HEAT PIPE TECHNOLOGY

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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 April, May, and June of 1972. It is the second 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

72021 HEAT PIPE AT LOS ALAMOS
J. E. Kemme (Los Alamos Scientific Lab, New Mexico) From Eleventh International Conference on Thermal Conductivity, Albuquerque, New Mexico. September 28, 1971, Avail: TAC

B. HEAT PIPE APPLICATIONS

B. 1 General Applications

72022 HEAT PIPE OVEN APPLICATIONS. I. ISOTHERMAL HEATER OF WELL-DEFINED TEMPERATURE. II. PRODUCTION OF METAL-VAPOR-GAS MIXTURES

C. R. Vidal and F. B. Haller (National Bureau of Standards, Boulder, Colorado). Review of Scientific Instrumentation, 1971, 42(12), p. 1779-1784, Avail: TAC

A concentric heat pipe oven is described, which serves as an oven with a highly homogeneous temperature distribution as required by such applications as crystal growing, thermal treatment of materials, and radiation standards. The design is simpler than conventional ovens with similar temperature stability and homogeneity. The temperature control is replaced by a pressure control. This device is used in a modification of the heat pipe oven that generates homogeneous mixtures of a vapor (such as a metal vapor) and an inert gas at well-defined total pressure, partial pressure, temperature and optical path length. All the features of the previously described heat pipe oven are maintained with the additional option that allows quantitative total and partial pressure measurements without relying on vapor pressure curves.

B. 2 THERMIONIC AND THERMOELECTRIC CONVERTERS

72023 OUT-OF-CORE THERMIONIC POWER PLANT FOR MANNED SPACE STATION

A. Schock, M. J. Abbate, C. L. Eisen (Fairchild Hiller Corporation, Farmingdale, New York). Pages 169-178 of IEEE Conference Record of 1970 Thermionic Conversion Specialist Conference, New York; Institute of Electrical Electronics Engineers, Inc. (1970). From Thermionic Conversion Specialist Conference; Miami Beach, Florida. October 26, 1970, 15 refs., Avail: TAC

An out-of-core design for a reactor-heated thermionic power plant is described. The design strives for maximum redundancy, to permit continued operation after local failures of various components. To illustrate the concept, a specific power plant design for a manned space station is presented. In order to meet the long mission-life requirement, the design permits periodic replacement of critical system components. Sizes and weights are given, both for the replaceable items, and for the permanent parts of the power plant, which include a man-rated, isotropic 4π-shield.

72024 RADIOISOTOPE THERMIONIC GENERATOR (RTIG)
Rouklove, Peter (Jet Propulsion Lab., Pasadena, California). Contract NAS 7-100. Pages 382-387 of IEEE Conference Record of 1970 Thermionic Conversion Specialist Conference. New York; Institute of Electrical and Electronics Engineers, Inc. (1970). From Thermionic Conversion Specialist Conference; Miami Beach, Florida. October 26, 1970. Avail: TAC

The unmanned exploration of the planets eventually requires the landing of spacecraft or probes on the planet surface. Basic economic considerations and weight restrictions favor the use of efficient, solar independent, lightweight, impact-resistant power packages. In some cases estimated surface conditions preclude the use of contemporary power sources. Radioisotope-heated thermionic power sources, however, may successfully operate in these conditions and fulfill the mission requirements. An analysis was performed to define the optimum thermionic converter configuration based on mission requirements and constraints, considering reliability of the system, weight, output power, output voltage, and efficiency of the complete power package and making the maximum use of present technology. The results of this analysis were compared with existing concepts. Two of these concepts were selected for further investigation, one using a heat pipe as the heat transfer and support medium, the other using small independent converters assembled in a multiconverter array. The results obtained in the development of the first concept, a multiconverter array connected to the isotope power source through a heat pipe, are presented.

