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HEAT PIPE TECHNOLOGY

QUARTERLY UPDATE

JANUARY 1 THROUGH MARCH 31, 1972

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TECHNOLOGY APPLICATION CENTER
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ALBUQUERQUE, NEW MEXICO 87106

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HEAT PIPE TECHNOLOGY

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QUARTERLY UPDATE

MARCH 31, 1972

ASSEMBLED BY

THE HEAT PIPE INFORMATION OFFICE

of

THE TECHNOLOGY APPLICATION CENTER
INSTITUTE FOR SOCIAL RESEARCH & DEVELOPMENT
THE UNIVERSITY OF NEW MEXICO
ALBUQUERQUE, NEW MEXICO

PREFACE

Heat Pipe Technology is a continuing bibliographic summary of research on the subject of the heat pipe. The first volume was published in the spring of 1971 and is cumulative through March of that year. A 1971 Annual Supplement has been published and distributed. Additional copies are available from the Technology Application Center.

This update to Heat Pipe Technology cites the additional references identified during January, February, and March of 1972. It is the first in a 1972 quarterly series intended to provide "current awareness" to heat pipe researchers.

A library containing essentially all of the articles and publications referenced in this update, the cumulative volume, and in the 1971 Annual Supplement has been established. Although a considerable effort has been made to insure that the bibliography is complete, readers are encouraged to bring any omissions to the attention of this office.

The Technology Application Center is one of six regional dissemination centers established by NASA's Technology Utilization Program to evaluate and disseminate new technology to the general public and commercial business.

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A. GENERAL INFORMATION, REVIEWS, SURVEYS

No citations in update, March 31, 1972

B. HEAT PIPE APPLICATIONS

B. 1 General Applications

72000 LOW TEMPERATURE HEAT PIPE USED AS A THERMAL SWITCH
Kopf, L. (Bell Telephone Laboratories, Inc., Murray Hill, N.J.). Review of Scientific Instrumentation, 1971, 42(12), p. 1764-1765, Avail: TAC

A device, based on the heat pipe principle, is described in an application as a thermal switch at very low temperatures. The presence or absence of a high purity liquefied gas in the heat pipe is the basis for the switch being on or off.

72001 TECHNIQUE FOR MEASURING HIGH-TEMPERATURE THERMAL CONDUCTIVITY OF SOLIDS BY THE USE OF A HEAT PIPE
R. Forman (NASA, Lewis Research Center, Cleveland, Ohio) Journal of Applied Physics, Vol. 42, Dec. 1971, p. 5872-5874, Avail: TAC

A suggested technique for accurately measuring thermal conductivity of solids in the temperature range 800-1500 C is presented. The procedure employs the sample to be tested in series combination with a high-temperature heat pipe and a heat-transfer device, which has a variable thermal conductance. By changing the thermal conductance of the heat-transfer unit and measuring the change in heat pipe power input to maintain a constant heat pipe temperature, one can accurately measure the heat flux through the sample in conjunction with the temperature drop across it. This steady state technique has some inherent advantages over methods currently employed to measure thermal conductivity at elevated temperatures.

72002 A NEW COOLING METHOD FOR METAL CUTTING TOOLS PHASE I
N.P. Jeffries, R.D. Zerkle, and P.A. Marks, prepared for U.S. Naval Ordnance Systems Command, Industrial Resources Division ORD 047, Washington, D.C., November 1969, 83 p., 75 refs., Avail: TAC

The report presents results of an experimental and analytical study of the use of heat pipes to cool metal cutting tools. The effectiveness of this cooling method depends upon cutting conditions, materials, and coolant properties. However, a considerable temperature reduction, may be obtained by this system under most practical cutting conditions. The new method decreases flank wear and increases tool life. Sketches of the tool and improvements in the cooling system design are also included.

72003 THE HEAT PIPE - OVERCOMING THE THERMAL RESISTANCE BARRIER

A.J. Streb (Dyna-Therm Corp., Cockeysville, Md.), Electronic Packaging and Production, Vol. 11, Dec. 1971, p. 40-42, 44, Avail: TAC

Discussion of heat pipe technology applications. Special attention is given to heat removal from large discrete components, to the incorporation of heat pipes into totally enclosed package structures as required in hostile environments, and to their use in variable conductance temperature levellers as a simple and reliable remedy for performance fluctuations and loss of reliability in electronic systems exposed to environment temperature variations. Numerous useful applications in electronic packaging are visualized for variable conductance heat pipes with and without feedback.

