT PHENOMENA. C.Rigaux.
J. Phys. Chem. Solids (GB), Vol. 23, 805-17 (June, 1962). In French.

Galvanomagnetic and thermoelectric effects were measured on extrinsic tellurium with bismuth-doped samples between 77° and 250°K. The experimental results are quantitatively interpreted by a twelve-ellipsoid model for the constant energy surfaces of the valence band. The principal effective masses and the angular orientation of ellipsoids in the Brillouin zone are determined. In the intrinsic range, the second Hall and Seebeck reversals are explained by the existence of two conduction bands separated by an energy of about 0.36 eV.

PA '62

16760 ANOMALOUS SEEBECK EFFECT IN SEMICONDUCTORS
P.C.Newman.
Proc. Phys. Soc. (GB), Vol. 79, Pt 6, 1299-1300 (June, 1962).

An anomalous Seebeck effect in semiconductors may arise from the increasing formation of imperfections, either donors or acceptors, with temperature. A model is proposed which indicates two possible anomalous effects: the activation energy for the carrier concentration can be greater than half the forbidden energy gap in a certain temperature range; and the thermoelectric power can be of opposite sign to the Hall coefficient, and can increase quite strongly with increasing temperature. Semiconductors in which either or both of these anomalies have been observed are enumerated.

J.B.Birks
PA '62

16761 SEEBECK EFFECT IN Mg_2Si SINGLE CRYSTALS.
M.W.Heller and G.C.Danielson.
J. Phys. Chem. Solids (GB), Vol. 23 601-10 (June, 1962).

The Seebeck coefficients (thermoelectric powers), resistivities and Hall coefficients of Mg_2Si single crystals were measured from 7° to 1000°K. At low temperatures, the magnitude of the Seebeck coefficient showed a pronounced maximum which is interpreted in terms of the phonon drag effect. Both n-type and p-type crystals exhibited this effect. The magnitude of the phonon contribution to the Seebeck coefficient was found to be proportional to $T^{-3.0}$ at temperatures above the boundary scattering range. In the intrinsic temperature range (650°K to 1000°K), the Seebeck coefficients of the n-type samples were proportional to 1/T and implied a ratio of electron to hole mobility of about 3.5. The density-of-states effective mass parameters were calculated both from data in the extrinsic temperature range (200° to 300°K) and from data in the intrinsic temperature range. Consistent results of $m_n = 0.5\,m_o$ and $m_p = 2m_o$ were obtained if it was assumed that optical mode scattering predominated in the pure n-type samples above 200°K, but that optical mode scattering and ionized impurity scattering were comparable in the doped p-type samples between 200° and 300°K.

PA'62

18759 THE THERMOELECTRIC PROPERTIES OF $AgSbTe_2-AgBiTe_2$, $-PbTe$ AND $-SnTe$ SYSTEMS.
T.Ono, T.Tanahama and T.Irie.
J. Phys. Soc. Japan, Vol. 17, No. 6, 1070-1 (June, 1962).

The electrical conductivity, thermoelectric power and lattice conductivity for $AgSbTe_2-AgBiTe_2$, $AgSbTe_2-PbTe$ and $AgSbTe_2-SnTe$ were measured on samples with varying proportions of the two constituents, and some results are presented.

B.R.Holeman
PA62

18698 CONDUCTIVITY AND THERMOELECTRIC POWER OF SAMPLES OF CADMIUM OXIDE.
Y.Colin and C.Fourrier.
C.R. Acad. Sci. (France), Vol. 254, No. 26, 4453-5 (June 25, 1962).
In French.

The thermoelectric power and electrical conductivity of samples of compressed CdO powder were measured over the temperature range 80°-400°K. The results indicate a degenerate n-type semiconductor in which the diffusion of conduction electrons occurs via impurities or excess interstitial Cd.

J.Holt
PA'62

913 $Bi_2Te_3-Sb_2Te_3$ ALLOYS WITH ADDED TELLURIUM. AND SELENIUM. J.Rupprecht.
Z. Naturforsch. (Germany), Vol. 17a, No. 7, 628-9 (July, 1962).
In German.

These alloys were studied for their suitability for thermoelectric refrigeration. Basic alloys in the composition range 73 mol.% Sb_2Te_3-27 mol.% Bi_2Te_3 to 80 mol.% Sb_2Te_3-20 mol.% Bi_2Te_3 with 2 to 8 wt.% Te and Se amounting to half to ⅓ of the excess Te added were considered the most suitable.

H.Mykura
PA 63

O termoelektrodvizhushchei sile v vismute i v ego splavakh s tellurom, D.V.GITSU, G.A.IVANOV, A.M.POPOV. Fizika Tverdogo Tela v 4 n 1 Jan 1962 p 22-8; see also English translation in Soviet Physics, Solid State v 4 n 1 July 1962 p 15-19. On thermoelectromotive force in bismuth and bismuth-tellurium alloys; it is shown that in pure bismuth thermo-emf has large anisotropy, which falls sharply with addition of Te and practically disappears in Bi-Te alloys containing more than 0.1 at% Te; this is in agreement with theory; in anisotropic semiconductors anisotropy of thermo-emf is to be expected in region of intrinsic conductivity and not in region of impurity conductivity. EI 63

23398 PHENOMENA OF CHARGE AND HEAT TRANSPORT IN N TYPE INDIUM ARSENIDE AT LOW TEMPERATURES. S.S.Shalyt.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 7, 1915-27 (July, 1962). In Russian.

To find the mechanism of electron scattering at 77°K in a sample with an electron density of 3×10^{18} cm^{-3} the following properties were studied: electrical conductivity, Hall effect, magnetoresistance, thermoelectric power, and Nernst–Ettingshausen effects. Heat conduction and thermoelectric power were investigated between 2-5°K and 100°K. The effects of geometrical shape of samples on magnetoresistance and magnetothermo-e.m.f. were compared. [English translation in: Soviet Physics -- Solid State (USA)]. S.Chomet

PA '62

AD-404 613 Div. 25, 4, 7
(TISTM/PCR) OTS price $1.10

Stanford Research Inst., Menlo Park, Calif.
THERMOELECTRIC MATERIALS.
Bimonthly progress rept. no. 20, 1 May-1 July 62, by J. W. Johnson. 17 July 62, 4p.
Contract NObs77017, SRI Proj. SU2681
Unclassified report

Descriptors: *Thermoelectricity, Thermal conductivity, Electrical properties, Copper compounds, Sulfides, Tellurides, Resistance (Electrical), Test methods, High temperature research, Mixtures, Tables, Materials.

'63

AD-405 621 Div. 7, 17, 25
(TISTM/PCR) OTS price $5.60

Servomechanisms, Inc., Goleta, Calif.
(No title).
Final rept.
July 62, 51p.
Contract NObs86367, Proj. SR007 12 01
Unclassified report

Descriptors: *Thermoelectricity, Encapsulation, Tests, Pressure, Thermal stresses, Shock (Mechanics), Fracture (Mechanics), Thermal expansion, Materials, Lead compounds, Tellurides, Semiconductors, Life expectancy, Compatibility, Sintering, Heat treatment, Compressive properties, Design, Manufacturing methods.

A study was made of one method of thermoelectric application technique. Specifically, the work involved fabrication and test to investigate a method of structural encapsulation of washer-shaped thermoelectric elements under pressure. One goal of the program was to verify preliminary evidence that thermoelectric elements are free from formation of mechanical cracks due to thermal shock, high thermal gradients, or thermal expansion problems when the thermoelectric material is held beyond its compressive yield strength. Thus, short path-length elements may be used with high thermal gradients, resulting in high electrical yield per kilogram of thermoelectric material with low degradation over long operating life. (Author)

'63

29854 (MND-2584-4) RADIOISOTOPE SEMICONDUCTOR AND THERMOELEMENT RESEARCH AND DEVELOPMENT. Final Technical Report, February 13, 1961–July 17, 1962. N. G. Asbed (Martin-Marietta Corp. Aerospace Div., Baltimore). Contract AT(30-1)-2698. 74p.

A description is given of work in support of the concept that a radioisotope can be made an integral part of the thermoelectric arm of a generator and that the decay energy of the emitted particles can be converted to electricity by direct conversion. In particular, n-type strontium and cerium titanates were prepared to house strontium-90 and cerium-144, respectively. The blend consisting of $SrTiO_3$ (+20-wt % Fe) +20-wt % $CeTiO_3$ has an average figure of merit of $1.9 \times 10^{-4} \cdot C^{-1}$ between 200 and 1100°C; the corresponding thermoelectric conversion efficiency is ~4%. Strontium titanate was prepared by reacting strontium carbonate and titanium dioxide in air. The addition of 20-wt % pyrophoric iron and the subsequent reduction in dry hydrogen at 1475°C rendered the titanate into an n-type semiconductor with a thermoelectric figure of merit of 1.1×10^{-4} per degree centigrade at 600°C. This material withstands temperatures to 1200°C in the absence of oxygen, without a deterioration of its thermoelectric properties. The material is mechanically strong and hard. Cerium titanate was prepared for the first time by a process similar to the one used to make semiconducting strontium titanate, and was shown to have the formula $CeTiO_3$. A thermoelectric arm of iron-doped strontium titanate was prepared, with 20 curies of strontium-90 concentrated as an ingredient of the thermoelectric material at one end. This device had an open-circuit emf of 1.20 millivolt, and delivered 0.48 microwatt to a matched load. A program for the IBM 7090 computer was modified to permit optimization of a thermoelectric arm, of varying composition, which contains an internal heat source. (auth)

NSA '63

541 THEORETICAL CONSIDERATIONS WITH RESPECT TO THE DEFINITION OF THE ELECTROLYTIC PELTIER EFFECT. Y.Thouvenin.
C. R. Acad. Sci. (France), Vol. 255, No. 4, 674-6 (July 23, 1962). In French.

After consideration of the historical definition of the Peltier effect, an up-to-date version is given as the amount of heat involved at an isothermal junction of two phases traversed by an electric current when the irreversibility of the phenomenon is negligible. In the particular case of an electrochemical system, it is the quantity of heat liberated by the reversible passage of a mole of the electroactive ion from one phase to the other [cf. ibid., Vol. 25, No. 7, 959 (Aug. 17, 1960)].

H.H.Hodgson

EEA '63

16729 ELECTRICAL PROPERTIES OF HEAVILY DOPED NIOBIUM PENTOXIDE. R.Valletta.
J. chem. Phys. (USA), Vol. 37, No. 1, 67-71 (July 1, 1962).

An analysis of the resistivity and thermoelectric power of heavily doped Nb_2O_5 [over-all composition $(Nb_{1-x}W_x)_2O_5$ where x varies from 0.0025 to 0.15] shows that mixed valence semiconduction was observed. The major factor determining the value of the thermoelectric power at high temperatures appears to be an entropy of mixing term. In samples with $x > 0.10$, it is concluded that the electrons can be trapped on tungsten ions as well as niobium ions. The low-temperature resistivity data indicate that the conduction mechanism is not simply described at temperatures where the tungsten impurity ions are incompletely ionized. PA '62

Leitfaehigkeit und Hallkonstant—16, 17, 22, 23, W.KOESTER, D.HAGMANN, T.RICKER, W.GMOEHLING. Zeit fuer Metallkunde v 52 n 11 Nov 1961 p 721-35, v 53 n 7 July 1962 p 456-65. Pt 16. Electric conductivity, susceptibility, thermoelectric power, and Hall effect of solid solutions of palladium with its neighbor elements in Periodic System, i.e., Ag, Cd, In, Rh, Ru, Mo, Cb, Zr, Au, and U, generally in amounts of 2 and 4, sometimes up to 15 at.%; excepting thermoelectric power, results of measurements can be explained by simple band model. Pt 17. Application of double band model to electric properties of palladium; measurements of electric resistivity, Hall effect, susceptibility, thermoelectric power, and Ettinghausen-Nernst effect are used to calculate variables of band theory for Pd; useful results were obtained only when interaction between bands was taken into consideration. 32 refs. Pt 22. Theoretical investigation of temperature dependence of electric conductivity and Hall effect; for general isotropic case, effect of degree of disintegration of electron gas on 2 properties is calculated; for case of transition metals, mutual effects of s and d bands are taken into consideration; methods for numerical solution of equations are discussed. Pt 23. Temperature dependence of electric conductivity and Hall effect of palladium solid solutions; determination of temperature coefficients of electric resistivity and Hall effect of Pd with small amounts, usually 2 and 4 at.%, of Ag, Cb, Cd, In, Mo, Rh, Ru, V, and Zr and with 2-80 at.% Au; both properties were decreased by all additions; effect is explained by electron scattering. 27 refs.

E762

14488 ELECTRICAL RESISTIVITY AND THERMOELECTRIC POWER OF PALLADIUM AFTER HYDROGEN DESORPTION. R.J.Smith, A.I.Schindler and E.W.Kammer.
Phys. Rev. (USA), Vol. 127, No. 1, 179-83 (July 1, 1962).

The electrical resistivity and thermoelectric power of desorbed palladium-hydrogen samples were measured as functions of temperature from 4.2° to 300°K, and 77° to 273°K, respectively. The thermoelectric power of the desorbed specimens lies intermediate between the values of annealed and cold-worked palladium. An increase in the residual resistivity and a decrease in the value of $d\mu/dT$ is found for the desorbed samples. The results are explained in terms of an experimentally observed expanded lattice. PA62

14394 COMMENTS ON "THERMAL CONDUCTIVITY IN TWO-PHASE ALLOYS." R.W.Ure,Jr.

J. appl. Phys. (USA), Vol. 33, No. 7, 2290-2 (July, 1962).

It is shown that there is an error in Schroeder's calculation (Abstr. 14188 of 1961) of the electronic thermal conductivity due to circulating currents in a two-phase material. With reasonable values for the properties of the two phases, quantitative agreement between the predictions of the model and the experimental data of Cosgrove, McHugh, and Tiller (Abstr. 8969 of 1961) is obtained for both the electronic thermal conductivity and the Seebeck coefficient.

from the formula of Macdonald and Nordheim and the mean value of the product of resistivity for large specimens and the mean free path was ~ 10^{-11} Ω cm^2 which agrees with Chambers value for lead.

D.J.Oliver

PA '62

21150 SEMI-CONDUCTIVITY AND THERMOELECTRIC POWER OF CADMIUM OXIDE.

E.F.Lamb and F.C.Tompkins.

Trans Faraday Soc. (GB), Vol. 58, Pt 7, 1424-38 (July, 1962).

The electrical conductance and thermoelectric power of pellets of sintered cadmium oxide powder were measured at various oxygen pressures and temperatures. Both electrical properties follow closely the requirements of Wright's equations for fully degenerate semiconductors. It is, however, not possible to reconcile the results obtained at different oxygen pressures with Wagner's theory relating the concentration of conduction electrons to the dissociation pressure of oxygen of an excess semiconductor. Furthermore, in a study of the attainment of equilibrium with gaseous oxygen, it was found that long periods were required to obtain constant electrical properties; it was therefore concluded that although surface equilibrium was rapidly attained, lattice diffusion was extremely slow. The different rates of these two processes are thought to be, in part, responsible for the complex conductance against temperature plots obtained at the various stages of equilibration; other complicating factors; such as surface adsorption and the "structure" of the sintered pellet, are also discussed.

PA '62

23466 PHYSICAL PROPERTIES OF Cu-Zn-Sb ALLOYS.

V.A.Yurkov.

Fiz. Metallov i Metallovedenie (USSR), Vol. 14, No. 2, 172-81 (Aug., 1962). In Russian. English translation in: Phys. Metals and Metallography (USA), Vol. 14, No. 2, 11-18 (1962; publ. June, 1963).

Investigation has been made of the microstructure, microhardness, density, line broadening, electrical and thermoelectric properties of the alloys $CuZn_3-Zn_3Sb_2$, $Cu_5Zn_3-Zn_3Sb_2$, $CuZn-Zn_3Sb_2$. From the structural point of view these alloys are a mechanical mixture of practically pure components. The lines joining $CuZn_3$, Cu_5Zn_3 and CuZn with the compound Zn_3Sb_2 appear in the ternary system Cu-Zn-Sb as the position of the pseudo-binary sectors.

PA '63

1824 APPLICATIONS OF THE PELTIER EFFECT.

J.E.Parrott and A.W.Penn.

AEI Engng (GB), Vol. 2, No. 4, 202-7 (July-Aug., 1962).

A study of the design of thermocouples, embodying a p-type and an n-type semiconductor, to give optimum results. High values of electron mobility and effective mass of electrons and holes are aimed at and doped alloys of bismuth-antimony telluride and bismuth telluride-selenide were chosen for the p-type and n-type elements respectively. Operating characteristics and transient effects are discussed. Applications described include transistor stabilizers, cooling envelopes for electron microscope specimens, and thermoelectric recording hygrometers. A domestic refrigerator operating on this principle would be a marginal proposition.

H.G.M.Spratt

EEA 63

5106 SEMICONDUCTOR COOLING ELEMENTS OPERATING BY THE PELTIER EFFECT B.Böhme.
Elektronik (Germany), Vol 11, No 8, 225-6 (Aug., 1962). In German.
New semiconductor materials have made possible economic utilization of the Peltier effect, known since 1834, for thermoelectric refrigeration. The Sirigor cooling elements developed by the Siemens-Schuckert company are cooling units ready for connection. They consist of 18 series-connected individual elements with a cooling power of approx. 15 W. They have already found uses in minor cooling applications, but will probably exercise a decisive influence on the entire refrigeration and air-conditioning techniques of the future.
EEA '63

Materials for Engineering Thermoelectric Devices, J.W.DAVISSON, J.PASTERNAK. Electro-Technology v 70 n 2 Aug 1962 p 128-33. Status report on progress in thermoelectricity; examination of characteristics of available experimental thermoelectric materials; developments in thermoelectric devices; cost-efficiency analysis of materials.
EI62

Thermoelectric Properties of Cadmium Antimonide, T.MIYAUCHI, K.MATSUI. Inst Elec Engrs Japan—J v 82 n 887 Aug 1962 p 1258-62. Preparation of CdSb by fusion; data on thermoelectric and thermal properties; results of resistivity, thermoelectric power and thermal conductivity measurements; it is pointed out that increase in impurity concentrations of CdSb may cause increase of thermal conductivity; in low resistivity samples, thermal conduction is dominated by impurity scattering of phonons. In Japanese with English summary.
EF '63

12394 TECHNIQUE TO CONSTRUCT FINE WIRE THERMOCOUPLES. J.W.Denison, Jr.
Rev. sci. Instrum. (USA), Vol.33, No.8, 870-1 (Aug., 1962).
Utilization of the melting point difference between pure platinum (1774°C) and platinum-10% rhodium alloy (1875°C) enables construction of fine wire thermocouples. A micro-torch, made of drawn quartz tubing, supplies sufficient heat to melt the end of the platinum wire placed in "T" configuration with the Pt-10% Rh wire. The wires are held in this position by small clamps supported by heavy pure tin wire mounted in a stainless steel block. The tin wire allows exact wire positioning since it is ductile, does not possess springback properties, and does not work harden. The flame from a microtorch, when carefully applied to the free end of the platinum wire, causes it to melt and pull back as a surface-tension ball. When the ball comes in contact with the Pt-10% Rh wire, the heat is quickly removed to allow freezing of the platinum ball.
EUA62 G.W.A.Dummer

Experimental Determination of Thermoelectric Power in Liquid Metals and Alloys, C.C.BRADLEY. Philosophical Mag v 7 n 80 Aug 1962 p 1337-47. Series of experiments in which absolute thermoelectric power of number of liquid metals and liquid alloys was measured over range of temperatures from their melting points up to about 500 C; use was made of recently established absolute thermoelectric scale which is more reliable than previous ones; results explained in terms of electron scattering by pseudo-potentials and density fluctuations in liquid. 22 refs.
EJ '63

AD-410 434 Div. 17, 7, 25
(TISTM/AMS) OTS price $7.60

Westinghouse Electric Corp., Pittsburgh, Pa.
THERMOELECTRICITY.
Quarterly progress rept. no. 2, May-Aug 62.
Aug 62, 1v.
Contract NObs86595

Unclassified report

Descriptors: (*Thermoelectricity, Materials), Cobalt alloys, Antimony alloys, Bismuth alloys, Tellurium alloys, Zinc alloys, Intermetallic compounds, Vaporization, Vapor pressure, Germanium alloys, Powder metallurgy, Power supplies, Indium alloys, Processing, Manufacturing methods, Thermocouples, Thermal conductivity, Electrical properties, Test, Test methods, Pellets, Life expectancy, Resistance (Electrical), Reports.

Effort on new material development during the period was confined to the Co-Sb system. Further evidence was obtained for the possibility of developing matched p and n materials that will have mechanical properties conducive to reliability with moderate conversion efficiency. The first report, Sb2-xBixTe3 Alloys for Thermoelectric Power Generation, summarizes the development work on this series of alloys. Compositions, processing, and contacting methods are presented. Alloys have been optimized for use at hot side temperatures up to 425 C. The report entitled, The Preparation and Evaluation of Indium-Antimony-Tellurium Alloys for Thermoelectric Power Generation, likewise summarizes the work on this alloy system. The last two reports, Vaporization of Zinc Antimonide and The Vapor Pressure of Germanium Telluride, provide additional data pertinent to the application of these materials. (Author)

21149 SOME PROPERTIES OF PURE POLYCRYSTALLINE BORON. T.Niemyski and W.Zawadzki.
Phys. Letters (Netherlands), Vol. 2, No. 1, 30-1 (Aug. 1, 1962).

The eutectic temperature in the boron–platinum system is 750 ± 10°C. The electrical conductivities of seven boron samples were measured from 20° to 750°C: all samples were p-type. Specimens with impurities of 10^{-5}% Si, 10^{-5}% Mg gave results corresponding to activation energies of ~ 1.1 eV. The thermoelectric power was measured over the same temperature range.

M.A.Taylor
PA '62

16717 ANISOTROPY OF THE ELECTRICAL CONDUCTIVITY AND THE SEEBECK COEFFICIENT OF $Bi_8Te_7S_5$.
H.H.Soonpaa.
J. appl. Phys. (USA), Vol. 33, No. 8, 2542-6 (Aug., 1962).

Electrical conductivity and the Seebeck coefficient of $Bi_8Te_7S_5$ were measured in the two main crystallographic directions of the rhombohedral lattice, parallel and perpendicular to the hexagonal (basal) plane. The ratio of the two electrical conductivities has a value of 7.56 at liquid nitrogen temperature. The Hall effect along the basal plane was measured. The properties change with temperature in a manner that indicates a complicated degenerate conduction band.

PA '62

621.362

2791 EFFECTS OF A MAGNETIC FIELD ON THE THERMOELECTRON PROPERTIES OF A BISMUTH–ANTIMONY ALLOY. R.Wolfe and G.E.Smith.
Appl. Phys. Letters (USA), Vol. 1, No. 1, 5-7 (Sept., 1962).

The changes with magnetic field in the Seebeck coefficient, the resistivity, and the thermal conductivity of bismuth–antimony alloys were measured between 78° and 295°K. The magnetoresistance and magnetothermal resistance effects are shown to be similar to those observed in pure bismuth, but no quantitative interpretation of the results is given.

A.Taylor
EEA '63

Inversion der Thermokraft bei gesinterten thermoelektrischen Werkstoffen. H.SCHREINER, F.WENDLER. Metall v 16 n 5, 9 May 1962 p 399-402, Sept p 855-8. Inversion of thermal power in sintered thermoelectric materials. Series of investigations dealing with possible advantages of producing thermoelectric semiconductors by powder metallurgy methods rather than melting. May. Effect of lattice defects in powder metal processes. Sept. Experimental results obtained with compacted and sintered bismuth tellurides in which either pure Bi_2Te_3 was used or telluride doped with 0.15% AgI; in former, repeated inversion of thermal power was observed with increasing sintering temperature. 27 refs.

EI 62

21109 ELECTRICAL AND THERMAL PROPERTIES OF MATERIALS IN THE SYSTEM As_2Te_3–Tl_2Te–As_2Se_3.
H.L.Uphoff and J.H.Healy.
J. appl. Phys. (USA), Vol. 33, No. 9, 2770-3 (Sept., 1962).

Seven compositions were prepared in the system As_2Te_3–Tl_2Te–As_2Se_3. Some of the samples were amorphous while others were diphasal including both amorphous and crystalline phases. The electrical and thermal properties of the samples were structure-dependent. At room temperature the resistivity values ranged from 4.7×10^{-3} to 1.8×10^{5} Ω cm, Seebeck coefficient values were 40 to 1210 μV deg^{-1} K and thermal conductivity values were 18.1 to 2.2 mW cm^{-1} deg^{-1}.

PA '62

AD-291 739 Div. 7, 25, 17
(TISTM/ODN) OTS price $4.60

Air Force Cambridge Research Labs., Bedford, Mass.
SINGLE CRYSTAL BISMUTH TELLURIDE,
by A. C. Yang and F. D. Shepherd, Jr. Sep 62, 36p. incl. illus. tables, 26 refs. (Rept. no. AFCRL 62-362)
(Proj. 5621) Unclassified report

DESCRIPTORS: *Single crystals (Metallurgy), *Intermetallic compounds, *Semiconductors, *Thermoelectricity, *Single crystals, X-ray photography, Bismuth compounds, Tellurides, Crystals, Preparation, Melting, Rotation, Crystallization, Optics, Test equipment, Transmission, Physical properties, Chemical impurities, Copper compounds, Materials, Growth.

Bismuth telluride single crystals were grown by the Czochralski pulling method in a furnace similar to that used by Ainsworth. Bismuth rich and stoichiometric melts led to p-type crystals. Large excesses of Te and doping with Cu2Te led to n-type crystals. Single crystal growth was sustained at rates as high as 8.5 cm/hr from p-type melts and 0.5 cm/hr from n-type melts. Growth rates above 3 cm/hr resulted in rectangular cross sections. Those below 1 cm/hr resulted in elliptical cross sections similar to those reported by Ainsworth. Typical cross section dimensions were 1.5 x 0.5 cm. Single crystals have been grown up to 22 cm in length. The variation of thermoelectric power with melt composition was observed for compositions near stoichiometry. Normal p-type thermoelectric powers (Seebeck coefficient) ranged from 220 to 260 microvolts/deg C. Normal n-type thermoelectric powers of -15 to -250 microvolts/deg C were obtained. X-ray diffraction lines observed agree with the ASTM index to within experimental error. A transmission edge was observed at approximately 0.145 ev. (Author)

'63

4958 EFFECTS OF A MAGNETIC FIELD ON THE THERMOELECTRIC PROPERTIES OF A BISMUTH-ANTIMONY ALLOY. R.Wolfe and G.E.Smith.
Appl. Phys. Letters (USA), Vol. 1, No. 1, 5-7 (Sept., 1962).
The changes with magnetic field in the Seebeck coefficient, the resistivity, and the thermal conductivity of bismuth-antimony alloys were measured between 78° and 295°K. The magnetoresistance and magnetothermal resistance effects are shown to be similar to those observed in pure bismuth, but no quantitative interpretation of the results is given.
A.Taylor

PA 63

8827 EFFECTS OF A MAGNETIC FIELD ON THE THERMOELECTRIC PROPERTIES OF A BISMUTH-ANTIMONY ALLOY. R. Wolfe and G. E. Smith (Bell Telephone Labs., Inc., Murray Hill, N. J.). Appl. Phys. Letters, 1: 5-7(Sept. 1962).
The thermoelectric properties of an alloy of 88 at. % bismuth and 12 at. % antimony in transverse magnetic fields up to 17,000 Oe are reported. Graphs of variation of resistivity with magnetic field strength and of variation of thermoelectric figure of merit with temperature show that resistivity rises with field strength. Magnetothermoelectric results with pure bismuth are similar to those for this alloy. (D.C.W.)

NSA '63

63

AD-291 235 Div. 8, 20
(TISTE/CAM) OTS price $8.10

Naval Radiological Defense Lab., San Francisco, Calif.
RADIATION EFFECTS IN THERMOELECTRICS. I. TECHNIQUES FOR DETECTION OF TRANSIENT EFFECTS AND THEIR APPLICATION TO COMMERCIAL GRADE BISMUTH TELLURIDE,
by J. W. Winslow and R. R. Hart. 13 Sep 62, 78p. incl. illus. tables, 7 refs. (Rept. no. NRDL TR-581)

Unclassified report

DESCRIPTORS: *Thermoelectricity, *Semiconductors, *Radiation effects, Resistance, Bismuth compounds, Tellurides, Neutrons, Gamma rays, Photons, Test equipment, Test methods, Experimental data, Nuclear energy, Thermopiles, Production.

Two satisfactory laboratory methods for detecting and studying transient radiation effects on Seebeck coefficient, S, and electrical resistivity, Rho, of materials having large thermoelectric figures of merit, z, were developed. The transient effects of intense beams of 2 Mev electrons on z in commercially available, thermoelectric grade bismuth telluride, were deduced from separate observations of S and Rho made using these methods, together with previously reported observations of thermal conductivity. These observations indicate that ionizing radiation has no transient effects on the point value of z, within experimental limits of accuracy amounting to ± 50%. Secondary effects very probably arising from inhomogeneity of the test material were observed. A simple model for, and some of the implications of, these observations are discussed. (Author)

1.

'63

17971 THERMOELECTRIC PROPERTIES OF CADMIUM ANTIMONIDE ALLOYED WITH ELEMENTS OF GROUPS I, III, IV and VI. S.M.Gusev and G.V.Rakin.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 9, 2328-37 (Sept., 1962). In Russian. English translation in: Soviet Physics–Solid State (USA), Vol. 4, No. 9, 1704-11 (March, 1963).

The following properties of CdSb monocrystals and polycrystals, pure and alloyed with Cu, Ga, In, Ge, Sn, Pb, Se and Te, were studied: (1) the temperature dependence of the electrical conductivity, the Hall effect, the thermoelectric power, the transverse Nernst–Ettingshausen (NE) effect; (2) the magnetic-field dependence of the electrical resistance and the NE coefficient. The energy gap at T = 0°K was found to be 0·58 eV. The temperature dependence of the carrier mobility in the impurity region was found from the Hall effect and the conductivity; in the intrinsic region it was deduced from the temperature dependence of the NE effect. The ratios of the effective masses were determined for the intrinsic region and the effective masses of holes and electrons were found in the impurity region at 100° K. The effect of impurities on the sign of conduction, carrier density, the magnitude of the thermoelectric power and other properties was established.

S.Chomet

PA 63

AD-404 614 Div. 25, 4, 7
(TISTM/PCR) OTS price $1.10

Stanford Research Inst., Menlo Park, Calif.
THERMOELECTRIC MATERIALS.
Bimonthly progress rept. no. 21, 1 July-1 Sep 62, by J. W. Johnson. 14 Sep 62, 5p.
Contract NObs77017, SRI Proj. SU2681

Unclassified report

Descriptors: *Thermoelectricity, Electrical properties, Copper compounds, Sulfides, Bismuth compounds, Resistance (Electrical), High temperature research, Mixtures, Tables, Nickel compounds, Test methods, Tellurides, Lead compounds, Materials.

'63

23417 THE PROPERTIES OF $ZnSnAs_2$ AND $CdSnAs_2$.
D.B.Gasson, P.J.Holmes, I.C.Jennings, B.R.Marathe and J.E.Parrott.
J. Phys. Chem. Solids (GB), Vol. 23, 1291-1302 (Sept., 1962).

Differential thermal analysis and X-ray powder diffraction show that $ZnSnAs_2$ transforms from chalcopyrite to disordered zinc blende structure at 650°C and melts at 775°C. The thermal conductivity at room temperature is 0.070 W cm^{-1} deg^{-1} for the disordered phase and 0.115 W cm^{-1} deg^{-1} for the ordered phase. The electrical properties depend markedly on heat treatment, but the compound is always p-type. The observed hole concentration varied between 2×10^{19} and 3×10^{21} cm^{-3} (the highest observed hole mobility being 22 cm^2 V^{-1} sec^{-1}). Thermoelectric measurements suggest that the hole effective mass $m^* = 0.5\ m_0$ and the optical energy gap is about 0.6 eV. Similar experiments on $CdSnAs_2$ confirm previously reported results.

PA 62

AD-405 620 Div. 17, 26
(TISTM/AMS) OTS price $1.60

Whirlpool Corp., St. Joseph, Mich.
THERMOELECTRIC JUNCTIONING PROJECT.
Progress rept. no. 2, 1 July-30 Sep 62,
by R. G. Sickert. 31 Oct 62, 16p.
Contract NObs86483, Proj. SR007 12 01, Task 806
Unclassified report

Descriptors: *Soldering, *Thermoelectricity, *Soldering alloys, Ultrasonic radiation, Low pressure research, Soldering fluxes, Hydrochloric acid, Bismuth alloys, Indium alloys, Tin alloys, Antimony alloys, Zinc compounds, Chlorides, Surface properties, Aging (Materials), Experimental data.

The effort expended in the second quarter was mainly concerned with evaluation of solder alloys and their characteristics. The best solder series discovered during this period was a combination of bismuth, tin and antimony. Workable solders of this series were developed with melting points ranging from 400 to 273 F. Because surface cleanliness and preparation technique are extremely important in producing a superior solder joint, studies involving surface examination through electron microscopy were initiated to determine the surface contaminants. The sensitivity of the joint resistance scanner was improved by one order of magnitude to accurately determine resistance to 1 x 10 to the -7th power ohms. (Author)

163

AD-297 918 Div. 4, 7, 14, 17
(TISTM/ODN) OTS price $3.60

General Electric Co., West Lynn, Mass.
SEMICONDUCTING COMPOUNDS FOR THERMOELECTRIC POWER GENERATION.
Final rept., 1 July-30 Sep 62,
by R. Bobone, L. F. Kendall, and R. H. Vought.
30 Sep 62, 31p.
(Contract DA 44-177-tc-639)
(TCREC Tech. rept. 62-112)
Unclassified report

DESCRIPTORS: *Intermetallic compounds, *Semiconductors, *Thermoelectricity, Chemical compounds, Copper compounds, Tin compounds, Sulfides, Germanium compounds, Alloys, Magnesium alloys, Tin alloys, Germanium alloys, Synthesis (Chemistry), Silicon alloys, Lead alloys, X-ray diffraction analysis, Thermal conductivity, Gallium compounds, Indium compounds, Antimony compounds, Bismuth compounds, Silver compounds, Lead compounds, Materials. 163

23372 TRANSPORT PROPERTIES OF p-TYPE Bi_2Te_3–Sb_2Te_3 ALLOYS IN THE TEMPERATURE RANGE 80-370°K.
L.R.Testardi, J.N.Bierly, Jr and F.J.Donahoe.
J. Phys. Chem. Solids (GB), Vol. 23, 1209-17 (Sept., 1962).

The Seebeck coefficients, electrical and thermal conductivities and Hall coefficients of a number of p-type alloys from the $(Bi,Sb)_2Te_3$ pseudo-binary system were measured in the temperature range 80°-370°K. The results are found to be generally consistent with the assumptions of a many-valley valence band and charge carrier mobility limited by acoustical scattering, once corrections for the effects of degeneracy have been made using exact statistics. The possibilities of temperature and degeneracy-dependent band structures are discussed in relation to anomalies in the Hall and Seebeck coefficients. The Klemens–Drabble theory of thermal resistance (Abstr. 13499 of 1960) due to point defect scattering (with a slightly modified form for the mass fluctuation parameter) is in good agreement with the experimental values for the lattice thermal conductivity of these alloys. The doping behaviour of the alloys at room temperature also confirms the assumption of acoustical scattering of the charge carriers.

PA 62

20290 EFFECT OF MUTUAL ELECTRON AND PHONON DRAG ON THE THERMO-E.M.F. AND THE NERNST EFFECT [IN DEGENERATE SEMICONDUCTORS].
A.L.Natadze and A.L.Éfros.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 10, 2931-9 (Oct., 1962). In Russian. English translation in Soviet Physics-Solid State (USA), Vol. 4, No. 10, 2149-54 (April, 1963).

The effect of mutual electron and phonon drag on the thermo-e.m.f. and the Nernst effect in degenerate semiconductors in strong magnetic fields was investigated. It was shown that at low temperatures the thermo-e.m.f. increases in the ratio ζ/kT, and the temperature dependence of the Nernst effect is changed when mutual drag is taken into account.

PA 63

2926 THERMAL CONDUCTIVITY, ELECTRICAL CONDUCTIVITY, HALL EFFECT, THERMOPOTENTIAL AND SPECIFIC HEAT OF Ag_2Se.
Y.Baer, G.Busch, C.Fröhlich and E.Steigmeier.
Z.Naturforsch. (Germany), Vol. 17a, No. 10, 886-9 (Oct., 1962). In German.

The thermal conductivity, electrical conductivity, Hall coefficient and thermoelectric power of Ag_2Se were measured between 80° and 600°K. In the low temperature semiconductor phase the thermal conductivity increases with increasing temperature due to the high amount of carrier contribution. The latter were calculated using the Price formula. Agreement with experiment is satisfactory. The specific heat was measured between 30° and 200°C. For the latent heat a value of (5·7 ± 0·5) cal/g was determined in agreement with measurements of Bellati and Lussana. In addition to the transition at 133°C an unknown new transition was found at about 90°C.

PA 163

Electron Transport Properties in Liquid Gallium, N.E.CUSACK, P.W.KENDALL, A.S.MARWAHA. Philosophical Mag v 7 n 82 Oct 1962 p 1745-52. New measurements of Hall coefficient and absolute thermoelectric power of liquid gallium; Hall coefficient has "free electron" value; all known electron transport properties of liquid Ga are collected and discussed in relation to recent theory of Ziman; previously unpublished X-ray diffraction observations are quoted and used. 21 refs.

EI 163

2983 THERMOELECTRICITY IN IRRADIATED GLASS.
F.C.Hardtke.
Phys. Rev. Letters (USA), Vol. 9, No. 8, 339-41 (Oct. 15, 1962).

Electric charge displacements were measured in glass plates, previously irradiated by a Co^{60} source, heated in temperature gradients of 20 to 40°C per mm. An explanation of the phenomenon in terms of Compton scattering in the glass plate and surrounding material, is discussed.

J.N.Hodgson
PA 163

6522 (NRL-Memo-1361) STATUS REPORT ON THERMOELECTRICITY. J. W. Davisson and Joseph Pasternak (Naval Research Lab., Washington, D. C.). Oct. 1962. 153p.

A review of progress is presented on thermoelectric materials with emphasis on reliability and radiation effects. Other information is included concerning development of devices. It is noted that development of power-generating materials for intermediate temperature ranges continues to move slowly. Development of liquid thermoelectric materials is noted along with magnetic effects at cryogenic temperatures. Continued progress is noted in large refrigeration equipment and in 250-w power generators. (J.R.D.)

11 SA 63

AD-404 085 Div. 25
(TISTM/AW) OTS price $4.60

Du Pont de Nemours, E. I., and Co., Inc., Wilmington, Del.
THERMOELECTRIC PROPERTIES OF SELENIDES AND TELLURIDES OF GROUPS VB AND VIB METALS AND THEIR SOLID SOLUTIONS,
by W. T. Hicks and H. Valdsaar. 31 Oct 62, 27p.
Contract NObs84824, Proj. SR007 12 01, Task 802
Unclassified report

Descriptors: *Selenides, *Tellurides, *Semiconductors, Tungsten alloys, Molybdenum alloys, Hall effect, Tantalum alloys, Synthesis (Chemistry), Thermal conductivity, Thermoelectricity, Group V elements, Group VI elements, Chalcogens, Thermocouples, Rhenium, Solutions, Electrical properties, Intermetallic compounds.

The study of the tantalum-doped solid solutions of the compounds WSe2, WTe2, MoSe2 and MoTe2 was continued. To date, these complex materials showed no practical advantage over tantalum-doped tungsten diselenide. Incidental observations made in the course of this study have revealed occasional difficulties in reproducing earlier data. Hall coefficient data were obtained on several W(1-x)Ta(x)Se2 compositions at temperatures up to 600 C and were interpreted to yield information on the scattering mechanism at various doping levels and on the relation between chemical dopant concentration and carrier density. Hall effect measurements were also made on rhenium-doped molybdenum diselenide. A number of niobium and tantalum tellurides and selenides were synthesized in exploratory work. They show no promise of practical value as thermoelectric materials. Several test modules utilizing tantalum-doped tungsten diselenide were constructed; the results suggest that this p-type material may be useful in cascaded generators between 500 and 1000 C. (Author)

'63

AD-404 781 Div. 7
(TISTE/JWS) OTS price $5.60

General Electric Co., West Lynn, Mass.
RESEARCH AND DEVELOPMENT OF MATERIALS AND FABRICATION TECHNIQUES FOR THERMOELECTRIC POWER GENERATION.
Quarterly progress rept. no. 3, 1 Aug-30 Oct 62. 30 Jan 63, 55p.
Contract NObs86854, Proj. SR007 12 01, Task 802
Unclassified report

Descriptors: *Thermoelectric converters, Life expectancy, Tests, Soldering, Soldering fluxes, Lead alloys, Tellurides, Brazing, Welding, Test equipment, Bonding, Manufacturing methods.

Life test data to 2000 hours of operation with temperature cycling were obtained. Agreement with the predicted power level is considered excellent, but significant problems remain. Our solution to these problems along with test data is presented. A study was completed to determine the optimized cartridge configuration. Many improvements in design were made possible from experience obtained from test and fabrication problems encountered in the original design. Junction electrical resistance are reduced by techniques described. It is believed that the greatest significant attainment exists in the solution to the junction problem. (Author)

'63

AD-290 222 Div. 25, 14
(TISTM/BRW) OTS price $3.00

Naval Research Lab., Washington, D. C.
THERMOELECTRICITY.
Quarterly status rept. no. 9,
by J. W. Davisson Joseph Pasternak and B. B. Rosenbaum. Oct 62, 150p. incl. illus. tables.
(NRL memo. rept. no. 1361)
(In cooperation with Bureau of Ships, Washington, D. C.

Unclassified report

DESCRIPTORS: *Thermoelectricity, Power supplies, Thermal conductivity, Liquids, Solids, Sulfides, Selenides, Tellurides, Semiconductors, Oxides, Materials.

Westinghouse Electric Corporation has partially reduced troublesome cracking in thermocouples of pure GeTe by the addition of approximately 10% TlBiTe2. General Atomic division of General Dynamics Corporation found that barium doping improved the thermoelectric performance of cerium sulfide. Chrysler Corporation, in their investigation of compounds of high atomic weight refractory metals (Hf, Ta, W, Re) with IV B(Ge), V B(As, Sb, Bi), and VI B(Se, Te) elements, found that these are not promising as thermoelectric materials. Similarly, investigation of thorium and uranium sulfides, selenides, and tellurides by Electro-Optical Systems, Inc., did not appear promising. Thermal instability has thus far limited MoTe2 and WTe2 alloys to 400 to 500 C at the most. An investigation by the U.S. Naval Engineering Experiment Station of twenty commercial n-type lead tellurides indicated that no improvement in material efficiency should be expected by changing cylindrical-shaped elements to truncated conical shapes. (Author)

'63

1124 (NAA-SR-7036) PROCESS DEVELOPMENT AND FABRICATION OF PbTe THERMOELECTRIC ELEMENTS. F. R. Bennett and K. Langrod (Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.). Oct. 30, 1962. Contract AT(11-1)-Gen-8. 24p.

The development and fabrication of Pb-Te pellets, contacted to Fe end caps, for use as elements in thermoelectric converters for the SNAP 10A program, is described. The method adopted consists of contacting, by hot pressing in a controlled atmosphere, 24 pellets simultaneously, using 4-layer, 6-cavity graphite dies. The optimum hot pressing parameters were found to be 5000 psi at 1550°F for 30 min. Several thousand elements were produced by this relatively high-volume process, modifying the normally slow and expensive hot pressing by the use of multilayer, multicavity dies and automatic controls. (auth) NSA '63

1825 THERMOELECTRIC INSTABILITY OF SOME NOBLE METAL THERMOCOUPLES AT HIGH TEMPERATURES.
B.E.Walker, C.T.Ewing and R.R.Miller.
Rev. sci. Instrum. (USA), Vol.33, No.10, 1029-40 (Oct., 1962).

Thermoelectric instabilities of noble metal thermocouples and individual thermoelements (platinum, rhodium, iridium, iridium-50% rhodium, and several platinum-rhodium alloys) were studied in the temperature range from 1000° to 1700°C under oxidizing and neutral atmospheres. The principal source of instability was found to be contamination of the thermoelements by impurities from ceramic protection tubes. Several grades of alumina sheathing were tested, and thermocouple errors associated with each grade are reported. Criteria are discussed for the selection and application of noble metal thermocouples to attain maximum thermoelectric stability.

EEA '63

4822 OPERATING CHARACTERISTICS OF TRANSVERSE (NERNST) ANISOTROPIC GALVANO-THERMOMAGNETIC GENERATORS. T.C.Harmon and J.M.Honig.
Appl. Phys. Letters (USA), Vol. 1, No. 2, 31-2 (Oct., 1962).

Discusses theoretically the optimal efficiency of a set of such devices connected thermally in parallel and electrically in series, showing that this depends not only on the figure of merit $Z = (HN+P)^2/KR$ but also on $r = (HN-P)/(HN+P)$, where N and P are the overall Nernst and Seebeck coefficients, K and R the overall thermal conductance and electrical resistance and H is the magnetic field.

ECA'63 J.Hawgood

Thermoelectric Properties of Binary and Ternary Copper-Nickel Alloys, D.D.POLLOCK. Met Soc of AIME—Trans v 224 n 5 Oct 1962 p 892-903. Mott and Jones theory of thermoelectricity for alloys of transition and noble metals is found by measurements on relatively pure Cu-Ni alloys to apply also to binary alloys of transition elements; theory is extended to show that emf behavior of dilute ternary 60%Cu-40%Ni base alloys may be described in terms of scattering mechanism; modified Mott and Jones equation is derived which accurately expresses behavior of ternary and quaternary Cu-Ni alloys. 23 refs.

EI'63

Thermoelectric Instability of Some Noble Metal Thermocouples at High Temperatures, B.E.WALKER, C.T.EWING, R.R.MILLER. Rev Sci Instruments v 33 n 10 Oct 1962 p 1029-40. Study of thermocouples and individual platinum, rhodium, iridium, iridium-50% rhodium, and several platinum-rhodium alloy thermoelements in temperature range from 1000 to 1700 C under oxidizing and neutral atmospheres; principal source of instability was found to be contamination of thermoelements by impurities from ceramic protection tubes; criteria are discussed for selection and application of noble metal thermocouples to attain maximum thermoelectric stability.

EI 62-1

AD-406 122 Div. 17, 7
(TISTM/BRW) OTS price $8.60

Westinghouse Electric Corp., Pittsburgh, Pa.
THERMOELECTRICITY.
Quarterly progress rept. no. 3.
Oct 62, 1v.
Contract NObs86595

Unclassified report

Descriptors: *Thermoelectricity, *Intermetallic compounds, Antimony alloys, Tellurides, Tellurium alloys, Bismuth alloys, Cobalt alloys, Germanium alloys, Impurities, Hydrogen, Oxygen, Iron, Tin, Copper compounds, Sulfides, Degasification, Thermal conductivity, Resistance (Electrical), Temperature, Thermal expansion, Reduction (Chemistry), Heat treatment, Microstructure, Transformations, Air conditioning equipment, Materials, Preparation.

Work is continuing on the Co-Sb system to develop a matching 'p' and 'n' material. Thermoelectric property measurements are being extended to higher temperature for the 'n' material, and mechanical property measurements are being made. Material having 'p' type thermoelectric properties over a broad temperature range was made, but the properties are not optimum. Most of the contaminants, present as residuals in the raw materials, and those with which the alloy may come into contact during processing, such as O2 and H2, are 'n' type dopes. The 'p' doping characteristics of Fe and Sn were established. Thermal cycling tests were run to provide further data on the effects of chemistry and processing on the thermal cracking of GeBiTe. Evaluation was made in terms of change in resistance and microstructure. Three Reports are appended: 'Environmental Suit Generator' describes the design, construction, and testing of a thermoelectric heating and ventilating unit;' 'Determination of the Figure of Merit of Thermoelectric Materials' discusses methods for measuring thermoelectric properties and 'The Thermal Conductivity of Molten Cu2S.25-Te.7 and Molten Cu2S presents a review of the method and the results of measurements. (Author)

'63

Effect of Pressure on Electrical Resistance of Lithium, Sodium and Potassium at Low Temperatures, J.S.DUGDALE, D.GUGAN. Roy Soc Lond—Proc Ser A v 270 n 1341 Nov 13 1962 p 186-211. Electrical resistivity measured at temperatures between 2 and 300 K and at pressures up to 3000 atm; there is linear relation between temperature and volume coefficients of ideal resistivity for each metal; magnitude of volume coefficient of ideal resistivity does not, at high temperatures at least, agree with present theoretical predictions; this coefficient is closely connected with high-temperature value of thermoelectric power. 54 refs. EJ '63

13144 THERMOELECTRIC PROPERTIES OF THE SINGLE-PHASE OF $AgSbTe_2$. T.Irie.
J. Phys. Soc. Japan, Vol. 17, No. 11, 1810-11 (Nov., 1962).
Electrical resistivity (σ) and thermoelectric power (α) were studied between 80° and 300°K. From thermal conductivity measurements, lattice thermal conductivity was estimated to be about $0{\cdot}65\times10^{-2}$ W deg^{-1} C cm^{-1}. A linear relation between ln σ and α was found. M.H.Khan
PA '63

AD-404 615 Div. 25, 4, 7
(TISTM/PCR) OTS price $1.10

Stanford Research Inst., Menlo Park, Calif.
THERMOELECTRIC MATERIALS.
Bimonthly progress rept. no. 22, 1 Sep-1 Nov 62, by J. W. Johnson. 15 Nov 62, 3p.
Contract N0bs77017, SRI Proj. SU2681
Unclassified report

Descriptors: *Thermoelectricity, Copper compounds, Iron compounds, Sulfides, Resistance (Electrical), High temperature research, Tables, Electrical properties, Mixtures, Test methods, Materials.
'63

41523 (AFCRL-62-1047) CALCULATION OF THERMOPOWER FACTORS FOR A PLASMA AND A METAL. Scientific Report No. 3. Jack Davis and Giovanni Lanza (Northeastern Univ., Boston) Nov. 1, 1962. Contracts AF19(604)-7358 and AF19(604)-8462. 14p. (AD-293411)
The classical theory of transport phenomena, as applied to thermocouples, is developed using the Boltzmann transport equation. A comparison of the thermopower factors for a plasma and a metal, derived using Boltzmann statistics for the plasma and Fermi statistics for the electron gas in a metal, shows that the plasma thermopower factor is much larger than that for a metal. (D.C.W.) NSA '63

2918 ELECTRICAL CONDUCTIVITY AND THERMOELECTRIC POWER OF INDIUM OXIDE. M.J.Arvin.
J. Phys. Chem. Solids (GB), Vol.23, 1681-3 (Nov.,1962).
The electrical conductivity and thermoelectric power of powder compacts of In_2O_3 were measured over the temperature range 180° to 460°C. The dominant effects observed are attributed to the presence of PbO_2 impurity. J.Holt
PA '63

2871 MOBILITY AND THERMOELECTRIC POWER IN MANY-VALLEY POLAR SEMICONDUCTORS.
D.J.Olechna and H.Ehrenreich.
J. Phys. Chem. Solids (GB), Vol. 23, 1521-4 (Nov., 1962).
The mobility μ and the thermoelectric power Q are calculated variationally for polar semiconductors having ellipsoidal energy surfaces in which the polar electron-phonon interaction is dominant. Equations applicable to both Fermi and Boltzmann statistics are presented. Numerical results for μ and Q for the latter case are given as a function of temperature for varying degrees of ellipticity. These show that the thermoelectric power is relatively insensitive to changes in ellipticity. A simple appromimate formula for the mobility given previously (Abstr. 1073 of 1961) is shown to agree well with the results of the variational method.
PA '63

22948 PRESSURE DEPENDENCE OF THE ELECTRICAL PROPERTIES OF PbTe AND PbS.
A.A.Averkin, S.Kasimov and E.D.Nensberg.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 12, 3667-9 (Dec., 1962).
In Russian. English translation in: Soviet Physics—Solid State (USA), Vol. 4, No. 12, 2681-2 (June, 1963).
The variation of the thermoelectric power and the electrical conductivity with uniform pressure up to 9000 kg cm^{-2} was measured at room temperature for single-crystal n- and p-type specimens of PbTe and PbS. J.B.Birks
PA '63

Termoelektricheskie svoistva tverdogo rastvora Mg_2Si-Mg_2Sn, E.N.NIKITIN, V.G.BAZANOV, V.L.TARASOV. Fizika Tverdogo Tela v 3 n 12 Dec 1961 p 3645-9; see also English translation in Soviet Physics, Solid State v 3 n 12 June 1962 p 2648-51. Thermoelectric propoeties of solid solutions Mg_2Si-Mg_2Sn; thermoelectric power, electrical conductivity, thermal conductivity and their temperature dependence investigated.

ET-162

UNCLASSIFIED

107940 STRUCTURAL INVESTIGATIONS IN THERMOELECTRIC MATERIALS
(Period covered: October 1-December 31, 1962)
Pollak, P. I.; Conn, J. B. (et al)

Unclassified

Merck, Sharp & Dohme Research Laboratories
NObs-88112
QR-1

The system $xCuSbSe_2 \cdot (1-x)Cu_3SbSe_4$ has been studied over its complete range. Within the internal $x \leqslant 0.4$, the chalcopyrite structure of Cu_3SbSe_4 is dominant, and marginal thermoelectric properties are exhibited. Based on information thus far collected, the system is degenerate, with electrical conductivity largely controlled by mobility. The best figure of merit was shown by the alloy $x = 0.4$, with 5 atom per cent of antimony replaced by bismuth, the value being $0.48 \times 10^{-3}/K°$.

Materials, thermoelectric

UNCLASSIFIED

23028 THERMOELECTRIC PROPERTIES OF TELLURIUM AND THE EFFECTIVE MASS OF HOLE CARRIERS.
I.N.Timchenko and S.S.Shalyt.
Fiz. tverdogo Tela (USSR), Vol.4, No.12, 3612-17 (Dec., 1962).
In Russian. English translation in: Soviet Physics-Solid State (USA), Vol.4, No.12, 2642-5, (June, 1963).

The thermoelectric properties were investigated of annealed single crystals of tellurium with different carrier concentrations (10^{14} to 10^{19} cm^{-3}) over the temperature range from 77° to 200°K. The effective mass of the hole carriers was determined on the basis of the data thus obtained.

PA b3

2981 DEPENDENCE OF THE THERMOELECTRIC FIGURE OF MERIT ON ORIENTATION IN UNIAXIAL CRYSTALS.
J.R.Madigan.
J. appl. Phys. (USA), Vol.33, No.12, 3564-7 (Dec., 1962).

The thermoelectric figure of merit was determined as a function of the angle between the principal symmetry axis and either the field vectors $\vec{E}$ and $-\nabla T$ or the current densities $\vec{j}$ and $\vec{q}$ for uniaxial crystals, assuming isotropy of the Seebeck coefficient. For any orientation of these vectors other than parallel or perpendicular to the principal symmetry axis, the figure of merit in the direction of the current densities is always less than that in the direction of the field vectors. The latter situation is realized experimentally in thin disk samples while the former is characteristic of long rods. When these expressions are averaged over the angle between the cleavage planes and the appropriate vectors, the figure of merit in the direction of the field vector is 86% while that parallel to the current densities is 72% of the maximum value for Bi_2Te_3 crystals. These values should be characteristic of sintered powder samples.

PA b3

AD-294 562 Div. 25, 30, 26
(TISTM/EJH) OTS price $6.60

Denver U., Colo.
VACUUM DEPOSITED THERMOCOUPLES.
Master's thesis,
by Richard C. Gerhardt. Dec 62, 59p. incl. illus. tables, 10 refs.
(Contract N123(60530)10049A)
Unclassified report

DESCRIPTORS: *Thermocouples, *Thermoelectricity, *Thin films, Vapor plating, Metallic films, Materials, Semiconductors, Tellurium, Antimony, Aluminum, Bismuth, Resistance, Thickness, Nickel alloys, Aluminum alloys, Metallic smoke deposits, Coatings.

This thesis is concerned with properties which influence the use of thermocouples formed by vacuum deposition. Studies of various single films were made, and the results provided an aid to the understanding of the properties of thin film thermocouples. The thinness of a film forming a vacuum deposited thermocouple is limited by the resistance of the film rather than the thermoelectric power. The thermoelectric powers of the films studied are nearly independent of thickness above the lower limits set by the resistance. Deposition of the thermocouple materials is best done during a single pumpdown of the vacuum system. Silver ink painted over the copper wire leads produced the best contacts between these leads and the thin film. Pure metals exhibited lower thermoelectric power than the corresponding material of lower purity. This is true of some semiconductors in their bulk forms (e.g., tellurium) and it was also found to be true of thin films (e.g., antimony). (Author)
'63

AD-404 023 Div. 14, 25
(TISTM/AW) OTS price $4.60

E. I. Du Pont de Nemours and Co., Inc., Wilmington, Del.
THERMOELECTRIC PROPERTIES OF SELENIDES AND TELLURIDES OF GROUPS VB AND VIB METALS AND THEIR SOLID SOLUTIONS.
Quarterly rept. no. 6, 1 Oct-30 Dec 62,
by W. T. Hicks and H. Valdsaar. 8 Feb 63, 1v.
Contract Nobs84824, Proj. SR007 12 01, Task 802
Unclassified report

Descriptors: *Selenides, *Tellurides, *Semiconductors, Group VI elements, Group V elements, Tungsten alloys, Lead alloys, Encapsulation, Thermal conductivity, Thermoelectricity, Tantalum, Chemical reactions, Thermocouples, Resistance (Electrical), Electrical properties, Intermetallic compounds.

Improved procedures in synthesis and in measurements have eliminated unreproducibilities in tantalum-doped tungsten diselenide preparations, giving a well-substantiated Figure of Merit of about 0.5 x 10 to the minus 3 power/deg in the 500 to 1000 C range. An apparatus for direct efficiency measurements is under construction. It is planned to incorporate tantalum-doped tungsten diselenide (p-type) in a practical thermoelectric module, cascaded with p-type lead telluride and encapsulated in a ceramic-coated constantan can which will also serve as the n-leg of the couple. Experimentation with the details of construction is underway. (Author)
'63

3842 COOLING MICROMODULES INTERNALLY WITH PELTIER JUNCTIONS. D.K.Allison.
Electronics Reliability and Microminiaturization (GB), Vol. 1, 359-63 (Oct.-Dec., 1962).

Heat dissipation from microminiature components encapsulated or otherwise enclosed within microminiature systems can prove a difficult problem. Four suggested methods are considered but each has its limitations. The Peltier-junction refrigeration system is a classic heat-pump most compatible with microminiature units; a microjunction comparable in size to a microtransistor will dissipate the heat from five such transistors. Typical constructions are described (usually semiconductors) and operating parameters, automatic control and most suitable materials are discussed, i.e. p-type Sb, Pb, Bi telluride; n-type Pb and Bi telluride; Cr-constantan Sb-Bi, Bi telluride thermocouples. Overall electrical efficiency is increased by obtaining the necessary current from Seebeck generators, positioned in the hotter regions of the equipment. E.H.Dock

EEA '63

23486 THERMOELECTRIC POWER OF QUENCHED PLATINUM. J.Polák and K.Míšek.
Czech. J. Phys., Vol. 12, No. 6, 492-3 (1962).

Preliminary experiments on the effect of quenching and work hardening on the thermoelectric power of annealed platinum wire.

P.A.Walker

PA '62

20343 SEMICONDUCTING PROPERTIES OF SILVER TELLURIDE (Ag_2Te). O.Böttger and W.Meister.
Ann. Phys. (Germany), Vol. 9, No. 7-8, 367-81 (1962). In German.

The results are given of the measurement of thermal e.m.f.s, conductances and Hall effect parameters, for bulk samples (4 mm × 4 mm × 30 mm) over the temperature range +20° to −190°C. The influence of small departures from exact stochiometric proportions is reported. An energy level system is proposed upon which the results can be explained.

J.Muir

PA 63

14964 METHOD FOR THE DETERMINATION OF THE TIME CONSTANT OF THERMOCOUPLES. E.Gehrmann and I.Schusta.
Wiss. Z. Hochsch. Elektrotech. Ilmenau (Germany), Vol. 8, No. 5, 419-21 (1962). In German.

Discusses the difficulties which arise in determining the response time of thermocouples. These arise mainly from the necessity to amplify without distortion a small signal over a frequency band ranging from d.c. to 50 kc/s. An arrangement is described which incorporates a d.c. amplifier with a gain of 300 and which is convenient for couples with an intermediate time constant.

R.Parker

EEA '63

15640 BISMUTH-ANTIMONY THERMOJUNCTIONS. D.C.Kane.
Proc. Iowa Acad. Sci. (USA), Vol. 69, 451-5 (1962).

High purity bismuth and antimony were deposited by evaporation under high vacuum in separate processes onto glass substrates to form thermojunctions. Substrate cleaning methods, and means of attaching leads are mentioned. Measurements of the thermal e.m.f. produced are discussed. Devices for regulating and measuring the temperature of the substrate in order to find the e.m.f.-temperature relationship of Bi-Sb thermojunctions are also discussed.

PA 63

13141 VARIATION IN THERMOELECTRIC FORCE OF IRON DURING PLASTIC DEFORMATION. N.A.Karelin.
Fiz. Metallov i Metalloveden. (USSR), Vol. 13, No 5, 763-5 (May, 1962). In Russian. English translation in: Physics of Metals and Metallography (GB), Vol 13, No. 5, 118-20 (1962; publ. March, 1963).

Annealed mild steel wires containing 0·14% C were deformed by rolling, shearing and stretching. In all cases the form of the thermal e.m.f. versus deformation curve is the same; for small deformations the (negative) e.m.f. increases linearly and rapidly with deformation; at larger deformations the e.m.f. still increases linearly with deformation but it increases more slowly. The change-over point is dependent upon the annealing conditions but occurs at the same e.m.f. values in extension and in rolling. M.A.Taylor.

PA '63

36463 THERMOELECTRICITY. Frank E. Jaumot, Jr. (General Motors Corp., Kokomo, Ind.). Adv. Electron. Electron Phys., 17: 207-43(1962).

A review of the principles involved in thermoelectricity is presented with particular emphasis on gaps in the present knowledge of the phenomenon. The materials systems of greatest interest and the approximate temperature at which the system appears to be most useful are reported. The figure of merit, materials fabrication, and device design are considered. The theoretical parameters involved and their effects on thermoelectric cell development are discussed. Applications of the thermoelectric cells are also considered. (C.E.S.)

NSA '63

18649 ELECTRICAL PROPERTIES OF TITANIUM CARBIDE–TITANIUM NITRIDE ALLOYS.
S.M.L'vov, V.P.Nyemchenko and H.V.Samsonov.
Ukrayin. fiz. Zh. (USSR), Vol. 7, No. 5, 331-5 (1962). In Ukrainian.

The concentration dependence of resistivity, Hall constant, thermal e.m.f. and thermal coefficient of resistivity for alloys in a TiC–TiN system were investigated. According to the data obtained the electrical conductivity of the edge phases and all the intermediate alloys in the system are mainly dependent on the titanium 4s-electrons and to some extent on the 3d-band holes, the latter become more significant with transition from TiC to TiN.

PA '62

9913 THE ELECTRICAL PROPERTIES OF BROMIDE-DOPED SELENIUM WITH THALLIUM ADDITION.
L.Gombay, J.Gyulay, J.Kispéter and J.Lang.
Acta. phys. chem. Szeged. (Hungary), Vol. viii, No. 1-2, 30-45 (1962). In German.

The temperature dependence of electrical conductivity and thermoelectric power were determined for polycrystalline selenium layers which had been annealed at 120° C. Similar measurements were made on selenium doped with various concentrations of Br and Tl, and with both the latter elements. The hole concentration and mobility of the materials was evaluated from the results. These suggest that thallium bromide is formed and that only the excess impurity influences the electrical properties of selenium. The influence of bromine is enhanced in the presence of a small concentration of thallium bromide. R.Parker

CEA '63

18762 THERMOELECTRIC AND ELECTRIC PROPERTIES OF THE SECTION ZnSb–CdSb.
V.Ye.Shmayevs'kyi and T.P.Metil'.
Ukrayin. fiz. Zh. (USSR), Vol. 7, No. 3, 294-6 (1962). In Ukrainian.

The temperature relationships α and σ are determined for equilibrium alloys on the section ZnSb–CdSb. It is shown that annealing has a substantial effect on the properties of the specimens. The conclusion is drawn that at a temperature above 150°C there occurs an ordering of the solid solution which contains 50 mol.% ZnSb and 50 mol.% CdSb.

PA '62

11611 THERMOCOUPLE MATERIALS.
F.R.Caldwell.
Nat Bur Stand. Monogr. (USA), No 40, 43 pp (1962).

Thermocouple materials are considered that are used primarily as immersion temperature sensors in the range from 0°C up. Included are the conventional thermocouples that have survived since the beginnings of the art of thermoelectric temperature measurement, newer noble metal thermocouples, and thermocouples of refractory metals for use in the extreme range for immersed sensors. Thermocouples for thermoelectric generators are not considered, nor are the types commonly used chiefly in radiation receivers such as those containing antimony, bismuth, and their alloys. Because of the wide use and increasing popularity of ceramic-packed thermocouples in metal sheaths, they are included. Limitations of the thermocouple wires are given as to range, stability, environment including atmosphere, magnitude of thermoelectric e.m.f., and accuracy of commercially available materials of standard and extra quality. In addition, properties of the separate elements that are pertinent to the selection or use of thermocouples have been compiled. Among these are: chemical behaviour, mechanical properties, specific heat, density, thermal conductivity, thermal coefficient of expansion, emissivity, electrical resistivity, and magnetic and catalytic properties. In the case of the ceramic-packed thermocouples the following properties are presented: temperature range of the sheath, mechanical properties of the sheath, kinds of packed insulation, resistance between thermocouple wires and between wires and sheath, minimum bending radius of the packed stock, gas-tightness of the packed insulation, and types of measuring junctions available, i.e., grounded, ungrounded, bare, totally enclosed, stagnation mounting, etc. Not all of the above information is presented for all thermocouples, but all that is readily available in the general literature, catalogues, and by private communication is included. Limitations on use of thermocouples normally are given in the text, and properties of the materials generally are presented in tables.

PA 62

18761 THERMOELECTRIC POWER OF VANADIUM PENTOXIDE UNDER THE ACTION OF NUCLEAR RADIATION. I.Maxim and L.Rîbco.
Stud. Cercetari Fiz. (Roumania), Vol. 13, No. 2, 289-95 (1962).
In Roumanian.

PA '62

8574 ON THE DEPENDENCE OF THE THERMOELECTRIC, RESISTIVE AND PHOTOELECTRIC CHARACTERISTICS OF Cs–Sb LAYERS ON THE FORMING CONDITIONS. U.Heilig.
Phys. Status solidi (Germany), Vol. 2, No. 12, K296-K299 (1962).
In German.

The characteristics of the layers were measured during the forming process. The resistance rises with Cs content giving maxima for Cs–Sb, Cs_5Sb_4 and Cs_3Sb, the photoelectric yield rising steadily with Cs content. The thermoelectric power gives maxima for the above compositions but not all are observed for a given specimen.

G.F.J.Garlick

PA '63

10894 EFFECTS OF A MAGNETIC FIELD ON THE THERMOELECTRIC PROPERTIES OF BISMUTH-ANTIMONY ALLOYS. R.Wolfe and G.E.Smith.
"Semiconductor" Conference, Exeter, 1962 (see Abstr. 6566 of 1963) p. 771-6.

The effects of a transverse magnetic field on the thermoelectric properties of single crystals of bismuth–antimony alloys were investigated between 77° and 295°K. Large increases in the Seebeck coefficient and the thermoelectric figure of merit Z were observed. With the direction of current flow parallel to the threefold symmetry axis, the increases in the Seebeck coefficient S, resistivity ρ, thermal resistivity $1/\kappa$ and $Z(= S^2/\kappa\rho)$ are greatest when the magnetic field is parallel to a bisectrix axis. As the field is increased, the figure of merit rises to a maximum (as much as 2·8 times greater than the zero field value in (88%) Bi–(12%) Sb at 220°K). In higher fields, Z decreases as S and κ begin to saturate and ρ continues to increase with field. The field at which the maximum Z occurs is proportional to $T^{2\cdot7}$ for (95%) Bi–(5%) Sb and to $T^{3\cdot8}$ for (88%) Bi–(12%) Sb. At 100°K this field is 1000 Oe for both alloys. In the 5% antimony alloy, the Z at room-temperature was increased from $1\cdot7\times10^{-3}$ deg C^{-1} to $3\cdot0\times10^{-3}$ deg C^{-1} in a field of 16000 Oe. The highest figure of merit measured was $8\cdot6\times10^{-3}$ deg C^{-1} at 100°K in 1000 oersteds for the 12% antimony alloy. The large changes with field in all of the measured properties are associated with the presence of equal densities of high mobility anisotropic electrons and holes.

PA '63

Bismuth Telluride and Some of Its Alloys, H.J.GOLDSMID. G.E.C. J Science & Technology v 29 n 3 1962 p 158-67. Preparation and physical properties of semiconductor Bi_2Te_3, and its alloys with Sb_2Te_3, and Bi_2Se_3; methods of producing polycrystalline and single crystal material; electric, optical and thermal properties of Bi_2Te_3, are discussed with emphasis on characteristics in thermoelectric applications. 54 refs.

EI 62

4694 MEASUREMENT OF FIGURE OF MERIT FOR THERMOELECTRIC MATERIALS. H.Nettelbladt.
Elteknik (Sweden), Vol. 6, No. 1, 13-15 (Jan., 1963). In Swedish.

A modification of the Battelli Memorial Institute method is described. The voltage across the sample is measured when current is first applied and when thermal equilibrium is reached, using the step of oscilloscope deflection when switches are closed.

H.Jefferson

EEA'63

Transport Properties of Bismuth Single Crystals, C.F.GALLO, B.S.CHANDRASEKHAR, P.H.SUTTER. J Applied Physics v 34 n 1 Jan 1963 p 144-52. Absolute Seebeck coefficient, electrical resistivity, and thermal resistivity simultaneously measured on pure bismuth single crystals of various orientations between approximately 80 and 300 K; parameters of overlap energy and Fermi energy, density of states effective mass of electrons and of holes, separate electronic and lattice thermal conductivities, actual index of thermoelectric efficiency, and hypothetical "optimum" index of thermoelectric efficiency were calculated. 47 refs. EI'63

20341 THE MECHANISM OF CONDUCTION IN ORGANIC SEMICONDUCTING POLYMERS.
A.V.Airapetyants, R.M.Voitenko, B.É.Davydov and B.A.Krentsel'.
Dokl. Akad. Nauk SSSR, Vol. 148, No. 3, 605-8 (Jan. 21, 1963).
In Russian.

The temperature-dependence of the specific resistance and the differential thermal e.m.f. in polyacrilonitrile was measured, and the effect of processing temperature and absorbed gases was determined. The results are interpreted in relation to the nature of the carriers in polyacrilonitrile.

R.F.S.Hearmon

PA63

20427 THE [THERMOELECTRIC] CONDUCTIVITY MECHANISM OF FERROMAGNETIC Ni-Cu ALLOYS.
A.J.Schmidt and K.M.Koch.
Z. Naturforsch. (Germany), Vol. 18a, No. 1, 31-6 (Jan., 1963).
In German.

The variation of thermoelectric power in longitudinal and transverse magnetic fields was determined in nickel-rich Ni-Cu alloys. In the low-field range there was a rapid decrease of the thermoelectric power with fields applied along the temperature gradient and an increase in fields normal to this gradient. This phenomenon is associated with the orientation of Weiss domains. In high fields the change in thermoelectric power becomes more gradual and independent of the field direction. This is associated with the increase in spontaneous magnetization. The relative changes of power as a function of field follow curves which are somewhat similar to those of the magnetoresistance in these alloys. The concentration dependence of thermoelectric power and the influence of a magnetic field may be understood in terms of a contribution which depends upon the spontaneous magnetization.

R.Parker

PA'63

20422 THE THERMOELECTRIC POWER OF METALS.
P.L.Taylor.
Phys. Letters (Netherlands), Vol. 3, No. 5, 245-6 (Jan. 15, 1963).

It is shown that a positive contribution to the thermoelectric power arises from the presence of "Kohn anomalies" in the phonon dispersion relations. Since a metal having a spherical Fermi surface has such an anomaly for only one phonon wave vector, whilst a metal having a multiply connected Fermi surface has at least seven corresponding to each element of the surface, it is predicted that this positive contribution should be an order of magnitude greater for metals having such a multiply connected Fermi surface.

K.G.Major

PA63

17970 INVESTIGATION OF THE THERMOELECTRIC POWER AND MAGNETOTHERMAL EFFECTS OF ALLOYS IN THE $CdSnAs_2$–2InAs system.

D.N.Nasledov, S.Mamaev and O.V.Emel'yanenko.

Fiz. tverdogo Tela (USSR), Vol. 5, No. 1, 147-50 (Jan., 1963).

In Russian. English translation in: Soviet Physics–Solid State (USA).

The longitudinal and transverse Nernst–Ettingshausen coefficients and the thermoelectric power of $CdSnAs_2$, InAs, and $CdSnAs_2$–InAs solid solutions were measured at 100-600° K. In the compounds electrons are scattered mainly on impurity ions and lattice vibrations, while in the solid solutions they are scattered mainly on the disordered structure defects. The effective electron mass determined from the thermoelectric power was the same in all samples and amounted to about 0·045 m_0, where m_0 is the free-electron mass.

S.Chomet

PA '63

Measurement of Thermal Conductivity Using Peltier Effect, D. J.McNELL. Brit J Applied Physics v 14 n 2 Feb 1963 p 113-16. Modification of Harman "Z-meter" technique for measurement of thermal conductivity of thermoelectric materials; heat losses are taken into account in thermal conductivity equation, and experimental technique derived which enables losses to be eliminated; theory is tested by measurements on specimen of FeSi-4% $CoSi_2$ alloy.

Properties of Pulled Bi_2Te_3 Single Crystal, K.AKIYAMA, Y. ONODERA, S.FUJIWARA, T.NAKAJIMA. Nat Tech Report v 9 n 1 Feb 1963 p 13-23. Data obtained at room temperature are presented on Hall mobility, resistance, thermoelectric power and carrier concentration; temperature dependence of Hall mobility. 30 refs. In Japanese with English summary.

EI '63

818 (NP-13266) THERMOELECTRIC MATERIALS. Final Report. Merton H. Brooks, ed. (Titanium Alloy Mfg. Div., National Lead Co., Niagara Falls, N. Y.). Jan. 31, 1963. Contract No. NObs-78326. 82p.

Three hundred twenty-three oxide, silicate, and metal hydride combinations were prepared and fabricated into test specimens by a variety of forming and firing techniques. Of these combinations, 309 were examined electrically for Seebeck effect and resistivity from 600 to 1200°C; the remaining few failed in test. Titanium dioxide plus 2.0 mole % Nb_2O_5 exhibited a Seebeck coefficient of −400 μv/°C and resistivity of 0.1 ohm-cm over the entire temperature range of test. Barium titanate plus 0.5 mol/% Nb_2O_5 had a Seebeck coefficient of −1700 μv/°C at 750°C that increased in magnitude to −3000 μv/°C at 1225°C; the resistivity of this composition is unknown but is greater than 5 ohm-cm. No p-type electronic semiconductor with consistent carrier type over the entire temperature range of test was developed. Positive Seebeck coefficients of considerable magnitude were developed in ionic conductors; ZrO_2–7 mol/% Y_2O_3 solid solution plus 10 mol/% Nb_2O_5 exhibited a Seebeck coefficient of +1000 μv/°C at 800°C that rose to +1600 μv/°C at 1100°C. The electrical resistivity of this composition was also greater than 5 ohm-cm. In general, most oxide semiconductors examined were found to be ionic conductors; Li_2TiO_3 was the example of such a material. None of the compositions tested gave indication of truly efficient conversion of heat to electricity; the TiO_2 plus 2.0 mol/% Nb_2O_5 had an approximate figure of merit of 7.0×10^{-4}/°C. (auth)

NSA '64

4800 IN-PILE THERMOELECTRIC POWER MEASUREMENTS OF GERMANIUM BOMBARDED BY FAST NEUTRONS.

M.Bartenbach, Z.Tomczak and J.Kołodziejczak.

Acta phys. Polon. (Poland), Vol. 23, No. 2, 189-95 (Feb., 1963).

The thermoelectric power and electrical conductivity of germanium bombarded by fast neutrons in the reactor at Swierk were measured simultaneously as functions of the irradiation time in the neighbourhood of the instrinsic region of conductivity. Using the theory of thermoelectric power, the dependence of the thermoelectric power on time of irradiation is calculated and compared with experiment. A good agreement was found, indicating the consistency of the theory of thermoelectric power and conductivity. Some evidence was also found for the existence of four times the number of minima in the conduction band of germanium.

EEA '63

5936 THE THERMOELECTRIC PROPERTIES OF $AgSbTe_2$–$AgBiTe_2$, $AgSbTe_2$–PbTe and–SnTe Systems.
T. Ide, T.Takahama and T.Ono.
Japan. J. appl. Phys., Vol. 2, No. 2, 72-82 (Feb., 1963).

Thermoelectric properties of $AgSbTe_2$–$AgBiTe_2$, $AgSbTe_2$–PbTe and –SnTe systems are studied. In these alloys and also in $AgSbTe_2$, when prepared by the usual method of zone melting, the thermoelectric power and electrical conductivity vary along the length of the bar and the mode of variation depends strongly on the speed of zone-passing. These facts are probably related to the mode of precipitation of Ag_2Te or Sb_2Te_3. The Hall mobility of $AgSbTe_2$, which does not contain the precipitate Ag_2Te, was found to change with absolute temperature with an exponent of –0·7 and –1·3 for two specimens. In $AgSbTe_2$–$AgBiTe_2$ and–PbTe systems, the electrical conductivity decreases and the thermoelectric power increases with increase of $AgBiTe_2$ or PbTe content. In the $AgSbTe_2$–SnTe system, the electrical conductivity increases and the thermoelectric power decreases with increase of SnTe. The lattice thermal conductivity decreases with increase of $AgBiTe_2$ in the $AgSbTe_2$–$AgBiTe_2$ system while it has a broad minimum in the range of PbTe content from 20 to 60% in the $AgSbTe_2$–PbTe system. In $AgSbTe_2$–SnTe the lattice thermal conductivity increases with increase of SnTe. EEA '63

7177 THE THERMOELECTRIC PROPERTIES OF MIXED CRYSTALS OF $Mg_2Ge_xSi_{1-x}$.
R.J.LaBotz, D.R.Mason and D.F.O'Kane.
J. Electrochem. Soc. (USA), Vol. 110, No. 2, 127-34 (Feb., 1963).

A determination of the thermoelectric properties of the pseudobinary system Mg_2Si–Mg_2Ge. The compositions investigated were Mg_2Si, $Mg_2Ge_{0.2}Si_{0.4}$, $Mg_2Ge_{0.4}Si_{0.6}$, $Mg_2Ge_{0.6}Si_{0.4}$, $Mg_2Ge_{0.8}Si_{0.2}$, and Mg_2Ge. X-ray diffraction lattice parameter measurements and differential thermal analysis measurements established the existence of complete solid solubility between Mg_2Si and Mg_2Ge. Both the lattice parameter and liquidus temperature show almost linear variation with composition in this system. The melting temperature of Mg_2Si was found to be 1070° ± 5°C, while that of Mg_2Ge was found to be 1102° ± 5°C. Electrical resistivity and Hall effect measurements indicated that at 300°K the electron Hall mobility in the mixed crystals is essentially the same as that of the pure compounds. Maximum values obtained were slightly above 300 cm^2/volt sec. The forbidden energy gap appeared to vary monotonically from about 0·78 electronvolt (eV) for Mg_2Si to about 0·70 eV for Mg_2Ge. Thermal conductivity measurements on the pseudobinary system showed that the lattice thermal conductivity of the solid solutions is substantially lower than that of either of the pure compounds at 300°K. At this temperature the lattice thermal conductivity of $Mg_2Ge_{0.6}Si_{0.4}$ was found to be 0·0268 watt/cm °K. The maximum thermoelectric figure of merit which could be obtained with these materials is not as good as that of other materials now in use.
EEA '63

8573 EXPERIMENTAL VERIFICATION OF THE KELVIN RELATION OF THERMOELECTRICITY IN A MAGNETIC FIELD. R.Wolfe and G.E.Smith.
Phys. Rev. (USA), Vol. 129, No. 3, 1086-7 (Feb. 1, 1963).

The Seebeck coefficient (S) for a particular orientation of a bismuth single crystal at 78°K changes by 40% when a transverse magnetic field (B) of 10 000 Oe is reversed in direction ("Umkehreffekt"). The Peltier coefficient (Π) also changes by the same proportion, but the field direction which gives the larger Seebeck effect, gives the smaller Peltier effect. This is a verification of the modified Kelvin relation, $\Pi(B) = TS(-B)$. PA '63

10893 THERMOELECTRIC PROPERTIES OF DIPHASAL SYSTEMS COMBINING As_2Te_3 AND Tl_2Se WITH Sb_2Te_3, Bi_2Te_3, OR Sb_2Se_3. H.L.Uphoff and J.H.Healy.
J. appl. Phys. (USA), Vol. 34, No. 2, 390-5 (Feb., 1963).

Fourteen sample compositions, representing combinations of As_2Te_3 and Tl_2Se with Sb_2Te_3, or Sb_2Se_3, were prepared and tested. A number of the samples were amorphous while others were diphasal including both amorphous and crystalline phases. The material parameters were structure-dependent with room temperature parameters ranging from $7{\cdot}2\times10^{-4}$–$1{\cdot}8\times10^{9}$ Ω cm in resistivity, 3·1–1040 /deg K in Seebeck coefficient magnitude, and 3·6-19·0 mW/cm deg in thermal conductivity. PA 63

10897 THE THERMOELECTRIC ANOMALY AT 35°C IN CHROMIUM. A.R.Edwards.
Phil. Mag. (GB), Vol. 8, 311-22 (Feb., 1963).

The thermoelectric power of chromium against copper was investigated in the range 30–40°C using 20 specimens of chromium varying in purity, grain size and state of strain. In all cases there is a sharp fall in thermoelectric power as the temperature rises through ~ 35°C. For all high-purity specimens this transition temperature is in the range 35·3 ± 0·8°C. The strength of the anomaly is affected very little by variations in the interstitial impurities nitrogen and oxygen, but is clearly influenced by small strains in the material and by changes in grain size. The results are considered in terms of antiferromagnetic ordering and the influence of internal stresses on domain structure.

PA '63

UNCLASSIFIED

110290 STRUCTURAL INVESTIGATIONS IN THERMOELECTRIC MATERIALS (Period covered: January 1-March 31, 1963)
Pollak, P. I.; Conn, J. B. (et al)

Unclassified

Merck Sharp and Dohme
Research Laboratories
NObs-88112
QR-2

Investigation into the thermoelectric properties of homogeneous quaternary systems with exploration of compositional types: Cu_x(Zn, Cd, Hg) (Ge, Sn) $(Se, Te)_{2x}$ is discussed.

5847 NERNST EFFECT IN N-TYPE GaSb.
S.J.Silverman, R.O.Carlson and H.Ehrenreich.
J. appl. Phys. (USA), Vol. 34, No. 3, 456-9 (March, 1963).

The Nernst coefficient, the Hall coefficient, the electrical resistivity, and the Seebeck coefficient were measured on Te- and Se-doped GaSb between 60° and 800°K. The two-minima conduction band model, as applied to the present group of measurements, provides a qualitative description of conditions under which certain scattering mechanisms will dominate the transport phenomena.

EEA '63

8514 MEASUREMENTS OF SOME ELECTRICAL AND THERMOELECTRICAL PROPERTIES OF ANTIMONY TELLURIDE FILMS. N.S.Rajagopalan and S.K.Ghosh.
Physica (Netherlands), Vol.29, No.3, 234-42 (March, 1963).

Measurements of Hall mobility and conductivity at room temperature and of the variation of resistance and thermoelectric power with temperature were made on antimony telluride films prepared by vacuum evaporation. Results of the measurements show the presence of intercrystallite barriers; the barrier height reduces to one tenth of its value on heat-treatment. An increase in Hall mobility is observed with thickness of the deposited films, and in general a small increase is found after heat treatment. Large increase in conductivity is obtained after heat treatment. The thermoelectric power at room temperature reduces to one third of its original value after heat treatment. The results obtained are discussed.

PA '63

Criteria for Selecting Thermoelement Materials for Thermoelectric Peltier Devices, F.HUNEIDI. ASHRAE J v 5 n 3 Mar 1963 p 80-2. Discussion of properties of metals, semiconductors and insulators to estimate their values as thermoelement material; equation for figure of merit; semiconductors appear to remain most favorable materials for use in thermoelectric cooling. EI '63

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Northwestern Technological Inst., Evanston, Ill.
THERMOELECTRIC POWER IN NONSTOICHIOMETRIC ALPHA-Nb205,
by R. F. Janninck and D. H. Whitmore, 29 Mar 63, 9p. TR4
Contract Nonr122816, Proj. NR032 459
AEC Rept. no. NP12698 Unclassified report

Descriptors: (*Thermoelectricity, Crystal structure), (*Oxides, Thermoelectricity), (*Niobium compounds, Oxides), Powders, Semiconductors, Ions, Electrons, Entropy.

Thermoelectric power measurements have been made on nonstoichiometric alpha-Nb205 over the temperature range from 300 to 1270 K. The measurements show that, for all compositions in the single-phase, alpha-Nb205-x region (0.0012 $\leq$ + $\leq$ 0.1545), the majority charge carriers are electrons. These thermoelectric power data have been interpreted in terms of a simple semiconductor exhibiting conduction in a narrow d-band with the conduction electrons being assigned an effective mass equal to four times that of the rest mass. (Author)

'63

8599 DETERMINATION OF SEEBECK AND PELTIER COEFFICIENTS. R.Tougas. 621.365
Ingenieur (Canada), Vol. 49, No. 193, 42-5 (Spring, 1963). In French.
A method of determining Seebeck and Peltier coefficients at liquid-solid junctions of metallic systems is described. For pure tin, it was found that α_{LS} = 0·002 46 ± 0·000 25 mV/° K and π_{LS} = 0·001 24 ± 0·000 12 at 505° K.

EEA '63

13262 MAGNETO-THERMOELECTRIC POWER AND MAGNETOSTRICTION OF FeNi$_3$ SINGLE CRYSTALS.
T.Minegishi.
Japan. J. appl. Phys., Vol. 2, No. 3, 151-5 (March, 1963).
The change in thermoelectric power due to magnetization of ferromagnetic substances, i.e. the magneto-thermoelectric power, and linear magnetostriction at given temperatures were measured. on single crystals of Fe-Ni alloy (about 24% Fe). The single crystal behaviour of magneto-thermoelectric power in these f.c.c. crystals is similar to that of magnetostriction. The constants $(E_m)_{100}$, $(E_m)_{111}$ and λ_{100}, λ_{111} which specify magneto-thermoelectric power and linear magnetostriction in the [100] and [111] directions, respectively, were determined. The magneto-thermoelectric power depends on the orientation of the crystal axes and is always negative. The numerical values obtained are as follows: $(E_m)_{100} = -0{\cdot}84 \times 10^{-6}$ V/deg, $(E_m)_{111} = -0{\cdot}53 \times 10^{-6}$ V/deg and $\lambda_{100} = 8{\cdot}4 \times 10^{-6}$, $\lambda_{111} = 1{\cdot}3 \times 10^{-6}$

PA '63

10896 SIZE DEPENDENCE OF THE MAGNETO-SEEBECK EFFECT IN BISMUTH-ANTIMONY ALLOYS.
M.E.Ertl, G.R.Pfister and H.J.Goldsmid.
Brit. J. appl. Phys., Vol. 14, No. 3, 161-2 (March, 1963).
It is pointed out that the Seebeck coefficient in a magnetic field should be very sensitive to the ratio of length to width of the sample. Measurements made at 80° K in fields up to 5000 Oe are presented graphically for alloys containing 7% Sb and 5% Sb whose length-width ratios were reduced from 2·55 to 1·39 to 0·71 and from 1·75 to 0·39 respectively. Results in the latter sample are compared with a phenomenological theory. The significance of the observations to the design of Bi-Sb thermoelectric refrigerator elements is indicated.
L.M.Roberts

PA 63

10140 THE THERMOELECTRIC POWER IN CHROMIUM AND VANADIUM. A.R. [illegible] and [illegible] Still.
J. Phys. Chem. Solids (GB), vol. 24, 501-6 (April, 1964).

The thermoelectric power in pure chromium and vanadium was measured between 4.2° and 340°K and found to be positive in both metals over the whole temperature range. Maxima in the curves of thermopower against temperature at low temperatures are interpreted in terms of a phonon drag component. An anomaly in the results for both monocrystalline and polycrystalline chromium at the Néel temperature is interpreted in terms of the Lidiard-Overhauser model of conduction-electron antiferromagnetism. Hysteresis in the measurements on chromium over the whole temperature range is attributed to the effect of antiferromagnetic domains. An anomaly in the thermopower of vanadium at approximately 217°K is attributed either to a transition to an antiferromagnetic state or to a structural phase transition, possibly involving ordering impurities. Experiments for distinguishing between these possibilities are suggested.

PA63

Negative Thermoelectric Figure of Merit in Magnetic Field, R. WOLFE, G.E.SMITH, S.E.HASZKO. Applied Physics Letters v 2 n 8 Apr 15 1963 p 157-9. Negative values of figure of merit, Z, of single crystal of bismuth at 78 K in transverse magnetic field; it is shown that same specimen may behave as n-type material in Seebeck measurement (or thermoelectric generator) and as p-type material in Peltier experiment (or thermoelectric refrigerator) and that concept of unique thermoelectric Z is, in general, not valid in presence of magnetic field.

EI 63

9526 CHARACTERISTICS OF THERMOELECTRIC MATERIALS. W.G.Evans.
Semiconductor Prod. (USA), Vol. 6, No. 4, 34-9 (April, 1963).

Emphasizes the characteristics of power generation materials that make them useful in devices and that set limits on their usefulness. Various thermoelectric materials are discussed from the viewpoint of: efficiency, figure of merit, life, cost, electrical and mechanical properties, thermal and mechanical stresses, effect of size, shape and weight, and causes of failure.

EEA '63

13138 THERMOELECTRIC PROPERTIES OF NON-STOICHIOMETRIC BISMUTH-ANTIMONY-TELLURIDE ALLOYS. P. Bergvall and O. Beckman.
Solid-State Electronics (GB), Vol. 6, 133-6 (March-April, 1963).

The thermoelectric properties of p-type alloys of the composition $Bi_{24}Sb_{60+x}Te_{150+x}Se_6$ were studied for $4 \leq x \leq 12$. The lattice thermal conductivity is found to decrease when the tellurium content is increased in excess of the stoichiometric composition $x = 12$, whereas the quantity $\mu_0(m^*/m)^{3/2}$ is relatively constant. A maximum figure of merit $Z_p = 3 \cdot 2 \times 10^{-3}$ (°K)$^{-1}$ is found for $x = 8$.

PA '63

10031 SEMIMETALS AS THERMOELECTRIC MATERIALS. R.Wolfe and G.E.Smith.
Semiconductor Prod. (USA), Vol. 6, No. 4, 29-33 (April, 1963).

Semimetals, which contain equal numbers of electrons and holes, have recently returned to the list of optimum thermoelectric materials. Values of the figures of merit as high as 6×10^{-3}/°K have been measured at low temperatures on single crystals of the semimetallic bismuth-antimony alloys. Most of the properties of these materials are very sensitive to an applied magnetic field. The figure of merit, for certain orientations and magnitudes of magnetic field, can be more than twice as large as the zero field value. Values of Z up to $8 \cdot 6 \times 10^{-3}$/°K have been measured in a field of 1000 G at 100°K. These results are discussed in terms of the cooperative behaviour of equal numbers of high-mobility, anisotropic electrons and holes.

EEA '63

24049 (NRL-Memo-1404) STATUS REPORT ON THERMOELECTRICITY. J. W. Davisson and Joseph Pasternak (Naval Research Lab., Washington, D. C.). Mar. 1963. 107p.

Progress is reported on materials research and development including preparation of high-temperature broad-band semiconductors, research on high-temperature semiconducting compounds for thermoelectric power generation, structural investigations in thermoelectric materials, studies of thermoelectric properties of selenides and tellurides, high-temperature metallurgy research on thermoelectric materials, development of a semiconductor film-type thermocouple converter, development of a thermoelectric nuclear fuel element, preparation of a Sr^{90}-fueled thermoelectric generator power source for 5w U. S. Coast Guard light buoy, testing of solar thermoelectric panels, design and application of Peltier heat pumps, module improvement program, and studies of bonding Be-clad UO_2 fuel elements. (M.C.G.) NSA '63

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Du Pont De Nemours, E. I. and Co., Inc., Wilmington, Del.
THERMOELECTRIC PROPERTIES OF SELENIDES AND TELLURIDES OF GROUPS VB AND VIB METALS AND THEIR SOLID SOLUTIONS.
Quarterly rept. no. 7, 1 Jan-30 Mar 63, by W. T. Hicks and H. Valdsaar. 1 May 63. 30p.
Contract NObs84824, Proj. SR 007 12 01, Task 802
Unclassified report

Descriptors: *Selenides, *Tellurides, *Semiconductors, Intermetallic compounds, Tungsten alloys, Selenium alloys, Lead alloys, Tellurium alloys, Impurities, Tantalum, Sodium, Electrical properties, Group V elements, Group VI elements, Metals, High temperature research, Resistance (Electrical), Thermal conductivity, Thermocouples, Thermoelectricity, Materials.

Calculations were made of idealized efficiencies for various operating conditions and geometries of thermoelectric modules with segmented elements of Ta-doped WSe2 in combination with Na-doped PbTe, encapsulated in constantan cylinders serving as the n-type element. These calculations followed a 704-Computer program developed in another organization. An efficiency of 9.6% was calculated for the combination W0.98Ta0.02Se2 and PbTe + 0.3 at .% Na operating in the gradient 1000 to 25 C. The power per unit volume is 0.47 w/cc compared with 0.19 w/cc for PbTe-based modules. Studies of improved preparative techniques for the diselenides were continued, and doped lead telluride specimens were obtained for assembly into test modules for direct experimental measurement of efficiencies in an apparatus now completed. Observations on the thermal decomposition of WSe2 indicate a measurable pressure of Se at 400, which remains considerably below 1 atm at 100 C. (Author) '63

23029 X-RAY STUDY AND THERMOELECTRIC PROPERTIES OF THE $W_xTa_{1-x}Se_2$ SYSTEM. L.H.Brixner.
J. Electrochem. Soc. (USA), Vol. 110, No. 4, 289-93 (April, 1963).