B. 3 AEROSPACE ORIENTED APPLICATIONS

72025 HEAT PIPE APPLICATIONS FOR THE SPACE SHUTTLE
M. Tawil, J. Alarid, and R. Prager (Grumman Aerospace Corporation, Bethpage, New York), and R. Bullock (NASA Manned Spacecraft Center, Houston, Texas). AIAA 7th Thermophysics Conference, San Antonio, Texas, April 10-12, 1972. AIAA Paper No. 72-272. Avail: TAC

It seems fitting that what may be the simplest, most efficient thermal control tool be employed on the most efficient space carrier. This paper discusses six specific applications for heat pipe (HP) devices on the Space Shuttle. These applications were chosen from 27 concepts formulated as part of a study to evaluate the potential benefits associated with HP use. The formulation process is briefly described along with the applications which evolved. The bulk of the discussion deals with the "top" six, namely HP radiators for waste heat rejection, a HP augmented cold rail, HP circuit for electronic equipment cooling, modular heat sink for control of remote packages, HP temperature control for compartments, and air cooled equipment racks. The philosophy, physical design details, and performance data are presented for each concept along with a comparison to the baseline design where applicable. (Author)

72026 HEAT PIPE THERMAL CONTROL SYSTEM CONCEPT FOR THE SPACE STATION

T. R. Scollon, Jr. (General Electric Company, Valley Forge, Pennsylvania) and G. A. Robinson (NASA Marshall Space Flight Center, Huntsville, Alabama). (Paper prepared under Marshall Space Flight Center Contract NAS8-26252). AIAA 7th Thermophysics Conference, San Antonio, Texas, April 10-12, 1972. AIAA Paper No. 72-261. Avail: TAC

This paper presents the results of a program undertaken to design and evaluate a high reliability, long life thermal control system for Space Station application. The program consisted of three sequential steps: (1) investigate many thermal control elements to select the most reliable; (2) combine these elements into several system concepts which maintain the high reliability offered, and analytically evaluate parameters; and (3) select the most desirable approach and determine its characteristics. The result of this project is a conceptual thermal control system design that employs heat pipes as primary components both for heat transport and variable temperature control. The system is described in this paper. (Author)

B. 4 NUCLEAR SYSTEMS

72027 ISOTOPE KILOWATT PROGRAM QUARTERLY PROGRESS REPORT FOR PERIOD ENDING SEPTEMBER 30, 1971.

A. P. Fraas, G. Samuels (Oak Ridge National Lab., Tennessee) November 1971. Contract W-7405-eng-26, (ORNL-TM-3592). 39 pages, Avail: TAC

The organic capsule test continued during the quarter and completed 6576 h of operation. Construction of the 1/4 scale organic fluid decomposition test loop is proceeding. Most of the components have been fabricated and the measurements of the dose rates in the boiler region of the heat block shield were completed. Efforts to correct conditions that might cause a loss in the capillary pumping capacity of the heat pipe have continued to meet with little success; a pronounced loss in performance still occurs when the boiler is tilted a bit above the level of the condenser. Further investigation was discontinued due to lack of funds. Performance tests on the thermoelectric module were completed and the unit was delivered to ORNL for further testing. Two performance maps were completed for hot junction temperatures of 1000 and 1055°F (at 8 amps). The 1000°F hot junction map shows the unit output to be about 170 watts rather than the predicted value of 200 watts. Further tests of the aluminum wire screen thermal insulation-thermal fuse indicate that the combined effects of a low rate of temperature rise inherent in the application at hand, the very substantial heat of fusion of aluminum, and the inhibiting effects to the flow of molten aluminum imposed by a thick aluminum oxide film lead to a much less sharp melting of the thermal fuse than had been anticipated. To reduce thermal radiation losses, the next test sample has aluminum foil in the aluminum screen. A nitrogen atmosphere was employed to minimize the effects of the oxide film. At 15 psia and a mean temperature of 600°F the thermal conductivity was found to be 0.77 compared to 0.114 Btu/hr-ft-°F found during tests without the foil. A significant reduction in the thermal conductivity was also observed at 1.0 psia. However, during the course of this test the value of the conductivity shifted upward to form a higher curve. These tests will be repeated. A conceptual design for the dummy heat pipes for the test of the heat block with a thermoelectric module and 11 dummy modules has been prepared. A topical report reviewing the status of the development of various small turbine-and engine-generator units suitable for Navy undersea nuclear power plants was prepared. This indicates that the most promising candidate for an organic Rankine cycle system is the Sundstrand 6kW(e) turbine-generator unit. The design of a full-scale organic Rankine cycle system employing the Sundstrand kW(e) turbine-generator unit is proceeding. A layout drawing was obtained from Sundstrand showing the revised arrangement of the 13 pipes and electrical cables which must be coupled to the turbine-generator-pump unit. The installation design problems associated with these connections were reviewed with Sundstrand and a satisfactory layout evolved. Arrangements for the procurement of the turbine-generator-feed pump unit have been initiated.