B. 2 THERMIONIC AND THERMOELECTRIC CONVERTERS

72004 MODERATED THERMIONIC REACTOR CORE

Robert R. Hobson, Robert N. Scott, Paul R. Hill, U.S. Patent 3,607,631, Sept. 21, 1971. Filed November 6, 1968, See Patent Section (order as a patent), Avail: TAC

A moderated thermionic core assembly has been provided which employs vapor chamber condenser-cooled stacked thermionic fuel elements. A cylindrical moderator block is provided with a plurality of radial wells drilled in an ordered array about the periphery of the moderator block. Each well is adapted to receive a tubular fuel element which includes two series-connected nuclear fueled thermionic converter elements having a neutral plasma maintained between the emitter and collector electrodes of each converter. Each fuel element includes a vapor chamber condenser which extracts excess heat from the collectors and transmits it to an external reflector from which the excess heat is radiated to space.

72005 REFERENCE DESIGN FOR A THERMOELECTRIC ISOTOPE POWER UNIT EMPLOYING HEAT PIPE MODULES

A.P. Fraas, M.E. LaVerne (Oak Ridge National Lab, Tennessee) November 1971, Contract W-7405-eng-26, 58 p., Avail: TAC

A reference design for a 2 kW(e) thermoelectric power unit has been evolved to serve as the basis for technology evaluation tests in Task II of the Isotope Kilowatt Program. This reference design makes use of potassium heat pipes to transport heat to thermoelectric modules from the same basic heat block-shield assembly as would be used for the organic and steam Rankine cycle systems of this program. The heat block-shield employs seven capsules of ^{90}Sr in the form of $SrTiO_3$ encased in Hastelloy. Designs for both iron and nickel heat block-shield units have been prepared. Twelve thermoelectric modules; each with a 1-in. diameter, 79-in. long heat pipe, are designed to produce 167 W each at 24 V. They can be coupled in a series-parallel arrangement to yield 2 kW(e) at 48 V. The design is based on lead telluride thermoelectric junctions, but is equally well suited to use with advanced materials yielding a higher efficiency when these become available. The design studies have been extended to include an investigation of the improvement in performance that might be obtained with the new TPM-217 thermoelectric material under development at the 3M Company. Studies at 3M under an ORNL subcontract show promise of increasing the overall thermal efficiency from the 8.5% estimated for the present lead telluride material to 11.1% for the TPM-217 material. This improvement would entail increasing the hot junction temperature from 1050 to 1350°F, and would require the use of nickel in place of iron for the heat block-shield assembly.

72006 PLANNING AND OPTIMIZATION OF A FAST HEAT PIPE THERMIONIC REACTOR
H. Hanke (University of Stuttgart), Atomkernenergie; 18: No. 2, 143-150, 1971, In German, Avail: TAC

By means of the reflector economy concept and for a given arrangement of fission zone and reflector, an analytical connection can be established between the geometry and reactor power, weight, and cost. Because of this fact, analytical optimization becomes possible. Optimal dimension and, thereby, reactor cost strongly depend on thickness of the reflector whereby radial and axial thickness must be treated separately. If properly constructed, fast thermionic reactors, in spite of high cost of fission material, can compete with thermal thermionic reactors even at small power demands. Fast thermionic reactors may even become more economical than thermal reactors because of their compactness requiring a relatively low weight of shielding.

B. 3 AEROSPACE ORIENTED APPLICATIONS

No citations in update, March 31, 1972

B. 4 NUCLEAR SYSTEMS

72007 DYNAMICS OF HEAT PIPE REACTORS
G.F. Niederauer (NASA, Lewis Research Center, Cleveland, Ohio) American Nuclear Society, Winter Meeting, Miami Beach, Florida, Oct. 17-21, 1971, 11 p., 8 refs., Avail: TAC

A split-core heat pipe reactor fueled with either 233-UC or 235-UC in a tungsten cermet and cooled by 7-Li-W heat pipes is examined for the effects of the heat pipes on this reactor in trying to safely absorb large reactivity inputs through inherent shutdown mechanisms. Limits on ramp reactivity inputs due to fuel-melting temperature and heat pipe wall heat flux are mapped for the reactor in both startup and at-power operating modes.