A wide range of compositions of the system were prepared with x ranging from 0·10 to 0·99, and X-ray parameters and pertinent thermoelectric properties such as Seebeck coefficient, electrical resistivity, and thermal conductivity were determined. Particular emphasis was given to the range of x from 0·95 to 0·99, where useful thermoelectric properties yielding figures of merit between $0{\cdot}5\text{-}0{\cdot}9 \times 10^{-3}$ deg^{-1} are experienced at elevated temperatures. PA 63

Physics of Thermoelectricity, R.WOLFE. Semiconductor Products v 6 n 4 Apr 1963 p 23-8. Choice of optimum thermoelectric materials requires understanding of such basic properties of semiconductors as electrical and thermal conductivities as well as various thermoelectric effects; these properties, along with thermoelectric "figure of merit" which they determine, are defined and discussed, first from phenomenological point of view and then in terms of electron theory of semiconductors. EI 63

Thermoelectric Properties of Some Transition Thermoelements in Common Use, D.D.POLLOCK, G.P.CONARD, Il.Met Soc AIME—Trans v 227 n 2 Apr 1963 p 478-82. Abbreviated method is given for obtaining Mott and Jones approximation for absolute thermoelectric power of metals; when this is applied to thermoelements in common use, it is found that their absolute electromotive forces are linear functions of temperature; this explains why couples involving transition thermoelements are preferred for measurement of elevated temperatures. EI '63

22956 A NEW SEMICONDUCTOR PHASE OF THE ZINC-ANTIMONY SYSTEM.
Ya.A.Ugai, E.M.Averbakh, Yu.Ya.Gukova and V.V.Lavrov.
Dokl. Akad. Nauk SSSR, Vol. 149, No. 6, 1387-9 (April 21, 1963). In Russian.
Describes preparation and investigation of a new semiconductor intermetallic phase β-Zn_4Sb_3 obtained in single-crystal form (it is possible to purify it by zone crystallization). Conductivity and thermoelectric power measurements are reported for a range of temperatures in zone crystallized and cooled specimens.
J.K.Skwirzynski
PA 63

20336 ELECTRICAL PROPERTIES OF NICKEL-ZINC FERRITES.
A.G.Rustamov, A.A.Samokhvalov and I.G.Fakidov.
Fiz. tverdogo Tela (USSR), Vol. 5, No. 4, 1031-9 (April, 1963). In Russian. English translation in: Soviet Physics-Solid State (USA).
To find the mechanism of electrical conduction and to determine the energy spectrum of electrons, as well as the relationship between electrical and magnetic properties of complex 3d-oxides the electrical conductivity, permittivity at microwave frequencies, thermoelectric power, Hall effect, magnetoresistance, saturation magnetization and paramagnetic susceptibility were measured as a function of composition and temperature. From the information obtained on the parameters of carriers the possible mechanisms of electrical conduction are deduced.
S.Chomet
PA 63

34336 THERMOELECTRIC POWER SYSTEMS. N. F. Schuh. Astronaut. Aerospace Eng., 1: No. 4, 80-3(May 1963).
Improvements in mechanical strength, contacting techniques, heat transfer, and utilization of available materials for improved conversion efficiency and overall in thermoelectric power systems are reported. Pb-Te, Ge-Si, and Ge-Bi-Te alloys are the thermoelectric materials considered. (C.E.S.)
NSA '63

On Relationship between Resistivity and Thermo-e.m.f., D. SMART, E.SMART. Philosophical Mag v 8 n 88 Apr 1963 p 643-50. Qualitative indications are given that for number of thermocouples, relationship between resistivity and thermo-emf is fairly simple; under certain conditions Mott's equation for thermo-power is directly integrable and leads to equation for couple of metals A and B, with junctions of T_1, T_2; data for Pt and Cu are consistent with equation and data for some other nontransition metals are not inconsistent. EI '63

13143 THERMOELECTRIC POWER OF NaCl CONTAINING $CdCl_2$. R.W.Christy, Y.W.Hseuh and R.C.Mueller. J. chem. Phys. (USA), Vol. 38, No. 7, 1647-51 (April 1, 1963).
The thermoelectric power of NaCl has been measured as a function of temperature between 550°C and the melting point, using Pt-metal electrodes. Measurements were made on pure material, and also on material doped with 0·1% $CdCl_2$. Compared with the theory of Howard and Lidiard, the results yield a value of the order of −1 eV for the sum of the cation and anion vacancy heats of transport, although the accuracy is low because of reactions occurring at the electrodes and uncertainties in the ratio of defect mobilities. PA '63

32587 URANIUM COMPOUNDS AS THERMOELECTRIC MATERIALS. I. H. Warren (Univ. of British Columbia, Vancouver). Can. Mining Met. Bull., 56: 288-98(Apr. 1963).
The properties required for a compound to form useful thermoelectric materials are described. Uranium compounds that might have the properties are reviewed. Several of the compounds were prepared and fabricated into compacts. The apparatus used for hot pressing, and for the measurement of thermoelectric power, electric conductivity, and thermal conductivity, is described. Detailed attention was given to the properties of the nitrides. Preliminary studies on a number of other U compounds are reported. The figures of merit of the best materials so far examined are one-tenth of those necessary for a useful thermoelectric material. (auth)
NSA '63

Theory of Materials for Thermoelectric and Thermomagnetic Devices, R.W.URE, Jr. IEEE—Proc v 51 n 5 May 1963 p 699-713. Relation between device performance and properties of materials such as electron mobility, density-of-state, effective mass, energy gap, and thermal conductivity, for device using classical Seebeck and Peltier effects; conditions under which magnetic field effects are important are evaluated. 54 refs. EI 62

22940 SEMICONDUCTING PROPERTIES OF CADMIUM OXIDE POWDERS. Y.Colin and R.Tufeu.
C.R. Acad. Sci. (France), Vol. 256, No. 20, 4195-8 (May 13, 1963).
In French.

Thermoelectric power and resistivity were measured as a function of temperature (77 - 400° K) for pressed powder samples containing either excess cadmium or excess oxygen. The results indicate the presence of both impurity and lattice scattering, with a transition point between the two depending on stoichiometry.

D.L.Greenaway

PA 63

20346 SOME ELECTRICAL PROPERTIES OF THE INTERMETALLIC COMPOUND ϵ-Zn_3Sb_2.
Ya.A.Ugai and E.M.Averbakh.
Fiz. tverdogo Tela (USSR), Vol. 5, No. 5, 1291-2 (May, 1963). In Russian. English translation in: Soviet Physics—Solid State (USA).

The temperature dependence of the electrical conductivity and thermoelectric power was obtained at 20-470°C for polycrystals of stoichiometric ϵ-Zn_3Sb_2 obtained by slow cooling of the melt. The polycrystals were p-type semiconductors with a forbidden bandwidth of 0·2 eV. The Hall effect at room temperature gave the hole mobility 200 $cm^2 V^{-1} sec^{-1}$. The observed discontinuities of the thermoelectric power at 405 and 437°C are due to phase transitions in Zn_3Sb_2.

S.Chomet

PA 63

Effects of Transition Metal Solutes on Thermoelectric Power of Copper and Gold, E.L.CHRISTENSON. J Applied Physics v 34 n 5 May 1963 p 1485-91. Thermoelectric powers (TEP) of Cu alloys containing dilute amounts of Fe, Co, or Cr and up to 10 at.% Mn or Ni measured between 4.2 and 1000 K; similar alloys of Au measured between 4.2 and 100 K; individual solutes produce comparable effects in either solvent; all of solutes exhibited minima in TEP vs temperature data; several of alloys exhibited maxima in 4.2 K region, similar to results obtained by others with nontransition solutes.

E/63

13139 EFFECTS OF TRANSITION METAL SOLUTES ON THE THERMOELECTRIC POWER OF COPPER AND GOLD.
E.L. Christenson.
J. appl. Phys. (USA), Vol. 34, No. 5, 1485-91 (May, 1963).

The thermoelectric powers (TEP) of copper alloys containing dilute amounts of iron cobalt, or chromium and up to 10 at. % manganese or nickel have been measured between 4·2° and 1000°K. Similar alloys of gold have been measured between 4·2° and 100°K. The individual solutes produce comparable effects in either solvent. In copper, 0·1% iron produces a minimum TEP of $-14\ \mu V/deg\ K$ near 20°K. A similar level of cobalt produces a TEP of $-10\ \mu V/deg\ K$ near 200°K. All of the solutes measured exhibited minima in the TEP versus temperature data, but nickel, manganese, and chromium are much less effective than cobalt or iron in altering the TEP of copper. The thermopower does not increase indefinitely with concentration. In gold, iron produces its maximum TEP at about 0·2 at. % concentration, cobalt at about 2%. Several of the alloys measured also exhibited maxima in the 4·2K region, similar to results obtained by others with nontransition solutes. Resistivity counterparts for these TEP-temperature curves have been published earlier (Abstr. 17605 of 1961).

PA 63

13011 THEORY OF THERMOELECTRIC POWER IN LOW-MOBILITY SEMICONDUCTORS.

M.M.Chadda and A.P.B.Sinha.

Indian J. pure appl. Phys., Vol. 1, No. 5, 161-3 (May, 1963).

Investigates the thermoelectric properties of low-mobility semiconductors, in which the charge carriers are localized and the electrical conduction takes place through their hopping motion. The heat of transport (Q^*) and the energy lowering (ϕ) due to the polarization of the lattice shown to be related by the expression $Q^* = \phi_h - \phi_c$ where ϕ_h and ϕ_c are respectively the components due to polarizations associated with the ions in the hot and cold parts of the semiconductor. It is shown that the conribution of Q^* to the thermoelectric power can be appreciable in some cases. The values of Q^*/ϕ are theoretically evaluated for a face-centred cubic crystal for certain select directions of temperature gradient.

EEA 163

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Naval Research Lab., Washington, D. C.
A BRIEF SURVEY OF ELEMENTARY THERMOELECTRIC THEORY,
by William H. Lucke. 3 May 63, 15p.
NRL 5888

Unclassified report

Descriptors: *Thermoelectricity, *Electrons, Theory, Transport properties.

The three fundamental effects of thermoelectricity - Seebeck, Peltier, and Thomson - are presented and the corresponding coefficients are defined. Following a simplified derivation of the Kelvin relations, a more sophisticated and detailed presentation of the irreversible thermodynamic approach to these relations is made. It is demonstrated that these relations are valid in spite of the arbitrary assumptions as the separation of thermal and electrical conduction made in the former derivation. Next, a brief summary is given of a derivation of the expression for the Seebeck coefficient based on a quasi-free electron model and simple energy dependence of an isotropic relation time. In closing, the attempt to apply band theory to the search for better thermoelectric materials is briefly described and some interesting ideas for improvement are mentioned along with criticisms concerning predictions of the maximum possible figure of merit. (Author)

163

Leitfaehigkeit und Hallkonstante—26, W.KOESTER, W.GMOEHLING, D.HAGMANN. Zeit fuer Metallkunde v 54 n 6 June 1963 p 325-30. Electric conductivity and Hall effect, including temperature dependence, and thermoelectric power of binary solid solutions of palladium with 2-100 at.% of platinum or rhodium or 2-20 at.% of molybdenum or vanadium were determined; results are discussed in terms of electron exchange between solute atoms and conductivity bands of Pd; all additions changed sign of temperature coefficient of Hall effect. 33 refs.

EI 163

Experiments with Peltier Junctions Pulsed with High Transient Currents, M.IDNURM, K.LANDECKER. J Applied Physics v 34 n 6 June 1963 p 1806-10. Experimental method used for investigation of bismuth telluride junction; it is very likely that accuracy of measurements cannot be expected to be improved as long as grown crystalline n and p branches are used; it is hoped to produce sintered junctions of more suitable shape and greater mechanical strength for further experiments.

EI 163

20426 THERMOELECTRIC POWER OF P-TYPE GERMANIUM AS A FUNCTION OF THE CARRIER DENSITY AND TEMPERATURE.

M.N.Vinogradova, O.A.Golikova, I.N.Dubrovskaya and B.Ya.Moizhes.

Fiz. tverdogo Tela (USSR), Vol.5, No.6, 1657-67 (June, 1963). In Russian. English translation in: Soviet Physics-Solid State (USA).

The power was determined over the carrier density range $n = 7\times10^{17} - 7\times10^{20}$ cm^{-3} at 300-950°K. The discrepancies between the theoretical and experimental values of the power at $n > 10^{20}$ cm^{-3} and T = 300°K, and at T > 300°K at lower carrier densities are due to the deviation from the quadratic dispersion law with increase of the energy. This explanation agrees with measurements of the electrical conductivity, Hall coefficient, and thermoelectric power in the near-intrinsic conduction region.

S.Chomet

OA 63

Selection of Melting Points and Energy Gaps for Optimized Performance of Thermoelectric Materials, N.SCHWARTZ, W.TANTRAPORN, W.J.Van der GRINTEN. Advanced Energy Conversion v 3 n 2 Apr-June 1963 p 419-25. It is recommended that materials for use in thermoelectric cooling, and particularly in power generation, be selected for operation in vicinity of their melting points and that, through solid solution alloying accompanied by disordered mass scattering on sub-lattice, their energy gap be adjusted to specified value at this temperature; theoretical investigations predict strong temperature dependence of phonon thermal conductivity as function of melting temperature.

EI 63

20337 INVESTIGATION OF THE CARRIER MOBILITY IN NiO WITH Li IMPURITY.

Ya.M.Ksendzov, L.N.Ansel'm, L.L.Vasil'eva and V.M.Latysheva. Fiz. tverdogo Tela (USSR). Vol. 5, No. 6, 1537-47 (June, 1963). In Russian. English translation in: Soviet Physics - Solid State (USA).

A study was made of the electrical conductivity, thermoelectric power and Hall effect of solid solutions $Li_xNi_{1-x}O$ with $0{\cdot}01 \leq x \leq 0{\cdot}2$ in the temperature range from liquid nitrogen to 300°C. The experimental data are satisfactorily explained within the framework of the usual energy-band model with a narrow polaron band (formed by holes at Ni^{+} levels) and acceptor levels lying 0·2 eV or more (depending on the concentration of lithium) above the Ni^{++} levels. allowance was made in calculations for the partial compensation of

PA 63 1

17972 ANISOTROPIC THERMOELECTRIC POWER OF AuSn.

J.-P.Jan and W.B.Pearson. Phil. Mag. (GB), Vol. 8, 911-17 (June, 1963).

The absolute thermoelectric power of single crystals of AuSn was measured between 2·5° K and room temperature for various orientations with respect to the hexagonal axis. The results exhibit a very pronounced anisotropy. A maximum is found in the a direction around 25° K and attributed to anisotropic phonon-drag effects. The temperature dependence and the anisotropy are discussed, and some speculations are presented regarding the electronic structure of AuSn.

PA 63

Thermal Conductivity of Molten $Cu_2S_{0.25}Te_{0.75}$ and Molten Cu_2S, E.W.JOHNSON, R.L.READAL. Advanced Energy Conversion v 3 n 2 Apr-June 1963 p 407-18. Experimental measurements for liquid $Cu_2S_{0.25}Te_{0.75}$ semiconductor for thermoelectric energy conversion at temperatures above 1000 C are reported for temperature range 1040 to 1310 C; corrected data are presented for thermal conductivity of molten copper-rich cuprous sulfide at 1100 to 1630 C.

25246 PHONON-DRAG SEEBECK EFFECT IN A STRONG MAGNETIC FIELD. T.Ohta.

J. Phys. Soc. Japan, Vol. 18, No. 6, 909 (June, 1963).

A quantum theory is outlined for the phonon-drag thermoelectric power $Q_p(H)$ of a pure semiconductor in a magnetic field which is so strong that the carriers are all in the lowest Landau level. It is assumed that the phonon energy is negligible compared with the magnetic energy of the carrier, and only the role of acoustic phonons is considered. Longitudinal and transverse magnetic fields are separately considered, and expressions are obtained for the ratio $Q_p(H)/Q_p(0)$, where $Q_p(0)$ is the zero field value.

L.M.Roberts

PA 63

Preparation and Thermoelectric Properties of β-Ag_2Se, R.SIMON, R.C.BOURKE, E.H.LOUGHER. Advanced Energy Conversion v 3 n 2 Apr-June 1963 p 481-505. Thorough investigation of properties of variously doped polycrystalline and single-crystalline specimens of silver selenide is presented, made with purpose of clarifying thermoelectric behavior of compound, with ultimate aim of determining its suitability for use as thermoelectric cooling material.

UNCLASSIFIED

115366 STRUCTURAL INVESTIGATIONS IN THERMOELECTRIC MATERIALS
(Period covered: April 1-June 30, 1963)
Pollak, P. I.; Conn, J. B. (et al)

Unclassified

Merck Sharp & Dohme
Research Laboratories
NObs-88112
QR-3

Temperature curves of resistivity and Seebeck coefficient for the defect quaternary $Cu_{12}Cd_6Sn_6Se_{23}$ show an almost discontinuous anomaly in the range 125-175°C, characterized by abrupt increase in resistivity and decrease in Seebeck coefficient. The anomaly is not accompanied by any phase-change detectable by differential thermal analysis. It is postulated that the effect is caused by emptying of electron traps.

20423 SIMPLE EVALUATION OF THE MAXIMUM THERMO-ELECTRIC FIGURE OF MERIT, WITH APPLICATION TO MIXED CRYSTALS $SnS_{1-x}Se_x$. J.D.Wasscher, W.Albers and C.Haas. Solid-State Electronics (GB), Vol. 6, No. 3, 261-4 (May-June, 1963).

The approximate maximum figure of merit is calculated by Joffe (1957), $z_j = (4k^2/q)(\mu/\lambda)e^{r}N_v$, may be rewritten as $z_j = (2k/eq)^2(\sigma/\lambda)\exp(q\alpha/k)$, where α and σ are the Seebeck coefficient and electrical conductivity of any non-degenerate and extrinsic sample of the semiconductor investigated; λ is the lattice thermal conductivity. The second equation makes it possible to evaluate z_j easily and without knowledge of the values of the scattering parameter r and the effective density of states N_v. In an Appendix it is shown that the rigorously calculated maximum of the dimensionless figure of merit zT is mainly a function of z_jT. Room-temperature values of z_jT are given for p-type mixed crystals of SnS and SnSe. From 0·28 for SnS, z_jT rapidly decreases to about 0·14 for $SnS_{0.6}Se_{0.4}$ and then slowly increases to 0·15 for SnSe.

PA63

8488 DEPENDENCE OF THE ELECTRICAL CONDUCTIVITY AND THERMOELECTRIC POWER OF PURE AND ALUMINUM-DOPED RUTILE ON EQUILIBRIUM OXYGEN PRESSURE AND TEMPERATURE. J.Yahia. Phys. Rev. (USA), Vol. 130, No. 5, 1711-9 (June 1, 1963).

The electrical conductivity σ and thermoelectric power Q were measured as a function of equilibrium oxygen pressure in crystals of pure and Al-doped rutile. The pressure was varied over the range 10^{-4} mm Hg to $\sim 10^3$ mm Hg with the temperature held constant at several fixed values in the vicinity of 1000°K. The electrical conductivity of the pure material varied with pressure according to the relation $\sigma \propto p^{-1/x}$, with $x \approx 6$ for $p > 10$ mm Hg and $x \approx 5$ for $p < 10$ mm Hg. For the Al-doped crystal, σ reached a minimum for $p = p_0$ mm Hg. At low pressures σ followed a relation of the form $\sigma \propto p^{-1/x}$ with $x \sim 5$, whereas at high pressures a relation of the form $\sigma \propto p^{+1/x}$ with $x \sim 5$ was obeyed. The thermoelectric power exhibited a reversal near p_0, being negative at lower pressures and positive for $p > p_0$. For pure rutile a defect model involving anion vacancies and estimated values of equilibrium constants leads to a pressure dependence of the conductivity: $\sigma \propto p^{-1/6}$, whereas for a model involving titanium interstitials the pressure dependence is $\sigma \propto p^{-1/6}$ On the basis of the present measurements it seems that for pure rutile the anion vacancy mechanism obtains at "high" pressures with the titanium interstitials mechanism predominating at "low" pressures. For Al-doped rutile, both the anion vacancy model and the titanium interstitials model are shown to give rise to approximately the observed pressure dependence of conductivity. The anion vacancy model equations are solved in detail (assuming certain values of the equilibrium constants). The titanium interstitials model equations are not solved explicitly for this case but it is shown that for a certain combination of reaction constants the observed pressure dependence may be approximated. Assuming a two-band formalism to be valid—and therefore, a formalism into which the results derived from any defect model must fit—the data are analysed and it is shown that reasonable agreement with observation results. Some indications that hole mobilities at 1000°K are considerably larger (~ 180 cm²/V sec) than those of the electrons are discussed. Assuming high-temperature polar scattering to obtain, a hole effective mass 10^{-2} m_0 (where m_0 is the free-electron mass is deduced as a consequence of the mobility calculations.

EEA '63

20471 FUNDAMENTAL OPTICAL ABSORPTION, ELECTRICAL CONDUCTIVITY, AND THERMOELECTRIC POWER OF CALCIUM OXIDE. H.H.Glascock, Jr, and E.B.Hensley. Phys. Rev. (USA), Vol. 131, No. 2, 649-52 (July 15, 1963).

The opacities of thin backed films of CaO were measured at room temperature over the energy range 5·5 to 11·3 eV. At energies below 6 eV the opacity was low. A sharp peak, attributed to the formation of excitons, was observed at about 7·0 eV. A second strong peak was observed at 8·3 eV. This peak appears to have a doublet splitting of about 0·2 eV and probably should also be ascribed to excitons. Other peaks were observed at higher energies but were less reproducible. The width of the forbidden band was estimated to be near 7·7 eV. The electrical conductivity and thermoelectric power of sprayed aggregates of CaO were measured, as a function of temperature, for several states of activation and were found to exhibit the characteristics of a pore conductor. Using these data and the theory for pore conduction, the electron affinity for CaO was estimated to be 0·7 eV.

PA '63

14955 MAGNETIC BRILLOUIN ZONE EFFECTS IN THE THERMOELECTRIC POWER AND MAGNETORESISTANCE OF α-MANGANESE. D.Griffiths and B.R.Coles.
Proc. Phys. Soc. (GB), Vol. 82, Pt 1, 127-32 (July, 1963).

Evidence from electrical resistivity studies of a modification of the electronic structure of α-manganese below the Néel temperature was supplemented by thermoelectric and magnetoresistive data. The thermoelectric power changes from negative to positive on cooling through the Néel temperature (~95°K). The magnetoresistance increases by a factor of 10 between 110 and 65°K.

EEA '63

14953 CONDUCTIVITY AND THERMOELECTRIC POTENTIAL MEASUREMENTS ON PERYLENE: METAL HALIDE COMPLEXES. M.S.Frant and R.Eiss.
J. Electrochem. Soc. (USA), Vol. 110, No. 7, 769-72 (July, 1963).

The conductivities and Seebeck coefficients of a series of perylene complexes with metal halides from groups IIB, IIIA, IVA, VA, VB, VIB, VIIA, and VIII of the periodic table were studied to determine possible dependence of these properties on the nature of the halide. No direct correlation was found between conductivity and position on the periodic table. The complexes having a conductivity of $> 10^{-8}$ mho/cm ($InCl_3$, PCl_5, $FeCl_3$, ICl, $SbCl_5$, I_2) were black in colour; none of the others were black. Activation energies were measured for materials having a conductivity $> 10^{-11}$ mho/cm and were 0·60 eV or lower. There was an approximate straight line relationship between the log conductivity and the activation energy, indicating that conductivity for the series is determined primarily by the number of thermally activated carriers rather than by the reservior of available carriers in lower energy states. As a rule the most conductive materials had the lowest Seebeck coefficients. It was found that perylene: $FeCl_3$ could be prepared as either p- or n-type depending on the initial reactant ratio, with the perylene-rich material showing p-type properties.

EEA '63

20335 HgTe-MnTe ALLOYS. II. ELECTRICAL PROPERTIES. R.T.Delves.
J. Phys. Chem. Solids (GB), Vol. 24, No. 7, 885-97 (July, 1963).

The Hall effect magnetoresistance and Seebeck effect were measured at 77° and 300°K in sintered samples of $Hg_{1-x}Mn_xTe$ alloys which have the zinc blende type lattice. The hole mobility is about 100 cm^2/V sec at 77° and 300°K and $m^*+/m = 0{\cdot}3$ when $x < 0{\cdot}2$. A conduction band, probably from an (000) valley with mobility = $2-4 \times 10^4$ cm^2/V sec at 77°K and $m^*-/m = 0{\cdot}005-0{\cdot}012$ overlaps the valence band when $x < 0{\cdot}13$. An energy gap develops when $x > 0{\cdot}13$, and another conduction band with a lower mobility replaces the (000) valley when $x > 0{\cdot}15$. Only p-type material has been obtained when $x > 0{\cdot}25$. Most stoichiometric samples contained at least 10^{17} cm^{-3} acceptors. Some could be removed by annealing, others may be due to metallic impurities or oxygen. Excess tellurium and copper are acceptor impurities. Excess mercury is a donor when $x < 0{\cdot}05$, and has a complicated effect when $x > 0{\cdot}05$. The number of holes increases when oxygen is added and the energy gap appears to decrease as well.

PA '63

20425 THE ISOTHERMAL PELTIER COEFFICIENT AND PHONON-DRAG IN COPPER. W.G.Henry.
Canad. J. Phys., Vol. 41, No. 7, 1094-1101 (July, 1963).

An apparatus is described for making direct measurements of small Peltier coefficients of the order of 1 mV and less below room temperature. The Kelvin relationship between the thermopower and the isothermal Peltier coefficient is shown to hold for the copper-lead couple from 77·4° to 298°K.

PA '63

17973 ANOMALOUS THERMOELECTRIC POWER AS EVIDENCE FOR TWO-VALENCE BANDS IN SnTe.

R.F.Brebrick and A.J.Strauss.

Phys. Rev. (USA), Vol. 131, No. 1, 104-110 (July 1, 1963).

The thermoelectric power (α) of p-type SnTe was measured between room temperature and 450° C for apparent hole concentrations ($p^* = 1/eR_{300}$) between 1×10^{20} and $1{\cdot}8 \times 10^{21}$ cm^{-3}. At room temperature, α does not decrease monotonically with increasing p^* in the usual manner for a p-type semiconductor. Instead, it increases from 5-8 μV/deg at $p^* = 1\text{-}2 \times 10^{20}$ cm^{-3} to a maximum of 34 μV/deg at $p^* = 8 \times 10^{20}$ cm^{-3}, after which it decreases to 20·5 μV/deg at $p^* = 1{\cdot}8 \times 10^{21}$ cm^{-3}. The maximum gradually disappears with increasing temperature. At 400° and 450° C, α decreases monotonically with increasing p^*. By means of numerical calculations for a particular set of band parameters, it is shown that this type of anomalous variation in α can be exhibited by a p-type semiconductor with two nondegenerate valence bands. It is found that the observed properties of SnTe, including the variation of Hall coefficient with temperature and carrier concentration, are qualitatively consistent with a two-valence-band model, but are difficult to explain on the assumption that SnTe is a semimetal. However, it has not been possible to obtain a quantitative fit to the data with a two-band model in which both bands are of simple parabolic form.

PA '63

17969 THE THERMOELECTRIC POWER OF OXIDE CATHODES ON PLATINUM CORES. N.A.Surplice and R.P.Jones.

Brit. J. appl. Phys., Vol. 14, No. 7, 444-8 (July, 1963).

The thermoelectric power of barium oxide, strontium oxide and mixed barium and strontium oxides on platinum cores has been investigated over the range of temperature from 70 to 800°C. Curves of thermoelectric power against temperature showed the following regions: (i) less than 1 mV deg C^{-1} at low temperatures, (ii) thermoelectric power increasing rapidly from 180 to 300° C, (iii) constant at more than 2 mV deg C^{-1}, (iv) thermoelectric power remaining constant at temperatures up to 800° C for single oxides, but for mixed oxides falling sharply to a slightly lower value at the highest temperatures. After the oxides had been aged at 750-800° C for a year, with no current load, region (i) had disappeared and the thermoelectric power increased rapidly from 70 to 300° C. With barium oxide the disappearance of region (i) of the thermoelectric power characteristic was accompanied by a similar disappearance of the region of crystal conduction from the electrical conductivity plot (logarithm of conductivity against reciprocal temperature), but there was no change in thermal conductivity. With strontium oxide and mixed oxides there was no such simple correlation between the change in thermoelectric power and the change in electrical conductivity, and the thermal conductivity had decreased. These results are interpreted in terms of Loosjes and Vink's pore conduction theory of an oxide cathode and Metson's work on the thermal stability of the alkaline-earth oxides.

PA '63

17967 THEORETICAL BOUND ON THE THERMOELECTRIC FIGURE OF MERIT OF TWO-BAND SEMICONDUCTORS.

E.S.Rittner and G.F.Neumark.

J. appl. Phys. (USA), Vol. 34, No. 7, 2071-7 (July, 1963).

The Simon two-band semiconductor model is investigated further theoretically to determine whether a finite upper bound can be imposed on the thermoelectric figure of merit. It is shown that limitations on the adjustability of the Fermi level and use of reasonable physical values for the band parameters do lead to a finite upper bound for the two-band model which is of the same order of magnitude as that derived earlier by Rittner for a one-band model. The former can be severalfold higher than the latter but only at pathologically high values of the effective mass ratio m_h/m_e. Other factors which favour a high value of the upper bound are discussed.

PA '63

13155 ELECTRON AND PHONON SCATTERING. II THERMOELECTRICITY IN RUBIDIUM CAESIUM AND ALLOYS AT VERY LOW TEMPERATURES.
A.M.Guénault and D.K.C.MacDonald.
Proc. Roy. Soc. A (GB), Vol. 274, 154-62 (July 23, 1963).
For Pt I, see Abstr. 17814A of 1961; ibid., Vol. 264, 41-59

(Oct. 24, 1961). Following earlier measurements on pure potassium and alloys, a corresponding study has been made at very low temperatures of thermoelectricity in rubidium, caesium, and their alloys with each other and with potassium. The results have proved in accord with the interpretation of earlier work, and the trends observed in both the "electron diffusion" and "phonon-drag" contributions to the absolute thermoelectric power are discussed. Both contributions as observed in these metals are consistent with a larger distortion in the Fermi surface of caesium than in those of potassium or rubidium. It appears that the changes in the thermoelectric diffusion term can be attributed consistently to the difference arising from large-angle and small-angle scattering. It is supposed that in turn these types of electron scattering arise from the presence of homovalent and heterovalent impurity centres.

EFA '63

23026 THERMOELECTRIC POWER IN NONSTOICHIOMETRIC α-Nb_2O_5. R.F.Janninck and D.H.Whitmore.
J. chem. Phys. (USA), Vol. 39, No. 1, 179-82 (July 1, 1963).
Thermoelectric power measurements have been made on nonstoichiometric α-Nb_2O_5 over the temperature range from 300° to 1270°K. The measurements show that, for all compositions in the single-phase, α-Nb_2O_{5-x} region ($0{\cdot}0012 \leq x \leq 0{\cdot}1545$), the majority charge carriers are electrons. These thermoelectric power data have been interpreted in terms of a simple semiconductor exhibiting conduction in a narrow d band with the conduction electrons being assigned an effective mass equal to four times that of the rest mass.

JA '63

9892 RESISTIVITY, HALL CONSTANT, AND SEEBECK COEFFICIENT OF CsAu. F.Wooten and G.A.Condas.
Phys. Rev. (USA), Vol. 131, No. 2, 657-9 (July 15, 1963).
Measurements of resistivity, Hall constant, and Seebeck coefficient have established that CsAu is an n-type semiconductor with carrier concentrations 10^{18}-10^{19} cm^{-3}. The carrier concentration is essentially independent of temperature over the range 4·2–300°K and the mobility is 30-60 $cm^2 V^{-1} sec^{-1}$. It is suggested that excess caesium introduces an impurity band which overlaps the conduction band. The Seebeck coefficient (−0·023 mV deg^{-1} K at 300°K) indicates that the Fermi level lies about 0·02 eV above the conduction band based on optical lattice scattering.

EEA '63

Galvanomagnetic and thermoelectric coefficients of tetragonal crystalline materials. W. C. Hernandez, jr. and A. H. Kahn. biblog diags J Res Nat Bur Stand 67A:293-9 Jl '63

AS+TI '63

11680 THEORY OF GALVANO-THERMOMAGNETIC ENERGY CONVERSION DEVICES. V. DEVICES CONSTRUCTED FROM ANISOTROPIC MATERIALS.
T.C.Harman, J.M.Honig and B.M.Tarmy.
J. appl. Phys. (USA), Vol. 34, No. 8, 2225-9 (Aug., 1963).
Operating characteristics of galvanothermomagnetic generators and refrigerators for any anisotropic material are summarized in tubular form for both the longitudinal (thermoelectric) and transverse (Nernst) devices and for isothermal and adiabatic operating conditions. In the most general case, device performance is governed not only by the figure of merit, but also by an anisotropy factor. This factor involves off-diagonal elements of the Nerst and Seebeck tensors for Nernst devices and diagonal elements of the Nernst and Seebeck tensors for thermoelectric devices. It is believed that the "umkehr" effect (such as observed in Bi) is due to a nonvanishing diagonal component of the Nernst tensor.

EEA '63

Liquids for Thermoelectric Generation, J.W.GARDNER. English Elec J v 18 n 4 July-Aug 1963 p 16-21. Characteristics of liquid semiconductors, especially of cuprous sulfide and cuprous telluride are reviewed; possibilities of using molten salts for thermoelectric power generation.
EI 63

Elektrischer Widerstand und Thermospannung von Uran waehrend der Oxydation bei 10^{-3} Torr und 200 bis 400 C, S.STEEB, R. ROSSBERG. Zeit fuer Metallkunde v 54 n 8 Aug 1963 p 483-9. Electric resistivity and thermoelectric power of uranium were determined on vapor deposited films while these were charged with oxygen at 200-400 C and 10^{-3} Torr; band model was used for interpretation of results; effects of interruption of oxygen treatment are discussed; samples oxidized to saturation at 400 C had better thermoelectric properties in vacuum than sintered uranium oxide.
EI 63

14958 THERMOELECTRIC MATERIALS. S.Hahnel.
Tekn. Ukeblad (Norway), Vol. 110, No. 29, 685-90 (Aug. 15, 1963). In Norwegian.

The utilization of the thermoelectric effect has long been limited to metallic materials, but the discovery that semiconductors can give much better results than metals aroused interest in the practical use of thermoelements, and intensive research work is being carried out on the development of thermoelectric materials. The best results so far have been achieved with lead telluride, which is relatively cheap and capable of an efficiency of 8·5%. A table of the thermoelectric properties of semiconductors and their prices is given. J.Smuts

14954 THERMOELECTRICITY IN GOLD AT LOW TEMPERATURES. H.H.Andersen and M.Nielsen.
Phys. Letters (Netherlands), Vol. 6, No. 1, 17-18 (Aug. 15, 1963).

The thermal e.m.f. and electrical conductivity of gold were measured in the temperature range 2°-9°K, the thermal conductivity in the range 2°-17°K. The samples (40 μ foils) were either annealed in vacuum or in air for 24 h at 950°C. The resistance of the vacuum-annealed sample is reduced by the ratio $(R_{273} - R_{4\cdot2}/R_{4\cdot2}) = 32\cdot2$, while for the air annealed sample the ratio is 607. The thermal conductivity is given by the relation $1/K = aT^2 + bT$. The thermal e.m.f. of the air-annealed sample behaves normally and is of the order 1×10^{-8} V/degK for about 4°K. It is always positive. The vacuum annealed sample behaves like a sample with iron content, its e.m.f. being negative and of the order of -14×10^{-8} V/degK. The e.m.f. shows a broad minimum at about 6°-8°K. K.Heime
EEA 63

25424 PHONON-DRAG SEEBECK EFFECT IN A STRONG MAGNETIC FIELD. I. LONGITUDINAL CASE. T.Ohta.
J. Phys. Soc. Japan, Vol. 18, No. 8, 1166-73 (Aug., 1963).

A quantum theory is developed for the phonon-drag thermoelectric power of semiconductors in a longitudinal strong magnetic field with the use of the quantum-limit approximation. Thermoelectric power in the pure crystal is first calculated to give

$$\Delta Q(B)/Q(0) = k_{(ijk)}(\hbar\omega_c/kT)^{1/2}$$

where $\Delta Q(B)$ is the incremental thermoelectric power due to magnetic field, $Q(0)$ is the thermoelectric power without the field, $k_{(ijk)}$ is a constant dependent on the crystal direction [ijk], and ω_c is the cyclotron frequency. This can explain an experiment approximately. Saturation effect, impurity scattering effect, and Herring's hydraulic analogue (1954) are also discussed taking the magnetic field into account.
PA 63

25317 A NOTE ON THE GALVANOMAGNETIC AND THERMOELECTRIC COEFFICIENTS OF TETRAGONAL CRYSTALLINE MATERIALS. W.C.Hernandez, Jr and A.H.Kahn.
J. Res. Nat. Bur. Stand. (USA), Vol. 67A, No. 4, 293-9 (July-Aug., 1963).

The independent Hall, magnetoresistive, and thermoelectric coefficients for a tetragonal crystal are tabulated and geometric configurations for their experimental measurement determined. These coefficients are calculated on assumptions of several simple ellipsoidal models, in the range of nondegenerate statistics. Implications of experimentally observed isotropy or anisotropy of transport properties on the structure of the energy surfaces are noted.
PA 63

23030 APPROXIMATE DYNAMIC RESPONSE CALCULATIONS FOR THERMOELECTRIC PELTIER-EFFECT DEVICES.

P.E.Gray.

Solid-State Electronics (GB), Vol. 6, No. 4, 339-48 (July-Aug., 1963).

In most applications of thermoelectric cooling devices that require close control of temperature, the dynamic or non-steady-state behaviour of the entire system is important. Previously reported dynamic characterizations of such systems have yielded predictions of performance that are in good agreement with observed performance. However, these methods, which take into account the distributed nature of the thermoelectric device, give moderately complicated results that are not easy to apply. It is shown that for most cases of practical interest the dynamic response of the thermoelectric temperature-control system is dominated by the thermal mass of the load. Accordingly, the dynamic operation of the thermoelectric cooling device can be regarded as a succession of steady states, and the distributed system can be lumped, thus yielding accurate approximate results that are simple and easy to apply. The conditions under which such a representation is valid are delineated, and the corresponding approximate results are obtained in the form of transfer functions. The step response of a temperature control system is determined by means of this approximate method and compared with the response determined from consideration of the complete distributed system. This comparison shows that the lumped approximation is a valid and useful characterization of thermoelectric temperature-control systems.

PA '63

25428 THERMOELECTRIC EFFECT IN SINGLE-CRYSTAL CUPROUS OXIDE AT HIGH TEMPERATURES.

M.H.Zirin and D.Trivich.

J. chem. Phys. (USA), Vol. 39, No. 4, 870-5 (Aug. 15, 1963).

The thermoelectric effect in single-crystal cuprous oxide, measured at temperatures of 500° to 1130°C and oxygen pressures P of 160 to 2×10^{-8} torr, was found always to be positive, indicating that the material is a p-type semiconductor in these ranges of conditions. Plots of the thermoelectric power Q versus 1/T at different constant oxygen pressures yield parallel straight lines with a slope of 0·75 V. Plots of Q versus log P are mostly straight lines with slopes approximating $(-2{\cdot}3k)/(8q)$, in which k is Boltzmann's constant and q is the electronic charge. These results can be explained fairly satisfactorily in terms of a modified Wagner model for the defect structure of Cu_2O and existing theories of the thermoelectric effect in semiconductors. It is assumed that the concentration of acceptors is a function of both the oxygen pressure and the temperature and that a gradient of acceptors exists along the temperature gradient. Thus, the model shows that the factor 8, originally obtained from conductivity measurements, should also be contained in the slope of Q versus log P. The slope of 0·75 V for the plot of Q versus 1/T can be related to the energy of creating an acceptor, i.e. a copper atom vacancy, plus the energy of ionizing this acceptor.

PA63

37561 ELECTRIC RESISTANCE AND THERMOELECTRIC POWER OF URANIUM DURING OXIDATION AT 10^{-3} TORR AND 200 TO 400°C. Siegfried Steeb and Rolf Rossberg (Max-Planck-Institut für Metallforschung, Stuttgart). Z. Metallk., 54: 483-9(Aug. 1963). (In German)

An apparatus is described for the production of thin films of uranium by evaporation and for the consequent measurement of electric conductivity and thermoelectric power. Uranium films were treated between 200 and 400°C with oxygen (10^{-3} Torr), and at the same time the electric conductivity and thermoelectric power were measured. The band model was used for the interpretation of the resistance vs. time curves. Valence and conduction bands were 3 ev apart, while the acceptor and donor levels were 0.5 or 0.55 ev distant from the band above or below. These values were obtained from the measured temperature-resistance curves. The measurement of thermoelectric power showed that uranium oxides exhibit p-type conductivity at small oxygen contents and n-type conductivity at larger oxygen contents. The absolute values of thermoelectric power against platinum are given, as well as its dependence on the oxygen content. It is important for practical application that the thermoelectric power have a temperature-dependent maximum at a certain uranium/oxygen ratio. The behavior of electric resistivity and thermoelectric force caused by interruption of the oxygen treatment is discussed. Samples which were oxidized to saturation at 400°C show better thermoelectric properties in vacuum than sintered bodies of uranium oxide. (auth)

NSA '63

25428 THERMOELECTRIC EFFECT IN SINGLE-CRYSTAL CUPROUS OXIDE AT HIGH TEMPERATURES.
M.H.Zirin and D.Trivich.
J. chem. Phys. (USA), Vol. 39, No. 4, 870-5 (Aug. 15, 1963).

The thermoelectric effect in single-crystal cuprous oxide, measured at temperatures of 500° to 1130°C and oxygen pressures P of 160 to 2 × 10^{-6} torr, was found always to be positive, indicating that the material is a p-type semiconductor in these ranges of conditions. Plots of the thermoelectric power Q versus 1/T at different constant oxygen pressures yield parallel straight lines with a slope of 0·75 V. Plots of Q versus log P are mostly straight lines with slopes approximating (−2·3k)/(8q), in which k is Boltzmann's constant and q is the electronic charge. These results can be explained fairly satisfactorily in terms of a modified Wagner model for the defect structure of Cu_2O and existing theories of the thermoelectric effect in semiconductors. It is assumed that the concentration of acceptors is a function of both the oxygen pressure and the temperature and that a gradient of acceptors exists along the temperature gradient. Thus, the model shows that the factor 8, originally obtained from conductivity measurements, should also be contained in the slope of Q versus log P. The slope of 0·75 V for the plot of Q versus 1/T can be related to the energy of creating an acceptor, i.e. a copper atom vacancy, plus the energy of ionizing this acceptor.

PA '63

Preparation, phase-boundary energies, and thermoelectric properties of InSb-Sb eutectic alloys with ordered microstructures. W. K. Liebmann and E. A. Miller. bibliog il diags J Ap Phys 34:2653-9 S '63

Some thermoelectric properties of polycrystalline lanthanum telluride, $LaTe_{1.5}$ to $LaTe_{1.8}$. T. H. Ramsey and others. bibliog J Ap Phys 34:2917-18 S '63

ASTI '63

25426 THE THERMOELECTRIC POWER OF OXIDE CATHODES ON NICKEL CORES. N.A.Surplice and R.P.Jones.
Brit. J. appl. Phys., Vol. 14, No. 10, 725-6 (Oct., 1963).

The thermoelectric power has been measured for barium oxide, strontium oxide and mixed barium and strontium oxides on O-nickel cores, over the range of temperature 70° – 800°C. The magnitude of the thermoelectric power and its variation with temperature was similar to that reported previously for the same oxides on platinum cores. When the oxides were aged at 750° – 800°C with no current load, their thermoelectric power was decreased though not so drastically as it had been for the same oxides on platinum cores.

PA '63

25427 THERMOELECTRIC PROPERTIES OF CHROMIUM AND COBALT-SILICIDE. T.Sakata and T.Tokushima.
Trans Nat. Res. Inst. Metals (Japan), Vol. 5, No. 2, 34-48 (1963).

Examinations were made on the results of measurements of specific resistance, thermoelectric power and Hall coefficient of $CrSi_2$ and CoSi between – 200° and + 1200°C. The effects of addition of transition metals on the conductivity characteristics of $CrSi_2$ and CoSi were examined using V and Mn for the former and Mn and Fe for the latter. Descriptions are made of trial production and characteristics of thermoelements composed of $CrSi_2$ as the p-branch and CoSi as the n-branch.

PA '63

14961 UNUSUAL THERMOCOUPLES AND ACCESSORIES.
Instrum. Control Syst. (USA), Vol. 36, No. 8, 130-3 (Aug., 1963).
A survey of unusual thermocouples and accessories.

CEA '63

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THERMOELECTRIC MATERIALS.

4 Final rept., Jan 60-Aug 63, ed. by Merton H. Brooks. 31 Jan 63, 1v.
Contract NObs78326

Unclassified report

Descriptors: *Thermoelectricity, *Ceramic materials, Crystals, Semiconductors, Ionic current, Resistance (Electrical), Heat, Electricity, Oxides, Silicates, Hydrides, Titanium compounds, Niobium compounds, Barium compounds, Zirconium compounds, Yittrium compounds, Thermal conductivity, Electrical properties, Complex compounds, Lithium compounds, Magnesium compounds, Lead compounds, Chromium compounds, Tantalum compounds, Experimental data, Tables, Porosity, High-temperature research, Materials.

Three hundred twenty-three oxide, silicate, and metal hydride combinations were prepared and fabricated into test specimens by a variety of forming and firing techniques. Of these combinations, 309 were examined electrically for Seebeck effect and resistivity from 600 to 1200 C; the remaining few failed in test. None of the compositions tested gave indication of truly efficient conversion of heat to electricity; the TiO2 plus 2.0 mole percent Nb205 had an approximate figure of merit of 7.0 x 10 to the -5th power per degree centigrade. (Author)

'63

39246 LIQUID METALS FOR AEROSPACE ELECTRIC-POWER SYSTEMS. L. Rosenblum (Lewis Research Center, Cleveland). J. Metals, 15: 637-41(Sept. 1963).
Liquid metals and their properties, as applied to space electric-power systems, are discussed as possible heat-transfer and thermodynamic working fluids. Representative liquid metals, Li, Na, K, NaK-78, Pb, and Bi, are discussed and compared. Space power requirements are listed and used as a basis for evaluating the potentialities of the liquid metals. (auth)

NSA '63

Elektrisches, magnetisches und galvanomagnetisches Verhalten von Kupfer-Titan- und Gold-Titan-Mischkristallen, H.D.HAHL-BOHM. Zeit fuer Metallkunde v 54 n 9 Sept 1963 p 515-18. Electric, magnetic, and galvanomagnetic behavior of Cu and Au rich copper titanium and gold titanium solid solutions was studied as part of more extensive investigation of alloys consisting of elements of 4th Period and monovalent precious metals; results of determinations of electric resistivity, effect of magnetic field on resistivity, Hall constant, thermal electromotive force, and magnetic susceptibility are plotted, including some temperature coefficients, and discussed in terms of electron theory.

EI '64

23401 PREPARATION, PHASE-BOUNDARY ENERGIES, AND THERMOELECTRIC PROPERTIES OF InSb-Sb EUTECTIC ALLOYS WITH ORDERED MICROSTRUCTURES.
W.K. Liebmann and E.A.Miller.
J. appl. Phys. (USA), Vol. 34, No. 9, 2653-9 (Sept., 1963).
Two-phase solids, single-crystal rods of Sb in a matrix of single-crystal InSb, have been prepared by eutectic crystallization. The size of the Sb rods decreases with increasing crystallization velocity. in quantitative agreement with the theory of eutectic crystallization. The boundary energy between the InSb and the Sb phases was determined both from the parameters of the crystallization and from a dislocation model. Both values agree, indicating that the strain energy of the dislocations at the phase boundary is the chief contributor to the interfacial energy. The electrical resistivity ρ, the thermoelectric power Q and the thermal conductivity K have been measured as a function of the structural arrangement of the two phases in the alloys. The magnitudes of ρ and Q have been explained by simple electrical analogues of the eutectic structure. A characteristic decrease of the thermal conductivity of the eutectic alloys has been observed. The reduction in K is probably caused by interaction of phonons with the phase boundaries.

PA '63

621.362

14959 THE THERMOELECTRIC POWER OF OXIDE CATHODES ON NICKEL CORES. N.A.Surplice and R.P.Jones.
Brit. J. appl. Phys., Vol. 14, No. 10, 725-6 (Oct., 1963).

The thermoelectric power has been measured for barium oxide, strontium oxide and mixed barium and strontium oxides on O-nickel cores, over the range of temperature 70°-800°C. The magnitude of the thermoelectric power and its variation with temperature was similar to that reported previously for the same oxides on platinum cores. When the oxides were aged at 750°-800°C with no current load, their thermoelectric power was decreased, though not so drastically as it had been for the same oxides on platinum cores.
EEA '63

14960 THE THERMOELECTRIC POWER OF V_3X COMPOUNDS. M.P.Sarachik, G.E.Smith and J.H.Wernick.
Canad. J. Phys., Vol. 41, No. 10, 1542-6 (Oct., 1963).

The thermoelectric powers of the intermetallic compounds V_3Ge, V_3Si, V_3Ga, and V_3Sn have been measured from their superconducting transition temperatures to room temperature. It is found that the thermoelectric coefficients are all positive and about 10 $\mu V/deg^{-1}$ K at room temperature. The coefficients for V_3Si, V_3Ga, and V_3Sn are monotonically increasing functions of the temperature, whereas for V_3Ge there is a pronounced maximum at about 60°K. The results are discussed in terms of a two-band model consisting of a conduction band and a d-band.
EEA '63

X-Ray Study and Thermoelectric Properties of $W_{x/2}Mo_{x/2}Ta_{1-x}Se_2$ System, L.H.BRIXNER, G.TEUFER. Inorganic Chem v 2 n 5 Oct 1963 p 992-6. Pseudobinary system between compounds $TaSe_2$ and $W_{0.5}Mo_{0.5}Se_2$ was investigated structurally and with regard to such thermoelectric parameters as Seebeck coefficient, electric resistivity, and thermal conductivity; compounds of interest for thermoelectric power generation in intermediate temperature range (500-700 C) were found for values of x from 0.9-0.99; preliminary data.
EI 64

36477 PRECISION NONDESTRUCTIVE TESTING OF THERMOELECTRIC MATERIALS. S. H. Fitch and J. W. Morris (Atomics International, Canoga Park, Calif.).
Nondestructive Testing, 21: 306-10(Sept.-Oct. 1963).

The direct conversion of heat to electrical energy and the application of this (thermoelectric phenomenon to Systems for Nuclear Auxiliary Power (SNAP) for space vehicles is discussed. The development of a complete quality control system for the evaluation of thermoelectric materials, as-received, in-process, and after assembly, is outlined. The contributions of nondestructive testing and statistical quality control in enhancing the assurance of acceptable quality and reliability of the end product are demonstrated by actual test records and control charts. (auth)
NSA '63

9802 THEORETICAL ANALYSIS OF THERMOELECTRIC CHARACTERISTICS OF AN IONIZED FLUID. R. Monti and L. G. Napolitano (Universitá, Naples). Preprint Paper 41, Session IV. Prepublication Copy. 8p.

A unified irreversible thermodynamic analysis of conversion processes with n independent fluxes and forces is presented. The coefficients of conductivity (ratio between fluxes and forces), force cross-effect (ratio between two forces), and flux cross-effect (ratio between two fluxes) are self-consistently defined, and their values are derived in terms of the kinetic phenomenological coefficients. A general definition of figure of merit is proposed and is valid when more than one cross-effect is present. The application of the analysis to a ternary equilibrium isotropic plasma is outlined. The value of the force cross-effect (Seebeck) coefficient was determined and found to compare favorably with those of good semiconductors. (M.P.G.)
NSA '63

24271 THEORETICAL ANALYSIS OF THERMOELECTRIC CHARACTERISTICS OF AN IONIZED FLUID. R.Monti and L.G.Napolitano.
Instn Elect. Engrs Conf. Rep. Ser. (GB), No. 4, 130-2, 142-3 (1963). [Magnetoplasmadynamic Power Generation Symposium, Newcastle, 1962 (see Abstr. 21966 of 1963)].

Discusses the formulation of a general, unified and self-consistent basis for studying the feasibility of plasma as a medium for energy conversion. As an example the Seebeck coefficient of a uniform isotropic plasma is evaluated and is found to compare favourably with those of good semiconductors. J.A.Nation
PA '63

10899 THERMOELECTRIC EFFECTS IN ICE CRYSTALS. I. THEORY OF THE STEADY STATE. C.Baccard.
Phys. kondens. Materie (Germany), Vol. 1, No. 2, 143-51 (1963).

Starting from the phenomenological equations which describe the currents of the four specific ice lattice defects (OH_3^+, OH^-, doubly occupied and vacant hydrogen bonds), the electrochemical and homogeneous thermoelectric power are calculated for the current-free steady state under the assumption of immobile chemical impurities. The expression for the homogeneous thermoelectric power agrees with the experimental value (1·8 mV/°C) if the energy values obtained from the electrical properties are inserted, and if the diffusivity ratios of the ions D^-/D^+ and of the valence defects D^F/D^D are assumed to be much smaller than unity and 1·2, respectively. The formulae are also applied to ice doped with hydrofluoric acid, and the magnitudes of the Seebeck, Peltier and Thomson effects are derived.

PA '63

22947 THE MEASUREMENTS OF GALVANOMAGNETIC AND THERMOELECTRIC PROPERTIES OF InSb-p.
J.Ginter and W.Szymańska.
Phys. Status solidi (Germany), Vol. 3, No. 8, 1398-1407 (1963).

The conductivity, Hall coefficient and thermoelectric power of p-type InSb were measured in the temperature range 77° to 300°K. The experimental results are analysed on the basis of a spherical and parabolic valence band structure (with a heavy hole mass $m_h = 0{\cdot}35\ m_0$), and mixed scattering of holes by acoustic phonons and ionized impurities. The influence of phonon drag on the thermoelectric power is considered over the temperature range investigated.

PA 63

Thermoelectric Properties of Enargite-Type Compounds. R.L. CARPENTER, J.S.MURRAY, T.D.ROBERTS. U S Bur Mines—Report Investigations 6200 1963 8 p. Thermal conductivity, electrical resistivity, and Seebeck coefficient for 9 compounds, based on formula for enargite Cu_3AsS_4, were measured in search for efficient materials to be used in thermoelectric generators or refrigerators; results indicate that one of these compounds, Cu_3SbSe_4, has thermoelectric properties approaching those of bismuth telluride; investigation of effect of adding small quantities of tellurium to Cu_3SbSe_4 and Cu_3SbS_4 in order to improve their properties.

EI 63

22952 MAGNETO-ELECTRIC AND THERMOELECTRIC PROPERTIES OF SOLID SOLUTIONS OF SELENIUM-TELLURIUM. I.Rosenman.
Phys. Status solidi (Germany), Vol. 3, No. 8, 1429-40 (1963).
In French.

In polycrystalline Se-Te alloys with Se contents up to 40 atomic percent electrical conductivity, Hall-effect and thermo-e.m.f. were investigated. All alloys were p-type, the carrier concentrations were 10^{16}-10^{17} cm^{-3}. The variation of Hall-mobility with temperature is explained by a mixed scattering mechanism by acoustical phonons and ionized impurities. A method for calculating the influence of each of the mechanisms on the electrical conductivity is given. At room temperature the effective mass varies from 0·21 m_0 for Te to 0·77 m_0 for the 40% Se alloy. In the intrinsic range the conductivity decreases exponentially with increasing Se content. This is explained by the increasing band gap ($5{\cdot}7 \times 10^{-3}$ eV/% Se).

K.Heime
PA 63

17869 ELECTRIC AND THERMOELECTRIC PROPERTIES OF THE SYSTEM $(Bi_{x-x_1}Sb_{2-x_1}Te_{x_1})(Te,Se_{1-y})$.
G.Gramberg and H.G.Plust.
Helv. phys. Acta (Switzerland), Vol. 36, No. 2, 237-47 (1963).
In German.

The mixed crystals specified in the title were investigated for $x = 0{\cdot}6$, $y = 2{\cdot}875$, $0 < x_1 < 0{\cdot}2$. The most desirable thermoelectric properties were found for $x_1 = 0{\cdot}1$. Temperature dependence of Hall effect and of conductivities were investigated, and the results discussed.

P.T.Landsberg
PA 63

20325 THE INFLUENCE OF IMPURITIES ON THE ELECTRIC AND THERMOELECTRIC PROPERTIES OF CdSb SINGLE CRYSTALS. K.Šmirous, A.Hrubý and L.Štourač.
Czech. J. Phys. B, Vol.13, No.5, 350-7 (1963).

The influence of impurities on CdSb single crystals prepared by the modified Czochralski method and the method of zone melting was studied. It was found which impurities are electrically active and which give rise to electron and hole conductivity and a schematic model of their substitutions in the CdSb lattice was proposed. The temperature dependence of the mobility was found for both electrons and holes and the density effective masses were determined.

PA '63

14962 THE EFFECT OF HYDROSTATIC PRESSURE ON THE THERMOELECTRIC POWER IN INDIUM ANTIMONIDE.
S.Porowski, A.Duracz and S.Żukotyński.
Phys. Status solidi (Germany), Vol. 3, No. 9, 1555-62 (1963).

The thermoelectric power in InSb at 300°K was measured as a function of pressure up to 16 000 atm. The experimental data obtained for n-type samples are in good agreement with the Kane model of the conduction band, and also offer new evidence that ionized impurity scattering and optical mode scattering are dominant for electrons. It is shown that the results for p-type InSb can be explained by assuming that the effective mass of holes is equal to 0·42 m_0 and that the dominant scattering is by optical phonons.

EEA '63

25350 ELECTRICAL PROPERTIES OF SOME TERNARY COMPOUNDS. Z.I.Ornatskaya.
Semiconductor Materials Conference, Moscow (see Abstr. 13056 of 1963) p. 117-18.

Polycrystalline samples of the semiconducting compounds $ZnIn_2Se_4$, $ZnIn_2Te_4$, $CdIn_2Se_4$, $CdIn_2Te_4$ were prepared. X-ray analysis of the compounds $CdIn_2Te_4$, $CdIn_2Se_4$ and $ZnIn_2Se_4$ showed them to have a structure of the diamond type with lattice constants of 5·801, 5·303 and 5·690 respectively. The variation of resistivity and thermal e.m.f. with temperature was studied and the following band gaps determined:- $ZnIn_2Te_4$, 1·8 eV; $CdIn_2Te_4$, 0·88 eV; $ZnIn_2Se_4$, 1·95 eV.

PA '63 C.H.Gooch

11544 THE INFLUENCE OF IMPURITIES ON THE ELECTRIC AND THERMOELECTRIC PROPERTIES OF CdSb SINGLE CRYSTALS. K.Šmirous, A.Hrubý and L.Štourač.
Czech. J. Phys. B, Vol. 13, No. 5, 350-7 (1963).

The influence of impurities on CdSb single crystals prepared by the modified Czochralski method and the method of zone melting was studied. It was found which impurities are electrically active and which give rise to electron and hole conductivity and a schematic model of their substitutions in the CdSb lattice was proposed. The temperature dependence of the mobility was found for both electrons and holes and the density effective masses were determined.

EEA '63

17968 CHARACTERISTIC THERMOELECTRIC POWER OF BOUNDARY SURFACE ATOMS. R Nossek.

Z. Phys. (Germany), Vol. 174, No 2, 296-300 (1963). In German.

For a single-band conductor where two or more scattering mechanisms are present, each giving rise to a characteristic thermoelectric power S_α and an electrical resistivity ρ_α, the resultant thermoelectric power S is given, as a first approximation, by $S = \sum_\alpha \rho_\alpha S_\alpha / \rho$. Denoting with S_0 the characteristic thermoelectric power due to the scattering of the conduction electrons by the boundary atoms, and with S_i and ρ_i the resultant thermoelectric power and electrical resistivity arising from all other scattering mechanisms, one may write $S = S_0 + \rho_i (S_i - S_0)/\rho$. The thermoelectric power S and the electrical resistivity ρ of thin layers of potassium, evaporated in vacuum $\sim 5 \times 10^{-7}$ torr on a glass substrate at 90° K temperature, were measured at different thicknesses. The variation of S as a function of $1/\rho$ verifies the above relation. Thus, the thermoelectric power characteristic for the scattering by potassium boundary atoms can be determined. PA63

25427 THERMOELECTRIC PROPERTIES OF CHROMIUM AND COBALT-SILICIDE. T.Sakata and T.Tokushima.

Trans Nat. Res. Inst. Metals (Japan), Vol. 5, No. 2, 34-48 (1963).

Examinations were made on the results of measurements of specific resistance, thermoelectric power and Hall coefficient of $CrSi_2$ and CoSi between −200° and +1200°C. The effects of addition of transition metals on the conductivity characteristics of $CrSi_2$ and CoSi were examined using V and Mn for the former and Mn and Fe for the latter. Descriptions are made of trial production and characteristics of thermoelements composed of $CrSi_2$ as the p-branch and CoSi as the n-branch. PA63

20162 (BNL-756(p.262-75)) LIQUID METAL RESEARCH AT NASA-LEWIS RESEARCH CENTER.

James P. Lewis (National Aeronautics and Space Administration. Lewis Research Center, Cleveland).

Liquid-metal research activities are summarized with emphasis on the heat transfer aspects of these studies. A two-phase flow loop, constructed of stainless steel, is being operated with sodium. A sodium turbine facility, pump test facilities, liquid alkali metal heat transfer facility, space radiator and condenser facility, and equipment for bearing and seal studies are being constructed. Experiments are being planned to study the flow and heat transfer processes in a typical SNAP-8 radiator tube. Materials support programs are discussed. (M.C.G.) PA63

10895 DOPING PROPERTIES OF $Bi_2Te_{2.7}Se_{0.3}$. O.Beckman and P.Bergvall.

Ark. Fys. (Sweden), Vol. 24, Paper 10, 113-22 (1963).

Thermoelectric properties of n-type $Bi_2Te_{2.7}Se_{0.3}$ doped with Cu, CuBr, $CuBr_2$, BiClO and BiI_3 are studied. The lattice thermal conductivity is 1·03 W/m deg K and $\mu_0 (m^*/m)^{3/2}$ parallel to the cleavage plane ranges from 0·036 to 0·032 m^2/V sec giving an optimum Z-value of $3{\cdot}0 \times 10^{-1}$ $(°K)^{-1}$. Galvanomagnetic studies give a band structure close to that of n-type Bi_2Te_3. The effective mass m^* is $0{\cdot}57 m_0$ and the anisotropy factor for Hall effect measurements with ρ_{123} equals 0·24. The number of charge carriers related to the amount of doping molecules is discussed. PA63

II. MATERIALS

B. Thermionic properties

Thermionic emission from spherical metallic particles. M. S. Sodha. J Ap Phys 32:2059-60 O '61

AS+TI '61

11693 CORRELATION OF THE VELOCITY DISPERSION TO THE DECAY PHENOMENA OF THERMIONIC EMISSION FROM OXIDE CATHODE. E.Sugata and S.Nakamura.
Technol. Rep. Osaka Univ. (Japan), Vol. 11, 237-44 (Oct., 1961).

The relation of the decay phenomena to initial velocity distribution of electrons from an oxide coated cathode was examined by the pulsive retarding potential method. When the oxide cathodes are poisoned by O_2 gas, the velocity dispersion of electrons increases. It was found that on a cathode of BaO poisoned by O_2 gas, (BaSr)O, and a composite-one(BaO covered with an evaporated SrO film), the extent of velocity dispersion at the low-duty cycle is large, but as the duty cycle increases, the velocity dispersion becomes smaller. The decay of pulsive emission from the composite cathode for the high-duty cycle depends on the thickness of the SrO film, which has poor conductivity. It is concluded that the initial decay of emission from the oxide coated cathode, which has poor conductivity, depends mainly on the donor depression at the cathode surface.

PA '62 1

7600 INVESTIGATIONS ON THE DIRECT CONVERSION OF ENERGY WITH A Cs-DIODE. K.G.Günther.
Z. angew. Phys. (Germany), Vol. 13, No. 11, 501-8 (Nov., 1961).
In German.

An experimental Cs-diode was constructed. Electrode spacings were from 1 mm to 1 cm and the electrodes had a planar configuration. The effects of the electrode materials and coatings on the performance of the Cs-diode were observed. The emitters (cathodes) were tantalum and molybdenum disks with coatings of LaB_6 and ThO_2, and the collectors (anodes) were copper disks with chromium, nickel and silver coatings. A maxiumum efficiency of 16% was observed for a ThO_2 coated emitter and Cr coated collector with a caesium pressure of 0.3 torr and an emitter temperature of 2200° K.

C.Greaves

PA '62

Thermionic properties of HfC. J. H. Ingold.
J Ap Phys 32:2651 D '61

AS+TI '61

3069 SEARCH FOR A NUCLEAR THERMIONIC EMITTER. P.Stephas.
Nucleonics (USA). Vol. 19, No. 12, 66. 70. 72, 73 (Dec., 1961).

Materials with high melting points and low evaporation rates at high temperatures together with the available data on their thermionic properties are tabulated. Data is inadequate, but the carbides and borides of transition metals are promising materials for use in thermionic converters.

R.D.Smith

PA '62

11696 PHOTOEMISSION FROM GALLIUM ARSENIDE.
A.N.Arsen'eva-Geil' and Van Bao-kun' [Wang Pao-k'un].
Fiz. tverdogo Tela (USSR), Vol. 3, No. 12, 3621-7 (Dec., 1961).
In Russian.

The energy distribution of photoelectrons emitted when gallium arsenide is illuminated by ultraviolet light was determined quantitatively for various carrier densities (n- and p-type). As the number of electrons increased, the thermoelectric and photoelectric work functions decreased and the number of fast electrons increased. Observations suggest the existence of a compound band. The photoelectric work function rose linearly with the photon energy, and this cannot at present be explained. See also following abstract. [English translation in: Soviet Physics—Solid State (USA)].

G.D.Archard

PA 162

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Electron Tube Research Lab., U. of Minn. Minneapolis.
STUDIES OF PRIMARY ELECTRON SOURCES.
Scientific rept. no. 3, 1 Sep-1 Dec 61, by D. E. Anderson. Aug 62, 44p. incl. illus. tables, refs.
(Contract AF 19(604)8381, Proj. 4619)
(AFCRL 62-597) Unclassified report

DESCRIPTORS: *Thermionic emission, *Oxide cathodes, *Cathodes (Electron tubes), *Superconductors, Alkaline earths, Semiconductors, Barium compounds, Oxides, Aluminum compounds, Tantalum compounds, Tantalum, Photoemission, Life expectancy, Anodes (Electron tubes), Photoelectric effect, Temperature, Electron tubes.

An experiment in which oxygen and hydrogen were admitted to a tube containing an active-based oxide cathode is described. The admission of oxygen poisoned the cathode early in life and permanently reduced the emission by an order of magnitude. Operation at an elevated temperature and a complete reconversion to 1323 K did not change the emission. Hydrogen was admitted at low pressures and caused small changes in the emission. The problem of evaporative cooling in an oxide cathode during current drain was analyzed. Further data on the photoelectric yield and thermionic pulse emission from BaO cathodes produced by converting $BaCO_3$ are presented. The time-temperature dependence of the photoelectric yield following a life period on a cathode is discussed. Measurements of tunnel current through Al_2O_3-Al samples are discussed. Results of tunnel current measurements on thin film Ta-Ta_2O_5-metal devices are described. Measurements were made on samples having active areas with Al and also with Au overlayers. Further data are presented on the enhanced electron emission from a superconducting field emitter which occurs when the transition from superconducting to normal state is approached. (Author)

163

3464 (ARA-1029) STUDY OF MATERIALS FOR THERMIONIC CONVERTERS. Summary Report No. 1. Philip Goodman and Harold Homonoff (Allied Research Associates, Inc., Boston). Dec. 31, 1961. Contract Nonr-3385 (00). 80p. (AD-273533)

An examination was made of the fundamental properties of materials, from a solid-state physics and chemistry point of view, with regard to those properties which most influence their performance in thermionic converters. The underlying structural causes which determine the values of such material properties as work function, electron affinity, heat of vaporization, vapor pressure, thermal conductivity, Fermi level, etc. were examined for metals, insulators, and semiconductors. Both quantitative calculations and qualitative correlations for various material classes are discussed. In connection with this study, a compilation was made of experimentally determined thermionic work functions and Richardson A values for most non-elemental emitters. (auth)

NSA 63

2010 PROCEDURE FOR DETERMINING THE WORK FUNCTION OF SURFACE MICROREGIONS ON THERMIONIC CATHODES

A.V.Druzhinin.

Izv. Akad. Nauk SSSR, Ser. fiz., Vol. 25, No. 6, 730-4 (1961). In Russian. English translation in: Bull. Acad. Sci. USSR, phys. Ser. (USA), Vol. 25, No. 6, 742-7 (June, 1961).

"Electron Microscopy" Conference Paper, Leningrad, October, 1960 (see Abstr. 22268 of 1962). The distribution of the work function over the surface of compressed cathodes composed of barium-calcium tungstate, aluminium and tungsten, and of L-cathodes was investigated by measurement of the current density in an element of the image in an emission microscope and application of the Richardson formula. The resolution of the method is mainly determined by the chromatic aberration of the electrostatic immersion objective employed in the instrument. The results show a small scale distribution (1 μ dia. patches) of high emission and further variation over a large scale (10 μ dia. patches).

NSA 63 V.R.Switsur

Magneto-Thermionic Power Generation, A.SCHOCK. AIEE-Trans v 80 pt 2 (Applications & Industry) n 58 Jan 1962 p 398-403. Design concept presented improves under certain conditions, efficiency of thermionic generators, and envisages application of magnetic field perpendicular to electrode surface; applied field counteracts adverse effect of self-induced transverse magnetic fields present in large thermionic generators; in addition, applied magnetic field may be used as modulating device in order to generate alternating current. Paper 60-1033.

EI 63

22160 THE ANODES OF THERMOELECTRONIC CONVERTERS.
V.G.Bol'shov and A.A.Zharinov.
Zh. tekh. Fiz. (USSR), Vol. 32, No. 2, 214-19 (Feb., 1962).
In Russian.

The power and efficiency of a thermoelectronic (thermionic) converter can be increased by reducing the average work function of the anode. During operation cathode materials are evaporated on to the anode and control the work function. A contact potential difference method was used to determine the work functions of ZrC, TaC, and UC + ZrC evaporated layers in Cs vapour at various pressures. The Cs vapour has most effect on the TaC evaporation products, reducing the work function to about 1.0 eV at a pressure of 10^{-2} mm Hg. [English translation in: Soviet Physics—Technical Physics (USA), Vol. 7, No. 2, 152-5 (Aug., 1962)]. C.Greaves

PA 62

22249 THERMOELECTRON EMISSION OF SOME REFRACTORY COMPOUNDS. T.L.Matskevich and T. V.Krachino.
Zh. tekh. Fiz. (USSR), Vol. 32, No. 2, 220-3 (Feb., 1962). In Russian.

Measurements were made of the temperature dependence of the thermionic emission current density for NbC, solid solutions of NbC—UC with 14.4% U and TaC—UC with 20% UC, and ZrC. The results indicated that even when activation was not very careful, current densities of 1 and 4 A/cm² were obtained from non-deactivated NbC—UC and TaC—UC at 1830° and 2130°K respectively. These materials are therefore of interest for use as cathodes in thermionic convertors. [English translation in: Soviet Physics—Technical Physics (USA), Vol. 7, No. 2, 156-8 (Aug., 1962)]. C.Greaves

PA 62

AD-299 966 • Div. 8
(TISTE/OHD) OTS price $9.10

Electron Tube Research Lab., U. of Minn., Minneapolis.
STUDIES OF PRIMARY ELECTRON SOURCES.
Scientific rept. no. 4, 1 Dec 61-1 Mar 62, by D. E. Anderson Sep 62, 68p. illus.
(Contract AF 19(604)8381, Proj. 4619)
(AFCRL 63-5) Unclassified report

DESCRIPTORS: *Thermionic emission, *Cathodes, *Field emission, Oxide cathodes, Electromagnetic pulses, Thickness, Measurement, Dielectric films, Metal films, Superconductors, Electrons.

163

11336 (UCRL-6820) THE EFFECT OF BAND STRUCTURE ON THERMIONIC EMISSION. W. E. Spicer (California. Univ., Livermore. Lawrence Radiation Lab.). Mar. 13, 1962. Contract W-7405-eng-48. 21p.

The problem of thermionic emission from a solid was treated theoretically for any general band structure without assuming the Drude-Sommerfeld free electron model. It is shown that only the bands which have a finite density of states near the vacuum affect the emission. For these bands, it is the areal density of states in the plane perpendicular to the direction of emission near the band minima which are of importance. Specifically, the rate of arrival of electrons with sufficient energy to escape over the surface barrier is $J_c = eD_c \exp(-e\phi_c/kT)$ where D_c is a function of the band structure near the band minima in the plane perpendicular to the direction of emission and of the temperature. For emission into a vacuum, the maximum value of the current density is $AT^2 \exp(-e\phi_c/kT)$ where $A = 120$ amp/cm^2(°K)^2; however, A may have any value less than 120, depending on the band structure of the solid. In the latter case, there will be a reflectivity of magnitude $(1 - A/120)$ due to the density of states in the solid for external electrons incident on the solid with thermal energies. (auth)

NSA 163

11689 SPECTRAL ANALYSIS OF LIGHT EMITTED FROM AN OXIDE-COATED CATHODE DURING THERMIONIC EMISSION. C.H.B.Mee.
Nature (GB), Vol. 193, 1066 (March 17, 1962).

The green-blue discharge observed when high current densities are drawn in vacuum tubes containing oxide-coated cathodes was examined spectrographically. Lines due to Ba, Sr and Ca were observed; in addition to those in the range 4300-5600 A, previously reported by Debiesse and Champeix (Abstr. 3093 of 1949), relatively intense lines in the region 4300-5600 A were obtained.

C.H.B.Mee

PA 162

8952 (UCRL-6809(Rev. 1)) EMISSION CHARACTERISTICS OF TANTALUM, TUNGSTEN, RHENIUM, AND IRIDIUM IN PLASMA DIODES. W. H. Gust (California. Univ., Livermore. Lawrence Radiation Lab.). Apr. 2, 1962. Contract W-7405-eng-48. 18p.

Experimental determinations of the ionic and electronic emission characteristics of tantalum, tungsten, rhenium, and iridium cathodes in vapor thermionic converters are compared. It is shown that tantalum provides superior thermal ionization qualities at high pressure compared with tungsten, rhenium, and iridium. High electronic current densities may be obtained from cesium on rhenium and cesium on iridium at much lower cesium vapor pressures than for tantalum or tungsten. (auth)

NSA 163

18992 DETERMINATION OF MECHANICAL, CHEMICAL AND THERMIONIC PROPERTIES OF THORIATED TUNGSTEN. P.Schneider.
Vide (France), Vol. 17, 182-5 (March-April, 1962). In French and English.

Using an apparatus described in a previous paper (Abstr. 3209 of 1958), the critical load and the critical deflection were determined for six samples carbonized under standard conditions (specified), five of which were also additionally carbonized for 5, 10, 15, 20 and 25 sec. The curves showing the dependence of critical load and critical deflection on the time of additional carbonization were found to be straight lines (with a negative slope for the low-quality, and zero slope for the good-quality material). The content of Th (beside ThO_2) was determined by using Complexone III (EDTA). The average contents should be 1.5-2.0% ThO_2 and 0.1-0.5% Th. The thermionic emission and activation were determined in a laboratory diode.

F.Lachman
PA62

11691 EMISSION CHARACTERISTICS OF A PHILIPS IMPREGNATED CATHODE. R.F.Hill and S.R.Rouze.
J. appl. Phys. (USA), Vol. 33, No. 4, 1607-8 (April, 1962).

The emission characteristics of a Philips Impregnated-Type B Cathode were investigated on a thermionic emission microscope at various operating temperatures. Before "activation" the emission was patchy, but after activation at 1250°C the surface was more uniform. A granular structure was observed at about 980°–1040°C and again above 1150°C. However, in the recommended operating region between 1090° and 1150°C, a monotone surface of median structure was observed.

C.Greaves
PA62

2016 DETERMINATION OF THE THERMAL EMISSION CONSTANTS FROM THE ENERGY DISTRIBUTION CURVES FOR THERMOELECTRONS AND POSITIVE IONS.
É.Ya.Zandberg, N.I.Ionov, V.I. Paleev and A.Ya.Tontegode.
Zh. tekh. Fiz. (USSR), Vol. 32, No. 4, 503-16 (April, 1962). In Russian.
English translation in: Soviet Physics - Technical Physics (USA), Vol. 7, No. 4, 363-72 (Oct., 1962).

A qualitative investigation is made of the delay curves, $\ln J = f(V)$, of the thermionic current in the absence of a volume charge. The study is made for both plane and cylindrical electrodes with a non-uniform work-function, for two cases: compensated and uncompensated external spot contact field. It is shown that the delay curves permit determination of the temperature distribution of the thermoelectrons and evaluation of the degree of nonuniformity of the electrode work-functions. The relation between the conventional contact potential difference V_1^* determined from the delay curve, and the contact potential difference obtained from the difference of the average values of the cathode φ_1^* and anode φ_2^* work-functions, averaged over the total current, is found. An analogous investigation is carried out for positive-ion current delay curves, the positive ions appearing at the cathode due to surface atom ionization. The results of the analytic study were verified for the case of the compensated spot field by means of a study of the delay curves for thermoelectrons and positive caesium ions for a cylindrical triode filled with caesium vapour. A study was also made, using the same tube, of thermoelectronic space-charge compensation by positive caesium ions.

PA63

32639 DETERMINATION OF MECHANICAL, CHEMICAL AND THERMIONIC PROPERTIES OF THORIATED TUNGSTEN. Petr Schneider. Vide, 17: 182-5(Mar.-Apr. 1962). (In French)

Thoriated W samples were subjected to graphite layer removal, carbonizing, and decarbonizing in hydrone and benzene vapor atmospheres at 2200°K, then they underwent mechanical property measurement at specified critical loading, quantitative chemical determination, and thermionic testing at 1900 to 2200°K at specified voltage and pressure, to study the amount of thoria and Th content, thermionic emission, mechanical properties, critical deflection, and weight changes. (Rev. Metal Lit., 19: No. 9, Sept. 1962)

N SA '63

3463 (AD-276411) HEAT DIODE CONVERTER. Interim Scientific Report No. 4, February 1, 1962—April 30, 1962. (Westinghouse Electric Corp. Research Labs., Pittsburgh). May 30, 1962. Contract AF33(616)-8262. 89p.

Work on the thermionic emission properties of refractory materials in cesium vapor progressed and some new features of the behavior of refractory metals in high cesium pressure were observed. Measurement was continued of saturation emission currents in a cesium plasma anode discharge tube. The electron reflection measurement technique proved satisfactory, and a set of experiments for copper is reported. A complete set of measurements was taken for the thermal conductivity of cesium vapor. A complete analysis was carried out for all the previously done measurements of the evaporation of molybdenum in cesium vapor. (auth)

N SA '63

18660 THE EFFECT OF AN ELECTRIC FIELD ON THE ELECTRON TEMPERATURE, ELECTRICAL CONDUCTIVITY AND THERMIONIC EMISSION OF SEMICONDUCTORS. V. I.M.Dykman and P.M.Tomchuk.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 5, 1082-94 (May, 1962). In Russian.

The results of earlier work (Abstr. 14419-21 of 1961) are generalized to the case when the conduction electron density differs from the concentration of impurity ions. The role of the optical lattice vibrations and their effect on the conductivity and the electron gas temperature are discussed. A method of allowing for the optical vibrations is given for the case of interaction between electrons. The coefficient β in $\sigma = \sigma_0(1 + \beta F^2)$ is calculated; here, σ is the conductivity, σ_0 is the ohmic value and F is the electric field. The value of β is affected by the choice of the electron momentum distribution. [English translation in: Soviet Physics—Solid State (USA)].

S.Chomet

P A '62

23289 THE EFFECT OF AN ELECTRIC FIELD ON THE ELECTRON TEMPERATURE, ELECTRICAL CONDUCTIVITY AND THERMIONIC EMISSION OF SEMICONDUCTORS. V. I.M.Dykman and P.M.Tomchuk.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 5, 1082-94 (May, 1962). In Russian. English translation in: Soviet Physics—Solid State (USA), Vol. 4, No. 5, 798-806 (Nov., 1962).
For abstract see Abstr. 18660 of 1962.

P A '62

2982 THERMIONIC EMISSION OF IONIC SEMICONDUCTORS IN STRONG FIELDS. K.B.Tolpygo and G.V.Chaika.
Fiz. tverdogo Tela (USSR), Vol.4, No.5, 1146-53 (May, 1962). In Russian. English translation in: Soviet Physics—Solid State (USA), Vol.4, No.5, 845-9 (Nov., 1962).
For abstract see Abstr. 21203 of 1962.

P A '63

21203 THERMOELECTRIC EMISSION OF IONIC SEMICONDUCTORS IN STRONG FIELDS.
K.B.Tolpygo and G.V.Chaika.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 5, 1146-53 (May, 1962).
In Russian.

The thermoelectric emission from a semiconductor cathode is calculated taking into account both concentration and temperature of the electrons under the action of an external field. It is shown that under normal conditions the variation in thermoelectric emission due to heating up of the electron gas by the passage of current plays only a minor role because of the increased concentration of electrons and the enhanced conductivity within the surface layer of the semiconductor. The heating of the electrons need only be taken into consideration for semiconductors with high electron mobility and for large currents. For this case the calculation confirms qualitatively the conclusion of Levitin about the presence of a second space charge region. In addition there is also the possibility of a "break" and a sharp increase of emitted current on attaining a definite anode voltage. [English translation in: Soviet Physics–Solid State (USA)].

PA 62 T.Mulvey

13584 THERMIONIC EMISSION FROM MOLYBDENUM IN VAPORS OF CESIUM AND CESIUM FLUORIDE.
R.L.Aamodt, L.J.Brown and B.D.Nichols.
J. appl. Phys. (USA), Vol. 33, No. 6, 2080-5 (June, 1962).

"S curves", similar to those given by Langmuir for electron emission from tungsten in caesium vapour, are presented for electron emission from molybdenum in caesium vapour. It is shown that the addition of caesium fluoride greatly enhances the electron emission. The minimum effective work function of the Cs–CsF–Mo surface is 1.38 ± 0.05 eV, while that of the Cs–Mo surface is 1.68 ± 0.05 eV. The new cathode may be useful in thermionic converters.

PA 162

2017 EMISSION OF "HOT" ELECTRONS FROM GERMANIUM.
Yu.K.Pozhela and V.I.Shilal'nikas.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 6, 1601-3 (June, 1962). In Russian. English translation in: Soviet Physics – Solid State (USA), Vol. 4, No. 6, 1173-4 (Dec., 1962).
For abstract see Abstr. 20017 of 1962.

PA 163

1735 EMISSION OF "HOT" ELECTRONS FROM GERMANIUM.
Yu.K.Pozhela and V.I.Shilal'nikas.
Fiz. tverdogo Tela (USSR), Vol. 4, No. 6, 1601-3 (June, 1962). In Russian. English translation in: Soviet Physics – Solid State (USA), Vol. 4, No. 6, 1173-4 (Dec., 1962).
For abstract see Abstr. 12200 of 1962.

EEA 163

1000 THE APPLICATION OF THORIUM CARBIDE TO THE THERMIONIC CONVERSION OF HEAT INTO ELECTRICAL ENERGY. N.D.Morgulis and Yu.P.Korchevoi.
Atomnaya Energiya (USSR), Vol.16, No.6, 317-19 (June, 1962). In Russian. English translation in: Reactor Sci. Technol (GB), Vol.16, 317-19 (June, 1962).

This paper is the result of studies into the production of a single component material giving an appreciable emission at temperatures of the order of 2000°K which at the same time would not have too low a work function. It was found that it was possible to achieve an efficiency of 10 to 15% and a power density of about 10 W cm^{-2} at 2000°K using a thorium carbide cathode in a caesium vapour diode.

D.Llanwyn-Jones

PA '63

23393 RECOMBINATION RADIATION EMITTED BY GALLIUM ARSENIDE. R.J.Keyes and T.M.Quist.
Proc. Inst. Radio Engrs (USA), Vol. 50, No. 8, 1822-3 (Aug., 1962).

Forward-biassed Ga arsenide diodes, made by diffusing Zn into an n-type monocrystalline wafer, were found to radiate energy at levels corresponding to the energy gap. At 77°K the conversion efficiency of injected holes to photons at 1.44 eV, assuming a quantum efficiency of unity, may be as high as 85%; radiation extending into the visible region was also observed. At 298°K two peaks were observed, one at 1.33 eV and a lesser, flatter peak at 0.95 eV. The diodes could be switched in 2 nsec, so that the emission could be modulated at 100 Mc/s. Forward-biassed diodes with high-conversion efficiencies producing emission close to the band gap act as refrigerators, because the injected holes came from the high-energy tail of the Fermi distribution.

C.Fromberg

PA '62

Ionization of Cesium at Surfaces, W.B.NOTTINGHAM. Massachusetts Inst Technology—Research Laboratory of Electronics—Tech Report 405 Aug 17 1962 p 1-12. Indications from voltage-current curves of thermionic power converters suggest increased ionization at, or very near, cesium-coated surfaces by low-energy electrons; experiments conducted to study this phenomenon quantitatively for low cesium concentration. EI '63

Energy Distribution for Electrons in Thermionic Diode Plasma Cannot be Truly Maxwellian, W.B.NOTTINGHAM. Massachusetts Inst Technology—Research Laboratory of Electronics—Tech Report 405 Aug 17 1962 p 13-28. For refractory emitters operated in energy-conversion diode, ratio of emitter temperature to cesium temperature strongly influences operating properties; if this ratio exceeds 3.2, ion-rich sheath usually forms at emitter surface; electrons are accelerated in plasma space by this injection potential; analysis shows that at open-circuit condition, energy distribution of electrons at plasma edge of emitter sheath cannot be true Maxwellian over entire range in electron energy. EI '63

AD-289 548 Div. 8
(TISTP/WH) OTS price $4.60

Hewlett-Packard Co., Palo Alto, Calif.
INVESTIGATION OF HOT ELECTRON EMITTER.
Scientific rept. no. 1, 1 June-31 Aug 62.
31 Aug 62, 1v. incl. illus. 5 refs.
(Contract AF 19(628)1637, Proj. 4608)
(AFCRL 62-772) Unclassified report

DESCRIPTORS: *Semiconductors, *Thin films, *Electrons, *Triodes, *Electrical properties, Gold, Silicon.

A theoretical and experimental study has been carried out on the characteristics of semiconductor-metal barriers. Particular emphasis was on details of mechanisms relating to the possibility of utilizing such barriers as emitters of hot electrons or hot holes for high frequency thin film triode applications. (Author)

'63

5577 (GA-3523) INVESTIGATIONS OF CARBIDES AS CATHODES FOR THERMIONIC SPACE REACTORS. Final Report, May 15, 1961 – August 31, 1962. A. F. Weinberg, R. G. Hudson, L. Yang, and F. D. Carpenter (General Atomic Div. General Dynamics Corp., San Diego, Calif.). Contract NAS 5-1253. 160p.

The physicochemical properties of mixed carbides of U and Zr were measured to determine the usefulness of these materials as nuclear-heated thermionic emitters or as the nuclear fuel for refractory-metal thermionic cells. Property measurements of other carbide systems having potential as thermionic emitters were also performed. Vapor-loss data for mixed carbides were obtained in vacuum to determine the effects of temperature, time of exposure, U : Zr ratio, and specimen density. At 1988 to 2083°K, the rate of weight loss for specimens of nominal composition 90 mol-% UC-10 mol-% ZrC can be expressed as $\log \dot{w} = 9.72 - 3.05 \times 10^4(1/T)$, where $\dot{w}$ is the rate of weight loss in mg/cm²/sec and T is the absolute temperature. At 2130 to 2400°K, the rate of weight loss for specimens with compositions ranging from 14 mol-% UC – 86 mol-% ZrC to 19 mol-% UC – 81 mol-% ZrC can be expressed as $\log \dot{w} = 8.30 - 3.03 \times 10^4(1/T)$. The introduction of a low-pressure (0.06 to 0.09 Torr) Cs-vapor environment was found to have no effect on the rate of weight loss. Studies were also conducted on the redistribution of the carbide components during long-time exposures and the relation of this redistribution to the rate of weight loss and the electron-emission characteristics. The rate of weight loss for a specimen of nominal composition 20 mol-% UC – 80 mol-% HfC was determined at 2063° ± 11°K. Vacuum electron-emission measurements were made for a series of mixed carbides of varying U : Zr ratio. It was determined that these carbides behave as dispenser cathodes whose emission is not dependent upon the bulk U content. Methods of disturbing the U-metal monolayer on the specimen surface, which is requisite to good electron emission, were studied, as were methods of "reactivating" the layer after it had been removed. Electron emission from all of the carbides attained the useful level of 5 amp/cm² at temperatures below 2000°K. In this temperature range, the materials loss from specimens of high UC content would be less than 3 mils/yr and that from specimens of low UC content less than 1 mil/yr. Materials compatibility as related to the "marriage" of reactor fuels to refractory-metal thermionic emitters was studied. Four metals — W, Mo, Nb, and Ta were studied in combination with UC, UC_2, and UZrC at 1200 to 2000°C for times up to 1000 hr. The tests showed that only two of these materials combinations are compatible at temperatures to 1800°C: W with UC (or UZrC mixtures), and Mo with UZrC mixtures of low UC content. Barrier layers of Re, W – 25 wt-% Re alloy, and ZrC were also investigated, with only ZrC proving effective for this application. To provide data for the engineering design of thermionic reactors using mixed carbides, measurements were also made of the electrical and thermal conductivities of these materials at temperatures up to reactor operating ranges. (auth)

NSA '63

20611 ACTIVATION PHENOMENA IN URANIUM-BEARING EMITTERS. G. A. Haas (Naval Research Lab., Washington, D. C.). Advan. Energy Conversion, 2: 389-90 (July-Sept. 1962).

Activation effects in the thermionic emission of various uranium compounds appear to be caused by the formation of free uranium on the surface of the emitter. (auth)

14819 (GEST-2009) THERMIONIC EMITTER MATERIAL PROPERTIES. Technical Summary Report, September 15, 1961 through September 15, 1962. L. N. Grossman, E. W. Hoyt, J. H. Ingold, A. I. Kaznoff, and M. J. Sanderson (General Electric Co. Vallecitos Atomic Lab., Pleasanton, Calif.). Oct. 15, 1962. 208p.

The thermal, mechanical, chemical, and electrical properties of uranium and thorium-bearing carbides and two rare earth hexaborides, EuB_6 and YB_6, have been studied to determine their applicability as fuel-emitter materials. The thermal shock resistance of uranium bearing carbides is inadequate to maintain the required fuel-emitter structural integrity. The thermal and electrical properties of carbide materials are superior to corresponding oxide materials and have significant uses in clad fuel-emitter concepts. The work functions of bulk carbides generally fall below that of tungsten. The work functions of rare earth hexaborides range from ~4.8 v for EuB_6 to ~2.2 v for YB_6. The vapor pressures of the rare earth borides indicate that an upper temperature of ~1400°C exists for any application involving prolonged time. Cesium compatibility tests indicate marked sensitivity of carbon-rich carbide materials to cesium attack in periods <500 hr. Boride materials appear resistant to cesium attack, which produced deterioration of the carbides. (H.G.G.)

NSA '63

2041 AN OPTICALLY LARGE-FIELD EMISSION MICROSCOPE FOR THERMIONIC RESEARCH. A.Sandor. J. Electronics and Control (GB), Vol. 13, No. 3, 231-47 (Sept., 1962).

Based on the philosophy that stationary large-field observations of emission phenomena are very suitable for promoting research in thermionic emission, a large-object and large-screen electron emission microscope of great experimental versatility was realized. In an effort to study basic physical factors it is more stimulating to work with an optically large-field and low magnification system which greatly increases the chances of finding single phenomena among a large number of discrete ones. This eliminates the need for a laborious isolation from a multitude of unilateral conditions of unpredictable characteristics such as, for instance, emission from random planes in single cystals. Worth-while phenomena may then be singled out for studies or reproduction on a model scale. With the magnetic two-stage emission microscope observations of 3 mm diameter emitter surfaces on a 530 mm diameter phosphor screen are made with a resolving power of 2000 A at moderate voltages not higher than 16 kV. Vacuum resolution is estimated to reach the practical limit of 1100 A. It is shown that a race for extreme magnifications and acceleration voltages is futile since there are basic limitations to resolving power due to the initial velocity spread of electrons, to diffraction, refraction and to surface structure. The development of the instrument is shown in detail employing concepts of applied electron-optics. Observations of several emission phenomena made so far led already to new knowledge in various branches of thermionic emission. PA 163

20621 EXPERIMENTAL STUDIES OF THE EMISSION AND DISCHARGE CHARACTERISTICS OF THE Ta-Cs SYSTEM. M. D. Gibbons (General Electric Co., Schenectady, N. Y.). Advan. Energy Conversion, 2: 527-43(July-Sept. 1962).

Emission and discharge measurements made on a Cs-Ta emitter in a tube with parallel electrode geometry and with an adjustable emitter-collector spacing are described. Emission results indicated that this particular Ta-Cs emitter surface has an emission capability greater than that reported by Taylor and Langmuir for Cs-W, while the emission maxima are shifted to lower temperatures. This increase in emission over that usually reported for Cs-Ta is believed due to a preferred orientation of the Ta surface. The large enhancement of the emission during the discharge is believed due to the lowering of the work function by the effective increase in the adsorption of Cs which is due to the increased arrival rate caused by the retarding field for ions. This mechanism is probable in the region where the surface ionization is expected. The discharge studies involve the measurement of the breakdown and maintenance potentials of the hot cathode arc discharge for various emitter-collector spacings, emitter temperatures, and Cs pressures. Corrections for the contact potential and sheath potentials are applied to the experimental data. For a pressure the order of 1 mm, and high emitter temperatures, the results indicate that the magnitude of the emitter sheath potential is close to the first resonance level of Cs. This strongly suggests a multi-step process. (auth) NSA 16:3

AD-286 700 Div. 7
(TISTP/MS) OTS price $2.60

General Atomic Div., General Dynamics Corp., San Diego, Calif.
HIGH-TEMPERATURE VAPOR-FILLED THERMIONIC CONVERTER.
Quarterly technical progress rept. 1 July-30 Sep 62,
by W. Godsin. 10 Oct 62, 14p. incl. illus. 2 refs. (Rept. no. GA-3562)
(Contract AF 33(657)8563, Proj. 8173)
Unclassified report

DESCRIPTORS: *Electric power production, *Power supplies, *Thermionic emission, Uranium compounds, Carbides, Zirconium compounds, Vacuum systems.

Cell E was operated for 1034 hours, proving the feasibility of continuous high-temperature long-term operation of carbide emitters. The output current (and power) of the cell was lower than desired due to apparent low emission from the carbide emitters used in Cell E. The reasons why the expected higher currents were not obtained in Cell E, remains the central problem under investigation. A 10 UC - 90 ZrC emitter is installed in Cell F. Thermocouple installation and calibration and high-temperature vacuum emission tests are being conducted prior to the final closure of the cell. A second cell structure is on hand and an emitter will be installed pending the results of surface preparation. Vacuum emission studies of three UC compositions--10 UC 90 ZrC, 30 UC - 70 ZrC, and 90 UC - 10 ZrC--demonstrate that emission behavior is essentially independent of bulk uranium content. The presence of some uranium on the emitting surface is of the utmost importance. Intentional poisoning of the surface of sample emitters was produced by exposure to air at room temperature. In order to maximize the probability of satisfactory performance, we have concluded that it is necessary to properly activate the emitter surface in addition to providing a clean cell environment during operation. (Author) 163

AD-296 369 Div. 8
(TISTE/OHD) OTS price $9.10

David Sarnoff Research Center, Princeton, N. J.
RESEARCH IN ELECTRON EMISSION FROM SEMICONDUCTORS.
Final rept., 1 Oct 60-30 Sep 62,
by R. E. Simon, E. K. Gatchell and others.
30 Sep 62, 99p. incl. illus. tables, refs.
(Rept. no. 16)
(Contract DA 36-039-sc-87388, Proj. 3A99-13-001-01)

Unclassified report

DESCRIPTORS: *Semiconductors, *Thermionic emission, Electron transitions, Electric fields, Cathodes, Field emission, Cesium, Silicon, Analysis, Semiconducting films, Diffusion, Solid state physics, Injection, Heat treatment, Argon, Ion bombardment, Manufacturing methods, Photoelectric effect, Measurement.