B. 5 ELECTRONIC APPLICATIONS

72028 A VARIABLE CONDUCTANCE HEAT PIPE/RADIATOR FOR THE LUNAR SURFACE MAGNETOMETER

J. P. Kirkpatrick (NASA Ames Research Center, Moffett Field, California) and B. D. Marcus (TRW Systems, Redondo Beach, California). AIAA 7th Thermophysics Conference, San Antonio, Texas, April 10-12, 1972. AIAA Paper No. 72-271. Avail: TAC

A cold reservoir, variable conductance heat pipe/radiator was developed to supplement the existing cooling system of the Apollo 16 Lunar Surface Magnetometer (LSM). Analysis and tests showed that two such devices, inserted by an astronaut into receptacles on opposite sides of the electronics package, would reduce the diurnal temperature variation by about 40% and thereby would considerably increase the reliability of 50,000 welded connections. Although the Apollo Configuration Control Panel eventually decided that the heat pipe radiator was not required for flight, the usefulness and flexibility of variable conductance heat pipes in solving difficult thermal problems was demonstrated in a very real way. The LSM design constraints, selection of a variable conductance technique, heat pipe/radiator design features, and thermal performance are discussed. (Author)

72029 APPLICATION OF HEAT PIPES TO ELECTRONIC EQUIPMENT COOLING

Carl J. Feldmanis (Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio). AIAA 7th Thermophysics Conference, San Antonio, Texas, April 10-12, 1972. AIAA Paper 72-269. Avail: TAC

Analytical and experimental work has been performed to investigate the feasibility of applying heat pipe technology to the thermal control of electronic equipment. Temperature level and uniformity, and the amplitude and frequency of thermal cycling are known to have significant adverse effects upon the reliability and operating characteristics of electronic equipment. In order to promote heat transfer, improve temperature distribution, and reduce thermal cycling, electronic equipment cooling plates (cold plates) were provided with integral heat pipes. The experimental cold plates can be divided into three general categories: (1) a conventional fin-tube configuration, and (2) a flat, continuous cavity configuration, and (3) a fin-tube configuration with noncondensible gas chambers for temperature control. Actual and simulated electronic components were used as thermal sources. Test results have shown that the high thermal conductance of the heat pipes provided excellent temperature distribution throughout the plates, thus maintaining the attached equipment at a uniform temperature. Very close temperature control was achieved with the variable conductance heat pipes. Use of such cold plates will not only improve the reliability of electronic equipment, but will also simplify the entire thermal control system while reducing weight and pumping power requirements. (Author)

C. HEAT PIPE THEORY

C. 1 GENERAL THEORY

72030 MULTICHAMBER CONTROLLABLE HEAT PIPE
A. P. Shlosinger (TWR Systems Group, TWR, Inc., Under Contract to AMES Research Center). 1 page Tech Brief, Avail: TAC

The paper shows how the rate of transfer of energy by a heat pipe is controlled by controlling the rate of transfer of vapor between the heat input surface and heat rejection surface of a heat pipe.

C. 2 HEAT TRANSFER

72031 VAPORIZATION HEAT TRANSFER IN HEAT PIPE WICK MATERIALS
J. K. Ferrell, E. G. Alexander, and W. T. Piver. North Carolina State University, Raleigh, North Carolina. AIAA 7th Thermophysics Conference, San Antonio, Texas, April 10-12, 1972. AIAA paper No. 72-256, Avail: TAC

Vaporization heat transfer characteristics were measured for several wick materials including five samples of felted metal (nickel, copper, and stainless steel), and three samples of sintered copper metal powder. Properties such as permeability, static wicking height and thermal conductivity were also measured. The experimental apparatus consisted of a 2.5 by 2.5 inch heated surface arranged so that the fluid was drawn to the heated surface by capillary forces up to a maximum of 12 inches. Data are presented for a vertical arrangement and for various angles including horizontal. Data for dry out, or critical heat flux, and the heat transfer coefficient are presented and compared with theory. (Author)