72008 OPTIMIZATION OF A SHIELD FOR A HEAT PIPE COOLED FAST REACTOR DESIGNED AS A NUCLEAR ELECTRIC SPACE POWER PLANT

W.W. Engle, Jr., R.L. Childs, F.R. Mynatt, and S. Lorraine, June 15, 1971, 41 p., Refs. Contract W-7405-eng-26, Avail: TAC

An optimization procedure based on the ASOP shield optimization computer code and the DOT radiation transport code was used to determine a minimum-weight shield for a small fast reactor designed for a space nuclear electric power plant. The cylindrical reactor, is fueled with UN and cooled by liquid K circulating through a matrix of stainless steel heat pipes embedded in the core; the design power is 450 kW(t). The surrounding shield is typically asymmetric. The dose constraints are 3 mrem/hr at all 100-ft radii falling within the shadow cast by the base of the cone and 300 mrem/hr at all other 100-ft radii. The optimized shield consists of alternate layers of W and LiH, the thick bottom section extending out to a radius of 112 cm and the tapered side decreasing to a radius of 89 cm. The top heat pipe shield region consists of a 59-cm-thick inner layer of a stainless-steel-B4C mixture and a 30.5 cm thick outer layer of a BeO-B4C mixture. The total shield weight is 25,589 lb. A partially optimized shield has a total weight of 14,708 lb. These shield weights include an allocation for 3.5 vol% of stainless steel structure in the LiH regions.

B. 5 ELECTRONIC APPLICATIONS

No citations in update, March 31, 1972

C. HEAT PIPE THEORY

C. 1 GENERAL THEORY

72009 HEAT PIPES - A SURVEY
L.L. Vasil'ev and S.V. Konev (Akademiia Nauk Belorusskoi, SSR, Institut Tepol-i Massoobmena, Minsk, Belorussian SSR) (Inzhenerno-Fizicheskii Zhurnal, Vol. 20, March 1971, p. 550-566) Heat Transfer - Soviet Research, Vol. 3, November, December , 1971, p 96-113, 7 refs, Translation, Avail: TAC

A review is presented of the recent progress achieved in theoretical understanding of the operating conditions of heat pipes. The processes occurring in the evaporator, condenser, adiabatic part of the tube, and in the wick are examined. The theory of capillary transport of fluids is employed to present a method for heat pipe calculation. Experimental data on the operating conditions are given, and several applications of heat pipes are dealt with.

72010 TUBE WITH HIGH HEAT TRANSFER CAPACITY
A. Leca (Inst. Politeh-Bucuresti, Bucharest, Rom) Energetica 1971, 19(8), 409-13 (Rom), 11 refs., Avail: TAC

A review is given of the theory and operating characteristics of heat pipes (heat transfer devices, combining vaporization-condensation and capillary force effects) used for very high thermal conductance.

72011 TWO-METAL HEAT PIPE OVEN OPERATION, DYNAMICS AND USE IN SPECTROSCOPIC INVESTIGATIONS
M.M. Hessel, P. Jankowski (Physics Department, Fordham University, Bronx, New York) Journal of Applied Physics 1971, 43(1), p. 209-211, Avail: TAC

Two different metals in a heat pipe oven will form separate metallic-vapor zones. These zones can be moved so that in a crossed heat pipe oven, spectroscopic studies of intermetallic molecules can be made at the interface between the two zones. The operation and construction are described of the two-metal heat pipe oven as well as a laser technique that can be used to study some of the dynamics of the heat pipe.

72012 THE ROLE OF TWO-PHASE MACH NUMBERS IN HEAT PIPE ANALYSIS
Joseph W. Bursik (Rensselaer Polytechnic Institute, Troy, New York) AIAA 10th Aerospace Sciences Meeting, San Diego, California, January 17-19, 1972, AIAA Paper No. 72-22, 8 p. 7 refs., Avail: TAC

Imposition of non-zero mass injection and zero axial velocity at the upstream end of a heat pipe evaporator leads to an initial positively infinite temperature gradient of the vapor in an ideal gas model, and an initial tendency for saturated vapor to become superheated in a two-phase model. It is shown that a boundary condition utilizing axial evaporation from the closed end leads to an initial negative ideal gas gradient and eliminates the superheating tendency in the two-phase model. For the latter model, a two-phase Mach number is introduced, thereby facilitating analysis of choking phenomenon.

C. 2 HEAT TRANSFER

72013 A FEASIBILITY STUDY OF HEAT PIPE COOLED LEADING EDGES FOR HYPERSONIC CRUISE AIRCRAFT
Calvin C. Silverstein, Washington, NASA, Contract NAS1-9872, November 1971, 148 p., Refs., Avail: TAC

A theoretical study of the use of heat pipe structures for cooling the leading edges of hypersonic cruise aircraft was carried out over a Mach number range of 6 to 12. Preliminary design studies showed that a heat pipe cooling structure with a 33-in. chordwise length could maintain the maximum temperature of a 65 degree sweepback wing with a 0.5 in. leading edge radius below 1600 F during cruise at Mach 8. A few relatively minor changes in the steady-state design of the structure were found necessary to insure satisfactory cooling during the climb to cruise speed and altitude. It was concluded that heat pipe cooling is an attractive, feasible technique for limiting leading edge temperatures of hypersonic cruise aircraft.