These studies of hot electron emission from semiconductors include a review of the literature on hot electron effects in semiconductors and the theoretical study of electron-electron interactions in semiconductors and metals. The requirements for a p-n junction hot electron emitter are discussed, and a method of preparation of these emitters of silicon and studies of their properties are described. An emitter with an injection contact is described but emission measurements of this device have not been made.

Attempts to clean silicon in vacuum by low temperature heating and by argon bombardment without annealing are discussed. Measurements on the interaction of cesium with silicon are reported. While it has not yet been possible to produce an emitter with optimum properties, the groundwork for such an emitter has been laid. (Author)

63

AD-286 693 Div. 8, 26
(TISTE/JBM) OTS price $2.60

Atomics International, Canoga Park, Calif.
UNIFORM WORK FUNCTION CATHODE STUDIES FOR THERMIONIC CONVERTERS.
Quarterly rept. no. 1, 12 July-12 Oct 62,
by M. N. Huberman. Oct 62, 25p. incl. illus.
4 refs.
(Contract AF 33(657)8726)

Unclassified report

DESCRIPTORS: *Thermionic emission, *Cathodes, *Generators, *Electric power production, Cesium, Diodes, Temperature, Tests, Measurement, Work functions, Manufacturing methods, Test equipment, Standardization, Materials, Molybdenum, Sodium compounds, Hydroxides, Electrodes, Vapor plating, Crystals, Growth, Pyrolysis, Molybdenum compounds, Fluorides, Chlorides, Carbides, Casting, Chemical milling, Potassium compounds, Processing.

Uniform work functions of thermionic converters were investigated. The performance of cylindrical converters which have emitters with uniform work function surface was evaluated. Chemical vapor deposition techniques were developed for the fabrication of nonplanar emitters of practical design which have improved uniformity of work function over the uniformity of work function of standard polycrystalline emitters. The development of thermionic converters having emitters of improved uniformity of work function may result in increased efficiency and power density. A converter test stand was assembled, equipment associated with the test stand was calibrated, and deposition samples were fabricated. (Author)

63

70,313 EXPERIMENTAL RESULTS ON SELECTION OF THERMIONIC CATHODES FOR REACTOR APPLICATION

Yang, L., Weinberg, A. F., Carpenter, F. D., Hudson, R. G.
(General Dynamics Corp., San Diego, Calif.)

American Rocket Society, Inc., New York, N.Y.
2550-62
(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25–28, 1962)

Two arrangements of thermionic emitters with uranium-bearing fuel elements are being investigated for application in the direct conversion of fission heat to electricity. They are (1) uranium-containing carbides which serve as both fuel element and emitter, and (2) refactory metal emitters clad around uranium-containing fuel. Both types must meet the nuclear requirements of a reactor fuel element as well as the thermionic requirements of a power converter. For carbide cathodes, material loss by vaporization and emission degradation from surface changes are the factors which determine converter life and performance. For refractory-metal-clad cathodes, the diffusion of the components of the fuel into the clad and degradation of emission from cathode surface contaminative are the critical factors. These aspects are discussed on the basis of existing experimental data.

AD-290 955 Div. 7, 8
(TISTE/OHD) OTS price $3.60

Texas Instruments, Inc., Dallas.
LOW WORK FUNCTION SEMICONDUCTOR COLLECTORS.
Summary rept. no. 1, 1 July-31 Oct 62 on Basic Research in Thermionics, Part 2,
by R. A. Chapman, H. W. Hemstreet and others.
Nov 62, 30p. incl. illus. tables, 32 refs.
(Contract Nonr-370500, Proj. NR 099-364)
Unclassified report

DESCRIPTORS: *Thermionic emission, *Work functions, *Semiconductors, Cesium compounds, Thin films, Semiconducting films, Vapor plating, Voltage, Antimony, Tellurium, Tungsten, Tantalum, Experimental data.

Cesium-antimony and, in one case, cesium-tellurium compounds as film coatings on nickel substrates were investigated for possible collectors in thermionic energy converters. The reactant metal was deposited on the substrate and later reacted with cesium. No difference was detected among antimony films evaporated in the experimental tube, evaporated before assembly, and electroplated. Film thicknesses were in the range 1000 - 10,000 A. Two types of metal-glass experimental devices were utilized. In most cases, the thermionic work function was measured by contact potential difference with an electron-emitting refractory metal. Cesium reservoir temperatures were used from 75 to 125 C. The collector temperature in most cases was not more than 15 C higher than the cesium reservoir temperature, but in one device was roughly 100 C higher. It was found: (1) the thermionic work function of the cesium-antimony coated nickel collector was in some experiments 1.5 ± 0.1 eV, (2) the thermionic work function of the cesium-tellurium coated nickel collector was consistently 1.2 ± 0.1 eV in the one experiment run with this collector; (3) more control must be obtained over film thickness and chemical purity to determine the cause of the variation in observed thermionic work function. (Author)

163

AD-295 109 Div. 17, 25
(TISTM/EJH) OTS price $4.60

Denver Research Inst., Colo.
INVESTIGATION OF THE CHARACTERISTICS OF INTERMETALLIC COMPOUNDS AS THERMIONIC EMITTERS.
Annual technical summary rept. no. 1, 1 Nov 61-31 Oct 62,
by C. B. Magee, M. J. Pool and others.
31 Dec 62, 43p. incl. illus. tables (Rept. no. DRI 2079)
(Contract Nonr-336101, Proj. NR 099-362)
Unclassified report

DESCRIPTORS: *Intermetallic compounds, *Beryllium alloys, *Zirconium alloys, *Niobium alloys, *Thermionic emission, Vaporization, Heat of sublimation, Enthalpy, Thermodynamics, Diodes, Laboratory equipment, Cesium, Vapors, Thermoelectricity, Vacuum apparatus.

Equipment was designed and fabricated for the determination of evaporation rates of intermetallic compounds by means of the Langmuir free evaporation technique. Evaporation rate data were obtained in the temperature range from 900 to 1200 C for metallic Be and for ZrBe13, NbBe12, and Nb2Be17. Assuming the evaporating species to be monatomic Be, vapor pressures were calculated from evaporation rates and Van't Hoff plots were made. The standard enthalpies of sublimation, in kilocalories per gram atom Be determined from these plots are: for Be, 79.0; for ZrBe13, 85.0; for NbBe12, 19.9 and 59.5; and for Nb2Be17, 98.0 and 55.8. That there are two enthalpies of sublimation for the Nb beryllides may be due to the existence of a heretofore unknown beryllide intermediate in Be content between Nb2Be17 and NbBe3. Possibly both NbBe12 and Nb2Be17 decompose upon evaporation to the intermediate species which decomposes to NbBe3. A high-vacuum diode for the determinating thermionic emission parameters of intermetallic compounds was designed and constructed. A second diode with improvements over the first design is being constructed.

'63

AD-296 233 Div. 25, 8
(TISTP/WH) OTS price $8.10

Texas Instruments, Inc., Dallas.
BASIC RESEARCH IN THERMIONICS. PART I. CESIUM PERMEATION THROUGH TANTALUM.
Summary rept. no. 1, 1 Nov 61-31 Oct 62,
by R. A. Chapman, D. A. Peterman and others.
Jan 63, 73p. incl. illus. tables, 28 refs.
(Contract Nonr-370500, Proj. 099-364)
Unclassified report

DESCRIPTORS: *Thermionic emission, *Tantalum, *Cesium, *Plasma physics, *Diffusion, Diodes, Crystals, Ions, Space charges, Metallic crystals.

A plasma thermionic converter concept has been proposed which uses cesium permeation through a tantalum emitter to obtain space charge neutralization of electron current from this emitter. The objective of this project was to determine if the permeation rate of cesium through tantalum was sufficiently large for feasibility of the concept. It has been shown that the concept is not feasible because the permeation rate of Cs through tantalum is too small. Cesium permeation through tantalum has been studied in the temperature range 1400 to 1800 C with cesium pressures up to 13 mm Hg. This phenomenon was investigated for potential application as a hollow, ion-dispensing emitter for a plasma thermionic converter. Three methods were used in this study: (1) measurement of ion current from a hollow, polycrystalline tantalum emitter internally connected to a cesium reservoir, (2) measurement of weight-loss from a hollow, polycrystalline tantalum container with a cesium reservoir attached, with both suspended from a microbalance into a radiant furnace, and (3) direct measurement of the diffusion coefficient in single-crystal and polycrystalline tantalum utilizing radioactive Cs-134. (Author)

'63

'445 LIMITATIONS TO RESOLVING POWER IN THE THERMIONIC EMISSION MICROSCOPE. A.Sandor.
J. Electronics and Control (GB), Vol. 13, No. 4, 295-304 (Oct.,1962).

Formulation of resolving power as a function of electron chromatism at the source only cannot account for the large deviation from practical resolution figures measured for emission microscopes, not even when best corrected lens systems and very high accelerating potentials are employed. Considering electron diffraction only as the decisive resolution limiting factor, too low a value is obtained. Hence, it appears, that the optimum practical resolution of 800 A would lie between the two functions. An approximation is given for computing the effective resolving power. It demonstrates the little influence of the field strength at the emitter surface on overall resolution. This then also implies that the use of very high first anode voltages add little only to enhance image quality. It is shown how severe the resolution degrading property of surface irregularities is as evidenced by photographs taken from a 21 in. directly viewed screen. Surface depressions, elevations and pores may lead to serious misinterpretations of the actually existing emission mechanism due to electron ray refraction by distorted equipotential planes which shape the trajectories in peculiar ways. Bunching, focusing and divergence effects are shown to influence the emission patterns on the screen, also preparing the way for a proper interpretation of observations on more difficult surfaces such as oxide cathodes or any other irregular surface. Special situations are also discussed which produce electron-optical illusions on the screen such as loss of surface detail, splitting of electron sheets, multi-helical paths and multi-circular patterns.

PN '63

36293 (DRI-2079) INVESTIGATION OF THE CHARACTERISTICS OF INTERMETALLIC COMPOUNDS AS THERMIONIC EMITTERS. First Annual Technical Summary Report, November 1, 1961 to October 31, 1962.
C. B. Magee, M. J. Pool, W. D. McMullen, R. C. Jerner, and D. G. Ellis (Denver. Univ. Denver Research Inst.). Dec. 31, 1962. Contract NONR 099-362. 43p. (AD-295109)

Equipment was designed and fabricated for the determination of evaporation rates of intermetallic compounds by means of the Langmuir free evaporation technique. Evaporation rate data were obtained in the temperature range from 900 to 1200°C for metallic Be and for $ZrBe_{13}$, $NbBe_{12}$, and Nb_2Be_{17}. Assuming the evaporating species to be monatomic Be, vapor pressures were calculated from evaporation rates and Van't Hoff plots were made. The standard enthalpies of sublimation, in kilocalories per gram atom Be determined from these plots are: for Be, 79.0; for $ZrBe_{13}$, 85.0; for $NbBe_{12}$, 19.9 and 59.5; and for Nb_2Be_{17}, 98.0 and 55.8. That there are two enthalpies of sublimation for the Nb beryllides may be due to the existence of a heretofore unknown beryllide intermediate in Be content between Nb_2Be_{17} and $NbBe_3$. Possibly both $NbBe_{12}$ and Nb_2Be_{17} decompose upon evaporation to the intermediate species which decomposes to $NbBe_3$. A high-vacuum diode for the determination of thermionic emission parameters of intermetallic compounds was designed and constructed. A second diode with improvements over the first design is being constructed. (auth) NSA '63

14663 THE ION THERMIONIC EMISSION OF METALS IN AN ATMOSPHERE OF VARIOUS GASES.
Ya.M.Fogel', L.P.Rekova and V.Ya.Kolot.
Zh. tekh. Fiz. (USSR), Vol. 32, No. 10, 1259-65 (Oct., 1962).
In Russian. English translation in: Soviet Physics-Technical Physics, (USA), Vol. 7, No. 10, 929-33 (April, 1963).

The effect of various gases (O_2, H_2, CCl_4, NH_3, air) on thermionic emission of nickel and platinum was studied. Experiments on the action of CCl_4 vapour on the surface of incandescent nickel situated in a stream of air at atmospheric pressure led to the conclusion that changes in the total thermionic emission current, after evacuation of gases which act on the emitter, are due to changes in the emission of alkali metal ions. Incandescent platinum was exposed to the above gases at a pressure of $\sim 10^{-4}$ mm Hg: simultaneous observations were made on the behaviour of the total thermionic emission current and individual components on this current, separated by a mass spectrometer. It was again found that all changes in the total thermionic emission current were due to corresponding changes in the emission of alkali metal ions. PA '63

883 HOT-ELECTRON EMISSION FROM SEMICONDUCTORS.
R.J.Hodgkinson.
Solid-State Electronics (GB), Vol. 5, 269-72 (Sept.-Oct., 1962).

Describes the emission of high-energy electrons from p-n junctions in silicon and silicon carbide. The distribution of emitting areas was studied by means of a fluorescent screen. It was proved that in silicon the emission pattern is closely related to the microplasma pattern in the junction and that electrons are emitted across the thin n-type surface layer. In silicon carbide this layer was too thick and only peripheral emission was observed. The relative merits of very shallow (100 Å) silicon junctions and of silicon carbide junctions are discussed. PA '63

7631 THERMOELECTRONIC EMISSION OF TaB_2.
T.L.Matskevich, T.V.Krachino and A.P.Kazantsev.
Radioteknika i Elektronika (USSR), Vol. 7, No. 11, 1972-3 (Nov., 1962). In Russian.
Quotes some experimental data. The method etc. is as in Abstr. 22249 of 1962 and Zh. tekh. Fiz. (USSR), Vol.32, No. 10, 1266-74 (Oct., 1962).
D.E.Brown
PA'63

422 SHALLOW DONOR THERMIONIC EMITTER.
J.K.Gorman.
J. appl. Phys. (USA), Vol.33, No.11, 3170-7 (Nov., 1962).
A possible approach to the development of a low work function thermionic emitter involves the introduction of shallow donor states into a matrix having a low electron affinity. It is the intent of this paper to explore the concept of a shallow donor emitter from both a general point of view and with specific application to barium oxide as the host lattice. The problem is discussed in terms of the single-donor model with consideration given the various characteristics which would be required for a practical matrix-additive system. Although the electron affinity of BaO has been estimated to be as low as 0.6 eV, the ordinary oxygen vacancy donor present is a deep level with an ionization energy of about 1.4 eV; it yields a work function of 1.4 to 1.5 eV at 1000°K. By comparison, a work function of 0.83 eV would be expected for shallow donor BaO at this temperature. The substitution of a tripositive rare-earth ion for a Ba^{2+} ion in the lattice is presented as a possible mechanism for the incorporation of an impurity donor centre. Some speculation is offered concerning the ionization energy of this type of donor as well as the associated activation process. An attempt was made to observe the donor behaviour of several rare-earth ion additives in BaO and also SrO by studying the temperature dependence of the effective work function. Data were secured for La, Gd, Nd, Er, and Eu in BaO, and Eu and Sm in SrO at analytical concentrations of from 0.01 to 0.05 mole %. While no lowering of the work function is reported, it is clear that no definitive interpretation of a negative result can be made until certain other experimental information becomes available, particularly the solubility and oxidation state of the additive ion in the matrix crystal.
PA 63

AD-294 507 Div. 4, 25
(TISTM/ODN) OTS price $1.60

Foreign Tech. Div., Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.
BORIDES OF TRANSITION METALS AND THEIR ELECTRON-EMISSION PROPERTIES,
by G. A. Kudintseva, B. M. Tsarev and V. A. Epel'baum. 3 Dec 62, 11p. incl. tables, 10 refs. (Trans. no. FTD-TT-62-1506 from Konferentsii Po Khimii Bora i Yego Soyedineniy, Moscow, Goskhimizdat, pp. 106-111, 1958)
Unclassified report

DESCRIPTORS: *Borides, *Metals, *Electrons, *Thermionic emission, *Secondary emission, Zirconium compounds, Chromium compounds, Titanium compounds, Vanadium compounds, Manganese compounds, Synthesis, Stability, USSR, Transition elements.

The developed method of obtaining diborides of Ti, Zr, V, Cr, Mn and other transition metals upon the combined reduction by carbon of mixtures of oxides of the corresponding metal and boron permits the production of borides in large quantities from abundant raw material. In a series of diborides of Ti, V, Cr, and Mn of small emissions, comparable with emissions of cerium hexaboride, chromium diboride is possessed, which can be used as material of thermo-cathodes. The diborides possess a coefficient of secondary emission lower than one and, consequently, can be used as antidynatron coatings. (Author)

AD-296 172 Div. 8, 14
(TISTE/OHD) OTS price $1.60

General Electric Co., Schenectady, N. Y.
INVESTIGATION OF VARIOUS ACTIVATOR REFRACTORY SUBSTRATE COMBINATIONS,
by J. H. Affleck and W. T. Boyd. 27 Dec 62, 11p. incl. illus. 18 refs. (Scientific rept. no. 4)
(Contract AF 19(628)279, Proj. 4619)
(AFCRL 63-11) Unclassified report

DESCRIPTORS: *Cathodes (Electron tubes), *Thermionic emission, *Electron tubes, Barium compounds, Work functions, Vacuum apparatus, Impurities, Test sets, Test equipment (Electronics), Refractory materials.
'63

UNCLASSIFIED

117066 THERMIONIC EMITTER MATERIALS RESEARCH PROGRAM
(Period covered: July 1-December 31, 1962)
Kitrilakis, S. S.; Rasor, N. S. & van Someren, L.
Unclassified
(TEE 4015-3)

Thermo Electron
Engineering Corp.
NOnr-3563(00)
Semi-Annual TSR

This report covers the first six month period of the second year of this contract. In the first annual report the significance of patchy emission was discussed. In the six month period that elapsed, progress has been made in systematizing this analysis. Experiments have been designed and conducted aimed at investigating and defining 'patchiness," and metallurgical techniques have been employed in an attempt to correlate the metallurgical features of emitter surfaces to their thermionic emission.

Converters, thermionic
Energy conversion

UNCLASSIFIED

AD-403 362 Div. 8, 30
(TISTE/JWS) OTS price $1.75

Ford Instrument Co., Long Island City, N. Y.
EMITTER MATERIALS STUDY THERMIONIC ENERGY CONVERTERS.
Final technical rept.
31 Dec 62, 1v.
Contract Nonr369600, Proj. NR391 429
Unclassified report

Descriptors: *Thermionic converters, *Electrodes, Oxides, Radiation damage, Structural properties, Fast neutrons, Cesium, Calcium compounds, Strontium compounds, Barium compounds.

An experimental program was conducted on selected emitter materials to determine their potential for use in low-temperature thermionic energy converters. One oxide emitter and four different dispenser types were evaluated in parallel plate and cylindrical geometry in both glass and metal ceramic construction. With respect to power density the various dispenser emitter types showed suitable and reasonably similar performance. Performance degradation was reversed in some of these diodes and its mechanism explored and explained. (Author)

'63

AD-298 838 Div. 10
(TISTM/AM) OTS price $1.60

Stanford Research Inst., Menlo Park, Calif.
THE ROLE OF ALUMINUM AND ITS OXIDES IN SOLID PROPELLANTS.
Quarterly rept. no. 2, 1 Oct-31 Dec 62,
by G. Neil Spokes. Jan 63, 9p.
(Contract AF 04(694)128, Proj. no. PAU-4134)
(SSD-TDR-63-41) Unclassified report

DESCRIPTORS: *Thermionic emission, *Aluminum compounds, *Exhaust gases, Aluminum, Theory, Analysis, Ionization, Measurement, Impurities, Radiometers, High-temperature research, Solid rocket propellants, Oxides, Particles

AD-299 245 Div. 10, 27
(TISTA/GEC) OTS price $3.60

Reaction Motors Div., Thiokol Chemical Corp., Denville, N. J.
ROCKET EXHAUST SAMPLING SYSTEM FOR TWO-PHASE EXHAUST FLOW SYSTEMS.
Final rept.,
by J. I. Schaeffer. 28 Sep 61, 30p. (Rept. no. RMD 2103-F)
(Contract AF 04(611)6351, Proj. 3850)
Unclassified report

DESCRIPTORS: *Exhaust gases, *Rocket motors (Liquid propellant), Chemical analysis, Design, Tests, Combustion, Model tests, Pentaboranes, Gas flow, Sampling, Rocket motor nozzles, Test equipment.

'63

AD-299 431 Div. 8, 17
(TISTM/RGR) OTS price $6.60

Thermo Electron Engineering Corp., Waltham, Mass.
THERMIONIC EMITTER MATERIALS RESEARCH PROGRAM.
Semi-annual technical summary rept., 1 July-31 Dec 62,
by S. S. Kitrilakis, N. S. Rasor, and L. vanSomeren. 31 Dec 62, 62p. (Rept. no. 20-63; Rept. no. TEE 4015-3)
(Contract Nonr-356300)
Unclassified report

DESCRIPTORS: *Thermionic emission, *Iridium, Temperature, Anodes, Cathodes, Surface properties, Rhenium, Tungsten, Cesium electron tubes, Crystals, Thermoelectricity, Work functions, Energy conversion.

'63

AD-400 734 Div. 25, 4, 17
(TISTM/AMS) OTS price $2.25

Allied Research Associates, Inc., Concord, Mass.
STUDY OF MATERIALS FOR THERMIONIC CONVERTERS.
Summary rept. no. 2,
by Harold Homonoff and Stanley Ruby. 31 Dec 62, 83p. (Document no. ARA-T-9159-2)
(Contract Nonr-338500)
Unclassified report

DESCRIPTORS: *Thermionic emission, Data, Experimental data, Impurities, Theory, Semiconductors, Transport properties, Surface properties, Chemisorption, Adsorption, Equations, Mathematical analysis, Work function, Cathodes, Crystal structure, Chemistry, Alkali metals, Group I elements, Group V elements, Oxides, Alkali metal compounds, Solid state physics, Coatings, Photoelectric effect, Monomolecular films, Solids, Temperature, Materials.

'63

'2015 OBSERVATION OF THERMOELECTRONS BY MEANS OF GEIGER-MÜLLER COUNTERS.
K.W.Ettinger and W.Mościcki.
Acta phys. Polon. (Poland), Vol. 22, No. 1(7), 129-32 (1962).
Preliminary investigations were made on the detection and measurement of thermionic emission currents by means of specially constructed Geiger-Müller counters. When operating in argon the work functions of W and CuNi emitters were found to be 4·1 eV and 2·9 eV respectively. These results do not agree with known published values, probably because of surface contamination. It is concluded that with improved experimental techniques this method of studying thermionic emission should prove useful in physical research.
C.Greaves
PA 63

10913 DIRECT ENERGY CONVERSION WITH AN IONIZED VAPOUR STEAM. S.Klein.
CEGB Conference on Gas Discharges and The Electricity Supply Industry, Leatherhead, 1962 (see Abstr. 3511 of 1963) p. 648-53.
Previous experiments [Abstr. 19671A of 1960; 7020A of 1961; 9519A of 1962; C.R. Acad. Sci. (France), Vol. 251, 657, 2492 (1960); Vol. 254, 1946 (1962).] have shown that it is possible to obtain an electromotive force of the order of few volts when two metallic electrodes are inserted into an ionized condensable vapour such as mercury, caesium, or water. This e.m.f. may be obtained provided that one of the electrodes is kept at a temperature lower, and the other electrode at a temperature higher, than the condensation temperature of the vapour. The colder electrode always becomes positive with respect to the warmer. These experiments seemed to indicate that the main mechanism for the appearance of this e.m.f. was associated with the thin gaseous layer which was found to surround the cold electrode. This paper describes new experiments which contribute to a better understanding of the physical properties of this gaseous layer. Within this layer the electron and ion temperature are considerably decreased, the gas density increases and condensation droplets make their appearance. The improvements in convertor performance due to these recent experimental results, are described.
EEA '63

17863 ELECTRON AND ION EMISSION FROM CERTAIN MATERIALS WITH REFERENCE TO THEIR UTILIZATION IN THERMIONIC ENERGY CONVERTERS.
B.I.Mykhailovskyi.
Ukrayin. fiz. Zh. (USSR), Vol. 7, No. 1, 75-7 (1962). In Ukrainian.
Brief note on ThO_2, ZrC and LaB_6.
PA '62

AD-413 928 Div. 14, 8
(TISTM/AM) OTS price $13.50

General Telephone and Electronics Labs. Inc., Bayside, N. Y.
STUDIES OF ELECTRON TUBE MATERIALS AND THERMIONIC EMISSION PROCESSES.
Final rept.,
by John V. Florio, A. Sandor and Robert A. Wallace. 31 Jan 63, 186p. Rept. no. TR62 704 104 204 208 23
Contract AF19 604 7286, Proj. 4619, Task 461901
AFCRL 63 194 Unclassified report

Descriptors: (*Thermionic emission, Materials), Coatings, Cathodes (Electron tubes), Nickel, Test method, Microscopy, Emissivity, Oxides, Instrumentation, Vacuum, Diffusion, Diodes, Tungsten, Impregnation, Mass spectroscopy, High temperature research, Liarium, Tables, Design, Aging (Materials), Anodes (Electron tubes), Molybdenum, Theory, Test equipment.

The thermionic emission properties of ultra-pure nickel-base oxide cathodes in a clean test diode were investigated. The effects of electrolytic activation, life-test conditions and gas ambient on thermionic emission were evaluated. The emission properties of pure nickel-base cathodes are compared with cathodes containing known impurities in the base metal or the coating and the effects of these impurities on emission are evaluated. The influence of the anode on cathode activation is shown. Measurements of the sublimation from various metal-base oxide cathodes are described. A Knudsen cell mass spectrometer system was designed and assembled for the study of high-temperature reactions between tube materials. The Knudsen cell was operated in the mass spectrometer at temperatures up to 2600 K, and the system was calibrated on the basis of published data of vapor pressure versus temperature for pure silver. (Author)

AD-296 458 Div. 8, 26
(TISTM/SJR) OTS price $3.60

Atomics International, Canoga Park, Calif.
UNIFORM WORK FUNCTION CATHODE STUDIES FOR THERMIONIC CONVERTERS.
Quarterly rept. no. 2, 12 Oct 62-12 Jan 63,
by M. N. Huberman. Jan 63, 33p. incl. illus. tables, 6 refs.
(Contract AF 33(657)8726)
Unclassified report

DESCRIPTORS: *Thermionic emission, *Cathodes, *Molybdenum, Chlorides, Fluorides, Pyrolysis, Reduction, Crystal structure, Crystal growth, X-ray diffraction analysis, Photomicrography, Metallography, Grain structures (Metallurgy), Molybdenum compounds, Mandrels, Electron microscopy, Processing, Vapor plating.

Chemical vapor deposition techniques are being studied as a possible means of producing non-planar thermionic cathodes having a high degree of uniformity of work function. Vapor deposited molybdenum coatings have been produced by chemical reduction of molybdenum hexafluoride pyrolysis of molybdenum hexacarbonyl and pyrolysis of molybdenum pentachloride. Plating conditions were varied for each process to determine the effect of plating conditions on the preferred orientations of crystallographic planes parallel to the plating surfaces. Both (100) and (111) preferred orientations have been found for the hexafluoride reductions. The pentachloride samples have strong (100) orientations. The hexacarbonyl samples apparently are not pure molybdenum and do not have the expected molybdenum diffraction pattern. (Author)

63

16768 (AGN-8075) RUBIDIUM/CESIUM EVALUATION PROGRAM. Quarterly Progress Report, October 1 through December 31, 1962. C. R. Fisher and P. Y. Achener (Aerojet-General Nucleonics, San Ramon, Calif.). Jan. 31, 1963. Contract AT(04-3)-368. 35p.

The characteristics of Rb and Cs at temperatures up to about 2000°F are being investigated. The current program includes studies of the boiling heat transfer and two-phase flow characteristics, and measurements to determine the latent heat of vaporization, density, specific heat, viscosity, thermal conductivity, and electrical resistivity of the liquid phases of these elements. Work performed during the period is summarized. Results of the error analyses are given and details concerning the operating parameters for the heat transfer and fluid flow work are included. The apparatus to be used to measure latent heat of vaporization, specific heat, and density is also described. (auth) NSA 63

AD-296 862 Div. 7, 20, 8
(TISTM/EJH) OTS price $4.60

Aerojet-General Nucleonics, San Ramon, Calif.
FEASIBILITY DETERMINATION OF A NUCLEAR THERMIONIC SPACE POWER PLANT.
Quarterly technical progress rept., 1 Nov 62-31 Jan 63.
31 Jan 63, 39p. incl. illus. (Rept. no. AN-856)
(Contract AF 33(657)8977, Proj. 8173)
Unclassified report

DESCRIPTORS: *Nuclear power plants, *Thermionic emission, *Electric power production, Heat exchangers, Liquid metals, Spacecraft, Reactor coolants, Cesium, Vapors, Materials, Manufacturing methods.

Contents:
TASK 2 - Liquid metal tubing - converter bond
General approach
Alumina coatings
Brazing studies
Conclusions
TASK 3 - Thermal transport analysis
Heat rejection
Reactor characteristics
TASK 4 - Series unit loop test
General loop configuration
Main heater
Heat sink
Surge tank
Thermionic generators

163

AD-401 666 Div. 7, 17
(TISTM/BRW) OTS price $5.60

Armour Research Foundation, Chicago, Ill.
STRESS DEPENDENT INTERACTIONS BETWEEN CESIUM AND OTHER MATERIALS.
Summary rept., 15 Feb 62-15 Feb 63.
by David W. Levinson. 22 Mar 63, 55p. incl. illus. tables, 14 refs. (Rept. no. ARF-B215-12)
(Contract Nonr-344100)
Unclassified report

DESCRIPTORS: *Thermionic converters, *Liquid metals, Alloys, Metals, Ceramic materials, Brittleness, Surface active substances, Mercury, Brass, Fracture (Mechanics), Aluminum alloy, Stainless steel, Molybdenum, Titanium, Niobium, Tantalum, Silver solders, Tungsten, Nickel, Tensile properties, Ductility, Mechanical properties, Materials, Cesium.

Metals and alloys germane to thermionic energy converter usage were screened for embrittlement by liquid cesium metal. The results of the screening evaluations are reported and techniques are described for more detailed studies of ceramics and susceptible metals. Definite reductions in tensile ductility were observed for 302 stainless steel and molybdenum. Bend ductility was lowered in the cases of unalloyed titanium, titanium-6 aluminum -4 vanadium alloy, columbium, tantalum and silver-copper eutectic solder. Some difficulty in reproducibly wetting samples was evident throughout the study. Slightly contaminating the cesium with oxygen (or water) was observed to increase cesium wettability markedly. (Author) 163

14528 THERMAL ELECTRIFICATION AND REMOVAL OF ELECTRONS BY SOLID PARTICLES IN A GAS. S.L.Soo.
Phys. of Fluids (USA), Vol. 6, No. 1, 145-6 (Jan., 1963).
Calculates the equilibrium concentration of free electrons in a hot gas containing refractory dust particles, taking account of thermionic emission by the dust. Taking a temperature of 3000°K, it is found that this emission can be expected to have a significant effect on the electron concentration. R.S.Pease
PA 163

AD-298 983 Div. 7, 8, 25
(TISTE/OHD) OTS price $9.60

Allison Div., General Motors Corp., Indianapolis, Ind.
INVESTIGATION OF THE MONOCAPILLARY THERMIONIC EMITTER AS A DUAL SOURCE OF IONS AND ELECTRONS.
Quarterly technical progress rept. no. 4, 15 Aug 62-15 Feb 63,
by D. L. Dresser and W. Laurita. 15 Feb 63,
98p. illus. (Rept. no. EDR 3207)
(Contract AF 33(616)8299, Proj. 8173)
Unclassified report

DESCRIPTORS: *Thermionic emission, Ionic current, Electron beams, Temperature, Thermoelectricity, Analysis, Plasma sheath, Analog computers, Cesium.

63

AD-299 479 Div. 25
(TISTE/CAM) OTS price $1.10

Radio Corp. of America, Lancaster, Pa.
THE DEVELOPMENT OF A LOW-WORK-FUNCTION COLLECTOR FOR THERMIONIC ENERGY CONVERTERS.
Bimonthly status rept. no. 1, 15 Dec 62-15 Feb 63,
by W. B. Hall, R. J. Hill, and J. J. O'Grady.
15 Feb 63, 7p. 3 refs.
(Contract Nonr 401200)
Unclassified report

DESCRIPTORS: *Thermionic converters, *Work functions, *Electrodes, Design, Model tests, Operation, Surface properties, Cesium, Additives, Electric potential, Electric arcs, Measurement, Energy conversion, Thermionic emission.

63

19306 INDUCED PHOTO- AND THERMO-ELECTRON EMISSION FROM Na_2CO_3. A.Scharmann and G.Seibert.
Z. Naturforsch. (Germany), Vol. 18a, No. 2, 257-8 (Feb., 1963).
In German.

It has been shown that in general the removal of water of crystallization by heating a crystal is accompanied by electron emission [Hanle, Scharmann and Seibert (Abstr. 5689 of 1963)]. The emission is increased by an order of magnitude if the crystal is previously bombarded with an electron beam (4 keV and 4×10^{15} electrons per cm^2). It is now found that the emission is further increased, about twice, if the crystal is irradiated with visible light after electron bombardment and during the heating (at 0·5°C sec^{-1}). Results are shown for $Na_2CO_3.10\ H_2O$, but the alkali halides are stated to behave similarly. The maximum emission (5×10^4 counts sec^{-1}) occurs at the same temperature (100°C) as in the dark, but the output-temperature curves are not otherwise identical. From this, and other differences in behaviour, it is concluded that the sites for electron- and photo-induced emission are not identical, the former being in the surface layer and the latter deeper in the crystal.

V.E.Cosslett
PA 63

AD-401 933 Div. 8, 14, 25
(TISTM/EJH) OTS price $9.10

General Electric Co., Schenectady, N. Y.
INVESTIGATION OF VARIOUS ACTIVATOR REFRACTORY SUBSTRATE COMBINATION.
Final rept.,

by J. H. Affleck. 5 Mar 63, 1v. incl. illus. tables, refs.
(Contract AF 19(628)279, Proj. 4619)
(AFCRL 63-69) Unclassified report

DESCRIPTORS: *Thermionic emission, *Cathodes (Electron tubes), Diodes (Electron tubes), Cesium, Refractory materials, Catalysts, Surfaces, Tungsten, Nickel, Molybdenum, Molybdenum compounds, Barium compounds, Calcium compounds, Borides, Silicides, Silicates, Aluminates, Oxides, Films.

An investigation was conducted to study thin-film activator-refractory substrate combinations for new materials capable of producing high emission density cathodes. Consideration was given to the nature of the boundary, the surface of the cathode, and vacuum in an externally dispensed system. Although a relation between the relative evaporation rate of electrons and the evaporation rate of the activator may be obtained, experimental confirmation in compliance with the basic assumptions is difficult. An empirical examination of internally dispensed systems was made to show what effect the substrate has on the thermionic properties of a dispenser cathode. A number of systems are reported which combine a barium compound with a refractory material such as tungsten, tantalum, molybdenum, or one of the carbides, borides or silicides of these same elements. It appears that the activator-substrate combination has only a secondary effect on the thermionic properties in the system examined. (Author) '63

27960 SOME CRITICAL MATERIALS PROBLEMS OF THERMIONIC CATHODE SYSTEMS FOR FISSION-HEAT CONVERSION. L. Yang, R. G. Hudson, F. D. Carpenter, and A. F. Weinberg (General Atomic Div., General Dynamics Corp., San Diego, Calif.). Advanced Energy Conversion, 3: 93-9(Jan.-Mar. 1963).

Out-pile problems associated with the two types of thermionic emitters considered for direct conversion of fission heat to electrical energy are analyzed. For the carbide-cathode systems (particularly, UC-ZrC) composed of uranium-bearing carbides to serve as the fission-heat source as well as the emitter, loss of cathode materials by vaporization at useful temperatures is the greatest obstacle. For the metal-cathode systems, interaction between the refractory-metal emitter surrounding the uranium-bearing fuel is of chief concern. The feasibility and status of the two systems are also discussed. (D.C.W.) NSA '63

27968 ANALYSES OF THE CHEMICAL REGENERATION OF SUBLIMATING THERMIONIC COMPONENTS. L. K. Tower (Lewis Research Center, Cleveland). Advanced Energy Conversion, 3: 185-98(Jan.-Mar. 1963).

The process of chemical regeneration of hot metallic surfaces, which may find application in very high temperature thermionic devices, is discussed. In the process, gaseous materials such as chlorine form compounds with the metal departing from the hot emitter surface. The metallic compounds return the metal to the emitter surface where it is redeposited. An analysis of chemical regeneration under conditions of free molecule flow (Knudsen conditions) in which particles are assumed not to interact in the interspace is presented. Partial or complete equilibration is assumed at the walls, the degree of equilibration being expressed by a recombination coefficient, γ. The analysis prescribes conditions within the system required to prevent destruction of the surfaces. A simplification of the analysis yields a thermodynamic criterion for selection of materials to be tested in regenerative systems. Hypothetical systems considered as examples are: W-Cl, Mo-Cl, W-Mo-Cl, and W-O. The possible difficulty in constructing a stable device with an emitter and collector of the same material is discussed, together with a solution to the problem. (auth) NSA '63

27969 URANIUM CARBIDE AS A THERMIONIC EMITTER. A. D. Elcombe and D. A. Wright (Univ. of Durham, Eng.). Advanced Energy Conversion, 3: 199-202 (Jan.-Mar. 1963).

The properties of uranium carbide as a thermionic emitter were studied in vacuum diodes. The cathodes were tantalum strips coated with a layer of uranium carbide about $^1/_{10}$ mm thick. The carbide contained excess carbon and was applied to the strip over a thin sintered layer of tungsten powder, which was used to improve adhesion. Water cooled copper anodes were employed. Richardson plot analysis showed that the initial properties were characterized by a work function ϕ of 3.9 ev, and an A value of 20,000. Activation occurred during operation at 2000°K for about 50 hr, leading to a peak performance represented by $\phi = 3.3$ ev, A = 200. After operation at 2000°K for 180 hr drawing 1 A/cm^2, the emission fell to half this value, leading to a state with $\phi = 4.6$ ev, A greater than 10^5. It is probable therefore that there is little if any uranium carbide remaining on the cathode at this stage. Further analysis of the Richardson plots showed temperature-hysteresis effects. With the coating in its early stages of activation the behavior resembles that of various complex cathodes, and suggests the presence of an adsorbed layer on the surface, which lowers the work function, the coverage of this layer depending on diffusion from within the coating and evaporation from it. Different states can therefore be "frozen in" at low temperatures depending on the treatment at higher temperatures. It is possible that this effect is due to dissociation, the diffusing active material being free uranium. In the highwork function states there is evidence of high coating resistance. Such effects could explain both the hysteresis and the high Richardson plot A values, since internal concentration and surface coverage could both be temperature dependent, causing a temperature dependence of the work function. (auth) NSA '63

27961 INTERDIFFUSION BETWEEN URANIUM-BEARING REACTOR FUELS AND REFRACTORY-METAL THERMIONIC EMITTERS. A. F. Weinberg and L. Yang (General Atomic Div., General Dynamics Corp., San Diego, Calif.). Advanced Energy Conversion, 3: 101-11(Jan.-Mar. 1963).

Material compatibility as related to the "marriage" of reactor fuels to refractory metal thermionic emitters is under investigation. Four fuel materials, UC, UC_2, UC-ZrC, and UO_2, are studied in combination with W, Mo, Ta, and Nb over the temperature range 1200 to 2000°C. A technique was developed for simultaneously studying the interdiffusion between a given uranium-bearing material and each of the four refractory metals. UC in contact with Nb and Ta at 1875° ± 20°C and 1925 ± 30°C, respectively, reacted to form a liquid phase identified as almost pure uranium metal. Mo also reacted with UC at 1800 ± 20°C, while at the same temperature W appeared relatively unaffected. However, after being contacted with UC at 2000° ± 20°C for 30 hr, W exhibited a mild reaction. The reaction mechanism for all of these metals appears to be UC + M = MC + U. Formation of this liquid phase was suppressed at 1800°C when UC-UC_2 mixtures were substituted for the UC. The kinetics of uniform metal carbide layer formation were studied for UC-UC_2 mixtures in contact with the four refractory metals at 1800°C. In addition to the uniform carbide layers formed, severe carbide penetration of the grain boundaries was observed in Nb, Ta, and Mo. Investigation of the interaction between UZrC (6.0 mole % U; 45.8 mole % Zr; 48.2 mole % C) and the same four refractory metals at 1800°C for 50 hr showed that the stabilization of the carbide phase by the addition of Zr dramatically improves the diffusion characteristics. Electron micro-probe analyses of these diffusion couples were made and the results are discussed. Preliminary investigations of UO_2-refractory metal compatibility were completed for three temperatures: 1200, 1800, and 2000°C. Indications of transport of one or more of the fuel components through grain boundaries were observed. (auth) NSA '63

27962 THE DEVELOPMENT OF EMITTER MATERIALS FOR USE IN THE NOBLE GAS PLASMA DIODE. R. F. Hill (General Motors Corp., Warren, Mich.) and D. L. Keller. Advanced Energy Conversion, 3: 113-21(Jan.-Mar. 1963).

The operating characteristics of the noble gas plasma diode thermionic converter require that the emitter contain a high surface concentration of enriched uranium. The emitter materials were limited to uranium carbide of both the ceramic and cermet systems. The ceramic materials investigated were pure UC and the mixed carbide UC-ZrC. The cermet materials investigated were UC-Nb, UC-Mo, UC-W, and UC-Re. The chemical reactivity between the uranium carbide and the metal in the four cermet systems varied quite markedly; the UC-Re system appearing to be the most stable one at 2000°K. A reference emitter material composed of 80 v/o UC-20 v/o Re was selected. The emitter discs were fabricated by the gas pressure bonding process. This process can be utilized to densify the core and simultaneously clad and bond the core into an integral assembly in a one-step operation. Results of the fabrication studies as well as some thermodynamic considerations for the cermet systems are presented. (auth) NSA '63

27976 THERMIONIC PROPERTIES OF UC, UC-ZrC AND Ta. K. F. Bainton (Atomic Energy Research Establishment, Harwell, Berks, Eng.). Advanced Energy Conversion, 3: 273-7(Jan.-Mar. 1963).

Using planar diode geometry and long pulse measuring techniques, a study was made of thermionic emission from samples of UC, UC-ZrC and Ta. Richardson constants deduced for UC (A 55.5 ϕ 3.11) and Ta (A 47.1 ϕ 4.12) are in fair agreement with values obtained by other investigators. The emission from a UC-ZrC solid solution (A 0.44 ϕ 2.69) was less than that previously reported. (auth) NSA '63

27966 PHYSICOCHEMICAL PROPERTIES OF BORIDE THERMIONIC CATHODE MATERIALS. A. I. Kaznoff, E. W. Hoyt, and L. N. Grossman (General Electric Co., Pleasanton, Calif.). Advanced Energy Conversion, 3: 167-73(Jan.-Mar. 1963).

Lanthanide hexaborides have been shown to cover a wide range of thermionic work functions. This range covers the span of 2.2 to 4.9 ev. The materials problems encountered in working with these emitter materials are discussed. The materials studied were YB_6 and EuB_6, the first having the lowest reported work function of the hexaborides (2.2 ev), the second having the highest work function (4.9 ev). The following topics are discussed: synthesis of the hexaborides, fabrication of the hexaborides, bonding of the hexaborides to refractory metal substrates, sublimation behavior at high temperatures and decomposition products, and compatibility of the hexaborides with cesium. Physicochemical properties of YB_6 and EuB_6 are also summarized. (auth) NSA '63

27977 THERMIONIC EMISSION FROM ZIRCONIUM CARBIDE WITH CAESIUM VAPOUR PRESENT. J. Myatt (Atomic Energy Research Establishment, Harwell, Berks, Eng.). Advanced Energy Conversion, 3: 279-85(Jan.-Mar. 1963).

Measurements of electron emission from ZrC, both under high vacuum conditions and in an atmosphere of cesium vapor, are presented. Under vacuum conditions the following emission constants were determined: $A = 3.03 \times 10^4$ $A/cm^2\ °K^2$ and $\phi = 4.48$ ev. Cesium was found to increase this emission by a factor of 10^4 at low emitter temperatures. Langmuir type S curves were observed, but even at the highest temperatures reached (1920°K) the emission was still a factor of 8-10 times greater than from the clean ZrC. (auth) NSA '63

27978 STUDY OF THERMOEMISSIVE PROPERTIES OF URANIUM CARBIDES BY AN EMISSION ELECTRON MICROSCOPE. B. Devin, G. Gayte, L. Koch, and L. Sondaar (CEN, Saclay, France). Advanced Energy Conversion, 3: 287-94(Jan.-Mar. 1963).

The image of the electron emission of uranium carbide is obtained in an experimental microscope in which the object to be studied is heated to emission temperature by electron bombardment. The tests were performed on disks obtained by sintering or by fusion. The difference of emission between the various elementary crystals depends upon the crystalline orientation of the face considered. It is possible to measure the difference between the work functions and to relate this to the orientation of the surface plane. The method enables one to see the influence of surface impurities (e.g.: O_2, UO_2) and to observe the evolution of grains boundaries during heating. (auth) NSA 63

36536 MATERIALS REQUIREMENTS FOR THERMIONIC ENERGY CONVERSION. R. C. Allen and C. H. Skeen (Atomics International, Canoga Park, Calif.). 41p. (CONF-59-2)

From American Society for Metals, Western Metal Congress, Los Angeles, Mar. 1963.

The fundamentals of the thermionic energy conversion and its potential applications are reviewed. Materials problems associated with thermionic emitters are considered in relation to the following: work function; emissivity; vaporization; thermal, mechanical, and electrical properties; chemical stability; permeation; and stability under nuclear radiation. Cesium purity and materials suitable for collectors, electrical leads, support structures, insulators, and seals are also discussed. Experimental work on problems involved is reviewed. It is concluded that significant developments have occurred recently in all areas of thermionic energy conversion. (40 references) (A.G.W.) NSA 63

27979 SPECTRAL EMISSIVITIES OF ELECTRODE MATERIALS. J. R. Branstetter (Lewis Research Center, Cleveland). Advanced Energy Conversion, 3: 295-303 (Jan.-Mar. 1963).

Many of the high temperature metals and carbides being considered as electrodes in thermionic convertors possess spectral emissivities that are sensitive to both wavelength and temperature. For these materials the gray-body procedure for computing the net radiant heat exchange can yield results considerably different from those obtained by the more exact method of summing the monochromatic heat flux over several hundred increments of wavelength. For tungsten, the flux obtained by summation has been shown to be as much as 23 per cent greater than the gray-body flux when both computational procedures were based on the same emissivity data. Current progress towards obtaining spectral emissivity data on other materials (such as tantalum) is discussed along with the amount of emissivity data required for any given material in order to calculate summed net heat flows having good accuracy and the extent to which simple equations can be made to fit these heat flow data. The analytical procedure used by the NASA data-reduction center to compute net heat flux for particular geometries is mentioned. Emphasis is placed on how the procedure can be applied to a variety of geometries and materials. (auth)

AD-402 697 Div. 8, 26
(TISTE/JWS) OTS price $2.60

Autonetics, Downey, Calif.
UNIFORM WORK FUNCTION CATHODE STUDIES FOR THERMIONIC CONVERTERS.
Quarterly rept. no. 3, 12 Jan-12 Apr 63,
by M. N. Huberman and R. A. Mohr. Apr 63, 29p.
Contract AF33 657 8726
Unclassified report

Descriptors: *Thermionic converters, *Cathodes (Electron tubes), Analysis, Tests, Microstructure, Vapor plating, X-ray absorption analysis, Surface properties, Crystal structure, Molybdenum, Electron microscopy, Manufacturing methods.

X-ray analysis of vapor deposited molybdenum shows that either (111) or (100) preferred orientations can be obtained. Further work indicates that precise control of impurities is needed before reproducible results can be obtained. Cathodes having (111) orientations were produced using vapor deposition techniques. Methods of polishing cathode surfaces were studied. X-ray studies show that heat treatment is adequate to restore the preferred orientation at a mechanically polished surface. The reproducibility of performance of test diodes was established by comparison of current data with data from previous work. Construction of an emission electron microscope for cathode work function distribution studies is in progress. Preliminary work has been done with electron mirror microscope. (Author) 63

24331 EMISSION OF HOT ELECTRONS FROM GERMANIUM. Yu.K.Pozhela and V.I.Shilai'nikas.
Fiz. tverdogo Tela (USSR), Vol. 5, No. 3, 730-3 (March, 1963).
In Russian. English translation in: Soviet Physics – Solid State (USA), Vol. 5, No. 3, 532-5 (Sept., 1963).

A study was made of emission of hot electrons from germanium treated in caesium vapour and placed in a strong electric field. The dependence of the emission current and the semiconductor's resistivity change on the field intensity were investigated. Emission of hot electrons from germanium covered with a BaO film was observed. PA 63

AD-402 639 Div. 7, 25
(TISTE/JBM) OTS price $1.10

Radio Corp. of America, Lancaster, Pa.
THE DEVELOPMENT OF A LOW-WORK-FUNCTION COLLECTOR FOR THERMIONIC ENERGY CONVERTERS.
Bi-monthly status rept. no. 2, 15 Feb 63-15 Apr 63,
by W. B. Hall, R. J. Hill and J. J. O'Grady.
26 Apr 63, 4p.
Contract Nonr4012 00

Unclassified report

Descriptors: *Thermionic converters, *Electrodes, *Work functions, Cesium, Design, High temperature research, Aging (Materials), Electron bombardment, Heating, Rhenium, Ceramic materials, Tungsten, Niobium, Nickel, Molybdenum, Stainless steel, Tantalum, Iridium, Purification, Electric arcs, Thermionic emission.

Research was continued on the development of a low-work-function collector for thermionic converters operating in the ''Ball-of-Fire'' mode of the low-voltage arc. Changes in work function will be determined by comparative measurement in actual operation of converters under identically controlled conditions. Three approaches will be investigated: (1) the development of a material or surface which, when partially coated with cesium, gives a low-work-function, (2) the development of a low-work-function surface which is kept free of cesium, and (3) the addition of gas additives which, in conjunction with cesium on the base material, produces a low-work-function. (Author)

'63

AD-404 255 Div. 7
(TISTE/JWS) OTS price $2.60

General Electric, Schenectady, N. Y.
THERMIONIC CONVERTER SURFACE CONDITIONS.
Quarterly technical progress rept. no. 1, 15 Feb-30 Apr 63,
by V. C. Wilson and J. Lawrence. 30 Apr 63, 12p.
Contract AF33 657 10132, Proj. 8173, Task 817305 27

Unclassified report

Descriptors: *Thermionic converters, Molybdenum, Niobium compounds, Carbides, Tungsten, Tests, Temperature, Anodes, Cathodes, Surface properties, Cesium.

A short review of the program of work is given. A parallel-plane cesium converter having an emitter of niobium carbide and a collector of molybdenum was operated. Comparison is made between its operation and that of a similar converter having a cathode of polycrystalline tungsten. The power output of the niobium-carbide converter is considerably lower than with tungsten. (Author)

'63

12235 THERMIONIC EMISSION FROM DISPENSER CATHODES. H.Ahmed and A.H.W.Beck.
J. appl. Phys. (USA), Vol. 34, No. 4 (I), 997-8 (April, 1963).

Dispenser cathodes were studied in the scanning electron microscope with resolution better than 250 A. After activation, the cathodes had a layer of 1-5 μ thickness formed on their surfaces. Drawing current then produces a characteristic surface rearrangement or microstructure. Photographic evidence of these effects is given.

A.H.W.Beck

UA 163

19304 LASER BEAM INDUCED ELECTRON EMISSION. D.Lichtman and J.F.Ready.
Phys. Rev. Letters (USA), Vol. 10, No. 8, 342-5 (April 15, 1963).

Sharp pulses of thermionic electron emission from carbon and tungsten targets were observed when the targets were illuminated with the focused output from a ruby or neodymium laser. Each pulse lasted between 0·1 and 1 microsecond and its magnitude was about 50 microamperes. The current density from the target surface was hundreds of A cm^{-2}, and can adequately be explained by the heating of the target surface during the pulse, the rate of temperature rise being about 10^{10} deg K sec^{-1}.

J.H.Sanders

PA '63

33393 MATERIALS PROBLEMS ASSOCIATED WITH THE DESIGN OF RADIATORS FOR SPACE POWERPLANTS. James H. Diedrich (Lewis Research Center, Cleveland). 20p. (CONF-94-4)

From American Nuclear Society Meeting, Nuclear Materials for Space Application, Cincinnati, Apr. 1963.

The Rankine cycle turbogenerator and thermionic emitter (both employing a nuclear energy source) have the greatest potential for producing a minimum weight system (~10 to 20 lb per electric kw output), but for both large amounts of waste heat must be rejected in space by radiation. Environmental factors and design considerations that will influence the materials selection for the radiator are discussed. Parameters that reflect minimum weight and meteorite penetration resistance are used to evaluate several candidate materials for a tubular-fluid radiator. The results indicate that beryllium and pyrolytic graphite will be best, but preliminary hypervelocity impact tests indicate a need for further development work on beryllium. (D.L.C.) M 163

117170 THERMAL ELECTRIFICATION AND IONIZATION OF SOLID PARTICLES
Soo, S. L.
April 1963
Virginia, Univ. of
School of Engineering &
Applied Science
Aerospace Engineering Dept.
Nonr 3623(00)
TR

Unclassified
(TR-ILL-10-P)
(Projects: Squid)

Distribution of an electron cloud around a solid particle charged by thermal electrification was studied. It was shown that most of the electron emitted by thermionic emission are bounded by the charge of the solid particle. Ionization of this system can be produced by an electromagnetic field or scattering by gas molecules.

36535 THERMIONIC EMISSION ENHANCEMENT FROM CESIUM COATED RHENIUM IN ELECTRIC FIELDS.
J. G. de Steese and R. J. Zollweg (Westinghouse Research Labs., Pittsburgh). 9p. (CONF-68-2)
From Electrochemical Society, Pittsburgh, Apr. 1963.
The plasma-anode technique was used to observe anomalously high thermionic emission from a rhenium surface with small cesium coverage, where the work function of the composite surface is greater than the ionization potential of cesium. Data suggest that emission enhancement is caused by increased cesium coverage because of cesium-ion trapping near the emitter surface under the influence of an ion-rich sheath. (auth)
NSA'63

AD-405 695 Div. 8, 25
(TISTP/MH) OTS price $1.60

Foreign Tech Div., Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.
STUDY OF THERMAL ELECTRON EMISSION FROM A HOLLOW CATHODE,
by M. B. Pyt'yeva and Ye. M. Dubinina. 13 May 63, 13p.
FTD TT63 367
Unclassified report

Trans. from Russian periodical, Izvestiya akademii nauk SSSR, Seriya fizicheskaya, 26:11. pp. 1343-1348, 1962.

Descriptors: *Thermionic emission, Oxide cathodes, Emissivity, Electric currents, Density, Electric potential, Structures, Magnetic fields, Electron tubes, Electron beams, Anodes, Cathodes.

The great interest in hollow oxide cathodes has been brought on by the considerable current densities of cathode emission, by the low voltages at which they may be obtained, as well as by the small effective dimensions of the electron source and the insensitivity of the cathode to ionic bombardment. However, the mechanism of its emission has not yet been sufficiently studied; visual investigation of the structure of the beam formed by a system with a hollow cathode attests to its complexity. An attempt was made to explain current anomalies of the cathode on the basis of the structural characteristics of the beam. (Author)
'63

AD-408 972 Div. 7, 25
(TISTM/BRW) OTS price $9.10

Allison Div., General Motors Corp., Indianapolis, Ind.
INVESTIGATION OF THE MONOCAPILLARY THERMIONIC EMITTER AS A DUAL SOURCE OF IONS AND ELECTRONS.
Quarterly technical progress rept. no. 5, 15 Feb-15 May 63,
by D. L. Dresser, J. D. Dunlop and R. T. Schneider.
15 June 63, 1v. EDR 3390
Contract AF33 616 8299, Proj. 8173, Task 817305
Unclassified report

Descriptors: (*Thermionic converters, Experimental data), (*Tungsten, Thermionic emission), Thermoelectricity, Plasma sheath, Ionic current, Ion sources, Temperature, Impurities, Electrical properties, Electric currents, Electric potential, Tantalum, Cooling, Test equipment (Electronics), Cesium, Electric arcs, Spectroscopy, Theory, Porous metals, Cathodes, Electrons.

Experimental data is reported on a multicapillary converter, Converter G, which was operated for over 300 hours. Data included (1) current-voltage characteristics for the temperature range from 1800 to 2100 K, (2) high frequency oscillations, (3) ion current measurements, and (4) spectroscopic data. The data in the temperature range from 1800 to 2100 K agree with the random current model of the capillary emitter; at 2000 and 2100 K the data indicate several competitive advantages over conventional converters, including wider electrode spacings, higher converter voltage, and lower cesium bath temperature. The high frequency oscillation data show that the peak current-voltage points form an arc mode characteristic. The ion currents at high collector temperature appear to be due to cesium atoms evaporating from the collector and impinging on the emitter surface. Spectrographic data indicate elevated electron temperatures in the arc mode. When high frequency oscillations are present in the passive mode, the line intensities of lower energy excited states are increased. (Author)
'63

27989 GRAPHICAL METHOD FOR OPTIMIZATION OF CESIUM-SURFACE IONIZER MATERIALS. G. Kuskevics (Electro-Optical Systems, Inc., Pasadena, Calif.). AIAA (Am. Inst. Aeron. Astronaut.) J., 1: 1455-8 (June 1963).

A graphical method is proposed for the optimization of cesium ionizer material, structure, and operating point. Proper selection of the ionizer material, its structure and work function, and the design point optimizes the propellant-utilization efficiency, power efficiency, and, to some extent, life of the cesium-ion engine. The method is illustrated by optimization of the design point for a solid tungsten ionizer using exponential and linearized plots and by selection of optimum material based on preliminary experimental critical temperature curves and theoretical neutral fraction curves. (auth)

NSA '63

19305 LASER-INDUCED THERMIONIC EMISSION. C.M.Verber and A.H.Adelman. Appl. Phys. Letters (USA), Vol. 2, No. 11, 220-2 (June 1, 1963).

The interaction of laser beams with a heated thoriated tungsten filament was investigated using a ruby laser and an optically accessible vacuum diode. An electron emission signal was obtained, which consisted of an initial peak and a slowly rising long signal. A theoretical interpretation indicates that this long signal is in fact thermionic emission. Attempts are now being made to bring the theoretical and experimental values of the laser-induced temperature rise into closer agreement. C.Greaves

PA 63

19307 INVESTIGATION OF THE PROPERTIES OF THORIATED TUNGSTEN CATHODES AT HIGH EMISSION CURRENTS. H.J.Booss and W.Seiffarth. Z. angew Phys. (Germany), Vol. 15, No. 6, 505-9 (June, 1963). In German.

When large currents are drawn from electronic valves containing thoriated tungsten cathodes the electron emission frequently falls off. A method is developed for investigating the influence of the cathode materials on this behaviour. An impulse method is used to measure the saturated emission in a test diode while a large current is actually being drawn. The initial results indicate several essential differences in the various commercially available materials examined. C.Greaves

PA 63

37532 THERMIONIC PROPERTIES OF SOME REFRACTORY METAL CARBIDES. J. H. Ingold (General Electric Co., Pleasanton, Calif.). J. Appl. Phys., 34: 2033-9 (July 1963).

The low-field thermionic emission properties of vacuum hot-pressed samples of MoC, $Ta_{0.8}Zr_{0.2}C$, TiC, HfC, TaC, and ZrC in polycrystalline bulk form were measured over the temperature range 1300 to 1900°K. The samples were well characterized by metallographic examinations and x-ray diffraction analyses. A correlation between microstructure and thermionic emission was observed. The MoC sample was found to be the most copious electron emitter, while the ZrC sample, which was carbon deficient, had the smallest electron emission over the temperature range investigated. (auth)

NSA '63

16974 THERMIONIC PROPERTIES OF SOME REFRACTORY METAL CARBIDES. J.H.Ingold. J. appl. Phys. (USA), Vol. 34, No. 7, 2033-9 (July, 1963).

The low-field thermionic emission properties of vacuum hot-pressed samples of MoC, $Ta_{0.8}Zr_{0.2}C$, TiC, HfC, TaC, and ZrC in polycrystalline bulk form were measured over the temperature range 1300° to 1900°K. The samples were well characterized by metallographic examinations and X-ray diffraction analyses. A correlation between microstructure and thermionic emission was observed. The MoC sample was found to be the most copious electron emitter, while the ZrC sample, which was carbon deficient, had the smallest electron emission over the temperature range investigated.

PA 63

AD-409 015 Div. 7, 14, 20
(TISTM/BRW) OTS price $7.60

General Motors Research Labs., Warren, Mich.
DEVELOPMENT OF BARIUM OXIDE-URANIUM OXIDE-TUNGSTEN AND BARIUM OXIDE-URANIUM OXIDE-RHENIUM EMITTERS FOR USE IN NUCLEAR HEATED THERMIONIC CONVERTERS.
Annual rept.
1 July 63, 70p.
Contract Nonr387000

Unclassified report

Descriptors: (*Thermionic converters, Materials), (*Materials, Thermionic emission), (*Cermets, Preparation), Barium compounds, Uranium compounds, Oxides, Tungsten, Rhenium, Electrons, Emissivity, Porous metals, Impregnation, Evaporation, X-ray diffraction analysis, Thermochemistry.

The results of experimental and theoretical investigations that were conducted on various BaO-UO2 emitter materials are presented. X-ray analysis, evaporation rate studies, thermochemical calculations, electron emission studies and thermionic emission microscope examinations are discussed in detail. The results indicate that emitters contining 60 mol-% and 40 mol-% UO2 dispersed in a matrix of either tungsten or rhenium are comparable to the commercial dispenser type emitters that employ tribarium aluminate impregnated in tungsten. The use of UO2 in the emitter materials produced an emitter with a self contained heat source when operated in a nuclear environment.

'63

19303 CRYSTAL PHASES OF NICKEL AS RELATED TO ADHESION OF THERMIONIC COATINGS AND TO EMISSION PHENOMENA. A.Sandor.
J. Electronics and Control (GB), Vol. 15, No. 1, 1-19 (July, 1963).
For conventional oxide cathodes the possibility of forming microseparations between the nickel base and the coating during the activation phase is demonstrated in a large-screen thermionic emission microscope. When using work-hardened nickel shearing forces necessarily occurring during recrystallization owing to crystal growth and grain boundary expansion must lead to disruption of the base-to-coating contact. Severe limitations to emission current by increased resistance, next to interface resistance, are imminent. A preventive measure of pre-heating all cathode sleeves at 1200°C is recommended. Artificial activation of the polycrystalline nickel base by a thin-film barium layer leads to the qualitative observation of anomalous emission phenomena as caused by the anisotropy of different crystal planes. Emission reversal with decreasing temperature, crystal memory shapes, preferential etchability of higher work function planes, recovery after apparent barium exhaustion and after hot oxygen poisoning are among the observations. Theoretical efforts for reconciling apparent contradictions seem essential since thin-film activation appears to be the ultimate mechanism of electron emission in any thermionic cathode structure.

PA '63

21857 LASER-INDUCED THERMIONIC EMISSION.
F.Giori, L.A.MacKenzie and E.J.McKinney.
Appl. Phys. Letters (USA), Vol. 3, No. 2, 25-7 (July 15, 1963).
Describes an experimental study of the electron emission characteristics of a tungsten cathode when its surface was impulse-heated with a sharply focused laser light beam. Time-correlation traces of emission current and laser output are given; the relation between the two gives a perfect correspondence of occurrence of laser output peaks and jumps in the emission current, but the actual intensities are not well correlated, and emission peaks appear sometimes to occur just before laser peaks. J.Hawgood

PA '63

21856 WORK FUNCTION AND THERMAL DESORPTION IN THE SYSTEM THORIUM-ON-RHENIUM.

J.Anderson, W.E.Danforth and A.J.Williams, III.

J. appl. Phys. (USA), Vol. 34, No. 8, 2260-5 (Aug., 1963).

This investigation consists of two different but related parts. (1). The thermionic properties of rhenium and rhenium with an adsorbed layer of thorium atoms, were investigated. The Richardson constants for rhenium were found to be $\varphi = 4{\cdot}85$ eV, $A = 66$ A $cm^{-2}deg^{-2}$. The work function decreases with increasing thorium coverage σ to a minimum of 3·15 eV at $\sigma = 4{\cdot}2 \times 10^{14}$ atoms per sq cm then rises to a constant value of 3·3 eV at $\sigma = 8 \times 10^{14}$ atoms per sq cm. A comparison with the system tungsten-thorium shows that: (a) φ_{min} occurs at the same surface density in both cases, (b) φ_{const} is attained at the same surface density in both cases, and this density is that of the atoms in a (100) plane of thorium metal, and (c) the values of φ_{const} are equal and different from that of bulk thorium by only 0·1 eV. On the basis of these regularities a model is proposed to explain the variation of φ with σ. (2). The thermal desorption of the adsorbed atoms was studied at temperatures between 2203° and 2468°K. At low coverage the desorption rate per atom n_0, was found to be constant with coverage, and to obey the relation $n_0 = CT \exp(-\epsilon/kT)$ with $C = 4 \times 10^{10}$ sec^{-1} deg^{-1} and $\epsilon = 8{\cdot}30$ eV. The desorption rate increased for coverages between 0·05 and 0·5 monolayer and this increase agreed well with the predictions of a theory based on interactions among the adsorbed atoms.

PA 63

21859 THEORY AND EXPERIMENT ON THERMIONIC EMISSION FROM BARIUM-COATED ALLOYED NICKEL. I.

A.Sandor.

J. Electronics and Control (GB), Vol. 15, No. 2, 101-10 (Aug., 1963).

Efforts were mainly directed toward the conception of a theoretical basis which would permit reconciliation of all the phenomena observed so far during investigations on barium-coated polycrystalline nickel in a large-screen thermionic emission microscope. It was felt that any further planning on experimental methods for further research would be sensible only if a solid concept, explaining all effects in a unified manner, could be established. A comprehensive, although largely qualitative theory was developed which filled the existing gaps. Topics which were reconciled by this theory are: (1) Distortion of nickel crystal planes during recrystallization. (2) Uniformity of emission density on each crystal face. (3) Preferential etchability of crystal faces showing increased emission. (4) Crystal faces undergoing emission reversal with temperature develop an emissive dot pattern. (5) Emission reversal from a few crystal planes only. (6) Contrast anomaly with temperature. (7) Emission recovery after hot oxygen poisoning by vacuum heating. (8) Reactivation of the nickel/barium emitter when exposed to oxygen in the cold state. In order to verify the general validity of the theory developed here, suitable measurements were performed on the phosphor screen by checking local brightness values which are proportional to emission current densities.

PA 63

21860 THEORY AND EXPERIMENT ON THERMIONIC EMISSION FROM BARIUM-COATED ALLOYED NICKEL. II. A.Sandor.

J. Electronics and Control (GB), Vol. 15, No. 2, 111-29 (Aug., 1963).

The research goals set forth in Pt I (see preceding abstract) were pursued further with emphasis on investigations on the emission reversal phenomenon and its reversibility as manifested on certain barium-coated nickel crystal planes and as viewed, quantitatively recorded and interpreted from the phosphorescent pattern of the 21 in. large-screen thermionic emission microscope. Differential packing densities of nickel atoms in different crystal planes, exhibiting various degrees of adhesion and chemisorptive properties, hold impurities of different concentration levels which determine the anisotropic work function conditions on nickel crystal faces. Their shifting to the surface by thermal diffusion and evaporation depletes the bulk to yield to a purified nickel, the crystal faces of which do not exhibit any significant work function differences. Ionization in the barium contact layer also varies with this concentration and determines the rate of holding forces which work against or in favour of early evaporation of barium. Contrast anomaly in the image and emission recovery by hot and cold oxygen infusion also finds an explanation by the autoionization concept.

PA 63

21858 TEMPERATURE TRANSIENTS IN OXIDE-COATED CATHODES DURING PULSED OPERATION.

D.A.Campbell and W.G.Shepherd.

J. appl. Phys. (USA), Vol. 34, No. 8, 2473-82 (Aug., 1963).

Experimental results presented demonstrate that transient changes in the thermionic emission of oxide-coated cathodes which occur during heavy pulse current drain depend upon the anode material and its past history. When an anode is used which has not been suitably processed a decay characterized by a 100 μsec time constant occurs similar to that described by Sproull (1945), and by Matheson and Nergaard (1952). When a Ti anode which has been suitably processed is used the emission decay no longer occurs and contrariwise an emission enhancement is observed. An experimental study of the emission enhancement leads to the postulate that the effect is a consequence of a temperature increase at the emitting surface. A solution to the heat equation subject to boundary conditions appropriate to an oxide-coated cathode during pulsed current drain is obtained taking into account the Joule heating ($J^2\rho$), emission cooling ($J\chi$), and radiation at the emitting surface. The analysis shows that for active cathodes significant temperature changes can develop at the surface of the oxide coating during single pulses of microseconds duration. The temperature changes inferred from experimental results presented are in agreement with the predictions of the theory. A numerical solution appropriate for conditions during temperature limited current drain is obtained for the nonlinear heat equation which shows that a thermal instability can develop in active cathodes passing high current densities. It is proposed that this thermal instability can account for the phenomenon of cathode sparking. PA63

24335 EFFECT OF DAUGHTER Rb^{85} ON THE CHARACTERISTICS OF A THERMIONIC DIODE CONTAINING Kr^{85}.

R.Forman and J.A.Ghormley.

J. appl. Phys. (USA), Vol. 34, No. 8, 2498-9 (Aug., 1963).

The current-voltage characteric shifted with time towards more negative anode voltages despite constant cathode emission. It is shown that the anode work function was being lowered by deposition of Rb^{85}.

J.W.Sturgesa

PA 63

39717 (GEST-2021) RESEARCH AND DEVELOPMENT PROGRAM OF THERMIONIC CONVERSION OF HEAT TO ELECTRICITY. Technical Summary Report. (General Electric Co. Vallecitos Atomic Lab., Pleasanton, Calif.). Aug. 30, 1963. Contract NObs-88578. 95p.

Two emitter-collector spacing configurations for thermionic converters successfully completed component testing. A thermionic diode configuration, making available a close match to the environment expected on spacing configurations in nuclear thermionic diodes, is in the final stages of assembly. An assembly to allow the testing of a number of concepts of possible cesium passages from one thermionic diode to the next in a series arrangement was designed and fabricated. An electron-beam furnace for the study of UO_2-refractory metals interactions at temperatures from 1650 to 2200°C completed the checkout phase. Careful characterization of two grades of tungsten was completed and samples of UO_2 clad in tungsten are under test. An experimental study to determine the phase equilibria between Y_2O_3 and four refractory metals (tungsten, rhenium, tantalum, and molybdenum) revealed no intermediate compounds along the pseudo-binaries Y_2O_3–W, Y_2O_3–Re, Y_2O_3–Ta, or Y_2O_3–Mo between 1500°C and 2000°C. No indication of metal solubility in Y_2O_3 was observed by x-ray techniques. A search for reaction between cesium vapor and Y_2O_3 at 1600°C revealed no reduction of Y_2O_3 at a cesium vapor pressure of 4 torr. The thermal expansion coefficient of Y_2O_3 was measured to be: $\alpha \times 10^6 = 5.143 + 0.185\ T^{1/2} - 0.0021\ T$, where: α is expressed in $°C^{-1}$ and T is expressed in °C and encompasses the range $75°C < T < 1050°C$. The melting point of Y_2O_3 was measured to be 2420°C ∓ 35°C. The development of high temperature metal-to-ceramic seals is getting underway. (auth)

NSA'63

Ion-emission requirements for removal of electron space-charge barriers. L. K. Hansen and C. Warner. 3d. bibliog diag J Ap Phys 34:2574-7 S '63

Photoelectric and thermionic Schottky deviations for tungsten single crystals. D. F. Stafford and A. H. Weber. bibliog diags J Ap Phys 34:2667-70 S '63

AS + TI '63

21863 PHOTOELECTRIC AND THERMIONIC SCHOTTKY DEVIATIONS FOR TUNGSTEN SINGLE CRYSTALS.

D.F.Stafford and A.H.Weber.

J. appl. Phys. (USA), Vol. 34, No. 9, 2667-70 (Sept., 1963).

The periodic Schottky deviations have been obtained for photoelectric and thermionic emission in the [111] direction from a tungsten single crystal in a dual experiment. The thermionic deviations, compared with well-established experimental results and theory, serve as a check on the photoelectric work. The photoelectric deviations, not previously established experimentally in detail, are compared with theory. A composite theory, using Cutler-Gibbons thermionic parameters in Juenker's photoelectric analysis, is in best agreement with the experimental photoelectric results. The photoelectric deviations are in fair agreement in period and phase with the thermionic deviations, the agreement being better at the larger applied electric fields (corresponding to the earlier time of a run) than at the smaller field values. The photoelectric deviation amplitude is 1·7% at $E^{1/2} = 350\ (V/cm)^{1/2}$.

PA '63

41675 THERMIONIC SCREENING OF BODIES IN THE ATMOSPHERE AND INTERPLANETARY SPACE. C. S. Shen (Goddard Inst. for Space Studies, New York) and K. P. Chopra. J. Atmospheric Sci., 20: 359-65(Sept. 1963).

Problems are considered that accompany thermionic emission of electrons from a hot body surrounded by a plasma. In the absence of other mechanisms, an electric potential is established at the surface of the body through the balance of thermionic emission and accretion of electrons from the external plasma. Analytical solutions are obtained for the electric potential field and the electron density distribution around the body. A possible application of this analysis to objects in space is indicated. (auth)

NSA '63

41594 IMPROVED THERMIONIC EMITTER USING UNIAXIALLY ORIENTED TUNGSTEN. Ira Weissman and M. L. Kinter (Varian Associates, Palo Alto, Calif.). J. Appl. Phys., 34: 3187-94(Nov. 1963).

Emission from most practical electron sources is nonuniform over the emitting area. Ordinary metallic surfaces are polycrystalline and their emission comes from many different small crystal facets whose work functions can vary over a wide range of values. As an example, the range of work functions of tungsten goes from a low of 4.3 for the (116) face to a high of 5.9 ev for the (110) face. Substantially improved uniformity of work function and current density would result if the entire emitting surface contained only a single-crystal plane. The use of a single crystal as a means of obtaining such a surface is costly and wasteful since its unique bulk properties are superfluous and do not in any way contribute towards the improved performance. Even more important, using a single crystal inherently limits one to planar geometries. Many polycrystalline materials of arbitrary shape, among them the refractory metals, when prepared by chemical vapor deposition can be made to exhibit a high degree of uniaxial crystal orientation with their preferred axis centered about the direction of growth. Given proper treatment after deposition, the surface of such materials predominantly consists of a single-crystal plane. X ray, optical, and thermionic-emission measurements are described that were made on vapor-deposited tungsten prepared by the hydrogen reduction of tungsten hexafluoride. By comparing volt-ampere characteristics of high-vacuum diodes, one of which contains a conventional tungsten filament and the other a chemically vapor-deposited one, of identical dimensions, it is found that there is an expected improvement in emission uniformity owing to the uniaxial grain orientation in the latter. By a similar comparison of cesium-neutralized energy-converter diodes, it is shown that the improved surface uniformity results in significantly improved power quadrant characteristics. (auth)

NSA '63

III. POWER GENERATION

A. Thermoelectric converters

29853 (MND-1123) RADIOISOTOPE FUELED AUXILIARY POWER UNIT. Quarterly Progress Report No. 2, April–July 1957. (Martin Co., Baltimore). Contract AT (30-3)-217. 76p.

Development of a radioisotope heat source for a satellite power plant is summarized. Possible operational hazards during the lifetime of the system are discussed. The development of the boiler design, fabrication of cerium compounds, pump assembly, turbine, and mercury heat transfer medium are summarized. The effect of gamma radiation on Kodak Microfile film is studied. (N.W.R.) NSA '63

31760 (MND-P-1175) RADIOISOTOPE FUELED AUXILIARY POWER UNIT. PIED PIPER APU. Quarterly Progress Report No. 3, July 1, 1957–October 1, 1957. (Martin Co., Baltimore). Contract AT(30-3)-217. 51p.

Progress made in the development of SNAP-1 is reported. Drawings of the shielding and remote handling equipment are given. The hazards of this power plant are summarized. The conceptual design of the boiler is revised. The CeO_2 fuel capsules will be mounted in a block of molybdenum by drilling longitudinal holes and inserting. The thermal bond material between the molybdenum block and the mercury bearing coil will be molten lead. Results of studies on fabrication of CeO_2 cermets are given. Equipment for static corrosion testing with mercury and lead is diagramed. Development work on the power conversion system is discussed. (N.W.R.) NSA '63

31761 (MND-P-3001) RADIOISOTOPE FUELED AUXILIARY POWER UNIT. Quarterly Progress Report No. 4, October 1957–January 1958. (Martin Co., Baltimore). Contract AT(30-3)-217. 73p.

Work was directed toward building a suitable mercury heat transfer loop that can be operated with a full-size boiler mockup under environmental conditions of both launch and outer space. A new half-power boiler mockup was designed to replace the full-size boiler in the heat transfer test loop. Fuel assembly studies were made on the stabilization of CeO_2 and the oxidation of molybdenum. Corrosion test results on stainless steels, chromium steels, and nickel alloys in contrast with liquid lead, mercury vapor, and liquid mercury are presented. The test rig checkouts were essentially completed and testing was initiated in every area of the power conversion system program. All component groups were directed toward obtaining experimental verification of the individual component designs established for the turbine-alternator dynamometer. (N.W.R.) NSA '63

31762 (MND-P-3002) RADIOISOTOPE FUELED AUXILIARY POWER UNIT. Quarterly Progress Report No. 5, January–April 1958. (Martin Co., Baltimore). Contract AT(30-3)-217. 60p.

Progress made in the development of the radioisotope-fueled thermoelectric generator (SNAP-1) is reported. Shipping procedures and the boiler loading and installation philosophy were determined. The core integrity test program was defined in further detail to include tests to evaluate launch abort damage and simulate re-entry heating conditions. A shielding analysis, to facilitate design of the boiler insulation and biological shield, was completed. Assembly of the mockup boiler heat transfer loop was completed and initial testing started. Engineering drawings for the new half-power boiler were completed and fabrication initiated. Development testing continued on CeO_2 pellets to improve stability and corrosion resistance. A corrosion program to determine the effect of biological shield mercury on surface emissivities of insulating metal was initiated. Development of the power conversion system components (turbine, pump, controls, alternator, and bearings) was continued. (N.W.R.) NSA '63

31763 (MND-P-3003) RADIOISOTOPE FUELED AUXILIARY POWER UNIT. Quarterly Progress Report No. 6, April 1958–July 1958. (Martin Co., Baltimore). Contract AT(30-3)-217. 125p.

A modular concept has evolved which permits testing of SNAP-1 as an attachable unit. Integrity testing of fuel elements in simulated pad aborts is reported. The adequacy of a full-scale boiler mockup in vaporizing mercury at the design point was tested; a new boiler coil designed to prevent slugging was tested. The sintering properties of CeO_2 were further investigated. Dynamic mercury corrosion testing of Croloy 5 Si and Croloy 5 Ti is reported. Static lead tests of CeO_2 pellets, brazed joints, and flame sprayed coatings continued. Testing of the power conversion system turbine, centrifugal pumps, controls, radial gap alternator, bearings, and steels is described. Design of a facility for testing the APU module is under way. A conceptual design of SNAP-3 was delineated. (N.W.R.) NSA '63

31764 (MND-P-3004) RADIOISOTOPE FUELED AUXILIARY POWER UNIT. Quarterly Progress Report No. 7, July–September 1958. (Martin Co., Baltimore). Contract AT(30-3)-217. 116p.

Progress made in the development of SNAP-1 and -3 is reported. SNAP-1 development reported includes: boiler development, fuel development, properties of cerium dioxide, materials corrosion, power conversion system development, shielding analysis, hazards evaluation, and ground test development. SNAP-3 development includes: power conversion analysis, thermoelectric generator development and fuel element development. Information is given on the handling and transportation equipment for SNAP-1. (N.W.R.)

28560 NUCLEAR DEVICE FOR GENERATING ELECTRIC POWER. Francis E. Jablonski and Charles B. Leffert (to General Motors Corp.). U. S. Patent 3,093,567. June 11, 1963. Filed Mar. 30, 1959.

A nuclear power plant in which d-c power is directly generated from the reactor heat by thermoelectric cells composed of one fuel element each is described. The fissile material forms the cathode of a diode that is separated by a fission-fragment-ionized plasma from a cooled conducting surface forming the anode. Power outputs of about 50 watts/cm^2 can be achieved with conversion efficiencies of about 30%. (D.C.W.)

NSA '63

29855 (MND-P-3008) RADIOISOTOPE FUELED AUXILIARY POWER UNIT. Quarterly Progress Report No. 11, July–September 1959. (Martin Co. Nuclear Div., Baltimore). Contract AT(30-3)-217. 144p.

Progress made in the development of the radioisotope-fueled thermoelectric generators (SNAP-IA, SNAP-IIIA, -B, -C, and -D, and SNAP-VII) is reported. SNAP-IA development is reported in relation to the overall system, structure and containment, heat element development and testing, environmental and qualification testing, ground handling and transportation, conversion system, and operational hazards. SNAP-III-A, -B, -C, and -D development of the thermoelectric generator is concerned mostly with molybdenum fuel capsule development, vehicle integration, fuel element design and testing, generator design and testing, and hazards testing. SNAP-VII development is concerned with generator design, fuel development, program management and integration, and hazards analysis. (N.W.R.)

NSA '63

9234 SOME NOTES ON THE POSSIBLE APPLICATION OF THERMOELECTRIC DEVICES TO THE GENERATION OF ELECTRIC POWER. P.J.Bateman.
Aeronaut. Res. Coun. Curr. Pap. (GB), No. 499 (July, 1959), 13 pp.

When waste head is available in a convenient form, conversion to useful electrical power should be possible by means of thermoelectric devices which, fabricated from semiconductor materials already developed, should give a power output per unit weight comparable with that of conventional small d.c. power sources. This can only be realized in practice if installation and construction problems can be overcome, and the effective hot and cold junctions are of the order of 1 cm apart. Efficiencies are, however, so low at present that it is unlikely that thermoelectric devices will be produced for the large scale production of electrical power.

EEA '62

29856 (MND-P-3009) RADIOISOTOPE FUELED AUXILIARY POWER UNIT. TASK 2. Quarterly Progress Report No. 12, September–December 1959. (Martin Co. Nuclear Div., Baltimore). Contract AT(30-3)-217. 115p.

Progress made in the development of the radioisotope-fueled thermoelectric generator (SNAP-IA) is reported. Information is given on system design, materi. ! analysis, hazards analysis, fabrication techniques, and system and components testing. Special emphasis is given to the cerium fuel development program. (N.W.R.) NSA '63

71,512 PRELIMINARY OPERATIONAL SAFETY REPORT FOR THE TASK 5.6 THERMOELECTRIC GENERATOR
Knighton, D.
May 1960

Martin-Marietta Corporation, Nuclear Division, Baltimore, Md.
MND-P-2356

The operational hazards associated with the use of a plutonium-fueled thermoelectric generator in a terrestrial satellite are evaluated. The hazard problems are discussed by extrapolating analytical and test data from previous final analyses performed for similar isotopic power devices. It appears that the plutonium fuel can be consumed and dispersed at high altitude during re-entry, following a successful mission. As an alternative, however, since the fuel (Pu^{238}) is an alpha emitter with a long half-life, random intact re-entry following a successful mission may also be feasible. However, as a precaution against aborted missions, the launch azimuth should be over water as much as possible to avoid impact or dispersion in areas of significant population density.

4359 (TID-17306) APPLICATION OF NUCLEAR POWER SUPPLIES TO SPACE SYSTEMS. (Sigma Corp., Los Altos, Calif.). June 30, 1960. For Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif. Contract AT-11-1-GEN-8. 98p. (LA-3301)

Studies were made to ascertain what useful satellite and/or space missions may be accomplished with the SNAP 2, 8, and 10 power systems within the 1960 to 1970 time period, to delineate useful satellite and/or space missions which would most profitably employ nuclear power sources, to ascertain what restrictions are imposed on various payloads as a result of having a nuclear power system on board, and to investigate the general vehicle integration and installation requirements of the SNAP 2 and 10 power units. Space flight programs, characteristics and limitations of SNAP, applications of nuclear power supplies, design integration, and system integration are discussed. (M.C.G.)

NSA '63

258 (FTD-TT-62-226) EXAMPLES OF THERMOELECTRIC DEVICES (CHAPTER IV). A. F. Ioffe. Translation of p.126-53 (Chapter IV) of "Poluprovodnikovye Termoelementy" (a publication of the Publishing House of Military Literature, Academy of Sciences, USSR, Moscow, 1960). 32p.

Discussions are included on thermoelectric generators, thermoelectric refrigerators, heating and airconditioning, measurement of heat flows and radiant fluxes, aspects of crystallization, and high-temperature thermoelements. (J.R.D.)

NSA '63

2566 (WCAP-1818(Vol.I)(Del.)) DESIGN STUDY OF PORTABLE THERMOELECTRIC NUCLEAR SYSTEMS. L. Chajson, A. R. DelCampo, H. B. Kellogg, et al. (Westinghouse Electric Corp. Atomic Power Dept., Pittsburgh). July 1961. Contract AT(30-1)-2176. 199p.

Design studies were performed and costs were estimated for an air transportable, 10 Mw(t), pressurized light water thermal circulation reactor, combined with a direct conversion thermoelectric generator and static electrical inversion equipment. This "TCR-TE" concept appears to have potential for ultimate use as a remote unmanned power station. Based on an extrapolation of present reactor technology and on assumed thermoelectric materials properties forecasted to January 1, 1963, a net a-c electrical output of 315 Kw is estimated, assuming the use of 80°F local water for cooling purposes. An alternate concept using 80°F air for cooling produces 271 Kw, net. These electrical output figures can be improved significantly through a recommended research and development effort. The design and construction of a prototype plant is also recommended. (auth)

NSA '64

22159 THERMOELECTRIC POWER GENERATION. P.J.Bateman. Contemporary Physics (GB), Vol. 2, No. 4, 302-11 (April, 1961).

Using existing semiconductor materials, it should be possible to produce thermoelectric generators with efficiencies of about 14%. Despite future improvement in material properties it appears unlikely that an efficiency greater than 40% of that of the Carnot cycle can be obtained. This renders thermoelectric devices unsuitable for the large scale production of electric power, and limits their usefulness to certain specialized applications where a suitable heat source and sink are available. When this is the case a generator which would have a power-to-weight ratio comparable with that of conventional small d.c. power sources seems feasible.

PA '62

2574 (WCAP-1818(Vol.II)(Del.)) DESIGN STUDY OF PORTABLE THERMOELECTRIC NUCLEAR SYSTEMS. L. Chajson, A. R. DelCampo, H. B. Kellogg, et al. (Westinghouse Electric Corp. Atomic Power Dept., Pittsburgh). July 1961. Contract AT(30-1)-2176. 170p.

The design of a thermal circulation reactor with thermoelectric elements is considered. Topics covered include: recommended research and development programs, cost analysis, alternate concepts considered, generator control considerations, thermal and hydraulic analysis, thermoelectric performance calculations, possible design improvements and advancements, procedure use for reactor core thermal and hydraulic calculations, and thermoelectric material properties and technology. (M.C.G.)

NSA '64

11986 (NAA-SR-6307) THE SNAP II POWER CONVERSION SYSTEM TOPICAL REPORT NO. 15. CRU DESIGN AND DEVELOPMENT. (TAPCO. Div. of Thompson Ramo Wooldridge Inc., Cleveland). July 1961. For Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif. Contract AT-11-1-GEN-8, Subcontract N 843 FS-101221. 103p. (TRW-ER-4108)

SNAP II is the designation for a 3-kw nuclear auxiliary power unit to be used in a satellite vehicle. This system consists of a reactor heat source, a mercury Rankine engine and an alternator. The alternator, mercury pump, turbine, and reactor coolant pump are mounted on a common shaft supported by mercury lubricated bearings. Design details and test results concerning the combined rotating unit (CRU) development are described. (auth)

NSA '63

22277 (TID-18323) RADIOISOTOPE-FUELED POWER SUPPLIES. Lecture Presented at University of California, Los Angeles, California, UCLA Short Course, Space Power Systems, July 17-28, 1961. J. G. Morse (Martin Co., Baltimore). 133p. Contract AT(30-3)-217. 133p.

Considerations that permit selection of a radioisotope that meets the complex requirements of the desired power supply are discussed. Methods of separation and purification of useful isotopes are outlined. Brief mention is made of the principles of direct conversion of heat to electricity. Design approaches for isotopic power units are described. A delineation of the approach to the solution of the nuclear safety problem is made, followed by predictions for the future of isotopic power. Sample problems of the type solved in the SNAP program are given. (M.C.G.) NSA '63

37660 (TID-19333) THE CESIUM-137 POWER PROGRAM. Quarterly Report No. 2. (Royal Research Corp., Hayward, Calif.). July 31, 1961. Contract AT(04-3)-366. 86p. (RRC-0101)

Research on cesium-137 power is described. Basic components are clarified, using criteria of safety, reliability, and longevity. It is found that a generator fueled with cesium-137 can be constructed to operate at a continuous power level of 5 watts and 12 volts in a sub-sea environment of great depth. Moreover, the generator may be easily transported to its destination because of its compactness and light weight. A cesium polyglass fuel form is developed into which a maximum of 43 per cent elemental cesium may be safely incorporated. Conversion of the raw fission product into a compound form suitable for firing is accomplished, proving that a single ion exchange column can achieve the desired results. Extraneous contaminants are entrained upon the column and the resulting product is elementally pure. Samples of cesium polyglass containing cesium-137 tracer are subjected to distilled and natural sea water solubility testing. Data indicate a decreasing rate of dissolution to less than 1 ppm per week, after 45 days of immersion at elevated temperatures. Investigation of heat transfer properties inherent to cesium-137 fuel results in the formulation of a thermal barrier of such excellence that only 21 thermal watts are expended in providing the required 500°C "hot shoe" temperature. The final configuration is a composite consisting of conductive and radiant heat barriers. Tests are conducted in an aqueous medium to 0°C as well as in ambient air. Approximately 1.9 in. of tungsten should be required to shield the source. The general configuration of the 5-watt device is determined and conceptual drawings made. (auth) NSA '63

7643 (MND-P-3016-I) SNAP RADIOISOTOPE SPACE PROGRAMS. Quarterly Progress Report No. 8, Task 7, July 1 through September 30, 1961. (Martin Co. Nuclear Div., Baltimore). Contract AT(30-3)-217. 50p.

Activities in a program devoted to the safety evaluation of isotopic power systems in space applications are reported. In the study of upper atmosphere re-entry, flare and telemetry test capsules were completed for scheduled re-entry tests. The altitude of re-entry burn-through for all phase I and II test capsules and nose cone-vehicle-pod relative position data were determined. These data were used in determining the optimum positions and headings for the optical and optical-telemetry aircraft. A 100-lb test pod containing simulated SNAP 3 fuel cores was shot into space in July 1961. Two of these were flare capsules containing Na and K, and one was a telemetry capsule containing a transmitter. The flares were sighted and a telemetry signal was received in this test. The high altitude diffusion and dispersion study was concluded with the writing of equations for turbulence-induced cloud growth, wind-induced translational motion and gravity-induced vertical motion. Results of the program for predicting fuel particle size as a function of initial size and re-entry velocity and altitude are included. Work on the radioisotope shielding code was continued. (J.R.D.) NSA '63

1684 (MND-P-2640) INSTRUCTION MANUAL—SNAP-7C ELECTRIC GENERATION SYSTEM. [E. Blazek] (Martin Co. Nuclear Div., Baltimore). Oct. 1, 1961. Contract AT(30-3)-217. 60p.

A description of SNAP-7C isotope-fueled electric generation system is presented. The operational limits and transportation, handling, installation, and adjustment procedures are described. Maintenance instructions and emergency and safety precautions are included. (M.C.G.) NSA '63

31766 (TID-17004) THE CESIUM-137 POWER PROGRAM. Quarterly Report No. 3. (Royal Research Corp., Hayward, Calif.). Oct. 31, 1961. Contract AT(04-3)-366. 100p. (RRC-0102)

Progress made in the development of the Cs^{137} fueled thermoelectric generator for marine power applications is reported. Information is given on thermoelectric generator design, shielding, power conversion system, hazards evaluation, fuel element forming and cladding, fabrication, and heat transfer. Cs^{137} energy calculations are presented along with shielding calculations. The development and fabrication of cesium polyglass for fuel application are included. (N.W.R.) NSA '63

4356 (MND-P-2483-4) SNAP 7 PROGRAM: TASK 8—STRONTIUM-90 FUELED THERMOELECTRIC GENERATOR DEVELOPMENT. Quarterly Progress Report No. 4, August 1, 1961 - October 31, 1961. W. S. West (Martin-Marietta Corp. Aerospace Div., Baltimore). Contract AT(30-3)-217. 108p.

Progress during the period includes completion of the SNAP 7C system tests, completion of safety analysis for the SNAP 7A and C systems, assembly and initial testing of SNAP 7A, assembly of a modified reliability model, and assembly of a 10-W generator. Other activities include completion of thermal and safety analyses for SNAP 7B and D generators and fuel processing for these generators. (J.R.D.) NSA '63

4353 (AFSWC-TDR-61-99) NAP-100 THERMOELECTRIC GENERATOR REPORT. G. Spira and T. M. Corry (Westinghouse Electric Corp. New Products Labs., Cheswick, Penna.). Nov. 1961. Contract AF30(602)-1875. 38p. (AD-274280)

The development and performance are presented of a 100-w isotopic fuel, thermoelectric generator designated NAP-100 (Nuclear Auxiliary Power). The generator unit was treated as an integrated system to minimize size and weight without undue sacrifice in efficiency. The 3 basic elements of the generator are: (1) the cold side convective heat exchanger, (2) the thermoelectric couple assembly, and (3) the heat source (an electrical heater which simulated the thermal performance of the nuclear heat source was designed and delivered with the generator). (auth) NSA '63

13679 (NAA-SR-6305) THE SNAP II POWER CONVERSION SYSTEM. ORBITAL FORCE FIELD BOILING AND CONDENSING EXPERIMENTS (OFFBACE). Topical Report No. 13. C. T. Jaenke, Alfred Koestel, and John G. Reitz (TAPCO. Div. of Thompson Ramo Wooldridge Inc., Cleveland). Nov. 1961. For Atomics International, Div. of North American Aviation, Inc., Canoga Park, Calif. Contract [AT(11-1)-Gen-8]; Subcontract N843FS-101221. 153p. (ER-4670)

Boiling and condensing experiments under zero gravity conditions were conducted to investigate the operation of a mercury Rankine cycle power system similar to SNAP I and SNAP II designs. A detailed analysis of the phenomena involved in condensing under various gravity conditions is included. Empirical correlations based on mercury condenser pressure drop data were developed and further interfacial stability tests were made. (J.R.D.) NSA '63

Efficiency of thermoelectric devices. E. T. B. Gross. bibliog Am J Phys 29:729-31 N '61
ASDTI '62

J9689 (TID-15222) HIGH ACCELERATION FIELD HEAT TRANSFER FOR AUXILIARY SPACE NUCLEAR POWER SYSTEMS. Quarterly Technical Report, September 1 through November 30, 1961. H. F. Poppendiek, N. D. Greene, and H. G. Hughes (Geoscience Ltd., Solana Beach, Calif.). Contract AT(04-3)-409. 31p. (GLR-6)

Research results on liquid metal heat and momentum transfer are presented. A review and summary are presented of previously obtained data on liquid metal non-boiling and boiling heat transfer and non-boiling momentum transfer. A convective heat transfer solution is described which can be used to predict heat transfer in liquid metals flowing turbulently in channels and longitudinally past fuel rods in reactor cores prior to the initiation of boiling. Several mathematical two-phase flow models are analyzed and the solutions evaluated; the results can be used to estimate pressure drop in boiling liquid metal flow systems under zero and artificial radial gravity conditions. A design for an experimental, flow visualization system for the purpose of studying two-phase flow phenomena under centrifugal fields is presented. The preliminary design of an Hg heat transfer system in which boiling and condensation mechanisms are to be studied is also reviewed. (auth) NSA '63

AD-282 213 Div. 7
(TISTP/FR) OTS price $1.50

General Atomic Div., General Dynamics Corp., San Diego, Calif.
FLAT-PLATE SOLAR THERMOELECTRIC CONVERSION PANELS.
Final rept., Nov 60-Dec 61,
by Arthur N. Himle, Daniel S. Brush and others.
May 62, 47p. incl. illus. tables, 3 refs.
(Contract AF 33(616)7676, Proj. 8173)
(ASD TDR 62-214) Unclassified report

DESCRIPTORS: *Thermoelectricity, *Power supplies, *Sandwich panels, Aluminum, Lead compounds, Tellurides, Zinc compounds, Antimonides, Solar energy.

Procedures were developed for constructing a lightweight solar energy converter, using thermoelectric materials sandwiched between flat sheets of aluminum. Two panels, each one foot square, have been delivered to the Flight Accessories Laboratory, Aeronautical Systems Division. Each panel contains 153 n-type PbTe elements and 153 p-type ZnSb elements, arranged in eighteen alternating rows of seventeen elements each. According to measurements made on test panels constructed in a similar fashion, the delivered panels are capable of an output of at least 1.33 w/sq ft when subjected to an incident energy of 1400 w/sq m, which is equal to the solar energy intensity at the Earth's distance from the sun. At this output, the solar panel weighs 96 pounds per electrical kilowatt. The observed ouput is lower than is calculated from the properties of the materials used; however, it is anticipated that improved performance can be obtained in future panels. (Author) 162

Sun-powered electric plant for underdeveloped areas; thermoelectric power plant. Westinghouse Eng 21:195-6 N '61
ASDTI '62

7754 THE PERFORMANCE OF A CONVECTIVELY COOLED THERMOELEMENT USED FOR POWER GENERATION.
N.Rollinger and J.E.Sunderland.
Solid-State Electronics (GB), Vol.3, No.3-4, 268-77 (Nov.-Dec., 1961).

The differential equations which describe the steady-state temperature distribution in a thermoelement with constant properties and with convective heat transfer from its longitudinal surface are presented and solved by analytical methods. The closed-form analytical solutions are applied to a single-element thermoelectric generator to determine the effect of surface heat transfer upon the power output and efficiency over a range of values for the heat-transfer parameters. The results show that in all cases the surface heat transfer increased the power output under matched load conditions; in many cases both the power output and the thermal efficiency were increased through the use of surface heat transfer. The conclusion is drawn that surface heat transfer can be beneficial in many applications, especially in cases where maximum power output is of primary importance, or in cases where the cold-junction fin area is greatly restricted by weight, space, or cost considerations.

EEA62

9235 THERMOELECTRIC GENERATION.
D.A.Wright.
Direct Current (GB), Vol.6, No.9, 275-7 (Dec., 1961).

A figure of merit, that combines the electrical and thermal conductivity and the Seebeck coefficient, is used to classify materials from the point of view of thermoelectric applications. Semiconductors in general, and bismuth and lead-tellurides in particular, are discussed. The reduction in the figure of merit of semiconductors, caused by increasing temperatures changing them from extrinsic to intrinsic, is reviewed; general data on efficiency are given. Molten semiconductors and materials with refractory properties are mentioned for high temperature work. Compactness and silence and freedom from moving parts are some of the important ones among the attractive features of thermoelectric generation. Direct conversion of heat from nuclear reactors is of interest, in-pile use is discussed. J.R.M.Szogyen

EEA '62

9242 THE INITIAL BEHAVIOR OF A THERMOELECTRIC GENERATOR. F.G.Stremler and P.E.Gray.
Trans Amer. Inst. Elect. Engrs I, Vol.80, 367-72 (1961) = Commun. and Electronics, No.56 (Sept., 1961).

The results of the solution to the nonlinear problem of predicting the start-up output transients of the thermoelectric generator under load prove to be quite valid when the solution is obtained in a perturbative manner. At the outset a number of simplifying assumptions have to be introduced and convenient notations and normalizing factors chosen to yield a tractible solution. A first solution is worked out for zero temperature distribution in a thermoelectric generator consisting of one p-type semiconductor; Thomson coefficients $\tau = 0$ are implied. It is found that the convergence of such a perturbation process is directly related to the device efficiency. Since efficiency is low for the materials in present use, one perturbation is sufficient for the practiced case. Accuracy of the method also depends to a great deal on a parameter c which represents the total specific heat of the hot junction connecting strap, normalized to the specific heat of the elements. With an identical perturbation method the effect of load on the transient behaviour of the device is described; the steady state operating point is lower and the settling time is less. Comparison of calculated values and experimental results for a bismuth-telluride p-n junction showed good agreement for a measured value of c = 0·304. 13 references. M.F.A.Wesseling

EEA62

7755 THERMOELECTRICITY APPLICATION CONSIDERATIONS. A.A.Sorensen.
Trans Amer. Inst. Elect Engrs. II, Vol. 80, 285-9 (1961) = Applic. and Industr., No. 57 (Nov., 1961).

Discusses general design data and enumerates the required characteristics of high electrical output, low thermal conductivity, stability and adaptability to production processes for the metals or alloys used for thermopile construction. With lead-telluride as an example graphs are given of Seebeck e.m.f. and resistivity versus temperature. Technological problems as well as weight and heat transfer or cooling considerations are examined. Temperature limitations of the heat source, electrodes, seals, support materials and electrical and thermal insulation strongly influence the overall design of a power conversion system. Typical applications are given for space, terrestrial and marine installations with their power ratings, specific limitations and efficiency. M.F.A.Wesseling

EEA62

6892 ELECTRIC ANALOG OF TRANSPORT PHENOMENA IN A THERMOELECTRIC GENERATOR. M.E.Talaat.
Trans Amer. Inst. Elect. Engrs I, Vol. 80, 427-31 (1961) = Commun. and Electronics, No. 56 (Sept., 1961).

The basic principles of thermoelectric transport phenomena and those of heat transfer are used to derive an electric circuit analogue of an arm of a thermoelectric couple where the thermal conductances are represented by electric conductances, and where the rates of input heat (Peltier, Joule, and Thomson heat) and the electric power output are represented by current sources. The equivalent thermal circuit is shown to satisfy the transport equations of one of the arms of a thermoelectric couple. The basic equivalent thermal circuit of an arm of a thermoelectric couple is next applied to the derivation of an over-all thermal equivalent circuit of a typical isotope-fueled thermoelectric generator. The electric analogue of the entire system enables the designer to determine the over-all efficiency of the thermoelectric generator as well as its temperature distribution, and to set the problem on the analogue or digital computer and vary the different parameters of the circuit to optimize the over-all design.

EEA'62

Note on Thermoelectric Power and Inelastic Scattering, A.M. GUENAULT, D.K.C.MacDONALD. Philosophical Mag v 6 n 70 Oct 1961 p 1201-6. It has been proposed that spin-dependent scattering of electrons by magnetic impurity ions would provide mechanism to account for "giant" thermoelectric powers observed in certain dilute alloys at very low temperatures; simplified model is discussed which indicates directly that essential requirement is that of 2 largely independent groups of conduction electrons whose mobilities are significantly different. EI 62

Reliability factors in thermoelectric generator design. M. R. Seiler and T. S. Shilliday. diag Inst Radio Eng Proc 49:1952-3 D '61

Thermoelectric Generators with Surface Heat Loss, H.B.NOTTAGE, P.S.STARRETT, P.L.WINSKELL. ASME—Paper 61-WA-46 for meeting Nov 26-Dec 1 1961 12 p. Influence of surface heat loss is treated analytically for unidimensional thermoelectric energy converters; conditions are formulated whereby gain in thermoelectric generator system efficiency can result from transfer of heat from thermoelectric conductors to convecting fluid; influences of surface heat loss are discussed and demonstrated upon longitudinal temperature distribution and source and sink heat conduction rates. EI62

Thermoelectricity Application Considerations, A.A.SORENSEN. AIEE—Trans v 80 pt 2 (Applications & Industry) n 57 Nov 1961 p 285-9. Engineering design of thermoelectric devices for power generation; thermoelectric materials; space, terrestrial and marine applications of thermoelectric devices. Paper 60-1066. EI62

Thermoelectric Power Supplies, M.FRASER, J.SHIELDS. AEI Eng v 1 n 12 Dec 1961 p 452-8. Potentialities of using Seebeck effect, reviewed on background of investigation of semiconductor thermocouples carried out in AEI Research Laboratory at Rugby. EI63

Optimal'nye rabochie tochki na vol'tampernoi kharakteristike termoelektronnogo preobrazovatelya energii. I.A.REZGOL. Radiotekhnika i Elektronika v 6 n 11 Nov 1961 p 1906-13; see also English translation in Radio Eng & Electronic Physics (pub by AIEE) v 6 n 11 Nov 1961 p 1699-1705. Optimum operating points on v-amp characteristic of thermoelectric converter; theoretical investigation of vacuum thermocouple with compensation of electron space charge; equations for connection between resistance of "matched" load and internal resistance of device under 2 optimal conditions. E.I 62

Foot-square thermoelectric source generates three-house power. Machine Design 33:15 D 7 '61

✓ 11609 THE PERFORMANCE OF A CONVECTIVELY COOLED THERMOELEMENT USED FOR POWER GENERATION.
C.N.Rollinger and J.E.Sunderland.
Solid-State Electronics (GB), Vol. 3, No. 3-4, 268-77 (Nov.-Dec., 1961).

The differential equations which describe the steady-state temperature distribution in a thermoelement with constant properties and with convective heat transfer from its longitudinal surface are presented and solved by analytical methods. The closed-form analytical solutions are applied to a single-element thermoelectric generator to determine the effect of surface heat transfer upon the power output and efficiency over a range of values for the heat-transfer parameters. The results show that in all cases the surface heat transfer increased the power output under matched load conditions; in many cases both the power output and the thermal efficiency were increased through the use of surface heat transfer. The conclusion is drawn that surface heat transfer can be beneficial in many applications, especially in cases where maximum power output is of primary importance, or in cases where the cold-junction fin area is greatly restricted by weight, space or cost considerations.

PA62

UNCLASSIFIED

110594 FLAT-PLATE SOLAR THERMOELECTRIC CONVERSION PANELS
(Period covered: November 1960-December 1961)
Himle, Arthur N.; Brush, Daniel S. (et al)
May 1962 — Unclassified
General Atomic — (R-GA-2823)
AF 33(616)7676 — (Air Force Dept. ASD-TDR-62-214)
Final Report

Procedures have been developed for the construction of a lightweight solar energy converter, using thermoelectric materials sandwiched between flat sheets of aluminum. Each panel contains 153 n-type PbTe elements and 153 p-type ZnSb elements, arranged in eighteen alternating rows of seventeen elements each. According to measurements made on test panels constructed in a similar fashion, the delivered panels are capable of an output of at least 1.33 w/ft^2 when subjected to an incident energy of 1400 w/m^2, which is equal to the solar energy intensity at the Earth's distance from the sun. At this output, the solar panel weighs 96 pounds per electrical kilowatt.

Space power systems
Solar energy devices
Solar panels

UNCLASSIFIED

Cesium-137 Thermoelectric Generator. H.O.BANKS.Jr. W.W. T.CRANE. IRE—Trans on Military Electronics v MIL-6 n 1 Jan 1962 p 98-102. Equipment designed to supply power for undersea seismic station; cesium generator incorporates external shell that will withstand compressive forces at greatest ocean depths, and power conversion system employing lead-telluride thermocouples mounted on printed circuit board; combination radiation shield and heat sink, surrounded by special complex of thermal reflectors and compacted insulation, utilizes practically all of decay heat.

EI62

Problem Areas and Operating Experiences with Thermoelectric Equipment, A.B.NIELD, Jr. SAE—Paper 463C for meeting Jan 8-12 1962 11 p; see also SAE—J v 70 n 2 Feb 1962 p 41-5. Efforts made by U S Naval Eng Experiment Station in developing generator converting heat directly to electricity; possible applications; use of reversible thermoelectric power phenomenon for refrigeration or air conditioning; temperature dependent materials parameters which affect conversion efficiency of thermoelectric material are Seebeck coefficient, thermal conductivity, and electrical resistance.

EI63

✓ 11605 THERMOELECTRIC GENERATOR DESIGN, PERFORMANCE, AND APPLICATION.
T.M.Corry and G.Spira.
IRE Trans Military Electronics (USA), Vol. MIL-6, No. 1, 34-40 (Jan., 1962).

PA 162

Thermoelectric Generator Design, Performance, and Application, T.M.CORRY, G.SPIRA. IRE—Trans on Military Electronics v MIL-6 n 1 Jan 1962 p 34-40. Design procedure for free convection air cooled generators; performance of power thermocouples as function of junction temperature; effects of varying thermocouple length on generator efficiency and specific power; methods of predicting generator performance for thermoelectric materials of equal figures of merit but different values of thermal conductivity.

EI63

1724 THE CESIUM-137 THERMOELECTRIC GENERATOR. H. O. Banks, Jr. and W. W. T. Crane (Royal Research Corp., Hayward, Calif.). IRE (Inst. Radio Engrs.), Trans. Military Electron., MIL-6: 98-102 (Jan. 1962).

Designed for the initial application of supplying power for an under-sea seismic station to be supervised by Lamont Geological Observatory researchers, this cesium generator incorporates an external shell that will withstand compressive forces at the greatest of ocean depths and a power-conversion system employing lead-telluride thermocouples mounted on a printed circuit board. A combination radiation shield and heat sink, surrounded by a special complex of thermal reflectors and compacted insulation, utilizes practically all of the decay heat. A very high degree of safety from radioactivity is assured, due to double encapsulation of fuel increments, an ultrastrong radiation shield for containment of the latter, and an external shell that will withstand 16,000 psi pressure. (auth) NSA 63

*5638 (AFCRL-62-148) OPTIMUM IMPURITY CONCENTRATION IN SEMICONDUCTOR THERMOELEMENTS. Scientific Report No. 6. Jose M. Borrego-Larralde (Massachusetts Inst. of Tech., Cambridge. Energy Conversion and Semiconductor Lab.). Jan. 15, 1962. Contract AF19(604)-4153. 125p. (AD-275052)

Research was carried out on the problem of obtaining the maximum efficiency of a thermoelectric generator. Expressions for the optimum current and maximum efficiency were obtained for the case of temperature-dependent parameters by using a first-order approximate solution to the heat-conduction equation. A figure of merit is defined for the case of temperature-dependent parameters. Equations were derived for the optimum carrier concentration, which yield a stationary value for the figure of merit. Conditions that are mathematically sufficient were obtained for the stationary value to be a maximum. Solutions of the equations for the optimum carrier concentrations are given for a non-degenerate extrinsic semiconductor. It was assumed that the lattice thermal conductivity and the carrier mobility were independent of the carrier concentration. The maximum figures of merit for both constant and variable carrier concentrations were compared. (auth) NSA 63

9239 THERMOELECTRIC GENERATOR DESIGN, PERFORMANCE, AND APPLICATION. T.M.Corry and G.Spira. IRE Trans Military Electronics (USA), Vol. MIL-6, No.1, 34-40 (Jan., 1962).

Many of the practical problems that are encountered in building present-day generators are illustrated. A design procedure for free convection air-cooled generators is described. The performance of power thermocouples as a function of junction temperature is discussed and curves illustrating couple efficiency, power output, heat flux and voltage as a function of hot junction temperature are shown. The effects of varying thermocouple length on generator efficiency and generator specific power are shown graphically and methods of predicting generator performance are illustrated for thermoelectric materials of equal figures of merit but different values of thermal conductivity. The paper also discusses free convection heat exchangers and fossil-fuel burners. The thermoelectric generator performance on a W/lb basis is compared with battery- and gasoline-engine-driven generator performance for specific missions. EEA62-

1717 PROGRESS IN THERMOELECTRICITY. Paul H. Egli (Naval Research Lab., Washington, D. C.). IRE (Inst. Radio Engrs.), Trans. Military Electron., MIL-6: 27-34 (Jan. 1962).

Of the several processes by which heat is directly transformed to useful electric power, thermoelectricity offers unique advantages for several areas of application. The absence of moving parts and the simplicity promise high reliability, silence, and long-lived, maintenance-free operation both as a power source and as a heat pump for refrigeration and temperature control. A substantial effort devoted to materials development has produced new semiconductors with an integrated theoretical efficiency of about 20 per cent. Further progress in materials development is needed to achieve major goals in both military and commercial applications, but important uses can already be visualized. Small power plants for remote areas and auxiliary power supplies for space vehicles are awaiting engineering improvements, some of which again require improved materials for use as electrical contacts and electrical and thermal insulators. Similarly in refrigeration, important military applications and special commercial devices can be produced with existing thermoelectric materials when engineering problems and the auxiliary materials problems are solved. (auth) NSA 63

71,969 THERMOELECTRIC GENERATORS AND MATERIALS: RADIATION EFFECTS, RELIABILITY, LIFETIME, AND FAILURE. AN ANNOTATED BIBLIOGRAPHY
Graziano, E.
January 1962
Lockheed Missiles and Space Co., Sunnyvale, Calif.
SB-61-60
ASTIA AD-273,953

This literature search was conducted as part of research on the problems of using thermoelectric generators which would directly convert heat from nuclear sources into electricity. The purpose of the search was to bring to light any information regarding reliability, lifetime, and mean time of failure of thermoelectric generators and materials due to oxidation, cracking, galvanic action, short circuits, radiation effects, and sublimation.

/ 9231 APPLICATIONS OF THERMO-ELECTRIC ELEMENTS. Elektron. Rundschau (Germany), Vol. 16, No. 1, 12 (Jan., 1962). In German.

Brief data describes thermo-electric generation of electricity from burning gas to provide 130 watts for fan drive, application in domestic heating, generation from nuclear heat to provide 150 watts fro small unmanned radio and weather stations, thermoelectric generation in a natural gas well to prevent corrosion of steel linings, 5000 watts generated from chemical heat, and 200 watts for water pump drive, generated from sunlight. H.V.Harley EEA'62

/19690 (TID-15223) HIGH ACCELERATION FIELD HEAT TRANSFER FOR AUXILIARY SPACE NUCLEAR POWER SYSTEMS. [1961]. Quarterly Technical Report, December 1 through February 28, 1962. H. F. Poppendiek, N. D. Greene, H. G. Hughes, and C. M. Sabin (Geoscience Ltd., Solana Beach, Calif.). Contract AT(04-3)-409. 49p. (GLR-8)

Research results on liquid metal heat and momentum transfer are presented. A review and summary of boiling heat transfer models found in the literature are presented; nucleate pool and film boiling models are examined, and a comparison of the various models is made. Several boiling heat transfer analyses are outlined. One analysis considers free convection film boiling from a vertical plate and the other describes forced convection film boiling in a pipe. Additional two-phase flow analyses conducted include turbulent-viscous pipe flow, turbulent-turbulent pipe flow, and viscous-viscous curvilinear channel flow. A number of preliminary two-phase, curvilinear flow experiments were completed in pipes containing helical guides. Information on flow patterns and phase separation was obtained using air and water. The results of studies on the Mollier Diagrams and physical properties of Hg and K are also included. (auth)

NSA '63

High Voltage Output with Oxide Thermoelectric Generators, R. D. FENITY. Electronics v 35 n 5 Feb 2 1962 p 39-41. Ceramic technology forms basis of thermoelectric generator described; generator is capable of producing 100 v in 20 cu in. package heated to 2400 F.

EI 63

Sur un effet de conversion directe de la chaleur en électricité, S. KLEIN. Acad des Sciences—CR v 254 n 11 Mar 12 1962 p 1946-7. One of effects of direct conversion of heat into electricity; it is advanced that emf is originated from formation of cold gaseous layer around cold electrode; experimental measurements of electron temperature and electron conductivity in close vicinity of this cold wall; results seem to confirm advanced hypothesis.

EI '63

All-Ceramic Thermoelectric Generator, G.L.VINCENT. Cer Industry v 78 n 3 Mar 1962 p 52-4. Minneapolis-Honeywell 100-v unit for U S Army Picatinny Arsenal program uses high alumina substrates and separators coated with platinum and lithia doped nickel oxide; spiral cut, scored with diamond, forms continuous series of junctions for developing voltages; it can operate at 2400 F; waste heat from rocket engine exhausts and re-entry nose cone heating, nuclear energy, and industrial ceramic heat sources could be used; diagram.

EI '62

80,693 **INVESTIGATION OF PHOTOEMISSION SOLAR ENERGY CONVERTERS**
Stahl, H. A., Peifer, W. K. (RCA, Lancaster, Pa.)
February 1962
Aeronautical Systems Division, Flight Accessories Lab., Wright-Patterson AFB, Ohio
ASD TR 61-619

Photoemissive solar energy converters are investigated both in theory and on a laboratory basis. Theory indicates that with optimum surfaces and configuration, 3-percent efficiency is attainable, although the efficiency actually attained was only 0.1 percent. The program, however, does not demonstrate that the 3-percent efficiency cannot be attained, but that many fabrication problems still exist. Supporting research was done on photoemitters for prolonged use under high light intensity and on the development of low sheet resistance emitters and collectors. Fabrication techniques were developed, and envelope materials were studied briefly.

Basic solar thermoelectric power unit. R. Lang and B. T. Lubin. il Aerospace Eng 21:6-15 F '62

AS&TI '62

All-ceramic thermoelectric generator. G. L. Vincent. il Cer Ind 78:52-4 Mr '62

AS&TI '62

/11598 **CELL AND THERMOELECTRIC EFFECTS OF TANTALUM ELECTROLYTIC CAPACITORS.**
J.M.Law and W.C.Richards.
J. Electrochem. Soc. (USA), Vol. 109, No. 3, 215-21 (March, 1962).

A voltage is normally present across the terminals of electrically isolated electrolytic tantalum capacitors. The magnitude, cause, and source impedance of this voltage were investigated. Wet-electrolyte units generate a small, high-impedance, cell e.m.f. between the tantalum anode and the silver case. This e.m.f. increases with film thickness to a maximum of 3 V at elevated temperatures. Solid-electrolyte units generate a small, high-impedance e.m.f., apparently thermoelectrically, normally not exceeding a few millivolts, but on some units, reaching a few hundred millivolts. Larger voltages are generally due to a residual charge from previous electrification, either from a slow decay rate or from dielectric hysteresis.

PA 62

11300 (ASD-TDR-62-214) FLAT-PLATE SOLAR THERMOELECTRIC CONVERSION PANELS. Final Report. Arthur N. Himle, Daniel S. Brush, John B. Roes, and Edward L. Brady (General Atomic Div. General Dynamics Corp., San Diego, Calif.). Mar. 19, 1962. Contract AF33(616)-7676. 47p.

Procedures were developed for the construction of a lightweight solar energy converter, using thermoelectric materials sandwiched between flat sheets of aluminum. Two panels, each one foot square, were delivered to the Flight Accessories Laboratory, Aeronautical Systems Division. Each panel contains 153 n-type PbTe elements and 153 p-type ZnSb elements, arranged in eighteen alternating rows of seventeen elements each. According to measurements made on test panels constructed in a similar fashion, the delivered panels are capable of an output of at least 1.33 w/ft^2 when subjected to an incident energy of 1400 w/m^2, which is equal to the solar energy intensity at the Earth's distance from the sun. At this output, the solar panel weighs 96 pounds per electrical kilowatt. The observed output is lower than is calculated from the properties of the materials used; however, it is anticipated that improved performance can be obtained in future panels. (auth)

NSA 63

12752 (ASD-TDR-62-94) SOLAR THERMIONIC ELECTRICAL POWER SYSTEM. D. L. Cuthbert, D. L. Purdy, E. W. Williams, J. A. Ruff, D. L. Kerr, W. G. Flanigan, R. Luck, Jr., D. Jones, and E. Baum (General Electric Co. Missile and Space Vehicle Dept., Philadelphia). Mar. 1962. Contract AF33(616)-7008. 148p. (AD-277555)

Progress is reported on the design and development of a solar thermionic electrical power system (STEPS). The design objective was to size the system to generate 500 watts of electrical power in space when operating in a simulated orbit over a 35-minute-dark, 55-minute-light cycle. Vacuum thermionic converters were used. The system was to be ground-operated with the hardware as close to flight type as possible. Details of the design, development, fabrication, and performance of the system are included. (auth)

NSA 63

12392 MAXIMUM EFFICIENCY OF A THERMOELECTRIC GENERATOR. Yu.V.Mal'stev. Inzhen.-fiz. Zh. (USSR), Vol. 5, No. 3, 113-17 (March, 1962). In Russian.

The conditions for obtaining the highest efficiency of a thermoelectric generator are given.

ECA 62

1711 (WCAP-1900(Add.)) THERMOELECTRIC NUCLEAR FUEL ELEMENT. Addendum to Final Report. Joseph C. Danko (Westinghouse Electric Corp. Atomic Power Dept., Pittsburgh). Mar. 30, 1962. Contract AT (30-3)-500. 10p.

A twenty-couple fission-heated thermoelectric generator, TE-5, was tested in the Westinghouse Testing Reactor. The open circuit voltage, instantaneous closed circuit voltage, steady state closed circuit voltage, instantaneous closed circuit current, and steady state closed circuit current were monitored during the 23-day cycle. The initial power output was 110 watts (48 amps at 2.3 volts) at a T_H of 660 to 690°C and a T_C of 130°C. After 23 days the output was approximately one watt. (auth)

4638 (AD-274164) HIGH TEMPERATURE THERMOELECTRIC GENERATOR. Quarterly Progress Report No. 2, January 1, 1962 – March 30, 1962. C. M. Henderson and R. G. Ault (Monsanto Research Corp. Dayton Labs., Ohio). Contract AF33(657)-7387. 50p.

The development continued of a 5-watt laboratory thermoelectric generator capable of operating at a hot junction temperature of 1200°C in a vacuum of 0.00001 mm Hg. Fourteen candidate junction materials were screened for use with MCC 50 in the production of thermocouple modules. Of these, C, Mo, and W are being considered for the end product generator. Three methods for fabricating thermocouple modules with MCC 50 were studied and a hot-press/braze method selected for use in the making of modules for the end product. In sublimation rate loss tests conducted for 500 hr at 1200°C at 0.00001 to 0.000001 mm Hg, MCC 50 thermoelectric material lost only 0.53% weight. The rate of sublimation loss appears to decrease with time. Measurements of electrical properties of modules, before and after 100 hr tests at 1200°C, indicate the end product generator can be operated well beyond 1000 hrs, the design goal. Merit factors (Z) of MCC 50, based on extrapolations of thermal conductivity measurements from 1000°C, range from 0.0006 to 0.0011 per degree at 1200 to 1500°C. A 4-module prototype generator unit was constructed and is being tested at 1200°C in a vacuum. (auth)

NSA 63

Prospects for Large-Scale Thermoelectric Power Generation, K.H.SPRING, D.T.SWIFT-HOOK. Brit J Applied Physics v 13 n 4 Apr 1962 p 159-67. It is shown that with conventional fuels thermoelectric device, from economical point of view, can be used only as "topping" device, i.e. which may enable top cycle temperature to be raised; for nuclear reactor in-pile generation, thermoelectric material needs small neutron absorption, stability to radiation, and to be developed to at least ZT=2.

EI 63

Thermoelectric generator protects pipeline. Il Oil & Gas J 60:168 Ap 2 '62

ASTTI 62

O vybore optimal'nogo rezhima kaskadnogo termoelementa, B. Ya.MOIZHES, A.V.PETROV, Yu.P.SHISHKIN, L.A.KOLOMOETS. Zhurnal Tekhnicheskoi Fiziki v 32 n 4 Apr 1962 p 461-72; see also English translation in Soviet Physics, Tech Physics v 7 n 4 Oct 1962 p 336-43. Determination of optimum operating conditions for cascade thermoelectric element; design of cascade thermoelectric generator in which various sections of branches are made of different semiconducting materials which are optimum for given temperatures.

EI 63

6890 PROSPECTS FOR LARGE-SCALE THERMOELECTRIC POWER GENERATION. K.H.Spring and D.T.Swift-Hook. Brit. J. appl. Phys., Vol. 13, No. 4, 159-67 (April, 1962).

A study is made of the possible application of thermoelectric methods to large-scale generation. It is shown that conventional methods of generation using steam plant are much more economic over the temperature range usually associated with this plant. It is further shown that this situation is likely to remain true, even if foreseeable developments in thermoelectric materials (which are discussed) are taken into account. There is no economic case for using thermoelectric materials in a steam condenser to carry out thermodynamic "tailing", but there is some prospect for "topping" above temperatures now currently used in steam cycles. There is a marginal possibility that, as nuclear and thermoelectric technologies develop, direct in-pile thermoelectric generation could become economic.

EEA'62

O vybore optimal'nogo rezhima kaskadnogo termoelementa, B. Ya.MOIZHES, A.V.PETROV, Yu.P.SHISHKIN, L.A.KOLOMOETS. Zhurnal Tekhnicheskoi Fiziki v 32 n 4 Apr 1962 p 461-72; see also English translation in Soviet Physics, Tech Physics v 7 n 4 Oct 1962 p 336-43. Determination of optimum operating conditions for cascade thermoelectric element; design of cascade thermoelectric generator in which various sections of branches are made of different semiconducting materials which are optimum for given temperatures.

EI 62

Vliyanie ob"emnogo zaryada na nagruzochnye kharakteristiki i eds termoelektronnogo preobrazovatelya energii, A.A.OSTROUKHOV. Zhurnal Tekhnicheskoi Fiziki v 32 n 5 May 1962 p 613-25; see also English translation in Soviet Physics, Tech Physics v 7 n 5 Nov 1962 p 445-53. Effect of space charge on load characteristics and emf of thermoelectric energy converter; equations taking into account space charge in vacuum established for I-p; relation between thermo-emf and cathode temperature calculated.

EI 63

Direct generation of electricity; abstract, B. C. Lindley. Metal Prog 81:178-80 My '62

ASTI'62

Modular Solar Thermoelectric Generator (Some Design Criteria and Experimental Results), R.LANG. SAE—Paper 515C for meeting Apr 3-6 1962 10 p. Approach applied by United Aircraft Corp for solving design, manufacturing, and evaluation problems in development of generator for interplanetary vehicles and satellites; system consists of array of many I-v unit cells each lending itself to building block techniques to provide power outputs up to 3 kv; performance characteristics based on 100 hr of testing; study of methods of maintaining alignment between array axis and solar axis.

EI 62

Integrating Isotopic Power Systems, R.T.CARPENTER, D.G.HARVEY. Astronautics v 7 n 5 May 1962 p 30-1, 58-61. Isotopic power system must be physically and mechanically integrated with space vehicle structure and designed to withstand mechanical loads imposed upon it, as part of payload, by launch vehicle; characteristics which cause unique interface problems between isotopic power supply and payload are same characteristics allowing system to fulfill some missions that other power systems cannot; consideration of electrical, thermal and radiative interface problems.

EI'62

Device uses line gas, pays in protection: thermo-electric generator. Il Pet Management 34:274 My '62

ASTI'62

Nuclear Auxiliary Power Unit for Lunar Exploration, R.J.WILSON, A.J.STREB, T.S.BUSTARD. SAE—Paper 515A for meeting Apr 3-6 1962 5 p. Radioisotope-fueled thermoelectric generator is ideally suited to nighttime power requirements of unmanned soft lunar landing experiments; design of generator by Martin Marietta Corp, producing 25 w of electric power and thermal energy for environmental control of electronic components; sufficient curium-242 encapsulated provides operational life of 90-120 days in 30 lb unit extending data gathering capability over conventional power supplies.

EI 62

Thermoelectric Generator Protects 6 Miles of Line. Pipe Line Industry v 16 n 5 May 1962 p 73. Eight watt thermoelectric generator on Pennsylvania pipe line provides sufficient cathodic current to protect 6 1/2 mi of buried, coated 20 in. steel pipe line against corrosion; ground bed is abandoned parallel pipe line; generator is presently developing 1.3 amp of d-c at 2.4-v from burning of 3.9 cu ft of natural gas/hr; life expectancy of unit is over 12 yr.

7642 (AD-276092) SOLAR THERMOELECTRIC GENERATOR SYSTEM CONCEPT AND FEASIBILITY STUDY. Quarterly Report No. 1, February 15, 1962 – May 15, 1962. A. J. Krause, J. L. McCabria, and Dale A. Naumer (Westinghouse Electric Corp., Lima, Ohio). May 15, 1962. Contract AF33(657)-8089. 27p.

A sixty inch government surplus searchlight has been modified for use as a collector concentrator. Problem areas related to thermal energy storage have been brought to light. Operating conditions and power output have been defined through mathematical analysis. An increase in the surface area of the radiator has lowered the operating temperature and increased the expected power output. A preliminary system design has been initiated. Component testing and completion of the system design are planned for the next quarter. (auth) NSA '63

19691 (TID-16052) HIGH ACCELERATION FIELD HEAT TRANSFER FOR AUXILIARY SPACE NUCLEAR POWER SYSTEMS. Quarterly Technical Report, March 1 through May 31, 1962. H. F. Poppendiek, N. D. Greene, H. R. Wright, and A. S. Thompson (Geoscience Ltd., Solana Beach, Calif.). Contract AT(04-3)-409. 27p. (GLR-9)

Research results on liquid metal heat and momentum transfer are presented. A summary of the experimental single- and two-phase (water and air) pressure drop measurements in a single fluted helix is presented; photographic descriptions of the geometrical characteristics of the two-phase flow are also given. The experimental pressure drop results are compared with Martinelli's correlation and the viscous-turbulent separated, two-phase flow pressure drop solution presented in the previous quarterly report. Analytical studies are outlined for the velocity decay of thin laminar and turbulent liquid layers in vortex motion in a circular pipe. The predictions for single-phase flow are compared with experimental decay measurements. Velocity decay solutions for the case where gaseous films exist between the thin rotating liquid layers and the stationary wall are also described. A description is given of the characteristics of the lig heat transfer system whose components are being procured. Equations were derived for void coefficients of reactivity in bare, homogeneous, uniform reactors cooled by boiling liquid metals. It is shown that for a boiling coolant having a fixed ratio of absorption-to-scattering cross section, there is a size of reactor above which the void coefficient is positive and below which it is negative. (auth) NSA '63

Thermoelectric generators made available in commercial line. il Elec Eng 81:379 My '62
ASTI '62

9241 THERMO-ELECTRICAL ENGINEERING. A.G.Heaton.
Proc. Instn Elect. Engrs (GB), Paper 3867, publ. May, 1962 (Vol. 109B, 223-32).

The engineer's interest in thermo-electric phenomena has in the past been mainly confined to devices, based on the Seebeck effect, for the measurement of temperature and r.f. power and radiation by means of thermocouples or thermopiles constructed from metals. Even with the best combination of metals available the use of the Seebeck effect for generation is barely feasible, and the use of the Peltier effect for refrigeration is quite impracticable. The success of germanium and silicon in the production of transistors and junction rectifiers has encouraged the study of the mechanism of electrical and thermal transport in semiconductors. Thus, it has been possible to select potentially efficient thermoelectric alloys and compounds from the vast range of semiconductors available. In the case of bismuth telluride a high figure-of-merit material has been obtained which makes refrigeration of small volumes a practical proposition. A generator efficiency approaching 5% is possible with bismuth telluride in the case where the ideal efficiency would not exceed 25% with temperature limits of 300-400°K. The salient features which emerge indicate the potentialities of bismuth telluride for the generation of power and heat pumping, in particular refrigeration of small volumes and local cooling. The paper is based on work carried out by the author on the engineering applications of bismuth telluride. EEA '62

Generation of electricity by unconventional methods; thermo-electric generators. H. Billett and others. diags Combustion 33:33-5 My '62
ASTI '62

12390 THERMOELECTRIC APPLICATIONS TO INDUSTRIAL PROBLEMS. J.C.R.Kelly, Jr.
IRE Trans industr. Electronics (USA), Vol. IE-9, No. 1, 61-5 (May, 1962).

The efficiency and durability of thermocouples have been improved by recent research and development. This has led to a number of prototype applications for both cooling and power generating devices. The inherent characteristic of a thermoelectric system that lends itself to easy modular design and adaptation is the thermocouple itself. Each couple may be rated by watts of power produced or consumed. Examples of a number of different applications are given. EEA '62

80,293 FLAT-PLATE SOLAR THERMOELECTRIC CONVERSION PANELS
Himle, A. N., Brush, D. S., Roes, J. B., Brady, E. L.
(General Dynamics Corp., General Atomic Div., San Diego, Calif.)
May 1962
Aeronautical Systems Division, Flight Accessories Lab., Wright-Patterson AFB, Ohio
ASD TDR 62-214

Procedures have been developed for the construction of a lightweight solar energy converter, using thermoelectric materials sandwiched between flat sheets of aluminum. Two panels, each one foot square, were delivered to the Flight Accessories Laboratory, Aeronautical Systems Division. Each panel contains 153 *n*-type PbTe elements and 153 *p*-type ZnSb elements, arranged in eighteen alternating rows of seventeen elements each. The panels are capable of an output of at least 1.33 w/ft² when subjected to an incident energy of 1400 w/m², which is equal to the solar energy intensity at the Earth's distance from the Sun. At this output, the solar panel weighs 96 lb per electrical kilowatt.

Power for experiments on moon could come from curium-242-fueled apu; abstract. R. J. Wilson and others. diag S A E J 70:98 Je '62

ASATTI '62

Array of tiny units forms solar-thermoelectric generator; abstract. R. Lang. il S A E J 70:96-7 Je '62

ASTTI '62

12395 EFFECTS OF SURFACE HEAT TRANSFER ON THE PERFORMANCE OF A THERMOELECTRIC GENERATOR. L.J.Ybarrondo and J.E.Sunderland.
Solid-State Electronics (GB), Vol. 5, 143-54 (May-June, 1962).

Analytical solutions are given for the steady-state temperature distribution, power output, and efficiency of a thermoelement which is used in a thermoelectric power generator. The longitudinal surface of the thermoelement is divided into three regions. The first region is exposed to convection with the environment at the cold junction; the second region is thermally insulated; the third region is exposed to convection with the environment at the hot junction. The relative sizes of the three regions are variable. The solutions are useful for predicting the performance of thermoelectric power generators and for showing the improvements in performance that can be gained through the use of surface heat transfer. It is shown that substantial increases in the power output can be gained if the thermoelements are exposed to surface heat transfer. It is possible to use surface heat transfer to reduce greatly the amount of fin surface needed at the hot and cold junctions. A numerical example is presented in which no fins are used at the hot and cold junctions; it is shown in this example that by using surface heat transfer, 97% of the maximum theoretical output can be achieved.

EEA '62

2790 EXPERIMENTAL THERMOELECTRIC GENERATOR SNAP-3. J.Gajewski.
Przegląd elektrotech. (Poland), Vol. 38, No. 6, 252-4, (June, 1962). In Polish.

The generator was designed for the USA Atomic Energy Commission. It found wider application in coastal navigation, meteorological, communication relay stations etc. They may be driven by different isotopes according to the application. In the prototype a thermal source ^{210}Po was used. At the time of the half life the following data existed: radiation source 2100 c, energy (thermal) 69 W, electrical energy 4 W. The temperature of hot and cold junctions was 621° and 116°C respectively. The thermoelectric unit is described as well as application of SNAP-3 for navigational purposes.

M.W.Makowski
EEA '63

542 THE CONVERSION OF THERMO-PHOTO-ELECTRIC ENERGY. A.Fortini.
Onde elect. (France), Vol. 42, No. 3, 530-40 (June, 1962). In French.

Treats solar energy conversion on a theoretical basis showing silicon as the most useful conversion medium and analyses a PINI cell as developed from PN junction by the addition of an intermediary material to increase the life of electron holes from 10 μ, to 500 to 1000 μ, for germanium. The cell characteristics are discussed under open and short circuit conditions, with respect to series resistance losses and output. Describes a thermo-photoelectric convertor having an ellipsoidal shape with a heat source and a cell at the two focal points and a filter at the minor axis which, with a major axis of 10 cm produces 50 W output for very little input.

R.W.J.Cockram
EEA '63

✓6222 EFFECTS OF SURFACE HEAT TRANSFER ON THE PERFORMANCE OF A THERMOELECTRIC GENERATOR. L. J. Ybarrondo and J. E. Sunderland (Northwestern Univ., Evanston, Ill.). Solid-State Electron., 5: 143-54(May-June 1962).

Analytical solutions are given for the steady-state temperature distribution, power output, and efficiency of a thermoelement which is used in a thermoelectric power generator. The longitudinal surface of the thermoelement is divided into three regions. The first region is exposed to convection with the environment at the cold junction; the second region is thermally insulated; the third region is exposed to convection with the environment at the hot junction. The relative sizes of the three regions are variable. The solutions are useful for predicting the performance of thermoelectric power generators and for showing the improvements in performance that can be gained through the use of surface heat transfer. It is shown that substantial increases in the power output can be gained if the thermoelements are exposed to surface heat transfer. It is possible to use surface heat transfer to reduce greatly the amount of fin surface needed at the hot and cold junctions. A numerical example is presented in which no fins are used at the hot and cold junctions; it is shown in this example, that, by using surface heat transfer, 97 per cent of the maximum theoretical output can be achieved. (auth) NSA '63 /

Effects of Surface Heat Transfer on Performance of Thermoelectric Generator, L.J.YBARRONDO, J.E.SUNDERLAND. Solid-State Electronics v 5 May-June 1962 p 143-54. Analytical solutions for steady-state temperature distribution, power output, and efficiency of thermoelement used in thermoelectric power generator; solutions are useful for predicting performance of generators and for showing that substantial improvements in performance can be gained through use of surface heat transfer; it is possible to use surface heat transfer to reduce greatly amount of fin surface needed at hot and cold junctions. EI 63

23489 THERMOELECTRIC NUCLEAR CONVERTORS USING SEMICONDUCTORS. Nguyen Van Dong.
Onde elect. (France), Vol. 42, 517-22 (June, 1962). In French.

The results of Rodot's calculations (see preceding abstract) on thermoelectric generators introduce a discussion on the use of these generators for converting the energy from radionuclides and nuclear reactors directly into electricity. A battery which uses the radionuclide Po^{210} is described and a plan for a system powered by a nuclear reactor is outlined. The author considers that future progress may lie in operating at much higher temperatures.

L.M.Roberts
PA '62

AD-296 193 Div. 7, 8
(TISTE/OHD) OTS price $12.00

General Electric Co., West Lynn, Mass.
VOLTAGE REGULATION AND CONVERSION IN UNCONVENTIONAL ELECTRICAL GENERATOR SYSTEMS.

Progress rept. nos. 1-2, 1 Jan-30 June 62. 30 June 62, 166p. incl. illus. tables, 5 refs. (Contract NOw 62-0984-d; Continuation of Contract NOw 60-0824-c)

Unclassified report

DESCRIPTORS: *Electric power production, *Voltage regulators, *Fuel cells, *Thermoelectricity, Design, Transients, Switching circuits, Transistors, Weight, Mathematical analysis, Capacitors, Coils, Circuits, Magnetic cores, Stability, Transformers, Inverters.

The study of voltage regulation and conversion in unconventional electrical generator systems is presented. The approach and work plans for the complete study are given. The progress to date in developing a light-weight, efficient dc-to-dc circuit known as the flyback circuit is included. Information giving the results to date in a high-frequency switching investigation aimed at reducing circuit weight is presented. A discussion of power transistor characteristics pertinent to voltage conversions circuits is included. Design data permitting the design of a minimum weight inductor or transformer for any given power loss is given. (Author)

Direct Conversion Thermoelectric Reactors Studies, J.C.DANKO, G.R.KILP, E.G.SCHWARTZ. Nuclear Eng & Science Conference, 7th New York City, June 4-7 1962—Paper 11 31 p. (Published by Engrs Joint Council, New York). Westinghouse Atomic Power Dept initiated studies on combining merits of thermoelectric power generation with those of nuclear reactor heat source; reactor was light water cooled and moderated; thermoelectric nuclear fuel element consists of electrical series of N- and P-type PbTe positioned around nuclear fuel material; juncture between element cladding and PbTe becomes hot junction while reactor coolant establishes cold juncture. EI 62

✓19888 THERMOELECTRIC SOLAR CONVERTERS. Nguyen Thien Chi.
Onde elect. (France), Vol. 42, 554-62 (June, 1962). In French.

A theoretical analysis of the planar thermoelectric solar energy converter, including a detailed discussion of the practical factors likely to reduce the efficiency of the device. In spite of these (which include atmospheric contamination of the transparent face of the cell, re-radiation from the components of the cell, the parasitic resistance of the thermo-junctions and the limitations imposed by the external circuit) planar converters offer certain advantages over cells which require the solar radiation to be focused on them. It is estimated that under good sunshine conditions powers of about 9 W/m^2 can be obtained; during a whole day, about 40 Whr/m^2 might be expected.

C.H.B.Mee
PA '62

14448 THERMOELECTRIC NUCLEAR CONVERTORS USING SEMICONDUCTORS. Nguyen Van Dong.
Onde elect. (France), Vol.42, 517-22 (June, 1962).In French.

The results of Rodot's calculations (see preceding abstract) on thermoelectric generators introduce a discussion on the use of these generators for converting the energy from radionuclides and nuclear reactors directly into electricity. A battery which uses the radionuclide Po^{210} is described and a plan for a system powered by a nuclear reactor is outlined. The author considers that future progress may lie in operating at much higher temperatures. L.M.Roberts
EEA '62

19890 EFFECTS OF SURFACE HEAT TRANSFER ON THE PERFORMANCE OF A THERMOELECTRIC GENERATOR. L.J.Ybarrondo and J.E.Sunderland.
Solid-State Electronics (GB), Vol. 5, 143-54 (May-June, 1962).

Analytical solutions are given for the steady-state temperature distribution, power output, and efficiency of a thermoelement which is used in a thermoelectric power generator. The longitudinal surface of the thermoelement is divided into three regions. The first region is exposed to convection with the environment at the cold junction; the second region is thermally insulated; the third region is exposed to convection with the environment at the hot junction. The relative sizes of the three regions are variable. The solutions are useful for predicting the performance of thermoelectric power generators and for showing the improvements in performance that can be gained through the use of surface heat transfer. It is shown that substantial increases in the power output can be gained if the thermoelements are exposed to surface heat transfer. It is possible to use surface heat transfer to reduce greatly the amount of fin surface needed at the hot and cold junctions. A numerical example is presented in which no fins are used at the hot and cold junctions; it is shown in this example that, by using surface heat transfer, 97% of the maximum theoretical output can be achieved.

PAG2

14449 THERMOELECTRIC SOLAR CONVERTERS. Nguyen Thien Chi.
Onde elect. (France), Vol.42, 554-62 (June, 1962). In French.

A theoretical analysis of the planar thermoeletric solar energy convertor, including a detailed discussion of the practical factors likely to reduce the efficiency of the device. In spite of these (which include atmospheric contamination of the transparent face of the cell, re-radiation from the components of the cell, the parasitic resistance of the thermo-junctions and the limitations imposed by the external circuit) planar convertors offer certain advantages over cells which require the solar radiation to be focused on them. It is estimated that under good sunshine conditions powers of about 9 W/m^2 can be obtained; during a whole day, about 40 Whr/m^2 might be expected.

C.H.B.Mee

EEA'62

AD-281 859L Div. 7, 12
(TISTA/SEB)

General Atomic Div., General Dynamics Corp., San Diego, Calif.
LIQUID-METAL-HEATED, THERMOELECTRIC, SPACE POWER SYSTEM.
Monthly rept. no. 1,
by R. Campana. June 62, 10p. (Rept. no. GACD-3290)
(Contract NOw 62-0841-c)
Unclassified report

Notice: Only government agencies may request from ASTIA. Others request approval of Bureau of Naval Weapons, Navy Dept., Wash. 25, D. C.

DESCRIPTORS: *Thermoelectricity, Liquid metals, Space flight, Generators, Magnets, Pumps, Design, Materials, Voltage regulators, Sodium, Potassium, Power supplies.

62-

21369 (NAA-SR-Memo-7573) THERMAL ANALYSIS OF R-C 13, LAUNCH PHASE. P. W. Johnson (Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.). July 18, 1962. Contract [AT(11-1)-Gen-8]. 50p.

Aerodynamic heating of the SNAP-2 radiator-condenser is an important design consideration. Heat creating temperatures in the 550 to 900°F range will rule out many optimum weight configurations. The effects of aerodynamic heat on the temperatures of twenty-seven specific cases of an Al-steel radiator-condenser are summarized. The maximum skin temperatures and skin-tubing differential temperatures are presented to aid in the selection of an optimum design. Future design work will be assisted by the plots of "heat sink" values as a function of temperature. In the past, various radiator-condenser designers used a minimum value of 0.2 $BTU/ft^2 \cdot F$; the included plot indicates the validity of this assumption. Other heat sink values ranging from 0.145 to 0.267 are presented with their maximum skin temperatures at various radiator-condenser stations. (auth)

NSA '63

2627 (MND-P-2483-7) SNAP 7 PROGRAM — TASK 8 — STRONTIUM-90 FUELED THERMOELECTRIC GENERATOR DEVELOPMENT. Quarterly Progress Report No. 7, May 1 through July 31, 1962. W. A. McDonald (Martin-Marietta Corp. Aerospace Div., Baltimore). Contract AT(30-3)-217. 20p.

The effort on SNAP 7A and 7C was confined to operating the reliability model. There were fluctuations in output power that can be attributed to variations in the operating parameters, plus an increase in the internal resistance. In the SNAP 7B project the second 60-watt generator was completed and has undergone the beginning-of-life (maximum input, helium gas) portion of the parametric tests. The performance was nearly identical to that of the first 60-watt generator. The unit will be used with the SNAP 7B system. The installation concept for the SNAP 7B system was approved by the U. S. Coast Guard. The generator is to be housed in a finned aluminum container that will provide the required radiator surface. This container will be filled with a water-ethylene glycol mixture that is necessary to transfer the heat from the generator into the container. The battery-converter compartment is an integral part of the container lid. During the time the entire SNAP 7D system was subjected to shock and vibration tests, no mechanical or functional deficiencies were detected. The required temperature tests followed the mechanical tests. During this period the complete system was operated at maximum intermediate and minimum temperatures. Design objectives were satisfied throughout the test. The SNAP 7D generator was fueled at Oak Ridge National Laboratory (ORNL) on June 12, 1962, with a total thermal input of 1435 watts. The fueled generator was returned and integrated with the system. The system was demonstrated and accepted on July 3, 1962. (auth)

NSA '63

Radioisotope-fueled thermoelectric generators. W. E. Kershaw. diag Electro Tech 70:12-13 Jl '62

ASVTF'62

Thermoelectric Generators for Cathodic Protection, E.P.DOREMUS, F.B.THORN, Jr. Oil & Gas J v 60 n 33 Aug 13 1962 p 111-13, 115. Results of 10-mo operation of 8-w thermoelectric generator installed on pipe line show that packaged units available offer reliable current source for cathodic protection installations; thermoelectric generators may be used in series or in parallel for higher driving voltages or higher current output; comparative outputs for magnesium, duriron, and steel groundbeds with that obtained by using resistive load equal to measured resistance of groundbed. EI 163

9140 THERMOELECTRIC ELEMENTS HAVING GRADED ENERGY GAP. Fred D. Rosi (to Radio Corp. of America). U. S. Patent 3,050,574. Aug. 21, 1962.

The thermoelectric generator comprises two circuit members of thermoelectrically opposite semiconductor materials. The two members form a thermoelectric junction, at least one of the members having a varying composition such that its energy gap is graded from one end to the other. (R.J.S.) NSA 163

Thermoelectric generators off-the-shelf tool for cathodic protection. E. P. Doremus and F. B. Thorn, Jr. il Oil & Gas J 60:111-13+ Ag 13 '62

Thermoelectric generators with surface heat loss. H. B. Nottage and others. bibliog diags A S M E Trans ser C 84:193-204; Discussion. C. N. Rollinger. 204-6 Ag '62

AS & TI 163

AD-404 893 Div. 8
(TISTP/FR) OTS price $4.60

Army Electronics Research and Development Lab., Fort Monmouth, N. J.
DESIGN AND EVALUATION OF THERMOELECTRIC THERMAL BARRIER FOR MICRO-MODULES,
by Robert D. FitzGerald and Herbert C. Frankel.
Sep 62, 37p.
DA Task 3A99 15 002 03
USAELRDL TR2308

Unclassified report

Descriptors: *Thermoelectricity, Cooling, Heat transfer, Temperature, Miniature electronic equipment.

Use of a specific Peltier temperature control device, called a 'thermoelectric thermal barrier, to protect heat-sensitive electronic circuit elements from closely associated heat-producing elements in a microelectronic assembly is discussed. Test results on a simulated binary divider micro-module indicate the feasibility of the thermoelectric thermal barrier approach. Experimental results with a simulated micro-module operating at temperatures between 25 C and 95 C indicate that it is possible under certain circumstances to protect a heat-sensitive element from a heat-generating element within the same micro-module by means of a small, low current Peltier device built directly into the micro-module between these elements. (Author) '63

19687 (NAA-SR-7797) SNAP AEROSPACE SAFETY PROGRAM QUARTERLY TECHNICAL PROGRESS REPORT, JULY-SEPTEMBER 1962. (Atomics International. Div. of North American Aviation. Inc., Canoga Park, Calif.). Mar. 20, 1963. Contract AT(11-1)-Gen-8. 56p.

Statements are presented concerning project objectives, major accomplishments in FY 1962, progress during the report period, evaluation of effort to date, and next report period activities. The subject material covers reactor separation and fuel element ejection, reactor transient and excursion tests, reactor end-of-life shutdown devices, fission product release studies, critical configuration tests, mechanical and thermochemical effects, and fuel element burnup and fission products dispersal. Major emphasis for the period was concentrated on the design of the SNAPTRAN 2/10A-1 and -2 machines and the models for the Reentry Flight Demonstration (RFD-1). Planning of the SNAPTRAN experimental program was undertaken. Analytical effort was concentrated on developing the several computer codes required for interpreting and understanding the data acquired or to be acquired from the experiments. The majority of the Phase I mechanical and thermochemical effects test program was completed. A few fission product releases were conducted at the NRTS. Necessary test apparatus for the water immersion critical experiment was designed and fabricated. (auth) NSA 163

2559 THERMOCOUPLE ELECTRIC MOTORS. J.E.C.Stringer.
Nature (GB), Vol. 195, 988-9 (Sept. 8, 1962).

The motor described operates from a single massive iron-constantan couple of 520 μohms. Excitation is provided by a cylindrical loud-speaker magnet with poles arranged to form a concentric air gap. In this gap rotates an open-ended copper cylinder, contact to its centre and edge being by means of mercury pools. The motor starts to run at a hot-junction temperature of 100°C and with a temperature of 700-800°C develops 1·4 W. Suggestions are made for improving the performance.

F.G.Spreadbury
EEA '63

Cathodic protection with a thermoelectric generator. L. Stoll. il diags Gas 38:65-9 S '62

Thermoelectric-generator design. T. M. Corry and G. Spira. diags Electro Tech 70:156+ S '62

AS & TI 163

80,695 DEVELOPMENT OF A PHOTOEMISSIVE SOLAR ENERGY CONVERTER

Fowler, P., Koller, L. R., Scharank, M. P. (National Research Corp., Cambridge, Mass.)

September 1962

Aeronautical Systems Division, Directorate of Aeromechanics, Wright-Patterson AFB, Ohio

ASD TDR 62-600

The characteristics of a photoemissive solar energy converter were studied. The practical form of this device is a perforated sheet of a dielectric such as polyethylene terephthalate resin coated with a photoemitter on one side and with a low work function conductor on the other. Photoelectrons emitted from the front surface by solar radiation fall back through the holes and are collected on the back surface. The resulting charge transfer builds up a potential difference which may be employed to perform useful work. Models were constructed and tested in evacuated glass envelopes of ultraviolet-transmitting glass using a xenon arc as a solar simulator. Findings and conclusions are given.

AD-286 567 Div. 7
(TISTP/FR) OTS price $3.60

Foreign Tech. Div., Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.
EXAMPLES OF THERMOELECTRIC DEVICES (CHAPTER IV), by A. F. Ioffe. 12 Sep 62, 32p. incl. illus. tables (Trans. no. FTD-TT-62-226 from Poluprovodnikovyye Termoelementy, IZDVO AN SSSR, Moscow pp. 126-153 (Chapter IV) 1960)
Unclassified report

DESCRIPTORS: *Thermoelectricity, Power supplies, Cooling, Refrigeration systems, Microtomes, Hygrometers, Thermometers, Crystallization, Materials.

Contents:
Thermoelectric generators
Refrigerators
Microtome
Thermode
Microscope stage
Condensation hygrometer
Heating and air conditioning
Meters for radiant fluxes and heat flows
Surface temperature measurement
Crystallization
High-temperature thermoelements

'63

70,560 PRELIMINARY DESIGN ANALYSIS OF SOLAR-POWERED, LONG DURATION SPACE POWER SYSTEMS FOR A POWER RANGE OF 1 TO 25 KW

Barber, R. E., Mullaney, J. E., Bailey, R. N. (Sundstrand Aviation-Denver, Colo.)

American Rocket Society, Inc., New York, N.Y.

2569-62

(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25–28, 1962)

A generalized weight estimate of the solar concentrator, heat receiver, support and deployment structure, and orientation system is presented for the power range 1 to 25 kw. A weight estimate of the combined power unit and radiator is presented for four example solar energy space power systems over the power range considered. The four example systems are (1) rubidium, Rankine cycle–turbine prime mover; (2) biphenyl, Rankine cycle–turbine prime mover; (3) steam, Rankine cycle–free piston prime mover; and (4) xenon, Brayton cycle–turbine prime mover.

70,319 FLAT PLATE SOLAR THERMOELECTRIC GENERATOR SYSTEM CONCEPT
Glassburn, C. W. (Aeronautical Systems Division, Wright-Patterson AFB, Ohio)
American Rocket Society, Inc., New York, N.Y.
2573-62
(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25–28, 1962)

Details are presented of flat-plate solar thermoelectric generator research results. The concept operation is discussed from a systems standpoint. Systems factors and potential are based on completed research and the author's estimate of concept potential if the concept is developed to the point where operational feasibility is established.

70,561 A MODULAR SOLAR THERMONUCLEAR POWER SUPPLY SYSTEM
Lang, R., Lubin, B. (United Aircraft Corp., Windsor Locks, Conn.)
American Rocket Society, Inc., New York, N.Y.
2574
(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25–28, 1962)

A modular solar thermoelectric power supply system which includes thermal energy storage and orientation devices is reviewed. The incorporation of concepts outlined is expected to contribute to long life requirements of communication and weather satellites. Thermal storage is compared with other systems for supplying continuous power.

106934 HIGH TEMPERATURE THERMOELECTRIC GENERATOR
(Period covered: September 30, 1961-September 30, 1962)
Henderson, C. M.; Ault, R. G., (et al)
October 1962
Monsanto Research Corp.
AF 33(657)-7387
Report

UNCLASSIFIED
Unclassified
(Air Force Dept. ASD-TDR-62-896)

Research and development of a laboratory type high-temperature thermoelectric generator having a nominal output of 5 watts at a hot-junction temperature of 1200°C and a cold-junction temperature of 700°C in a vacuum is described. Based on the modular concept, the generator is comprised of 9 series-connected sections of three parallel-connected modules each.

AD-293 986 Div. 7, 13
(TISTE/OHD) OTS price $3.60

Battelle Memorial Inst., Columbus, Ohio.
MULTIFUELED THERMAL-ENERGY-CONVERSION SYSTEMS.
Quarterly progress rept. no. 1, 1 July-30 Sep 62,
by H. R. Hazard, D. A. Trayser and others.
Sep 62, 32p. incl. illus. tables, 14 refs.
(Rept. no. 1)
(Contract DA 36-039-sc-90838, Proj. 3A99-09-001)
Unclassified report

DESCRIPTORS: *Electric power production, *Gas generating systems, *Thermoelectricity, *External combustion engines, Laboratory furnaces, Wood, Coal, Fuels, Internal combustion engines, Analog computers, Tellurides, Bismuth compounds, Germanium compounds, Selenides, Semiconductors, Lead compounds, Thermocouples.

Operating and control characteristics of several combustion chambers for solid fuels were studied experimentally. It was possible to maintain a uniform exit-gas temperature of 1150 C over a period of several hours in a self-feeding unit fired with green wood or charcoal. This permits heat flux consistent with usual practice in design of thermoelectric generators, at about 4.5 thermal watts/sq. cm., with moderate pressure drop for heat transfer. Design studies of a Stirling-cycle air engine are in progress, and thermoelectric properties of several combinations of semiconductive thermoelectric materials were studied. Research on these studies will continue, followed by studies of vapor-cycle engines and metallic-thermocouple systems. (Author)

'63

R1602 PORTABLE GENERATOR UTILIZING DIRECT CONVERSION OF HEAT TO ELECTRICITY. Gilbert W. Meyers (to North American Aviation, Inc.). U. S. Patent 3,056,848. Oct. 2, 1962.

A fuel-fired portable generator is designed which has a long lifetime, is resistant to mechanical shock, and can be operated for long periods of time under subzero weather conditions. The generator uses thermoelectric devices to effect the conversion of thermal to electric energy. Gasoline is used as fuel, and the output is 30 watts and 6 volts for 12-hr continuous operation. The lifetime is 1000 hr with 12 hr on-12 hr off cycle. (D.L.C.) NSA '63

Measurements on Vacuum Thermo-Electric Generator, M.OZAWA, T.MORITA, K.OGASAWARA. Electrotech Laboratory (Tokyo) —Bul v 26 n 10 Oct 1962 p 752-8. Results for W and Th-W electrodes in vacuum; emitter and collector are separately heated to 600-2400 C by Joule heat, and interelectrode distance is kept between 3/100 and 10/100 mm; for constant temperature of collector there is certain temperature of emitter at which its induced voltage is minimum and is even lower than that of collector; in thermoelectron generator with W-emitter, changing collector material from W to Th-W results in 0.8 v increase in induced voltage. In Japanese with English abstract.
EI 63

18264 (NAA-SR-6309) THE SNAP II POWER CONVERSION SYSTEM. TOPICAL REPORT NO. 17. MERCURY BOILING RESEARCH. R. G. Gido and Alfred Koestel (TAPCO. Div. of Thompson Ramo Wooldridge Inc., Cleveland). Oct. 1962. For Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif. Contract AT-11-1-GEN-8, Subcontract N843FS-101221. 184p. (TRW-ER-4833)

Activities in a boiling research program to provide data on heat transfer and pressure drop during vortex once-through forced convection boiling of Hg are reported. A test rig was built for test section configurations with swirl wire inserts; or in one case, a bare tube. Efforts were made during the testing of one swirl wire test section to obtain data on the independent effect of temperature difference, pressure level, flow rate, and quality level on heat transfer rate. The data are correlated according to forced convection vortex boiling theory. The data are meant to form part of the basis for improved design of SNAP II and similar boilers. (J.R.D.) NSA '63

1603 THERMOELECTRIC GENERATOR. Jan Forman (to Burroughs Corp.). U. S. Patent 3,056,912. Oct. 2, 1962.

A thermionic generator is designed which has means for heating the anode (collector electrode) to increase the electron discharge current between the cathode (emitter electrode) and the anode. The anode is heated to a temperature above 400°C but less than 90%, on an absolute temperature scale, of that of the cathode. (D.L.C.) NSA '63

70,540 RADIONUCLIDE POWER SOMETHING NEW UNDER THE SUN
Morse, J. G.
Interavia, v. 17, no. 10, pp. 1301–1303, October 1962

The principles involved in the operation of thermoelectric converters which use nuclear heat are described. *SNAP* generators are discussed in relation to present applications, specifications, and operational characteristics.

Back pack thermoelectric generator under development. Il Elec Eng 81:809 O '62
ASTI '63

3605 MOBILITY AND THERMOELECTRIC POWER IN MANY-VALLEY POLAR SEMICONDUCTORS. Doris J. Olechna and H. Ehrenreich (General Electric Research Lab., Schenectady, N. Y.). Phys. Chem. Solids, 23: 1513-20(Nov. 1962). (In English)

The mobility, μ, and the thermoelectric power, Q, were calculated variationally for polar semiconductors having ellipsoidal energy surfaces in which the polar electron phonon interaction is dominant. Equations applicable to both Fermi and Boltzmann statistics are presented. Numerical results for μ and Q for the latter case are given as a function of temperature for varying degrees of ellipticity. These show that the thermoelectric power is relatively insensitive to changes in ellipticity. A simple approximate formula for the mobility given previously is shown to agree well with the results of the variational method. (auth) NSA '63

20174 (TID-17707) HIGH ACCELERATION FIELD HEAT TRANSFER FOR AUXILIARY SPACE NUCLEAR POWER SYSTEMS. Quarterly Technical Report, September 1 to November 30, 1962. H. F. Poppendiek, N. D. Greene, F. R. MacDonald, and H. R. Wright (Geoscience Ltd., San Diego, Calif.). Contract AT(04-3)-409. 42p. (GLR-11).

A detailed description is presented of the completed design for the experimental boiling and condensing liquid-metal heat transfer system. The experiments can be conducted with either mercury or potassium. Photographs and drawings show the important system components (preheater, boiler, condenser, subcooler, storage tanks, separator, instrumentation systems, etc.). A discussion is given of high temperature containment and material compatibilities problems in addition to the estimation of argon solubility in liquid metals. The results of some mercury safeguard studies are summarized. Several analytical heat and momentum transfer studies were conducted. One investigation describes simultaneous heat transfer and fluid flow under zero gravity, forced flow film boiling or condensation in a tube. Other studies define the velocity decay of thin, rotating liquid layers in stationary tubes whose walls are separated from the liquid layers by a thin, viscous gas film. These solutions can be used to predict heat transfer and fluid flow in high vapor quality boiling and condensing Rankine cycle space power plants. (auth) NSA '63

3546 THE PROBLEM OF ELECTRIC JET ENGINES AND DIRECT CONVERSION OF THE HEAT ENERGY INTO ELECTRICAL. A.E.Kaplyanskii.
Elektrichestvo (USSR), 1962, No. 11, 7-13 (Nov.). In Russian.

Under the general heading of improvement of efficiency of the thermo-electric stations and design of engines for distant cosmic flights the following topics are discussed: (i) direct conversion of the thermal energy into electrical: the properties of special-to-purpose generators are stated; (ii) distant cosmic flights: design problems of engines for space crafts are examined. Acceleration, velocity and trajectories of these crafts are analysed neglecting, for simplicity, the aerodynamic resistance of the earth's atmosphere; (iii) the principles of operation of the electric jet engines and generators of the new type are stated and classified into the following: electrothermal jet engines, magnetic-plasma machines and electro-ion machines. Z.F.Voyner
EEA '63

AD-291 432 Div. 7
(TISTM/BRW) OTS price $3.60

Westinghouse Electric Corp., Lima, Ohio.
SOLAR THERMOELECTRIC GENERATOR SYSTEM CONCEPT AND FEASIBILITY STUDY.
Quarterly rept. no. 3, 15 Aug-15 Nov 62, by A. J. Krause and J. L. McCabria. 15 Nov 62, 33p. incl. illus.
(Contract AF 33(657)8089, Proj. 8173)
Unclassified report

DESCRIPTORS: *Thermoelectricity, Solar energy, Power supplies, Generators, Thermocouples, Heat exchangers, Design, Feasibility studies.

A heat-exchanger has been assembled and tested to determine the performance of the waste heat radiator and to determine the heat losses from the thermoelectric power converter. A thermoelectric module efficiency tester was built and a typical section of thermopile was tested. The test results show that the power required by the thermocouples is 30% greater than anticipated. The power input is greater than anticipated since the efficiency of the couple is 15% lower and the power out is 13.9% greater than the calculated values. Delays are still being encountered in the thermal energy storage system. (Author) '63

Alternating Current Thermoelectric Generator, H.B.NOTTAGE, P.L.WINSKELL. ASME—Paper 62-WA-157 for meeting Nov 25-30 1962 20 p. Analytical formulation of design and performance of a-c thermoelectric generator utilizing periodic flow of heat across surface, with thermoelectric conductors in form of deposited films or ribbons woven through dielectric sheet; efficiency of thermoelectric generator is formulated in manner which will lead to payoff optimizations in accord with various application criteria. EJ '63

20282 THE WINNING OF ELECTRICAL ENERGY FROM RADIOACTIVE ISOTOPES. P. Wenzel. Energietecknik, 12: 504-7(Nov. 1962). (In German)

After detailed statements of general viewpoints, such as the selection of suitable isotopes, the various well-known nuclear batteries are described. (tr-auth) NSA '63

AD-404 193 Div. 7, 17, 26
(TISTE/JBM) OTS price $7.60

Tyco Inc., Waltham, Mass.
POWER DEFENSE THERMOELECTRIC MODULE.
Interim rept., 3 July 61-2 Nov 62.
ed. by Martin Weinstein. 2 Nov 62, 65p.
Contract NObs86015,

Unclassified report

Descriptors: *Thermoelectricity, *Generators, Mechanical properties, Lead alloys, Tellurium alloys, Bonding, Ultrasonic radiation, Temperature, Thermocouples, Resistance (Electrical), Diffusion, Fixed contacts, Metallurgy, Electrodes, Iron, Oxidation, Chemical milling, Weight, High temperature research, Electric potential, Power, Sodium, Manufacturing methods, Processing, High pressure research, Thermal conductivity, Extrusion, Sintering, Effectiveness.

Efforts concerned optimizing the power-to-weight ratio of a lead telluride thermoelectric generator by developing bonding techniques and material preparation processes. A technique which utilizes a SnTe braze, was developed for bonding P and N-type PbTe to pure Fe electrodes. Contact resistances fall in the range of [illegible] - 15 micro-ohm per sq. cm. A bonding technique involving the interdiffusion of Fe and N-type PbTe at 850 C was developed. Contact resistances fall in the range of 10 - 20 micro ohm per sq. cm. N-type PbTe directionally solidified under the influence of ultrasonic oscillations was found to possess mechanical properties superior to presently available material. Bonded and unbonded PbTe were found to be capable of sustaining, without any visible damage, a temperature gradient of 510 C for over 250 hours. (Author)

'63

24724 (AI-7950) APPLICATION OF SNAP 2 TO MANNED ORBITAL SPACE STATIONS. H. N. Rosenberg, ed. (Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.). Dec. 16, 1962. 90p.

The results of a study of the installation and operational characteristics of a SNAP reactor system integrated with a manned space station are presented. The reference system selected was an 11 kw(e) version of a SNAP 2 system employing multiple power conversion units coupled to a single reactor source. Of prime importance is the reactor radiation shield required for the manned system and the use of design features which minimize the shield weight. The weight of the radiation shield is highly dependent upon the geometrical configuration of the space station and the reactor since "shadow" shielding of the manned compartments is required for minimum weight systems. The installation and shielding requirements of the 11 kw(e) system were considered for two types of space station configurations; one was a 10 ft dia cylindrical station with a reactor separation distance of 50 ft and the other a 150 ft dia toroidal station with the reactor located in the hub. The weight of the power system installed in the cylindrical space station was about 9000 lb of which 6000 lb was required for shielding. The weight of the system for a toroidal station was ~25,000 lbs of which 20,000 lbs was required for shielding. However, these weights are relatively insensitive to power level and doubling or tripling the power output will only increase these weights by a small percentage. In addition, the designs developed for these two concepts permit the replacement of the reactor and power conversion system with the radiation shields becoming essentially a permanent part of the space station. Hence the large weight penalty associated with the reactor shield only has to be incurred once during the life of the space station. Because of the dominance of the reactor shield weights for manned systems, parametric curves of shielding weight are presented to enable the space vehicle designer to estimate nuclear power system weights for configurations other than those selected in this report. (auth)

NSA 63

3103 THERMOELECTRIC GENERATOR. Henry L. Imelmann. (to Thermo Power, Inc.). U. S. Patent 3,064,063. Nov. 13, 1962.

A simple and compact apparatus is described for converting heat directly into electric energy. Relative movement between the heat source and the junctions defining the thermoelectric generator occurs so as to efficiently utilize the heat source for heating the junctions. (R.J.S.)

NSA 63

8313 THERMOELECTRIC GENERATOR WITH ENCAPSULATED ARMS. William J. van der Grinten and Erwin Fischer-Colbrie (to General Electric Co.). U. S. Patent 3,070,644. Dec. 25, 1962. Filed Feb. 11, 1960.

Attempts are made to improve the thermal, mechanical, and compositional stability, as well as the electrical performance, of a thermoelectric generator. The particular generator involved is a static device for converting heat to direct current electricity without the use of moving parts. The individual thermocouple arms in the generator are encapsulated so that all surfaces of the thermoelectric materials are sealed. Encapsulated arms are produced which form generator pairs with superior stability. (R.J.S.) NSA 63

AD-294 624 Div. 7
(TISTE/OHD) OTS price $4.60

Monsanto Research Corp., Dayton, Ohio.
HIGH TEMPERATURE THERMOELECTRIC GENERATOR.
Quarterly progress rept. no. 4, 1 Oct-31 Dec 62,
by C. M. Henderson, R. G. Ault and others.
31 Dec 62, 47p. incl. illus. tables.
(Contract AF 33(657)7387, Proj. 8173)
Unclassified report

DESCRIPTORS: *Thermoelectricity, *Generators, *Thermionic emission, Nuclear power plants, Electric power production, High temperature research, Vacuum apparatus, Experimental data, Heating elements, Semiconductors, Graphite, Additives, Coatings, Power metallurgy.

The experimental model generator has completed more than 800 hrs of operation of a sustained performance test at a hot end temperature of 1200 C (+25 -0 C), cold end at about 714 C (+12 -0 C) in a vacuum of 10 to the -5 mm Hg without degradation of its power producing characteristics. Progress was made in efforts to improve the properties of high temperature n-and p-type, proprietary, thermoelectric materials. Ihvestigations were initiated to develop improved emissive cold-end radiator coatings and new methods for fabricating thermoelectric modules. (Author)

'63

1

8944 (NP-12477) HIGH TEMPERATURE THERMOELECTRIC GENERATOR. Fourth Quarterly Progress Report, October 1, 1962–December 31, 1962. C. M. Henderson, R. G. Ault, Emil Beaver, R. J. Janowiecki, H. B. Jankowsky, and L. Reitsma (Monsanto Research Corp. Dayton Labs., Ohio). Contract AF33(657)-7387. 52p.

The experimental model generator completed more than 800 hrs of operation of a substained performance test at a hot end temperature of 1200°C (+25, −0°C), cold end at about 714°C (+12, −0°C) in a vacuum of 10^{-5} mm Hg without degradation of its power producing characteristics. The test is continuing. Progress was made in efforts to improve the properties of high temperature n- and p-type thermoelectric materials needed to supplement p-type MCC 50, the thermoelectric material used in the experimental model generator now under test. Investigations were initiated to develop improved emissive cold-end radiator coatings and methods for fabricating MCC 50 thermoelectric modules. (auth)

NSA '63

11314 (NAA-SR-7288) STATISTICAL ANALYSIS OF SNAP 10A THERMOELECTRIC CONVERTER ELEMENT PROCESS DEVELOPMENT VARIABLES. S. H. Fitch and J. W. Morris (Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.). Dec. 15, 1962. Contract AT-11-1-GEN-8. 41p.

Statistical analysis, primarily analysis of variance, was applied to evaluate several factors involved in the development of suitable fabrication and processing techniques for the production of lead telluride thermoelectric elements for the SNAP 10A energy conversion system. The analysis methods are described as to their application for determining the effects of various processing steps, establishing the value of individual operations, and evaluating the significance of test results. The elimination of unnecessary or detrimental processing steps was accomplished and the number of required tests was substantially reduced by application of these statistical methods to the SNAP 10A production development effort. (auth) NSA '63

7560 (NAA-SR-7140) TEMPERATURE COEFFICIENTS AND SPECTRA IN THE HYDRIDE MODERATED SNAP REACTORS. J. Miller, R. L. Brehm, and W. J. Roberts (Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.). Dec. 30, 1962. Contract AT(11-1)-Gen-8. 56p.

A summary of SNAP temperature coefficient measurements accomplished on the SNAP Experiment and Developmental Reactors is presented. Isothermal measurements, transient experiments, and power coefficient measurements are included. Analysis of the experiments resulted in isolation of component effects. The thermal spectrum temperature coefficient for these zirconium hydride moderated systems is shown to be on the order of −0.04¢/°F. A new model for the energy transfer process in zirconium hydride is presented which reproduces measured spectra and results in temperature coefficients of the magnitude measured. The calculational model is phenomenologically based and uses Fermi-Dirac statistics to describe the state populations of the protons in the zirconium hydride. (auth)

NSA '63

UNCLASSIFIED

107548
107549 SNAP 10A NUCLEAR AUXILIARY POWER UNIT DEVELOPMENT (U)
(Period covered: January-March 1962)
December 28, 1962 — Confidential
Atomics International — (NAA SR-7193)
AT (11-1)-GEN-8 — (AEC TIS
PR — NAA SR-7193)

Test results confirm selection of SiGe pellet converter concept. Major effort is directed toward scale-up for production of qualification test system units. Pump development effort is concentrated toward PbSnTe with SiGe as a backup thermoelectric material. The first non-nuclear thermal test APU was completed. Preliminary review of the hazards analysis associated with shipping of APU and with the flight testing of APU were completed. (U)

/3293 (EDR-3113) SYSTEMS ANALYSIS OF NUCLEAR (SNAP II) LIQUID METAL CELL SPACE POWER SYSTEM. (General Motors Corp. Allison Div., Indianapolis). Dec. 5, 1962. 195p.

A systems analysis and conceptual design data are presented for a nuclear direct conversion space power system concept. This system is an electrochemical device based on concentration cell principles and employing liquid metals as reactants. A detailed parametric analysis of cell performance based on current and projected technology is presented. Performance and conceptual design data on other system components, such as electromagnetic pumps, regenerat r, boiler-separator, condenser, cooler, and radiator, are included. Analysis of the K-Hg liquid metal cell coupled to a SNAP II reactor is also presented. Attention is focused upon a 2-kw(e) space power system, and a detailed weight breakdown is given. (D.L.C.) NSA'64

19165 POSSIBLE METHOD FOR CONVERSION OF THERMAL ENERGY INTO ELECTRICITY. E.V.Teodorovich. Zh. tekh. Fiz. (USSR), Vol. 32, No. 12, 1490-2. (Dec., 1962). In Russian. English translation in: Soviet Physics-Technical Physics (USA), Vol. 7, No. 12, 1101-2 (June, 1963).

The new technique suggested for this conversion is based on the partial ordering of the random thermal motion of charged particles (electrons) in a non-uniform magnetic field, which leads to the production of a current and an effective e.m.f. A possibility for its practical realisation is envisaged in the use of the electron acceleration mechanism now proposed in conjunction with a thermionic converter for increasing the total effeciency of the converter.

H.H.Hodgson

PA '63

11314 (NAA-SR-7288) STATISTICAL ANALYSIS OF SNAP 10A THERMOELECTRIC CONVERTER ELEMENT PROCESS DEVELOPMENT VARIABLES. S. H. Fitch and J. W. Morris (Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.). Dec. 15, 1962. Contract AT-11-1-GEN-8. 41p.

Statistical analysis, primarily analysis of variance, was applied to evaluate several factors involved in the development of suitable fabrication and processing techniques for the production of lead telluride thermoelectric elements for the SNAP 10A energy conversion system. The analysis methods are described as to their application for determining the effects of various processing steps, establishing the value of individual operations, and evaluating the significance of test results. The elimination of unnecessary or detrimental processing steps was accomplished and the number of required tests was substantially reduced by application of these statistical methods to the SNAP 10A production development effort. (auth) NSA'63

5937 STATIC NUCLEAR THERMOELECTRIC SYSTEM FOR SPACE. P.E.Kueser, P.S.Merrill and F.G.Tauch. Trans Amer. Inst. Elect. Engrs II, Vol. 81, 402-5 (1962) = Applic. and Industr., No. 64 (Jan., 1963).

A completely static nuclear-powered thermoelectric generator is discussed. The reactor, designed for Snap-10 (Systems for Nuclear Auxiliary Power), uses U_{235}-zirconium-hydride fuel moderator and is capable of operating a thermoelectric generator at a hot-side temperature of 1000 to 1200°F. A prototype thermoelectric generator is described which produced 250 W of electric power at spacing operating temperatures. Waste-heat radiators for the system, having constant and tapering fin thicknesses, are discussed. Curves are presented of performance versus fin number and length for both tapered and constant-thickness fins. Weight and electric power capability of a present state-of-the-art thermoelectric generator-radiator system is presented in curve form and shows a 245 lb weight for a 250 W system exclusive of the reactor and shielding.

EEA '63

Applying Thermoelectric Devices—System Design Considerations, J.C.R.KELLY, Jr. Automatic Control v 17 n 5 Dec 1962 p 34-7. Practical applications of thermoelectricity for power generating and cooling purposes are discussed on background of recent developments of thermocouples, etc.

EI '63

Conversion directe d'énergie thermique en mouvement, C.VERIE. J de Physique et Radium (Physique Appliquée) v 23 n 12 Dec 1962 p 166A-8A. Direct conversion of thermal energy into motion; method is proposed for directly converting thermal energy into mechanical energy by means of thermoelements; simple device described; first experimental results show that technique has many advantages in case of low energies.

EI '63

10212 SPACE PROBE LIMITATIONS ON NUCLEAR-ELECTRIC POWER SUPPLIES. Owen W. Welles (Space-General Corp., El Monte, Calif.). ARS Preprint No. 2527-62. New York, American Rocket Society, 1962. Prepublication Copy. 8p. $1.00.

The various relations between a deep space probe and its nuclear-electric power supply are reviewed, in order to predict the constraints of the probe on the supply. The relations include the magnitude and type of power consumed by the probe, the relative weights of probe and power supply, and the mission duration. The environment created by the power supply constitutes another class of relations. Physical relations are associated primarily with the large radiators required for the power supply. It is shown that certain of the constraints considerably influence the power-supply design features. These constraints include control of scatter radiation, cancellation of rotating inertias, design for failure life much longer than wear-out, and provision for folding the radiators is most probes. (auth) NSA'63

10213 THE NASA NUCLEAR ELECTRIC POWER PROGRAM. Fred Schulman (National Aeronautics and Space Administration, Washington, D. C.). ARS Preprint No. 2522-62. New York, American Rocket Society, 1962. Prepublication Copy. 11p. $1.00.

The projected requirements and capabilities for space electric power in the ranges below 0.5 kw, on the order of 10 kw, and on the order of 10 Mw are discussed. The uses of radioisotope, reactor, and advanced systems to fulfill the requirements are outlined. (T.F.H.) NSA '63

9128 A MODULAR SOLAR THERMOELECTRIC POWER SUPPLY SYSTEM. Ronald Lang and Barry Lubin (United Aircraft Corp., Windsor Locks, Conn.). ARS Preprint No. 2574. New York, American Rocket Society, 1962. Prepublication Copy. 6p. $1.00.

Review is presented of a modular solar thermoelectric power supply system, which includes thermal energy storage and orientation devices. Incorporation of concepts outlined is expected to satisfy some long-life requirements of communication and weather satellites. A comparison of thermal storage with other systems for supplying continuous power is presented. (auth) NSA '63

9119 ELECTROSTATIC POWER GENERATORS FOR SPACE. C. Coenraads, A. S. Denholm, J. Lavelle, and F. McCoy (Ion Physics Corp., Burlington, Mass.). ARS Preprint No. 2555-62. New York, American Rocket Society, 1962. Prepublication Copy. 32p. $1.00.

The development of electrostatic generators that combine low weight with electromechanical stability and flashover elimination is discussed. Power/mass ratios better than 0.5 kw/lb can be obtained at 20 kv output voltage, and these ratios become lower as the output voltage decreases. (T.F.H.) NSA '63

14930 (CEA-Bib-33) GENERATEURS D'ENERGIE ELECTRIQUE ET IRRADIATEURS EQUIPES DE SOURCES DE PRODUITS DE FISSION AUX U.S.A. (Electrical Energy Generators and Irradiators Equipped with Fission Product Sources in the U.S.A.). H. Emmanuel (France. Commissariat à l'Energie Atomique. Centre d'Etudes Nucléaires, Saclay). 1962. 10p.

Tables of information on research and applications achieved in U.S.A. in the fields of isotope-fueled power generators, and irradiation facilities equipped with fission product sources are presented. (auth) NSA '63

9132 FLAT PLATE SOLAR THERMOELECTRIC GENERATOR SYSTEM CONCEPT. Charles W. Glassburn (Wright-Patterson Air Force Base, Ohio). ARS Preprint No. 2573-62. Prepublication Copy. 7p. $1.00

Details are presented of flat-plate solar-thermoelectric generator research results, and the concept operation discussed from a systems standpoint. System factors and potentials are estimated, assuming the concept to be developed to the point where operational feasibility is established. (auth) NSA '63

2635 NUCLEAR REACTOR SPACE POWER SYSTEMS. J. R. Wetch and M. G. Coombs (Atomics International, Canoga Park, Calif.). Preprint Paper No. CP 62-1203. New York, American Institute of Electrical Engineers, 1962. 13p. $1.00.

The status of the space reactor program is reviewed. The SNAP 10A, a 500-watt thermoelectric system; the SNAP 2, a 3-kw mercury turboelectric system; and the SNAP 8, a 30-kw scale-up of the SNAP 2 system are described. Factors that influence the design of a nuclear space power system are presented, and the prospects for future higher power nuclear systems are discussed. (auth) NSA '63

2637 RADIOISOTOPE POWER SYSTEM OPERATION IN THE TRANSIT SATELLITE. P. J. Dick (Martin Marietta Corp., Baltimore) and R. E. Davis. Preprint Paper No. CP 62-1173. New York, American Institute of Electrical engineers, 1962. 11p. $1.00.

Day-to-day telemetry readout of stabilized radioisotope-powered generator load voltage from the Transit 4B satellite shows that early thermoelectric system mortality does not occur and that sun-to-shade generator surface temperature variations are about 40°F. The application of a closely matched, input-regulated, step-up voltage converter in conjunction with the radioisotope power supply (RIPS) also shows that multiple voltages can be supplied to the electronic packages while maintaining conversion efficiencies in the range of 70 to 85%. By use of converter output filters, voltage ripple can be held below 0.5% and radiofrequency interference is essentially eliminated. (auth) NSA '63

Moderne Methoden der direkten Energieumwandlung. J.J.STUDER. Scientia Electrica v 8 n 4 1962 p 133-48. Modern methods of direct energy conversion; application of thermoelectric effects to thermoelectric generation and cooling; efficiency of generators and heat pumps; figure of merit of materials used; different forms of thermoelectric generator. EI 63

9128 A MODULAR SOLAR THERMOELECTRIC POWER SUPPLY SYSTEM. Ronald Lang and Barry Lubin (United Aircraft Corp., Windsor Locks, Conn.). ARS Preprint No. 2574. New York, American Rocket Society, 1962. Prepublication Copy. 6p. $1.00.

Review is presented of a modular solar thermoelectric power supply system, which includes thermal energy storage and orientation devices. Incorporation of concepts outlined is expected to satisfy some long-life requirements of communication and weather satellites. A comparison of thermal storage with other systems for supplying continuous power is presented. (auth) NSA '63

UNCLASSIFIED

115917 STATUS REPORT ON THERMOELECTRICITY, PART II: DEVICES
Davisson, J.W. & Pasternak, Joseph
January 1963 Unclassified
Navy Dept.
Office of Naval Research
Naval Research Laboratory
NRL MR-1361, Pt. II

Various applications of thermoelectricity are studied. Systems included are food storage refrigeration, air conditioning for submarines, nuclear reactors, thermoelectric generators, solar panels, and cooling of semiconductor components.

29861 STATIC NUCLEAR THERMOELECTRIC SYSTEM FOR SPACE. P. E. Kueser (Westinghouse Electric Corp., Lima, Ohio), P. S. Merrill, and F. G. Tauch. Appl. Ind., No. 64, 402-5(Jan. 1963).

A completely static nuclear-powered thermoelectric generator is discussed. The reactor, designed for SNAP-10, uses U_{235}-zirconium-hydride fuel moderator and is capable of operating a thermoelectric generator at a hot-side temperature of 1,000 to 1,200°F. A prototype thermoelectric generator is described that produced 250 watts of electric power at spacing operating temperatures. Waste-heat radiators for the system, having constant and tapering fin thicknesses, are discussed. Curves are presented of performance versus fin number and length for both tapered and constant-thickness fins. Weight and electric power capability of a present state-of-the-art thermoelectric generator-radiator system is presented in curve form and shows a 245-pound weight for a 250-watt system exclusive of the reactor and shielding. (auth) NSA '63

71,082 POWER REQUIREMENTS FOR DIRECT-BROADCAST SATELLITES
Davis, H. L.
Nucleonics, v. 21, no. 1, pp. 53–56, January 1963

Development of the *SNAP-8*-powered electrical system for direct satellite broadcasting to home receivers is described. The communication satellite systems considered are the synchronous orbit and the low altitude systems. Calculations are made of the power requirements.

71,603 STATIC NUCLEAR THERMOELECTRIC SYSTEM FOR SPACE
Kueser, P. E., Merrill, P. S., Tauch, F. G.
Institute of Electrical and Electronics Engineers, Transactions of the, Part II—Applications and Industry, no. 64, pp. 402–405, January 1963

A prototype thermoelectric generator is described which produced 250 w of electric power at spacing operating temperatures. Waste-heat radiators for the system, having constant and tapering fin thicknesses, are discussed. Curves are presented of performance versus fin number and length for both tapered and constant-thickness fins. Weight and electric power capability of a present state-of-the-art thermoelectric generator-radiator system is presented in curve form and shows a 245-lb weight for a 250-w system exclusive of the reactor and shielding.

Portable Thermoelectric Generators, A.B.NEILD, Jr. SAE—Paper 645A for meeting Jan 14-18 1963 9 p. Development and application of portable thermoelectric generators at U S Naval Eng Experiment Station; schematic cross-section of 2-couple thermoelectric generator using cubical semiconductor thermoelectric elements is shown; recent developments in thermoelectric materials, couple designs, and couple compartment fabrication showed promise for successful generator sizes that can meet present needs for portable power up to 500 w; thermoelectric generator-powered beacon light system fueled by propane is described. EI '63

AD-296 238 Div. 7
(TISTE/CAM) OTS price $1.60

Martin-Marietta Corp., Baltimore, Md.
DEVELOPMENT OF AN ENCAPSULATED THERMIONIC POWER GENERATOR.
Quarterly technical progress rept., 1 Nov 62-31 Jan 63.
15 Feb 63, 5p. illus. (Rept. no. MND-2945-1)
(Contract AF 33(657)10077, Proj. 8173)
Unclassified report

DESCRIPTORS: *Nuclear power plants, *Generators, *Thermoelectricity, Power equipment, Metal seals, Cathodes, Electrodes, Refractory coatings, Processing, Electric power production.

The engineering design of the double diode thermionic power generator has been completed. Fabrication of several component parts has been initiated. The parts for the fueled emitters are almost completely fabricated with only assembly and final machining remaining. The manufacture of other generator components including the collector temperature control assembly and the ceramic-to-metal seals has been initiated. The engineering design of the clad fuel elements has been completed and the first element, similar in configuration to the fueled emitter, has been fabricated. The vacuum test chamber has been fabricated and is undergoing preliminary outgassing. (Author) '63

18901 (NYO-9783) POWER FLATTENING STUDIES FOR RADIOISOTOPE-THERMOELECTRIC GENERATORS. Final Report. R. E. Rush and H. Belofsky (General Instrument Corp. Thermoelectric Div., Newark, N. J.). Feb. 18, 1963. Contract AT(30-1)-2783. 132p.

The natural exponential decay of a radioisotope used as a heat source for a thermoelectric generator makes the use of a "power flattening" device highly desirable, especially when the duration of the mission is large compared to the half life of the radioisotope. Power-flattening devices are considered which either dump excess heat outside the thermoelectric generator or use the characteristics of the generator to absorb the excess heat and thereby regulate the hot junction temperature. A number of power-flattening devices were studied both analytically and experimentally with a view toward operability in space. The most promising concepts are (a) to utilize a secondary radiator of variable area; (b) to provide thermal shunts that are sequentially removed during the mission; (c) to use a secondary radiator coupled to the heat source through a slowly evaporating thermal connection. (auth) NSA '63

Design Parameters for Thermoelectric Generators, J.L.McCABRIA, N.F.SCHUH. IEEE—Special Publ S-145 Feb 1963 p 72-89. Method for evaluating performance capabilities of thermoelectric generator is presented; fundamental equations by Ioffe and others are modified to include effective figure of merit of array of couples, in place of figure of merit of thermoelectric materials; practical factors such as electrode and contact resistance are considered; performance calculations for typical generator show that these factors have significant influence on performance of light weight generator. EI '63

SNAP II-Miniature Power Plant for Space Vessel. Mech Power v 59 n 699 Mar 1963 p 71-2. Features of mercury vapor turbo-alternator weighing 30 lb and designed to run in space for several years, taking its power from small nuclear reactor; rotating assembly runs at 40,000 rpm and 2-phase 115 v alternator produces output of 3 kw at 2000 cps. EI '63

AD-402 071 Div. 7, 12
(TISTE/CAM) OTS price $4.60

Monsanto Research Corp., Dayton, Ohio.
HIGH TEMPERATURE THERMOELECTRIC RESEARCH.
Quarterly progress rept. no. 5, 1 Jan - 29 Mar 63,
by C. M. Henderson. 29 Mar 63, 42p. incl. illus. tables.
(Contract AF 33(657)7387, Proj. 8173)
Unclassified report

DESCRIPTORS: *Generators, *Thermoelectricity, Electric power production, Electric potential, Thermocouples, Refractory materials, Refractory coatings, Molybdenum, Graphite, Reliability, Design, Model tests, Temperature, Spacecraft.

An experimental model 5-watt (nominal) generator completed 2556 hrs of a sustained performance test at a hot-end temperature of 1200 C (+25 C-4 C), cold end at 714 C (+12 C-0 C), in a vacuum of 1/100000-10 to the minus 6th power. mm Hg without degradation in power producing characteristics. The power/weight ratio of this generator, exclusive of heat source, ranged from 2.70 to 2.86 watt/lb. Tests at 1300 C and higher temperatures will be attempted with this generator. Graphite-ended segmented modules of n- and p-type thermoelectric materials to supplement p-type MCC 50, the thermoelectric material used in the 5-watt generator, were fabricated and partially evaluated. The first such p-n couple produced 250% more power than the p-type MCC-molybdenum couple used in the 5-watt generator. Improved emissive coatings and lightweight junctions between modules were produced. These developments suggest that an advanced experimental 50-watt generator having a power/weight ratio of 10-20 watt/lb is feasible. (Author) '63

/ 22273 (MND-P-2835) SNAP 7D—STRONTIUM-90 FUELED THERMOELECTRIC GENERATOR POWER SOURCE. THIRTY-WATT U. S. NAVY FLOATING WEATHER STATION. Final Report. C. N. Young (Martin-Marietta Corp. Aerospace Div., Baltimore). Mar. 15, 1963. Contract AT(30-3)-217. 102p.