72014 VAPOR COMPRESSIBILITY EFFECTS IN HEAT PIPES
Edward K. Levy (Lehigh University, Bethlehem, Pa., Dept. of Mechanical Engineering) August 31, 1970, Final Report AEC Contract AT(30-1)-4095, 27 p., Avail: TAC

Investigations were carried out on the relation of the gasdynamic choking phenomenon to maximum heat transfer rates in sodium heat pipes and on the characteristics of incompressible laminar vapor flows within the condenser regions of heat pipes. The results of these two studies are summarized in this report.

72015 THEORY OF A ROTATING HEAT PIPE
S.H. Chan (New York University, N.Y.) Z. Kanai, W.T. Yang, Journal of Nuclear Engineering, Vol. 25, No. 10, p. 479-487 (October 1971) Avail: TAC

Based on a simple model, an analytical solution is obtained to predict the heat transfer rate of a wickless heat pipe which is conical in shape and rotates about its longitudinal axis. The rotating heat pipe utilizes centrifugal force, instead of capillaries, for the return-pumping of the condensate. The heat transfer rate of the rotating heat pipe is then compared with the existing data for a conventional capillary heat pipe to demonstrate the merit of the former.

C. 3 CONDENSATION AND EVAPORATION

72016 LENGTH OF THE EVAPORATION ZONE OF A HEAT PIPE
I.M. Blinchevskii and B.F. Aptekar: Teplofizika Vysokikh Temperatur, Vol. 9, Sept.-Oct. 1971, p. 1089-1093, In Russian, Avail: TAC

The length corresponding to total desiccation of the fluid in the capillaries of a heat pipe is assessed analytically. Formulas, using which the "desiccation length" can be calculated for given values of the capillary cross section and of the thermal load per unit length of the capillary are derived. Knowledge of the desiccation length is essential for selecting the evaporation zone of a heat pipe.

C. 4 FLUID FLOW

No citations in update, March 31, 1972

D. DESIGN AND FABRICATION

D. 1 GENERAL

72017 QUARTERLY STATUS REPORT ON THE SPACE ELECTRIC POWER R AND D PROGRAM FOR THE PERIOD ENDING JULY 31, 1971, PART I.

Los Alamos Scientific Laboratory, New Mexico, August 1971, Contract W-7405-eng-36, LA-4746, 5 p., Avail: TAC

Research and development progress is reported on heat pipe systems. Activities are summarized on tests of high-purity Li heat pipe, effects of impurities in heat pipes, and impurity removal methods. A method of constructing an in-pile test heat pipe is described.

D. 2 WICKS

72018 FABRICATION AND EVALUATION OF ALUMINUM HEAT PIPES

W.B. Bienert (Dynatherm Corporation, Cockeysville, Maryland) (Prepared for Goddard Space Flight Center, Greenbelt, Md.) Contract No: WAS5-11271, 45 p., Avail: TAC

The current heat pipe system on the OAO spacecraft was evaluated to increase its capability for future missions. A detailed analysis was made of the requirements, and approaches for the design of optimized heat pipes to meet future needs were identified. The experimental effort led to the development of a new, composite wick heat pipe which has significantly higher transport capability than those of current, conventional wick design.

D. 3 MATERIALS

No citations in update, March 31, 1972

E. TESTING AND OPERATION

72019 ULTIMATE PERFORMANCE AND LIFE TESTS OF LOW TEMPERATURE HEAT PIPES

M. Groll, H. Kreeb, P. Zimmermann (Inst. Kernenberg, Univ. Stuttgart, Stuttgart, Germany) IEEE Conf. Rec. Thermion. Convers. Spec. Conf., PAP Annu. Conf., 9th, 1970, 562-566, Avail: TAC

Heat pipes were treated inductively by a high-frequency generator over 100mm length. Calorimeter cooling was used over 150mm length. The heat flux density depended on the pitch angle in threaded artery heat pipes. These pipes had a much higher radial heat flux density above 210^{o}K than screen heat pipes of similar stainless steel/ammonia construction. Ammonia was superior to all other heat carriers up to 345^{o}K. Above 345^{o}K, H_2O was superior, but stainless steel/H_2O systems required special pretreatment to avoid gas generation. Stainless steel pipes with alcohol acetone, or hexane heat carriers have axial heat flux densities of 12 W/cm^2 at 330^{o}K with lifetimes >3000 hr. The Cu/H_2O system had an axial heat flux density of 14 W/cm^2 at 380^{o}K with a lifetime >3500 hr. No corrosion problems were found by using Cu with H2O, ammonia, alcohols, acetone, or hexane. Brass systems were unsuitable due to technological and corrosion problems.