The objectives of the SNAP-7D program were to design, manufacture, test and deliver a thirty-watt electric generating system for a modified U. S. Navy NOMAD-class weather buoy to be stationed in the Gulf of Mexico. The sixty-watt Sr^{90} thermoelectric generator, the relay panel, the batteries, and the installation of the system in a boat-type buoy are described. In addition to delivering the power supply, many tests were required for the SNAP-7D system to demonstrate its conformance to the contract statement of work. The electrical tests of the generator and of the system, the shock and vibration tests, and the tests at the environmental temperature extremes are discussed. (auth) NSA63

Y16190 ENERGY FOR REMOTE AREAS. J. G. Morse (Martin Marietta Corp., Baltimore). Science, 139: 1175-80(Mar. 22, 1963).

Radioisotope-fueled generators are being used to supply power in small terrestrial and space systems. The fuel choice, energy conversion system, and effects of environment on the generator design are discussed. Various generators now in operation or under development are described. (D.L.C.) NSA'63

AD-411 858 Div. 7, 20, 12
(TISTA/GEC) OTS PRICE $3.60

Monsanto Research Corp., Dayton, Ohio.
HIGH TEMPERATURE THERMOELECTRIC RESEARCH.
Quarterly progress rept. no. 5, 1 Jan-29 Mar 63, by C. M. Henderson. 29 Mar 63, 42p.
Contract AF33 657 7387, Proj. 8173, Task 817302 9
AEC Rept. no. NP12763 Unclassified report

Descriptors: (*Thermal reactors, Generators), (*Generators, Thermoelectricity), Nuclear power plants, Spacecraft, Feasibility studies, Operation, Electric power production, Temperature, Graphite, Molybdenum, Satellites (Artificial), Performance (Engineering).

An experimental model 5-watt (nominal) generator completed 2556 hrs of a sustained performance test at a hot-end temperature of 1200 C (+25 C-4 C), cold end at 714 C (+12 C-0 C), in a vacuum of (10 to the minus 5th power to 10 to the minus 6th power) mm Hg without degradation in power producing characteristics. The power/weight ratio of this generator, exclusive of heat source, ranged from 2.70 to 2.86 watt/lb. Tests at 1300 C and higher temperatures will be attempted with this generator. Graphite-ended segmented modules of n- and p-type thermoelectric materials to supplement p-type MCC 50, the thermoelectric material used in the 5-watt generator, were fabricated and partially evaluated. The first such p-n couple produced 250% more power than the p-type MCC-molybdenum couple used in the 5-watt generator. Improved emissive coatings and lightweight junctions between modules were produced. These developments suggest that an advanced experimental 50-watt generator having a power/weight ratio of 10-20 watt/lb is feasible. (Author)

71,510 RADIONUCLIDE POWER FOR SPACE—PART I ISOTOPE COSTS AND AVAILABILITY
Davis, H. L.
Nucleonics, v. 21, no. 3, pp. 61-65, March 1963

To meet the needs for space-power radionuclides recently forecast by user agencies such as the National Aeronautics and Space Administration, the Division of Isotope Development has made new, more detailed projections of the upper limits on isotope availability over the next 20 years, and has taken steps to expand production in almost all instances—but notably for Pu^{238}—and to initiate production of at least one entirely new isotope—Cm^{244}.

71,511 ENERGY FOR REMOTE AREAS
Morse, J. G.
Science, v. 139, no. 3560, pp. 1175-1180, March 22, 1963

The method of obtaining electrical power from radioisotopes is described, and the design concept for a radioisotope generator is discussed from the point of view of (1) the heat source or fuel (alpha-emitter or fission product, short or long half-life), (2) the energy conversion system (thermoelectric or thermionic), and (3) constraints imposed by various environments and types of missions. Radionuclide power systems now in operation or under development (including various *SNAP* and *Transit* generators) are described, and a table listing the characteristics of the thermoelectric generator is presented.

AD-411 369 Div. 7
(TISTE/OHD) OTS price $2.60

Battelle Memorial Inst., Columbus, Ohio.
MULTIFUELED THERMAL-ENERGY-CONVERSION SYSTEMS.
Quarterly progress rept. no. 3, 1 Jan-31 Mar 63, by H. R. Hazard, G. R. Whitacre, M. R. Seiler, and A. B. Timberlake. 1963, 18p. Rept. no. 3
Contract DA36 039sc90838, Proj. 3A99 09 001
Unclassified report

Descriptors: (*Thermionic converters, Combustion chambers), (*Thermoelectricity, High-temperature research), (*Electric power production, Fuels), Effectiveness, Lead compounds, Tellurides.

Operation of several compact combustion chambers was studied experimentally, and it was found possible to maintain uniform exit-gas temperatures of 1100 C to 1225 C when firing charcoal, green wood, animal dung, and small grains. A simulated internally fired thermoelectric unit containing a heat meter and calorimeter, and with thermal characteristics simulating those of a thermoelectric unit, was designed and tested. Heat-transfer effectiveness was far higher than in previous units, ranging from 58 to 74%; this compares with corresponding values of 18 to 30% for previous units. This performance permits design of a thermoelectric unit, based on lead telluride technology, having thermal efficiency of about 3.0 3.5%. (Author)

Thermoelectric Power Generation—How Far Are We, J.H.BREDT. Power Eng v 67 n 2, 3, 4 Feb 1963 p 64-6, Mar p 56-8, Apr p 56-9. Theoretical and practical aspects of thermoelectric system analysis; energy conversion process; characteristics of performance of various thermoelectric materials; comparison of energy conversion efficiencies and heat transfer coefficients of PbTe and germanium silicon alloy thermoelements; limits of thermoelectric generator use. EI '63

17607 RADIONUCLIDE POWER FOR SPACE. PART 2. ISOTOPE-GENERATOR RELIABILITY AND SAFETY. D. G. Harvey, P. J. Dick, and C. R. Fink (Martin Co., Baltimore). Nucleonics, 21: No. 4, 56-9(Apr. 1963).

The operating experience of SNAP devices in the Transit 4A and 4B satellites is described. Only two power excursions were observed which are probably due to a capacitor failure in the power conditioning system. The results and tests indicate that the reliability of the generator unit and thermoelectric couples will be satisfactory. Exhaustive proof testing has shown that containment of the radioactive fuel can be absolutely guaranteed during the launch and that the fuel will burn up on re-entry at orbital velocities. The possibility of only partial burnup at suborbital velocities is an improbable one. (D.L.C.) NSA '63

24730 ELECTROMAGNETIC TORQUES OPERATING ON SATELLITES USING SNAP REACTOR POWER SYSTEMS. J. H. Bick (North American Aviation, Inc., Canoga Park, Calif.). AIAA (Am. Inst. Aeron. Astronaut.) J., 1: 963-4(Apr. 1963).

The electromagnetic torques developed by the interaction of the electric and magnetic fields generated by SNAP reactor power systems in satellites with the geomagnetic field are investigated. The torques are expressed as a function of time in order that they may be used as an inhomogeneous forcing function in the dynamic altitude control equations for the satellites. (C.E.S.) NSA '63

19688 (NAA-SR-8097) SNAP AEROSPACE SAFETY PROGRAM. Quarterly Technical Progress Report, October–December 1962. (Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.). Apr. 1, 1963. Contract AT(11-1)-Gen-8. 40p.

Progress made during the period is reported including analyses of experiments and tests, and evaluation of effort. The subject material concerns reactor transient and excursion tests, fission product release studies, end-of-life shutdown devices, critical configuration studies, mechanical and thermochemical effects, reactor separation and fuel element ejection, and reentry burnup of fuel elements. The design of the SNAPTRAN 2/10A-1 and -2 machines was essentially completed and fabrication of major components was initiated. The fission product release tests at the NRTS were completed. Some progress was made on the explosive shutdown projectile design. A practical shipping sleeve design was demonstrated which will maintain the SNAP 2/10A assembly in a subcritical condition as a result of postulated shipping accidents. The Phase I ground test series were completed. The computer code, RESTORE, was shown to be excellent for the calculation of reentry trajectories. The calculation of fuel rod heating and ablation using a digital thermal analyzer program resulted in an improved and more elaborate analytical model. (auth) NSA '63

500-w [illegible] thermoelectric unit may come within two years. A. B. Neild, jr. Il diag S A E J 71:32-4 Ap '63

AS+TI '63

16189 FISSION-FRAGMENT CONVERSION REACTORS FOR SPACE. C. J. Heindl, W. F. Krieve, and R. V. Meghreblian (California Inst. of Tech., Pasadena). Nucleonics, 21: No. 4, 80-5(Apr. 1963).

A typical fission-electric cell is described, in which a very thin layer of fissionable material covers a cylindrical cathode and a second concentric cylinder acts as an anodic fission-fragment collector. Continued open-circuit operation of the cell should lead to a buildup potential of 4×10^6 volts. Among the problems to be solved is unwanted electron emission. The research program being carried out on the cell is described together with some experimental results; a voltage of 810 volts has been obtained. An analysis of the cell performance is given. In-pile experiments and high-voltage experiments now in progress are described. (D.L.C.) NSA '63

9527 THERMOELECTRIC GENERATORS - STATUS 1963. L.J.Schmerzler. Semiconductor Prod. (USA), Vol. 6, No. 4, 39-44 (April, 1963).

Thermoelectric power generators present one of the most promising technological developments today. Overall thermal efficiencies of 2-3% exist using hydrocarbon fuels and 4-6% using radioisotope fuels at system specific power outputs of 4-8 W/lb and costs of $30-$100/W. Thermoelectric material costs have dropped from $1500 to $100/lb within the last three years and much lower costs are anticipated as material usage increases. Overall system operating thermal efficiencies of 14-18% at specific power outputs of 40-70 W/lb of system are projected for 1980. EEA '63

Product Engineering fourth annual master design awards: thermoelectric generator. il diag Product Eng 34:91 My 13 '63

Development of thermoelectric power generators. R. W. Fritts. bibliog il diag IEEE Proc 51:713-21 My '63

AS+TI '63

Nuclear Reactor Systems. G. MONTGOMERY ANDERSON. Astronautics & Aerospace Eng v 1 n 4 May 1963 p 27-36. Snap (System for Nuclear Auxiliary Power) program involves development of 10 systems using compact reactors and radioisotope heat energy sources; Snap 10A, 500-w (electric output) system uses thermoelectric conversion, and Snap 2, 3-kw system employs mercury-vapor-turbogenerator power-conversion unit; objectives of orbital flight tests of Snap-10A and Snap-2 systems programmed for 1964 and 1966; design criteria, features, characteristics, components and various test phases of 2 systems. EI '63

Encapsulated thermoelectric generator. L. H. Griffin. il Materials in Design Eng 57:116 My '63

Space electrical power: thermoelectric power systems. N. F. Schuh. bibliog il diags Astronautics & Aerospace Eng 1:80-3 My '63

AS+TI '63

AD-415 431 Div. 12, 7
(TISTA/FRL) OTS price $1.75

Lockheed Aircraft Corp., Sunnyvale, Calif.
FLAT PLATE SOLAR THERMOELECTRIC GENERATOR ORBITAL EXPERIMENT,
by E. L. Brady and A. N. Himle. May 63, 57p.
Contract AF04 647 673, Proj. 8173, Task 817302 12
ASD TDR63 479 Unclassified report

Descriptors: (*Generators, Thermoelectricity), (*Generators, Solar radiation), Launch vehicles (Aerospace), Satellites (Artificial), Polar orbit trajectories.

The flat plate Solar thermoelectric generator orbital experiment was performed to obtain data on flat plate generator panels functioning in an actual space environment and to correlate these data with laboratory data. These data extend the state-of-the-art and define the problem areas of the concept development and evaluation techniques. Two orbital experiments were performed on Agena satellite systems in polar orbit. In each experiment, three thermoelectric generator panels were extended from the vehicle on an erecting oriented boom to approximate the environment of an actual generator array. Two of the six orbited panels produced about 85 percent of laboratory-measured performance with no measured deterioration during the 39 orbits when data were available. The three panels flown in the first flight had lower performance and showed increased performance as a function of time. The solar intensity measurement variations were greater than anticipated. (Author) '63

AD-407 371 Div. 7, 26
(TISTE/JWS) OTS price $4.60

General Electric Co., Philadelphia, Pa.
ADVANCED SOLAR THERMIONIC GENERATORS.
Quarterly technical progress rept. no. 3, Mar-May 63,
by R. R. Herrick, H. C. Keyser and L. L. Dutram. June 63, 37p.
Contract AF33 657 8947, Proj. 8173, Task 817305 16
Unclassified report

Descriptors: *Thermionic generators, Temperature, Life expectancy, Manufacturing methods, Rhenium, Tantalum, Molybdenum, Electron beams, Welding, Brazing, Cathodes Electric potential, Electric currents, Cesium, Solar radiation.

Fabrication of advanced solar thermionic converters, both B and C series, is outlined, noting the significant problem areas. Results of testing of the B series have given performance up to 9.6 watts/cm2 at 1950 K and 3.0 watts/cm2 at 1550 K. Converter C-3 has completed a 510 hour test, including 210 hours of thermal cycling. Electron beam welding of rhenium resulted in a brittle phase and leaking joints. (Author) '63

AD-407 384 Div. 7
(TISTE/JBM) OTS price $1.60

Westinghouse Electric Corp., Lima, Ohio.
SOLAR THERMOELECTRIC GENERATOR SYSTEM CONCEPT AND FEASIBILITY STUDY.
Quarterly rept. no. 5, 15 Feb-15 May 63,
by J. L. McCabria. 15 May 63, 13p.
Contract AF33 657 8089
Unclassified report

Descriptors: *Thermoelectricity, *Solar radiation, *Generators, Feasibility studies, Models (Simulation), Spacecraft, Electric power production, Theory, Life expectancy, Lithium compounds, Hydrides, Stainless steel, Thermocouples, Storage, Thermodynamics, Tests.

Research continued on a program to establish the feasibility of a solar thermoelectric generator for use in space vehicles. All of the thermal storage units planned for evaluation have been tested and analyzed. The final unit was cycled for over 1000 hours. From an initial value of 92.5% lithium hydride within the container 91.1% still remained. An extension program has been finalized and work initiated on it. (Author) '63

29076 (TID-18996) HIGH ACCELERATION FIELD HEAT TRANSFER FOR AUXILIARY SPACE NUCLEAR POWER SYSTEMS. Quarterly Technical Report, March 1 to May 31, 1963. H. F. Poppendiek, N. D. Greene, F. R. MacDonald, C. M. Sabin, and R. K. Livett (Geoscience Ltd., Solano Beach, Calif.). Contract AT(04-3)-409. 22p. (GLR-14)

The liquid-metal heat-transfer system was operated with both water and mercury to date. Nonboiling water heat-transfer conductances were found to differ from predicted values by 6 to 15%. A low-power, nonboiling heating experiment was conducted using mercury; heat balances accounting for over 90% of the electrical input were obtained. A radiantly heated boiler test section which will be used for high-quality experiments was constructed and all associated instrumentation procured. Preliminary experiments were conducted of the vaporization of water droplets on a hot surface. A number of materials evaluation studies were made in support of the liquid metal system. Three forced-flow, saturation-boiling heat-transfer models were evaluated and compared. Information on axial boiling conductance variations for different types of vapor-liquid patterns was obtained. Also, one model has yielded data on wall temperature transients in a boiler under slug flow conditions. Analytical studies were made of the vaporization of liquid drops contiguous to a hot wall; droplet lifetimes and thickness of vapor films between the droplet and hot wall were determined. (auth) NSA '63

26927 RADIOISOTOPE POWER SOURCES. J. P. Culwell (Atomic Energy Commission, Washington, D. C.). IAFA Preprint No. CN-14/41. 18p. (TID-18754)

To be published in proceedings of Conference on the Application of Large Radiation Sources in Industry, held in Salzburg, Austria, May 27-31, 1963.

Radioisotope power systems are particularly suited for remote applications where long-lived, compact, reliable power is needed. Able to perform satisfactorily under extreme environmental conditions of temperature, sunlight and electromagnetic radiations, these atomic batteries are attractive power sources for remote data collecting devices, monitoring systems, satellites, and other space missions. Radioisotopes used as fuels generally are either alpha or beta emitters. Alpha emitters are the preferable fuels but are more expensive and less available than beta fuels and are generally reserved for space applications. Beta fuels separated from reactor fission wastes are being used exclusively in land and sea applications at the present.

Prototype thermoelectric generators, fueled with strontium-90 and cesium-137, are now in operation in weather stations, marine navigation aids, and deep sea monitoring devices. Plutonium-238 thermoelectric generators are in orbit operating as electric power sources for TRANSIT satellite. Rigid safety requirements are established and extensive tests are conducted to insure that these systems can be employed without creating undue hazards. (auth) NSA '63

31088 (NYO-10462) ECONOMIC FACTORS OF MFP THERMOELECTRIC GENERATORS. Final Report. E. J. Lemanski (General Instrument Corp. Thermoelectric Div., Newark, N. J.). May 1963. Contract AT(30-1)-2605. 40p.

Economic aspects of power generation from underwater thermoelectric generators fueled with Mixed Fission Products (MFP) are given. Costs are estimated to be less than $0.15 per thermal watt for two year old MFP. Studies are on a conceptual design of a unit capable of withstanding pressures equivalent to 18,000 feet submergence on the ocean bottom and 300 year containment of the nuclear heat source. Low cost biological shields of both high density concrete and cast iron were considered. Studies establish the possibility of power costs as low as $10 per watt-year in the kilowatt size, to $100 per watt-year in the 10 watt range. A comparison of the MFP generator with an equivalent SNAP-7 strontium-90 type indicates that the MFP power costs are far below those for separated radioisotope power, primarily because the highest cost item in the SNAP unit is the purified strontium-90 fuel. A one kilowatt MFP unit would weigh in the order of 20 to 30 tons maximum depending on fuel energy density, and have a diameter of 6 to 10 feet. Optimization studies were made for such factors as fuel geometry, fuel age, energy density, and insulation thickness to determine the most productive areas of reducing the original cost and overall weight estimates. (auth) NSA '63

35224 NUCLEAR REACTOR SYSTEMS. G. Montgomery Anderson (Atomic Energy Commission, Washington, D. C.). Astronaut. Aerospace Eng., 1: No. 4, 27-36(May 1963).

The objectives of the orbital flight tests of the Snap-2 and Snap-10A are briefly outlined. Fundamental criteria for safety throughout all phases of the flight test are given. The flight design of the reactor, shield, thermoelectric generator, thermoelectric pump, and structure of the Snap-2 and -10A systems are also discussed. The performance characteristics of the Snap-2, -8, -10A are presented. (C.E.S.) NSA '63

35225 ORBITAL TESTING OF SNAP SYSTEMS. George E. Austin (Air Force Systems Command, Los Angeles). Astronaut. Aerospace Eng., 1: No. 4, 37-42(May 1963).

Objectives to be accomplished in orbital testing of Snap-2 and Snap-10A are outlined. The ability of vehicle components and subsystems to survive in the radiation environment, mechanical, thermal, and electrical interface problems unique to the utilization of nuclear power, and radiological safety precautions and procedures to be established in the orbital testing of Snap systems are discussed. (C.E.S.) NSA '63

80,604 ORBITAL TESTING OF SNAP SYSTEMS
Austin, G. E.
Astronautics and Aerospace Engineering, v. 1, no. 4, pp. 37–42, May 1963

Orbital proof tests of *SNAP-10A* and *SNAP-2* are considered as necessary steps toward the ultimate emergence of large space nuclear powerplants. Nuclear power also has advantages in the sub-kilowatt and low kilowatt ranges where solar power is competitive. Flight-testing program responsibilities are given.

80,605 NUCLEAR REACTOR SYSTEMS
Anderson, G. M.
Astronautics and Aerospace Engineering, v. 1, no. 4, pp. 27–36, May 1963

Orbital flight tests of the *SNAP-10A* and *SNAP-2* systems are programmed for 1964 and 1966. The objectives of these flights are to (1) demonstrate *SNAP-10A* and *SNAP-2* for use as operational systems, (2) observe time-dependent operational characteristics in space and establish time-to-failure in diagnosing failure modes, (3) demonstrate the planned procedures for safety, ground handling, launch, and remote start-up in orbit, (4) resolve *SNAP*-vehicle integration problems, such as thermal compatibility, radiation-dose mapping, and shielding, that are difficult to determine on Earth, and (5) demonstrate the boiling and condensing features of *SNAP-2* in "zero gravity."

80,748 THERMOELECTRIC POWER SYSTEMS
Schuh, N. F.
Astronautics and Aerospace Engineering, v. 1, no. 4, pp. 80–83, May 1963

The advanced state of development of thermoelectric power systems, attributed to basic studies and recent progress with available materials, is discussed. Systems are now being used or considered for power levels of a few watts for navigation satellites to several kilowatts for larger spacecraft.

80,340 THE DEVELOPMENT OF THERMOELECTRIC POWER GENERATORS
Fritts, R. W.
IEEE, Proceedings of the, v. 51, no. 5, pp. 713–721, May 1963

The technical developments that have led from early semiconductor research to the emergence of the thermoelectric generator are reviewed.

Thermoelectric Power Systems, N.F.SCHUH. Astronautics & Aerospace Eng v 1 n 4 May 1963 p 80-3. Review of present state of art shows that against background of several years of basic studies, and recent progress with available materials, emphasis shifts to design of practical devices for space systems; making of good electrical contacts between thermoelectric materials and conductors in couple received greatest development effort during past 3 yr; description of 3 contacting methods; various thermoelectric couple configurations; overall efficiencies of space thermoelectric systems under development vary from 2% for nuclear system to 4% for solar-powered system. EI '63

Thermoelectric Generators for Battery-Charging Applications, D. W.BARGEN. Advanced Energy Conversion v 3 n 2 Apr-June 1963 p 507-14. Details are given of generator with output of approximately 10 w, designed and constructed for use as source of power for Coast Guard navigational aids; heat-to-electrical energy conversion efficiencies of up to 8.5% were observed immediately after construction; completed generator with gas burner yielded chemical-to-electrical energy conversion efficiency of 4.9%. EI 63

Radionuclide Power Sources, J.G.MORSE. Brit Interplanetary Soc —J v 19 n 3 May-June 1963 p 87-92. Paper reviews fundamental characteristics of power sources in which decay heat of radioisotope is converted into electricity by some direct energy conversion device; thermoelectric converter in present devices; work carried out in U S Atomic Energy Commission's SNAP Program is described, including experiments to study operational safety, and particular sources developed for Transit and communications satellites /and for Surveyor lunar probe. EI '63

/ 26924 SYSTEMS FOR NUCLEAR AUXILIARY POWER. Atomics, 16: No. 3, 18-23(May-June 1963).
An outline is presented of the SNAP program. The power requirements of communications satellites are examined briefly. The organization of the SNAP program is described briefly, and the characteristics of the various SNAP projects are tabulated. The radioisotope and reactor projects are discussed, particularly the SNAP-50/SPUR. (D.L.C.) NSA 63

26100 SNAP-50/SPUR REACTOR DEVELOPMENT. Frank D. Haines (Atomic Energy Commission, Middletown, Conn.). Trans. Am. Nucl. Soc., 6: 88(June 1963). NSA 63

31767 RADIONUCLIDE POWER SOURCES. J. G. Morse (Martin Marietta Corp., Baltimore). J. Brit. Interplanet. Soc., 19: 87-92(May-June 1963).

A review is given of the fundamental characteristics of power sources in which the decay heat of a radioisotope is converted into electricity by some direct energy conversion device—a thermoelectric converter in present devices. Some work carried out in the U. S. Atomic Energy Commission's SNAP Program is described, including experiments to study operational safety, and particular sources developed for the Transit and communications satellites and for the Surveyor lunar probe. (auth) NSA'63

AD-407 489 Div. 7, 25
(TISTE/JBM) OTS price $2.40

General Instrument Corp., Newark, N. J.
SOLAR FLAT PLATE THERMOELECTRIC GENERATOR RESEARCH.
Quarterly rept. no. 1, 1 Mar-1 June 63.
15 June 63. 14p.
Contract AF33 657 10335, Proj. 8173, Task 817302
Unclassified report

Descriptors: *Solar panels, *Thermoelectricity, *Generators, Test equipment (Electronics), Tests, Optical coating, Electric power productions, Solar radiation, Spacecraft, Fixed contracts, Plastics, Aluminum, Design, Structural parts, Optical properties, Thermal radiation, Semiconductor, Tellurium alloys, Bismuth alloys, Lead alloys, Processing, Nickel, Gold, Aluminum, Reflectors, Honeycomb cores, Sandwich construction, Bonding, Temperature.

Research concerns the development of solar flat plate thermoelectric generators for spacecraft. A solar flat plate thermoelectric generator consists of a collector plate with an optically selective coating, small size semiconductor thermoelements, a radiator plate and a support structure. Three months of research and development work on this space auxiliary power system is described. The technical problem areas investigated include; collector coatings, thermoelectric materials and contacts and support structures. Collector coating samples suitable for evaluation

9 '63

28578 RADIOACTIVE POWER SUPPLY SYSTEM. Ernest G. Linder (to U. S. Air Force). U. S. Patent 3,093,788. June 11, 1963. Filed Aug. 26, 1955.

A lightweight, simplified system for radioactively generating electrical energy for missiles and rockets is described. The system consists of two electrically conductive bodies of quite unequal sizes connected through the work load, this entire system being enclosed in a vacuum or other non-conductive non-ionizable medium. Emission of charged particles by a radioactive coating on the smaller body results in a potential difference across the load as charged particles flow from the larger body. (D.C.W.) NSA'63

Efficiency calculations of thermoelectric generators with temperature varying parameters. R. W. Cohen and B. Abeles. J Ap Phys 34:1687-8 Je '63

AS+TI '63

31086 (NP-12988) HIGH TEMPERATURE THERMOELECTRIC RESEARCH. Quarterly Progress Report No. 6, March 29, 1963-June 28, 1963. C. M. Henderson (Monsanto Research Corp. Dayton Labs., Ohio). Contract AF33(657)-7387. 83p.

The experimental model generator, previously operated for 2556 hr at 1200°C in a vacuum of 10^{-5} to 10^{-6} mm Hg without degradation of power output, was disassembled and examined. No physical change or damage to its MCC 50-graphite thermoelements was found. Formulations of new p- and n-type thermoelectric materials, to supplement MCC 50, were standardized and techniques developed for forming them into segmented thermoelements. Realistic measurements of segmented p- and n-type thermoelements showed that efficiencies ranging from 3% for p-type to 6% for n-type can be attained for such units when operating between 1200 and 460°C. Emittance measurements on a new coating for use on the copper radiators of the advanced experimental model generator, or the surface of space vehicles, showed that it is capable of ϵ's ranging from 0.9 at 500°C to 0.98 at 900°C. Progress in overcoming hot-pressing problems and flame-spraying techniques concerned with making segmented thermoelements is described and a detailed design for an advanced experimental model generator capable of a nominal 50 watts output at ~10 watt/lb ratio is presented. (auth) NSA '63

35231 ADVANCED 1-MEGAWATT SPACE POWER PLANT STUDY. L. Schipper, R. S. Siegler, and E. B. Zwick (Rocketdyne, Canoga Park, Calif.). New York, American Inst. of Aeronautics and Astronautics, 1963, Preprint 63-270, 61p., $1.00. (CONF-97-8)

From Summer Meeting, Los Angeles, June 1963.

The potential of an advanced nuclear thermomechanical system was investigated. A 1-megawatt power level was chosen for this study because it is within the range of interest of the anticipated power requirements for the next decade. The study considered the effects of such advanced components as the belt radiator and the Nadyne generator. The system is a double-loop type with the primary reactor loop using lithium as the working fluid. Both potassium and rubidium were investigated as working fluids in the secondary Rankine loop. Many variations of the basic Rankine cycle were studied, including both wet and dry expansions, reheat, and superheat. Particular attention was given to exploring the broad interaction between components of the system, as well as to the weight and performance effects on key components because of changes in such prime variables as temperature, power level, and meteoroid puncture probability. Some of the dry cycles evaluated have performance capabilities equivalent to or better than the currently proposed wet cycles, even when operating between the same temperature limits. The use of a dry cycle would eliminate wet-vapor erosion in the turbine as a major problem in the development of alkali-metal turbines. Dry cycles also appear attractive when combined with the use of a belt radiator that optimizes at a lower heat-rejection temperature than a conventional radiator. The higher-cycle temperature ratios achievable can lead to substantial improvement in thermodynamic cycle efficiency and lower system weight. (auth) NSA '63

8598 FFFICIENCY CALCULATIONS OF THERMOELECTRIC GENERATORS WITH TEMPERATURE VARYING PARAMETERS. R.W.Cohen and B.Abeles.
J. appl. Phys. (USA), Vol. 34, No. 6, 1687-8 (June, 1963).

A simple analytic expression for the efficiency of a thermoelectric power generator with temperature varying parameters is obtained in terms of temperature averages of these parameters. The expression is derived assuming that the Thomson effect may be treated as a small perturbation on the heat flow in the generator. The assumption is also made that half the Thomson heat generated (absorbed) in the generator flows to (from) the hot junction and the other half flows to (from) the cold junction. Using this method, the performances of three hypothetical generators are calculated and found to be in excellent agreement with exact machine calculations.

EEH '63

UNCLASSIFIED

116784 STUDY OF SNAP POWER SYSTEMS IN THE LUNAR ENVIRONMENT, VOLUME I
Ackermann, W. O.; Wimmer, R. E. (et al)
July 1, 1963
Atomics International
NAS 3-2530
Report
Unclassified
(R-AI-8576, Vol. I)
(Projects: SNAP)

The purpose of this report is to define the environment, the power requirements, and the general characteristics of the nuclear power supply for lunar operations. While other lunar applications for nuclear power plants exist, the primary emphasis has been placed on the installation for a base.

34078 THE THERMOELECTROMAGNETIC PUMP.
S. Hufnagel (Technische Hochschule, Munich). Kerntechnik, 5: 286-93(July 1963). (In German)

An electromagnetic pump that is simultaneously designed as a thermoelement so it can produce its own power current, heated either from the outside or from the inside by the pumped material (liquid metal) is described. Such a pump, of which the initial model containing a copper constant thermoelement and the operating results are described, appears particularly useful for revolving suitable primary coolants in nuclear reactors since it can operate in a capsule, service-free, and without wear and tear, is partly self-regulating and, at the same time, acts as a heat-transfer agent between the primary coolant and a secondary material current. (auth)

NSA 63

MHD power conversion. W. E. Gunson and others. bibliog diags Nucleonics 21:43-7 Jl '63

AS, TI '63

Comparison of solar-thermal and solar-electrical-thermal propulsion methods. H. D. Linhardt. bibliog il diag AIAA J 1:1568-75 Jl '63

AS TI '63

31730 (NAA-SR-8468) STATISTICAL TREATMENT OF HOT CHANNEL FACTORS FOR COMPACT REACTORS.
P. D. Cohn and H. A. Evans (Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.). July 15, 1963. Contract AT(11-1)-Gen-8. 39p.

The theoretical development, statistical treatment, and application of hot channel factors in compact SNAP reactors as represented by the SNAP 8 experimental core loading are presented. The channel and rod power effects of variation in the concentrations of uranium, hydrogen, and poison in the fuel rods are given. The statistical distributions of all variables are examined. A random selection of rods and channels is compared to the actual SNAP 8 configuration, with no difference noted. Confidence limits are set on hot rod and hot channel factors. Various other factors and aspects of the problem are discussed. The results of the study showed that the hot channel factors may be reduced to less than +2% over the nominal power, as opposed to a hot channel factor of about +10% as previously determined by empirical methods. (auth)

NSA 63

10925 NERNST-ETTINGSHAUSEN (TRANSVERSE) ENERGY CONVERSION. T.C.Harman and J.M.Honig.
Semiconductor Prod. (USA), Vol. 6, No. 7, 19-24 (July, 1963).

The utilization of the Nernst and Ettingshausen (NE) effects in direct energy conversion is discussed. The operation of generators and refrigerators is described qualitatively. Equations specifying their operating characteristics are cited and compared with those pertaining to the usual thermoelectric devices. Criteria are developed which show the conditions that one should attempt to meet in order to attain the most efficient energy conversion with NE generators and refrigerators. Bismuth and Bi-Sb alloys show promise as materials for these energy converters, since figures of merit of 0·4 have been observed. It is stressed that the search for new materials should not be limited to substances with low thermal conductivities or equal hole and electron mobilities. EEA '63

14228 LIQUIDS FOR THERMOELECTRIC GENERATION. J.W.Gardner.
Engl. Elect. J., Vol. 18, No. 4, 16-21 (July-Aug., 1963).

A review is made of the potentialities of semiconducting liquids and molten salts as thermoelectric generators, with an initial recapitulation of the main facts about thermoelectrics in general. The main incentive for using liquid thermoelectrics are the higher temperatures at which they may operate, giving consequently higher Carnot cycle efficiencies. Material efficiencies, on the other hand, are difficult to determine for liquids because of the measurement of thermal conductivity (K) at high temperatures involved. For instance, the best experimental results we now have are for molten cuprous sulphide, and they give K with an uncertainty of ± 20%. Nevertheless, results up to now obtained for semiconducting liquids suggest that their material efficiency may significantly exceed the best values for solid thermoelectrics, and if they prove to be economic, they might be used in thermoelectric generators to give greater overall efficiency. The increase in efficiency could be just enough to make thermoelectric generation economic for "topping" units supplementing conventional turbo-generators. As for molten salts, in particular, they may offer advantages in situations where their electrolytic properties could be exploited. W.P.S.Lepecki EEA '63

AD-415 024 Div. 7
(TISTM/AMS) OTS price $2.60

Westinghouse Electric Corp., Lima, Ohio.
SOLAR THERMOELECTRIC GENERATOR SYSTEM CONCEPT AND FEASIBILITY STUDY.
Quarterly rept. no. 6, 15 May-15 Aug 63, by J. L. McCabria and D. A. Naumer. 15 Aug 63, 23p.
Contract AF33 657 8089, Proj. 8173, Task 817302 10

Unclassified report

Descriptors: (*Generators, Solar radiation), (*Solar radiation, Generators), (*Thermoelectricity, Solar radiation), Design, Feasibility study, Tests, Life expectancy, Experimental data, Gamma rays, Electric power production, Lithium compounds, Hydrides, Models (Simulators).

Ground level - natural sunlight testing of the solar powered thermoelectric generator has been completed. Evaluation of the test data has shown that the short within the generator, which occurred during simulated altitude evaluation, has been repaired. Maximum power output obtained during solar testing was 20 watts. The waste heat radiator was operated at a lower temperature than would be encountered in a space atmosphere. The rate of heat input to the thermopile was therefore greater than that to be expected under space flight conditions. This shortened the cycle from 90 to 83.3 minutes. The integrated average for an 83.3 minute cycle is 17.82 watts or 24.8 watt hours output. The overall efficiency for the cycle is 3.55% including convection losses. Assuming the collector concentrator efficiency to be 86.6% the generator efficiency including reradiation but excluding convection losses from the vacity is 4.53%. (Author)

Flat Plate Solar Thermoelectric Generator Orbital Experiment, G.W.GLASSBURN. IEEE—Trans on Aerospace v AS-1 n 2 Aug 1963 p 1396-1403. Preliminary analysis of orbital flight data, ground-test data, and correlation of orbital and ground-test results from flat plate solar thermoelectric generator orbital experiment; flight established that correlation of ground and orbital tests can be accomplished with reasonable success even though panels deteriorate significantly. EZ 64

39368 IMPROVEMENTS IN OR RELATING TO ELECTRICAL POWER SOURCES. (to Telefunken GmbH). British Patent 936,165. Sept. 4, 1963. Priority date Mar. 9, 1960, Germany.

A semiconductor power source, in which at least one p-n junction is irradiated to produce electrical power, is patented. A β source, such as Ni^{63} or Pd^{107}, is placed in or near the blocking layer in the semiconductor. The source should not exceed ~100 kev to prevent damage to the semiconductor crystals. The β rays cause more electrons than normal to be lifted from the valency band into the conductivity band, resulting in an increased charge carrier formation and generating a voltage at the p-n junction. (M.P.G.)

NSA '63

Design Parameters for Thermoelectric Generators, J.L.McCABRIA, N.F.SCHUN. IEEE—Trans on Applications & Industry v 82 n 68 Sept 1963 p 296-300. Method for evaluating performance capabilities of thermoelectric generator is presented; fundamental equations by Ioffe and others are modified to include effective figure-of-merit of array of thermocouples in place of figure-of-merit of thermoelectric materials; practical factors such as electrode and contact resistance are considered; performance calculations for typical generator show that these factors have significant influence on performance of light weight generator. Paper 62-1151. EI '63

SNAP 8 Reactor and Shield, C.E.JOHNSON, C.A.GOETZ. AIAA J v 1 n 10 Oct 1963 p 2355-61. Summary of SNAP 8 reactor design and shielding requirements; 35-kw electrical power supply for use on spacecraft employs nuclear reactor heat source to drive mercury Rankine cycle turbalternator; major performance objectives are 600 kw of thermal power, 1300 F NaK outlet temperature, 10,000 hr endurance, orbital startup and automatic control, high reliability, and low weight; use of 550 lb reactor imposes restrictions on spacecraft design; shield weight can vary from few hundred to several thousand pounds, depending on payload dose tolerance and spacecraft configuration. EI '64

Nuclear coffee can: contains thulium-170 modules as heat source. il Product Eng 34: 56-7 O 28 '63

ASTI '63

Experimental Thermoelectric Generator, S.M.THIRD, G.E.HARE. Instn Elec Engrs—Proc v 110 n 10 Oct 1963 p 1829-36. Low power device, simulating section from megawatt output generator is described, built to test new idea for arrangement of thermoelements around cylindrical pipe; device uses bismuth telluride type thermoelements and operates between condensing vapor source at 250 C, and sink of cooling water at about 20 C; maximum measured efficiency was 2.1% at 13 w output; improvements in contact techniques, and use of material such as copper for body of generator, should lead to efficiencies of about 5%. Paper 4300S. EI '64

Alternating current thermoelectric generator. H. B. Nottage and P. L. Winskell. il diags A S M E Trans ser A 85:311-23 O '63

ASTI '63

/529 (NASA-TN-D-2070) A NUMERICAL ANALYSIS OF DIRECT NUCLEAR ELECTROGENERATOR CELLS THAT USE CERIUM 144 BETA-EMITTING RADIOISOTOPE SOURCES. Allan J. Cohen (National Aeronautics and Space Administration. Lewis Research Center, Cleveland). Dec. 1963. 56p.

An analysis of a radioisotope electric cell that uses the beta emitter, cerium-144, was undertaken. The analysis, which relies on formats set forth for fission electric cells, takes into account the pertinent physical constraints in a more accurate manner than has been done previously. Results from the analysis are presented in tables and as representative plots. Comparisons between accurate and approximate solutions are also included. (auth) NSA '64

Cooling Devices for Thermoelectric Generator, D.G.GRITTON, Y.S.TANG. Chem Eng Progress Symposium Ser v 59 n 41 1963 p 18-24. Design methods and performance data for heat rejection devices applicable to thermoelectric generators; first one, wire-coiled extended surface, removes heat through natural convection mode; second one, transverse-finned surface, makes use of forced convection heat transfer for relatively large power output units. EI '63

/23569 AEROSPACE NUCLEAR SAFETY PROGRAM. W. K. Kern and G. B. Connor. p.25-8 of "Nuclear Safety. Vol. 4, No. 3."

A program is being conducted on the safety of the operation of reactors and radioisotopic thermoelectric generators, particularly SNAP devices, in space. The possible aerospace environments to which the devices might be subjected are outlined, and the scope of the program is described. The ground environment studies, flight tests, and excursion tests are discussed. (D.L.C.) NSA '63

/20149 (BNL-756(p.1-18)) DEVELOPMENT PROBLEMS OF SNAP REACTOR SYSTEMS. G. Montgomery Anderson (Division of Reactor Development, AEC).

Materials problems in the SNAP systems imposed by the launch and space environments that are accentuated by a requirement to push to higher temperature levels and endurance than can be met by some of the more conventional materials are discussed. Three SNAP systems, 10A 2, and 8, are considered. One basic objective of the SNAP reactors is that the N_H (number of hydrogen atoms/cc × 10^{-22}) must be maximized to achieve a minimum system weight. It is shown that fuel stability at elevated temperatures forces a compromise between allowable N_H and maximum reactor operating temperature. Problems with system actuators, motors, wiring, and electronic components that must operate in a radiation field under vacuum at elevated temperatures are described. (M.C.G.) NSA '63

1619 SNAP-7A, 7B, AND 7D (Engineering Materials). (Martin Co. Nuclear Div., Baltimore). 8 drawings. (CAPE-937)

These Systems for Nuclear Auxiliary Power use heat that is produced by the decay of Sr^{90} to generate electricity in thermoelectric converters. SNAP-7A and 7B are 5- and 30-w respectively, thermoelectric generators used by the U. S. Coast Guard in operating lighted marine aids to navigation. Converters and generators supply 10 and 60-w. SNAP-7C and 7D are also 5- and 30-w power supplies used by the U. S. Navy to provide power for unmanned, remote, automatic weather stations. The systems operate without moving parts. (F.L.S.)

NSA '63

UNCLASSIFIED

117473 A PARAMETRIC STUDY OF DIRECT NUCLEAR ELECTROGENERATOR CELLS
117474 USING A BETA EMITTING SOURCE (AIAA Electric Propulsion Conference, Broadmoor Hotel, Colorado Springs, Colorado, March 11-13, 1963)
Cohen, Allan J. & Low, Charles A., Jr.
Unclassified

American Institute of Aeronautics & Astronautics
P-63-048-B

A design analysis has been completed for direct nuclear electrogenerator cells using the beta emitting radioisotope cerium 144. The physical phenomena that complicate the design are the beta particle energy spectrum, the energy losses in the fuel and the support foil, and the relativistic motion of the particle in the electric field. This study shows that within reasonable construction and physical limits a simple, efficient, and lightweight direct nuclear electrogenerator can be designed for space power uses.

1685 (MND-P-2707) STRONTIUM-90 FUELED THERMOELECTRIC GENERATOR POWER SOURCE—FIVE-WATT U. S. NAVY WEATHER STATION. Final Report. (Martin-Marietta Corp. Aerospace Div., Baltimore). [nd]. Contract AT(30-3)-217. 127p.

The SNAP-7C 10-watt Sr^{90} thermoelectric generator, the converter, batteries, and weather station housing that were delivered to Antarctica in December 1961 are described. Thermoelectric analysis, thermal analysis, fuel form and shielding requirements, generator assembly, electrical system, operational tests, and environmental testing are discussed. (M.C.G.) NSA 16 3

20166 (BNL-756(p.294-325)) DEVELOPMENT OF SNAP 2 HEAT TRANSFER COMPONENTS. W. D. Leonard and R. D. Keen (Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.).

The development of 6 SNAP 2 heat transfer components is described. These are the expansion compensator, the parasitic load heater, the flow trimmer, the orbital start pump, the radiator-condenser, and the auxiliary ground heater. Results of system tests are discussed. (M.C.G.) NSA 16 3

14443 PORTABLE THERMOELECTRIC GENERATORS. A. Bayne Neild, Jr. (Naval Engineering Experiment Station. [Annapolis]). Preprint 645A. Detroit, Society of Automotive Engineers, 1963. 9p. $1.00.

Paper from Automotive Engineering Congress, Detroit, Jan. 1963.

The inherent advantages of quiet operation, few moving parts, and compact and lightweight construction make thermoelectric generators desirable for powering certain specialized military equipment. Recent developments in thermoelectric materials, couple designs, and couple compartment fabrication have shown promise for successful generator sizes that can meet present needs for portable power up to 500 w. (auth) NSA 16 3

33391 A PARAMETRIC STUDY OF DIRECT NUCLEAR ELECTROGENERATOR CELLS USING A BETA EMITTING SOURCE. Allan J. Cohen and Charles A. Low, Jr. (Lewis Research Center, Cleveland). New York, American Institute of Aeronautics and Astronautics, 1963, Preprint 63048E, 15p. (CONF-10-57)

From Electric Propulsion Conference, Colorado Springs, Colo., Mar. 1963.

A design analysis is completed for direct nuclear electrogenerator cells using the beta emitting radioisotope cerium-144. The physical phenomena that complicate the design are the beta particle energy spectrum, the energy losses in the fuel and support foil, and the relativistic motion of the particle in the electric field. In addition to these physical restrictions, the various cell parameters such as radius ratio, fuel layer thickness, support foil thickness, and collector thickness are interrelated in such a complex manner that the IBM 7090 digital computer is required to find the characteristics of the cells. Cylindrical and spherical geometries are studied to determine the minimum weight per unit power. The main details of the mathematical operations performed by the computer are outlined along with information pertinent to the input requirements and results of the program. The simple calculations necessary to complete the description of the specific cells are indicated. The cell characteristics that result from these procedures are the operating voltage, current and power per unit area, the temperatures of the emitter and collector, and the weight per unit power. From these characteristics, the cell parameters that yield the optimum feasible design can be logically determined by simple analytical methods, which are described. As a result of these studies, a few designs are presented that can have weight/power ratios of 0.3 to 0.5 kg/kw. The study shows that within reasonable construction and physical limits a simple, efficient, and lightweight direct nuclear electrogenerator can be designed for space power uses. (auth) NSA 16 3

30157 THE TECHNOLOGY OF RADIOISOTOPIC POWER. J. G. Morse (Martin Co., Nuclear Div., Baltimore). Proc. Japan Conf. Radioisotopes, 5th, No. 3, 296-302(1963). (In English)

Power systems deriving their energy from radionuclide decay have been under development for more than six years, under U. S. Atomic Energy Commission sponsorship. Called SNAP, these systems consist of large sealed sources of radioisotopes which generate heat through absorption of decay energy. Power is obtained by converting this heat into electricity using thermoelectric and thermionic devices. The physical, chemical, and nuclear characteristics of appropriate radioisotopes as they relate to the design of optimum thermoelectric generators are reviewed. The uniqueness of these power systems lies in their use of radionuclide heat and their design life-times are determined, in large part, by the decay rates of the high power density fuel materials. During the past year a number of radioisotopic power systems have proved to be practical devices for uses in remote locations. Technical considerations are described, which relate to the selection of the fuel, power density (thermal watts per cubic centimeter) of the chemical form used, operating temperatures, containment of fuel and safety of the system. (JAIF) NSA'63

35217 (CONF-17-7) POWER APPLICATIONS OF RADIONUCLIDES. Justin L. Bloom (Martin-Marietta Corp. Aerospace Div., Baltimore). [1963]. Contract [AT(30-1)-2345]. 26p.

From Oak Ridge Radioisotope Conference on Applications to Physical Science and Engineering, Gatlinburg, Tenn., April 1963.

The development and uses of SNAP power supplies whic derive their energy from the decay of radioactive isotopes are discussed. (N.W.R.) NSA '63

2125 ISOTOPIC POWER DEVELOPMENT. p.89-96 of "Isotopes and Radiation Technology. Vol. 1, No. 1."

A survey is presented of thermoelectric generators using radioisotopes which were designed for remote-area terrestrial use. The generators described include a 5-watt Sr^{90} generator for a weather station in the Arctic, a 10-watt Sr^{90} generator for a light buoy, a Ce^{144} heat source for water desalination, and a 5-watt Cs^{137} generator for an underwater seismograph. The use of calorimetry at ORNL for measuring the rates of heat production by radioisotopes is discussed, and the design and operation of temperature-gradient calorimeters are described. Applications of calorimetric measurements are considered. (D.L.C.) NSA'64

32831 ON THE CHOICE OF COORDINATES USED TO DESCRIBE THERMOELECTRIC AND THERMOMAGNETIC GENERATORS. J. F. Osterle and S. W. Angrist (Carnegie Inst. of Tech., Pittsburgh). New York, American Society of Mechanical Engineers, 1963, Preprint 63-APM-19, 4p. (CONF-6-1).

From Conference, Ithaca, N. Y., June 1963.

It is demonstrated that the form of the energy-dissipation equation which describes thermoelectric and thermomagnetic generators is greatly dependent on the choice of dependent variables in the coupled equations used to describe the devices. If "natural" coordinates are chosen, the energy dissipation will always contain two terms—the Fourier conduction term and Joulean heating term. If "unnatural" coordinates are chosen, the energy-dissipation equation will contain three terms. A brief solid-state consideration demonstrates how a bound on the figure-of-merit temperature product can arise in terms of fundamental physical parameters. (auth) NSA '63

B. Thermionic converters

16783 (LADC-5128) THERMIONIC EMISSION CHARACTERISTICS OF CERTAIN ACTINIDE COMPOUNDS. F. P. Cranston, Jr. and J. W. Barger (Los Alamos Scientific Lab., N. Mex.). [1960]. Contract W-7405-eng-36. 17p.

Thermionic emission constants of UC, $UMoC_2$, Pu_2O_3, Pu_2O_3 + PuC, UWC_2, and Np_2C_3 were measured. A cylindrical diode geometry was used. The emitter consisted of a 0.030-in. W wire coated electrophoretically with the desired substance. (auth) NSA 63

616 ON THE DIRECT CONVERSION OF HEAT TO ELECTRICAL ENERGY WITH THE THERMO-ELECTRONIC DIODE. H. Huber and J. Bensimon (Compagnie Generale de Telegraphie Sans Fil, France). Ann. Radioelec., 16: 155-202(Apr. 1961). (In French)

Apart from a few very special cases, two main classes of thermo-electronic converters are recognized, namely the vacuum diode and the cesium-filled diode. The behavior of the first type of converter can be described quite rigorously, but the investigation of the second type raises difficulties regarding the behavior of the cesium plasma. The distribution of the inter-electrode potential is discussed, and a sketch is given of the main aspects of the thermo-electronic conversion of heat into electricity. Conversion efficiency is treated. The experimental results for these two categories are summarized. (auth) NSA 63

5643 (UCRL-6553) HEAT-SHIELDED MAGNETICALLY CHANNELED PLASMA HEAT CONVERTER. Raymond Fox (California. Univ., Livermore. Lawrence Radiation Lab.). Aug. 5, 1961. Contract W-7405-eng-48. 27p.

A design for a thermionic converter is described which utilizes a permeable heat shield and a homogeneous magnetic field normal to the cathode and anode surfaces to minimize the radiant power loss without appreciably decreasing the electrical power output. The permeable heat shield consists of thin, close-spaced foils perpendicular to the cathode and anode surfaces. Radiant power transfer is expressed as a function of the spectral emissivities of the cathode and anode surfaces and the interfoil and interelectrode spacings. The heat shield is biased positive with respect to the cathode and anode surfaces to prevent positive ion loss, and, in conjunction with the normal homogenous magnetic field, channels the electrons and ions to the anode. The required heat-shield positive bias is deduced and given as a function of the parameters of the converter. The energy conversion efficiencies attainable with this converter appear to be close to the Carnot efficiency. (auth.) NSA 63

4357 (MND-P-2679) THERMIONIC ISOTOPIC POWER SYSTEM. Final Summary Report Through September 30, 1961. William E. Kortier and Thomas S. Bustard (Martin-Marietta Corp. Aerospace Div., Baltimore). Contract AT(30-3)-217. 243p.

A summary of research and development in the field of vacuum-diode thermionic energy conversion as it applies to radioisotope-fueled power systems is presented. The development work was done to improve diode performance, to decrease generator weight and size, to develop a radioisotope-fueled generator, and to develop a generator which can withstand missile launch. A generator which can withstand missile launch was developed during the period. A vacuum converter fueled with a radioisotope was developed which provides 2 watts for use in missile applications in space. It is noted that most of the developments associated with the vacuum diode generator are applicable in the CS generator which is under development. (J.R.D.)

3570 (ASD-TR-61-723) FEASIBILITY OF THE USE OF HOLLOW CATHODES FOR THERMIONIC ENERGY CONVERSION. I. Brodie and A. Niewold (Westinghouse Electric Corp. Electronic Tube Div., Elmira, N. Y.). Nov. 30, 1961. Contract AF33(616)-7912. 48p.

Theoretical and experimental studies are reported to determine the feasibility of applying "electron blackbodies" to thermionic energy conversion. The conclusion from this work is that the size of the effusing hole is governed largely, not by the size of the cavity to which it is the exit, but by the physical limitations imposed by the nature of the electron atmosphere within the cavity. It is shown that the density of the electron atmosphere within the cavity is only large in a region close to the surface of the emitting walls and may be characterized by a parameter d, which does not depend on the size of the cavity. A quantitative expression is given for the conditions under which the effusing hole behaves as an electron blackbody. It is shown that for the electron emission density to be large enough for useful thermionic energy conversion, the size of the effusing hole has to be too small for practical consideration. (auth) NSA 63

Materials Problems in Cesium Thermionic Converters. L. YANG, F.D. CARPENTER. Electrochem Soc—J v 108 n 11 Nov 1961 p 1079-86. Review of principles of cesium thermionic converter; requirements for materials used for cathodes; loss of materials by vaporization; corrosion of cathode materials by cesium vapor; compatibility of cathode and electric lead materials; irradiation effects; fission-product release; heat transfer; carbide cathodes; anode materials; ceramic insulating seals; in-pile test. EI 63

Space-Charge Instabilities in Electron Diodes and Plasma Converters. C.K. BIRDSALL, W.B. BRIDGES. J Applied Physics v 32 n 12 Dec 1961 p 2611-18. Space charge instabilities in diodes have been found to produce variations in potential and current that are larger than predicted from classical static analyses and produce sustained electrokinetic oscillations; tentative explanations are offered for recent observations of extra shot-noise smoothing and of oscillations in thermionic converters. EI 63

Search for Nuclear Thermionic Emitter, P.STEPHAS. Nucleonics v 19 n 12 Dec 1961 p 66, 70, 72-3. Important problems of developing thermionic device to convert nuclear heat into electrical energy is finding suitable thermionic emitter material to coat nuclear fuel; most promising are carbides and borides of rare earth and transition metals; systematic investigation of di-, tetra-, and dodecarborides would provide better understanding of thermionic properties of materials. 21 refs.
EI 63

New Approach to Thermionic Energy Conversion—Space Charge Neutralization by Auxiliary Discharge, W.BERNSTEIN, R.C.KNECHTLI. IRE—Proc v 49 n 12 Dec 1961 p 1932-6. Characteristics of auxiliary discharge thermionic energy converter are derived; power expended in auxiliary discharge can be as low as 10% of power generated by converter; thus efficiencies of about 25% and power output densities as high as 10 w/sq cm can be obtained at temperatures of about 1500 K provided low work function anodes, are developed.
EI '63

Fizicheskie svoistva tsezievoi plazmy termoelektronnogo preobrazovatelya energii. N.D.MORGULIS, Yu.P.KORCHEVOI. Radiotekhnika i Elektronika v 6 n 12 Dec 1961 p 2073-83; see also English translation in Radio Eng & Electronic Physics (pub by AIEE) v 6 n 12 Dec 1961 p 1859-68. Physical properties of cesium plasma in thermionic energy converter; it is shown that converter can operate in 2 essentially different modes: "quasi-vacuum" at low pressures, and "arc" at increased cesium vapor pressures; properties of plasma and all its parameters are noticeably different in 2 cases.
EI 63

O termoelektronnykh konstantakh, L.N.DOBRETSOV. Radiotekhnika i Elektronika v 6 n 12 Dec 1961 p 2054-62; see also English translation in Radio Eng & Electronic Physics (pub by AIEE) v 6 n 12 Dec 1961 p 1841-9. Thermionic constants; analysis of thermionic constants contained in various equations for density of thermionic current in case of homogeneous electrodes; problem is of interest in direct conversion of heat into electricity.
EI 63

4155 THE RESISTANCE OF A PLASMA FOR A THERMIONIC CONVERTER. D.A.Fraser.
"Ionization in Gases" Conference Paper, Munich, 1961 (see Abstr. 1928 of 1963), p. 819-24.

Measurements were made of the voltage-current characteristics of an independently produced plasma between two emitting electrodes. It is shown that the observed characteristics can be accounted for by the changes of the sheath voltages at the two electrodes, the plasma remaining closely unipotential.
PA '63

9008 THERMAL IONIC GENERATOR—POWER GENERATING EQUIPMENT OF THE FUTURE. Sheng Hsi. K'o Hsueh Ta Chung, No. 7, 220-2(1961).

Discussion is given on the thermionic generator, which converts heat energy directly into electrical energy. The principle of operation is the same as that of a diode electron tube. Thermionic generators with vaporized cesium have much higher efficiency than vacuum generators. They can be operated directly with an atomic reactor or a thermonuclear reaction without being contaminated by radiation. Applications of the thermionic generator are also discussed. It is believed that practical thermionic generators will eventually be developed. (P.C.H.)
NSA '63

3997 A NEW GASFILLED THERMIONIC CONVERTOR. W.Bloss.
"Ionization in Gases" Conference Paper, Munich, 1961 (see Abstr. 1928 of 1963), p. 815-18. In German.

Based on a theoretical treatment of the efficiency of thermionic energy convertors, experiments were performed using models of a new convertor type with cathode temperatures not exceeding 1000°C. The influence of a low-pressure plasma being generated in an auxilary discharge on the efficiency and the dependence of pressure and kind of gas was investigated. Noble gases with large mass numbers were proved to be advantageous. The output current was controlled by the auxiliary discharge. By this means it was possible to use the convertor as an a.c. generator operating at frequencies up to about 1000 c/s.
PA63

8946 (TID-15268) OPTIMIZATION OF EFFICIENCY OF A CESIUM-DIODE CONVERTER. C. K. Sanathanan (Argonne National Lab., Ill.). Jan. 1962. Contract [W-31-109-eng-38]. 11p. (UAC-5993)

The values of the heat-transfer coefficient and effective thermal emissivity of a cesium diode were varied and the effect on efficiency was studied. The efficiency was optimized with respect to the lead wire voltage and the load voltage. Results are presented in graphs. (M.C.G.) NSA 63

949 (AD-273067) INVESTIGATIONS ON THE DIRECT CONVERSION OF NUCLEAR FISSION TO ELECTRICAL ENERGY IN A PLASMA DIODE. Annual Report, January 1, 1961 to January 31, 1962. Frank E. Jamerson, ed. (General Motors Corp. Research Labs., Warren, Mich.). Jan. 31, 1962. Contract Nonr-3109(00). 83p.

Results of experimental and theoretical investigations are presented on the use of a nuclear generated plasma in a noble-gas plasma-diode thermionic converter. Related programs of emitter materials development and plasma measurements are described. These are presented in individual reports on noble gas plasma diode inpile experiment IV, noble gas plasma diode inpile experiment V, plasma sheath theory with voltage-independent ion sources, development of emitter materials for use in noble gas plasma-diodes, thermionic emission of UC-Nb and UC-Re, and spectroscopic measurements of plasma temperatures and densities in high pressure Cs-Diodes. (auth) NSA 63

Thermionic Conversion—State of Art. T.JARVIS. IRE—Trans on Military Electronics v MIL-6 n 1 Jan 1962 p 41-5. Brief discussion of fundamental principles; outline of different types of thermionic converters; status of individual conversion techniques reviewed; description of materials problems. NSA 63

7419 (AD-274920) LO-TEMP THERMIONIC PLASMA STUDY. Yearly Summary Technical Report. (Ford Instrument Co., Long Island City, N. Y.). Jan. 31, 1962. Contract NONR 3416(00). 60p.

Measurements of electron temperature, electron concentration and space potential in the plasma region of low temperature thermionic converters were determined by means of a pulsed Langmuir probe technique. The spatial distributions of these parameters, in parallel plate geometry, were measured with the aid of movable probes. The experimental values are shown to be consistent with a reasonable physical picture. Preliminary results obtained from converters, in which small amounts of O_2 were present in the discharge region are explored. The effects of Cs and patch effects on the surface characteristics of impregnated W emitters are discussed on the basis of a theoretical analysis and experimental results with numerous test cells. (auth) NSA 63

2361 (DCAS-TDR-62-20) ENERGY CONVERSION PROGRAM. THERMIONIC CONVERTER STUDIES. Semi-annual Technical Report, July 1–December 31, 1961. G. L. Johnston (Aerospace Corp., El Segundo, Calif.). Feb. 14, 1962. Contract AF04(647)-930. 19p. (AD-274694; TDR-930(2220-50)TR-2)

Work continued on the fabrication of the plane-parallel Cs thermionic converter and the spectroscopic converter, which are near completion, and on the analysis of a collector sheath of a plasma converter. Studies were initiated and completed on a glass envelope thermionic converter and on theoretical calculations of thermodynamics and transport properties of Cs vapor. Theoretical studies of the interaction of Cs vapor and refractory metal surfaces were initiated. (auth) NSA 63

1916 (ARF-2215-6) SEAL AND INSULATOR PROBLEMS IN THERMIONIC CONVERTERS. Summary Report, February 15, 1961–February 15, 1962. David W. Levinson (Illinois Inst. of Tech., Chicago. Armour Research Foundation). Mar. 12, 1962. Contract NONR-3441(00). 88p. (AD-273481)

A discussion of the materials requirements for seals and insulators for thermionic energy converters is presented. Based on the requirements and published physical property data, Al_2O_3 appeared to be the most desirable insulator material at temperatures below its melting point. NSA 63

4352 (AD-273692) LOW TEMPERATURE THERMIONIC CONVERTERS. Quarterly Technical Progress Report No. 1. December 1, 1961–March 1, 1962. (Ford Instrument Co., Long Island City, N. Y.). Mar. 1962. Contract AF 33(657)-7663. 17p.

Fabrication and development work performed in the investigation of low temperature thermionic converters are presented. The fabrication work included a high temperature metal-ceramic electron gun envelope, improvement in emitter brazing techniques, and anode cooling techniques. Improved anode temperature uniformity was achieved with a gas cooling loop shaped in the form of a pancake helix. Mo or Cu powder improved the heat transfer between the helix and cup bottom. Cell processing and evaluation data are given as well as results of destructive and shock tests. Techniques for solar and nuclear simulation are discussed. (auth) NSA 63

1719 THERMIONIC CONVERSION - - STATE OF THE ART. Theodore Jarvis (Ford Instrument Co., Long Island City, N. Y.). IRE (Inst. Radio Engrs.), Trans. Military Electron., MIL-6: 41-5(Jan. 1962).

After a brief discussion of fundamental principles, a family tree of the different types of thermionic converters is presented. The status of individual conversion techniques is then reviewed. A description of the materials problems is given. The review concludes with projections of development and performance trends of the most important types of thermionic converters. (auth) NSA '63

Spectroscopic Measurements of Temperatures and Densities in Cesium Plasma, R.J.DONOHUE, R.F.MAJKOWSKI J Applied Physics v 33 n 1 Jan 1962 p 3-10. Ion, electron and atom number densities, and electron temperatures of cesium plasma generated in diode have been measured by spectroscopic techniques; working equations are developed for determination of electron number density from continuum intensity and Stark broadening; temperatures in cesium plasma were 0.7 ev with ion and electron number densities of order of 10^{15}/cc. EI63

10924 CURRENT OSCILLATIONS IN THE SYSTEM OF A THERMIONIC ENERGY CONVERTER WITH CESIUM VAPOR. N.D.Morgulis, C.M.Levitskii and I.N.Groshev. Radiotekhnika i Elektronika (USSR), Vol. 7, No. 2, 352-3 (Feb., 1962). In Russian. English translation in: Radio Engng electronic Phys. (USA), Vol. 7, No. 2, 330-2 (Feb., 1962). EEA '63

Some Considerations of Dynamic Behavior in Plasma Thermocouple, R.W.BUSSARD. J Applied Physics v 33 n 2 Feb 1962 p 606-13. Analysis of role which stable electron oscillations of large amplitude may play in determining observed "steady state" characteristics of plasma filled thermionic diode; in operation such that net current flow is controlled by sheath potential distribution, it is found that time averaged net current may increase markedly in transition from nonoscillatory to oscillatory operation; comparison is made with some experimental results. 28 refs. EI63

182 THE ANODES OF THERMOELECTRONIC CONVERTERS. V.G.Bol'shov and A.A.Zharinov. Zh. tekh. Fiz. (USSR), Vol. 32, No. 2, 214-19 (Feb., 1962). In Russian. English translation in: Soviet Physics - Technical Physics (USA), Vol. 7, No. 2, 152-5 (Aug., 1962).

The power and efficiency of a thermoelectronic (thermionic) converter can be increased by reducing the average work function of the anode. During operation cathode materials are evaporated on to the anode and control the work function. A contact potential difference method was used to determine the work functions of ZrC, TaC, and UC + ZrC evaporated layers in Cs vapour at various pressures. The Cs vapour has most effect on the TaC evaporation products reducing the work function to about 1·0 eV at a pressure of 10^{-2} mm Hg. C.Greaves

EEA '63

24207 CURRENT OSCILLATIONS IN THE SYSTEM OF A THERMIONIC ENERGY CONVERTER WITH CAESIUM VAPOR. N.D.Morgulis, C.M.Levitskii and I.N.Groshev. Radiotekhnika i Elektronika (USSR), Vol. 7, No. 2, 352-3 (Feb., 1962). In Russian. English translation in: Radio Engng electronic Phys. (USA), Vol. 7, No. 2, 330-2 (Feb., 1962).

Some results already obtained in a systematic investigation of the current oscillations arising under certain conditions in thermionic diodes with Cs vapour (Gurtovoy, 1955) are reported. A tube filled with Cs vapour, containing a Ta strip cathode and a similar Cs-coated Ta anode with screening electrodes, the distance between which could be varied, was employed in the experiments. The variable parameters were T_k, cathode temperature; t, Cs vapour saturation temperature; and d, interelectrode distance. Two discrete regions of oscillations were obtained at about T_k = 1200° - 1400°K and above T_k = 1900° - 2380°K respectively, for d = 1 mm (the respective t values being 180° - 260°C and 20° - 140°C). The respective oscillations were sinusoidal, ν = 20 - 160kc/s, in the first region and non-sinusoidal, ν = 100 kc/s, in the second region, corresponding approximately to the quasi-vacuum and arc conditions of converter tube operation. It was demonstrated that the oscillations in the second zone have a considerable output power, the system being in principle a converter of thermal energy into energy of direct as well as alternating current of higher frequency. L.Mordecai

PA63

12747 (AFCRL-62-373) STUDIES OF ELECTRON TUBE MATERIALS AND THERMIONIC EMISSION PROCESSES. Eighth Scientific Report, January 1, 1962–March 31, 1962. (General Telephone and Electronics Labs. Inc., Bayside, N. Y.). Contract AF19(604)-7286. 41p. (AD-277556)

The thermionic emission properties of ultra-pure nickel-base oxide cathodes in the clean test diode are being investigated. A comparison of the emission results for active N4 and ultra-pure nickel-base cathodes shows that the active nickel-base cathodes are well activated after the four high-temperature processing treatments. The sublimation characteristics of a barium oxide platinum-base cathode were studied. The evaporation rates of molecular BaO as measured by the retarding field technique were in excellent agreement with previously reported values based upon mass spectrometric, chemical and radioactive tracer methods. Full operation of the Knudsen cell-mass spectrometer system provided an initial calibration of the instrument. The presence of silver and molecular beam operation was confirmed by a measurement of the isotopic abundance of the ions in question, by the mass scale constants for the instrument and by operation of the molecular beam shutter. The electron emissive properties of a triple oxide cathode were displayed on the screen of a 24-inch diameter sealed-off emission microscope tube. The size and location of emission sites were observed. (auth) NSA'63

2113 DIRECT TRANSFORMATION OF HEAT INTO ELECTRICITY WITH THE AID OF THERMIONIC CONVERTERS WITH CESIUM ATMOSPHERE. Pierre Boyer. Rev. Gen. Electron., 16: No. 184, 17-22(Mar. 1962). (In French)

The review of the direct transformation of heat into electricity is divided into two basic sections—electronic emission with surface ionization and surface ionization of cesium on tungsten. A number of specific applications to converters is given. A very recent biography is appended. (auth) NSA'63

20649 THERMIONIC ENERGY CONVERTER. L. N. Dobretsov (Dobrecov) (Inst. of Technical Physics, Leningrad). Cesk. Casopis Fys., 12: 428-38(Apr. 1962). (In Czech)

An interpretation is given of the physical processes in the activity of a thermionic converter. Information is presented on the state of research into practically applicable thermoelectron converters. Two types of converters are mentioned: a vacuum converter with a small distance between the electrodes; and a converter with cesium vapors, the construction of which is technically simpler. Three kinds of working regimes are described for the converter with cesium vapors: Knudsen, diffusion, and plasmatic. These regimes are evaluated from the point of view of suitability for application. In connection with the conversion of nuclear into electrical energy in a thermionic converter, a description is given of an existing converter. (auth) NSA'63

5637 (AD-275908) THERMIONIC CONVERTER RESEARCH. Report No. 3. Quarterly Progress Report No. 3, January 1, 1962–March 31, 1962. R. Laubenstein, W. Beyermann, and B. Chang (Marquardt Corp., Van Nuys, Calif.). Apr. 1962. Contract DA36-039 sc-87217. 37p.

Research on thermionic converters which are potentially capable of operation at temperatures obtained from the combustion of ordinary fossil fuels was continued. Measurements of the electrical resistivity of beta-eucryptite indicated that the relatively high resistivity may place severe restrictions on the design of an ion emission structure with a long operating lifetime. Arc mode operation of a cesium vapor thermionic diode with plane parallel molybdenum electrodes was obtained for emitter temperatures of 1300 to 1350°C. A power output density of 0.57 watt per cm^2 was obtained without optimizing all operating parameters. Negative emitter bias voltages of 0.2 to 0.5 volt were required to initiate the arc. (auth) NSA'63

14928 (ASD-TDR-62-324) THE DEVELOPMENT OF A LOW TEMPERATURE VAPOR FILLED THERMIONIC CONVERTER. F. G. Block and J. J. O'Grady (Radio Corp. of America. [Electron Tube Div.], Lancaster, Penna.). Apr. 5, 1962. Contract AF33(616)-7903. 168p. (AD-278810)

Applied research toward developing a low-temperature, plasma, thermionic converter is described. A third electrode is used in the converter to ionize plasma so as to neutralize the space charge. The lower temperature thus achieved should significantly prolong the life of the converter and contribute to the development of a more reliable power supply for space application. The program was directed toward optimizing geometry and operating characteristics and investigating the effects of temperature and pressure, starting pulse, magnetic fields, and operation in both series and parallel circuitry. Materials were investigated to achieve practical electrodes by determining compatibility of material, atmospheric corrosion, and gas permeation. Converters were fabricated, evaluated, and life tested with the parameters optimized by the test program. (auth) NSA'63

11837 (TID-16215) RF OSCILLATIONS AND POWER OUTPUT IN ALKALINE THERMIONIC CONVERTERS. H. K. Richards (Argonne National Lab., Ill.). Apr. 1962. Contract W-31-109-eng-38. 18p. (UAC-6389)

Experiments were made using a potassium plasma cell with a Ta emitter and a Ag-plated Cu collector. The r-f frequencies, rms voltages, power output, and other quantities were measured under various conditions of emitter temperature, potassium vapor pressure, and d-c and r-f loads. Ion and electron densities were calculated and compared with the oscillations occurring. (D.L.C.) NSA'63

UNCLASSIFIED

TR 32-171 A 500-ELECTRICAL-WATT SOLAR ENERGY THERMIONIC CONVERSION SYSTEM FOR A MARS SPACECRAFT
Smith, Arvin H.
April 15, 1962 Unclassified

The conceptual design of a solar energy thermionic conversion system suitable for use as the prime source of electrical power for a Mars spacecraft is described. Two designs of such a system are considered. The most promising design would employ an individual, 9.5-ft-diameter, rigid, parabolic mirror to intercept, reflect, and concentrate solar energy. A multidiode thermionic generator would convert the concentrated thermalized solar energy into electricity. An alternate design would incorporate a 5-ft-diameter mirror and a 135-watt thermionic generator. It is concluded that potentially advantageous solar energy thermionic conversion systems are possible, provided that long life and adequate reliability can be achieved.

Effect of Staging on Performance of Thermionic Converters. G. N. HATSOPOULOS. AIEE—Trans v 81 pt 1 (Communication & Electronics) n 59 Mar 1962 p 36-40. Effect of operating several thermionic stages thermally connected in series between 2 heat reservoirs at given temperatures. Paper 60-344. EI63

Electron Space-Charge-Limited Operation of Cesium Thermionic Converters. E.N.CARABATEAS. J Applied Physics v 33 n 4 Apr 1962 p 1445-9. Quantitative analysis of electron space-charge-limited operation; difference in emitter and collector work functions can be found from experimental current-voltage characteristic and conversely such characteristic can be plotted if sufficient information is given; method is applied to experimental I-V curves obtained from parallel plate converter with tantalum emitter. CJ63

8924 (JPL-TR-32-171) A 500-ELECTRICAL-WATT SOLAR ENERGY THERMIONIC CONVERSION SYSTEM FOR A MARS SPACECRAFT. Arvin H. Smith (California Inst. of Tech., Pasadena. Jet Propulsion Lab.). Apr. 15, 1962. Contract NAS 7-100. 14p.

The conceptual design of a solar energy thermionic (SET) conversion system suitable for use as the prime source of electrical power for a Mars spacecraft is described. Two designs of such a system are considered. The most promising design, designated SET (A), would employ an individual, 9.5-ft-diameter, rigid, parabolic mirror to intercept, reflect, and concentrate solar energy. A multidiode thermionic generator would convert the concentrated thermalized solar energy into electricity. SET (A) would utilize a 500-electrical-watt thermionic generator incorporating a cavity-type absorber, cesium-vapor-filled thermionic diodes, heat radiators, temperature-controlled cesium reservoirs, and a solar flux control mechanism. An alternate design, designated SET (B), would incorporate a 5-ft-diameter mirror and a 135-watt thermionic generator. Four such modules would be clustered to provide up to 540 watts of electrical power at Mars (aphelion). The design features of a 135-watt flight prototype, which is currently under active development, are presented. It is concluded that potentially advantageous solar energy thermionic conversion systems are possible, provided that long life and adequate reliability can be achieved. (auth) NSA'63

12752 (ASD-TDR-62-94) SOLAR THERMIONIC ELECTRICAL POWER SYSTEM. D. L. Cuthbert, D. L. Purdy, E. W. Williams, J. A. Ruff, D. L. Kerr, W. G. Flanigan, R. Luck, Jr., D. Jones, and E. Baum (General Electric Co. Missile and Space Vehicle Dept., Philadelphia). Mar. 1962. Contract AF33(616)-7008. 148p. (AD-277555)

Progress is reported on the design and development of a solar thermionic electrical power system (STEPS). The design objective was to size the system to generate 500 watts of electrical power in space when operating in a simulated orbit over a 35-minute-dark, 55-minute-light cycle. Vacuum thermionic converters were used. The system was to be ground-operated with the hardware as close to flight type as possible. Details of the design, development, fabrication, and performance of the system are included. (auth) NSA 63

AD-281 819 Div. 7, 8
(TISTM/EJH)

Atomics International, Canoga Park, Calif.
FLAME HEATED THERMIONIC CONVERTER RESEARCH.
Quarterly rept. no. 3, 1 Jan-31 Mar 62,
by W. R. Martini, R. L. McKisson, and E. V. Clark. 31 Mar 62, 68p. incl. illus. tables, 13 refs. (Rept. no. AI-7330)
(Contract DA 36-039-sc-88982, Proj. 3A99-09-002-04)

Unclassified report

DESCRIPTORS: *Electric power production, *Diodes, *Thermionic emission, *Power supplies, Materials, Refractory coatings, Silicon compounds, Carbides, Combustion chambers, Flames, Heat production, Molybdenum, Cesium, Vapors, High temperature research, Seals, Inverted rectifiers.

The 150 W(e) electrically heated diode developed a Cs leak in the seal insulator. However, before the Cs was exhausted, some data were obtained defining the necessary operating parameters for a triggered diode power inversion system. Four flame-heated thermionic converters are being constructed. The heater for these converters was tested. An emitter temperature of 1450 C was attained, along with a heat flux of 28 w/sq cm. An analysis of possible efficiencies for diode heaters emphasized that heaters employing fuel injection, in combination with high efficiency heat exchanger, must eventually be developed. Testing of Durak-B coating for Mo metal continued. Analysis of results showed that the coating fails due to depletion of Si. Si may evaporate as SiO2 or diffuse into the Mo metal. Flame corrosion tests on SiC refractories showed the superiority of KT SiC. '62

8924 (JPL-TR-32-171) A 500-ELECTRICAL-WATT SOLAR ENERGY THERMIONIC CONVERSION SYSTEM FOR A MARS SPACECRAFT. Arvin H. Smith (California Inst. of Tech., Pasadena. Jet Propulsion Lab.). Apr. 15, 1962. Contract NAS 7-100. 14p.

The conceptual design of a solar energy thermionic (SET) conversion system suitable for use as the prime source of electrical power for a Mars spacecraft is described. Two designs of such a system are considered. The most promising design, designated SET (A), would employ an individual, 9.5-ft-diameter, rigid, parabolic mirror to intercept, reflect, and concentrate solar energy. A multidiode thermionic generator would convert the concentrated thermalized solar energy into electricity. SET (A) would utilize a 500-electrical-watt thermionic generator incorporating a cavity-type absorber, cesium-vapor-filled thermionic diodes, heat radiators, temperature-controlled cesium reservoirs, and a solar flux control mechanism. An alternate design, designated SET (B), would incorporate a 5-ft-diameter mirror and a 135-watt thermionic generator. Four such modules would be clustered to provide up to 540 watts of electrical power at Mars (aphelion). The design features of a 135-watt flight prototype, which is currently under active development, are presented. It is concluded that potentially advantageous solar energy thermionic conversion systems are possible, provided that long life and adequate reliability can be achieved. (auth)

NSA '63

8912 (AD-277042) THE DEVELOPMENT OF AN AUXILIARY ELECTRODE THERMIONIC CONVERTER. Quarterly Technical Report No. 1, January 15, 1962–March 30, 1962. F. G. Block and J. J. O'Grady (Radio Corp. of America. Electron Tube Div., Lancaster, Penna.). Apr. 15, 1962. Contract AF33(657)-8005. 17p.

The efficiency and life expectancy of thermionic energy converters for space applications were studied. The objective of the program is to determine the feasibility and to demonstrate the practicality of a three-electrode thermionic converter having a third, positive ion-producing electrode, an efficiency of not less than 15%; an unattended life of not less than one year; and a maximum temperature of 1500 Kelvin. An approach using impact ionization will be pursued. (auth)

NSA '63

3539 THERMIONIC GENERATORS. D. A. Fraser and G. G. Isaacs (General Electric Co., Wembley, Eng.). Electron. Eng., 34: 307-11(May 1962).

Power output and efficiency under idealized conditions are calculated for various electrode materials and temperatures. Methods of space charge neutralization are considered, including ionization of cesium at the emitter surface and the use of auxiliary discharges for ion production. Possible applications cover a wide range of power. (auth)

NSA '63

22263 (AFCRL-62-669) PARAMETRIC STUDY OF CLOSE-SPACED CESIUM THERMIONIC CONVERTERS. Annual Technical Report. E. N. Carabateas, S. Kitrilakis, and J. H. Weinstein (Thermo Electron Engineering Corp., Waltham, Mass.). May 1962. Contract AF19(604)-8453. 82p. (AD-282895)

A variable spacing, Cs diode test vehicle, using a Nb emitter and Mo collector, was used for parametric tests of converter performance. The design and construction of the test vehicle were such that emitter temperature, collector temperature, and Cs pressure could be independently controlled. In addition, most of the important converter heat losses could be accurately measured. Extensive tests were conducted which resulted in a complete map of diode performance. Additional tests were conducted to supply data for analytical work on Cs conduction, converter operation, and surface phenomena. (auth)

NSA '63

6788 (EDR-2791) INVESTIGATION OF THE MONOCAPILLARY THERMIONIC EMITTER AS A DUAL SOURCE OF IONS AND ELECTRONS. Quarterly Technical Progress Report No. 2, February 15–May 15, 1962. D. L. Dresser and W. Laurita (General Motors Corp. Allison Div., Indianapolis). May 15, 1962. Contract AF33(616)-8299. (AD-275733)

Theoretical and experimental work is reported on the investigation of a capillary emitter serving as a dual source of ions and electrons in a thermionic converter. During this report period, improved agreement was achieved between the experimental data obtained on monocapillary test devices and a model based on the sheath potential concept. Several processes for fabricating multicapillary emitters are described, including stacking fine wires, spark machining, electrolytical etching, vapor deposition, and electrochemical deposition. Experimental results are given to show the feasibility of circulating Cs by means of an electromagnetic pump. The design and fabrication of a closed cycle (gravity feed) multicapillary thermionic converter are discussed. (auth)

NSA '63

12396 ENERGY CONVERSION TECHNIQUES. K. G. Hernqvist (RCA Labs., Princeton, N. J.). Proc. I.R.E. (Inst. Radio Engrs.), 50: 1285-8(May 1962).

The conception and evolution of the basic principles of thermionic energy conversion, the newest of the heat-to-electricity conversion methods, are described. The application of thermionic energy converters to its ideal heat source, the fission reactor, is discussed. It is believed that the state of the art is far enough advanced to make such a thermionic-reactor system practical within the next decade. (auth)

NSA '63

15880 ENERGY CONVERSION TECHNIQUES.
K.G.Hernqvist.
Proc. Inst. Radio Engrs (USA), Vol. 50, No. 5, 1285-8 (May, 1962).
The conception and evolution of the basic principles of thermionic energy conversion, the newest of the heat-to-electricity conversion methods, are described. The application of thermionic energy convertors to its ideal heat source, the fission reactor, is discussed. It is believed that the state of the art is far enough advanced to make such a thermionic-layer system practical within the next decade.
PA '62

9718 EFFECT OF SPACE CHARGE ON LOAD CHARACTERISTICS AND E.M.F. OF THERMIONIC ENERGY CONVERTOR.
A.A.Ostroukhov.
Zh. tekh. Fiz. (USSR), Vol. 32, No. 5, 613-25 (May, 1962). In Russian.
English translation in: Soviet Physics-Technical Physics (USA), Vol. 7, No. 5, 445-53 (Nov., 1962).
Equations for calculating the load characteristics and thermal e.m.f. at different cathode and anode temperatures with space charge in vacuum taken into account were obtained for the case of low pressures of filling vapour in a thermionic convertor. Simple calculations are given for: (1) relation between thermal e.m.f. and cathode temperature; (2) load characteristic. A comparison of the results of calculation with experiment shows that, even in the case of low pressures (about 10^{-3} mm Hg), the idea of free motion of particles in the interelectrode space is an approximate one. PA '63

11601 THERMIONIC GENERATORS.
D.A.Fraser and G.G.Isaacs.
Electronic Engng (GB), Vol. 34, 307-11 (May, 1962).
Experimental work on thermionic generators has shown that electrical output of about 10 W/cm² of emitter surface at overall efficiency of at least 10% is feasible. The power output and efficiency under idealized conditions are calculated for various electrode materials and temperatures. Methods of space charge neutralization are considered, including ionization of caesium at the emitter surface and the use of auxiliary discharges for ion production. Possible applications cover a wide range of power. Small units, producing a few watts, have already been made, but much technological development is required for larger thermionic generators for power station use.
PA '62

17776 THERMIONIC ENERGY CONVERSION DIODE USING A FILM BOILING LIQUID METAL ANODE. A.J.Ulrich.
J. appl. Phys. (USA), Vol. 33, No. 5, 1896-7 (May, 1962).
Recent experiments have shown that a diode for the purpose of energy conversion can be produced, which employs the phenomenon of film boiling at the alkali metal anode. The film boiling liquid is covered by an inert gas blanket to hold the vapour pressure at a few mm Hg. Voltage—current curves for successive time intervals from 10 to 220 sec are presented, with currents up into the 0.1 A region and associated voltages between 1 and 3 V. Construction of the diode is described, and the possible advantages over the conventional thermionic diode concept are outlined.
F.R.Walter
PA '62

Thermo-Electrical Engineering, A.G. HEATON. Instn Elec Engrs—Proc v 109 pt B (Electronic & Communication Eng) n 45 May 1962 p 223-32. Explanation of basic principles of thermoelectric generators and cooling units in quantitative manner; potentialities of bismuth telluride for generation of power and heat pumping and, in particular, for refrigeration of small volumes and local cooling; paper is based on work done by author on engineering applications of bismuth telluride. Paper 3867.
ET 62

17778 ENERGY CONVERSION BY AN IONIZED VAPOUR STREAM. M.Surdin.
J. Phys Radium (France), Vol. 23, No. 5, 297-8 (May, 1962).
In French.

A theory of Klein's [The direct conversion of thermal energy into electrical energy. (Proceedings of the 5th International Conference on Ionization Phenomena in Gases, 1962, Vol. 1, p. 806)] experiment on direct conversion of energy by an ionized vapour stream is given. The negative potential of the hot electrode is calculated assuming that electrons and ions obey a Maxwell–Boltzmann distribution. The positive potential of the cold electrode is calculated in the same manner. The negative charge carriers arriving at the cold electrode are water droplets. The short-circuit current is calculated, approximately, assuming that the electron short-circuit current compensate the ion current arriving at the cold electrode. PA '62

Thermionic Generators, D.A.FRASER, G.G.ISAACS. Electronic Eng v 34 n 411 May 1962 p 307-11. Power output and efficiency of generators under idealized conditions are calculated for various electrode materials and temperatures; methods of space charge neutralization, including ionization of cesium at emitter surface and use of auxiliary discharges for ion production. EI 63

Power Generation from Ionized Gases, D.W.GEORGE, H.K.MESSERLE. Instn Engrs, Australia—Elec & Mech Eng Trans v EM 4 n 1 May 1962 p 1-6. Possibility of generating large amounts of electric power directly from interaction of flowing hot gas with magnetic field; influence of gas conductivity, duct size, magnetic field strength and gas velocity on conversion process; problems associated with compressibility of gas that these may be overcome in practical design; alternative methods of obtaining degree of ionization required in gas; methods of reducing high operating temperatures when using thermal ionization; combination of conventional generating plant with plasma converter. EI '63

AD-282 895 Div. 7
(TISTM/GEC) OTS price $8.10

Thermo Electron Engineering Corp., Waltham, Mass.
PARAMETRIC STUDY OF CLOSE-SPACED CESIUM THERMIONIC CONVERTERS.
Annual technical summary rept., 10 Apr 61-10 Mar 62,
by E. N. Carabateas, S. S. Kitrilakis, and J. H. Weinstein. May 62, 1v. incl. illus. tables.
(Contract AF 19(604)8453, Proj. 6692)
(AFCRL 62-669) Unclassified report

DESCRIPTORS: *Power supplies, *Diodes, Niobium, Molybdenum, Energy, Temperature control, Tests, Pressure, Measurement, Temperature, Thermal conductivity, Thermionic emission, Cesium.

A variable spacing, Cs diode test vehicle, using a Nb emitter and Mo collector, was used for parametric tests of converter performance. The design and construction of the test vehicle were such that emitter temperature, collector temperature, and Cs pressure could be independently controlled. In addition, most of the important converter heat losses could be accurately measured. Extensive tests were conducted which resulted in a complete map of diode performance which will greatly aid the selection of design conditions for future hardware manufacture. Additional tests were conducted to supply data for analytical work on Cs conduction, converter operation, and surface phenomena. (Author) '62

Energy Conversion Techniques, K.G.HERNQVIST. IRE—Proc v 50 n 5 May 1962 p 1285-8. Conception and evolution of basic principles of thermionic energy heat conversion; application of thermionic energy converters to its ideal heat source, fission reactor. EI 63

Power Generation from Ionized Gases, D.W.GEORGE, H.K.MESSERLE. Instn Engrs, Australia—Elec & Mech Eng Trans v EM 4 n 1 May 1962 p 1-6. Possibility of generating large amounts of electric power directly from interaction of flowing hot gas with magnetic field; influence of gas conductivity, duct size, magnetic field strength and gas velocity on conversion process; problems associated with compressibility of gas that these may be overcome in practical design; alternative methods of obtaining degree of ionization required in gas; methods of reducing high operating temperatures when using thermal ionization; combination of conventional generating plant with plasma converter. EI 63

AD-291 223 Div. 25
(TISTP/JW) OTS price $1.10

Hughes Research Labs., Malibu, Calif.
CESIUM PLASMA STUDIES FOR THERMIONIC ENERGY CONVERSION.
Quarterly letter rept. no. 2, 1 June 61-31 May 62 on Phase 2,
by R. C. Knechtli. 31 May 62, 3p. 2 refs.
(Contract Nonr-350100)
Unclassified report

DESCRIPTORS: *Plasma physics, *Thermionic emission, Energy, Cesium, Ionization, Measurement, Electrons.

'63

UNCLASSIFIED

113167 THERMIONIC CONVERTER RESEARCH
(Period covered: July 1, 1961-June 30, 1962)
Laubenstein, R.; Beyermann, W. & Chang, B.

Marquardt Corp.
DA 36-039 SC-87217
Final Report-4

Unclassified
(R-25,057)
(ASTIA AD-284 457)

Low temperature converters with emitter temperatures of 1200°C or lower are potentially useful for operation with small heat sources which burn ordinary fossil fuels in air. Materials which emit positive ions when heated in the range of 1000°C to 1200°C have been studied. The principal problem areas in the use of these materials appears to be the short lifetime because of depletion of the material and the high electrical resistivity of the better ion emitters. Other problems include the contamination of ion and electron emitting surfaces in the same tube envelope, interaction of the ion emitter with its substrate material, and a geometric configuration of electron emitter, ion emitter and collector such that the ions from a large volume of ion emitter are effectively utilized for space charge neutralization.

UNCLASSIFIED

115151 HIGH TEMPERATURE THERMOELECTRIC GENERATOR
(Period covered: April 2-June 29, 1962)
Henderson, C. M. & Ault, R. G.

Monsanto Research Corp.
Dayton Laboratories
AF 33(657)-7387
QPR-3

Unclassified
(MRC 2509)

This report covers the development of a 5-watt laboratory thermoelectric generator for operating in space vehicles. Carbon was selected for use with MCC 50 in the fabrication of thermocouple-type modules made by hot-pressing for the 5-watt generator. Electrical properties of modules suffered no deterioration under actual power producing conditions in test periods to 90 hours at temperatures to 1200°C.

19885 MAXIMUM THEORETICAL EFFICIENCY OF THERMIONIC EMISSION ENERGY CONVERTORS.

Rendement théorique maximum des convertisseurs d'energie a émission thermoélectronique, B.DEVIN, M.VANDEVYVER. J de Physique et Radium (Physique Appliquée) v 23 n 6 June 1962 p 73A-90A. Maximum efficiency of energy converters with electron thermal emission; general equation for efficiency of thermionic converter in optimized conditions derived in terms of 2 fundamental parameters which are anode work function and cathode quality factor; maximum efficiency is calculated; relative magnitude of conduction and radiation losses is pointed out; sets of curves for various anode work functions presented. 32 refs. EF63

B.Devin and M.Vandevyver.
J. Phys. Radium (France), Vol. 23, Suppl. No. 6, 73A-90A. (June, 1962). In French.

The general equation for efficiency is derived in optimized conditions, in terms of the two fundamental parameters: anode work function and cathode quality factor. An optimum efficiency is calculated from the resulting expression. The relative magnitude of conduction and radiation losses is pointed out. Sets of curves are given for various anode work functions.

P062

AD-282 877 Div. 8
(TISTW/RD)

David Sarnoff Research Center, Princeton, N. J.
RESEARCH IN ELECTRON EMISSION FROM SEMICONDUCTORS.
Quarterly rept. no. 7, 1 Apr-30 June 62,
by R. E. Simon, W. H. McCarroll and others.
30 June 62, 29p. incl. illus. tables, 19 refs.
(Rept. no. 15)
(Contract DA 36-039-sc-87388, Proj. 3A99-13-001-01)

Unclassified report

DESCRIPTORS: *Thermionic emission, *Semiconductors, Argon, Ions, Ion bombardment, Silicon, Cesium, Tungsten, Adsorption, Alkali metals, Photoemission, Photoelectrons.

The results of argon ion bombardment of silicon p-n junction emitters are reported. A large increase in emission is found as a result of the bombardment. An emitter with an injecting contact has been fabricated. Experiments in which enhanced light emission has been observed are reported. An analysis of data on the adsorption of cesium on tungsten and silicon is presented. A method of obtaining information on the band structure of semiconductors from photoemission measurements is described. (Author) 162

AD-282 398 Div. 8
(TISTW/PCR) OTS price $11.50

General Electric Co., Owensboro, Ky.
RESEARCH AND INVESTIGATION ON RADIATION RESISTANT, HIGH TEMPERATURE THERMIONIC CIRCUITRY.
Interim engineering rept. no. 5, 1 Apr-30 June 62,
by Fred J. Schmidt. 30 June 62, 146p. incl. illus. tables, 6 refs.
(Contract AF 33(616)8096)
Unclassified report

DESCRIPTORS: *Thermionic emission, *Electronic circuits, Miniature electron tubes, Miniature electronic equipment, Radiation effects, Triodes, Pentodes, Resistors, Nickel alloys, Ceramic materials, Welding, Brazing, Radiofrequency oscillators, Radiofrequency amplifiers, Platinum, Titanium, Capacitors, Feedback, Bonding, Electroplating, Circuits.

TIMM tube research and development efforts were continued in the areas of electrical and mechanical design, materials evaluation, component fabrication and evaluation, module fabrication and radiation effects studies and evaluation. Triode grid investigation programs were continued with emphasis being placed on improvement of previously used tensioning techniques and the evaluation of new techniques and means to stretch the mesh and to control grid flatness in the finished device. An optical grid transparency measuring instrument has been designed and is currently being used for 100 per cent sorting of grids. Programs are continuing to design a hexagonal mesh grid, equivalent to the 0.004 x 0.040 rectangular mesh, for improved mechanical strength. A TIMM pentode is being developed for improved electrical performance. Design parameters are discussed and desired electrical characteristics and cross section views of the device are presented. (Author)

162

AD-284 410 Div. 7, 20
(TISTW/PCR) OTS price $2.50

General Atomic Div., General Dynamics Corp., San Diego, Calif.
HIGH-TEMPERATURE, VAPOR-FILLED THERMIONIC CONVERTER.
Final rept., 1 Aug 61-31 Jan 62,
by A. E. Campbell, F. D. Carpenter, and others. June 62, 112p. incl. illus. tables, 7 refs.
(Rept. no. GA-2911)
(Contract AF 33(616)7422, Proj. 3145)
(ASD TR 61-513, vol. 2)
Unclassified report

DESCRIPTORS: *Electric power production, *Power supplies, *Thermionic emission, High temperature research, Power reactors, Spaceships, Uranium compounds, Carbides, Zirconium compounds, Cesium, Plasma physics, Manufacturing methods, Tantalum, Copper, Tests, Instrumentation, Fuel elements, Specifications.

The development of a high-temperature, vapor-filled thermionic converter for application with a nuclear reactor for space-vehicle electrical power generation is described. Problems associated with the design and operation of a thermionic converter employing a UC - ZrC emitter, a cesium plasma for space charge neutralization, and a high-temperature collector are described. Emitter fabrication techniques are also described. A test cell employing a cylindrical UC - ZrC emitter, which was pressure bonded to a tantalum sleeve, and a low-temperature copper collector, was fabricated and operated for 400 hours to provide experimental data. The emitter was operated at temperatures of the order of 2000 C while the collector temperature was maintained at 200 to 300 C. A conceptual design study for a thermionic power reactor incorporating the thermionic converter under development is also included. (Author)

162

12744 (AD-277917) CESIUM PLASMA STUDIES FOR THERMIONIC ENERGY CONVERSION. Final Report. R. C. Knechtli and J. Y. Wada (Huges Research Labs. Div. of Hughes Aircraft Co., Malibu, Calif.). June 1962. Contract Nonr 3501(00). 30p.

A new method for measuring the volume recombination coefficient a of thermal cesium plasmas in steady state has been devised and perfected. In this method, a thermal cesium plasma column is magnetically confined between two plasma generators. The plasma is generated by contact ionization and thermionic emission. The rate of plasma generation is controlled by the cesium vapor pressure in the device, the latter being directly measured in absolute value. The rate of plasma loss (in the range of measurement of a) is predominantly controlled by volume recombination, i.e., by a and by the plasma density. The latter is measured by Langmuir probes. The recombination coefficient is then found as a function of the measured ion and neutral densities by equating the rates of ion generation and ion loss. The dynamics of plasma generation and loss in the apparatus described above has been analyzed in order to provide the relations needed for the determination of the volume recombination coefficient a as a function of the measured ion and neutral densities. Interpretation of measurements performed at relatively low densities ($n_+ < 4 \times 10^{12}$ ions/cm^3) indicate as an auxiliary result of these investigations that the probability of surface recombination of cesium ions on tantalum or tungsten appears to be substantially lower than that predicted by the Saha-Langmuir equation. Within the accuracy of our method of measurement, the values of a obtained in our experiments are in agreement with the values predicted by the theory of recombination by electron-electron-ion collisions. These seem to be the first extensive measurements providing quantitative verification of this theory. These measurements then lead to the conclusion that recombination by electron-electron-ion collisions predominates within the ranges of plasma densities (10^{12} to 10^{14} cm^{-3}) and degrees of ionization (5% to 90%) investigated. The numerical values obtained for a also show that volume recombination is of negligible importance in the operation of cesium plasma thermionic energy converters. A modification of the apparatus used for the recombination measurements has led to the observation of low frequency oscillations in a cesium plasma column between a plasma emitter and a collector. A simple physical model explaining these oscillations has been evolved, and a mathematical analysis based on this model has been performed. General agreement between theory and experiment has been found, leading to a satisfactory explanation of these oscillations, that seem to be of the same nature as those observed in some cesium plasma thermionic energy converters. The results of our investigations thus lead to an appropriate explanation for these converter oscillations. (auth)

12744 (cont.)

NSA 163

11295 (AD-277713) LOW TEMPERATURE THERMIONIC CONVERTERS Quarterly Technical Progress Report No. 2, March 1, 1962–June 1, 1962. (Ford Instrument Co., Long Island City, N. Y.). June 1962. Contract AF33(657)-7663. 11p.

Research in the development of low-temperature thermionic converters during the period has centered on improving the reliability of refractory metal envelopes relative to grain growth and subsequent permeability and on improving the output power density of the metal ceramic cells. New fabrication techniques for pure molybdenum and use of molybdenum alloys as well as tungsten have produced considerable improvement in the grain growth situation. Performance of new metal-ceramic cells that resulted from an analysis of previous cells is also evaluated. Geometry changes and new fabrication techniques offer improved performance. Tests on the various components are described, and the results are given. (D.C.W.) NSA 63

12745 (AD-277940) THE DEVELOPMENT OF AN AUXILIARY ELECTRODE THERMIONIC CONVERTER. Second Quarterly Technical Report, March 15, 1962 to June 15, 1962. F. G. Block and J. J. O'Grady (Radio Corp. of America. Electron Tube Div., Lancaster, Penna.). June 29, 1962. Contract AF33(657)-8005. 35p.

The feasibility and development program for the three-electrode thermionic converter was continued. Evaluations of several new geometries and processes were made with particular emphasis on the improvement of cesium purity. This last investigation produced impressive results in raising the power density and efficiency of the converters and achieving a more uniform product with which to evaluate changes in design. The overall design of the six-volt generator was determined. This design is being translated into component prints and assemblies and orders have been placed for the fabrication of the initial parts. Material investigations were performed at the three temperatures of interest. The program requires a 1000-hour test. This limitation resulted in a few evaluations of material compatibility with cesium. (auth) NSA '63

18889 (AD-284457) THERMIONIC CONVERTER RESEARCH. Report No. 4. Final Report, July 1, 1961–June 30, 1962. Report No. 25057. R. Laubenstein, W. Beyermann, and B. Chang (Marquardt Corp., Van Nuys, Calif.). Contract DA36-039-sc-87217. 63p.

Two methods were investigated for production of positive ions for neutralizing the electron space charge in a thermionic converter which operates at relatively low temperatures. Low temperature converters with emitter temperatures of 1200°C or lower are potentially useful for operation with small heat sources which burn ordinary fossil fuels in air. Data were obtained on arc mode operation of Cs vapor diodes with Mo and with Philips B emitters at 1000 to 1300°C. Power densities of about 0.3 to 1.0 w/cm^2 were obtained depending on emitter temperature and material. The presence of an auxiliary electrode in the form of a radiation shield surrounding the emitter had a significant effect on diode performance with the Philips B emitter. The effects of the auxiliary electrode include an increased power output and an increased voltage at maximum power. With the Philips B emitter the maximum power output occurred at a lower Cs pressure than with the Mo emitter. Materials which emit positive ions at 1000 to 1200°C were also studied. (auth) NSA '63

14934 (GA-3330) HIGH-TEMPERATURE VAPOR-FILLED THERMIONIC CONVERTER. Quarterly Technical Progress Report, March 15 through June 30, 1962. R. Skoff (General Atomic Div. General Dynamics Corp., San Diego, Calif.). July 13, 1962. Contract AF33(657)-8563. 14p. (AD-278816)

Research covers the work done on a bench test of an unclad thermionic converter. The objective is to produce an efficient, high-power-density, long-life thermionic power converter using a uranium-zirconium-carbide emitter and a high-temperature nickel collector. (auth) NSA '63

21368 (AD-282179) FEASIBILITY DETERMINATION OF A NUCLEAR THERMIONIC SPACE POWER PLANT. Quarterly Technical Progress Report for Period May 1, 1962 through July 31, 1962. (Aerojet-General Nucleonics, San Ramon, Calif.). Contract AF33(657)-8977. 12p. (AN-693)

Research on a thermionic radiation system is reported. In developmental work on bonding of energy converter materials to liquid metal tubing, a previously Al_2O_3-sprayed Nb tubing specimen was examined metallographically. Results showed that the coating has about 40% porosity and that the Al_2O_3-Nb bonding is good. Other samples involving plasma-sprayed Al_2O_3 on steel had about 10 to 15% porosity and good bonding. Other work is reported on preliminary design of a liquid metal loop for demonstration of thermionic converters. (J.R.D.) NSA '63

953 (ASD-TDR-62-412) DISCHARGE EFFECTS IN A CESIUM DIODE. James Lawson Coggins (Massachusetts Inst. of Tech., Cambridge. Research Lab. of Electronics). Aug. 15, 1962. Contract AF33(616)-7624. 36p.

An investigation to determine the feasibility of neutralizing the electron space charge in Cs thermionic converters with ions formed by the collisions of electrons with neutral atoms is described. Equations were set up for the ion density and subsequent potential function for a low-pressure plasma in which the ions are formed by collisions of atoms with electrons emitted from the cathode with a Maxwellian velocity distribution. The special case of zero field at the emitter was taken to simplify the mathematics. Voltage versus current characteristics were determined experimentally for a Cs diode with a low work-function impregnated W emitter operating at 1410°K and an electrode spacing of 0.254 cm. Cs vapor pressures corresponding to condensation temperatures of 30, 100, and 155°C were used. The results indicate that higher Cs pressures, leading to more dense plasmas and successive collisions between electrons and excited atoms, are needed for complete space-charge neutralization. (auth) NSA '63

19886 DIRECT CONVERSION OF FISSION HEAT TO ELECTRIC POWER. P.D.Dunn, G.Rice, L.G.Sanders, D.A.Watt, J.Adam, R.J.Hill, J.G.Purchas, C.C.H.Wheatley and J.A.McWilliams.
Nature (GB), Vol. 195, 65-6 (July 7, 1962).

Describes the construction of a caesium neutralized diode used in the reactor Pluto. The highest current achieved was 140 A with a voltage of 0.3 V across the load which was not matched. Efficiencies with a matched load would be between 5 and 10%. No deterioration in performance was noticed after 38 hours at output currents of about 70 A. J.W.Sturgess

NAL2

AD-284 457 Div. 7
(TISTE/CRJ) OTS price $7.60

Marquardt Corp., Van Nuys. Calif.
THERMIONIC CONVERTER RESEARCH,
Rept. no. 4 (Final), 1 July 61-30 June 62,
by R. Laubenstein, W. Beyermann, and B. Chang.
July 62, 63p. incl. illus. tables, 3 refs.
(Rept. no. 25057)
(Contract DA 36-039-sc-87217)
Unclassified report

DESCRIPTORS: *Thermionic emission, *Diodes, *Ionic current, Space charges, Ions, Heat production, Cesium, Electrodes, Design, Molybdenum, Production.

Two methods were investigated for providing positive ions for neutralizing the electron space charge in a thermionic converter which operates at relatively low temperatures. Low temperature converters with emitter temperatures of 1200 C or lower are potentially useful for operation with small heat sources which burn ordinary fossil fuels in air. Data were obtained on arc mode operation of cesium vapor diodes with molybdenum and with Philips B emitters in the temperature range 1000 to 1300 C. Power densities of about 0.3 to 1.0 watt per sq cm were obtained depending on emitter temperature and material. The presence of an auxiliary electrode in the form of a radiation shield surrounding the emitter had a significant effect on diode performance with the Philips B emitter. The effects of the auxiliary electrode includes an increased power output and an increased voltage at maximum power. With the Philips B emitter the maximum power output occurred at a lower cesium pressure than with the molybdenum emitter. Materials which emit positive ions when heated in the range of 1000 to 1200 C were also studied. (Author)

'62

Chemical-Thermionic Auxiliary Power Systems. C.V.BURKLAND. AIEE—Trans v 81 pt 2 (Applications & Industry) n 61 July 1962 p 193-6. Analysis of problems of matching performance of high-temperature plasma-thermionic static-energy conversion device to heat source consisting of combustion products of chemical fuels; it is concluded that chemical-thermionic power system is promising concept as source of electric power, in amounts ranging from watts to megawatts for number of aerospace applications. Paper 61-919.

EI '62

AD-282 990 Div. 8
(TISTW/RD) OTS price $9.60

Westinghouse Electric Corp., Elmira, N. Y.
HIGH TEMPERATURE PHOTOELECTRIC TECHNIQUES AND MATERIALS.
Final technical rept., Apr 59-31 July 61,
by Vincent J. Santilli, Harry Shabanowitz, and Zoltan Szepesi. July 62, 59p. illus. 15 refs.
(Contract NObsr-77556)
Unclassified report

DESCRIPTORS: *Photoelectric cells, *Photoelectric materials, *Phototubes, Photoemission, Photosensitivity, Photoconductivity, Camera tubes, Photomultipliers, Semiconductors, Arsenic compounds, Selenides, Sulfides, Alkali metal compounds, Thermionic emission, Iconoscopes.

Studies and investigations on high-temperature photoelectric techniques and materials were directed toward making available a means of sensing light for photosensitive devices operating in environments up to 120 C. Two general parallel approaches were followed: Approach A - Studies of photoemissive processing techniques and materials leading toward their applications in photomultiplier type tubes. Approach B - Studies of photoconductive processing techniques and materials leading to applications in vidicon type pickup tubes. The prime objective of each approach was supporting research to make possible photosensitive devices operable at elevated temperatures and responsive to low-level visible light such as emitted by cathode ray tube phosphor screens. Materials resulting from these investigations were to be capable of application in tubes in such a manner as to yield extremely uniform sensitivity over photocathode areas and remain stable over a reasonable period of life (100 to 200 hr).

'62

Thermionic Converters in Large Nuclear Electric Powerplant in Space. D.T.BERNATOWICZ. ARS J v 32 n 8 Aug 1962 p 1256-61. Parametric analysis is presented, and thermionic systems are compared to Rankine cycle turbogenerator on basis of radiator area per unit of output power; thermionic performance is computed with height of potential barrier above Fermi levels in cathode and anode as parameters; minimum possible radiator area is determined for several configurations as function of cathode and radiator temperatures; given scheme permits substantial savings in radiator area, up to 50% at cathode temperature of 1700 K and up to 80% at 2300 K.

EF '62

14925 (AD-278817) EVALUATION OF A MOLYBDENUM EMITTER, LOW VOLTAGE ARC THERMIONIC POWER CONVERTER. Quarterly Technical Progress Report No. 1. E. A. Baum (General Electric Co, Power Tube Dept., Schenectady, N. Y.). Aug. 1962. Contract AF33 (657)-8323. 22p.

Initial work is reported in a program to define and minimize the life-limiting factors affecting the usefulness of low-temperature Cs vapor thermionic converters. The program is basically directed toward life test evaluation of state-of-the-art vapor converters utilizing Mo cathodes. During the report period, design of the life test equipment was completed and fabrication started. Preliminary tests were made on one device. (J.R.D.)

NSA '63

Electrical Energy from High-Temperature Plasmas, J.F.WAYMOUTH. Instn Elec Engrs—J v 8 n 92 Aug 1962 p 380-3. Theoretical calculations and experimental data for hot and cold electrode converter for extracting power from high-temperature plasma; unlike other plasma converters, this can be h-v generator; efficiency of 36% has been obtained at power level of 25 w, and efficiency of 67% may be possible at thermonuclear temperatures. EI63

17777 EXTENDED SPACE-CHARGE THEORY IN LOW-PRESSURE THERMIONIC CONVERTERS.

R.G.McIntyre.

J. appl. Phys. (USA), Vol. 33, No. 8, 2485-9 (Aug., 1962).

The problem of space-charge limited currents in a diode with plane-parallel electrodes is considered for the case where space charge limitations are counteracted by the introduction of ions at the cathode. The "no-collision" approximation is used, in which inelastic and short-range elastic collisions are neglected, and each particle interacts with the Coulomb field of all the other particles. The electrostatic potential is determined, in a self-consistent manner, from Poisson's equation. The equations are simplified by transforming to reduced variables in a manner described by Langmuir and others. The first integrations of Poisson's equation are given for the six most important cases.. The first of these was reported by Auer, but rigorous analysis of the remaining five cases has not been previously reported. Analytical solution of the first order differential equations derived is impossible. Numerical solutions were obtained for illustrative purposes on the IBM 704 computer. More complete numerical solutions are being compiled. PH'62

AD-288 092 Div. 8, 25
(TISTP/WH) OTS price $5.60

Aerospace Corp., El Segundo, Calif.
EFFECT OF SCHOTTKY EMISSION ON THERMIONIC CONVERTER CURRENTS IN IGNITED MODE.
by G. L. Johnston. 15 Aug 62, 43p. incl. illus. table, 25 refs. (Rept. no. TDR-69(2220-50)TR-3)
(Contract AF 04(695)69)
(DCAS TDR 62-149) Unclassified report

DESCRIPTORS: *Thermionic emission, *Electric fields, *Work functions, *Anodes, *Electrons, *Electric currents, *Space charge, Cesium.

A theoretical model of a cesium thermionic converter operating in the ignited mode is investigated to determine the possible role of Schottky emission produced by the accelerating field of an ion rich emitter sheath in causing the high currents observed in that mode. The electric field intensity adjacent to the emitter is determined as a function of plasma density, electron temperature, and emitter sheath potential by integration of Poisson's equation between sheath edge and emitter. The interelectrode plasma is considerated to be uniform. Simultaneous solution of relationships permits generation of current-voltage characteristics. The Schottky effect is a substantial contributing factor in the production of observed high currents. The present analysis yields currents which saturate with reduced load voltage in contrast to the behavior of experimental characteristics. This strongly suggests the operation of other mechanisms, in addition to the Schottky effect, which produce a reduction of work function with reduction of load voltage. (Author)

163

AD-287 519 Div. 7, 8
(TISTE/CRJ) OTS price $7.60

Westinghouse Electric Corp., Pittsburgh, Pa.
HEAT DIODE CONVERTER.
Interim scientific rept. no. 5, 1 May-31 July 62. 20 Aug 62, 1v. incl. illus. table, 9 refs.
(Contract AF 33(616)8262)
Unclassified report

DESCRIPTORS: *Thermionic emission, *Diodes, *Electric power production, Rhenium, Materials, Electric fields, Tantalum compounds, Carbides, Voltage, Electric currents, Discharge tubes, Ionic current, Refractory materials, Thermal conductivity, Vapors, Rubidium, Temperature, Cesium, Theory

Contents:
Current-voltage characteristics of materials in variable spacing cell
Measurements in plasma anode discharge cell
Electron and ion emission from cesium coated refractory metals in electric fields
Electron reflection measurements
Rubidium vapor thermal conductivity

163

AD-284 678 Div. 8
(TISTP/FR) OTS price $1.00

Research Lab. of Electronics, Mass. Inst. of Tech., Cambridge.
DISCHARGE EFFECTS IN A CESIUM DIODE,
by James Lawson Coggins. 15 Aug 62, 29p. incl. illus. tables, 11 refs.
(Contract AF 33(616)7624, Proj. 8173)
(ASD TDR 62-412) Unclassified report

DESCRIPTORS: *Diodes, *Thermionic emission, *Space charges, Cathodes, Anodes, Cesium, Ions, Electrons, Atoms, Ionization.

The feasibility of neutralizing the electron space charge in a cesium thermionic converter with ions formed by the collisions of electrons with neutral atoms was investigated. Equations were set up for the ion density and subsequent potential function for a low-pressure plasma in which the ions are formed by collisions of atoms with electrons emitted from the cathode with a Maxwellian velocity distribution. The special case of zero field at the emitter was taken to simplify the mathematics. Voltage-versus-current characteristics were determined experimentally for a cesium diode with a low work-function impregnated tungsten emitter operating at 1410 K and an electrode spacing of 0.254 cm. Cesium vapor pressures corresponding to condensation temperatures of 30 C, 100 C, and 155 C were used. The results indicated that higher cesium pressures, leading to more dense plasmas and successive collisions between electrons and excited atoms, are needed for complete space-charge neutralization. (Author)

'63

36373 (ASD-TDR-62-693) POWER CONVERSION BY ELECTRON CONVECTION. S. R. Hoh and W. L. Harries (ITT Federal Labs. Div. of International Telephone and Telegraph Corp., Nutley, N. J.). Aug. 20, 1962. Contract AF33(616)-7941. 32p. (AD-291683)

A new electrohydrodynamic system that is capable of converting thermal into electrical power was studied. Conversion was accomplished by the forced convection of thermionic electrons emitted from an alkaline metal emitter. Analytical and experimental studies showed that this new type of converter is feasible and practical. Outputs up to 18 volts were obtained under open circuit condition with emitter temperatures as low as 450°C. Short circuit output currents were near the emission current of the emitter. (auth)

NSA '63

Present State of Energy Converters, H.BILLETT, P.D.DUNN. Engineering v 194 n 5027 Aug 24 1962 p 254-6. Current research is centered on 4 major fields all of which attempt to eliminate inefficient heat flow stage of conversion or highly stressed components in high temperature areas; thermionic generators of both close-spaced and neutralized type are suitable for low power applications, principles of magnetohydrodynamic converters have been demonstrated, hydrox is under development but at present applicable to low of perhaps medium powers; flow diagram shows magnetoplasmadynamic power generation experiment at Parsons Nuclear Research Centre.

EI 63

19884 ORIGIN OF THE OSCILLATIONS IN A LOW-PRESSURE THERMIONIC CONVERTER. P.Mazur.
J. appl. Phys. (USA), Vol. 33, No. 8, 2653 (Aug., 1962).

Many investigators have observed oscillations in gas-filled thermionic converters; these were thought to be due to small perturbations which caused the stationary states (solutions to the Vlasov equation) to oscillate. However, from observations made by the author, stationary states appear to be non-existent in the region where the oscillations were observed. C.Greaves

PA 62

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Foreign Tech. Div., Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.
THERMIONIC ENERGY CONVERTERS,
by I. I. Damaskina and G. A. Chetverikova.
28 Aug 62, 10p. incl. illus. table, 15 refs.
(Trans. no. FTD-TT-62-666 from Teploenergetika 3: pp. 82-86, 1962)
Unclassified report

DESCRIPTORS: *Thermionic emission, Power sources, Cesium, Vapors.

'63

V24726 (ASD-TDR-62-877) ADVANCED SOLAR THERMIONIC POWER SYSTEMS. [Period Covered] June 1960 to August 1962. (Thompson Ramo Wooldridge Inc., Cleveland). Aug. 1962. Contract AF 33(616)-7411. 239p. (ER-5038; AD-295917)

A state-of-the-art survey of all components required for solar thermionic power systems in the 1–10 kw range suitable for application in aerospace vehicles is presented. The results of the survey and development program are used in a comprehensive parametric study to determine design criteria. The development program includes evaluation of thermionic converters of the vacuum and vapor type. Design, fabrication, performance, and evaluation of thermionic converters and generators are presented. The design, performance, and test specification for a 1.5 kw, 28 volt solar thermionic power system are presented. (auth)

NSA 63

J14925 (AD-278817) EVALUATION OF A MOLYBDENUM EMITTER, LOW VOLTAGE ARC THERMIONIC POWER CONVERTER. Quarterly Technical Progress Report No. 1. E. A. Baum (General Electric Co. Power Tube Dept., Schenectady, N. Y.). Aug. 1962. Contract AF33 (657)-8323. 22p.

Initial work is reported in a program to define and minimize the life-limiting factors affecting the usefulness of low-temperature Cs vapor thermionic converters. The program is basically directed toward life test evaluation of state-of-the-art vapor converters utilizing Mo cathodes. During the report period, design of the life test equipment was completed and fabrication started. Preliminary tests were made on one device. (J.R.D.)

NSA 63

20604 EXPERIMENTAL OPTIMIZATION OF CESIUM VAPOR THERMIONIC CONVERTERS WITH METAL EMITTERS. C. C. Weeks, R. C. Dahleen, and J. E. Gingrich (Atomics International, Canoga Park, Calif.). Advan. Energy Conversion, 2: 315-23(July-Sept. 1962).

Parametric studies are being conducted utilizing both cylindrical fixed-spacing and parallel-plane, variable-spacing thermionic converters. A brief description of the design and fabrication of these converters is given, and the techniques of component preparation, the use of getters and the philosophy of operation are illustrated. The instrumentation for control and measurement of the various parameters is discussed. The emitters of these parallel plane and cylindrical diodes are heated by electron bombardment. Constant power input is achieved by using a controller which is insensitive to back heating from the emitter. The load which is used with these diodes can be varied to produce the full operating range from reverse currents to the applied voltage region. At the higher emitter temperatures, surface ionization appears to be sufficient for space charge neutralization. Under these conditions the power density of a converter, operated at constant emitter temperature and optimum cesium pressure, increases as the spacing is decreased. At lower emitter temperatures, approximately 1450°C and less for molybdenum, surface ionization is insufficient to neutralize the space charge. Thus, the additional ions must be supplied from volume ionization, resulting in an optimum spacing for maximum power densities. Curves showing power densities, optimum cesium pressures, and optimum collector temperatures versus spacing for the variable spacing diode are given and discussed. Efficiency curves for several refractory emitters are given. The effects of the individual optimization of cesium pressure, collector temperature, and load resistance are shown for both "ignited" and "unignited" modes of operation. (auth)

NSA 63

20605 EXPERIMENTAL MEASUREMENT AND INTERPRETATION OF VOLT-AMPERE CURVES. J. E. Gingrich, C. Warner, and C. C. Weeks (Atomics International, Canoga Park, Calif.). Advan. Energy Conversion, 2: 325-33(July-Sept. 1962).

Cylindrical and parallel-plane cesium vapor thermionic converters were used for obtaining volt-ampere curves for systematic variations of emitter, collector, and cesium reservoir temperatures, with electrode spacings ranging from a few to many mean free paths, and with space charge conditions varying from electron-rich to ion-rich. The resulting curves exhibit much variety. The saturation currents agree well with the data of Houston and Aamodt for the space charge neutralized, few-mean-free-path cases. "Apparent" saturation currents for space charge limited cases were observed and were always less than the currents predicted by Houston and Aamodt. Several discontinuities in slope were observed in the reverse current portion of the curves and these have tentatively been identified with volume ionization of atoms in both the ground and excited states. Similar processes may be important for obtaining the ignited mode. The methods used to measure static and dynamic volt-ampere curves are described. The use of a controlled-current load has yielded a "negative resistance" region in the curves which show the ignited mode. The curves obtained with poor current control do not show this phenomenon. Extinction is considered from the standpoint of Kaufmann's criterion for stability. (auth)

NSA 63

20606 DESIGN AND OPERATION OF LABORATORY TYPE PARALLEL PLANE CESIUM THERMIONIC CONVERTERS. V. C. Wilson and J. Lawrence (General Electric Co., Schenectady, N. Y.). Advan. Energy Conversion, 2: 335-40(July-Sept. 1962).

Two parallel-plane converters are described. Evidence presented suggests that an auxiliary discharge to a guard ring increases the output power of these converters. While driving one tube with a 60 cps transformer, a current of 110 amp/cm^2 was drawn at an emitter temperature of 2000°K and with the collector 1.5 v positive with respect to the emitter. (auth)

NSA 63

20607 CHARACTERISTICS AND LIFE TESTS OF CYLINDRICAL THERMIONIC CONVERTERS. J. Lawrence and V. C. Wilson (General Electric Co., Schenectady, N. Y.). Advan. Energy Conversion, 2: 341-51(July-Sept. 1962).

Three cylindrical thermionic converters with emitters of tantalum, molybdenum, and niobium have been built and are being life tested. They were designed specifically for life tests in air with electron bombardment heating. The dimensions and operating temperatures chosen are considered reasonable for a nuclear reactor application. Design details are presented and output characteristics such as functions of cesium pressure and emitter temperature are given for each converter. All three devices are now operating and have run from 2200–3300 hr. Although they have not yet achieved the normal life of a nuclear fuel element, it is encouraging that no basic failures have been experienced. (auth)

20608 NUCLEAR THERMIONIC FUEL ELEMENT EXPERIMENTS. H. M. Ogle, G. I. Samstad, and C. A. von Damm (General Electric Co., Pleasanton, Calif). Advan. Energy Conversion, 2: 353-61(July-Sept. 1962).

Several in-reactor tests of plasma diodes have been performed at the Vallecitos Atomic Laboratory to gain design information for reactor thermionic fuel elements. These experiments were designed to furnish data in three major areas: (1) comparison of out-of-pile performance and in-pile operation; (2) special diode fabrication techniques required for in-pile operation; and (3) test facility requirements for adequate control of converter parameters. In order to control the variables of interest an in-pile experimental facility has been developed for testing these diodes. A high neutron flux (4×10^{13} nV unperturbed) is available with provisions for controlling and monitoring cathode, anode, and cesium temperatures as well as diode output power. Problems encountered during in-pile tests and solutions that have been employed to solve these problems are discussed. Plasma diodes have been designed to operate in a high neutron flux, and to generate their own cathode heat by fission within the cathode. Several different geometries, materials, and fabrication techniques which have withstood the severe environment of a nuclear reactor have been tested. For example, a number of different methods have been employed for supporting the cathode of the converter. Preliminary findings of these tests are described. (auth)

20609 THERMIONIC CONVERTER EXPERIMENTS. J. H. Ingold, E. Blue, and W. J. Ozeroff (General Electric Co., Pleasanton, Calif.). Advan. Energy Conversion, 2: 363-73(July-Sept. 1962).

The thermionic properties of polycrystalline bulk samples of several refractory metal carbides in vacuo and in cesium vapor have been determined. Some typical Richardson plots of experimental data obtained by a low-field method are shown, and a summary of the results is presented in tabular form. Most of the carbides investigated can be characterized by an emission constant in the range 40–90 amp/cm^2 deg^2 and a work function in the range 4.0–4.2 v. In addition, current–voltage characteristics typical of those obtained for the same carbides immersed in cesium vapor are shown. No gross differences in the cesium characteristics of the different carbides were observed. Finally, current–voltage characteristics obtained for a thermionic converter operating with a collector temperature in excess of 1000°K are shown. A power output of 4.5 W/cm^2 was obtained for a planar Cs-on-Ta converter at an emitter temperature of 2250°K and a collector temperature of 1725°K. (auth)

20610 RESEARCH ON CESIUM-VAPOR CELLS EMPLOYING CARBIDE CATHODES. Hugh L. Garvin (General Atomics Div., General Dynamics Corp., San Diego, Calif.). Advan. Energy Conversion, 2: 375-87(July-Sept. 1962).

The status of a research program is reported in which the performance of cesium-vapor thermionic cells employing carbide emitters is being studied. Vacuum emission measurements were made on a series of samples, which were polycarbides of uranium and zirconium. Certain of these carbides were incorporated into parallel-plane cesium cells in which studies were made of the electrical output characteristics. Results indicated that the cells operate in a discharge mode for cesium pressures exceeding 0.1 mm Hg and that maximum power output decreases linearly as the interelectrode spacing increases. (auth)

20612 ANALYSIS AND NUMERICAL SOLUTIONS TO THE SPACE-CHARGE POTENTIAL PROBLEM IN LOW-PRESSURE THERMIONIC CONVERTERS. R. G. McIntyre (Texas Instruments Inc., Dallas). Advan. Energy Conversion, 2: 405-16(July-Sept. 1962).

The problem of space-charge potential distribution in a diode is considered for the case where limitations are counteracted by the introduction of ions at the emitter. The no-collision approximation is used, in which inelastic and short-range elastic collisions are neglected and each particle interacts with the Coulomb field of all the other particles. The electrostatic potential is determined, in a self-consistent manner, from Poisson's equation. The equations are simplified by transforming to reduced variables in a manner described by Langmuir and others. There are eight important cases, each describing a different type of spatial variation of potential in the emitter-collector interspace. Numerical solutions are presented showing the character of these potential shapes. For the cases of monotonic potential functions, for spacings on the order of Auer's characteristic distance, the curves are very nearly linear. For slightly wider spacings the curves begin to bend over until, finally, there clearly exist emitter and collector sheathes separated by a wide region at uniform potential. In the two cases where the potential reaches an extremum but does not return to zero, the results show an emitter sheath backed up by a region rich in the opposite sign. As spacings are increased an oscillatory solution with regions alternately rich in ions and electrons is found. For cases where the potential reaches an extremum and passes through zero to a collector potential of the opposite sign the results show a double sheath at the emitter and a simple sheath at the collector separated by a wide region of essentially uniform potential between zero and the collector potential. For certain collector potentials an extremum of the same sign but larger than the collector potential in absolute value also is found. In these cases, for wide spacings, one again finds spatially oscillatory solutions. The cases are found to be uniquely determined by the anode potential and the degree of space charge neutralization provided for. There appears no overlap of the cases. Smooth transitions are found in making a change in the externally controlled parameters. (auth) NSA 63

20613 A PLASMA-SHEATH THEORY FOR NOBLE GAS THERMIONIC CONVERTERS. C. B. Leffert (General Motors Corp., Warren, Mich.). Advan. Energy Conversion, 2: 417-36 (July-Sept. 1962).

A plasma-sheath theory is described for computing the V-I characteristics of noble gas thermionic converters. Application of this theory in the form of an IBM computer code to laboratory and in-pile experimental data is presented. The assumptions in the theory are twofold: (1) a spatially uniform ion density is assumed in the interelectrode plasma between the emitter and collector sheaths; and (2) the ion loss rate is taken to be independent of the diode voltage. The basic plasma-sheath equations are presented, and the operation of the computer code to produce the theoretical voltage-current characteristics is outlined. The experimental data from the operation of laboratory and in-pile thermionic converters are analyzed by adjusting plasma parameters to fit the theoretical to the experimental voltage-current characteristics. A reasonable fit of the theoretical curves to the experimental curves is obtained. It was found that the ion density in the plasma varies considerably with the diode voltage. The effects of such variables as volume recombination of ions, plasma resistivity, and tube geometry on the voltage-current characteristics are discussed. The general V-I characteristics obtained from the code for a Gabor-type triode are described. The results show a significant increase in the ratio of the output current to the ion source rate for a large collector to emitter area ratio not only for the plasma limited case but also for the power producing region of the emission limited case. (auth) NSA 163

20614 A PRELIMINARY ANALYSIS OF THE ARC MODE CESIUM CONVERTER. T. Jarvis (Ford Instrument Co., Long Island City, N. Y.). Advan. Energy Conversion, 2: 437-46 (July-Sept. 1962).

Thermionic converter operation has previously been observed to occur with emitter temperatures and work functions too low for surface ionization. In addition, discontinuities and quasi-stable operation were observed. A qualitative identification of this type of operation with the low voltage arc is made. Analysis of the arc requires solution to the three fundamental problems of ionization mechanism, thermalization, and energy balance. It is shown that a solution for the first presents an apparent violation of the third. Analysis of thermalization indicates that processes more rapid than the usual collective interaction must occur. In particular, Maxwellian electron energy distribution close to the collector, or the "Langmuir Paradox," indicates the need for an oscillatory interaction mechanism. A brief discussion of possible arc models is given together with a review of techniques for obtaining the temperatures and densities within the arc plasma. (auth) NSA 163

20615 THE SURFACE IONIZATION AND VOLUME IONIZATION MODES OF OPERATION IN THE THERMIONIC PLASMA ENERGY CONVERTER. M. E. Talaat (Martin Marietta Corp., Baltimore). Advan. Energy Conversion, 2: 447-58 (July-Sept. 1962).

The plasma diffusion equations for electrons and ions, Poisson's equation, the continuity equations, and the proportionality assumption are examined and solutions are obtained for two cases: (1) when the ions are primarily produced at the emitter electrode surface, and (2) when important volume ionization exists in the interelectrode space. These solutions are then used to examine typical examples of the two modes of operation of the thermionic plasma energy converter. One, the surface ionization mode of operation, is characterized by an output current density that represents a fraction of the Richardson saturation current density and the second mode, the volume ionization mode of operation, is characterized by an output current density approximately an order of magnitude higher than the surface ionization current density. It is shown that for the surface ionization mode of operation the current density at maximum power is proportional to the electron density at the emitter sheath edge, is proportional to the mean free path of the electron, and is inversely proportional to the interelectrode spacing. When the electron temperature is raised by going toward short circuit conditions, high volume ionization takes place and a new stable operating region may be reached when the electron temperature is such that the generated ion density in the interelectrode space gives rise to a high electric field ϵ at the emitter surface (due to the plasma ions reaching the emitter surface from the plasma region). The high volume ionization mode of operation is maintained as long as the energy balance equation is satisfied at the high electron temperatures necessary for maintaining the high plasma ion current density collected by the emitter electrode. The plasma ion current density reaches, in typical examples, values which are three orders of magnitude greater than the typical ion current density generated by surface ionization (the Saha-Langmuir equation). The latter current density is symptomatic of the surface ionization mode of operation. The transition from volume ionization mode to surface ionization mode is reached when the electron temperature necessary for adequate volume ionization does not satisfy the energy balance equation. (auth) NSA 163

20616 SPACE CHARGE ANALYSIS OF THE CESIUM-FILLED THERMIONIC DIODE. C. Warner (Atomics International, Canoga Park, Calif.). Advan. Energy Conversion, 2: 459-65 (July-Sept. 1962).

The space charge problem for a plane diode whose hot cathode emits both ions and electrons has been considered by Hernqvist and Johnson and by Auer. This model is appropriate for the analysis of the low-pressure cesium-filled thermionic converter in which the ions are generated by surface ionization at the cathode. Further, the electrode spacing must be such that the assumption of no collisions is valid. The variety of potential distributions that can arise is described, but few numerical results are given. The numerical results of machine calculations for potential distributions with various ratios of emitted electron to emitted ion density, electrode spacings, and applied potentials are systematized and discussed. Some analytical results, e.g., the necessary and sufficient conditions for the establishment of certain types of potential distributions, are given. Some typical theoretical V-A curves are compared with experimental data. (auth) NSA 163

20617 THE ENERGY DISTRIBUTION FOR ELECTRONS IN A THERMIONIC DIODE PLASMA CANNOT BE TRULY MAXWELLIAN. W. B. Nottingham (Massachusetts Inst. of Tech., Cambridge). Advan. Energy Conversion, 2: 467-79(July-Sept. 1962).

For the refractory emitters such as tungsten, tantalum, and molybdenum operated in an energy conversion diode, the ratio of the emitter temperature to the cesium temperature strongly influences the operating properties. If this ratio exceeds 3.2 an ion-rich sheath usually forms at the emitter surface. Electrons are accelerated in the plasma space by this injection potential. The analysis given here shows that at the open circuit condition, the energy distribution of the electrons at the plasma edge of the emitter sheath cannot be a true Maxwellian over the entire range in electron energy. Instead, it is thought to be made up of two quasi-Maxwellians. The low energy electrons are trapped and may have a high average energy close to that of the injection potential. The untrapped electrons will have an electron temperature equal to that of the emitter and their density will be that associated with an apparent or fictitious density many times that of the actual density. The theory is developed to describe quantitatively the relations that must be satisfied for the above description to apply. Typical numerical results applicable to specific diode configurations are presented. It is concluded that if the emitter to cesium temperature ratio exceeds 3.6, volume ionization is not required for a stable sheath. In the range 3.2 – 3.6 surface ionization is usually insufficient and it is necessary to have volume ionization to sustain the sheath. Further studies will be required to establish the mechanism. It may be direct ionization by high energy electrons or ionization from excited states of the cesium atoms. (auth)

NSA 16 3

20618 THE TRANSITION TO THE ARC MODE AND ITS INFLUENCE ON THERMIONIC CONVERTER PERFORMANCE. H. L. Steele and R. B. Gillette (Boeing Co., Seattle). Advan. Energy Conversion, 2: 483-97(July-Sept. 1962).

Several investigators have reported that a thermionic converter with a given emitter temperature can operate in either a high current or a low current mode. In earlier published work, the high current mode was attributed correctly to volume ionization. At that time, the conclusion that volume ionization was occurring was based on the appearance of a glow in the space between emitter and collector as the voltage of the collector was made more positive. The discontinuity in the volt-ampere curve at this breakdown voltage is very definite. The phenomenon was studied irrespective of whether it occurred in the power quadrant or with a positive potential applied to the collector. A detailed analysis of this phenomenon now can be presented. At low emitter and low cesium control temperatures breakdown occurs when a potential drop near the collector is equal to the ionization potential of cesium. At the high emitter and high cesium control temperatures, the breakdown occurs at higher currents with potential drop as low as 2 v. This indicates that ionization of excited cesium atoms is occurring when the converter is operating in the power quadrant. The V-A curve in the arc mode is logarithmic, and the voltage at which maximum power occurs is equal to the voltage equivalent of the electron temperature. It will be shown that electron temperature increases with cesium pressure. The short-circuit current in the arc mode was measured and compared with a new theory of the condition which determines if a given converter is operating electron-rich or ion-rich. The current output in the volume ionization mode is surprisingly independent of emitter temperature. This fact is especially important where series operation will be required, since it will be difficult to maintain the same emitter temperatures in all diodes. The higher efficiency obtainable in the high current mode and the relative independence of emitter temperature may help to accelerate the development of thermionic systems. (auth)

NSA 16 3

20619 LOW TEMPERATURE CESIUM PLASMA CONVERTER. W. Stenzel and M. Bernstein (Ford Instrument Co., Long Island City, N. Y.). Advan. Energy Conversion, 2: 499-521(July-Sept. 1962).

Measurements of space potentials, electron temperatures, electron concentrations, and electron energy distributions were made, with the aid of plane Langmuir probes by means of a pulsed technique developed by Waymouth, inside the discharge of low-temperature cesium plasma converters operating at an emitter temperature of 1500°K and a cesium temperature of 200°C. Data obtained at the center of the discharge showed electron temperatures of about 10,000°K, concentrations in excess of 10^{12} electrons per cm^3, and space potentials more than 1 v above the collector potential under normal operating conditions. The electron energy distributions were strictly Maxwellian. Adjustable probes were used to obtain variations of the parameters along the axis of the discharge. Their results showed that a "virtual collector" exists a short distance from the emitter surface whose potential is from 1.1 – 1.5 v above the collector potential with respect to the emitter. The potential curve then remains essentially flat within the main part of the discharge, the plasma region. The electron concentration has a sinusoidal variation, reaching a maximum near the center and having magnitudes between 10^{12} and 10^{13} electrons per cm^3. The electron energy distributions are Maxwellian in the center of the plasma, but exhibit an excess of high energy electrons near both electrodes. The electron temperature rises to a maximum above 10,000°K near the emitter and falls toward the collector. A simple physical picture of the discharge is developed, and it is shown that a one-step ionization process by the high energy tail of the electron distribution is sufficient to explain the degree of ionization required to maintain the discharge. Phenomena taking place at the collector surface are analyzed. One possible mechanism is developed which can lead to electron distributions of the same nature as is observed in front of the collector. This mechanism is also shown to aid in the explanation of the so-called "Langmuir paradox." (auth) NSA '63

20622 THE CESIUM VAPOR THERMIONIC CONVERTER. I. LIMITATIONS IMPOSED BY EMISSION PROCESSES. N. S. Rasor (Atomics International, Canoga Park, Calif.). Advan. Energy Conversion, 2: 545-67(July-Sept. 1962).

Performance limits imposed on the thermionic converter by the emission of electrons, ions, atoms, and photons are analytically defined, and their relative importance is appraised. Comparison of the analytical results with experimentally observed performance indicates that emission processes largely determine the required operating temperatures and cesium pressures in cesium diode converters. The performance characteristics and relative usefulness of various classes of emitter materials is estimated, leading to the conclusion that high work function refractory metals with adsorbed cesium have the greatest general utility. Criteria for the choice of emitter materials giving maximum efficiency at a given emitter temperature and spacing in the cesium diode converter are given, as well as relations permitting the choice of compatible emitter and ionizer materials in the surface ionization triode. (auth) NSA '63

20623 THE CESIUM VAPOR THERMIONIC CONVERTER. II. PATCH AND TRANSPORT EFFECTS. N. S. Rasor, G. N. Hatsopoulos, and S. Kitrilakis (Thermo Electron Engineering Corp., Waltham, Mass.). Advan. Energy Conversion, 2: 569-81(July-Sept. 1962).

Analysis of the electrical characteristics of cesium-vapor diode thermionic converters indicates that non-uniform emission from polycrystalline emitters can account for many of the major observed features of the characteristic behavior. A single crystal emitter showed gross changes in its output characteristics when its surface was etched, suggesting the creation of patches. Using the work function distribution obtained from the electrical characteristics, a simple model for ion emission neutralization permits computation of the saturation currents of the ignited and extinguished modes. The computed values are in semiquantitative agreement with the experimental data reported. Consideration of the energy balance and ion generation requirements for sustaining volume ionization and energy losses in the ignited mode yields expressions for the internal potential drop across the cesium vapor and the electron temperature. Consideration of the simplest of the energy loss contributions shows the assumptions to be consistent with the experimental data reported. (auth) NSA '63

20624 THE CESIUM VAPOR THERMIONIC CONVERTER. III. OBSERVED DEPENDENCE OF PERFORMANCE ON CESIUM PRESSURE, SPACING, EMITTER TEMPERATURE AND EMITTER MATERIAL. Sotiris Kitrilakis and George N. Hatsopoulos (Thermo Electron Engineering Corp., Waltham, Mass.). Advan. Energy Conversion, 2: 583-600(July-Sept. 1962).

Extensive data obtained on the performance of a cesium vapor diode thermionic converter are described. Volt-ampere characteristics were obtained for four spacings from 0.002 – 0.019 in., emitter temperatures in about 50° steps from 1600 – 2050°K, and cesium pressures to 30 torr. A set of such data for emitters of Nb, Ta, Mo, W, Re, and Ir have been obtained. Heat flow through the converter could be measured by an attached calorimeter. A systematic method is described for evaluating the practical significance of this large amount of data to permit the choice of optimum materials and operating points for efficient engineering design. Evidence is presented that the observed saturation current of the extinguished mode represents true temperature-limited emission, and thus may be used to obtain data equivalent to the Langmuir S curves. (auth) NSA '63

20625 SPACE CHARGE ANALYSIS OF A PLASMA DIODE. K. G. Hernqvist and F. M. Johnson (RCA Labs., Princeton, N. J.). Advan. Energy Conversion, 2: 601-11 (July-Sept. 1962).

A theoretical analysis of the space charge problem for a cesium plasma diode shows that operating conditions can be achieved for which there exists no simultaneous solution of the space charge and converter equations which relate current, voltage, and load impedance. These conditions correspond to those for which internal relaxation oscillations have been experimentally observed in a cesium vapor type thermionic energy converter. Examination of the normalized distance parameter used in the analysis indicates that potential distributions having a large number of potential maxima and minima may exist in the cesium plasma diode. This explains some irregularities found in the load characteristic and in plasma temperature measurements for the plasma diode. (auth) NSA '63

3271 (UCRL-7031) DESIGN AND CONSTRUCTION FEATURES OF A VARIABLE GAP THERMIONIC CONVERTER TUBE. W. H. Gust and E. S. McKee (California. Univ., Livermore. Lawrence Radiation Lab.). Sept. 27, 1962. Contract W-7405-eng-48. 11p.

Design and construction features are presented for a parallel-plane thermionic converter tube which has an interelectrode gap that may be precisely varied from zero to six inches. (auth) NSA '63

2128 CESIUM VAPOR DIODES. T. L. Matskevich (Leningrad Ioffe Inst. of Physics and Tech.). Zh. Tekhn. Fiz., 32: 1139-41(Sept. 1962). (In Russian)

Descriptions are given of a simple device with a thorium oxide cathode capable of thermoelectric energy transformation with a yield of 0.5 v. The influence of external magnetic field, perpendicular to the electron motion, on the thermoelectric energy transformation oscillation amplitudes was determined. Volt-amp characteristics were measured at various magnetic field intensities. (R.V.J.) NSA '63

20620 ELECTROSTATIC PROBE MEASUREMENTS IN A CESIUM PLASMA. R. H. Bullis (United Aircraft Corp., East Hartford, Conn.). Advan. Energy Conversion, 2: 523-6(July-Sept. 1962).

Electrostatic probe measurements have been made in a cesium plasma with an electron number density of $10^9/cm^3$ generated in a thermionic converter operating in the non-arc mode condition. Experimental results obtained using a conventional electrostatic probe with borosilicate glass as the electrical insulating material around the probe shank indicate that there is both surface and bulk electrical conduction through this material when it is placed in a high temperature cesium plasma. This surface leakage significantly changes the current-voltage characteristics of the probe so that the correct plasma properties cannot be obtained from this information. Tests of several other electrical insulating materials indicated that similar problems with electrical conduction were present when the probe was inserted in the cesium plasma. A novel probe design is described, which is comprised of a coaxial metal cylinder sandwiched between two layers of insulating material around the probe shank. By maintaining this coaxial cylinder at the same potential as the probe, the cylinder acts as a guard ring and prevents both surface and bulk electrical leakage. A comparison is presented of the experimental results obtained from measurements of the same cesium plasma with the two different probes. An electron temperature of 0.18 ev is measured with the coaxial probe where the emitter temperature corresponds to 0.12 ev. A measured electron to ion saturation current ratio of 616 is obtained with the coaxial probe where a saturation ratio of 494 would be expected in a thermalized cesium plasma. These results, when compared with an electron temperature of 0.65 ev and saturation ratio of 1.4 obtained with a glass shielded probe, are more consistent with existing converter conditions. (auth) NSA '63

20628 NOISE IN THERMIONIC CONVERTERS. E. Kuhn (Republic Aviation Corp., Farmingdale, N. Y.). Advan. Energy Conversion, 2: 637-8(July-Sept. 1962).

Emitter activity and patchiness can be assessed from shot noise response curves of shot noise voltage versus emitter temperature, and vapor pressure. Specifically the characteristics (a) temperature and pressure at which the noise sharply increases, (b) the rate of change in the slope of the curve in the transition region between space charge and temperature limited modes, and (c) the level of space charge limited noise can give indications of activity and patchiness at different times of emitter life. These characteristics can be used as a stethoscope to listen and predict trends in emission capabilities as a function of emitter lifetime before the effects are recognized in the output power. Appropriate shot noise sensing can be used as a reliability or quality indicator for electron emission in thermionic converters. (auth) NSA '63

UNCLASSIFIED

107061 ADVANCED NUCLEAR ELECTRIC POWER GENERATOR SYSTEM STUDY, VOLUME
107062 II: THERMIONIC NUCLEAR SPACE POWERPLANT
(Period covered: July 1-September 30, 1962)

Unclassified

Pratt and Whitney Aircraft (R-PWA-2107, Vol. II)
NASw-360
QPR

Although nuclear thermionic powerplants have not been designed or constructed, this new conversion technique offers significant potential for static lightweight space powerplants. Therefore, studies of thermionic power systems are required to indicate the design regimes where those systems will be most attractive. In any new technology there are a number of technical problems or unknowns which have to be identified and subsequently resolved before the full potential of the concept can be achieved. An examination of thermionic reactor designs is needed to indicate these problems and limitations. The objectives of this study are: (1) to investigate characteristics unique to the system; (2) to identify the technical uncertainties unique to the system; including design, material and fabrication considerations; and (3) to recommend future program areas for the study of feasibility and state-of-the-art limitations.

Nuclear power stations

UNCLASSIFIED

70,182 FUEL FORM SYSTEMS FOR NUCLEAR THERMIONIC ELEMENTS

Monroe, J. E., Jr. (Martin-Marietta Corp., Baltimore, Md.)
American Rocket Society, Inc., New York, N.Y.
2521-62
(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25–28, 1962)

Progress of the nuclear thermionic fuel form development program at the Nuclear Division of the Martin-Marietta Corporation is reported. Several alternate fuel form systems for a series of nuclear thermionic reactors are described from a conceptual design viewpoint. The fuel form system consists of refractory metal encapsulated fuel pellets fabricated from uranium monocarbide, uranium monitride, and uranium dioxide-refractory metal cermet systems. Critical design factors and basic problems associated with the use of each fuel form system are briefly discussed and initial solutions to these problems are presented. Basic techniques and materials utilized in the fabrication of these fuel form systems are discussed briefly, and initial results of the development program are summarized. Photomicrographs of the structure of the uranium monocarbide, uranium dioxide–molybdenum, and uranium dioxide–tungsten fuel form systems are presented.

70,062 COUPLING NUCLEAR-THERMIONIC POWER TO ELECTRIC SPACECRAFT PROPULSION

McCartney, J. F. (The Martin-Marietta Corp., Baltimore, Md.)
American Rocket Society, Inc., New York, N.Y.
2551-62
(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25–28, 1962)

Input requirements for electric spacecraft propulsion devices are reviewed. Basic conceptual designs for coupling nuclear thermionic power to the devices and other spacecraft loads are presented.

UNCLASSIFIED

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ARS-20
1962
Vols 1-2

SOLAR ENERGY THERMIONIC CONVERSION SYSTEM (Presented at the Space Power Systems Conference of the American Rocket Society at the Miramar Hotel, Santa Monica, California)
(Period covered: September 25-28, 1962)
Menetrey, W. R. & Smith, A.
Unclassified
American Rocket Society
P-2499-62

This paper summarizes the design, fabrication, and test efforts in the period, May, 1961, through September, 1962, accomplished in the SET (Solar Energy Thermionic) program under JPL contract No.950109, NAS 7-10, and related programs. The discussion includes the fabrication and performance of a 5-ft. solar concentrator, fabrication and test of 40 SET thermionic converters, and the fabrication of two SET thermionic generators along with test data using both solar radiation and electron bombardment heaters. A system efficiency of 3 percent and a specific weight of 2 watts/lb was demonstrated in the first prototype system test using solar radiation. As described, efficiency and specific weight are expected to increase significantly in the near future.

Thermionic converters
Thermionic generators
Solar concentrators

UNCLASSIFIED

70,317 **THERMIONIC CAVITY GENERATOR DEVELOPMENT**
Purdy, D. L. (Missile & Space Division, Valley Forge Space Technology Center, Philadelphia, Pa.)
American Rocket Society, Inc., New York, N.Y.
2572-62
(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25–28, 1962)

Work performed on the Cavity Vapor Generator Program is discussed, and the expected performance of future Solar Thermionic Space Power Systems is predicted. The system considerations involved in collector and generator sizing are discussed as well as converter to generator relationships.

Computations are described which define the thermal and electrical performance of the converters, cavity, insulation, collector and vacuum system. Measured values of thermal energy and electric power obtained during laboratory testing are described which result in a converter efficiency at cathode temperature of 1650°K of 6.5%. A description of the solar test and expected results is included.

70,163 **THERMAL ENERGY STORAGE FOR THERMIONIC CONVERSION**
Batutis, E. F., Purdy, D. L. (General Electric Co., Missile and Space Div., Valley Forge, Pa.)
American Rocket Society, Inc., New York, N.Y.
2505-62
(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25–28, 1962)

Silicon and a number of refractory oxide mixtures were studied in an investigation of materials having the properties of high heat of fusion and melting temperatures ranging from 1600 to 2200°K. These thermal energy storage materials were examined for usage in solar collector–thermionic converter electrical power systems employed in space vehicles.

70,477 PROGRESS TOWARD NUCLEAR THERMIONIC SPACE POWER
Voorhees, B. G. (General Electric Co., P'easanton, Calif.)
American Rocket Society, Inc., New York, N.Y.
2577-62
(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25–28, 1962)

State-of-the-art performance of laboratory converters is summarized in terms of output, efficiency, and life. Results of comparative analyses are presented for several combinations of thermionic converters with nuclear heat sources. These demonstrate the superior potential of the nuclear thermionic system in which the thermionic converters are integral with the nuclear fuel element. The particular merits of the cesiated refractory metal converters for this use are emphasized.

70,318 SOLAR THERMIONIC GENERATOR USES CESIUM DIODES
Space/Aeronautics, v. 38, no. 4, pp. 165–167, September 1962

A solar thermionic generator using cesium diodes is described.

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CESIUM THERMIONIC CONVERTERS AND GENERATORS FOR SOLAR SPACE POWER SYSTEMS (Presented at the Space Power Systems Conference of the American Rocket Society at Miramar Hotel in Santa Monica, California)
(Period covered: September 25-28, 1962)
Brosens, Pierre J. & Kitrilakis, Sotiris S.

Unclassified

American Rocket Society
P-2571-62

The research work on thermionic converters accomplished at Thermo Electron is reviewed. Data obtained for converters, using niobium, tantalum, tungsten, iridium, and rhenium emitters, as a function of interelectrode spacing and converter operating temperatures is given in the form of maximum power density maps. Theoretical work on the effect of crystallographic orientation of emitter surface on converter performance is described. General design requirements for solar thermionic generators for space applications are discussed. Although no inherent limitation has been observed on the life and reliability of Thermionic devices, life of the order of several thousands of hours and higher reliability must be and remains to be demonstrated.

Power generators Cesium
Converters

UNCLASSIFIED

71,208 SYMPOSIUM ON THERMIONIC POWER CONVERSION
Advanced Energy Conversion, v. 2, pp. 315–643, July–September 1962

The complete papers from Sessions I, II, and III of the Symposium on Thermionic Power Conversion held in Colorado Springs, Colorado, May 1962 are presented. The Sessions were: I—Converter Performance; II—Theoretical Models; and III—Correlation of Experiment and Theory and Oscillations.

70,225 THE THERMIONIC RADIATOR SYSTEM
Buck, K. E. (Aerojet-General Nucleonics, San Ramon, Calif.)
American Rocket Society, Inc., New York, N.Y.
2578A-62
(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25–28, 1962)

Aerojet-General Nucleonics is engaged in a program to determine the feasibility of a thermionic radiator system. The primary objective of the first phase of the program was to demonstrate the operation of a thermionic converter, using a liquid metal to supply thermal energy to the cathode. In addition, some limited systems analysis was performed. The first phase has just recently been completed, and the objectives were fully attained.

70,315 PERFORMANCE OF CESIUM THERMIONIC DIODES OPERATED IN SERIES-PARALLEL CIRCUITS
Holland, J. W. (North American Aviation, Inc., Canoga Park, Calif.)
American Rocket Society, Inc., New York, N.Y.
2570-62
(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25–28, 1962)

Electrical power degradation from the operation of many series-parallel circuited cesium diodes in a thermionic reactor must be considered when a nonflattened nuclear power distribution exists over the volume of the reactor core. The loss of power and efficiency due to unequal heat inputs to series- or parallel-connected diodes is measured, and the operating characteristics of a multiple diode system are studied. The results are applied to a specific thermionic reactor configuration with a ratio of maximum to minimum diode heat input of 1.85. The minimum degradation of power and efficiency was found to be 41 and 19%, respectively, at optimized operating conditions.

AD-289 355 Div. 8
(TISTE/OHD) OTS price $4.60

General Electric Co., Syracuse, N. Y.
EXPLORATORY STATIC ENERGY CONVERSION STUDY-MULTI-LAYER THERMIONICS.
Quarterly technical progress rept. no. 1, 1 July-30 Sep 62, by V. A. Russell, W. Tantraporn, and W. J. van der Grinten. 30 Sep 62, 41p. incl. illus. tables, refs.
(Contract AF 33(657)9204)
Unclassified report

DESCRIPTORS: *Thermoelectricity, *Thermal radiation, *Electric power production, Thermionic emission, Solid state physics, Thin films, High temperature research, Vapor plating, Germanium compounds, Evaporation, Measurement.

A new static heat-to-electricity conversion principle is desscribed which attempts to duplicate in the solid state at a lower temperature the high impedance performance of a vacuum thermionic converter. The basic arrangement is a multilayer structure of thin film semiconductors or insulators perpendicular to the heat flow, separated by thin layers of metals. The optimization of the transverse mean-free path of the charge carriers, film thickness, contact potentials and other parameters is discussed. An outline of the exploratory experimental study of this new concept and some practical details on film production and measurements are given. (Author)

163

AD-288 935 Div. 8, 25
(TISTM/BRW) OTS price $2.60

General Telephone and Electronics Labs., Inc., Bayside, N. Y.
STUDIES OF ELECTRON TUBE MATERIALS AND THERMIONIC EMISSION PROCESSES.
Scientific rept. no. 10, 1 July-30 Sep 62, by John V. Florio and T. G. Polanyi. 30 Sep 62, 17p. incl. illus. (Rept. no. TR 62-704-104-204-208.21)
(Contract AF 19(604)7286, Proj. 4619)
(AFCRL 62-905) Unclassified report

DESCRIPTORS: *Thermionic emissions, *Oxide cathodes, *Electron tubes, Cathodes (Electron tubes), Diodes, Materials, Nickel, Barium compounds, Oxides, Tantalum, Platinum, Chemical reactions, Mass spectroscopy, Barium, Evaporation, Coatings, Sublimation, Impurities, Molybdenum, Thin films.

A comparison of the emission properties of pure-Ni base cathodes with cathodes containing known impurities in either the base metal or the coating permitted a more critical evaluation of the effects of the impurities on emission. The slow activation of the W-Ni base oxide cathodes and the enhancement of emission with successive high-temperature processing treatments (increased reaction between W and the oxide) are in sharp contrast to results obtained with the binder. Electrolytic activation of an oxide cathode by drawing plate current has usually been ascribed to electrolytic dissociation of the cathode coating, evaporation of oxygen, and activation by the excess Ba residue. The results obtained on a special tube with movable anodes indicate that, under electron bombardment, evaporation of Ba from the anode back to the cathode is responsible for activation. The sublimation from a Ta-base oxide cathode has been measured as a function of cathode temperature. The sublimate is predominantly atomic Ba and the sublimation rates are considerably greater than those found for the Pt, pure Ni or N4 Ni cathodes. The Ta base cathode can thus be used as a convenient controlled source of Ba atoms in the study of cathode coating activation. (Author)

'63

40153 (AD-290727) INVESTIGATIONS ON THE DIRECT CONVERSION OF NUCLEAR FISSION ENERGY TO ELECTRICAL ENERGY IN A PLASMA DIODE. Period Covered: February 1, 1962 to October 31, 1962. Frank E. Jamerson, ed. (General Motors Corp. Research Labs., Warren, Mich.). Oct. 31, 1962. Contract NONR-3109(00). 137p.

Results of experimental and theoretical investigations are presented on the use of a nuclear generated plasma in a noble gas plasma diode thermionic converter. Related programs of emitter materials development and plasma measurements are described. These are presented in the following individual sections: inpile ion chamber experiment-theory and tube design, pulsed noble gas plasma diode experiments, electron mobility in gases, spectroscopic measurements in a cesium low voltage arc converter, and uranium carbide-rhenium cermet emitter. (auth)

NSA 163

36983 (AD-290068) FEASIBILITY DETERMINATION OF A NUCLEAR THERMIONIC SPACE POWER PLANT. Quarterly Technical Progress Report, August 1, 1962 through October 31, 1962. (Aerojet-General Nucleonics, San Ramon, Calif.). Contract AF33(657)-8977. 22p. (AN-778)

A research program on thermionic converter-radiator systems is being conducted to demonstrate the operation of at least 3 thermionic converters in a series array using heat from a liquid metal loop, and to demonstrate 1000 hr of thermionic operation using liquid metal heating. For the electrical insulation of the thermionic units from the heating pipe, Al_2O_3 coatings plasma-sprayed on Nb tubes were developed. The effects of sintering experiments on the coatings were studied. The brazing of an outer Mo sleeve to the Mo coating plasma-sprayed over the Al_2O_3 was investigated using three braze materials and found to be satisfactory. The analysis for the thermal radiator system for its characteristics and for design and development problem areas is discussed. Finally, progress on the loop test task is described. (D.L.C.)

NSA 163

UNCLASSIFIED

115927 BASIC RESEARCH IN THERMIONIC ENERGY CONVERSION (Period covered: November 1, 1961-October 31, 1962) Warner, C., III & Hansen, L.K. (et al)

Atomics International — Unclassified
Nonr-3192(00) — (AI-7979)
Annual TSR-2

This report presents the results of a continuing program to investigate basic processes in thermionic energy conversion important to a thermionic nuclear power plant for naval applications.

22257 SPACE-CHARGE NEUTRALIZATION AND NEGATIVE RESISTANCE IN THERMIONIC DIODES CONTAINING RADIOACTIVE KRYPTON. R.Forman and J.A.Ghormley. J. appl. Phys. (USA), Vol. 33, No. 10, 3057-60 (Oct., 1962).

Anode current—voltage characteristics of gas-filled thermionic diodes containing fission-product krypton were compared with characteristics of the same tubes containing natural krypton. Significant increases in current were observed in the diodes when radioactive krypton was substituted for natural krypton at pressures in the range of 20-340 mm Hg. In addition, diodes containing radioactive krypton displayed negative resistance.

PA62

14512 MEASUREMENTS ON VACUUM THERMO-ELECTRON GENERATOR. M.Ozawa, T.Morita and K.Ogasawara. Bull. Electrotech. Lab. (Japan), Vol. 26, No. 10, 32-8 (Oct., 1962). In Japanese.

Experimental results are described relating to a thermo-electron generator using W or Th-W electrodes in vacuum. The emitter and the collector are separately Joule heated to a temperature of 600 to 2400°C, and the inter-electrode distance is kept between 0·03 and 0·01 mm. The results are summarized as follows. 1. For a constant temperature of the collector, there is a certain temperature of the emitter at which its induced voltage is a minimum and is even lower than that of the collector. 2. An output current density of 0·3 A/cm² at 1/V is obtained when the inter-electrode distance is 0·03 mm. 3. In the thermo-electron generator with a W-emitter, changing of the collector material from W to Th-W results in an 0·8V increase in induced voltage under the same conditions, which is nearly equal to the difference in work function between those materials.

PA '63

/2024 BREAKDOWN PHENOMENA IN THERMIONIC GAS-FILLED DIODES. J.Cleary.

J. appl. Phys. (USA), Vol. 33, No. 10, 3142-3 (Oct., 1962).

Forman (Abstr. 13075 of 1961) discovered that the breakdown potential of thermionic gas-filled diodes can be lower than the ionization potential of the filling gas, and that the pre-breakdown anode current is not space-charge-limited, under certain conditions. These phenomena have since been observed in commercial "Tungar" rectifier diodes. In addition a hyperbolic relationship was found between breakdown voltage and cathode temperature, and a second discharge transition occurred after the initial breakdown if the voltage and current were allowed to increase sufficiently.

C.Greaves

PA '63

AD-291 683 Div. 9, 7
(TISTP/GRW) OTS price $1.00

ITT Federal Labs., Nutley, N. J.
POWER CONVERSION BY ELECTRON CONVECTION.
Final rept., Apr 61-June 62,
by S. R. Hoh and W. L. Harries. Oct 62, 32p.
incl. illus. tables, 6 refs.
(Contract AF 33(616)7941, Proj. 8173)
(ASD TDR 62-693) Unclassified report

DESCRIPTORS: *Electric power production, *Thermionic emission, *Electrons, Conversion ratio, Magnetohydrodynamics.

A preliminary research study was conducted on a new electrohydrodynamic system which is capable of converting thermal into electrical power. Conversion was accomplished by the forced convection of thermionic electrons emitted from an alkaline metal emitter. Analytical and experimental studies showed that this new type of converter is feasible and practical. Outputs up to 18 volts were obtained under open circuit condition with emitter temperatures as low as 450 C. Short circuit output currents were near the emission current of the emitter. (Author)

'63

AD-289 539 Div. 8
(TISTM/ODN) OTS price $3.60

General Atomic Div., General Dynamics Corp.,
San Diego, Calif.
RESEARCH OF CESIUM-VAPOR CELLS EMPLOYING CARBIDE EMITTERS.
Technical summary rept., 1 Feb-31 Oct 62,
by F. Carpenter, G. Cheney and others.
31 Oct 62, 36p. incl. illus. tables, 10 refs.
(Rept. no. GA-3593)
(Contract Nonr-319300)
Unclassified report

DESCRIPTORS: *Thermionic emission, *Cesium, *Carbides, Vapors, Vacuum systems, Uranium compounds, Zirconium compounds, Surfaces, Adsorption, Chemical analysis, High temperature research, Abrasion, Impurities, Mixtures, Electric currents, Work functions, Electrodes, Vaporization.

Emission poisoning can result when a UC-ZrC emitter is exposed to air after it has been heated to a high temperature. Suitable handling of the emitter after mechanical abrasion of the surface will completely remove the poisoned region and restore satisfactory emission behavior. It was established that thermionic emission from UC-ZrC emitters is largely independent of composition. However, UC-ZrC emitters with low mol-% UC composition are more readily poisoned than those with high mol-% UC compositions. Data on the vacuum thermionic emission of UC-ZrC solid solutions are consistent with the hypothesis that emission from UC and UC-ZrC emitters is controlled primarily by an adsorbed layer of uranium on the surface of the carbide. Work on the Mark I-D thermionic cell has produced a workable and versatile research cell. Initial operation at low temperatures revealed significant information concerning the thermionic effects of cesium on carbide surfaces. Consequently, cesium vapor adsorption causes a substantial modification of the thermionic work function of a carbide. (Author)

'63

AD-289 540 Div. 7, 20, 25, 8
(TISTP/WH) OTS price $10.50

General Atomic Div., General Dynamics Corp.,
San Diego, Calif.
PARAMETRIC STUDY OF DIRECT CONVERSION REACTOR POWER SYSTEMS.
Final technical rept., 1 Dec 60-31 Oct 62,
by W. B. Wright, Jr. 31 Oct 62, 133p. incl.
illus. tables, 24 refs. (Rept. no. GA-3540)
(Contract Nonr-337100)
Unclassified report

DESCRIPTORS: *Electric power production, *Thermionic emission, *Nuclear power plants, *Light water reactors, *Reactor theory, *Reactor cores, *Heat transfer, *Reactor kinetics, Power.

A mathematical formulation of thermionic-cell dynamics for use in thermionic reactor design is developed. The formulation developed was incorporated into a digital computer code. This code was used in conjunction with neutronics and heat transfer calculations to investigate the interrelated thermionic-neutronic-heat-transfer problems of thermionic reactor design. Two main problem areas in the nuclear design of water-cooled thermionic reactors, i.e., the inherently large parasitic capture in thermionic cells and the power-flattening problem, are discussed. In order to define the problems that might arise in the design of an actual thermionic reactor plant, a conceptual design study of a 1-Mw(e) water-cooled thermionic reactor system was undertaken. Tungsten-clad emitters were purposely used in this study in order to evaluate the suitability of using materials with very high parasitic capture rates in a water-cooled system. (Author)

'63

24029 (AD-286324) THE DEVELOPMENT OF AN AUXILIARY ELECTRODE THERMIONIC CONVERTER. Quarterly Technical Report No. 3. W. B. Hall and J. J. O'Grady (Radio Corp. of America. Electron Tube Div., Lancaster, Penna.). Oct. 1962. Contract AF33(657)-8005. 63p.

Research was continued in an effort to determine the feasibility and to demonstrate the practicality of a three-electrode thermionic converter having the following characteristics: a third, positive ion-producing electrode, an efficiency of not less than 15%, an unattended life of not less than 1 year, and a maximum temperature of 1500°K. Several experimental converter designs were fabricated and evaluated. Refinements in geometry and processes were tested to achieve more dependable design criteria with the greatest emphasis directed toward the improvement in Cs purity. Materials investigations completed the Cs compatibility data for the initial materials selected and a comprehensive report is included. (auth) NSA 63

24030 (AD-286693) UNIFORM WORK FUNCTION CATHODE STUDIES FOR THERMIONIC CONVERTERS. Quarterly Report No. 1. M. N. Huberman (Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.). Oct. 1962. Contract AF33(657)-8726. 25p.

Uniform work functions of thermionic converters were investigated. The performance of cylindrical converters that have emitters with uniform work function surface was evaluated. Chemical vapor deposition techniques were developed for the fabrication of nonplanar emitters of practical design that have improved uniformity of work function over the uniformity of work function of standard polycrystalline emitters. The development of thermionic converters having emitters of improved uniformity of work function may result in increased efficiency and power density. A converter test stand was assembled, equipment associated with the test stand was calibrated, and deposition samples were fabricated. (auth) NSA 63

24031 (AD-286711) EVALUATION OF A MOLYBDENUM EMITTER, LOW VOLTAGE ARC THERMIONIC POWER CONVERTER. Quarterly Technical Progress Report No. 2. E. A. Baum (General Electric Co. Power Tube Dept., Schenectady, N. Y.). Oct. 1962. Contract AF33(657)-8323. 24p.

Evaluation of Mo emitters for low voltage arc thermionic converters was continued. The objective was to define and minimize the life-limiting and degradation factors affecting the usefulness of the low-temperature Cs vapor converter. Work on the program was directed toward a life test evaluation of a state-of-the-art, planar Cs vapor thermionic converter. Research was continued on a technical specification for a state-of-the-art vapor converter utilizing a Mo cathode. Effort was directed toward the design and fabrication of life test equipment suitable for obtaining meaningful data on the state-of-the-art Cs vapor thermionic converter as well as the fabrication of devices for test, and toward completion of the life test equipment, initiation of life tests, and the acquisition of operational data. (auth) NSA 63

24725 (ASD-TDR-62-827) FEASIBILITY DETERMINATION OF A NUCLEAR THERMIONIC SPACE POWER PLANT. Final Report, April 1, 1961 to August 31, 1962. K. E. Buck, C. R. Fisher, and I. M. Rehn (Aerojet-General Nucleonics, San Ramon, Calif.). Oct. 15, 1962. Contract AF 33(616)-8119. 150p. (AN-700; AD-293453)

The first phase of a program to determine the feasibility of a nuclear space-power system that utilizes a thermionic radiator is described. In this concept, thermionic converters are mounted in the radiator of the power plant and lithium is circulated directly from the reactor through the radiator. Fins attached to the anode reject waste heat to space. The basic feasibility of the thermionic radiator concept was demonstrated. An electrically heated, refractory metal (Cb-1Zr) test loop which incorporated a centrifugal pump, thermionic converter, heat sink, and regenerator was constructed. Lithium was circulated to the thermionic converter at temperatures ranging from 2150 to 2260°F. A cylindrical thermionic converter with a cathode surface area of 80 cm^2 was operated at power densities up to 1 w/cm^2. Limited systems analysis was carried out to establish the potential performance of the power plant concept. (auth) NSA 63

3573 (NP-12206) THERMAL RADIATION GUIDES FOR POWER TRANSMISSION. Quarterly Progress Report No. 1, July 1 – September 30, 1962. W. J. Swenson (Electro-Optical Systems, Inc., Pasadena, Calif.). Oct. 15, 1962. Contract AF33(657)-8526. 37p. (EOS-3000-Q-2).

Progress in the development of thermal radiation focusing guides for power transmission is reported. Thermodynamic analyses that will lead to the development of equations assisting in the determination of optimum guide configurations and materials for applications are introduced and discussed. The fabrication of the guides by electrofining techniques is discussed along with the possibility of using other fabrication techniques. The feasibility of using radiation guides to supply power to two energy absorbers (the laser and thermionic diode) is discussed. Prototype radiation guide tests show good power transmission efficiencies. Factors entering into optimum guide dimensions are discussed. (N.W.R.) NSA 63

16769 (AI-7979) SECOND ANNUAL TECHNICAL SUMMARY REPORT FOR BASIC RESEARCH IN THERMIONIC ENERGY CONVERSION. [Covering Period] November 1, 1961 to October 31, 1962. C. Warner, III, L. K. Hansen, H. Hori, and R. L. McKisson (Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.). Contract NONR-3192(00). 133p.

Results of work in a continuing program to investigate basic processes in thermionic energy conversion related to thermionic nuclear power plants for naval applications are reported. The areas in which progress is reported include statistical mechanics of Cs adsorption, space charge analysis for low pressure thermionic diodes, emission requirements for removal of space charge barriers, unignited mode of thermionic converters, interpretation of volt-ampere characteristics, vaporization and deposition at Cs-covered surfaces, and Cs purification. (auth) NSA 63

AD-297 039 Div. 25, 20, 7
(TISTP/MB) OTS price $10.50

Atomics International, Canoga Park, Calif.
BASIC RESEARCH IN THERMIONIC ENERGY CONVERSION.
Annual technical summary rept. no. 2, 1 Nov 61-31 Oct 62,
by C. Warner, III, L. K. Hansen and others.
31 Oct 62, 133p. incl. illus. tables, 23 refs.
(Rept. no. AI-7979)
(Contract Nonr-319200)
Unclassified report

DESCRIPTORS: *Thermionic emission, Statistical mechanics, Cesium, Space charges, Transport properties, Adsorption, Energy conversion, Nuclear power plants, Purification, Vaporization, Diodes, Theory.

This report presents the results of the past year's work in a continuing program to investigate basic processes in thermionic energy conversion important to a thermionic nuclear power plant for naval applications. The previous work was reported in AI-6799, "First Summary Report of Basic Research in Thermionic Conversion Processes." The subjects discussed in the present report are: statistical mechanics of cesium adsorption, space charge analysis for low pressure thermionic diodes, Emission requirements for removal of space charge barriers, unignited mode of thermionic converters, interpretation of volt-ampere characteristics, vaporization and deposition at cesium covered surfaces, and cesium purification. (Author) 163

5083 ZERO-FIELD EMISSION FROM THERMIONIC HOLLOW CATHODES. I. Brodie and A. Niewold (Westinghouse Electric Corp., Elmira, N. Y.). J. Appl. Phys., 33: 3328-34(Nov. 1962).

An examination of the theory of the thermionic hollow cathode shows that several distinct modes of zero-field emission are possible. The mode that exists in any given case depends on the relationship between a certain parameter d, which characterizes the nature of the electron cloud within the cavity, and the size of the effusion hole and the cavity dimensions. A quantitative expression is given for the conditions under which the hollow cathode can be used for a precise determination of the thermionic constants by the method of Jain and Krishnan. Under other conditions a quasi-hollow beam is obtained and a theoretical prediction of the total zero-field current from the hole was found to be in order of magnitude agreement with experimental observations. An explanation of the similarity of emissions between "L" cathodes of different porosity is also given. (auth) NSA 163

5079 SHALLOW DONOR THERMIONIC EMITTER. John K. Gorman (Sperry Gyroscope Co., Great Neck, N. Y.). J. Appl. Phys., 33: 3170-7(Nov. 1962).

A possible approach to the development of a low work function thermionic emitter involves the introduction of shallow donor states into a matrix having a low electron affinity. It is the intent of this paper to explore the concept of a shallow donor emitter from both a general point of view and with specific application to barium oxide as the host lattice. The problem is discussed in terms of the single-donor model with consideration given the various characteristics which would be required for a practical matrix-additive system. Although the electron affinity of BaO has been estimated to be as low as 0.6 ev, the ordinary oxygen vacancy donor present is a deep level with an ionization energy of about 1.4 ev; it yields a work function of 1.4 to 1.5 ev at 1000°K. By comparison, a work function of 0.83 ev would be expected for shallow donor BaO at this temperature. The substitution of a tripositive rare-earth ion for a Ba^{2+} ion in the lattice is presented as a possible mechanism for the incorporation of an impurity donor center. Some speculation is offered concerning the ionization energy of this type of donor as well as the associated activation process. An attempt was made to observe the donor behavior of several rare-earth ion additives in BaO and also SrO by studying the temperature dependence of the effective work function. Data were secured for La, Gd, Nd, Er, and Eu in BaO, and Eu and Sm in SrO at analytical concentrations of from 0.01 to 0.05 mole %. While no lowering of the work function is reported, it is clear that no definitive interpretation of a negative result can be made until certain other experimental information becomes available, particularly the solubility and oxidation state of the additive ion in the matrix crystal. (auth) NSA 63

24035 (GA-3562(Rev.)) HIGH-TEMPERATURE VAPOR-FILLED THERMIONIC CONVERTER. Quarterly Technical Progress Report, July 1 through September 30, 1962. W. Godsin (General Atomic Div. General Dynamics Corp., San Diego, Calif.). Nov. 10, 1962. Contract AF 33(657)-8563. 14p. (AD-289805)

The post-test analysis of Cell E was completed with the exception of the microprobe analysis of the emitter structure. Interpretation of data from the analysis indicated the necessity of improving the cleanliness of future cell assemblies and especially the need for techniques to determine the emitter condition throughout final assembly. A 10 UC–90 ZrC emitter was installed in Cell F. Thermocouple installation and calibration and high-temperature vacuum emission tests are being conducted prior to the final closure of the cell. A second cell structure, Cell G, is on hand and an emitter will be installed pending the results of surface preparation. Vacuum emission studies carried out under other contracts on three UC compositions, 10 UC–90 ZrC, 30 UC–70 ZrC, and 90 UC–10 ZrC, demonstrate that emission behavior is essentially independent of bulk uranium content. Intentional "poisoning" of the surface of sample emitters was produced by exposure to air at room temperature. These findings were substantiated on the Mark V-E and V-F emitters. It was concluded, therefore, that the emitter surface must be activated in addition to providing a clean cell environment during operation. (auth) NSA 163

70,280 LARGE, LOW-COST THERMIONIC SOLAR CONCENTRATOR ANALYSIS AND DEVELOPMENT

Bagby, J. P., Erdmann, R. C., Biblarz, O. (Hughes Aircraft Co., Culver City, Calif.)

American Rocket Society, Inc., New York, N.Y.

2534-62

(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25-28, 1962)

Analysis and computer studies have shown that collectors of other than paraboloidal conic sections of revolution, which are used for solar concentrators, can achieve sufficient intensities to produce emitter temperatures required for satisfactory thermionic energy conversion. Lightweight solar concentrators of any conic of revolution have been formed without masters, by inflating and stretching aluminized mylar film prior to foam rigidization. The mathematical analysis of second-degree conic concentrators is presented as well as the fabrication techniques and optical performance tests used. A mosaic method of manufacturing very large low-cost concentrators is investigated.

15618 MODERN METHODS OF PLASMA PHYSICS FOR ENERGY CONVERSION. L. Rothhardt.

Technik (Germany), Vol. 17, No. 9, 624-9 (Sept., 1962). In German.

A brief review of existing and future energy converters is attempted. The principle of thermo-ionic diode converters with and without plasma is explained. Several types of so-called magneto-hydrodynamic generators are briefly described and their possible applications indicated. The author gives his opinions on future trends and a bibliography of 50 papers. H. Motz

PA '63

Thermoionische Konverter fuer die Direkterzeugung von Elektrizitaet aus Gas, G.N. HATSOPOULOS, J.A. WELSH. Gas- u Wasserfach v 103 n 39 Sept 28 1962 p 1042-7. Thermionic converter for direct generation of electricity from gas; principle of operation of thermionic converter; converter performing under vacuum; cesium filled converter; design of gas heated converter, combustion, heat exchange, and vacuum chamber.

EI '63

70,314 PERFORMANCE TEST OF A CUBICAL CAVITY SOLAR THERMIONIC GENERATOR

Leovic, W. J., Mueller, M. W., Stevenson, C. G. (Thompson Ramo Wooldridge, Inc., Cleveland, Ohio)

American Rocket Society, Inc., New York, N.Y.

2554-62

(Presented at the Space Power Systems Conference, Santa Monica, Calif., September 25-28, 1962)

Results are presented of a solar test program carried out on a prototype thermionic generator. This program, designed to evaluate the performance of the generator in conjunction with a 5-ft precision solar concentrator, has demonstrated the ability of such a combination to produce very nearly its design power output levels in a space environment. A complete description of all specialized equipment and techniques employed in carrying out the tests and evaluations is included. The pertinent data and results are summarized and analyzed for all major phases of the solar test effort.

344 THEORY OF NEGATIVE RESISTANCE CHARACTERISTICS IN IRRADIATED GAS THERMIONIC DIODES. R. Forman (Union Carbide Corp., Parma, Ohio). Phys. Rev., 128: 1487-92(Nov. 15, 1962).

A theory explaining negative resistance effects in the anode current-voltage characteristics of inert gas-filled thermionic diodes exposed to ionizing radiation is proposed. The theory shows that these effects are observed in argon-, krypton-, and xenon-filled diodes under appropriate conditions of anode spacing, gas pressure, and radiation dosage because these gases have a Ramsauer minimum in their electron scattering cross-section data. The theory also shows that gases not having this anomaly in their scattering cross section, such as neon or helium, do not show negative resistance effects. (auth) NSA 63

345 ELECTRICAL CONDUCTION THROUGH RADIATION-PRODUCED PLASMAS IN INERT GAS THERMIONIC DIODES. R. Forman, J. A. Ghormley, and J. R. Reiss (Union Carbide Corp., Parma, Ohio). Phys. Rev., 128: 1493-6(Nov. 15, 1962).

Properties of thermionic diodes containing inert gases at pressures from 1 to 600 Torr have been determined during irradiation with gamma rays and 1-Mev electrons at dose rates to 3×10^8 rads/h. Anode current maxima were observed at applied potential less than 4 V in tubes containing argon, krypton, or xenon, the gases having Ramsauer minima in their scattering cross sections. Negative resistance in the tube characteristics was not observed with helium, neon, or nitrogen which do not have scattering cross-section minima. Negative resistance was observed in diodes having both planar and cylindrical geometry. With all of the rare gases initiation of breakdown occurred, during irradiation, at applied potentials less than the ionization potentials of the gases. The diode current at a constant anode voltage increased linearly with dose rate at low radiation intensities and approximately as the square root of dose rates at higher intensities. (auth) NSA '63

20783 THE INFLUENCE OF THE ELECTRON CESIUM PLASMA ON CHARACTERISTICS OF A THERMOELECTRON TRANSFORMER. N. D. Morgulis and Yu. P. Korchevoii (Kiev State Univ.). Zh. Tekhn. Fiz., 32: 1487-9(Dec. 1962). (In Russian)

A special transformer cell with independent arc discharge and incandescent tungsten cathode was introduced into an intra-electrode cesium plasma in order to eliminate the interference of the plasma with cell performance. (R.V.J.) NSA '63

16790 (TID-18216) FIELD REVERSAL IN TENUOUS PLASMA: EQUIPMENT STATUS REPORT. W. Pak, K. C. Rogers, H. Huber, J. R. M. Coulter, and G. Schmidt (Stevens Inst. of Tech., Hoboken, N. J.). [1962]. Contract AT(30-1)-2813. 23p. (SIT-P85(2/63))

Components of the d-c system for producing the cesium plasma column are described, particularly the electrodes and the cesium source. Measurement of the magnetic field with a Hall effect probes is explained as in the calibration of the plate temperature. Preliminary measurements of plasma density with a Langmuir probe yielded values of about 10^{11} cm^{-3}. The single turn field coil, the capacitor bank, and the switches of the a-c system to be used in applying the reverse field are described. (D.C.W.) NSA '63

Thermionic conversion systems may be operational by 1970. diagrs Nucleonics 20:29-1 D '62

AS+TI '63

25879 MEASUREMENTS ON VACUUM THERMO-ELECTRON GENERATOR. Masayoshi Ozawa, Toshikatsu Morita, and Kohei Ogasawara. Denki Shikensho Iho, 26: 752-8(1962). (In Japanese)

Experimental results obtained for the thermo-electron generator with W or Th–W electrodes, while heating the emitter and collector separately to 600 to 2400°C and keeping the inter-electrode distance between 0.03 and 0.1 mm, are presented. For a constant collector temperature, there is a certain emitter temperature at which its induced voltage is minimum and is even lower than that of the collector. An output current density of 0.3 amp/cm^2 at 1/v is obtained when the inter-electrode distance is 0.03 mm. With a W emitter, changing from a W to a Th–W collector increased the induced voltage 0.8v for the same conditions. The increase almost equals the difference in the work functions of the two materials. (auth) NSA '63

Thermionic converters produce over 20 watts. Electronics 35:66 D 7 '62

AS+TI '63

24065 (FTD-TT-62-666) THERMIONIC ENERGY CONVERTERS. I. I. Damaskine and G. A. Chetverikova. Translated from Teploenerg., No. 3, 82-6(1962). 11p. (AD-286572)

Operational principles of thermionic converters are briefly discussed, and the need for low anode work functions is pointed out. Ways for overcoming electron space charge are examined, and results of studies of the operation of various diodes are reviewed. Preliminary results of an investigation of a converter consisting of a glass tube in which a W strip cathode and a Ni anode are arranged coaxially and are separated by 1.3 mm are given. Operating with a Cs vapor at a pressure of 10^{-2} mm Hg, an efficiency of 4% was obtained. (D.C.W.) NSA '63

AD-289 801 Div. 25, 7
(TISTP/WH) OTS price $2.60

General Electric Co., Schenectady, N. Y.
EXPLORATORY ENERGY CONVERSION STUDY OF PHOTON THERMIONICS.
Quarterly technical progress rept. no. 1, by W. J. Kearns. Nov 62, 20p. incl. illus. 9 refs. (Rept. no. R-635 Q-1)
(Contract AF 33(657)9202, Proj. 8173)
Unclassified report

DESCRIPTORS: *Photons, *Thermionic emission, *Gas ionization, *Cesium, *Photonuclear reactions, *Gas discharges, Vapors.

Investigation concerns the use of photon processes for thermionic converters. The program objective is to determine the feasibility of enhancing the performance of cesium vapor thermionic converters at low temperatures, i.e., 1200 C, through photon processes. These photon processes are expected to increase the power output of a cesium converter by reducing the drop through the converter under load conditions by (1) increasing the conductivity of the positive column, (2) altering the potential distribution in the inter-electrode space, or (3) a combination of such effects. There is, in addition to the effect on full load operation, the use of photons to aid in establishing the discharge by generating enough ion pairs to accomplish gas tube breakdown or arc initiation, in the usual sense. (Author)

'63

AD-293 453 Div. 7, 20, 8
(TISTM/ODN) OTS price $3.00

Aerojet-General Nucleonics, San Ramon, Calif.
FEASIBILITY DETERMINATION OF A NUCLEAR THERMIONIC SPACE POWER PLANT.
Final rept. for 1 Apr 61-31 Aug 62, by K. E. Buck, C. R. Fisher and I. M. Rehn. Nov 62, 150p. incl. illus. tables, 51 refs.
(Rept. no. AN-700)
(Contract AF 33(616)8119, Proj. 8173)
(ASD TDR 62-827) Unclassified report

DESCRIPTORS: *Power supplies, *Nuclear power plants, *Electric power production, *Thermionic emission, Liquid metals, Lithium, Radiators, Feasibility studies, Refractory materials, Niobium alloys, Zirconium alloys, Reliability, Space flight, Design, Cathodes, Stresses, Rupture, Creep, High temperature research, Electric insulation, Configuration, Anodes, Spaceships.

The first phase of a program to determine the feasibility of a nuclear space-power system that utilizes a thermionic radiator is described. In this concept, thermionic converters are mounted in the radiator of the power plant and lithium is circulated directly from the reactor through the radiator. Fins attached to the anode reject waste heat to space. The basic feasibility of the thermionic radiator concept was demonstrated. An electrically heated, refractory metal (Cb-1Zr) test loop which incorporated a centrifugal pump, thermionic converter, heat sink, and regenerator was constructed. Lithium was circulated to the thermionic converter at temperatures ranging from 2150 to 2260 F. A cylindrical thermionic converter with a cathode surface area of 80 sq. cm. was operated at power densities up to 1 watt/sq. cm. Limited systems analysis was also carried out in order to establish the potential specific performance of the power plant concept. (Author)

'63

2598 ERRATUM: ORIGINS OF OSCILLATIONS IN A LOW-PRESSURE THERMIONIC CONVERTER. P.Mazur. J. appl. phys. (USA), Vol. 33, No 11, 3387-8 (Nov., 1962).

A previous report (Abstr. 19884 of 1962), that self-consistent electrostatic potential distributions did not exist along the plateau of the V–I characteristic, has proved to be false. This was due to a faulty interpretation of the fact that dv/dI (v = output voltage, I = output current) was found to be infinite at a range of current values below the emitter saturation current. C.Greaves

EEA '63

3995 ERRATUM: ORIGIN OF OSCILLATIONS IN A LOW-PRESSURE THERMIONIC CONVERTER. P.Mazur. J. appl. Phys. (USA), Vol. 33, No. 11, 3387-8 (Nov., 1962).

A previous report (Abstr. 19884 of 1962), that self-consistent electrostatic potential distributions did not exist along the plateau of the V–I characteristic, has proved to be false. This was due to a faulty interpretation of the fact that dV/dI (V = output voltage, I = output current) was found to be infinite at a range of current values below the emitter saturation current. C.Greaves

EA '63

29663 GENERALIZED THEORY OF THE THERMIONIC PLASMA ENERGY CONVERTER. M. E. Talaat (Martin Co., Baltimore). Appl. Ind., No. 63, 309-20(Nov. 1962).

Basic principles of thermionic emission, ion generation, and plasma properties are used to examine a model of the vapor-filled thermionic plasma energy converter. The model divides the converter's interelectrode space into plasma, emitter, and collector sheath regions. At least seven main equations evolve from consideration of these three regions, namely, current, charge, plasma ion, plasma energy, and voltage balance equations. Repeated solutions of these equations at various load currents yield the current-voltage characteristic curve. A generalized efficiency expression is also presented. (auth) NSA '63

200

AD-294 423 Div. 8, 7
(TISTM/EJH) OTS price $3.60

General Electric Co., Schenectady, N. Y.
EVALUATION OF A MOLYBDENUM EMITTER, LOW VOLTAGE ARC THERMIONIC POWER CONVERTER.
Quarterly technical progress rept. no. 3, 15 Sep-30 Nov 62,
by E. A. Baum. Dec 62, 28p. incl. illus. table.
(Rept. no. R-606 Q-3)
(Contract AF 33(657)8323, Proj. 8173)
Unclassified report

DESCRIPTORS: *Cathodes (Electron tubes), *Cesium electron tubes, *Electric power production, *Thermoelectricity, Molybdenum, Life expectancy, Electrodes, Sintered cathodes, Casting, Electric arcs, Sapphires, Manufacturing methods, Deterioration, Seals, Thermionic emission.

Results of extended steady state operation of the Mo emitter Cs vapor converter show that at least 1000 hours of life can be expected with the present converter design at cathode temperatures in the range of 1450 to 1500 C. The power output level with polycrystalline arc-cast molybdenum electrodes was found to remain constant over this operating period, although the life of the converter structure has been shown to be considerably longer. An accumulated total of 4300 hours has been attained on 3 initial design converters operating with ceramic-to-metal seal temperatures between 600 and 650 C. The sapphire material used for maintaining the electrode separation was found to have deteriorated in 2 converters. It is significant that the sapphire spacer material showed evidence of reacting with the anode rather than with the cathode. Converters tested with electrodes fabricated from sintered Mo material showed higher initial power levels than the arc-cast material. Extended steady state operation of 3 converters resulted in an accumulation of 750 hours of operation. The results of the transient tests showed no major instabilities over the normal operating region of the converter. (Author)

163

AD-295 052 Div. 7
(TISTW/RD) OTS price $6.60

Radio Corp. of America, Lancaster, Pa.
THE DEVELOPMENT OF AN AUXILIARY ELECTRODE THERMIONIC CONVERTER.
Quarterly technical rept. no. 4, 15 Sep-15 Dec 62,
by W. B. Hall and J. J. O'Grady. Jan 63, 54p. incl. illus. tables.
(Contract AF 33(657)8005, Proj. 8173)
Unclassified report

DESCRIPTORS: *Thermoelectricity, *Power supplies, *Auxiliary power plants, Electrodes, Cesium, Ceramic materials, Electric power production, Space flight.

Progress is reported on research conducted to improve the efficiency and life expectancy of thermionic energy converters for space applications. The program has been modified to the development of a cylindrical converter, the emitter of which is thermally bonded to but electrically insulated from a central heat-source tubing carrying liquid metal. Significant progress has been achieved in the various portions of the program. A particular geometry employing the Cross-Current Converter principle was selected and the overall design has been determined. Two promising methods for the application of the emitter insulation are being evaluated. The effects of cesium on ceramics at the various temperatures of interest were observed and the results analyzed. (Author)

163

3999 OPTIMIZATION OF EFFICIENCY OF A CESIUM-DIODE CONVERTER. C.K.Sanatharan.
J. appl. Phys. (USA), Vol. 33, No. 12, 3491-3 (Dec., 1962).

When the inter-electrode spacing is very small in an alkali-metal vapour diode, plasma heat transfer cannot be neglected. An efficiency analysis very similar to that of Schock (Abstr. 1196 of 1961) includes this effect and compares it to that due to radiation loss. In the analysis the heat-transfer coefficient $h[W/(cm)^2(°K)]$ is given values 0, 0·005, and 0·01. This range is based on the experimental values of h obtained in potassium and caesium diodes. The greatest effect of h on efficiency is found theoretically to occur when the electron-emitter work-function or output voltage is larger than the optimum value for a particular temperature.

PA63

24206 EFFECT OF AN INTERELECTRODE CAESIUM PLASMA ON THE CHARACTERISTICS OF A THERMIONIC ENERGY CONVERTOR. N.D.Morgulis and Yu.P.Korchevoi.
Zh. tekh. Fiz. (USSR), Vol. 32, No. 12, 1487-9 (Dec., 1962). In Russian. English translation in: Soviet Physics-Technical Physics (USA), Vol. 7, No. 12, 1099-1101 (June, 1963).

The convertor unit was situated in a caesium plasma produced by an auxiliary arc discharge, hence the plasma parameters were not dependent on the operation of the convertor and could be varied over a wide range. It is shown that the chief effects acting in the convertor are electronic at the surface of the electrodes and that the volume effects are second order. J.W.Sturgess

PA63

5088 ENERGY OBTAINABLE FROM A CARNOT ENGINE WITH A THERMALLY IONIZED GAS AS THE WORKING FLUID. M. H. Dunn and A. Maitland (C. A. Parsons and Co., Ltd., Newcastle-upon-Tyne, Eng.). J. Appl. Phys., 33: 3598-9(Dec. 1962).

A magnetoplasmadynamic generator is considered that uses a closed-cycle seeded gas as the working fluid. It is shown that if the generator is operated as a Carnot engine, the existence of ionization in the gas leads to an increase in the work obtained over that obtained using an un-ionized gas. (T.F.H.)