72020 DEVELOPMENT OF A 600^{o} CENTIGRADE HEAT PIPE ASSEMBLY Final Technical Report, January 3, 1966-January 3, 1967 (Radio Corporation of America, Lancaster, Pa.) April 30, 1969 Contract AT(29-2)-2683, 112 p. (Tl-317-82-994-99), Avail: TAC

The program for development of a 600^{o}C automatic temperature-controlled heat pipe assembly was continued. Four heat pipes that were designed, fabricated, and tested were continued on life test for specific periods of time. Three of these heat pipes, Serial No. 3, 5, and 2, were removed from life test in operating condition after completing 6000, 6000, and 10,000 hours respectively. All three pipes were carefully packed and shipped to the Oak Ridge National Laboratories for detailed analysis. The result of the analysis showed a small area of erosion in the evaporator of each heat pipe. No other deleterious effects were observed. Heat Pipe, Serial No. 4, is continuing on life test and has accumulated over 20,000 hours of stable operation.

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DYNATHERM CORPORATION, COCKEYSVILLE, MARYLAND
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00020	OF THE EVAPORATION ZONE OF A	HEAT PIPE# LENGTH	72016	8
00150	OR COMPRESSIBILITY EFFECTS IN	HEAT PIPES.# VAP	72014	7
00190		HEAT PIPES-A SURVEY#	72009	6
00010	ON AND EVALUATION OF ALUMINUM	HEAT PIPES# FABRICATI	72018	9
00080	LIFE TESTS OF LOW-TEMPERATURE	HEAT PIPES# / PERFORMANCE AND	72019	10
00100	MICS, AND USE IN S/ TWO-METAL	HEAT-PIPE OVEN OPERATION, DYNA	72011	6
00160	DYNAMICS OF	HEAT-PIPE REACTORS#	72007	4
00170	FOR / A FEASIBILITY STUDY OF	HEAT-PIPE-COOLED LEADING EDGES	72013	7
00090	NG AND OPTIMIZATION OF A FAST	HEAT-PIPE-THERMIONIC-REACTOR# /	72006	4