NSA '63

AD-295 490 Div. 7
(TISTA/FRL) OTS price $2.75

General Electric Co., Philadelphia, Pa.
CAVITY VAPOR GENERATOR PROGRAM.
Final rept., June 61-Sep 62,
by D. L. Purdy, R. C. Keyser and others.
Dec 62, 138p. incl. illus. tables, 6 refs.
(Contract AF 33(616)8394, Proj. 8173)
(ASD TDR 62-899) Unclassified report

DESCRIPTORS: *Generators, Solar energy, Solar cells, Design, Tests, Vacuum systems, Theory, Thermionic emission.

A description is presented of the theoretical study, design, and test of a thermionic generator utilizing solar energy concentrated by means of a parabolic collector. The generator produced 21.25 watts at a cathode temperature of 1773 K in solar test with a five foot diameter, sixty degree rim angle, parabolic collector. Expected future performance of solar thermionic systems is discussed. (Author)

'63

AD-292 143 Div. 7
(TISTE/OHD) OTS price $5.60

General Electric Co., Philadelphia, Pa.
ADVANCED SOLAR THERMIONIC GENERATORS.
Quarterly technical progress rept. no. 1,
Sep-Nov 62,
by R. R. Herrick, R. C. Keyser and L. L. Dutram.
Dec 62, 52p. incl. illus. tables, 3 refs.
(Contract AF 33(657)8947, Proj. 8173)
Unclassified report

DESCRIPTORS: *Solar cells, *Thermionic emission, Cesium, Vapors, High temperature research, Molybdenum, Tantalum, Test methods, Cathodes.

Performance data is presented obtained during solar testing of the cavity vapor generator system with series and parallel converter arrangements at cathode temperatures of 1400 to 1500 C. Misorientation data and simulated orbital thermal cycling data have also been obtained. System studies are given for selection of a configuration suitable for solar evaluation. (Author)

'63

AD-296 020 Div. 7, 8
(TISTP/WH) OTS price $8.60

Martin-Marietta Corp., Baltimore, Md.
A STUDY PROGRAM ON CESIUM VAPOR-FILLED THERMIONIC CONVERTERS HAVING IRIDIUM EMITTERS.
Yearly summary rept., 1 Nov 61-30 Oct 62, by M. E. Talaat, D. S. Trimmer and A. J. Kennedy. Dec 62, 87p. incl. illus. 3 refs. (MND rept. no. 2934)
(Contract Nonr-363900, Proj. NR 099-363)
Unclassified report

DESCRIPTORS: *Thermionic emission, *Energy conversion, *Plasma physics, *Work function, *Cesium, *Discharge tubes, *Cathodes, Iridium, Rhenium, Rhodium, Platinum, Electric discharges, Adsorption, Electrodes, Filaments.

An extensive mapping of the performance of cesium vapor-filled energy conversion devices was obtained for the high vacuum work function emitter materials, iridium and rhenium, for the interelectrode gap of 0.030-in. Characteristic current-versus-voltage curves and summaries of the output power density and efficiency are given for the emitter temperature range of 1550-2000 K and the cesium temperature range of 475-600 K. The data shows a systematic superiority of iridium to rhenium. Tests with a platinum emitter device confirm the trend of good performance in cesium vapor with high vacuum work function emitter materials. Data is given showing a highly precise agreement between two iridium filament emitter devices and an electron bombardment heated device with iridium emitter. At the emitter temperature of 1700 K, liquid cesium temperature of 525 K, and interelectrode gap of 0.030-in., the output power density of the three devices was 5.6 ± 0.2 w/sq cm. and the energy conversion efficiency was 14.25 ± 1.25%. (Author)

'63

AD-295 917 Div. 7, 25
(TISTM/SJR) OTS price $3.50

Thompson Ramo Wooldridge, Inc., Cleveland, Ohio.
ADVANCED SOLAR THERMIONIC POWER SYSTEMS.
Final rept. June 60-Aug 62.
Dec 62, 239p. incl. illus. table (Rept. no. ER-5038)
(Contract AF 33(616)7411, Proj. 8173)
(ASD TDR 62-877) Unclassified report

DESCRIPTORS: *Thermionic emission, *Power supplies, *Solar cells, Generators, Vacuum systems, Thermoelectricity, Effectiveness, Cesium, Vapors, Storage batteries, Cadmium, Nickel, Silver, Plasma physics, Solar energy, Design.

A survey of all components required for advanced solar thermionic power systems in the 1-10 kw range suitable for application in aerospace vehicles is presented. The results of the survey and development program were used to determine design criteria applicable to these systems. The development program included evaluation of thermionic converters of the vacuum and vapor type. The details of the design, fabrication, performance tests, and evaluation of the thermionic converters and generators built during the program are presented. The importance of the proper selection of solar receiver configuration, as well as the requirement for high precision solar concentrators, is treated extensively. Consideration is also given to the requirements of the orientation subsystem, energy storage subsystem and the many control requirements necessary to adequately orient the solar concentrator arrays, store energy for the shade portion of the orbital cycle and properly condition the electrical power required by the vehicle load. The Appendix presents a detailed design, performance, and test specification for a 1.5 kw, 28 volts solar thermionic power system. (Author)

'63

6553 MATERIALS FOR THERMIONIC CONVERTERS. Coleman Kaplan (Marquardt Corp., Van Nuys, Calif.). p.453-66 of "Materials Science and Technology for Advanced Applications." Englewood Cliffs, N. J., Prentice-Hall, Inc., 1962.

The basic theory of the thermionic converter is reviewed. Various methods of reducing the space charge limitation of current in a thermionic converter are discussed. In vacuum converters, the effect of space charge can be reduced by very close spacing or by the use of a crossed electric and magnetic field (the magnetic triode). Space charge can also be neutralized by introducing positive ions into the converter. In the cesium diode and triode, the plasmatron converter, and the pulsed diode, positive ions are supplied by ionization of a low pressure gas. Solid materials which emit positive ions when heated are also being investigated as a source of positive ions for space charge neutralization. The electrical and mechanical requirements for the emitter, collector and auxiliary electrode materials are discussed, as well as the problems related to insulators, seals, and electrical leads. The materials problems involved in using the thermionic converter with a nuclear reactor or a combustion chamber as the heat source are mentioned. The nuclear-heated application requires fissionable fuels and reactor structural materials that will withstand high temperatures and radiation damage. The combustion heated thermionic system requires materials with a reasonable lifetime when subject to corrosion and erosion by hot gases. Both applications require materials that are compatible with and can be joined to the electron emitters and insulators of the converter cells. (auth) NSA '63

3268 (TID-17254) PERFORMANCE OF CESIUM THERMIONIC DIODES OPERATED IN SERIES-PARALLEL CIRCUITS. J. W. Holland (Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.). [1962]. Contract AT(11-1)-Gen-8. 32p.

Electrical power degradation from the operation of many series-parallel circuited cesium diodes in a thermionic reactor must be considered when a nonflattened nuclear power distribution exists over the volume of the reactor core. An experiment was carried out to measure the loss of power and efficiency due to unequal heat inputs to series- or parallel-connected diodes, and to study the operating characteristics of a multiple-diode system. The results were applied to a specific thermionic reactor configuration with a ratio of maximum to minimum diode heat input of 1.85. The minimum degradation of power and efficiency was found to be 41 and 19%, respectively, at optimized operating conditions. (auth) NSA '63

2139 THERMIONIC ENERGY CONVERTERS. E. F. Redden and A. E. Wallis (Aeronautical Systems Div., Wright-Patterson AFB, Ohio). Preprint Paper No. CP 62-1150. New York, American Institute of Electrical Engineers, 1962. 7p. $1.00.

The state-of-the-art for thermionic energy converters and the basic operating characteristics of various designs are reviewed. Problem areas in converter design are identified. Development trends are pointed out. It is concluded that extensive basic and applied research must be accomplished in thermionic technology and high temperature materials before practical application of thermionic energy converters can be possible. Discussions are presented without resort to highly technical details or complicated theoretical analysis. A comprehensive bibliography of pertinent literature is included. (auth) NSA '63

2138 THERMIONIC A-C GENERATION. C. L. Eleen and A. Schock (Republic Aviation Corp., Farmingdale, N. Y.). Preprint Paper No. CP 62-1160. New York, American Institute of Electrical Engineers, 1962. 22p. $1.00.

A system for modulating the output of a thermionic generator and delivering a high-voltage alternating current to the load is presented. After optimizing the mode of operation, equations for the maximum conversion efficiency are derived. For a given anode work function and cathode temperature, it is shown that the maximum a-c efficiency is equal to approximately 70% of the corresponding d-c value. An illustrative example, including a proposed design for a transformer, is appended. (auth) NSA '63

9113 THERMAL ENERGY STORAGE FOR THERMIONIC CONVERSION. E. F. Batutis and D. L. Purdy (General Electric Co., Valley Forge, Pa.). ARS Preprint No. 2505-62. New York, American Rocket Society, 1962. Prepublication Copy. 72p. $1.00.

Silicon and a number of refractory oxide mixtures were studied in an investigation of materials having the properties of high heat of fusion (weight basis) and melting temperatures ranging from 1600 to 2200°K. These thermal energy storage (TES) materials were examined for usage in solar collector-thermionic converter electrical power systems employed in space vehicles. A series of screening tests for silicon containment materials indicated that pyrolytic graphite, boron nitride, titanium boride and several other materials might be useful. Alternate TES materials in the form of eutectic oxides were found that had heats of fusion near or better than silicon. Fabrication and sealing problems of the silicon container materials shifted emphasis to the oxides. A system study was undertaken using the oxides as part of a solar thermionic electric power system. Calculated specific system weights ranged from 185 to 285 pounds per kilowatt with $4BeO-4MgO-Al_2O_3$ and $3BeO-2CaO$ respectively. The higher operating temperatures possible using oxides was the major parameter resulting in specific system weights lower than that calculated for silicon. (auth) NSA '63

9130 THERMIONIC CAVITY GENERATOR DEVELOPMENT. David L. Purdy (General Electric Co., Philadelphia). ARS Preprint No. 2572-62. New York, American Rocket Society, 1962. Prepublication Copy. 49p. $1.00.

Work performed on a cavity vapor generator is discussed, and attention is given to the expected performance of future solar-thermionic space-power systems. The system considerations involved in collector and generator sizing, as well as converter-to-generator relationships, are discussed. Computations are described that define the thermal and electrical performance of the converters, cavity, insulation, collector, and vacuum system. Measured values of thermal energy and electrical power obtained during laboratory testing are described, resulting in a converter efficiency at a cathode temperature of 1650°K of 6.5%. A description of a solar test and expected solar test results is included. (auth) NSA '63

9117 CESIUM THERMIONIC CONVERTERS AND GENERATORS FOR SOLAR SPACE POWER SYSTEMS. Pierre J. Brosens and Sotiris S. Kitrilakis (Thermo Electron Engineering Corp., Waltham, Mass.). ARS Preprint No. 2571-62. New York, American Rocket Society, 1962. Prepublication Copy. 9p. $1.00.

Data obtained for converters using niobium, tantalum, tungsten, iridium, and rhenium emitters, as a function of interelectrode spacing and converter operating temperatures, is given in the form of maximum power density maps. Theoretical work on the effect of crystallographic orientation of emitter surface on converter performance is described. General design requirements for solar thermionic generators for space applications are discussed. Generators can be designed to have the fast warm-up characteristics that must be achieved in satellite applications. Work on cylindrical monodiode and cubical multidiode generators is described. Although no inherent limitation is observed on the life and reliability of thermionic devices, life of the order of several thousands of hours and high reliability remain to be demonstrated. (auth) NSA '63

10215 COUPLING NUCLEAR-THERMIONIC POWER TO ELECTRIC SPACECRAFT PROPULSION. J. F. McCartney (The Martin Co., Baltimore). ARS Preprint No. 2551-62. New York, American Rocket Society, 1962. Prepublication Copy. 10p. $1.00.

Input requirements for electric spacecraft propulsion devices are reviewed, and basic conceptual designs for coupling nuclear thermionic power to the devices and other spacecraft loads are presented. The arc-jet engine requires power with a characteristic of high current at relatively low voltage, which requirement suggests the direct connection of the device to the thermionic system output. MHD propulsion devices, utilizing both the crossed-field and arc-discharge principles, may be supplied from a thermionic power source without the use of power conversion equipment. The ion-propelled spacecraft requires nearly 85% of the thermionic electrical output converted to high-voltage d-c for supplying the ionizer and accelerating potentials. It is expected that power conversion equipment can be developed to provide outputs for ion propulsion in the megawatt range with an efficiency of 95% and a weight equal to or less than 2 lb/kw, including the thermal radiator. (auth) NSA '63

9129 LARGE, LOW-COST THERMIONIC SOLAR CONCENTRATOR ANALYSIS AND DEVELOPMENT. John P. Bagby, Robert C. Erdmann, and Oscar Biblarz (Hughes Aircraft Co., Culver City, Calif.). ARS Preprint No. 2534-62. New York, American Rocket Society, 1962. Prepublication Copy. 55p. $1.00.

Analysis and computer studies show that collectors of other than paraboloidal conic sections of revolution, used for solar concentrators, can achieve sufficient intensities to produce emitter temperatures required for satisfactory thermionic energy conversion. Lightweight solar concentrators of any conic of revolution are formed without masters by inflating and stretching aluminized mylar film prior to foam rigidization. The mathematical analysis of second-degree conic concentrators is presented. The fabrication techniques and optical performance tests used are described. A mosaic method of manufacturing very large, low-cost concentrators is investigated. (auth) NSA '63

9126 SOLAR ENERGY THERMIONIC CONVERSION SYSTEM. W. R. Menetrey (Electro-Optical Systems, Inc., Pasadena, Calif.) and A. Smith. ARS Preprint No. 2499-62. New York, American Rocket Society, 1962. Prepublication Copy. 100p. $1.00.

The design, fabrication, and testing of solar-energy thermionic cells are described. The discussion includes the fabrication and performance of a 5-ft solar concentrator, fabrication and test of converters, and the fabrication of two thermionic generators along with test data using both solar radiation and electron bombardment heaters. A system efficiency of 3 percent and a specific weight of 2 watts/lb are demonstrated in a prototype system test using solar radiation. (auth) NSA '63

19887 CHARACTERISTICS OF THE PLASMA DIODE ENERGY CONVERTER WITH METALLIC CAESIUM CATHODES AT SMALL INTERELECTRODE DISTANCES.
Yu.P.Korchevyi and I.M.Hroshev.
Ukrayin. fiz. Zh. (USSR), Vol. 7, No. 4, 447-8 (1962). In Ukrainian.

9126 SOLAR ENERGY THERMIONIC CONVERSION SYSTEM. W. R. Menetrey (Electro-Optical Systems, Inc., Pasadena, Calif.) and A. Smith. ARS Preprint No. 2499-62. New York, American Rocket Society, 1962. Prepublication Copy. 100p. $1.00.

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NSA '63

36462 THERMIONIC ENERGY CONVERSION. J. M. Houston and H. F. Webster (General Electric Research Lab., Schenectady, N. Y.). Adv. Electron. Electron Phys., 17: 125-206(1962).

A brief summary of thermionic conversion analysis is presented. Equations for the current-voltage characteristics, power output, and efficiency of an idealized model of a thermionic converter are derived. The work functions of the surface of various materials and combinations of materials are discussed. The space charge, surface physics, and fabrication problems of vacuum thermionic energy converters are outlined. Cesium thermionic energy converters and devices using auxiliary discharges and fission fragments for ion production are discussed along with their applications. (C.E.S.)

NSA '63

9134 PERFORMANCE TEST OF A CUBICAL CAVITY SOLAR THERMIONIC GENERATOR. W. J. Leovic, M. W. Mueller, and C. G. Stevenson (Thompson Ramo Wooldridge Inc., Cleveland). ARS Preprint No. 2554-62. New York, American Rocket Society, 1962. Prepublication Copy. 11p. $1.00.

A solar test program carried out on a prototype thermionic generator is described. The program, which is designed to evaluate the performance of the generator in conjunction with a five-foot precision solar concentrator, shows the ability of such a combination to produce very nearly its design power output levels in a space environment. A description is given of all specialized equipment and techniques employed in carrying out the tests and evaluations. The pertinent data and results are summarized and analyzed for all major phases of the solar test effort. These major phases include the evaluation of concentrator efficiency, flux profile and power distribution measurements, cavity absorber efficiency, the environmental chamber and the influence of the transparent vacuum enclosure, a comparison and correlation of solar test generator performance with laboratory test data, and an extrapolation of the earth-bound test results to the true space environment. (auth)

NSA '63

Generation of electricity by unconventional methods; thermionic generators. H. Billett and others. diags Inst Mech Eng Proc 176 no 18:428-31 '62

ASTTI '63

206

V16186 CHARACTERISTICS OF SPACE-CHARGE THERMOELECTRIC CONVERTERS CONPENSATED BY A CESIUM PLASMA. Jean-Edgar Picquendar, Eugène Dieulesaint, and Philippe Defranould. Compt. Rend., 256: 103-5(Jan. 2, 1963). (In French)

Two types of thermoelectric converters in which the space charge is compensated for by a natural plasma of cesium ions were developed. The heating of the cathode is obtained in the first model by electron bombardment and, in the second, by a luminous radiation falling on the cathode. A maximum yield of 14% with 115 amp under 0.72 v was obtained. (tr-auth) NSA 16.3

VAD-295 907 Div. 7
(TISTM/EJH) OTS price $2.60

General Atomic Div., General Dynamics Corp., San Diego, Calif.
HIGH-TEMPERATURE VAPOR-FILLED THERMIONIC CONVERTER.
Quarterly technical progress rept., 1 Oct-31 Dec 62,
by W. Gudsin. 7 Jan 63, 21p. incl. illus. table (Rept. no. GA-3798)
(Contract AF 33(657)8563, Proj. 8173)
Unclassified report

DESCRIPTORS: *Power supplies, *Thermionic emission, Manufacturing methods, Filaments, Failure (Mechanics), Materials, Molybdenum, Aluminum compounds, Oxides, Tantalum, Carbides, Uranium compounds, Zirconium compounds, Cesium, Vapors, Tests, Thermocouples.

Cell F was operated at power for 484 hours. Cell F is the first cell in which the expected current emission density was observed from a carbide emitter in an engineered thermionic generator. Short-circuit currents of 120 amp were observed from the emitter in the cell. A maximum power output of 50 watts (5 w/sq cm) was obtained at an emitter temperature of 2440 K. During steady state operation power was in the range from 10 to 30 watts. The cell was not optimized for maximum power. The contact potential in the cell agrees with that expected from a low work function carbide emitter and a fully cesiated collector. For a nominal contact potential of 1 volt and a short-circuit current of 120 amp, the optimum power should have been 120 watts, assuming no transport defects in the cell. Actually the maximum power output corresponding to a short-circuit current of 120 amp was more nearly 40 watts, indicating transport defects in the cell. (Author) 163

UNCLASSIFIED

105163 CESIUM PLASMA STUDIES FOR THERMIONIC ENERGY CONVERSION
Received JPL: January 8, 1963 Unclassified
Hughes Aircraft Co. (ARPA Order No. 209-62)
Research Laboratories
Nonr 3501(00)
Quarterly Letter Report-2, Phase II

In order to investigate the process of the thermalization of streaming electrons in a cesium plasma, a series of preliminary measurements of the plasma electron temperature have been made using a probe instrumented cesium plasma generator. In these measurements, the injection of the electrons into the plasma is accomplished by means of generating the cesium plasma on one hot tantalum plate and injecting the electrons from the other negatively biased, electron emitting hot plate. Our theoretical studies have shown that the field free plasma column occupies most of the space between the two plates and that the potential drop due to the applied biased voltage appears mostly at the negatively biased plate.

41559 (RAC-1102) MAGNETIC FIELD EFFECTS IN THERMIONIC PLASMA DIODES. Final Technical Report. Alfred Schock, William E. Eaton, Charles L. Eisen, and Bernard Wolk (Republic Aviation Corp., Farmingdale, N. Y.). Jan. 1963. Contract Nonr-3285(00). 34p. (AD-296232)

Experiments to determine the effects of transverse and longitudinal magnetic fields on thermionic current transmission are described. The results obtained are in qualitative agreement with theoretical predictions and suggest the possibility of using magnetic modulation for a-c generation. (auth)

NSA '63

18900 (NP-12667) VAPOR-FILLED THERMIONIC CONVERTERS. First Quarterly Report, October 1, 1962 to December 31, 1962. K. G. Hernqvist and J. R. Fendley (David Sarnoff Research Center, Princeton, N. J.). Jan. 20, 1963. Contract NAS 3-2531. 19p.

An analysis of the Cs vapor arc discharge is described. It is assumed that the discharge operates in the ball-of-fire mode, that cumulative ionization via the two resonance-excited states is the predominant ionization mechanism, and that trapping in the plasma of the resonance radiation results in a long effective lifetime of the states. A volt-ampere characteristic is derived for the Cs arc, and the results are applied to the thermionic energy converter. Good qualitative agreement is obtained between theory and experiment. A duo-emitter diode for microwave studies of a Cs plasma and its application in a circuit are described. The ion emitter and electron emitter face each other. A test station for the monitoring and control of the gas environment in an operating Cs diode is described. It is a metal-ceramic system to which a mass spectrometer is attached for analysis of gases in the converter. Provisions are made for introducing different gases in addition to Cs. (auth)

NSA '63

42401 (AD-296862) FEASIBILITY DETERMINATION OF A NUCLEAR THERMIONIC SPACE POWER PLANT. Quarterly Technical Progress Report, November 1, 1962 through January 31, 1963. (Aerojet-General Nucleonics, San Ramon, Calif.). Contract AF33(657)-8977. 39p. (AN-856)

Design and performance feasibility studies are made for a nuclear thermionic space power plant. Topics covered include: bond investigation of alumina-coated niobium tubing with molybdenum coating (both coatings applied by plasma spraying) and finally sealed with a molybdenum sleeve brazed to the molybdenum coating, heat rejection problems of thermionic radiators, package power reactor characteristics, and natural-convection loop configuration and fabrication. (N.W.R.)

NSA '63

12589 (NP-12543) RESEARCH PROGRAM RELATED TO VAPOR THERMIONIC CONVERTERS FOR NUCLEAR APPLICATION. Quarterly Progress Report, September 27 – December 27, 1962. A. O. Jensen (Electro-Optical Systems, Inc., Pasadena, Calif.). Jan. 16, 1963. Contract NAS3-2529. 44p. (EOS-3410-Q-1)

Progress in an investigation of long-time temperature effects on the surface structure of polycrystalline Mo substrates is reported. The major effort is being directed toward determining the effects of such changes in the surface crystal structure on the performance of cesiated Mo emitters for use in nuclear powered thermionic converters. The material selected for use in the investigation is high-quality mill stock which is low in C content and interstitial gas impurities. Results of preliminary processing are given along with investigations of grain growth and cesiated emission. Other work is reported on selection of an electron microscope lens configuration, design of a lens support and a method of moving the emitter relative to the lens. (J.R.F)

NSA 63

AD-403 656 Div. 25
(TISTP/WH) OTS price $10.50

Ford Instrument Co., Long Island City, N. Y.
LO-TEMP THERMIONIC PLASMA STUDY.
Final rept.,
by Wolfram Stengel. 31 Jan 63, 1v.
Contract Nonr3416 00, Proj. NR099 356
Unclassified report

Descriptors: *Thermionic emission, *Energy conversion, *Plasma physics, Cesium, Oxygen, Tungsten, Electric discharges, Gas discharges.

Measurements of electron temperature, electron concentration and space potential in the plasma region of low temperature thermionic converters were determined by means of a pulsed Langmuir probe technique. The spatial distributions of these parameters, in parallel plate geometry, were measured with the aid of movable probes within these operating converters. The experimental values are shown to be consistant with reasonable physical models. Spectroscopic measurements were made in both the visible and infrared regions and the validity and applicability of the results are discussed. Results obtained from converters, in which small amounts of oxygen were present in the discharge region, are explored. The effects of cesium and "patch effects" on the surface characteristics of impregnated tungsten emitters are discussed on the basis of a theoretical analysis and experimental results with numerous test cells. (Author)

'63

AD-299 004 Div. 25, 7
(TISTE/CAM) OTS price $8.10

Tapco West Coast Engineering Thompson, Ramo Wooldridge Inc., Inglewood, Calif.
LONG-LIFE THERMIONIC CONVERTERS FOR SOLAR POWER SYSTEMS.
Final rept., Mar 61-Oct 62.
Feb 63, 82p.
(Contract AF 33(616)8114, Proj. no. 8173; Sub contract to Thermo Electron Engineering Corp., Cambridge, Mass.)
(ASD-TDR-62-1069) Unclassified report

DESCRIPTORS: *Thermionic converters, *Electric power production, *Thermionic emission, Design, Effectiveness, Temperature, Electric potential, Cesium, Instrumentation, Failure (Mechanics), Space environmental conditions, Test methods, Test facilities, Solar cells, Life expectancy. '63

32702 (ASD-TDR-63-442) THE DEVELOPMENT OF AN AUXILIARY ELECTRODE THERMIONIC CONVERTER. W. B. Hall and J. J. O'Grady (Radio Corp. of America. Electron Tube Div., Lancaster, Penna.). Feb. 1963. Contract AF33(657)-8005. 200p.

Work accomplished to improve efficiency and life expectancy of thermionic energy converters for space applications is described. A converter was developed which employed an emitter thermally bonded to, but electrically insulated from, a central heat source tubing suitable for liquid metal. Power levels in excess of one watt per square centimeter were obtained at an operating temperature of 1200°C with an efficiency of 5%. As a result of studies performed during the program, converters can now be designed which employ only materials compatible with cesium for greater reliability and longer life. Improved performance and series operation of converters on a liquid-metal loop were demonstrated. (auth) NSA '63

11313 (MND-2945-1) DEVELOPMENT OF AN ENCAPSULATED THERMIONIC POWER GENERATOR. Quarterly Technical Progress Report, November 1–January 31, 1963. (Martin-Marietta Corp. Aerospace Div., Baltimore). Feb. 15, 1963. Contract AF33(657)-10077. 15p.

The engineering design of the double diode thermionic power generator was completed. Fabrication of several component parts was initiated. The parts for the fueled emitters are almost completely fabricated with only assembly and final machining remaining. The manufacture of other generator components including the collector temperature control assembly and the ceramic-to-metal seals was initiated. The engineering design of the clad fuel elements was completed and the first element, similar in configuration to the fueled emitter, was fabricated. This element will be used to determine the changes in the vacuum emission characteristics over a 200 hour test period. The vacuum test chamber was fabricated and is undergoing preliminary outgassing. (auth) NSA '63

11315 (NAA-SR-7661) PERFORMANCE OF CESIUM THERMIONIC DIODES OPERATED IN SERIES-PARALLEL CIRCUITS. J. W. Holland (Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.). Feb. 1, 1963. Contract AT-11-1-GEN-8. 38p.

Electrical power degradation from the operation of many series-parallel circuited cesium diodes in a thermionic reactor must be considered when a nonflattened nuclear power distribution exists over the volume of the reactor core. This experiment measures the loss of power and efficiency due to unequal heat inputs to series- or parallel-connected diodes, and studies the operating characteristics of a multiple-diode system. The results are applied to a specific thermionic reactor configuration with a ratio of maximum to minimum diode heat input of 1.85. The minimum degradation of power and efficiency was found to be 41 and 19%, respectively, at optimized operating conditions. (auth) NSA '63

Thermionic Cell Generates A-C Power, W. BELLER. Missiles & Rockets v 12 n 6 Feb 11 1963 p 18-19. Advanced solar thermionic system for space vehicles, under development by Ford Instrument Co, incorporates thermionic cell able to generate a-c; cells is pulsed internally and operates at relatively low temperatures about 1250 C; block diagram and loss ledger of 100 w a-c thermionic converter system is shown; a-c thermionic cell, based on phenomenon of arc discharge in cesium vapor, has 2 modes of operation, arc and secondary mode. EI '63

Termoemisni menic tepla v elektrinu, J. KRAMAR. Elektrotechnicky Obzor v 52 n 2 Feb 1963 p 64-9. Thermionic converter of heat to electricity; method for calculating efficiency of converter is presented, based on assumption of total compensation of space charge between electrodes; procedure is applied to thermionic converter fed by radiation energy and fitted with emitter consisting of metallic tantalum cathode, or impregnated barium cathode, on porous tungsten. EI 63

Thermionic Energy Converters, E.F.REDDEN, A.E.WALLIS. IEEE—Special Publ S-145 Feb 1963 p 66-71; see also IEEE—Trans on Aerospace v AS 1 n 1 Feb 1963 p 30-3. Present state of art for thermionic energy converters and basic operating characteristics of various designs are reviewed; problem areas faced by designers of converters are identified; recent development trends are pointed out; it is concluded that more of extensive basic and applied research must be accomplished in thermionic technology and high temperature materials before practical application of thermionic energy converters will be possible. ET 63

Thermionic nuclear reactors, E. P. Gyftopoulos and G. N. Hatsopoulos. biblog diags Elec Eng 82:108-16 F '63

NSA TI '63

AD-402 844 Div. 7, 8
(TISTE/OHD) OTS price $9.10

General Electric Co., Schenectady, N. Y.
EVALUATION OF A MOLYBDENUM EMITTER, LOW VOLTAGE ARC THERMIONIC POWER CONVERTER.
Final rept.,
by E. A. Baum. Feb 63, 100p.
Contract AF33 657 8323, Proj. 8173, Task 817305 15
ASD TDR63 183

Unclassified report

Descriptors: *Thermionic converters, *Cesium electron tubes, Molybdenum, Cathodes (Electron tubes), Life expectancy, Tests, Temperature.

Results of life tests on the planar molybdenum-emitter cesium-vapor thermionic converter operating under steady-state conditions are presented along with a description of the life-test equipment. Transient data on the effect of variations in cathode, anode, and reservoir temperatures, as well as step changes in the load, are also presented. The steady-state life tests were performed at a cathode temperature of 1450 C on a 5 sq. cm. cathode area converter design with the thermal input being supplied by a radiation-type furnace in order to more closely simulate solar cavity heating. Seven converters were tested for extended periods with nominal power outputs of 1.5 watts/sq. cm. to 2.5 watts/sq. cm. The maximum life of the state-of-the-art structure on one converter was in excess of 3000 hours and four converters were operated beyond 1000 hours without major degradation in the power output. In addition, the analyses of two converters which operated for 1200 hours and 1400 hours are discussed. (Author)

'63

J 27981 INVESTIGATIONS ON NOBLE GAS FILLED THERMIONIC CONVERTERS. W. Bloss (Technische Hochschule, Stuttgart). Advanced Energy Conversion, 3: 315-21(Jan.-Mar. 1963).

A method for space charge compensation in noble gases and the performance of a special thermionic converter with operating temperatures not exceeding 1300°K are discussed. Low work function collector materials ($\phi_c \approx 1$ v) are feasible in high vacuum or in noble gases only. Positive ions of noble gases for electron space charge compensation are produced in an auxiliary discharge. The influence of the low pressure plasma on the efficiency of conversion is investigated experimentally in different noble gases. Values of experimental devices are given: Mean efficiency of conversion 8 per cent, highest efficiency obtained 20 per cent; output power density of emitter surface 1 W/cm^2. (auth)

NSA '63

J 27982 A THERMIONIC GENERATOR WITH ION INJECTION. K. G. Cook, D. A. Fraser, and G. G. Isaacs (General Electric Co., Wembley, Eng.). Advanced Energy Conversion, 3: 323-31(Jan.-Mar. 1963).

Research on thermionic generators in which the space charge is neutralized by ions generated in an auxiliary discharge is reported. Electrons are accelerated in an electron gun and subsequently produce ions by collision in the space between emitter and collector. The dimensions of the gun are sufficiently small that, at pressures up to about 0.1 torr of xenon, the electron current remains substantially space charge controlled with accelerating voltages up to two or three times the ionization potential of the gas. The advantages of such a system are given, and an experimental generator of this type is described. It comprises a thoriated tungsten emitter, a barium on nickel collector giving a work function of about 2 v, and an electron gun. The device is filled with xenon at a pressure of about 0.1 torr. Typical results obtained with this system are as follows: Output power 2 W, ratio of output power to injection power 5:1, measured thermal efficiency 2 per cent. The main defect of the system is the failure to draw more than about 30 per cent of the available cathode emission. This may be associated with the use of a directly heated emitter, since the load current introduces potential gradients along the emitter surface. Present work includes the use of indirectly heated cathodes. (auth)

NSA '63

UNCLASSIFIED

113104 ADVANCED NUCLEAR-ELECTRIC POWER GENERATOR SYSTEM STUDY, VOLUME II: THERMIONIC NUCLEAR SPACE POWERPLANT
(Period covered: January 1-March 31, 1963)
Unclassified
Pratt & Whitney Aircraft (R-PWA-2212, Vol. II)
NASw-360
QPR

The objectives of this study are: 1) to investigate characteristics unique to the system, 2) to identify the technical uncertainties unique to the system, including design, material and fabrication considerations, and 3) to recommend future program areas for the study of feasibility and state-of-the-art limitations. The reference design selected from the parametric studies for detailed design study consists of a Cb-1Zr, 16-segment rigid radiator operating at an inlet temperature of 1852°F. A study was performed to determine the performance and temperatures in a reactor thermionic converter cathode due to an eccentric location of the cathode with respect to the anode.

27964 EMITTER CORROSION IN THERMIONIC CONVERTERS. R. L. McKisson (Atomics International, Canoga Park, Calif.). Advanced Energy Conversion, 3: 137-56 (Jan.-Mar. 1963).

It was observed that under certain circumstances a relatively large amount of material was transported from a molybdenum thermionic emitter to the collector. Because of the serious implications of this transfer on diode life, an analysis of the chemical system within a cesium diode was made. The various chemical species expected, and their interactions under various conditions, are described. It is shown that a gross transfer of molybdenum is not likely in a system having only oxygen as an impurity. However, if hydrogen is also present within the diode, a mechanism for gross transfer of molybdenum is established, and a serious transfer problem will be produced. The analysis is extended to consideration of other emitter metals. The external corrosion of the molybdenum emitter sheath is a major detriment to the use of a fossil fuel flame as a thermionic generator heat source. However, since a flame-heated thermionic generator appears to be an attractive solution for certain specialized military tasks, this corrosion problem is currently being examined. Various protective coatings for molybdenum are described and discussed. Experimental results of tests of the silicon-base Durak-B coating are presented and analyzed. (auth) NSA '63

27963 PROGRESS IN THE DEVELOPMENT OF FLAME-HEATED THERMIONIC POWER SOURCES. W. R. Martini and R. L. McKisson (Atomics International, Canoga Park, Calif.). Advanced Energy Conversion, 3: 123-36 (Jan.-Mar. 1963).

Due to the inherent high power-to-weight ratio of a thermionic diode, development of flame-heated diodes is being pursued for application to small, lightweight, silent power sources. To demonstrate that power could be obtained from a flame-heated cesium-vapor diode, a furnace was built using surface combustion in a bed of zirconia chips to heat a molybdenum emitter to 1500°C. The exterior of the emitter was coated with Durak-B, a protective layer of molybdenum disilicide, and in addition, a wafer of silicon carbide was used as a barrier between the flame and the coated molybdenum. Although the overall heating efficiency of the above externally heated diode and furnace was found to be low, it is shown that the heating efficiency can be improved considerably by using an internally heated diode. Some successful experiments of burners designed to fit inside a large thermionic diode are described. A prototype internally heated thermionic diode using a 1-in. I-D molybdenum thimble with an 84 cm^2 emitter area was constructed and tested using electrical heating. Pertinent details of its construction and operation are described. In general, its performance was quite similar to that of our cylindrical diodes, with an observed 8 per cent conversion efficiency at a 1540°C emitter temperature. Plans for the future development of the flame-heated diode concept are briefly described. (auth) NSA '63

27965 A STUDY OF CESIUM VAPOR ATTACK ON THERMIONIC CONVERTER CONSTRUCTION MATERIALS. M. J. Slivka (General Electric Co., Schenectady, N. Y.). Advanced Energy Conversion, 3: 157-66(Jan.-Mar. 1963).

The rate of attack by cesium vapor on a number of ceramic, metallic and metal-ceramic seal materials considered for possible use in the construction of cesium vapor thermionic converters was studied to obtain data on which to select attack resistant materials for use in current thermionic converter work and to determine where concerted effort was needed and should be placed in more extensive attack rate experiments to follow. A description is given of a test vessel having an integral cesium source in which the attack experiments were conducted, as well as the processing and testing procedures that were followed. A considerable variation of attack rates was observed for various commercial and proprietary ceramic bodies between 600 and 900°C. What appears to be an anomalous variation in the attack rate with temperature was also observed for certain ceramic bodies. Photomicrographs are presented showing the results of attack on a variety of metallic materials of interest at 900°C along with similar results on representative active-alloy metal-ceramic seals. A brief description will be given of a program that is under way to investigate those areas determined to be in need of additional study, along with any pertinent early results obtained. (auth) NSA '63

27988 THERMIONIC ENERGY CONVERSION DIODE USING A FILM BOILING LIQUID METAL ELECTRON COLLECTOR. A. J. Ulrich (Argonne National Lab., Ill.). Advanced Energy Conversion, 3: 397-405(Jan.-Mar. 1963). (TID-14705; UAC-5121)

Recent experiments have shown that a diode can be produced consisting of a hot emitter and a liquid metal collector separated by the vapor film created in film boiling. In such a diode the metal vapor pressure can be brought in the range of a few millibars or less by, for example, controlling the pressure of an inert gas blanket that covers the film boiling liquid. If conditions in the film are appropriate for production of plasma a thermionic energy conversion plasma diode results. In initial experiments a drop of NaK (22% Na; 78% K) film boiled in a heated tantalum cup. The estimated heat flux required to support the vapor film was about 1/6 of the black body radiated heat when the emitter temperature was 1930°K. In later experiments, demonstrating continuous operation, a heated emitter was partially inserted into a pool of potassium which could be cooled below the boiling point. The maximum subcooling that permitted film boiling was found to be strongly dependent on vapor pressure and depth of submersion and weakly dependent on emitter temperature. However, greater thermal instability occurred at lower emitter temperatures. The current voltage shapes showed that the vapor film thickness was great enough for transport losses to be apparent under all of the conditions investigated thus far. (auth) NSA '63

27986 SPACE CHARGE NEUTRALIZATION IN THERMIONIC DIODES CONTAINING FISSION PRODUCT KRYPTON. R. Forman and J. A. Ghormley (Union Carbide Corp., Parma, Ohio). Advanced Energy Conversion, 3: 385-6(Jan.-Mar. 1963).

Currents in high-pressure (1-300 mm) inert gas diodes at filament temperatures around 3000°K are known to exceed those predicted by space charge limitations, perhaps due to thermal ionization. The possibility of achieving the same effect at lower temperatures by using a radioactive source as the ionizing medium was examined since calculations also showed that enough positive ions might be produced for space charge neutralization. Characteristics of cylindrical diodes with vacuum, natural Kr, and fission-product Kr and using Ta anodes with oxide cathode and thoriated-W filaments were studied. The thoriated-W diode filled with fission-product Kr showed current-voltage characteristics not predicted by space charge limitations, and the diodes containing fission-product Kr displayed negative resistance in the current-voltage characteristics. (D.C.W.) NSA '63

27985 NUCLEAR GENERATED PLASMAS IN NOBLE GAS THERMIONIC CONVERTERS. F. E. Jamerson, R. H. Abrams, Jr., C. B. Leffert, and R. Silver (General Motors Corp., Warren, Mich.). Advanced Energy Conversion, 3: 363-83(Jan.-Mar. 1963).

The generation of a plasma by fission fragment ionization in noble gas thermionic converters was investigated in a series of inpile experiments at the University of Michigan reactor. The plasma generated in Ne : Ar (1000 : 1) at a pressure of 20 mm Hg was investigated in a plane parallel diode with electrically heated emitter and collector of barium impregnated tungsten. The fission fragment source was uranium foil mounted on a third electrode. As calculated from diode V–I characteristics, ion densities of order 10^{10} cm^{-3} were generated by fission fragments in the space surrounding the converter, and ion densities of order 10^{11} cm^{-3} were present in the interelectrode gap due to the formation of ion trapping sheaths at the electrode surfaces during normal converter operation. The effect on converter operation of cesium generated in the fission process was investigated in a tube with a diode structure and filling as above, but with a fission product source shielded from the interelectrode space. No cesium effects were observed during the 11½ hr of tube operation. The ion density due to the reactor gamma flux was calculated from the V–I characteristic to be of the order 10^8–10^9 cm^{-3}. Fission product poisoning of the collector was observed at temperatures less than 1000°K; the collector could be reactivated. To investigate the plasma generated by fission fragments in Xe at a pressure of 8 mm Hg, a plane parallel diode was constructed with a nuclear heated emitter of uranium carbide–rhenium and a barium impregnated tungsten collector. The emitter operating temperature was 1950°K in a neutron flux of 5×10^{12} cm^{-2} sec^{-1}. Discontinuities were observed in the forward current characteristic between 6–7 v. The effects between 6 and 7 v were attributed to the formation of xenon metastable atoms in the collector sheath that could then produce additional ionization. The discontinuity at 10 v was attributed to Xe breakdown. The ion density calculated from the V–I characteristic before the first discontinuity was of order 10^9 cm^{-3}. (auth) NSA '63

27987 THERMIONIC ENERGY CONVERTER WITH A LIQUID COLLECTOR. P. Brosens and G. N. Hatsopoulos (Thermo Electron Engineering Corp., Waltham, Mass.). Advanced Energy Conversion, 3: 387-96(Jan.-Mar. 1963).

The advantages and disadvantages of thermionic diodes using liquid collectors are reviewed. It is pointed out that one of the major parameters upon which the practical value of such devices depends is the depth of immersion that the emitter walls can have without resulting in instability of the film boiling process. The flow conditions in the film are derived from first principles. These are then combined with the Helmholtz stability analysis for the boundary between two fluids to find the maximum depth of immersion that the heat source walls can have in a stable film boiling regime. It is also pointed out that, generally, only a fraction of this maximum immersion depth can be used owing to the excessive film thickness that is otherwise achieved near the liquid surface and for which no useful diode output can be obtained. Expressions for the film thickness and vapor velocity in the film are given. The results of mercury and cesium film boiling experiments are discussed. The major conclusion reached is that intense cooling of the film interface with the liquid is required in order to achieve depths of immersion exceeding one inch in practical cesium devices. (auth) NSA 63

813 (AD-298666) FIRST QUARTERLY REPORT FOR ADDITIVE CONVERTER STUDIES. Report No. 20-63. A. L. Hyland (Thermo Electron Engineering Corp., Waltham, Mass.). Mar. 1963. Contract AF33(657)-10130. 14p.

The reasons for the expectation of better performance of the thermionic converter, due to the addition of electronegative atoms, are given. The designs used in the experimental verification of these expectations are shown. Background work and plans for the future are discussed. (auth) NSA '64

31769 EXPERIMENTAL PERFORMANCE OF A HIGH-CURRENT-DENSITY CYLINDRICAL CONCAVE POROUS TUNGSTEN EMITTER FOR ION THRUSTORS. Joseph F. Wasserbauer (Lewis Research Center, Cleveland). New York, American Institute of Aeronautics and Astronautics, 1963, Preprint 63029-63, 11p. (CONF-10-13)

From Electric Propulsion Conference, Colorado Springs, Colo., Mar. 1963.

The performance of an experimental contact-ionization thrustor with cesium propellant is presented. The porous tungsten ionizer was of cylindrical-concave shape to minimize impingement. The ion thrustor employed focusing electrodes and an accelerating electrode positioned at accelerating distances of 2.00 and 2.50 mm. Current densities as high as 260 amp/m^2 were obtained with accelerator currents of 15 percent of the ionizer current. No recordable accelerator electrode current was obtained for ionizer current densities less than 70 amp/m^2 for an accelerator length of 2.00 mm and net accelerating voltages greater than 4 kv. A comparison is made between the experimental data and the results obtained from a numerical solution of the two-dimensional Poisson equation. Theoretical ion trajectories for a number of configurations are presented. (auth) NSA '63

27983 THEORY AND PERFORMANCE OF AUXILIARY DISCHARGE THERMIONIC ENERGY CONVERTERS. R. C. Knechtli and Marvin Fox (Hughes Research Labs., Malibu, Calif.). Advanced Energy Conversion, 3: 333-49(Jan.-Mar. 1963).

A theory of auxiliary discharge thermionic energy converters is presented. This theory permits the prediction of a converter's I-V characteristics as functions of auxiliary discharge current, auxiliary discharge voltage and geometry. It also permits the prediction of the resistive voltage drop across the plasma as a function of load current. Measurements of auxiliary discharge converter I-V characteristics were performed with auxiliary discharge current and voltage as parameters. These measurements are presented and compared with theoretical predictions. The relatively low auxiliary discharge currents, low auxiliary discharge powers, and low plasma resistivities observed in these experiments are found to be consistent with the theory. (auth)

NSA 163

AD-298 666 Div. 25, 8
(TISTE/CAM) OTS price $1.60

Thermo Electron Engineering Corp., Waltham, Mass.
ADDITIVE CONVERTER STUDIES.
Quarterly rept. no. 1,
by A. L. Hyland. Mar 63, 14p. (Rept. no. 20-63)
(Contract AF 33(657)10130)
Unclassified report

DESCRIPTORS: *Thermionic converters, *Energy conversion, *Thermionic emission, *Thermoelectricity, Design, Diodes (Semiconductor), Electrodes, Electron bombardment, Effectiveness, Surfaces, Test equipment, Oxygen, Fluorine, Cesium, Chlorine, Corrosion, Additives.

163

AD-401 659 Div. 25, 8
(TISTE/CAM) OTS price $5.60

Marquardt Corp., Van Nuys, Calif.
INVESTIGATION OF THE CURRENT DENSITY LIMITATIONS IN A THERMIONIC CONVERTER.
Annual summary rept., 1 Mar 62-28 Feb 63,
by Coleman Kaplan. Mar 63, 44p. incl. illus.
24 refs. (Rept. no. 25081)
(Contract Nonr 373800; Proj. NR 099-366)
Unclassified report

DESCRIPTORS: *Thermionic converters, *Triodes, *Diodes (Electron tubes), Electron beams, Electric potential, Temperature, Electric discharge, Pressure, Field emission, Ions, Space charges, Plasma physics, Work functions, Oscillation, Thermionic emission, Test equipment, Test methods, Electric currents, Cesium.

Oscillations in grid voltage, output voltage and output current were observed over a wide range of operating conditions with a cesium-vapor triode. At higher cesium pressures, the oscillation period is an increasing function of the cesium pressure, which implies that the oscillations are controlled by scattering of positive ions in the interelectrode region. An approximate calculation of the ion accelerating voltage required to transfer ions from the middle of the emitter-collector space to the collector indicates a voltage of between 0.5 and 1.0 volt. Pulsed-discharge experiments were to investigate current-density limiting factors in a cesium diode operating in the intermediate temperature range. The experimental technique consisted of applying a pulsed discharge to the test cell and observing the effect upon output current after the pulse. When the diode operation was space-charge limited, a large increase in current was observed after the pulse. Reasonable agreement was obtained between the current density measured after a pulsed discharge and the saturated electron current density obtained from the literature. Measurements of the time required to establish equilibrium after the pulsed discharged provided information on the physics of cesium diode thermionic converters. Calculations were performed. (Author)

163

27984 SOURCES OF POSITIVE IONS FOR SPACE CHARGE NEUTRALIZATION AT LOW TEMPERATURES. R. A. Laubenstein (Marquardt Corp., Van Nuys, Calif.), C. Kaplan, S. Schneider, and J. Creedon. Advanced Energy Conversion, 3: 351-61(Jan.-Mar. 1963).

Two methods for providing positive ions for space charge neutralization in thermionic cells using fossil fuels burned in air were investigated. These were: the thermionic emission of positive ions from solid compounds or mixtures of compounds, and the application of repeated short pulses of electric power to the converter to ionize the cesium vapor in the interelectrode space. Ion emission from the eucryptite analog of alkali metals and from mixtures containing alkali metal compounds was studied. Ion emission current densities of several milliamperes per cm^2 were obtained, but the lifetime of the emitter was often less than anticipated. Space charge neutralization electrons were demonstrated in a preliminary experiment using a three element structure with the ion emitter located between the electron emitter and collector. Pulsed operation of a thermionic diode was studied using a modified commercial diode to which cesium vapor was introduced at controlled pressures. During the application of a 10 to 20 v pulse, a discharge occurs in the cesium; and ions are formed. After the pulse is terminated, the ions formed neutralize the space charge and allow a high electron current to flow. The experimental tube has a nickel matrix emitter and a cesium coated copper collector so that the relative work functions of the emitter and collector do not allow useful power output densities to be obtained. However, an external bias voltage was used to adjust the interelectrode potential difference to simulate a thermionic converter. The diode current after the pulse was terminated was typically about 300 m amp compared to a steady state current before the pulse of about 0.3 m amp. Preliminary results indicate a charge transfer between emitter and collector between pulses that is 30 times the charge transfer during the pulse. Further work to optimize this ratio and to provide the pulse feedback of a portion of the diode output power is in progress. (auth)

NSA 163

AD-400 733 Div. 7
(TISTE/JBM) OTS price $1.25

General Electric Co., Philadelphia, Pa.
ADVANCED SOLAR THERMIONIC GENERATORS.
Quarterly technical progress rept. no. 2, Dec 62-Feb 63,
by R. R. Herrick, R. C. Keyser, and L. L. Dutram.
Mar 63. 44p.
(Contract AF 33(657)8947, Proj. 8173)
Unclassified report

DESCRIPTORS: *Thermionic converters, *Electric power production, Thermionic emission, Cathodes, Configurations, Effectiveness, Molybdenum, Tantalum, Rhenium, Temperature, Thermal radiation, Thermal conductivity, Ceramic materials, Electric potential, Anodes, Solar cells, Power, Generators, Tests, Thermal insulation, Electric currents.

'63

80,743 SYMPOSIUM ON THERMIONIC POWER CONVERSION
Advanced Energy Conversion, v. 3, no. 1, pp. 1–405, January–March 1963

The complete papers from Sessions IV, V, VI, and VII of the Symposium on Thermionic Power Conversion held in Colorado Springs, Colorado, May 1962 are presented. The sessions were: IV—Plasma Physics and Optical Spectra; V—Materials; VI—Surface Phenomena; and VII—Auxiliary Discharge, Nuclear Generated Ions and Liquid Metal Collectors.

Papers from Sessions I–III appeared in *Advanced Energy Conversion*, v. 2, no. 3, July–September 1962, and were cited in the *Astronautics Information Abstracts*, v. 7, no. 4, April 1963, Entry #71,208.

8018 THERMIONIC NUCLEAR REACTORS.
E.P.Gyftopoulos and G.N.Hatsopoulos.
IEEE Trans Commun. Electronics (USA), Vol. 65, 98-108 (March, 1963).

The coupling of nuclear reactors with thermionic convertors is reviewed. First, the principles of operation of thermionic convertors are discussed together with present and anticipated advancements. Particular emphasis is given to parameters that influence optimum performance and life of convertors; namely, work function of emitter and collector, spacing between the same, temperatures of operation, caesium vapour pressure, and materials. The discussion is illustrated by a series of experimental results and amplified by theoretical analysis. Next, three conceptual designs of thermionic nuclear reactors are reviewed and presented as reference points to establish performance characteristics and materials requirements, as well as problem areas that result from the marriage of nuclear reactors and thermionic convertors. Chief conclusions are: (1) the most efficient way of coupling thermionic convertors with a reactor is by dispersing the former throughout the volume of the nuclear core, and (2) thermionic nuclear reactors have several unique features for space, submarine propulsion, and applications in remote areas.

EEA '63

17586 METHOD OF AND APPARATUS FOR PRODUCING ELECTRICAL ENERGY FROM NUCLEAR FUEL.
Joseph Anthony McWilliams (to Boucher and Co. Ltd.).
British Patent 920,198. Mar. 6, 1963. Filed July 5, 1958.

A method and apparatus are described for producing electrical energy from nuclear fuel. The heat energy generated in a moderated or unmoderated nuclear fuel element produces electron emission from a surface in thermal communication with the fuel element. The collector electrode is surrounded by a gas, which undergoes ionization to facilitate electron transit. (C.E.S.)

NSA '63

24044 (NP-12763) HIGH TEMPERATURE THERMOELECTRIC RESEARCH. Fifth Quarterly Progress Report, January 1–March 29, 1963. C. M. Henderson (Monsanto Research Corp. Dayton Labs., Ohio). Contract AF 33(657)-7387. 47p.

An experimental model 5-w (nominal) generator completed 2556 hrs of a sustained performance test at a hot-end temperature of 1200°C (+25°C, −4°C), cold end at 714°C (+12°C, −0°C), in a vacuum of 10^{-5} to 10^{-6} mm Hg without degradation in power producing characteristics. The power/weight ratio of this generator, exclusive of heat source, ranged from 2.70 to 2.86 watt/lb. Graphite-ended segmented modules of n- and p-type thermoelectric materials to supplement p-type MCC 50, the thermoelectric material used in the 5-w generator, were fabricated and partially evaluated. The first such p-n couple produced 250% more power than the p-type MCC-molybdenum couple used in the 5-w generator. Improved emissive coatings and lightweight junctions between modules were produced. These developments suggest that an advanced experimental 50-w generator having a power/weight ratio of 10–20 watt/lb is feasible. (auth)

NSA '63

2580 NUCLEAR THERMIONIC SPACE POWER SYSTEMS. R. C. Howard and N. S. Rasor (Thermo Electron Engineering Corp., Waltham, Mass.). 62p. (CONF-286-1)
From 18th Annual IAS Propulsion Meeting, Cleveland, Mar. 1963.

The various concepts for utilizing thermionic conversion in space reactor power plants are described and evaluated. The problems (and progress toward their solution) of the in-core concept, particularly, are considered. Progress in thermionic conversion technology is then reviewed from both the hardware and research points of view. Anticipated progress in thermionic conversion and the possible consequences for the performance of electrical propulsion systems are summarized. 46 references. (D.C.W.)

NSA '64

AD-402 815 Div. 7, 12
(TISTA/GEC) OTS price $3.60

Radio Corp. of America, Lancaster, Pa.
THE DEVELOPMENT OF A THERMIONIC CONVERTER MODULE SUITABLE FOR LIQUID METAL HEATING.
Quarterly technical rept. no. 5, 15 Dec 62-1 Apr 63,
by W. B. Hall and J. J. O'Grady. Apr 63, 29p.
Contract AF33 657 8005, Proj. 8173, Task 817305 9
Unclassified report

Descriptors: *Thermionic converters, Heat transfer, Liquid metals, Thermal insulation, Ceramic materials, Auxiliary power plants, Space flight, Configurations, Effectiveness, Generators, Heating, Design.

Development continued of thermionic energy converters for space applications Work continued on optimization of geometry and ceramic insulation between emitters and the heat source. This work will include the development of a thermionic generator module to develop 3.0 V of potential from a liquid metal heat source. A converter, Type A-1198B, achieved output power in excess of 40 w at specified conditions. A three-converter unit was designed to investigate the processing assembly procedures and unwanted low voltage arcs before fabrication of 3-V generator begins. (Author)

'63

12588 POTENTIAL AND CONCENTRATION DISTRIBUTIONS IN A LOW-PRESSURE THERMIONIC ENERGY CONVERTOR.
A.A.Ostroukhov.
Radiotekhnika i Elektronika (USSR), Vol. 8, No. 4, 619-21 (April, 1963). In Russian.

Essentially a continuation of the author's article (see Abstr. 5165 of 1963). The theoretical expression for the distribution agrees fairly well with the experimental data; the agreement is not so good as regards the absolute values of the concentration. D.E.Brown

EEA '63

Solar thermionic generator. il diags Mech Eng 85:68 Ap '63

AS+T I '63

80,745 THERMIONIC FLIGHT EXPERIMENT STUDIED
Getler, M.
Missiles and Rockets, v. 12, no. 17, pp. 38, 42–43, April 29, 1963

The STEPS II (Solar Thermionic Electric Power System) program is discussed. Feasibility studies of solar thermionic conversion systems for manned space station applications are considered. Radiation shield materials that will improve efficiency and reduce thermal loss are described.

Solar generator to be used for space power. il Elec Eng 82:294-5 Ap '63

AS+T I '63

32830 CESIUM COMPOUND SEMICONDUCTORS AS LOW THERMIONIC WORK FUNCTION COLLECTORS IN THERMIONIC ENERGY CONVERTERS. R. A. Chapman, H. J. Caulfield, and H. W. Hemstreet (Texas Instruments Inc., Dallas). 18p. (CONF-46-12)

From American Physical Society Meeting, Washington, D. C., Apr. 1963.

The thermionic work function of films of cesium reaction products with antimony, tellurium, and silicon on nickel and tantalum substrates was studied in the presence of cesium vapor with reservoir temperatures as high as 110°C. These films ranged in thickness from 300 Å to 10,000 Å. Several of the films can be interpreted as cesium compound semiconductors with doping by excess cesium. The thermionic work function was measured by both emission measurements and diode contact potential difference techniques with most emphasis of the latter technique. In the case of the cesium–antimony and cesium–tellurium films, the minimum work functions were in the range of 1.2 ± 0.1 ev. The cesium–silicon film was found to have a thermionic work function near 1.7 ev. The effects of chemical impurities and film thickness were investigated. (auth) NSA '63

23472 LARGE-SCALE THERMIONIC POWER GENERATION FROM FOSSIL FUELS. C. V. Barnett (Central Electricity Generating Board, London), D. C. Gore, R. V. Harrowell, and J. K. Wright. Proc. Inst. Elec. Engrs., London), 110: 785-92(Apr. 1963).

A theoretical analysis is made of the use of thermionic diode convertors in electrical power generation from fossil fuels. It is shown that the best way to use such a diode is as a "thermodynamic topper": heat rejected from the diode stage is used in conjunction with a conventional steam generator. Various possible diode schemes are discussed: a diode having a cesium-on-tungsten cathode operating at about 1150°C shows most promise and should lead to an increase in overall efficiency from about 40% for the steam cycle to about 46% for the combined cycle. (auth) NSA '63

Feasible direct heat to power step sought by engineers. Steel 152:67 Ap 8 '63

AS+TI '63

39778 ANALYSIS OF THE ARC MODE OPERATION OF THE CESIUM VAPOR THERMIONIC ENERGY CONVERTER. K. G. Hernqvist (RCA Labs., Princeton, N. J.). Proc. IEEE (Inst. Elec. Electron. Engrs.), 51: 748-54 (May 1963).

An analysis of the cesium vapor arc discharge is presented. It is assumed that the discharge operates in the ball-of-fire mode, that cumulative ionization via the two resonance excited states is the predominant ionization mechanism, and that trapping in the plasma of the resonance radiation results in a long effective lifetime of the excited states. A volt-ampere characteristic is derived for the cesium arc and the results are applied to the thermionic energy converter. Good qualitative agreement is obtained between theory and experiment. (auth) NSA '63

34365 (LADC-5598) CERAMIC MATERIALS FOR NUCLEAR THERMIONIC CONVERTERS. Robert E. Cowan and Stephen D. Stoddard (Los Alamos Scientific La. Los Alamos). [1963]. Contract [W-7405-eng-36]. 21p. (CONF-50-1)

From American Ceramic Society Meeting, Pittsburgh, Apr.-May 1963.

The development and fabrication of ceramic-to-metal seals for thermionic converters which will operate in the temperature range of 700 to 1200°C are reported. Two ceramic-to-metal seal combinations were developed which show promise for specialized applications. For operation in an oxidizing atmosphere near 700°C, magnesia and nickel appear to be a good combination. Seals operating near 1200°C, if an oxidizing atmosphere is not present, may be composed of niobium and alumina with palladium serving as the brazing filler. The tungsten metallizing of alumina which contains yttria is a process which appears to have considerable merit. A reaction between the tungsten and yttria is thought to result in an improved ceramic-metal bond. (N.W.R.) NSA 63

39780 EFFECT OF ANODE EMISSION OF ELECTRONS ON SPACE-CHARGE THEORY OF THE PLASMA THERMIONIC CONVERTER. Robert G. McIntyre (Texas Instruments Inc., Dallas). Proc. IEEE (Inst. Elec. Electron. Engrs.), 51: 760-8(May 1963).

The space-charge potential theory in low-pressure thermionic converters is extended to cover emission of electrons at the anode as well as both ion and electron production at the cathode. The contribution of each of these three sources to the charge density is expressed as a function of potential for the ten most important cases. The first integrations of Poisson's equation are given for each of the cases. Previous analytical work reporting first integrations of Poisson's equation without anode emission appears as a special case. In addition, in each of the ten first-order differential equations there appears a term giving the contribution of anode emission. As before, analytical solution of the first-order differential equations is impossible. For illustrative purposes numerical solutions were obtained on the IBM 704 computer. Comparison with previous numerical solutions show the effect of anode emission on the space-charge potential in the diode. Also shown in figures is the effect of the variation of parameters for certain selected cases. (auth) NSA 63

41539 (ASD-TDR-63-748) THE EFFECT OF EMITTER WORK-FUNCTION PATCHES ON THE PERFORMANCE OF CESIUM THERMIONIC CONVERTERS. John W. Gadzuk (Massachusetts Inst. of Tech., Cambridge. Research Lab. of Electronics). May 1963. Contract AF33(616)-7624. 48p.

An experimental program to obtain the current-voltage characteristics of a metal cesium thermionic converter with a monocrystal molybdenum emitter showing the (110) crystallographic face to cesium vapor is described and the results are presented. It is shown that the continuous linear increase in output current with decreasing output voltage or, in other words, the fact that the emission current does not show a sharp saturation value, may be due to patches of different work function on the emitter surface. It is shown that an exponential Boltzmann distribution might be expected to describe the variation in work function over the emitter surface. Also, this Boltzmann distribution may account for the shape of the current-voltage characteristics obtained from a cesium thermionic converter with a monocrystal molybdenum emitter in the region of low output voltage. From the analysis of these characteristics, the percentage area with the exponential distribution is determined. The area of the exponential patch should increase as the coverage increases. Furthermore, the experimentally determined values of the patch area decrease linearly with increasing values of the ratio of emitter temperature to cesium reservoir temperature, from which it is concluded that these patches may be caused by thermal excitation of the adsorbed layer on a nonuniform substrate. (auth) NSA 63

39777 EMISSION PHYSICS OF THE THERMIONIC ENERGY CONVERTER. N. S. Rasor (Thermo Electron Engineering Corp., Waltham, Mass.). Proc. IEEE (Inst. Elec. Electron. Engrs.), 51: 733-47(May 1963).

Emission processes establish the upper limit of the performance obtainable in the thermionic converter. The basic factors are introduced that must be considered to achieve this limit and recent developments in the related technology are outlined. The basic elements of thermal excitation common to these processes are outlined and the results are used to illustrate the interdependence of the atom, electron and ion emission processes. The constraints imposed by this interdependence imply the existence of a natural limitation on vaporization lifetime for efficient operation using elementary emitter materials. This limitation is overcome by the use of emitters with an adsorbed layer of cesium and constraints imposed by the interdependence of the emission processes prescribe regions of efficient operation of these emitters. Consideration of the basic processes occurring in the adsorbed layer permits semiquantitative evaluation of the relative merit of different materials for use as emitters and collectors. The effect of nonuniform surfaces is reviewed and work in progress to understand the nature and origin of the nonuniformities is discussed. Substantial improvement in converter performance and reproducibility is possible through the development of uniform and optimum electrode surfaces. (auth) NSA '63

9523 EXPERIMENTAL STUDY OF THE IGNITED MODE IN CESIUM THERMIONIC CONVERTERS.
S.Kitrilakis and E.N.Carabateas.
IEEE Trans Commun. Electronics (USA), No. 66, 263-6 (May, 1963).

A variable spacing caesium thermionic convertor of planar geometry has been tested under different conditions of emitter temperature, caesium pressure, and interelectrode spacing. It has been found that at low emitter temperatures of the order of 1 300°C to 1 400°C (degrees centigrade), high-power densities in the range of 2 to 4 watts/cm² can be obtained with a molybdenum emitter. The performance under these conditions corresponds to an ignited mode where ions are introduced by a different mechanism than surface ionization. EEA '63

12560 PLASMA DIODE PERMITTING THERMIONIC CONVERSION.
J.E.Picquendar, O.Cahen. E.Dieulesaint and P.Defranould.
Rev. tech. CFTH (France), No. 38, 69-84 (May, 1963). In French.

Describes, from first principles, the development of a plasma diode giving an output of 0·6 W under adverse operating conditions.
R.W.J.Cockram
EEA '63

39779 RADIO-FREQUENCY OSCILLATIONS IN THERMIONIC DIODES. R. J. Zollweg and M. Gottlieb (Westinghouse Research Labs., Pittsburgh). Proc. IEEE (Inst. Elec. Electron. Engrs.), 51: 754-9(May 1963).

Radio-frequency oscillations are observed in alkali vapor-filled thermionic diodes at low vapor pressure. A review of the experimental phenomena and attempts at quantitative theoretical understanding is given. Possible applications are for energy conversion and as a diagnostic tool. (auth)
NSA '63

AD-407 926 Div. 25, 7
(TISTE/JBM) OTS price $1.60

General Electric Co., Schenectady, N. Y.
EXPLORATORY ENERGY CONVERSION STUDY OF PHOTON THERMIONICS.
Quarterly technical progress rept. no. 3, by M. D. Gibbons. May 63, 13p. Rept. no. R 635 23
Contract AF33 657 9202, Proj. 8173, Task 817305 18

Unclassified report

Descriptors: (*Thermionic converter, Photons), Vapors, Photon bombardment, Electrodes, Tungsten, Tantalum, Absorption, Waveguide windows, Cesium, Sapphires, Seals (Stoppers), Oxides, Ultraviolet radiation, Mercury lamps, Xenon, High temperature research, Experimental research, Experimental data, Electric potentials, Space charges, Flash lamps, Feasibility studies, Excitation.

Research was continued on a program to determine the feasibility of enhancing the performance of the cesium vapor thermionic converter by photon processes. Two experimental converters designed specifically to keep the absorption path to a minimum were completed. Five radiation sources were tested with the converters. The only radiation source that produced an effect on the converter operation was the xenon flash lamp, because probably the radiation intensity of this lamp is an order of magnitude greater than the other sources used. Its effect in the ion rich region is to cause a 20-percent increase in the short-circuit current, while in the electron rich region at least one order of magnitude changes have been observed. However, in the latter region, the current is still space-charge limited. (Author)
'63

In-Pile Diode Experiment for Thermionic Power Generation, P. D.DUNN. Engineer v 215 n 5597 May 3 1963 p 831. Nuclear reactor provides source for heat required by thermionic generator; using refractory carbides, cermets, or oxides, surface temperatures of 2000 C are possible; high reject temperature enables in-pile thermionic generator to be used as "thermodynamic topper" to conventional steam turboalternator plant, or alone where efficiency is of less importance than other factors, e.g., high reject temperature is suitable for radiation cooling in space satellite application. From paper before Instn Elec Engrs, Apr 1963. EI '63

AD-408 778 Div. 7, 25
(TISTM/BRW) OTS price $5.00

Westinghouse Electric Corp., Pittsburgh, Pa.
HEAT DIODE CONVERTER.

Final rept., May 61-Dec 62,
by Milton Gottlieb, R. J. Zollweg, L. S. Richardson, A. E. Fein, and J. G. DeSteese.
May 63, 1v. Rept. no. 62 918 274R4
Contract AF33 616 8262, Proj. 4156, Task 415604
ASD TDR62 1082 Unclassified report

Report on Heat Diode Converter.

Descriptors: (*Thermionic converters, Electrical properties), (*Refractory materials, Thermionic emission), (*Heat resistant metals & alloys, Thermionic emission), Plasma physics, Cesium, Cathodes, Tungsten, Tantalum, Molybdenum, Niobium, Rhenium, Iridium, Tantalum compounds, Carbides, Electric currents, Thermoelectricity, Electric potential, Design, Vapors, Experimental data, Theory.

Investigations were made on several aspects of the cesium plasma thermionic converter. Data were taken on the electron emission properties of tungsten, tantalum, molybdenum, niobium, rhenium, iridium and tantalum carbide. Two methods were used in this study; one was the measurement of the I-V characteristics of diodes using emitters of these materials and the other was the direct measurement of the saturation emission current density by the plasma-anode technique. It is possible to make some separation between emission effects and transport effects by combining results of those two measurements. (Author)

'63

24079 OPTIMIZATION OF A RADIATION-COOLED THERMIONIC CONVERTER. Edwin Blue and John H. Ingold (General Electric Co., Pleasanton, Calif.). AIAA (Am. Inst. Aeron. Astronaut.) J., 1: 1155-9(May 1963).

The electrical power output of a radiation-cooled thermionic converter with a fixed radiator area is maximized with respect to the anode work function and to the ratio of cathode area to radiator area. The results show that, at high cathode temperature, it is important to cool the anode at the expense of power-generating area, whereas at low cathode temperature, the reverse is true. In addition, the results show that, at high cathode temperature, the optimum anode work function and temperature are equal to about 75% of the corresponding cathode work function and temperature. (auth)

NSA '63

39781 SOME CHARACTERISTICS OF A CESIUM PLASMA CELL. M. Kihara, S. Ono, Y. Shibata, and Y. Koike (Tohoku Univ., Sendai). Proc. IEEE (Inst. Elec. Electron. Engrs.), 51: 769-73(May 1963).

Many studies about cesium plasma cells have been reported, but it seemed that there were few in which one could combine experimental results with theoretical ones in the sense that these experimental studies were carried out only in an operating region of almost constant cathode work function, that is, considerably high cathode temperatures. Our measurements were done only in the region of low cathode temperature and low gas pressure in which the interelectrode spacing was less than the mean free path of electrons, in order to examine these theories. The efficiency agreed well with one of these theories. Open-circuit voltage was also observed. (auth)

NSA '63

AD-410 984 Div. 25
(TISTP/RLG) OTS price $9.10

RCA Labs. Div., Radio Corp. of America, Princeton, N.J.
FUNDAMENTAL STUDIES OF THE CESIUM ARC-MODE THERMIONIC CONVERTER.
Annual technical summary rept., 1 May 62-31 May 63,
by Fred M. Johnson. 31 May 63, 89p.
Contract Nonr3826 00
Unclassified report

Descriptors: (*Thermionic converters, Cesium electron tubes), Experimental data, Optical analysis, Impurities. Vapors, Mass spectroscopy, Additives, Hydrogen, Theory, Electrons, Temperature, Ionization, Excitation, Molecules, Tables, Power, Plasma physics, Intensity, Resonance, Analysis, Operation, Ions, Molecular spectroscopy, Gases, Energy.

An experimental study was made using optical and electrical techniques relating to the fundamental processes associated with the high-pressure (similar to 1/2 - 2 torr), low-voltage cesium arc thermionic converter. Seven different optical methods were employed. Impurities present in the cesium vapor were analyzed by means of a mass spectrometer and the effects of gas additives were investigated. Hydrogen gas is the most damaging impurity since it causes an increase in the electron temperature and participates in hydrocarbon synthesis. A theory of the arc-mode operation was developed based on the optical results. The predicted IV-curve was in good agreement with the experimental results. The measured electron temperatures were in the 1750 - 2200 K range. A discussion of the ionization mechanism is given: Ionization by cumulative processes involving excited molecular cesium molecules is favored from an energy standpoint. (Author)

AD-407 826 Div. 25
(TISTP/RLG) OTS price $1.60

General Electric Co., Schenectady, N. Y.
SINGLE-CRYSTAL THERMIONIC CONVERTER STUDIES,
by H. F. Webster. May 63, 12p. Scientific rept. no. 3
Contract AF19 604 8424, Proj. 8659, Task 865902
AFCRL 63 452
Unclassified report

Descriptors: (*Thermionic converters, Single crystals), (*Thermionic emission, Surface properties), Tungsten, Anodes (Electrolytic cells), Cathodes (Electrolytic cell), Construction, Power, Cesium, Pressure, Crystal structure, Models (Simulation), Density, Electron microscopy, Monomolecular films, Atomic structures.

A thermionic converter is described in which the emitter is made of a single crystal of tungsten which has been cut to expose 16 square centimeters of 110 surface. Details of the cathode surface preparation, anode construction, and assembly techniques are presented along with some operating characteristics from the first successful run. The output power was not as large as expected. A second run following reprocessing demonstrated improved performance particularly at low cesium pressures. (Author)

'63

AD-406 325 Div. 8, 25, 9
(TISTP/JW) OTS price $3.60

General Atomic Div., General Dynamics Corp., San Diego, Calif.
HIGH-TEMPERATURE VAPOR-FILLED THERMIONIC CONVERTER.
Quarterly technical progress rept. 30 Apr 63, by W. Godsin and R. Skoff. 17 May 63, 34p.
GA4258
Contract AF33 657 8563, Proj. 8173, Task 817305 5
Unclassified report

Descriptors: *Thermionic emission, Electrolytic cells, Gases, Electron beams, Test methods, High temperature research.

Filament failure and power degradation forced discontinuation of some of the testing. Post-operative analysis revealed that the remaining emitter thermocouple had maintained its calibration and that vacuum emission currents were at least equal to the pre-lifetest values at high emitter temperature but exceeded the pre-lifetest values at lower emitter temperatures. A large leak was found in the emitter cavity, which explained the loss of cesium and the resulting power degradation as well as the erosion of the filament and filament holder. Chemical analysis of the emitter showed a loss of about 75% of the uranium. A structure rish in tantalum carbide had formed at the tantalum carbide interface and had penetrated the entire tantalum substrate. A theoretical study of cell contamination by fission products revealed that the fate of any one of the many elements may differ widely from that of others. The noble gases krypton and xenon presumably will have the least detrimental effect in a vented system. The electronegative fission products tend to combine with the cesium to some extent. Since the cesium reservoir will be at the lowest temperature in the cell, most of the condensates of the fission products should collect there. The remaining fission products will condense on the various components of the cell. (Author)

163

AD-406 131 Div. 7, 8
(TISTE/JBM) OTS price $4.60

General Electric Co., Schenectady, N. Y.
PERFORMANCE CHARACTERISTICS AND EMISSION COOLING MEASUREMENTS TAKEN ON A Cs VAPOR THERMIONIC CONVERTER WITH A THORIUM-TUNGSTEN EMITTER,
by J. M. Houston. May 63, 36p. SR1
Contract AF19 604 8424, Proj. 8659, Task 865902
AFCRL 63 450 Unclassified report

Descriptors: *Thermionic converters, *Cesium, *Power, Resistance (Electrical), Electrodes, Effectiveness, Stainless steel, Thorium alloys, Tungsten alloys, High temperature research, Electrons, Electric potential, Plasma physics, Temperature, Filaments, Space charges, Thermionic emission, Vapor pressure, Life expectancy Electric currents, Sintering, Seals (Stoppers), Measurement, Test equipment (Electronics), Atoms, Ions, Resonance absorption, Cooling.

Measurements were made on a cylindrical, indirectly heated Cs-vapor thermionic converter having a stainless steel collector spaced 1 mm from a 13.3 sq cm Th-W emitter. At an emitter temperature of 2100 K a power output of 4.4 w/sq cm (at 1.3 v) at a measured over-all efficiency of 8.5% was observed. At 2200 K, a power output of 8.8 w/sq cm at 11.9% efficiency was observed. Measurements of the cooling of the emitter due to electron emission indicate that in the retarding range of the converter the emission cooling is just what simple theory would predict, the plasma electron temperature being equal to that of the emitter. For collector-to-emitter voltages more positive than approximately -1.3 v, the emission cooling fell far below that predicted by simple electron emission from the emitter, indicating that a large amount of power (as much as 20 w/sq cm at positive collector voltages) was flowing from the plasma back to the emitter. This anomaly in the emission cooling is interpreted in terms of resonance dradiation, excited atoms, and ions returning to the emitter. These originate in a region of high electron temperature adjacent to the emitter. (Author)

163

AD-411 276 Div. 25
(TISTM/EJH) OTS price $10.10

Ford Instrument Co., Long Island City, N. Y.
RESEARCH STUDIES IN THE ROLE OF ADDITIVES IN THE LOW TEMPERATURE CESIUM DIODE.
Final rept.,
by M. Silverberg, L. Haring, J. McInally and M. Bernstein. May 63, 116p.
Contract AF19 604 8486, Proj. 6692, Task 66921
AFCRL 63 607 Unclassified report

Descriptors: (*Diodes, Thermionic emission), (*Thumionic emission, Cesium), (*Cesium, Thermionic emission), (*Thermionic converters, Cesium), Energy conversion, Ionization, Ions, Gases, Neon, Argon, Mixtures, Surfaces. Adsorption, Additives.

A system which successfully permits various gases to be added in controlled amounts to a thermionic diode was constructed and utilized. The addition of neon and argon to a low temperature (1200 C) cesium dicde resulted in improved performance at cesium bulb temperatures between 20 and 200 C. A tentative mechanism of cesium ion entrapment is forwarded as the basis for the enhanced discharge phenomena. (Author)

39776 TRANSPORT EFFECTS IN CESIUM THERMIONIC CONVERTERS. George N. Hatsopoulos (Thermo Electron Engineering Corp., Waltham, Mass.). Proc. IEEE (Inst. Elec. Electron. Engrs.), 51: 725-33(May 1963).

One of the primary reasons for the failure of thermionic converters to attain their ultimate theoretical performance is electron transport effects occurring in the interelectrode spacing. Two major types of transport effects, electron scattering and electron space charge, are discussed, and theoretical results are compared with experimental data. The uniform plasma theory is reviewed, and experimental data show that for a monocrystal emitter this theory is consistent with the energy equation. Space charge neutralization is discussed. Both surface ionization and volume ionization are considered. Experimental results indicate that surface ionization is not as effective as would be expected by theory. This fact is responsible for the discrepancy between theoretically expected and experimentally obtained performance of converters. Under the conditions where surface ionization is inadequate for space charge neutralization, volume ionization can provide the necessary ions. Volume ionization, however, is achieved at the expense of the output power of the converter. (auth) NSA'63

80,746 THERMIONIC CONVERTERS FOR SPACE POWER
Wilson, V. C., Hamilton, R. C.
Astronautics and Aerospace Engineering, v. 1, no. 4, pp. 62–67, May 1963

Thermionic converters are being developed to operate with 2000°K input and 1000°K rejection temperatures. Converters are shown schematically and described in detail. Results of tests on some prototypes show that thermionic converters are ready for serious consideration for space vehicles.

AD-403 935 Div. 7, 20
(TISTE/OHD) OTS price $4.60

Martin-Marietta Corp., Baltimore, Md.
NUCLEAR FUEL (OXIDE) CLAD THERMIONIC CONVERTERS.
Quarterly technical progress rept. no. 2, 1 Feb-30 Apr 63.
15 May 63, 35p. 2945 2
Contract AF33 657 10077, Proj. 8173, Task 817305 20

Unclassified report

Descriptors: *Thermionic converters, Thermionic emission, Diodes, Uranium compounds, Molybdenum, Metal coatings, Reactor fuels, Reactor cores, Reactor fuel cladding, Thermal conductivity, Resistance (Electrical), Dioxides, Nuclear power plants.

The engineering design of the double-diode thermionic converter was modified to incorporate a revised intermodule lead configuration. This new lead design promises to reduce the extent of back emission observed in the operation of double-diode devices. Manufacturing of the fueled-emitter components was completed. Fabrication of the remaining converter components is virtually complete. Fabrication of the fuel pellets to be subjected to the thermal endurance test was completed and a pre-test examination performed. The vacuum emission test using a fuel pellet similar to the fueled emitters was conducted. (Author)

'63

Space electrical power: thermionic converters for space power. V. C. Wilson and R. C. Hamilton. bibliog il diags Astronautics & Aerospace Eng 1:62-7 My '63

AS+TI '63

AD-410 495 Div. 25
(TISTP/RLG) OTS price $8.60

Allison Div., General Motors Corp., Indianapolis, Ind.
INVESTIGATION OF THE MONOCAPILLARY THERMIONIC EMITTER AS A DUAL SOURCE OF IONS AND ELECTRONS.
Quarterly technical progress rept. no. 5, 15 Feb-15 May 63,
by D. L. Dresser, J. D. Dunlop, and R. T. Schneider. June 63, 56p. Rept. no. EDR3390
Contract AF33 616 8299, Proj. 8173, Task 817305

Unclassified report

Descriptors: (*Thermionic converters, Operation), (*Thermionic emission, Experimental data), High-temperature research, Electric potential, Electric currents, Oscillation, Ionic current, Measurement, Spectroscopy, High frequency, Temperature, Cesium, Evaporation, Line spectrum, Tests, Analysis, Power, Impurities, Plasma physics, Electrons, Electron density, Ions, Photoelectric effect, Tables, Photographs, Cathodes.

Experimental data is reported on a multicapillary converter, Converter G, which operated for over 300 hours. Several types of data were obtained including: (1) current-voltage characteristics for the temperature range from 1800 to 2100 K; (2) high frequency oscillations; (3) ion current measurements; and (4) spectroscopic data. It is shown that the data in the temperature range from 1800 to 2100 K agrees with the random current model of the capillary emitter. For operation at 2000 and 2100 K the data indicates several competitive advantages over conventional converters, including wider electrode spacings, higher converter voltage, and lower cesium bath temperature The HF oscillation data shows that the peak current-voltage points form an arc mode characteristic. The ion currents at high collector temperature appear to be due to cesium atoms evaporating from the collector and impinging on the emitter surface. Spectrographic data indicate elevated electron temperatures in the arc mode. When HF oscillations are present in the passive mode, the line intensities of lower energy excited states are increased. (Author)

'63

UNCLASSIFIED

115113 HIGH POWER TUBE PROGRAM
June 30, 1963
Massachusetts Institute of Technology
Lincoln Laboratory
AF 19(628)-500
Semiannual TSR

Unclassified
(ARPA Order No. 85)
(Projects: Defender)

26101 EVALUATION OF ISOTOPE THERMIONIC GENERATORS. Robert J. Harvey (Thermo Electron Engineering Corp., Waltham, Mass.), Thomas C. Robinson, Joseph J. Fitzgerald, and Gordan Brownell. Trans. Am. Nucl. Soc., 6: 88-91(June 1963). NSA '63

26102 THE DEVELOPMENT OF A NUCLEAR-FUELED THERMIONIC-ENERGY CONVERTER. F. G. Block, G. Y. Eastman, and W. E. Harbaugh (Radio Corp. of America, Lancaster, Penna.). Trans. Am. Nucl. Soc., 6: 91-2(June 1963). NSA '63

36533 PERFORMANCE OF LOW TEMPERATURE THERMIONIC CONVERTERS. Michael Silverberg and Lewis Haring (Ford Instrument Co., Long Island City, N. Y.). New York, American Inst. of Aeronautics and Astronautics, 1963, Preprint 63-159, 5p, $1.00. (CONF-97-11)

From Summer Meeting, Los Angeles, June 1963.

The low-temperature thermionic converter described employs an impregnated tungsten dispenser emitter, a low-voltage arc for space charge neutralization, emitter collector spacing of about 0.2" and a cesium reservoir temperature of about 200°C. A life test is continuing after almost 6,000 hr of operation. About 3 watts/cm² are being produced at a true temperature of 1250°C. (A.G.W.) NSA '63

26103 TEST OF A PROTOTYPE NUCLEAR-FUELED THERMIONIC CONVERTER. W. L. Orr, R. M. Ball, and H. J. Worsham, Jr. (Babcock & Wilcox Co., Lynchburg, Va.). Trans. Am. Nucl. Soc., 6: 92-3(June 1963). NSA '63

26104 A 1-MW(e) THERMIONIC REACTOR CONCEPTUAL DESIGN. C. W. Savery, W. B. Wright, and D. L. Bosseau (General Atomic Div., General Dynamics Corp., San Diego, Calif.). Trans. Am. Nucl. Soc., 6: 93(June 1963). NSA '63

34540 (NP-13058) ADVANCED SOLAR THERMIONIC GENERATORS. Quarterly Technical Progress Report No. 3, April–May 1963. R. R. Herrick, R. C. Keyser, and L. L. Dutram (General Electric Co. Missile and Space Div., Valley Forge Space Technology Center, King of Prussia, Penna.). June 1963. Contract AF33(657)-8947. 44p.

Fabrication of development converters, both B and C series, is outlined, noting the significant problem areas. Results of testing of the B series have given performance up to 9.6 watts/cm² at 1950°K and 3.0 watts/cm² at 1550°K. Converter C-3 has completed a 510 hour life test, including 210 hours of thermal cycling. (auth) NSA 63

28103 METHODS OF AND APPARATUS FOR GENERATING ELECTRICAL ENERGY. Agust Valfells. British Patent 927,770. June 6, 1963. Priority date Apr. 3, 1961, United States.

A device for converting nuclear energy into electrical involves passing a gas composed of a fissionable isotope and an easily ionizable substance through a fission chamber Fission of the isotope heats and ionizes the gas, which expands and streams across a magnetic field. The current induced in the gas can then be drawn off by electrodes in the gas stream or in the magnetohydrodynamic generator. (D.C.W.) NSA '63

Vacuum Thermionic Energy Converter, J.E.BEGGS. Advanced Energy Conversion v 3 n 2 Apr-June 1963 p 447-53. Converter is operated by applying heat to external surface of one electrode; interior surface of this hot electrode operates in vacuum and is coated so that it is capable of emitting copious numbers of electrons; other electrode has coating on its interior surface that can provide low anode work function so as to increase energy available to external load; at emitter temperature of 1100 C, output of 1 w/sq cm and efficiency of 4.5% were attained; in practical applications, heating can be accomplished by use of chemical fuel, solar radiation, or nuclear energy. EJ 63

36372 (AD-410495) INVESTIGATION OF THE MONO-CAPILLARY THERMIONIC EMITTER AS A DUAL SOURCE OF IONS AND ELECTRONS. Fifth Quarterly Technical Progress Report for the Period February 15–May 15, 1963. D. L. Dresser, J. D. Dunlop, and R. T. Schneider (General Motors Corp. Allison Div., Indianapolis). June 15, 1963. Contract AF33(616)-8299. 94p. (EDR-3390)

Experimental data are reported on a multicapillary converter, Converter G, which operated for over 300 hours. Several types of data were obtained including: current-voltage characteristics for the temperature range from 1800 to 2100°K, high-frequency oscillations, ion current measurements, and spectroscopic data. It is shown that the data in the temperature range from 1800 to 2100°K agree with the random current model of the capillary emitter. For operation at 2000 and 2100°K the data indicate several competitive advantages over conventional converters, including wider electrode spacings, higher converter voltage, and lower cesium bath temperature. The high frequency oscillation data show that the peak current-voltage points form an arc mode characteristic. The ion currents at high collector temperature appear to be due to cesium atoms evaporating from the collector and impinging on the emitter surface. Spectrographic data indicate elevated electron temperatures in the arc mode. When high frequency oscillations are present in the passive mode, the line intensities of lower energy excited states are increased. (auth)

NSA '63

34654 GENERALIZED THEORETICAL STUDY OF VAPOR FILLED THERMIONIC CONVERTERS. John Psarouthakis (Martin Marietta Corp., Baltimore). New York, American Inst. of Aeronautics and Astronautics, 1963, Preprint 63-157, 18p, $1.00. (CONF-97-22)

From Summer Meeting, Los Angeles, June 1963.

A generalized theoretical model is proposed and used to derive a number of analytical expressions that predict the performance characteristics of vapor filled thermionic converters over a wide range of conditions. The analysis is made with primary consideration to: the coexistence of negative and positive sheaths at the emitter surface; influence of surface and collision ionizations; spacing of the converter; the variation of the electron temperature; the variation of the potential at which the ionization by collision becomes significant; patchy surfaces; and the energy balance. Comparison of the results of this theory is made with available experimental data on molybdenum and rhenium, which indicate an excellent agreement. (auth) NSA '63

35230 AN EVALUATION OF THE IN-RADIATOR APPROACH TO NUCLEAR-THERMIONIC SPACE POWER SYSTEMS. Donald W. Bell and Arthur I. Chalfant (United Aircraft Corp. Research Labs., East Hartford, Conn.). New York, American Inst. of Aeronautics and Astronautics, 1963, Preprint 63-219, 19p., $1.00. (CONF-97-17)

From Summer Meeting, Los Angeles, June 1963.

The approach of mounting thermionic converters in the radiator of a nuclear-thermionic space power system was explored by evaluating the effects of several system and thermionic converter design variables on the specific weight of tubular thermionic converters and their surrounding beryllium meteoroid armor and radiation fins. Overall radiator arrangement problems were also investigated. (auth)

NSA '63

32836 PROTOTYPE NUCLEAR-FUELED THERMIONIC CONVERTER TEST. W. L. Orr, R. M. Ball, and H. J. Worsham, Jr. (Babcock and Wilcox Co., Lynchburg, Va.). 16p. (CONF-39-13)

From American Nuclear Society Meeting, Salt Lake City, June 1963.

Results are reported of heat-transfer experiments and of a 300-hr in-pile test of a 150-watt thermionic converter using fission heat. In the in-pile test, the electrical output began to reduce slightly after 250 hr and became zero after 300 hr. (D.L.C.)

NSA '63

AD-414 505 Div. 7, 25
(TISTE/JBM) OTS price $1.60

Foreign Tech. Div., Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.
EFFECT OF A MAGNETIC FIELD ON PHENOMENA IN A DIODE WITH CESIUM VAPORS,
by N. D. Morgulis and Yu. I. Chutov. 19 June 63, 16p.
FTD TT63 351/1+2 Unclassified report

Trans from Ukrainian periodical, Ukrains'kiy Fizi hniy Zhurnal, 7:9, pp. 1003-1012, 1962.

Descriptors: (*Thermionic converters, Magnetic fields), (*Magnetic fields, Thermeonic converters), Thermoelectricity, Diodes, Cessium, Vapors, Electron beams, Electrodes, Electric fields.

The effect of a magnetic field on an electron short circuit stream and on the characteristics of the entire stream was investigated in a decelerating electric field in a diode with cesium vapors as a close model of a thermoelectron energy transformer; and interpretation is given on the obtained expreimental results. (Author)

34535 (CONF-78-4) STABILITY OF A THERMIONIC ENERGY CONVERSION DIODE USING A LIQUID METAL ELECTRON COLLECTOR. A. J. Ulrich (Argonne National Lab., Ill.). [1963]. Contract W-31-109-eng-38. 9p.

From American Physical Society 1963 Summer Meeting, Buffalo, June 1963.

An investigation was conducted on the thermal conditions for the formation of a stable or unstable film boiling sheath between the electron emitter and the liquid metal pool. A diode geometry with the emitter introduced into the pool from above was used. Results are presented in the form of collector temperature-saturation temperature graphs for potassium at emitter temperatures of 2025, 2240, and 2440°K. The region of stable operation and the maximum submersion both increase with temperature. (D.L.C.)

NSA '63

34530 (ASD-TDR-63-707) EXPLORATORY ENERGY CONVERSION STUDY OF PHOTON THERMIONICS. M. D. Gibbons (General Electric Co. Power Tube Dept., Schenectady, N. Y.). June 1963. Contract AF33(657)-9202. 40p.

This study was initiated to determine whether photon processes could increase thermionic converter performance. A converter designed specifically for program use was fabricated with a wire grid collector placed in grooves of a sapphire window and located opposite a planar emitter, then tested with five different radiation sources, each with a particular spectral characteristic. Only the 200 watt-sec xenon flash lamp produced an effect on converter operation. This lamp produced a 20% increase in short circuit current with the converter operating in the ion-rich region, and at least an order of magnitude change in short circuit current in the electron-rich region. In this latter region, the current was still somewhat space charge limited even with radiation. A third of the observed effect was due to 0.8 watt cm^{-2} of the first resonance radiation, while a fourth of the observed effect was due to one watt cm^{-2} of near ultraviolet. Photon-enhanced converters appear possible, but it must be demonstrated whether the increase in performance will be offset by the complexity of such a converter. (auth) NSA'63

35061 ION ACOUSTIC OSCILLATIONS IN PLASMA THERMIONIC ENERGY CONVERTERS. Jay S. Chivian (Texas Instruments Inc., Dallas). 29p. (CONF-78-9)

From American Physical Society 1963 Summer Meeting, Buffalo, June 1963.

It is shown that the oscillations in low-pressure-plasma thermionic energy converters are ion acoustic oscillations that may be explained on the basis of an electron beam-plasma interaction. A low-energy beam is formed by the acceleration of electrons through an ion sheath at the emitting surface. The ion acoustic oscillations are observed when the ordered beam velocity is greater than the phase velocity of the wave and less than the plasma electron thermal velocity. Their frequency is given by $f = \lambda^{-1}(\gamma_e kT_e/m_i)^{1/2}$ where the emitter to collector spacing is a multiple of the half wavelength. Langmuir probes indicate high effective electron temperatures, and agreement between calculated and measured frequency is good if a value of $\gamma_e = 3$ is used. (auth) NSA'63

AD-406 926 Div. 8
(TISTP/WH) OTS price $2.60

Thermo Electron Engineering Corp., Waltham, Mass.
ADDITIVE CONVERTER STUDIES.

Quarterly rept.,
by A. L. Hyland. June 63, 19p. 36 63
Contract AF33 657 10130, Proj. 8173,
Task 817305 28

Unclassified report

Descriptors: *Thermionic converters, *Diodes (Electron tubes), Cesium compounds, Fluorides, Chlorides, Oxygen compounds, Rhenium, Additives.

An account of the cesium characteristics of the experimental converter is given and the correlation to other rhenium emitter diodes is discussed. (Author)

'63

AD-411 279 Div. 7, 8, 25
(TISTP/WH) OTS price $2.60

Atomics International, Canoga Park, Calif.
CLAD CARBIDE NUCLEAR FUEL, THERMIONIC POWER, MODULES.
Quarterly progress rept. no. 1, 15 Mar-15 June 63.
June 63, 21p. Rept. no. AI8672
Contract AF33 657 10876, Proj. 8173, Task 817305 23

Unclassified report

Descriptors: (*Thermionic converters, Materials), Thermionic emission, Electrodes, Carbides, Oxides, Cesium, Vapors, Uranium compounds, Beryllium, Rhenium, Nuclear reactor, Simulation, Energy conversion.

The general objective is to evaluate a clad carbide emitter, thermionic power module which simulates nuclear reactor installation, design, and performance. The module is an assembly of two series-connected converters with a single common cesium reservoir. The program goal is 500 hours cumulative operation at a power density of 7 watts/square sm and an efficiency of 12%. This report describes progress made during the first program quarter, including: (1) Design finalization; (2) Component and fueled emitter design and fabrication; (3) BeO-Cs compatibility; and (4) Operation of a UC-Re planar electrode converter for the most successful high performance test ever achieved with a converter containing nuclear fuel, either inpile or out-of-pile. (Author)

Influence of ion reflection probability on potential distribution in low-pressure thermionic converters. P. Mazur. diag J Ap Phys 34:1611-14 Je '63

ASTI '63

AD-409 570 Div. 7, 20, 8
(TISTE/CAM) OTS price $4.60

Aerojet-General Nucleonics, San Ramon, Calif.
FEASIBILITY DETERMINATION OF A NUCLEAR THERMIONIC SPACE POWER PLANT.
Quarterly technical progress rept., 1 Feb-30 Apr 63.
June 63, 26p. Rept. AN 973
Contract AF33 657 8977, Proj. 8173, Task 817305 10

Unclassified report

Descriptors: (*Nuclear power plants, Thermionic emission), (*Thermionic emission, Thermionic converters), (*Thermionic converters, Electric power production), (*Electric power production, Spacecraft), Liquid metal, Heat exchangers, Heat transfer, Temperature, Thermal insulation, Cesium, Molybdenum, Feasibility, Meteors, Armor plate.

Effort was continued to develop a nuclear thermionic space power plant. Technical work was divided into the following three tasks: (2) liquid metal tubing - converter bond; (3) thermal transport analysis; and (4) series unit loop test. Attention was directed to degradation of converter performance resulting from series operation, the effect of emitter temperature variation on converter performance, and calculation of micrometeoroid armor requirements. (Author)

'63

80,744 VACUUM THERMIONIC ENERGY CONVERTER
Beggs, J. E.
Advanced Energy Conversion, v. 3, no. 2, pp. 447–453, April–June 1963

The design and construction of a small vacuum thermionic converter that can generate a watt or more of electric power are briefly described.

Direct generation of electricity. Engineer 215:1098 Je 7 '63

ASTI '63

AD-414 502 Div. 7, 25
(TISTE/SBM) OTS price $3.60

Atomics International, Canoga Park, Calif.
UNIFORM WORK FUNCTION CATHODE STUDIES FOR THERMIONIC CONVERTERS.
Quarterly progress rept. no. 4, 12 Apr-12 June 63,
by M. N. Huberman. July 63, 31p. AI8829
Contract AF33 657 8726
Unclassified report

Descriptors: (*Cathodes, Thermionic converters), (*Thermionic converters, Cathodes), Work functions, Electron microscopes, Vapor plating, Processing, Molybdenum, Thermionic emission, Electron bombardment, Single crystals.

Efforts were continued on a study program to improve the efficiency of thermionic converters which have nonplanar geometries. Specifically, the investigation concerns the production of nonplanar cathodes having more uniform work functions and surface characteristics than are obtained with standard cathode fabrication techniques. A thermionic emission electron microscope for observing work function uniformity was constructed. Arc cast, single crystal, and vapor deposited molybdenum cathodes were examined with the microscope. Active spots due to electropolishing were observed on the (110) face of the single crystal. A vapor deposited cathode was found to have areas of uniform work function. A brief summary is given of the over-all course of the first year of the program and its most significant achievements. (Author)

34538 (NP-13037) VAPOR-FILLED THERMIONIC CONVERTERS. Quarterly Report No. 3, April 1, 1963 to June 30, 1963. K. G. Hernqvist, J. R. Fendley, J. D. Levine, and F. X. Palacios (David Sarnoff Research Center, Princeton, N. J.). July 20, 1963. Contract NAS 3-2531. 8p.

Studies of hydrogen evolution in operating thermionic converters are described. It was found that hydrogen evolves from the cesium liquid used in the converters and that if the hydrogen is not removed the evolution rate is high enough to adversely affect the performance of the converter. A mechanism of hydrogen removal from converters having hot nickel anodes is proposed. Apparatus for xenon gas-dosing experiments is described. A program of fundamental adsorption physics is outlined. It is planned to extend the theoretical analysis of metallic adsorbates on metallic substrates to a system of two gases and to a system of metallic adsorbates on insulators. (auth)

NSA '63

36300 (NP-13070) RESEARCH PROGRAM RELATED TO VAPOR THERMIONIC CONVERTERS FOR NUCLEAR APPLICATION. Quarterly Progress Report, March 27–June 27, 1963. A. O. Jensen (Electro-Optical Systems, Inc., Pasadena, Calif.). July 30, 1963. Contract NAS 3-2529. 67p. (EOS-3410-Q-3)

The effects of long time at temperature on the surface crystal structure of polycrystalline molybdenum substrates and how these changes in surface crystal structure relate to the performance of cesiated molybdenum emitters for use in cesium vapor thermionic converters for nuclear application are investigated. Vapor deposited tungsten coatings are being fabricated for copper and molybdenum. Calibration and stability data are presented for W/5% Re–W/26% Re thermocouples at 1000 to 1515°C. (N.W.R.)

NSA '63

UNCLASSIFIED

115180
115181 EXPERIMENTAL INVESTIGATION OF CHEMICAL REGENERATION OF SURFACES IN SIMULATED THERMIONIC DIODES
Butze, Helmut F. & Smith, Arthur L.
July 1963 Unclassified
National Aeronautics & Space Administration
Lewis Research Center
NASA TN D-1877

An experimental investigation of chemical regeneration in a simulated thermionic diode indicated that sublimed emitter material can be removed from the collector by means of transport reactions using chlorine as the reacting gas. Back-transport reactions were observed at emitter temperatures ranging from 2170° to 2550°K at chlorine partial pressures as low as 4×10^{-4} torr. The results were consistent with those of an analytical study previously reported for free-molecule flow.

AD-415 798 Div. 7
(TISTM/AW) OTS price $1.25

General Electric Co., Schenectady, N. Y.
EXPLORATORY ENERGY CONVERSION STUDY OF PHOTON THERMIONICS.
Final rept.,
by M. D. Gibbons. July 63, 42p.
Contract AF33 657 9202, Proj. 8173, Task 817305 18
ASD TDR63 707 Unclassified report

Descriptors: (*Thermionic converters, Photons); (*Photons, Thermionic converters), Energy conversion, Design, Theory, Emissivity, Cesium, Vapor, Ionization, Equations, Test equipment, Test method, Ultraviolet radiation, Spectra (visible & ultraviolet), Mercury lamps, Xenon lamps, Data.

This study was initiated to determine whether photon processes could increase thermionic converter performance. A converter designed specifically for use on this program was fabricated with a wire grid collector placed in grooves of a sapphire window and located opposite a planar emitter. This converter was tested with five different radiation sources, each with a particular spectral characteristic. The only source that produced an effect on the converter operation was a 200-watt-second xenon flash lamp. This lamp produced a 20% increase in the short circuit current with the converter operating in the ion-rich region, and at least an order of magnitude change in short circuit current in the electron-rich region. In this latter region, the current was still somewhat space charge limited even with the radiation. One-third of the observed effect was due to 0.8 watt cm to minus 2 power of the first resonance radiation, while one-quarter of the observed effect was due to one watt cm to minus 2 power of near ultra-violet. It appears that photon enhanced converters are possible, but it remains to be demonstrated whether the increase in performance will be offset by the complexity of such a converter. (Author)

34369 (RBESO-3404-3) CERAMIC TO METAL SEALS FOR HIGH-TEMPERATURE THERMIONIC CONVERTERS. Quarterly Technical Report No. 3. (Bendix Corp. Red Bank Div., Eatontown, N. J.). July 15, 1963. Contract AF 33(657)-10038. 46p. (AD-410101)

The objective of this program is to develop seals which are capable of long life at 1500°C in cesium and vacuum environments, and to extend the sealing techniques developed to materials which are capable of long life at temperatures in excess of 2000°C. Work completed has enabled fabrication of alumina-molybdenum structures which can resist a 1500°C environment. Ceramic-refractory metal systems were identified which are stable and usable up to 2000°C. Preliminary experiments to determine means of bonding these materials for use at 2000°C were successful. Elimination of materials which are unstable when in the presence of cesium minimizes possible corrosion effects. Recommendations are made for limitation of the development activities to the most promising joint systems. (auth)

NSA '63

AD-410 257 Div. 7, 8, 20
(TISTE/OHD) OTS price $2.60

Union Carbide Corp., Parma, Ohio.
KRYPTON FILLED THERMIONIC CONVERTER.
Quarterly technical progress rept. no. 2, 1 Apr-30 June 63,
by R. Forman. July 63, 19p.
Contract AF33 657 10131, Proj. 8173, Task 817305
Unclassified report

Descriptors: (*Thermionic converters, Diodes), (*Nuclear power plants, Diodes), Argon, Krypton, Separation, Pressure, Electric power production.

Research work on irradiated inert gas thermionic diodes is presented. Tubes containing both argon and krypton gases have been tested in the radiation field of a 5 megawatt swimming pool type reactor. The pressure of the gas was varied in order to determine optimum conditions for operation. The results of these measurements are described and evaluated. Differences have also been observed on irradiated diodes having the same gas and pressure but different cathode-anode spacings. The differences, in contradistinction to cesium diodes, show that small cathode-anode spacing is not particularly advantageous. A proof in principle experiment is also described showing how an inert gas filled irradiated thermionic diode can be used as an a.c. thermionic generator. (Author)

35222 (PWA-2240) ADVANCED NUCLEAR ELECTRIC POWER GENERATOR SYSTEM STUDY. THERMIONIC NUCLEAR SPACE POWER-PLANT. Parametric Studies Report. (Pratt and Whitney Aircraft Div., United Aircraft Corp., Hartford, Conn.). July 30, 1963. Contract NASw-360. 125p.

A 1-Mw thermionic nuclear space power plant was studied parametrically to indicate promising designs and potential problem areas. The power system was studied for a mission of 16500 hr. The evaporation rate of the nuclear fuel in space was selected as a measurable design criterion, and a system minimum weight was found at a particular cathode temperature for each evaporation rate. Minimum specific weights of 14 and 12.4 were obtained for temperatures of 3200 and 3500°F and for evaporation rates of 0.002 and 0.020 in./yr. Two reactor coolant fluids and radiator heat transfer fluids (Li and Na-K alloy) were studied, as well as two radiator materials (Be and Nb). The use of Li in both the primary and secondary loops produced the lightest power plant. Use of Na-K in both loops gave a weight penalty of 3 to 4 pounds/kw. With Li the primary loop and Na-K in the radiator system, the weight penalty was approximately half. A monolithic Nb radiator seems promising. Parametric data for major system components are included. (auth)

NSA 63

14225 THE THERMIONIC CATHODE AND THE MAGNETRON EFFECT. J.Blaux, J.P.Durand and R.Mérard. Onde elect. (France), Vol. 43, 763-73 (July, 1963). In French.

Considering the thermionic diode for direct conversion of heat to electricity, the electrical power obtainable is proportional to the cathode current. The magnetic induction associated with this current, however, gives rise to a parasitic phenomenon called the "magnetron effect", which may reduce the current to a few percent of its expected value. An attempt is accordingly made to discover a cathode shape whose total efficiency is acceptably high in the presence of the parasitic effect, and truncated cone, cylindrical, disk and spherical cathodes are examined. D.J.Bailey

EEA '63

AD-411 342 Div. 7, 25
(TISTE/JBM) OTS price $4.60

Radio Corp. of America, Lancaster, Pa.
THE DEVELOPMENT OF A THERMIONIC CONVERTER MODULE SUITABLE FOR LIQUID METAL HEATING.
Quarterly technical rept. no. 6, 1 Apr-15 June 63, by W. B. Hall and J. J. O'Grady. July 63, 38p.
Contract AF33 657 8005, Proj. 8173, Task 817305 9
Unclassified report

Descriptors: (*Thermionic converters, Modules (Electronics)), (*Modules (Electronics), Thermionic converters), Spaceborne, Liquid metals, Heating, Thermal stresses, Pipes, Niobium alloys, Electrodes, Molybdenum, Tests, Processing, Aluminates, Cesium, Generators, Life expectancy, Electric potential, Sapphires, Electric insulation, Manufacturing methods.

An overall program to improve the performance and increase the reliability of thermionic energy converters for space applications is described. The immediate objective is the development of a converter design that can be used in series to form a thermionic generator module capable of producing a threevolt output when heated by liquid metal. The basic design has produced in excess of 40 watts at approximately 0.2 volt when electrically heated under specified conditions. A number of alternative arrangements of the emitter-heat source tubing were evaluated. In each case difficulties were experienced with the use of the columbium alloy. Tests have confirmed that the alumina-sprayed emitter leads and the sapphire insulation are compatible with cesium. Tests to define the performance limitations and life of the converter are continuing. (Author)

37747 EFFECT OF DAUTHTER Rb^{85} ON THE CHARACTERISTICS OF A THERMIONIC DIODE CONTAINING Kr^{85}. R. Forman and J. A. Ghormley (Union Carbide Corp., Parma, Ohio). J. Appl. Phys., 34: 2498-9 (Aug. 1963).

It was found that the current-voltage characteristic curve of thermionic diodes shifted with time toward more negative anode voltages. The constancy of the cathode emission suggested that the effects were to be attributed to a lowering of the anode work function by deposition of Rb^{85}, the decay product of the Kr^{85} contained in the diode. (R.E.U.)

NSA '63

34531 (ASD-TDR-63-723) EXPLORATORY STATIC ENERGY CONVERSION-MULTILAYER THERMIONICS. Final Report. P. R. Emtage and W. J. van der Grinten (General Electric Co. Electronics Lab., Syracuse, N. Y.) Aug. 1963. Contract AF33(657)-9204. 101p.

A static heat-to-electricity conversion principle was studied and is described. The principle involves an attempt to duplicate the performance of a vacuum tube thermionic converter, in the solid state and at a lower temperature. The basic arrangement is a multiple thin film structure, consisting of alternate layers of semiconductors and metals, arranged perpendicular to the direction of heat flow. Transverse and longitudinal Seebeck voltage measurements were made on mono- and multilayers of germanium films. Depending on the electrode material used, transverse p-type Seebeck voltages as high as 30 μv across 4000 Å of sputtered germanium were observed, using a heat pulse type technique. Thermoelectric anisotropies are very pronounced. Temperature dependencies in the vicinity of room temperature were found to be relatively small. Theoretical considerations suggest that the basic mean free path limitations that apply to charge carriers in a given semiconductor or insulator control the conversion efficiency of solid state thermionics to the same extent as they do in conventional thermoelectrics. No basic superiority can be attributed to either process. The experimental program is not sufficiently well developed yet to verify any of the theoretical criteria. (auth)

NSA '63

36455 (TRW-ER-5464) HIGH TEMPERATURE SOLAR THERMIONIC GENERATORS. First Quarterly Technical Progress Report, April 15, 1963-July 31, 1963. (TAPCO. Div. of Thompson Ramo Wooldridge Inc., Cleveland). Aug. 15, 1963. Contract AF33(657)-11169. 50p.

Progress is reported on work accomplished on applied research initiated on cesium-vapor thermionic converters. The two major goals of the program are: to demonstrate that cesium-vapor thermionic converters operating above 1600°C can have a satisfactory life of at least one year at efficiencies greater than 15% and at power densities greater than 12 watts/cm^2; and to demonstrate that such high-temperature converters can be incorporated into a cavity generator capable of sustained operation at the focal point of a solar concentrator. Toward these goals, a cavity type generator was extensively tested under a solar flux range of 80 to 100 watts/ft^2 during the first quarter of the program and good correlation of the generator solar performance with previous laboratory performance has been obtained. Further, an advanced thermionic converter design, fabrication and performance evaluation was successfully accomplished and an additional three converters of this configuration are undergoing fabrication. These converters will be subjected to sustained and cyclic life evaluations during the second and third quarter of the program. (auth)

NSA '63

34539 (NP-13044) THERMIONIC CONVERTER SURFACE CONDITIONS. Quarterly Technical Progress Report No. 2, May 1, 1963–July 31, 1963. (General Electric Co. Research Lab., Schenectady, N. Y.). Aug. 1963. Contract AF33(657)-10132. 25p.

Progress in a program to study various emitter materials and surface conditions in a plane parallel cesium vapor thermionic converter configuration is reported. The operation of a parallel-plane cesium converter with an emitter of oxygen-treated tantalum and a collector of molybdenum was investigated. When the converter was initially operated, the output power in the lower range of emitter temperatures was higher than that obtainable after some 30 hr of operation. After 40 hr of operation at various values of emitter temperature from 1550 to approximately 2085°K, the converter apparently settled down to a stable condition of operation. A slow variation of output power with collector temperature was found to be normal. (M.C.G.)

NSA '63

39710 (ASD-TDR-63-865) INVESTIGATION OF CAPILLARY EMITTER THERMIONIC CONVERTERS. D. L. Dresser, J. D. Dunlop, H. Huber, R. LeBihan, V. L. Hill, N. D. McMurray, and K. E. Muszer (General Motors Corp. Allison Div., Indianapolis). Aug. 1963. Contract AF33 (616)-8299. 190p.

A random current theoretical model is formulated to describe the emission of ions and electrons from a capillary thermionic emitter. Extensive experimental results from monocapillary and multicapillary devices are shown to be in good agreement with the theory. Practical power densities of 5 to 15 watts/cm^2 were obtained between 1900 and 2100°K. A modified capillary emitter in which no cesium flow is required was also investigated and found to agree with the random current model. Ion current measurements, high frequency oscillations, and spectroscopic data are used to interpret the operating conditions of the capillary emitter. Technology developments are reported on the subjects of emitter fabrication and chemical vapor deposition. (auth)

NSA '63

AD-413 409 Div. 7
(TISTN/AMS) OTS price $4.60

Tapco Div., Thompson Ramo Wooldridge, Inc., Cleveland, Ohio.
HIGH TEMPERATURE SOLAR THERMIONIC GENERATORS. Quarterly technical progress rept. no. 1, 15 Apr-31 July 63.
15 Aug 63, 44p.
Contract AF33 657 11169, Proj. 8173, Task 817305 24

Unclassified report

Descriptors: (*Thermionic converters, Cesium), (*Cesium, Thermionic converters), Vapors, High temperature research, Power, Tests, Design, Performance tests, Life expectancy, Test methods, Data, Electric potential, Electric currents, Test equipment, Electrical properties, Solar radiation.

The two major goals of the program are: (1) to demonstrate that cesium vapor thermionic converters operating at temperatures above 1600 C can have a satisfactory life of at least one year at efficiencies greater than 15% and at power densities greater than 12 watts/sq cm; and, (2) to demonstrate that such high temperature converters can be incorporated into a cavity generator capable of sustained operation at the focal point of a solar concentrator. Toward these goals, a cavity type generator has been extensively tested under a solar flux range of 80 to 100 watts/sq. ft. during the first quarter of the program and good correlation of the generator solar performance with previous laboratory performance has been obtained. Further, an advanced thermionic converter design, fabrication and performance evaluation has been successfully accomplished and an additional three converters of this configuration are undergoing fabrication. These converters will be subjected to sustained and cyclic life evaluations during the second and third quarter of the program. (Author)

39719 (MND-2945-3) NUCLEAR FUEL (OXIDE) CLAD THERMIONIC CONVERTERS. Quarterly Technical Progress Report, May 1 through July 31, 1963. (Martin-Marietta Corp. Aerospace Div., Baltimore). Aug. 15, 1963. Contract AF33(657)-10077. 61p. (AD-415102)

Fabrication of the components for the FDM-1 converter and its back-up device was completed. The FDM-1 converter was assembled, and preparations for testing were completed. Performance testing was initiated, and a total of 330 hours of operation above 1000°K in a cesium environment were logged. The peak emitter temperature reached was 2000°K with a thermionic output of nearly 2 watts/cm^2. Indications of a cesium leak were observed, and the device was shut down for examination. A 500-hour thermal endurance test of the clad fuel pellets was performed. A post-test examination was conducted, and no diffusion of UO_2 into the cladding was observed. A thermal conductivity test specimen was exposed to a temperature of 1550°C for 500 hours with the result that some intergranular diffusion was noted. The post-test examination of the vacuum emission test pellet was also completed. The design of the advanced double-diode thermionic converter utilizing the results of prior efforts was initiated. (auth)

NSA '63

37650 (NASA-TN-D-1879) THERMIONIC EMISSION FROM CESIUM-COATED ELECTROSTATIC ION-THRUSTER ELECTRODES. Thaine W. Reynolds and Edward A. Richley (National Aeronautics and Space Administration. Lewis Research Center, Cleveland). Sept. 1963. 33p.

An analysis indicates that electron-emission currents from a cesium coated tungsten accelerator electrode in an ion thrustor can be as high as 4 percent of the ion-beam current when the only source of adsorbed cesium is direct neutral flow from the ion emitter. If neutral-cesium atoms accumulate in the interelectrode space, electron emission from the accelerator electrode may become 40 percent of the ion-beam current. Either cooling or heating of the accelerator electrode could reduce the electron current considerably. (auth)

NSA '63

815 (AI-9050) CLAD CARBIDE NUCLEAR FUEL THERMIONIC POWER MODULES. Second Quarterly Report. (Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.). Sept. 1963. Contract AF33(657)-10876. 37p.

A clad carbide emitter, thermionic power module, which simulates nuclear reactor installation, design, and performance is evaluated. The module is an assembly of two series-connected converters with a single common cesium reservoir. The program goal is 500 hr cummulative operation at a power density of 7 watts/cm^2 and an efficiency of 12%. Progress made includes: minor design refinement of several components, completion of fabrication of all module components with the single exception of insulated collector structure, thermal stability tests of critical brazes and welds, completion of the module performance evaluation test setup, development and evaluation of fueled emitter fabrication techniques, and postoperation metallurgical examination of fueled planar emitter from fueled converter test. (auth)

NSA '64

823 THE NUCLEAR CESIUM CELL. H. Neu (Euratom, Ispra, Italy). Kerntechnik, 5: 365-72(Sept. 1963). (In German)

The nuclear cesium cell is a cesium-vapor filled energy-converter for direct conversion of nuclear heat to electric energy by thermionic emission of electrons. There are presented some general lines for design and construction of cells and the selection of useful materials. A short review about in-pile tests in the USA and Europe is given. A critical discussion of the results as well as the development goals is followed by some remarks on the application of nuclear cesium cells in a thermionic reactor for space flight and for commercial electric power production. (auth)

NSA '64

824 NOBLE GAS FILLED THERMIONIC ENERGY CONVERTER. W. Bloss (Technische Hochschule, Stuttgart). Kerntechnik, 5: 372-6(Sept. 1963). (In German)

The different methods of ion generation in noble gases for electron space charge compensation in thermionic diodes and in thermionic converters with an auxiliary electrode are described. Values of the operating temperature, plasma resistance, and efficiency of energy conversion for the different devices are given. The optimum operating conditions, the feasibility of a-c generation, and the fields of practical application are discussed. (auth)

NSA '64

822 PHYSICAL FUNDAMENTALS OF THERMIONIC CONVERTERS, AND SURVEY ON THEIR TECHNICAL APPLICATION. J. Bohdansky and R. Langpape (Brown, Boveri & Cie AG, Mannheim, Ger.). Kerntechnik, 5: 361-5(Sept. 1963). (In German)

The possibilities of directly producing electrical energy by thermionic emission are shown. Between both the discussed types of diodes, cesium and Noble-gas, the cesium diode now seems to be further developed and also longer lasting. Electrically heated diodes were already operated for several thousand hours with sufficient efficiency. Nevertheless, these elements are not sufficiently qualified for technical use on account of the small distance of the electrodes. Ways for eliminating these difficulties are demonstrated. The so-called cesiumfluoridediode is discussed. Several problems are still to be solved. Nevertheless, the thermionic element seems to become an important power generator for special use. The employment of thermionic elements for terrestrial purposes seems to be possible in further future, too. At this time, its employment will be rather a financial problem than a technical one. (auth)

NSA '64

36467 SPECTROSCOPIC INVESTIGATION OF A THERMIONIC CAPILLARY CESIUM ENERGY CONVERTER. R. T. Schneider and J. D. Dunlop (General Motors Corp., Indianapolis). Appl. Phys. Letters, 3: 73-5(Sept. 1, 1963).

A thermionic capillary cesium energy converter operating in the power generating region was investigated by means of spectroscopy. Spectra were presented for the four modes of operation: passive mode, oscillating region, ignited mode, and arc mode. The electron density, estimated by spectral line broadening measurements, was 2×10^{14} per cm^3. The electron temperature was determined by measurements of intensity ratios of lines originating from high energy levels. (C.E.S.)

NSA '63

820 (PWA-2275) LIQUID METAL-HEATED SPACE RADIATOR-MOUNTED THERMIONIC GENERATOR. Quarterly Report No. 1, July 1–September 30, 1963. F. C. Harter (Pratt and Whitney Aircraft Div., United Aircraft Corp., Hartford, Conn.). Contract AF33(657)-11320. 57p. (AD-422200)

The design of the thermionic converter to be evaluated was completed. The converter incorporates a tantalum-10% tungsten alloy liquid metal containment tube insulated by BeO from a tungsten-25% rhenium emitter. A nickel collector with an interelectrode space of 8 mils was selected. The predicted performance of this converter indicates a power output of 4.7 w/cm^2 with an efficiency of 12% when the emitter temperature is 1500°C. A bifilar tungsten filament was selected for use as a heater in this program based on a study contained in this report. (auth)

NSA '64

2575 TRANSIENT STARTUP PHENOMENA IN PLASMA THERMIONIC ENERGY CONVERTERS. J. S. Chivian, Texas Instruments, Inc., Dallas). Advan. Energy Conversion, 3: 565-8(July-Sept. 1963).

The slow approach to equilibrium operation in a plasma diode was previously ascribed to permeation of the hot refractory emitter by the alkali vapor. A dual diode was used to show that this transient behavior is controlled by the rate of arrival of the alkali vapor into the main interaction region, and by the adsorption of the vapor onto the walls of the enclosure. (auth)

NSA '64

Double diode thermionic converter. Mech Eng 85:63 O '63

AS+TI 163

UNCLASSIFIED

115821
115822 THEORETICAL AND EXPERIMENTAL INVESTIGATION OF ARC PLASMA-GENERATION TECHNOLOGY, PART II: APPLIED RESEARCH ON ELECTRIC ARC PHENOMENA, VOLUME 1: A THEORETICAL AND EXPERIMENTAL STUDY OF THERMIONIC ARC CATHODES
(Period covered: August 1, 1960-November 30, 1962)
Bade, W.L. & Yos, J.M.
September 1963
Avco Corp.
Research & Advanced
Development Division
AF 33(616)-7578
Report, Pt. II, Vol. 1

Unclassified
(Air Force Dept.
ASD TDR-62-729,
Pt. II, Vol. 1)

A theoretical model is formulated including important processes in the plasma of the cathode fall zome, at the plasma cathode interface, and in the cathode interior. An approximate analysis indicated that the system has two different types of solution, the occurrence of which depends primarily upon how well the cathode is cooled. Well cooled cathodes tend to operate with a concentrated arc spot, while very poorly cooled cathodes operate without such a spot.

814 (AD-420837) KRYPTON-FILLED THERMIONIC CONVERTER. Quarterly Technical Progress Report No. 3, July 1, 1963–September 30, 1963. (Union Carbide Corp. Parma Research Center, Ohio). Oct. 1963. Contract AF33(657)-10131. 26p.

Exploratory research work on irradiated inert gas-filled thermionic diodes is presented. Tubes containing xenon and krypton were tested in the radiation field of a 5-Mw swimming pool type reactor, and cathode current outputs in the range of 1 amp/cm^2 were obtained. Early breakdown effects were observed in irradiated xenon-filled diodes at voltages as low as 0.3 volt, and this effect appears to be dependent on cathode-anode spacing and pressure. At radiation dosages between 10^8–10^9 rads/hr, the current output of inert gas-filled thermionic diodes increases approximately linearly with radiation dosage. Experiments to increase output in the power quadrant of the thermionic diode, used as a converter, by the design of low anode work function tubes are also described. (auth)

NSA '64

Progress in Thermionic Conversion, J.W.GARDNER. English Elec J v 18 n 5 Sept-Oct 1963 p 24-9. Problems of thermionic conversion are reviewed as one of 4 direct conversion techniques which appear to offer best prospects for eventual economic large scale power generation; methods of overcoming space charges; problems of work function; nuclear applications and problem of ionization in reactors. 25 refs.

EI '63

Unconventional methods of electricity generation. F. D. Dunn and J. K. Wright. diags Inst E E Proc 110:1827-52 bibliog(p 1851-2); Discussion. 1853-4 O '63

AS+TI 163

810 (63SD862) OUT-OF-CORE NUCLEAR THERMIONIC STUDY. Quarterly Report No. 1, July 1–September 30, 1963. (General Electric Co. Missile and Space Div., Valley Forge Space Technology Center, King of Prussia, Penna.). Oct. 30, 1963. Contract NASw-741. 112p.

Results of analysis and design studies accomplished on one-loop and two-loop thermionic radiator-generator systems and the two-loop thermionic heat exchanger-generator are described. An extensive compilation of measured thermionic converter emission data at emitter temperatures of 1100, 1200, 1300, and 1400°C was prepared for a planar converter consisting of a molybdenum emitter and nickel collector with a 5-mil gap. These data were experimentally optimized with respect to cesium and collector temperatures, and were used to calculate parametric efficiencies and actual power densities for the cylindrical thermionic radiator and heat exchanger converter designs. An overall evaluation of the design and fabrication problems, system weight and performance, reliability, operational factors and growth potential, resulted in the conclusion that the heat exchanger location for mounting thermionic converters offers considerably more promise than the radiator location. (N.W.R.)

NSA '64

2568 DEVELOPMENT OF AN ADVANCED THERMIONIC CONVERTER FOR NUCLEAR REACTOR EXPERIMENTS. J. T. Ream and J. W. Holland (General Atomic Div., General Dynamics Corp., San Diego, Calif.). Trans. Am. Nucl. Soc., 6: 317-18(Nov. 1963). NSA '64

2578 MITIGATION OF OPEN-CIRCUIT FAILURES IN THERMIONIC REACTORS. William J. Levedahl (Martin Co., Baltimore). Trans. Am. Nucl. Soc., 6: 321(Nov. 1963). NSA '64

31085 (NP-12970) SECOND QUARTERLY REPORT FOR ADDITIVE CONVERTER STUDIES. A. L. Hyland (Thermo Electron Engineering Corp., Waltham, Mass.). 1963. Contract AF33(657)-10130. 23p.

An account of the cesium characteristics of the experimental thermionic converter is given, and the correlation to other rhenium emitter diodes is discussed. The experimental apparatus and the testing procedures are described. The program is designed to study the effect of additions of cesium compounds of electronegative elements such as fluorine, chlorine, and oxygen to the test chamber on the converter performance. (N.W.R.) NSA/63

42412 THE POTENTIAL OF SOLAR THERMIONICS FOR SPACE VEHICLE POWER. D. L. Dresser (General Motors Corp., Indianapolis). New York, Society of Automotive Engineers, Inc., 1963, Preprint 741B, 12p. (CONF-191-2)

From Society of Automotive Engineers National Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, Sept. 1963.

A summary is presented on theoretical and experimental results obtained during the past four years on the solar thermionic system. These results provide a basis for estimating the future competitive position of the thermionic system versus solar cells in space power. The basic characteristics of the system are outlined and recent developments are reviewed. A comparison is made of the thermionic and solar cell as power sources. (auth) NSA 63

AD-411 474 Div. 25
(TISTP/MFA) OTS price $1.60

United Aircraft Corp., East Hartford, Conn.
PROBE MEASUREMENTS IN A CESIUM PLASMA CONVERTER
by R. H. Bullis and W. J. Wiegand. 1963, 16p.
Rept. no. P B38
Contract AF49 638 1221
AFOSR 5141 Unclassified report

Presented at the 23rd Annual Conference on Physical Electronics, 22 Mar 63, at MIT.

Descriptors: (*Probes (Electromagnetic), Measurement), (*Thermionic converters, Plasma physics), Electrostatics, Plasma sheath, Cesium, Work functions, Electrons, Energy, Flame spraying, Thermionic emission, Pressure, Temperature, Cooling, Electrodes.

Measurements of the properties of the plasma in the interelectrode space of both conventional and arc mode thermionic converters were obtained with coaxial electrostatic probes. In the high-temperature cesium plasma present in the converter, it was found that severe distortion of the probe current-voltage characteristic occurs due to extraneous current leakage to the probe and thermionic emission from the probe tip. By means of techniques previously reported, these distortions were eliminated by employing a coaxial-type probe. A comparison of probe information is made to models of both types of converter. In the conventional mode of operation the measured electron energy distribution is Maxwellian with a temperature of 0.18 ev which corresponds closely to the emitter temperature of 0.12 ev. In the arc mode converter, probe studies indicate that the electron energy distribution is non-Maxwellian with two energy groups existing in the plasma. The high-energy group of electrons corresponds closely in energy to emitter electrons which were accelerated by potentials comparable to emitter sheath potentials. The lower energy group corresponds to electrons which are essentially in equilibrium with the cesium vapor in the interelectrode space of the converter. (Author)

36532 THEORY AND EXPERIMENT OF A CAPILLARY EMITTER IN A THERMIONIC CONVERTER. D. L. Dresser (General Motors Corp., Indianapolis), W. G. Laurita, J. D. Dunlop, H. Huber, and M. LeBihan. New York, American Inst. of Aeronautics and Astronautics, 1963, Preprint 63-156, 16p, $1.00. (CONF-97-16)

From Summer Meeting, Los Angeles, June 1963.

A capillary emitter concept in which a capillary structure is used as a dual source of electron emission and a dispenser of Cs ions is presented as a possible means of alleviating the close spacing requirement in thermionic converters. A random current theory is formulated in which the ion and electron currents are dependent upon the atom density at the capillary exit and the emitter temperature. The Cs flow equations are solved for the electrode geometry being studied to predict the exist pressure. The design and fabrication of two devices, a monocapillary structure and a multicapillary converter, are described. Experimental data from the multicapillary converter are compared with theory. It was found that the multicapillary converter is better than the ideal conventional converter at low Cs temperatures; at higher Cs temperatures a conventional device becomes better. In all cases where the multicapillary converter is superior, the absolute power density is too low for practical applications. (A.G.W.) NSA '63

4103 A NEW APPROACH TO THERMIONIC ENERGY CONVERSION. W.Bernstein.
"Ionization in gases" Conference Paper, Vol. II (see Abstr. 2102 of 1963) p. 1745-50.

The characteristics of an auxiliary discharge thermionic convertor are derived and compared with experimental results. It is shown that the power required in the auxiliary discharge can be as low as 0·1 W/A of convertor current. Thus, efficiencies of about 25% and power densities of 10 W cm^{-2} can be obtained at 1500°K provided suitable low work function anodes are developed. It is also shown that the plasma resistive loss is small for this type of convertor, although interelectrode spacings of several millimetres are used.

EEA '63

4172 PLASMA CONVERTER PERFORMANCE CHARACTERISTICS. H.K.Messerle.
"Ionization in gases" Conference Paper, Vol. II (see Abstr. 2102 of 1963) p. 1752-68.

A plasma convertor allows direct conversion of thermal energy of an ionized gas into electrical energy when the gas flows through a magnetic field. Performance of the convertor can be described with the aid of the basic laws of magnetohydrodynamics. Performance characteristics are established applying perturbation theory to the one dimensional flow equations for the convertor. It is shown that compressibility can be considered as a perturbation effect in the practical operating ranges of the device.

EEA '63

5187 A NEW THERMIONIC GENERATOR WITH ION INJECTION. H.A.Fatmi.
"Ionization in gases" Conference Paper, Vol. II (see Abstr. 2102 of 1963) p. 1739-44.

A new thermionic generator capable of producing direct or alternating current is described. The supply of ions is provided by a simple and highly efficient method, at a cost of only a few per cent of the useful power. Gabor's theory (Abstr. 411 of 1962) which assumes an almost uniform isothermal dark plasma in the main discharge space, limited by Langmuir-sheaths at the side of the emitter and the side of the collector, account for most experimental results. The efficiency is mainly a function of the radiation loss of the emitter per ampere current and efficiencies of 40-50% may be attainable if it is possible to reduce this figure to 1 W/A.

EEA '63

7421 A NEW THERMIONIC GENERATOR WITH ION INJECTION. H.A.Fatmi.
"Ionization in gases" Conference Paper, Vol. II (see Abstr. 1928 of 1963) p. 1739-44.

A new thermionic generator capable of producing direct or alternating current is described. The supply of ions is provided by a simple and highly efficient method, at a cost of only a few per cent of the useful power. Gabor's theory (Abstr. 18916 of 1961) which assumes an almost uniform isothermal dark plasma in the main discharge space, limited by Langmuir-sheaths at the side of the emitter and the side of the collector, accounts for most experimental results. The efficiency is mainly a function of the radiation loss of the emitter per ampere current and efficiencies of 40-50% may be attainable if it is possible to reduce this figure to 1 W/A.

PA '63

7422 A NEW APPROACH TO THERMIONIC ENERGY CONVERSION. W.Bernstein.
"Ionization in gases" Conference Paper, Vol. II (see Abstr. 1928 of 1963) p. 1745-50.

The characteristics of an auxiliary discharge thermionic converter are derived and compared with experimental results. It is shown that the power required in the auxiliary discharge can be as low as 0·1 W/A of converter current. Thus, efficiencies of about 25% and power densities of 10 W cm^{-2} can be obtained at 1500°K provided suitable low work function anodes are developed. It is also shown that the plasma resistive loss is small for this type of converter, although interelectrode spacings of several millimetres are used.

PA '63

III. POWER GENERATION

C. Miscellaneous thermal energy conversion devices

9150 RADIOACTIVE BATTERY. Harry C. Lieb and Stanley Wallack (to Leesona Corp.). U. S. Patent 3,069,571. Dec. 18, 1962. Filed Dec. 16, 1957.

A device is described that directly utilizes the electrical energy emitted from a gaseous or fluid radioactive material by collecting emitted electrons. The device is designed to function under extreme conditions of temperature and/or shock. (R.J.S.)

NSA '63

AD-284 662 Div. 25, 7
(TISTM/AW) OTS price $6.60

Marks Polarized Corp., Whitestone, N. Y.
THE CONVERSION OF HEAT TO ELECTRICAL POWER BY MEANS OF A CHARGED AEROSOL.
Quarterly rept. no. 4, 1 Apr-30 June 61.
14 Nov 61, 66p. incl. illus. tables, 6 refs.
(Contract NOw 60-0831-c)
Unclassified report

DESCRIPTORS: *Heat transfer, *Electric power production, *Thermodynamics, Ions, Effectiveness, Plasma physics, Gas ionization, Mathematical analysis, Aerosols, Gases.

The electrothermodynamics of an electric generator utilizing a charged aerosol was investigated for single and multiloop Carnot cycles. Parameters related to efficiency were established for pressure, temperature and isothermal and isentropic work. The charged aerosol is a new working substance uniquely adaptable to a variety of controlled electrothermodynamic operations. Heat interchange is facilitated between the highly dispersed liquid and gas components of the aerosol. The liquid/gas mass ratio of a charged aerosol controls the modes of operation during expansion or compression, thus enabling the predetermination of isothermal or isentropic operation, by adjusting the liquid/gas mass ratio. Electrical power is extracted during both isothermal and isentropic expansion of the charged aerosol. Compression may be effected by the reverse electrothermodynamic effect. New multiloop aerosol cycles having an overall efficiency of 60-80% appear feasible. (Author)

'63

7423 PLASMA CONVERTER PERFORMANCE CHARACTERISTICS. H.K.Messerle.
"Ionization in gases" Conference Paper, Vol. II (see Abstr. 1928 of 1963) p. 1752-68.

A plasma converter allows direct conversion of thermal energy of an ionized gas into electrical energy when the gas flows through a magnetic field. Performance of the converter can be described with the aid of the basic laws of magnetohydrodynamics. Performance characteristics are established applying perturbation theory to the one-dimensional flow equations for the converter. It is shown that compressibility can be considered as a perturbation effect in the practical operating ranges of the device.

PA '63

3996 THE DIRECT CONVERSION OF THERMAL ENERGY INTO ELECTRICAL ENERGY. S.Klein.
"Ionization in Gases" Conference Paper, Munich, 1961 (see Abstr. 1928 of 1963), p. 806-14. In French.

An important separation of positive and negative electric charges in a jet of ionized vapour, metallic or otherwise (mercury, caesium and water) which tends to condense at room temperature, was found. These pressurized vapours, ionized by a h.f. source, entered through a vent into an expansion chamber which contained several electrodes and in which a partial vacuum had been set up. These vapours, made up of molecules, ions and electrons, traversed the vent and the electrodes and expanded at different velocities and an electromotive force was produced between the electrodes. Also, similar results were obtained by using other ionization processes (flame, ultraviolet light, radioactive elements). The voltage distribution in the hot gas in relation to the electrodes was measured by means of small wire electrodes. The separation of charges was obtained without applying an electric or magnetic field in the vincinity of the electrodes. The difference of temperature between the electrodes played an essential part in this phenomenon. If the electrodes were at the same temperature, no electromotive force was produced.

PA 63

Magnetic triode; direct conversion of heat to electricity. G. F. Harris and others. biblog diags Electronic Tech 39:27-30 Ja '62

14504 THERMOMAGNETOELECTRIC (T.M.E.) EFFECT IN LAMINAR BISMUTH–METAL CONTACTS.
A.Luycks, J.P.Issi and G.Lontie.
Bull. Acad. Sci. Belgique Cl. Sci., Vol. 47, No. 11, 1138-40 (1961). In French.

A bismuth–copper thermocouple placed in a magnetic field H exhibits a TME effect. A relative increase in e.m.f. $\Delta E/E$ is observed independent of the direction of H. For a given H, $\Delta E/E$ depends on the temperature difference ΔT. For a given ΔT, $\Delta E/E$ is approximately proportional to H. The effect is increased by interposing a laminar bismuth foil between the Bi–Cu contact, and decreased by interposing a non-laminar bismuth plate. J.B.Birks

PA 62

13531 NEW CALORELECTRIC EFFECT.
J.R.Cozens and A.von Engel.
Nature (GB), Vol. 193, 1170-1 (March 24, 1962).

A physical mechanism is proposed to explain the new effect reported by Klein (Abstr. 19671 of 1960; 7020 of 1961) in which an oxygen–coal gas flame is directed onto two electrodes kept at temperatures differing by several hundred degrees, a potential difference of several volts appears between the electrodes.

C.A.Hogarth

PA 62

Sur l'utilisation de l'énergie d'une vapeur ionisée chaude, S. KLEIN, M.SURDIN. Acad des Sciences–CR v 254 n 13 Mar 26 1962 p 2303-4. Utilization of energy of hot ionized vapor; ionized flame cell can produce emf of 2 v by technique experimented by S.Klein; 2-stage production of power is proposed; first stage consists of multi-cell installation for direct conversion; in second stage remanent heat is utilized for gas turbine or for steam production.

CI 63.

11608 APPLICATION OF A FERROELECTRIC MATERIAL IN AN ENERGY CONVERSION DEVICE. J.D.Childress.
J. appl. Phys. (USA), Vol. 33, No. 5, 1793-8 (May, 1962).

The thermodielectric converter, a device employing a ferroelectric material as the active element in converting thermal to electrical energy, is analysed. The efficiency and power-handling capacity are calculated for operation of a ferroelectric material in the induced-ferroelectric region on the basis of an idealization of the polarization (P–E) characteristics. The idealization includes the induced-ferroelectric transition but excludes hysteresis and other nonlinear effects. For a barium titanate-like material, the following values are obtained: a maximum theoretical efficiency of about 0.5% in an ideal temperature cycle of Carnot efficiency 7.1%; and a power-handling capacity of roughly 32 W/lb per temperature cycle per sec.

PA 62

Sur la conversion d'énergie par jet de vapeur ionisée, M. SURDIN. J de Physique et Radium v 23 n 5 May 1962 p 297-8. Direct energy conversion from jet of ionized vapor; theory is advanced for S. Klein experiments on direct conversion; negative potential of hot electrode and positive potential of cold electrode calculated; negative charge carriers arriving at cold electrode are not electrons but water droplets; short-circuit current is calculated, approximately, assuming that electron current of external circuit compensates ion current arriving at cold electrode. EI63

Theory of Galvano-Thermomagnetic Energy Conversion Devices—1, 2, T.C. HARMAN, J.M. HONIG. J Applied Physics v 33 n 11 Nov 1962 p 3178-94. Pt 1. Generators using phenomenological equations in partially inverted form; operation of galvano-thermomagnetic generators has been analyzed for 6 different modes of operation. Pt 2. Refrigerators and heat pumps; it is shown that coefficients of performance of refrigerators and heat pumps differ by unity; upper bounds are placed on transverse figure of merit and brief discussion of main features of theory is given. 27 refs. E163

14927 (AGC-0528-01-2) INVESTIGATION OF AN ENERGY CONVERSION DEVICE. Quarterly Progress Report No. 2, October 1 to December 31, 1961. R. F. Fogle and H. E. Lawson (Aerojet-General Corp., Azusa, Calif.). May 1962. Contract DA-36-039-SC-87229. 9p. (AD-278480)

Activities in a program to develop a cell which produces electricity by recombination of thermally separated reactive elements are reported. Tests are reported in which reactants were lost from the cell during operation because of mechanical failure of the sealing materials; however, in intermittent tests, operation was increased to about 8 days. (J.R.D.) NSA '63

5617 A PROCESS FOR THE CONVERSION OF IONIZATION ENERGY TO ELECTRICITY. S. Klein and J. Prévé. J. Phys. Radium (France), Vol. 23, No. 8-9, 588-9 (Aug.-Sept., 1962). In French.

Following proposals for a method of direct conversion of heat into electricity (Abstr. 9519 of 1962) a device is described for directly converting atomic energy into electricity. An experimental device using X-rays as a source of ionization produced an open-circuit potential of 25 V and a short-circuit current of 22×10^{-6} A, and had an internal resistance of about 10^{6} ohms. C. Greaves PA63

Triode Concept of Direct Conversion, J.N. ANNO. Jr, S.L. FAWCETT. Battelle Tech Rev v 11 n 10 Oct 1962 p 3-9. Direct conversion of fission energy into electric energy as studied since 1958 at Battelle; concept is named Triode because cell consists of emitter, grid, and collector; fission fragments from emitter deposit their charge on collector; cell arrangement is analogous to capacitor; grid is required to suppress secondary electrons; irradiation is performed at Battelle Research Reactor; summary of experimental results. EI63

5162 ELECTRON EMISSION CURRENT NUCLEAR REACTOR. Rainer Guenther. British Patent 909,989. Nov. 7, 1962.

The electron emission current nuclear reactor is designed to convert nuclear energy directly into an electrical current. A core containing fissionable material is in direct contact with the emitter electrode, which is electrically isolated from the collector electrode. (R.J.S.) NSA '63

5080 THEORY OF GALVANO-THERMOMAGNETIC ENERGY CONVERSION DEVICES. I. GENERATORS. T. C. Harman and J. M. Honig (Massachusetts Inst. of Tech., Lexington). J. Appl. Phys., 33: 3178-88(Nov. 1962).

Using phenomenological equations in partially inverted form, the operation of galvano-thermomagnetic generators has been analyzed for six different modes of operation. The efficiency, figure of merit, and geometry optimization have been investigated. The two-dimensional temperature distribution prevailing in a device arm is also briefly analyzed. For the "longitudinal" case where heat flow and current are colinear in a transverse field, H_z, the mathematical relations conform to the standard theory, except that the transport coefficients depend on H_z. In the "transverse" case where heat flow, current, and magnetic field are mutually perpendicular, new expressions are obtained for the figure of merit and device efficiency. Furthermore, in the latter case the optimal operating conditions are those in which both device arms are made of the same material. The results are discussed in the light of some existing experimental data. (auth) NSA '63

5063 THE TRIODE CONCEPT OF DIRECT CONVERSION. James N. Anno, Jr. and Sherwood L. Fawcett. Battelle Tech. Rev., 11: No. 10, 3-9(Oct. 1962).

A direct-conversion cell is described in which the cathode is coated with a fissionable material and is separated from the anode by a negative-biased grid. When fissions occur in the fissionable coating, positively charged fragments at high energies and electrons at relatively low energies are emitted. The grid turns the electrons back toward the cathode, while allowing the positively charged (average charge = +21 e) ions to pass through to the anode. The positive potential of the anode is limited only by the dielectric breakdown characteristics of the cell, and may be on the order of several Mv. The cell may be used as an a-c generator by applying an alternating voltage to the grid. The use of banks of these cells as nuclear reactors is discussed for both stationary and space applications. It is noted that this system allows the kinetic energy of the fission fragments to be converted directly into electric energy without passing through the intermediate form of heat. (T.F.H.)

? NSA '63

7449 TEST OF A PHYSICAL INTERPRETATION OF A PHENOMENA OF THE CONVERSION OF ENERGY. J. Debiesse, S.Kiela and J.Taillet. C.R.Acad. Sci. (France), Vol.255, No.23, 3144-6 (Dec.5, 1962). In French.

Evidence is discussed concerning the production of potential differences of several volts across two electrodes in argon gas at atmospheric pressures when the gas is subjected to resonant pressure variations and X-ray irradiation in the 10 to 25 kV range. The possible charge carriers are divided into the fast primary electrons during the time their energy exceeds the first excitation level of the gas, the ions and slow electrons, and the fast secondary and the primary electrons after their relaxation through inelastic collisions.

M.F.Anderson

PA '63

Some Experimental Results Concerning Possibility of Direct Conversion of Thermal Energy into Electricity with M-G-D Methods, J.MILEWSKI, J.SMIGIELSKI. Acad Polonaise des Sciences—Bul—Ser des Sciences Techniques v 10 n 11 1962 p 629-34, plate. Description of work done from 1961 at IMP (Inst of Fluid Flow Machinery) of Poland Acad of Sciences; design of plasmatron; I-V curve of MGD (magneto-gas-dynamic) generator. 21 refs. EF '63

Theory of Galvano-Thermomagnetic Energy Conversion Devices —3. Generators Constructed from Anisotropic Materials, T.C. HARMAN, J.M.HONIG. J Applied Physics v 34 n 1 Jan 1963 p 189-94. Phenomenological equations in partially inverted form derived for anisotropic materials; characteristics for galvano-thermomagnetic Nernst generators operating under isothermal conditions formulated; efficiency is no longer exclusively determined by figure of merit as is case for isotropic generators; figure of merit required to reach Carnot efficiency becomes increasingly smaller.

EF '63

AD-295 456 Div. 8, 25
(TISTW/JEA) OTS price $1.10

Foreign Tech. Div., Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.
A METHOD FOR THE DIRECT TRANSFORMATION OF HEAT ENERGY INTO ELECTRICAL ENERGY,
by I. K. Vul'fel'dt. 9 Jan 63, 4p. incl. illus. (Trans. no. FTD-TT-62-759 from Soviet Patent No. 140920 (689180/24) 16 Dec 60)
Unclassified report

DESCRIPTORS: *Thermoelectricity, *Energy, Thermocouples, Dielectric properties, Capacitors, Reliability, USSR, Transformations, Frequency, Resonance, Heat transfer, Electric potential.

A method is proposed which excludes the necessity for initial capacitor activation in the sources and enables the efficiency and functional reliability of the energy converter to be raised and its weight, dimensions, and inertia to be lowered. This is attained by connecting a capacitor together with a linear inductance into a circuit operating at parametric resonance at a frequency half of that at which the dielectric heats. The essence of the method consists in alternately heating and cooling the capacitor, the dielectric of which possesses a penetrability which is a function of temperature. As a result of a change in the capacitance of the capacitor a variable electric current is excited in the circuit. (Author)

'63

End Losses in Magnetohydrodynamic Channels with Tensor Electrical Conductivity and Segmented Electrodes, G.W.SUTTON. J Applied Physics v 34 n 2 Feb 1963 p 396-403. End losses for magnetohydrodynamic power generator calculated; it was found that constant-current configuration is more efficient than constant potential difference case; efficiencies increase with increasing Hall effect, but constant magnitude extensions to magnetic field have bery little effect; theoretical efficiency for aspect ratio of 10 and product omega tau equal 2 is only 74%.

EI '63

16187 A NERNST EFFECT POWER GENERATOR.
S. W. Angrist (Carnegie Inst. of Tech., Pittsburgh). J. Heat Transfer, 85: 41-8(Feb. 1963).

The direct conversion of heat to electricity by means of the Nernst effect is analyzed. The Nernst effect is the creation of an electrical potential perpendicular to both an applied temperature difference and an applied magnetic field. The effect is pronounced in semiconductors which have large mobility, large mobility ratio, and relatively small energy gap. Indium antimonide exhibits theoretically the best performance to date. A Nernst effect generator using indium antimonide experiencing an applied temperature difference of 300 deg K and a magnetic flux density of 10 kilogauss would have a thermal efficiency of about 1.6 percent and a power density of 10 watts per cubic centimeter. (auth)

NSA '63

12039 POWER-PRODUCING SHIELD FOR SPACE REACTORS. Bernard Raab (Republic Aviation Corp., Mineola, N. Y.). Nucleonics, 21: No. 2, 46-7(Feb. 1963).

The active-shield or basic converter unit consisted of an assembly of high-Z and low-Z materials, divided about equally in weight and separated by a vacuum or dielectric. The reactor radiations interact with the active-shield to create anode-cathode voltage. (C.E.S.)

NSA '63

14224 FISSION-FRAGMENT CONVERSION REACTORS FOR SPACE. C.J.Heindl, W.F.Krieve and R.V.Meghreblian. Nucleonics (USA), Vol.21, No.4, 80-5 (April, 1963).

Fission-electric cells are constructed by coating cylindrical cathodes with a thin layer of fissionable material and collecting the fission fragments on a second cylinder separated by a high vacuum. A number of such cells can be assembled, with additional fissile material if necessary, to form a reactor. The cells will generate an open circuit potential of about 4 mV, but the reverse electron current produced when the fragments strike the collector must be suppressed by grids or a magnetic field. Test cells irradiated in a MTR have produced 10 μA and 11-810 V. The use of high-voltage cells will require development work on breakdown and leakage currents in the presence of high radiation fields. R.D.Smith

FEA '63

La conversione diretta dell'energia termica in elettrica per via magnetoplasmadinamica, A.ABETE. Elettrotecnica v 50 n 4 Apr 1963 p 253-62. Direct conversion of thermal energy into electricity by means of magnetoplasmadynamics (MPD); some deduction obtained from 1st symposium on magnetoplasmadynamic electrical power generation, in Newcastle-on-Tyne, England, Sept 1962; general aspect of MPD, its application to conversion, and actual experimental solutions. 22 refs. EI63

Fission-Fragment Conversion Reactors for Space, C.J.HEINDL, W.F.KRIEVE, R.V.MEGHREBLIAN. Nucleonics v 21 n 4 Apr 1963 p 80-5. Fission-electric conversion cell under investigation at Jet Propulsion Laboratory of California Inst Technology; cell essentially consists of very thin layer of fissionable material covering cathode separated by vacuum from anode that acts as fission-fragment collector; fragments carrying positive charges of about 80 Mev kinetic energy, h-v potential is buildup; h-v source is advantageous in some applications such as electrical propulsion of space vehicles. EI63

Conversion of Thermal to Electrical Energy with Ferroelectric Materials, S.R.HOH. IEEE—Proc v 51 n 5 May 1963 p 838-45.

It is shown that ferroelectric materials with high polarization and high dielectric strength can yield good conversion efficiencies; very high specific outputs are calculated for conversion of uncollected solar radiation by spinning space vehicle; such high specific outputs require suitable thin ferroelectric films of high thermal shock resistance; these requirements cannot be met in present experimental converters. EI63

34075 STORING THERMAL ENERGY. Edward F. Batutis (General Electric Co., Valley Forge, Penna.). Astronaut. Aerospace Eng., 1: No. 4, 102-3(May 1963).

Thermal-energy storage materials for high-temperature power-conversion systems are considered. The melting point, heat of fusion, and molecular or atomic weights of these materials are investigated. Optimum materials have a heat of fusion greater than 100 whr/lb. (C.E.S.) NSA'63

27531 RADIOACTIVE BATTERIES. Paul Rappaport (to Radio Corporation of America). U. S. Patent 3,094,634. June 18, 1963. Filed June 30, 1953.

A long-lived radioactive battery using semiconductors is designed which is especially suited for powering transistor circuits. In the battery, a junction or point-contact semiconductor device is irradiated by a radioactive source to liberate charge carriers therein and thereby generate a potential at the output terminals. Several embodiments of the battery are described. (D.L.C.) NSA'63

31608 MEASUREMENT OF THE THERMOELECTRIC POWER OF A FULLY IONIZED, LOW-TEMPERATURE PLASMA. N. Rynn (Princeton Univ., N. J.). Phys. Rev. Letters, 10: 465-7(June 1, 1963). (MATT-174)

The plasma generated in the Q-1 device by allowing a collimated beam of K to impinge upon a hot W plate is confined radially by a strong magnetic field and axially by hot plates. One plate was grounded while the other was allowed to float. The voltage generated in the thermocouple joints formed by the plasma, W plates, and voltmeter connectors as the temperature of the floating plate was varied permitted determination of the thermoelectric force as 3.8×10^{-3} volt/degree, in reasonable agreement with theory. (D.C.W.) NSA'63

14227 DIRECT CONVERSION OF VARIOUS FORMS OF ENERGY TO ELECTRICAL ENERGY. I. K.Simonyi.
Elektrotechnika (Hungary), Vol.56, No.6, 237-46 (June, 1963).
In Hungarian.

Concise introduction to the theoretical and practical problems of unconventional energy conversion. The operating principles of MHD generators are reviewed and the basic equations of electromagnetogasdynamics discussed. The characteristic quantities of plasma physics are described and conductivity examined in detail. Mathematical expressions for one-dimensional streamline flow is given.

P.Szekely
EE A '63

MHD Power Conversion, W.E.GUNSON, F.E.SMITH, T.C.TSU, J. H.WRIGHT. Nucleonics v 21 n 7 July 1963 p 43-7. Although still far from being reality, direct conversion of heat into electricity through interaction of working fluid with magnetic field now, because of recent developments, warrants serious attention. EI 63

AD-411 321 Div. 7, 12, 25
(TISTE/CAM) OTS price $7.60

Dynatech Corp., Cambridge, Mass.
PRELIMINARY DESIGN OF A SUPERCONDUCTING, ROTATING, ELECTRIC GENERATOR.
Quarterly progress rept. no. 1, July 63,
by E. H. Sibley, E. F. Doyle and C. J. Oberhauser.
July 63, 65p. Rept. no. 413
Contract AF33 657 11062, Proj. 8128, Task 812808
Unclassified report

Descriptors: (*Generators, Spaceborne), (*Superconductors, Generators), (*Electric power production, Superconductors), Velocity, Impellers, Electrical properties, Configuration, Magnets, Electromagnets, Heat transfer, Gamma rays, Cryogenics, Neutrons, Rotation, Refrigeration systems.

The object of this investigation is to determine the feasibility of the application of superconductor technology to the generation of electrical power by rotating electromagnetic devices. Since the anticipated use of such a generator is for long missions, a refrigerator with associated equipment must be considered part of the package. The work includes analytical and design studies of both electrical and mechanical components. The program may be divided into three parts: initial design, supporting tests, and final design; this first report deals with the initial design phase. (Author)

Magnetic Brillouin Zone Effects in Thermoelectric Power and Magnetoresistance of α-Manganese, D.GRIFFITHS, B.R.COLES. Phys Soc—Proc v 82 n 525 pt 1 July 1963 p 127-32. Evidence from electrical resistivity studies of modification of electronic structure of α-manganese below Neel temperature is supplemented by thermoelectric and magnetoresistive data; thermoelectric power changes from negative to positive on cooling through Neel temperature (about 95 K); magnetoresistance increases by factor of 10 between 110 and 65 K. EI '63

19184 THE CALORELECTRIC EFFECT IN FLAMES.
A.Von Engel and J.R.Cozens.
Proc. Phys. Soc. (GB), Vol. 82, Pt 1, 85-94 (July, 1963).

When two electrodes at different temperatures are placed in a reacting flame gas at atmospheric pressure, a potential difference is established between them. Its magnitude increases with rising temperature difference but it is independent of the electrode material. The cold electrode, usually kept at room temperature, always assumes a positive polarity. With a temperature difference of about 500°C a calorelectric force of several volts is obtained. The following mechanism is proposed: electrons, produced by the hot gas, gain kinetic energy from molecules and radicals in electronically and vibrationally excited states, resulting from combustion reactions. The reacting flame gas represents a non-uniform plasma in a steady state whose electrons acquire a temperature which is considerably above that of the hot neutral gas. As positive ions and electrons diffuse to the electrodes, the electrons lose a small fraction of their

ionic crystals is reviewed. The relationships with physical quantities such as discolouration, luminescence, and conductivity are discussed. There are 186 references.

C.Greaves
PA 63

IV. THERMOELECTRIC COOLING

22105 SOME COMMENTS ON THERMOELECTRIC REFRIGERATION AT LOW TEMPERATURES.
D.K.C.MacDonald and I.M.Templeton.
"Semiconductor Physics" Conference, Prague, 1960 (see Abstr. 21113 of 1962) p. 650-3.

The problems of thermoelectric refrigeration at very low temperatures differ in certain vital aspects from those at ambient temperatures. It still appears that a metal or dilute alloy offers the best hope at very low temperatures. In recent experiments below 2° to 4°K very dilute alloys of iron in gold showed absolute thermoelectric powers as large as ~ (–) 11 × 10^{-6} V^{-1} deg at ~ 1°K. However, a further increase of about an order of magnitude would be needed to hope to achieve practical refrigeration at low temperatures. The general study of the thermoelectric behaviour of dilute alloys with iron as solute is of fundamental interest in itself. Dilute iron alloys with Pd and Pt as parents show quite remarkable behaviour at temperatures even below 1°K; some results on such alloys are reported and discussed.

PA62- 2

6893 THERMOELECTRIC REFRIGERATION—A NEW APPLICATION OF SEMICONDUCTORS. F.W.Gasser.
Schweiz. tech. Z. (STZ) (Switzerland), Vol. 58, No. 36, 73-8 (Sept. 7, 1961). In German.

The paper gives an introduction, at a fairly elementary level, to the technique of Peltier cooling. The ratings and efficiencies of a few commercially available thermo-elements are quoted and the approximate cost of such elements for a typical domestic refrigerator is estimated. The figure of merit Z is introduced and its significance discussed in terms of elementary physics. K.W.Plessner

EEA'62

Some Problems in Development of Commercial Thermoelectric Refrigerator, T.B.BURNETT, H.O.LORCH, J.E.THOMPSON. Brit J Applied Physics v 12 n 11 Nov 1961 p 595-602. Accurate method for measuring junction electric resistance across p and n semiconductor bars; relative merits of various methods of forming cooling unit; heat balance equations for refrigerator which include cooling fin system; method of optimization of design is noted. Before Conference on Thermoelectricity, 1961, at Durham, Great Britain.

EI'62

Transient effects in Peltier coolers. A. D. Reich and others. J Ap Phys 32:2493-4 N '61

ASTI'62

9626 INFLUENCE OF THERMO-ELECTRIC COOLING ON THE MAGNITUDE OF THE COLLECTOR LEAKAGE CURRENT AND THE (DISSIPATION) POWER OF GERMANIUM JUNCTION TRANSISTORS. V.Ilberg and L.Štourač.
Slaboproudy Obzor (Czechoslovakia), Vol. 22, No. 12, 725-8 (1961). In Czech.

The cooling element employed was based on the Peltier effect and was in the form of a semiconductor system made from Bi-Te-Se and Bi—Te—Sb. A transistor having the maximum permissible collector dissipation P_{kmax} = 250 mW was mounted on the cooling element. When keeping the input power P_e to the cooling element at 2 W, it was found that P_{kmax} of the transistor could be increased four times at temperatures up to 60°C, while keeping the collector leakage current I_{ko} at its nominal value. The effect of variable P_e (at P_k = const.) on I_{ko} was also investigated. R.S.Sidorowicz

EEA'62

Comparison of Theory and Experiment for Thermoelectric Cooler, M.H.NORWOOD. J Applied Physics v 32 n 12 Dec 1961 p 2559-63. Performance of single-stage Peltier thermocouples was calculated using experimentally measured values of thermoelectric power, electrical resistivity, and thermal conductivity as functions of temperature; calculated behavior of thermocouples agreed well with measured performance in 3 cases studied; measured thermocouple figure of merit agreed with that calculated from material properties.

EI 62

AD-295 596 Div. 13, 8
(TISTE/OHD) OTS price $7.60

American-Standard Corp., Union, N. J.
FINAL DESIGN AND CONSTRUCTION DETAILS FOR A 6000 BTU/HR. THERMOELECTRIC AIR CONDITIONER,
by D. H. Howling and R. S. Bevans. 31 Dec 61, 1v. incl. illus. tables (Rept. no. TR-24-61-1)
(Contract DA 44-009-eng-4643)
Unclassified report

DESCRIPTORS: *Air conditioning equipment, *Thermoelectricity, Heat exchangers, Design, Electrodes, Gas flow, Tin, Tin alloys, Bismuth, Bismuth alloys, Lead alloys, Antimony alloys, Aluminum alloys, Indium, Zinc alloys, Tellurides, Semiconductors, Diffusion, Resistance, Electroplating, Mathematical analysis, Cooling.

The design details of a 6000 Btu/hr thermoelectric air conditioner are presented. The performance specifications are summarized and the design calculations are also outlined. At design operating conditions, this air conditioner should produce 6000 Btu/hr of cooling with an over-all coefficient of performance of 0.44. The unit is equipped with a number of small blowers which circulate air over the fins attached to the cold thermoelectric junctions and a second set of blowers which circulate air over the fins attached to the hot thermoelectric junctions. The air conditioner weighs approximately 85 pounds and is designed to fit conveniently in the wall of the enclosure to be cooled. Satisfactory junctions were produced by electroplating the thermoelectric elements with nickel, capping the nickel with a lead-tin alloy and then oven soldering these pellets to the tinned base of the aluminum fin blocks with a solder wafer placed between the capped element and the tinned base. The electrical contact resistance of a single junction is of the order of one micro-ohm and the joint can withstand a tensile load of at least 50 lb/sq. cm. (Author)

163

540 THERMOELECTRIC REFRIGERATION AND ITS TECHNICAL APPLICATIONS. S.Poganski.
AEG Mitt. (Germany), Vol. 51, No. 7-8, 259-65 (July-Aug., 1961). In German.

Knowledge gained of semiconducting compounds in recent years has made technical application of the Peltier effect possible. The theory of thermoelectric refrigeration, the present state of the art concerning semiconducting Peltier junctions and the performance of refrigeration devices developed therefrom are surveyed. The performance is also compared with that of conventional absorber and compression type refrigerating devices. S.S.Mitra

EEA '63

Unified Performance Calculations for Thermoelectric Cooling, A. WATANABE. J Applied Physics v 33 n 1 Jan 1962 p 130-5. Normalization of practical quantities has yielded systematic forms for performance calculations of idealized couple composed of 3 temperature independent parameters; effects of contact resistance, current ripple, and heat leak are also considered; proposed graphs of performance quantities are given including no fixed parameters; temperature difference normalized by its maximum is recommended as "figure of performance" as criterion for operating couple. EI62

Theory and background of thermoelectric cooling. W. Hellmann. Can Chem Process 46:53-4 Ja '62

AS+TI '62

Playing It Cool in Thermoelectrics. Can Chem Processing v 46 n 1 Jan 1962 p 52-4. Thermoelectric material, "pseudobinary compound" of bismuth, selenium, tellurium and antimony, can be made into thermocouples which will maintain temperature difference of 77 C, with hot junction of 27 C, under influence of direct current; applications include laboratory cooler for industrial use, thermoelectric baffle for vacuum pumps, and microtome table; material is made by Needco Cooling Semiconductors Ltd. EI62

240

Thermoelectric Phenomena Associated with Electron-Field Emission, P.H.LEVINE. J Applied Physics v 33 n 2 Feb 1962 p 582-7. Investigation of equilibrium temperature distribution in ideal metal rod, one end of which is subjected to intense electric field; conditions for cooling down emitting end are derived; viewed as "heat pump", for "field emission" refrigeration, it is found that rates in excess of 0.1 cal/sec/sq cm are possible at room temperature if emitter work function is less than electron volt.

EI 62

New ice making unit; York div., Borg-Warner corp. thermoelectric device. J. B. Elliot. il Iron Age 189:94 F 8 '62

Selection of hot junction temperatures for minimum fin area thermoelectric refrigerators. C. L. Feldman. ASHRAE J 4:68-71 F '62

AS 4TI '62

9232 BASES AND PROBLEMS OF THERMOELECTRIC REFRIGERATION. K.Sagel.
VDI Z. (Germany), Vol. 104, No. 7, 325-34 (March 1, 1962). In German.

The effectiveness of thermoelectric refrigeration as achieved today, cannot yet compete with compressor refrigeration in the most essential fields of application. In the field of small scale refrigeration, however, the great advantages of Peltier refrigeration render possible the development of new-type practical equipment and simple solutions of many technical problems. Starting from the basic principles of thermoelectric cooling and construction of thermo-elements, designs of actual cooling equipments are described and the costs of installation and running are estimated.

ELA '62

Zur Verbesserung der Effektivitaet von Peltier-Element-Werkstoffen, G.HAACKE. Kaeltetechnik v 14 n 3 Mar 1962 p 66-9. Improvement of effectivity of Peltier element materials; upper limit of effectivity is estimated, which has so far not been reached, and would require semiconductors with energy gaps greater than 0.15 ev; properties of some materials are considered, pertinence being to their use in refrigeration.

EI '62

AD-297 168 Div. 8
(TISTW/PCR)

Westinghouse Electric Corp., Youngwood, Pa.
THERMOELECTRIC TEMPERATURE CONTROL FOR QUARTZ CRYSTALS AND CRYSTAL OSCILLATORS.
Final rept., 1 Apr 61-31 Mar 62,

by T. D. Merritts and J. C. Taylor. 31 Mar 62, 124p. incl. illus. tables, 16 refs.
(Contract DA 36-039-sc-87190)
Unclassified report

DESCRIPTORS: *Thermoelectricity, *Thermocouples, *Crystal oscillators, Temperature, Theory, Cooling, Design, Semiconductors, Circuits, Rectifiers, Inverter circuits, Inverters, Resistance (Electrical), Thermal conductivity, Analog computers, Photographs, Control systems, Quartz.

An approximate design procedure on a thermoelectric single couple is presented using average values of material parameters. Emphasis is placed on which of the variables (hot side temperature, cold side temperature and net heat pumping rate), may be specified. Two basic unknowns arise in the solution for the behavior of a thermoelectrically cooled chamber. The first is the heat flow-temperature difference characteristic of the heat rejecting fins. The second is the rate of heat leak through the chamber walls into the enclosure from the surroundings. When both of these quantities are established, it is theoretically possible to describe the behavior of a given chamber and to analytically design the module needed for given ambient conditions and cold side temperature. (Author)

163

Thermoelectric air conditioner. Franklin Inst J 273:261 Mr '62

Thermoelectric ice cube maker developed. il diag Air Cond Heat & Ven 59:129 Mr '62

AS 4TI '62

Termoelektriska halvledarmaterial, O.BECKMAN, P.BERGVALL Elteknik v 5 n 4 Apr 1962 p 49-54. Thermoelectric semiconductors; examples of thermoelectric cooling and power generation to show how theory can help practical technology.

EI 162

Theory of Ettingshausen Cooler. M.R.EL-SADEN. J Applied Physics v 33 n 5 May 1962 p 1800-3. Cooling system based on Ettingshausen and Nernst-Ettingshausen effects; thermodynamic analysis is carried out and coefficient of performance is determined; dimensionless thermomagnetic figure of merit deduced; for effective cooling, materials with high thermomagnetic numbers are required; brief review of relevant transport processes is made, which shows that intrinsic semiconductors within certain temperature ranges, are most suitable for Ettingshausen cooler. EI '62

First thermoelectric cooler uses bismuth telluride heat pump. il diag Materials in Design Eng 55:12 My '62

AS&TI '62

Thermoelectric cooling arrives. il Iron Age 189:105 My 31 '62 F. J. Starin.

AS&TI '62

Thermoelectric Generators as Power Sources for Thermoelectric Refrigerators. B.J.STERN. Solid State Design v 3 n 5 May 1962 p 31-4. Analysis to obtain criterion for realizing optimum value of coefficient of performance of combination generator and refrigerator.

EI '62

Thermoelectric Devices and Materials. R.WOLFE, J.H.WERNICK. Bell Laboratories Rec v 40 n 6 June 1962 p 190-4. New types of thermoelectric refrigerators and electricity generators; theory of operation of semiconductors in thermoelectric cooling; use of disordered semiconductors and semimetals; applications to provide bias for tunnel diodes, laboratory refrigerators, optical maser coolers and quartz crystal oscillator temperature control. EI62

Thermoelectric air conditioner developed for navy. il Heating-Piping 34:43 Je '62

AS&TI '62

12393 THEORY OF MINORITY CARRIER THERMOELECTRIC COOLING. M.A.Melehy.

J. appl. Phys. (USA), Vol. 33, No. 6, 2106-6 (June, 1962).

The possibility of backward injection of minority carriers in p-n junctions is shown. It is predicted that in a forward-biased p-n junction where this type of injection occurs, heat energy is pumped out of the junction causing it to cool off. Some conditions which lead to backward injection of minority carriers are described. Theory is presented for a particular p-n junction model in which this new cooling effect takes place. It is shown that a given d.c. electrical energy may be used to pump nearly an equal amount of heat energy from one of the junctions to the neighbouring ones provided that the junction temperatures are sufficiently close to each other.

EEA '62

12389 THE PROSPECTS FOR ETTINGSHAUSEN AND PELTIER COOLING AT LOW TEMPERATURES.

R.T.Delves.

Brit. J. appl. Phys., Vol. 13, No. 9, 440-5 (Sept., 1962).

It is shown that the ambipolar Ettingshausen effect might be employed in a semi-metal or an intrinsic semiconductor to obtain useful cooling. The material should preferably have an energy gap less than kT, high effective masses and mobilities for both electrons and holes and a low lattice thermal conductivity. It is more likely that the right combination of properties will be found at low temperatures than at room temperature. It is also possible that phonon drag effects could increase the cooling effect. For this to happen the requirements are the same, except that the lattice thermal conductivity need not be low. So far, materials which have the required properties have not been found but by extrapolating from known semiconductors and semi-metals it is estimated that 80°C of cooling at 80°K might be obtained from purely electronic effects. Higher values are rather unlikely, unless phonon drag effects could be exploited. Peltier cooling at low temperatures is also discussed briefly.

EEA '62

Thermoelectric air conditioner for people tested. il Elec Eng 81:544 Jl '62

Refrigeration without a motor: thermoelectric cooling. diag Food Eng 34:81 S '62

AS&TI '62

1438 COMPARISON OF ZONE MELTED AND SINTERED MATERIAL FOR THERMOELECTRIC REFRIGERATION DEVICES. A.R.Sheard.

J. Electronics and Control (GB), Vol.13, No.3, 253-62 (Sept., 1962).

Some advantages of powder metallurgy techniques for the preparation of bismuth telluride type alloys are discussed. Emphasis is placed on the ease of preparation, uniformity, reliability and mechanical advantage of powder metallurgy products.

EEA '63

AD-286 385 Div. 25
(TISTM/EJH) OTS price $2.60

New York State Coll. of Ceramics, Alfred U.
STEADY STATE AND TRANSIENT THEORY OF THERMO-ELECTRIC COOLING JUNCTIONS.
Technical rept. on Semiconducting Materials, by T. J. Gray. Sep 62, 23p. incl. illus. table, 6 refs.
(Contract Nonr-150301, Proj. NR 015-215)
Unclassified report

DESCRIPTORS: *Thermoelectricity, *Cooling, *Semiconductors, Theory, Mathematical analysis, Integral transforms, Solid state physics,

The theory of Peltier cooling with semiconductors has, up to this date, been dealt with in a limited manner. Equations expressing the stationary and transient behavior of Peltier cooling junctions have been used to determine the theoretical behavior of thermoelements subject to direct current as well as to pulses of varying shape, length, and frequency. These equations have established results which, although agreeing in some respects, are not always consistent with experimental evidence. It seems that where disagreements do arise, the reason is that not all conditions intervening in Peltier cooling have been considered in these equations, conditions which are considered too important to be neglected. The exact solution of an equation which takes more factors into account and which expresses the stationary and transient behavior of Peltier cooling junctions is presented. (Author)

163

AD-404 802 Div. 25, 8, 9
(TISTM/PCR) OTS price $4.60

Rome Air Development Center, Griffiss Air Force Base, N. Y.
INVESTIGATION OF UNCONVENTIONAL COOLING TECHNIQUES,
by John B. McCormick and Thomas W. Walsh.
Nov 62, 43p.
Proj. 5519, Task 551904
RADC RAS TM62 6 Unclassified report

Descriptors: *Cooling, *Thermoelectricity, *Ultrasonic radiation, *Cryogenics, Materials, Manufacturing methods, Low temperature research, Power supplies, Resistance (Electrical), Resistors, Transistors, Germanium, Capacitors, Liquefied gases, Nitrogen, Electronic equipment, Solid state physics, Semiconductors, Capacitance, Electric potential, Bismuth compounds, Tellurides, Transducers (Acoustic), Titanates, Barium compounds, Silicon.

Thermoelectric and ultrasonic cooling techniques were investigated along with cooling by immersion in a cryogenic fluid. The purpose of this effort was to determine the applicability of these techniques for the cooling of electronic equipment. Experimental results are evaluated, a comparison of these techniques has been included, and recommendations concerning the application of each technique are presented. (Author)

163

Developments in Field of Thermo-Electricity, G.GRAMBERG, H.G.PLUST. Brown Boveri Rev v 49 n 11-12 Nov-Dec 1962 p 501-14. Principles of thermoelectric production of energy and electrothermal refrigeration are discussed in connection with production and properties, technological problems, and measurements of thermoelectric materials; salient points concerning development work of electrothermal refrigeration, construction of equipment and applications.

ET163

3398 THEORY OF THE NERNST-ETTINGSHAUSEN GENERATOR. D.A.Wright.
Brit. J. appl. Phys., Vol. 13, No. 12, 583-6 (Dec., 1962).

The theory is developed for using the Nernst-Ettingshausen effect in non-degenerate semiconductors as a generator of power. A figure of merit is determined, and it is shown that the maximum efficiency η_{max} depends upon this together with the operating temperatures. The efficiency is determined for the semiconductor itself, disregarding the power required to produce the magnetic field. For an extrinsic semiconductor η_{max} passes through a maximum as magnetic field rises, but for the temperatures considered ($T_H = 1000°C$, $T_c = 0°C$) this is only 0·75%, even when the semiconductor parameters are particularly favourable. For an intrinsic semiconductor, however, much better performance is possible, but only at very high magnetic fields and with favourable materials. Electrons and holes must both have high mobilities at the operating temperatures, and the lattice thermal conductivity must be very low. The energy gap must also be within an optimum range. Magnetic fields well above 10^4 Oe will be necessary. The use of superconducting magnets would, however, make this possible. PA '63

Thermoelectric cooling. J. E. Bean. il diags Ind Electronics 1:110-13 N; 132-4 D '62
AS & TI '63

Selection of Hot Junction Temperatures for Minimum Fin Area Thermoelectric Refrigerators, C.L.FELDMAN. ASHRAE—Trans v 68 1962 p 48-55. Comparative advantages of first order and second order theories used in calculation of hot junction temperatures; graphical solution to first order optimization equation; optimum temperature rise as function of thermoelectric Figure of Merit; optimum temperature difference found for 5 different temperature combinations. EI '63

AD-299 975 Div. 25
(TISTM/ODN) OTS price $6.60

Louisiana State U., Baton Rouge.
EFFECT OF PRESSURE ON THE OSCILLATION'S PERIOD IN THE ETTINGSHAUSEN-NERNST EFFECT IN ZINC AT HELIUM TEMPERATURE.
Interim rept. no. 3,
by R. J. Deck, C. G. Grenier, and J. M. Reynolds.
Jan 63, 62p.
(Grant DA-ORD-31-124-61-G76)
(AROD 1579:10) Unclassified report

DESCRIPTORS: *Zinc, *Thermoelectricity, Liquefied gases, Cryogenics, Hall effect, Helium, Hydrogen, Solidified gases, Oscillations, Brillouin zones, Pressure, Experimental data, Metallic crystals, Theory.
'63

Dynamic Behavior of Thermoelectric Heat Pump, R.ZITO, Jr. Electro-Technology v 71 n 2 Feb 1963 p64-9. Fundamental aspects of thermoelectric phenomena are outlined and their significance with regard to operation of heat pump (refrigerator) is given in detail; basic design parameters for such system. EI '63

3841 DYNAMIC BEHAVIOR OF A THERMOELECTRIC HEAT PUMP. R.Zito,Jr.
Electro-Technology (USA), Vol. 71, No. 2, 64-70 (Feb., 1963).

The fundamental aspects of thermoelectric phenomena are outlined and their significance with regard to the operation of a heat pump (refrigerator) is given in detail. An outline of the basic design parameters for such a system is presented. EEA '63

Thermoelectric cooling. O. Romaine. bibliog Space/Aeronautics 38 no 2:F 15-19 '62-63
AS & TI '63

14956 FOUNDATIONS OF THERMOELECTRIC REFRIGERATION. I. I.J.Navarro Martinez.
Rev. Cienc. apl. (Spain), Vol. 17, No. 1, 22-4 (Jan.-Feb., 1963).
In Spanish.

Reviews the thermodynamics of thermoelectric refrigeration.
L.Pincherle
EEA '63

8575 THE PERFORMANCE OF A THERMOELECTRIC HEAT PUMP WITH SURFACE HEAT TRANSFER.
C.N.Rollinger and J.E.Sunderland.
Solid-State Electronics (GB), Vol. 6, 47-57 (Jan.-Feb., 1963).

The differential equations which describe the steady state temperature distribution in a thermoelement with constant properties and with convective heat transfer from its longitudinal surface are presented and solved analytically. The solutions are applied to a single-element thermoelectric heat pump to determine the effect of surface heat transfer upon the maximum temperature difference, the maximum heat pumping, and the maximum coefficient of performance. The results show that each of these three performance criteria can be increased through the use of surface heat transfer. It appears that gains in the maximum heat pumping of the order of 200% are readily attainable through the use of this heat transfer mechanism. Gains in performance are found to increase as the convective heat transfer coefficient increases. The results show that in order to use surface heat transfer to improve performance, part of the element near the cold junction must always be insulated. The expressions which are presented can be used to calculate the optimum fraction of the element to be insulated for any given set of conditions. PA '63

Die elektrothermische Kuehlung, F.SAWITZKI. Elektrowaerme v 21 n 3 Mar 1963 p 117-21. Thermoelectric cooling; method based on Peltier effect is especially important in cases where small areas or spaces must be cooled; energy conversion phenomena occurring in cooling element are explained and relationship between rate of heat absorption and coefficient of performance and input of electric current described; design of Peltier element given; some applications are outlined to show type of cooling problems that can be solved advantageously by using modern Peltier units. EI 63

Theory of Nernst Generators and Refrigerators, M.H.NORWOOD. J Applied Physics v 34 n 3 Mar 1963 p 594-9. Formulas for efficiency and coefficient of performance derived for devices based on Nernst and Ettingshausen effects; equations reduce to those of Harman and Honig but they do not approach Carnot limits; to obtain better device theory, one must solve 2 dimensional partial differential equation in which current density is allowed to vary with position; Hg-Cd-Te alloys are perhaps best materials at present. EI 63

Thermomagnetic Figure of Merit and Ettingshausen Cooling in Bi-Sb Alloys, K.F.CUFF, R.B.HORST, J.L.WEAVER, S.R.HAWKINS, C.F.KOOI, G.M.ENSLOW. Applied Physics Letters v 2 n 8 Apr 15 1963 p 145-6. Cooling below heat sink temperature obtained using Ettingshausen cooler consisting of properly oriented single crystal of Bi(97)Sb(3); Ettingshausen refrigerator requires only 1 element in contrast to Peltier refrigerator which requires both n-type and p-type element; also, properly shaped single element can provide performance of infinitely staged cooler. EI '63

14957 FOUNDATIONS OF THERMOELECTRIC REFRIGERATION. II. J.Navarro Martinez.
Rev. Cienc. apl. (Spain), Vol. 17, No. 2, 126-31 (March-April, 1963).
Discusses particularly the figure of merit of various semiconductors. L.Pincherle
EFA '63

Review of Thermoelectric Refrigeration, R.L.EICHHORN. IEEE—Proc v 51 n 5 May 1963 p 721-5. Principles of thermoelectric refrigeration, and current state of art in thermoelectric materials; design problems in developing thermoelectric devices and some of current techniques used to solve them; some information is provided on devices that have been built for United States Navy and for commercial application. EI '63

Rapid freeze-drying of biological tissues with a thermoelectric unit. A. G. E. Pearse. bibliog il J Sci Instr 40:176-7 Ap '63
AS & TI '63

10027 THERMOELECTRIC TRANSIENTS.
J.B.Horvay.
IEEE Trans Applic. Industr. (USA), No. 66, 111-15 (May, 1963).
It is possible in a thermoelectric cooling device to obtain significantly reduced cold-junction temperatures, compared to the steady-state values, by utilizing transient conditions. This effect is only temporary, and it might find applications where the aim is to reach the coldest possible temperature with minimum equipment in the shortest time, without need to maintain that temperature once it is reached. A thermoelectric cooling device was built to demonstrate the practicality of the transient effect. EEA '63

Cooled microscope stage using semiconductor thermoelectric cooling. J. C. W. Crawley. diags J Sci Instr 40:330 Je '63

AS&TI '63

621.305

8600 THERMOELECTRIC AND THERMOMAGNETIC COOLING.
H.J.Goldsmid.
Industr. Electronics (GB), Vol. 1, No. 8, 441-4 (May, 1963).
Although the Peltier effect has been known a long time, it is only recently that materials have been developed which have enabled it to be of practical use. The article discusses the requirements and considers the possibilities of another effect—the little-known Ettingshausen effect. EEA '63

10029 CONSTRUCTIONAL DESIGN AND USE OF PELTIER REFRIGERATING UNITS IN REFRIGERATING SYSTEMS.
H.Müller.
Siemens-Z. (Germany), Vol. 37, No. 5, 383-8 (May, 1963). In German.
An account of thermoelectric phenomena is followed by details of the Peltier effect and the power balance of Peltier elements. An appraisal of the economy of Peltier refrigerating units indicates their possible range of application. In conclusion some examples of the use of Peltier refrigerating units in small refrigerating systems are noted. EEA '63

Thermoelectric Heating and Cooling—Application to Air-Conditioning Systems, A.B.NEWTON, K.V.SCHMITTLE. ASME—Paper 63-MD-10 for meeting May 20-23 1963 7 p. Application of semiconductor materials, e.g., bismuth telluride, to thermoelectric heat pump air conditioning system, resulting in improved operation and more precise control of temperature and humidity. EI 63

Ice point maintained thermoelectrically and regulated by change of state. C. D. Cox and W. D. Edwards. diags R Sci Instr 34: 704-5 Je '63

AS&TI 163

Theory of Longitudinally Isothermal Ettingshausen Cooler, C.F. KOOI, R.B.HORST, K.F.CUFF, S.R.HAWKINS. J Applied Physics v 34 n 6 June 1963 p 1735-42. Temperature distribution, maximum temperature difference, and coefficient of performance are determined for cooler of rectangular cross section; calculation is carried out for 2 cases, temperature independent transport coefficients and Nernst and resistivity coefficients proportional to T^{-1}; in both cases results differ from Peltier cooler only for temperature distribution; this allows validity of results to be established for all possible values of figure of merit. EI 63

Reference Junctions, L.SILVERMAN. Instruments & Control Systems v 36 n 6 June 1963 p 107-8. Thermocouple reference junctions are described to compensate for voltage produced by thermal emf at secondary junctions; junction by Consolidated Ohmic Devices, Inc are discussed, used in Saturn, Nike, Zeus and other missiles. EI 63

8604 EXPERIMENTS WITH PELTIER JUNCTIONS PULSED WITH HIGH TRANSIENT CURRENTS.
M.Idnurm and K.Landecker.
J. appl. Phys. (USA), Vol. 34, No. 6, 1806-10 (June, 1963).

Landecker and Findlay [see Abstr. 16762A of 1962; Solid-state Electronics (GB), Vol. 3, No. 3-4, 239-60 (Nov.-Dec., 1961)] that when transient currents are passed through a cooling Peltier junction the resulting transient temperature depends stongly on the current waveform. In particular, an extremal of the current as a function of time exists for which the resulting transient temperature is much lower than for any other current waveform. With the aid of an experimental method developed for the purpose, temperatures well below 100°K were in fact observed with bismuth telluride junctions. Since the occurrence of temperature transients producing such low junction temperatures is rather difficult to reconcile with some notions of solid-state theory, these results have been re-examined for current densities of up to ~4000 A/cm² using a modified technique that eliminates possible sources of systematic errors in the previous method. The results may be summarized as follows. Up to the highest current densities that could be produced a monotonic increase of the temperature drop with final current density was observed. The final temperature drops ranged from 205° to 120° measured from a reference temperature of ~20° (room temperature) depending on the efficiencies of the junctions. These efficiencies were difficult to predict from the performance of the junctions with stationary currents. For the highest currents and the very low transient temperatures an error of up to 150° may arise from imperfect heat transfer from the hot junctions to the water-cooled heat sinks unless special probes are provided to measure the Seebeck voltage. It is very likely that the accuracy of the measurements cannot be expected to be improved much further as long as grown crystalline n and p branches are used. It is hoped to produce sintered junctions of more suitable shape and greater mechanical strength for further experiments.

EEA '63

10026 GRAPHICAL METHODS OF SOLVING THERMOELECTRIC-HEAT-PUMP PROBLEMS. P.C.Watson.
Electro-Technology (USA), Vol. 71, No. 6, 74-7 (June, 1963).

A test procedure is outlined for producing characteristic data of heat-pump modules as the basis of working charts for cooling-systems design. Six examples and their solutions are presented.

EEA '63

Ettingshausen Cooling in Pyrolytic Graphite, D.A.WRIGHT. Brit J Applied Physics v 14 n 6 June 1963 p 329-34. One of few materials having small energy gap and high mobility of electrons and holes at low temperature is single crystal graphite; measurement of Nerst coefficient for pyrolytic graphite as deposited at 2100-2200 C; reheated pyrolytic graphite is not likely to give phonon-drag effects as large as in natural single crystals. EI '64

15638 MINORITY CARRIER THERMOELECTRIC COOLING. W.M.Bullis.
J. appl. Phys. (USA), Vol. 34, No. 6, 1648-9 (June, 1963).

The fallacy in a recently proposed theory of minority-carrier cooling is pointed out. The correct approach is given and the current literature on the subject is summarized. It is emphasized that cooling devices utilizing minority-carrier effects are normally less efficient than conventional thermocouple modules.

PA '63

Thermoelectric and Thermomagnetic Cooling, H.J.GOLDSMID. Indus Electronics v 1 n 8, 9 May 1963 p 441-4, June p 467-70. May. Review of principal physical parameters characterizing suitability of semiconductors for thermoelectric cooling; characteristics of bismuth telluride alone and alloyed with antimony telluride and bismuth selenide. June. Examples of thermoelectric cooling units; Ettingshausen (thermomagnetic) effect examined theoretically and its potential performance compared with Peltier (thermoelectric) effect; it is concluded that electronic cooling applications will probably favor thermoelectric cooling for room-temperature range, thermomagnetic cooling for extremely low-temperature range.

Experiments with Peltier junctions pulsed with high transient currents. M. Idnurm and K. Landecker. il diag J Ap Phys 34: 1806-10 Je '63

ASTI '63

19167 THERMOELECTRICAL COOLING: MATERIAL CHARACTERISTICS AND APPLICATIONS. A.G.Heaton. Proc. Instn Elect. Engrs (GB), Vol. 110, No. 7, 1277-87 (July, 1963).

The most outstanding and useful application of the reversible thermal and electrical effects, which occur at the junctions of certain semiconductors, is the application of the Peltier effect to small-scale cooling. The theory of Peltier cooling is outlined, together with methods of producing couples, or multi-couple units, from the basic p- and n-type thermoelements available commerically. Simple measurements can be made during construction to ensure that units perform in a predictable manner. To illustrate the particular problems involved in thermoelectric measurements, an account is given of rapid-check methods and of the more sophisticated techniques used to ascertain the quality of thermoelements and couples. The design of a manually-variable power supply capable of producing smooth direct current for a range of composite cooling units is considered, with a view to obtaining a compact reliable unit by using transductor control. A constant-temperature enclosure is described which is intended for use as a cold-junction reference for conventional thermocouples in place of the more usual ice/water reference used for temperature measurements. This is an example of a simple on-off control of cooling power. Finally the design and performance of a dew-point hygrometer are given in order to illustrate the potentialities of thermoelectric cooling applied under proportional servo-control conditions.

PA '63

Thermoelectric immersion cooler developed; Whirlpool corp. il Chem & Eng N 41:80 Jl 29 '63

Thermolectrical cooling; material characteristics and applications. A. G. Heaton. diags Inst E E Proc 110:1277-87 Jl '63

AS TI 163

Nernst-Ettingshausen (Transverse) Energy Conversion, T.C. HARMAN, J.M.HONIG. Semiconductor Products v 6 n 7 July 1963 p 19-24. Survey of direct energy conversion based on Nernst and Ettingshausen (NE) effects, comparing it with Seebeck-Peltier (SP) techniques; principles of NE generators and refrigerators; operating-characteristic equations of SP and NE devices compared as to optimal efficiency of generator, optimization requirement, figure of merit, optimal coefficient of performance of refrigerator, and optimal temperature difference of refrigerator under zero heat load; criteria for optimizing NE device performance; recent experiments and future prospects. 23 refs.

EI 64

Grundlagen der thermoelektrischen Kaelteerzeugung, E.B.PENROD. Kaeltetechnik v 15 n 8 Aug 1963 p 219-26. Fundamentals of thermoelectric refrigeration; Seebeck, Peltier, Thomson effects and Joule and conduction heat are in all thermocouples when they are used as thermoelectric refrigerating machines; these effects are clarified, and equations applicable to all thermocouples are introduced for determining performance characteristics of highly idealized thermoelectric refrigerator consisting of single thermocouple in module.

EI '63

13157 APPROXIMATE DYNAMIC RESPONSE CALCULATIONS FOR THERMOELECTRIC PELTIER-EFFECT DEVICES.
P.E.Gray.
Solid-State Electronics (GB), Vol. 6, No. 4, 339-48 (July-Aug., 1963).

In most applications of thermoelectric cooling devices that require close control of temperature, the dynamic or non-steady-state behaviour of the entire system is important. Previously reported dynamic characterizations of such systems have yielded predictions of performance that are in good agreeement with observed performance. However, these methods, which take into account the distributed nature of the thermoelectric device, give moderately complicated results that are not easy to apply. It is shown that for most cases of practical interest the dynamic response of the thermoelectric temperature-control system is dominated by the thermal mass of the load. Accordingly, the dynamic operation of the thermoelectric cooling device can be regarded as a succession of steady states, and the distributed system can be lumped, thus yielding accurate approximate results that are simple and easy to apply. The conditions under which such a representation is valid are delineated, and the corresponding approximate results are obtained in the form of transfer functions. The step response of a temperature-control system is determined by means of this approximate method and compared with the response determined from consideration of the complete distributed system. This comparison shows that the lumped approximtation is a valid and useful characterization of thermoelectric temperature-control systems.

EEA '63

13161 THE EFFECT OF FINITE HOT AND FINITE COLD JUNCTION FINS ON THE PERFORMANCE OF A THERMOELECTRIC HEAT PUMP. L.J.Ybarrondo.
Solid-State Electronics (GB), Vol. 6, No. 4, 357-64 (July-Aug., 1963).

Analytical solutions are given for the steady-state temperature distribution, no-load temperature difference, heat-pumping capacity and coefficient of performance of a thermoelement used as a thermoelectric heat pump with finite hot and cold junction fins. The longitudinal surface of the thermoelement is assumed to be insulated. The surface heat-transfer coefficient over the hot and cold junction fins is arbitrary. A numerical example is worked in which performance curves are compared for cases of infinite and finite fin conductance at the junctions of a simple thermoelectric heat pump. A method of augmenting device performance by realistic fin design is shown; or, conversely, a method of economizing on fin size and the anticipated decrease in device performance is shown.

EEA '63

Design-in your own thermoelectric cooling. R. Crump. il diags Product Eng 34:81-9 S 16 '63

AS&TI 163

Transient Performance of Thermoelectric Refrigerator under Step-Current Control, W.F.STOECKER, J.B.CHADDOCK. ASHRAE J v 5 n 9 Sept 1963 p 61-7. Equation is derived that gives accurate predictions for transient temperature of cold junction, provided assumed boundary conditions of equation are reasonably satisfied in operation of couple; laboratory experiments show that equation can be applied to calculation of performance of thermoelectric refrigerator during start-up from idle condition, or to cumulative performance which will result from capacity regulation by step-current control.

EI 63

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