00140	TUBE WITH HIGH	HEAT-TRANSFER CAPACITY#	72010	6
00140	TUBE WITH	HIGH HEAT-TRANSFER CAPACITY#	72010	6
00060	CTIV/ TECHNIQUE FOR MEASURING	HIGH-TEMPERATURE THERMAL CONDU	72001	2
00170	PIPE-COOLED LEADING EDGES FOR	HYPERSONIC CRUISE AIRCRAFT.# /	72013	7
00120	OR METAL CUTTING TOOLS. PHASE	I.# A NEW COOLING METHOD F	72002	2
00200	OD ENDING JULY 31, 1971. PART	I.# /ND D PROGRAM FOR THE PERI	72017	9
		'IN ' NOT INDEXED		
00100	ICS, AND USE IN SPECTROSCOPIC	INVESTIGATIONS# /RATION, DYNAM	72011	6
00070	E DESIGN FOR A THERMOELECTRIC	ISOTOPE POWER UNIT EMPLOYING H	72005	3
00200	PROGRAM FOR THE PERIOD ENDING	JULY 31, 1971. PART I.# /ND D	72017	9
00170	ITY STUDY OF HEAT-PIPE-COOLED	LEADING EDGES FOR HYPERSONIC C	72013	7
00020	OF A HEAT PIPE#	LENGTH OF THE EVAPORATION ZONE	72016	8
00080	HEA/ ULTIMATE PERFORMANCE AND	LIFE TESTS OF LOW-TEMPERATURE	72019	10
00130	AS A THERMAL SWITCH.#	LOW TEMPERATURE HEAT PIPE USED	72000	2
00080	PERFORMANCE AND LIFE TESTS OF	LOW-TEMPERATURE HEAT PIPES# /	72019	10
00030	YSIS# THE ROLE OF TWO-PHASE	MACH NUMBERS IN HEAT PIPE ANAL	72012	6
00060	RMAL CONDUCTIV/ TECHNIQUE FOR	MEASURING HIGH-TEMPERATURE THE	72001	2
00120	A NEW COOLING METHOD FOR	METAL CUTTING TOOLS. PHASE I.#	72002	2
00120	. PHASE I.# A NEW COOLING	METHOD FOR METAL CUTTING TOOLS	72002	2
00110	ORE#	MODERATED THERMIONIC REACTOR C	72004	3
00070	OWER UNIT EMPLOYING HEAT PIPE	MODULES.# /OELECTRIC ISOTOPE P	72005	3
		'NEW ' NOT INDEXED		
00050	ED FAST REACTOR DESIGNED AS A	NUCLEAR ELECTRIC SPACE POWER P	72008	5
00030	THE ROLE OF TWO-PHASE MACH	NUMBERS IN HEAT PIPE ANALYSIS#	72012	6
		'OF ' NOT INDEXED		
		'ON ' NOT INDEXED		
00100	N S/ TWO-METAL HEAT-PIPE OVEN	OPERATION, DYNAMICS, AND USE I	72011	6
00090	PE-THERMIONIC-R/ PLANNING AND	OPTIMIZATION OF A FAST HEAT-PI	72006	4
00050	HEAT PIPE COOLED FAST REACT/	OPTIMIZATION OF A SHIELD FOR A	72008	5
00100	USE IN S/ TWO-METAL HEAT-PIPE	OVEN OPERATION, DYNAMICS, AND	72011	6
00200	PERIOD ENDING JULY 31, 1971.	PART I.# /ND D PROGRAM FOR THE	72017	9
00080	LOW-TEMPERATURE HEA/ ULTIMATE	PERFORMANCE AND LIFE TESTS OF	72019	10
00200	POWER R AND D PROGRAM FOR THE	PERIOD ENDING JULY 31, 1971. P	72017	9
00120	THOD FOR METAL CUTTING TOOLS.	PHASE I.# A NEW COOLING ME	72002	2
		'PIPE ' NOT INDEXED		
00060	F SOLIDS BY THE USE OF A HEAT	PIPE.# /THERMAL CONDUCTIVITY O	72001	2
00180	ESISTANCE BARRIER# THE HEAT	PIPE-OVERCOMMING THE THERMAL R	72003	3
		'PIPES ' NOT INDEXED		
00150	MPRESSIBILITY EFFECTS IN HEAT	PIPES.# VAPOR CO	72014	7
00190	HEAT	PIPES-A SURVEY#	72009	6
00090	FAST HEAT-PIPE-THERMIONIC-R/	PLANNING AND OPTIMIZATION OF A	72006	4
00050	NUCLEAR ELECTRIC SPACE POWER	PLANT# / REACTOR DESIGNED AS A	72008	5
00050	D AS A NUCLEAR ELECTRIC SPACE	POWER PLANT# / REACTOR DESIGNE	72008	5
00200	REPORT ON THE SPACE ELECTRIC	POWER R AND D PROGRAM FOR THE	72017	9
00070	FOR A THERMOELECTRIC ISOTOPE	POWER UNIT EMPLOYING HEAT PIPE	72005	3
00200	SPACE ELECTRIC POWER R AND D	PROGRAM FOR THE PERIOD ENDING	72017	9
		'QUARTERLY ' NOT INDEXED		
00200	T ON THE SPACE ELECTRIC POWER	R AND D PROGRAM FOR THE PERIOD	72017	9
00110	MODERATED THERMIONIC	REACTOR CORE#	72004	3
00050	D FOR A HEAT PIPE COOLED FAST	REACTOR DESIGNED AS A NUCLEAR	72008	5
00160	DYNAMICS OF HEAT-PIPE	REACTORS#	72007	4
00070	LECTRIC ISOTOPE POWER UNIT E/	REFERENCE DESIGN FOR A THERMOE	72005	3
		'REPORT ' NOT INDEXED		
00180	PIPE-OVERCOMMING THE THERMAL	RESISTANCE BARRIER# THE HEAT	72003	3

00030	IN HEAT PIPE ANALYSIS# THE	ROLE OF TWO-PHASE MACH NUMBERS	72012	6
00040	THEORY OF A	ROTATING HEAT PIPE#	72015	7
00050	FAST REACT/ OPTIMIZATION OF A	SHIELD FOR A HEAT PIPE COOLED	72008	5
00060	ATURE THERMAL CONDUCTIVITY OF	SOLIDS BY THE USE OF A HEAT PI	72001	2
00200	UARTERLY STATUS REPORT ON THE	SPACE ELECTRIC POWER R AND D P	72017	9
00050	ESIGNED AS A NUCLEAR ELECTRIC	SPACE POWER PLANT# / REACTOR D	72008	5
00100	ERATION, DYNAMICS, AND USE IN	SPECTROSCOPIC INVESTIGATIONS# /	72011	6
00200	CTRIC POWER R AND / QUARTERLY	STATUS REPORT ON THE SPACE ELE	72017	9
00170	ING EDGES FOR / A FEASIBILITY	STUDY OF HEAT-PIPE-COOLED LEAD	72013	7
00190	HEAT PIPES-A	SURVEY#	72009	6
00130	E HEAT PIPE USED AS A THERMAL	SWITCH.# LOW TEMPERATUR	72000	2
00060	EMPERATURE THERMAL CONDUCTIV/	TECHNIQUE FOR MEASURING HIGH-T	72001	2
00130	A THERMAL SWITCH.# LOW	TEMPERATURE HEAT PIPE USED AS	72000	2
00080	ULTIMATE PERFORMANCE AND LIFE	TESTS OF LOW-TEMPERATURE HEAT	72019	10
		*THE * NOT INDEXED		
00040	#	THEORY OF A ROTATING HEAT PIPE	72015	7
00060	OR MEASURING HIGH-TEMPERATURE	THERMAL CONDUCTIVITY OF SOLIDS	72001	2
00180	THE HEAT PIPE-OVERCOMMING THE	THERMAL RESISTANCE BARRIER#	72003	3
00130	MPERATURE HEAT PIPE USED AS A	THERMAL SWITCH.# LOW TE	72000	2
00110	MODERATED	THERMIONIC REACTOR CORE#	72004	3
00070	NIT E/ REFERENCE DESIGN FOR A	THERMOELECTRIC ISOTOPE POWER U	72005	3
00120	LING METHOD FOR METAL CUTTING	TOOLS. PHASE I.# A NEW COO	72002	2
00140	APACITY#	TUBE WITH HIGH HEAT-TRANSFER C	72010	6
00100	TION, DYNAMICS, AND USE IN S/	TWO-METAL HEAT-PIPE OVEN OPERA	72011	6
00030	PIPE ANALYSIS# THE ROLE OF	TWO-PHASE MACH NUMBERS IN HEAT	72012	6
00080	TESTS OF LOW-TEMPERATURE HEA/	ULTIMATE PERFORMANCE AND LIFE	72019	10
00070	THERMOELECTRIC ISOTOPE POWER	UNIT EMPLOYING HEAT PIPE MODUL	72005	3
00100	OVEN OPERATION, DYNAMICS, AND	USE IN SPECTROSCOPIC INVESTIGA	72011	6
00060	CONDUCTIVITY OF SOLIDS BY THE	USE OF A HEAT PIPE.# /THERMAL	72001	2
00130	LOW TEMPERATURE HEAT PIPE	USED AS A THERMAL SWITCH.#	72000	2
00150	IN HEAT PIPES.#	VAPOR COMPRESSIBILITY EFFECTS	72014	7
		*WITH * NOT INDEXED		
00020	LENGTH OF THE EVAPORATION	ZONE OF A HEAT PIPE#	72016	8
00200	OR THE PERIOD ENDING JULY 31,	1971. PART I.# /ND D PROGRAM F	72017	9
00200	AM FOR THE PERIOD ENDING JULY	31, 1971. PART I.# /ND D PROGR	72017	9
00210	BLY.# DEVELOPMENT OF A	600 CENTIGRADE HEAT PIPE ASSEM	72020	10

00020	APTEKAR B F	72016	8
00010	BIENERT W B	72018	9
00020	BLINCHEVSKII I M	72016	8
00030	BURSIK J W	72012	6
00040	CHAN S H	72015	7
00050	CHILDS R L	72008	5
00050	ENGLE W W	72008	5
00060	FORMAN R	72001	2
00070	FRAAS A P	72005	3
00080	GROLL M	72019	10
00090	HANKE H	72006	4
00100	HESSEL M M	72011	6
00110	HILL P R	72004	3
00110	HOBSON R R	72004	3
00100	JANKOWSKI P	72011	6
00120	JEFFRIES N P	72002	2
00040	KANAI Z	72015	7
00190	KONEV S V	72009	6
00130	KOPF L	72000	2
00080	KREEB H	72019	10
00070	LAVERNE M E	72005	3
00140	LECA A	72010	6
00150	LEVY E K	72014	7
00050	LORRAINE S	72008	5
00200	LOS ALAMOS SCIENTIFIC LAB	72017	9
00120	MARKS P A	72002	2
00050	MYNATT F R	72008	5
00160	NIEDERAUER G F	72007	4
00210	RADIO CORP. OF AMERICA	72020	10
00110	SCOTT R N	72004	3
00170	SILVERSTEIN C C	72013	7
00180	STREB A J	72003	3
00190	VASILEV L L	72009	6
00040	YANG W T	72015	7
00120	ZERKLE R D	72002	2
00080	ZIMMERMAN P	72019	10

00001 HOBSON R R SCOTT R N
HILL P R
MODERATED THERMIONIC REACTOR CORE
U.S. PATENT 3607631
SEPTEMBER 21, 1971

00002 HOUSTON J M
VENT FOR NUCLEAR-THERMIONIC FUEL ROD
U.S. PATENT 3629063
DECEMBER 21, 1971

00003 SHLOSINGER A P
METHOD OF AND MEANS FOR REGULATING THERMAL
ENERGY TRANSFER THROUGH A HEAT PIPE
U.S. PATENT 3637007
JANUARY 25, 1971

00004 ARES R A
COLD-HEAT RECOVERY FOR AIR CONDITIONING
U.S. PATENT 3640090
FEBRUARY 8, 1972

00005 KIRKPATRICK M E
HEAT TRANSFER DEVICE
U.S. PATENT 3651240
MARCH 21, 1972

		'A ' NOT INDEXED
00004	COLD-HEAT RECOVERY FOR	AIR CONDITIONING#
		'AND ' NOT INDEXED
00004	ING#	COLD-HEAT RECOVERY FOR AIR CONDITION
00004	COLD-HEAT RECOVERY FOR AIR	CONDITIONING#
00001	MODERATED THERMIONIC REACTOR	CORE#
00005	HEAT TRANSFER	DEVICE#
00003	OF AND MEANS FOR REGULATING THERMAL	ENERGY TRANSFER THROUGH A HEAT PIPE#
		'FOR ' NOT INDEXED
00002	VENT FOR NUCLEAR-THERMIONIC	FUEL ROD#
00003	G THERMAL ENERGY TRANSFER THROUGH A	HEAT PIPE# / AND MEANS FOR REGULATIN
00004		COLD-HEAT RECOVERY FOR AIR CONDITIONING#
00005		HEAT TRANSFER DEVICE#
00003	TRANSFER THROUGH A H/ METHOD OF AND	MEANS FOR REGULATING THERMAL ENERGY
00003	HERMAL ENERGY TRANSFER THROUGH A H/	METHOD OF AND MEANS FOR REGULATING T
00001		MODERATED THERMIONIC REACTOR CORE#
00002	VENT FOR	NUCLEAR-THERMIONIC FUEL ROD#
		'OF ' NOT INDEXED
00003	RMAL ENERGY TRANSFER THROUGH A HEAT	PIPE# / AND MEANS FOR REGULATING THE
00001	MODERATED THERMIONIC	REACTOR CORE#
00004	COLD-HEAT	RECOVERY FOR AIR CONDITIONING#
00003	HROUGH A H/ METHOD OF AND MEANS FOR	REGULATING THERMAL ENERGY TRANSFER T
00002	VENT FOR NUCLEAR-THERMIONIC FUEL	ROD#
00003	METHOD OF AND MEANS FOR REGULATING	THERMAL ENERGY TRANSFER THROUGH A HE
00002	VENT FOR NUCLEAR-	THERMIONIC FUEL ROD#
00001	MODERATED	THERMIONIC REACTOR CORE#
00003	REGULATING THERMAL ENERGY TRANSFER	THROUGH A HEAT PIPE# / AND MEANS FOR
00005	HEAT	TRANSFER DEVICE#
00003	MEANS FOR REGULATING THERMAL ENERGY	TRANSFER THROUGH A HEAT PIPE# / AND
00002	#	VENT FOR NUCLEAR-THERMIONIC FUEL ROD

00004	ARES R A
00001	HILL P R
00001	HOBSON R R
00002	HOUSTON J M
00005	KIRKPATRICK M E
00001	SCOTT R N
00003	SHLOSINGER A P

HEAT PIPE RELATED PATENTS MARCH 31, 1972 UPDATE

00001	U.S. PATENT 3607631#
00002	U.S. PATENT 3629063#
00003	U.S. PATENT 3637007#
00004	U.S. PATENT 3640090#
00005	U.S. PATENT 3651240#