C. 3 CONDENSATION AND EVAPORATION

72032 EVAPORATION AND CONDESATION IN AN ENCLOSURE IN THE PRESENCE OF A NONCONDENSABLE GAS
J. W. McDonald (University of California, Los Angeles), V. E. Denny, and A. F. Mills; ASME. Heat Transfer in Low Reynolds Number Flow, Winter Annual Meeting, Washington, D.C., HTD-v-5 November 30, 1971, pages 1-11, 14 refs., Avail: TAC

The elliptic form of the conservation equations governing steady state transport of momentum, mass, species and energy are solved numerically in a cylindrical tube containing a binary vapor-gas mixture. The system is an idealized heat pipe; the working fluid is water and investigated is the effect of small concentrations of air on performance. Results are presented for mass flow rates corresponding to Reynolds numbers in the range 0.0095 to 0.15.

72033 INTERNAL TEMPERATURE DISTRIBUTIONS IN AN OPERATIONAL HEAT PIPE

Richard D. Fox, Kelly G. Carothers, and William J. Thomson. March 10, 1972. Backup Document for AIAA Synoptic Schedules for Publication in AIAA Journal in July 1972. 23 pages, refs, Avail: TAC

For the first time in an operational heat pipe, internal temperature distributions are obtained which are subsequently used to analyze the existing energy transport mechanisms. Two basic wick designs and two working fluids (water and methanol) are evaluated over a wide range of power levels and base temperatures. Results indicate that in both wicks and with both fluids a vapor film forms adjacent to the heat pipe wall at the base of the wick. Depending on the wick design and the power level, film boiling occurs and results in superheated vapor blowing through the wick into the vapor section of the pipe. The film thickness and magnitude of superheat are found to be dependent on the wick design, the power level and the saturation pressure. In all cases methanol is shown to be more susceptible to both film formation and film boiling. Despite the large vapor formations in the wick the pipe continues to operate although not isothermally, without burnout. Speculations are also offered on the burnout mechanisms of heat pipes employing low thermal conductivity fluids.

72034 BOILING TESTS PERFORMED ON OPEN GROOVE-CAPILLARY EVAPORATORS

Friedrich Ernst Reiss and Klaus Schretzmann. Forschung im Ingenieurwesen, Vol. 37 (1971), p. 55

Water was vaporized from open groove-capillary evaporators. Measurements determined water consumption and vaporization temperature as functions of applied heating power. The curve of pressure in the capillaries as the evaporators dried out was likewise measured and can be interpreted in terms of changes in the curvature of the surface of the liquid. Studies on evaporator spattering were also undertaken.

72035 DYNAMIC BUBBLE GROWTH DURING THE BOILING OF LIQUIDS ON HEATING SURFACES

Hans Beer. Forschung im Ingenieurwesen, Vol 37 (1971), pages 85-90. Avail: TAC

A precise determination of breakaway volume must be based, among other things, upon the dynamic forces acting on the bubble. Resistance coefficients for growing steam bubbles and steam overpressure in a bubble are determined mathematically with the aid of a force analysis and an energy equation, and temperature in the bubble is determined experimentally. Interferograms showed the temperature field around a growing steam bubble. Breakaway diameters can be determined more reliably than before through the use of a bubble-growth law with variable time exponents and the equilibrium of forces described.

72036 PRESSURE VARIATIONS IN AN INCOMPRESSIBLE LAMINAR TUBE FLOW WITH UNIFORM SUCTION

J. P. Quaile and E. K. Levy. Department of Mechanical Engineering and Mechanics, Lehigh University, Bethlehem, Pennsylvania. AIAA 7th Thermophysics Conference, San Antonio, Texas. April 10-12, 1972. AIAA Paper No. 72-257
Avail: TAC

New experimental data on the axial pressure vairations in a laminar incompressible flow through a porous circular tube are presented. The tube was closed at the downstream end and the fluid removed uniformly by suction through the porous cylindircal surface. Because of the similarity between this flow and the vapor flow in the condenser of a heat pipe the results should be applicable to the heat pipe. The non-similar "inlet region" solutions of Weisberg, Busse, and Bankston and Smith were found to compare favorably with the experimental data in the range $2.21 < Re_r < 5$. On the other hand, for $Re_r \gtrsim 2.21$, the similarity solutions of Yuan and Finkelstein were found to predict pressure variations much greater than those actually measured. (Author)

D. DESIGN AND FABRICATION

D. 1 GENERAL

72037 DEVELOPMENT OF A THERMAL DIODE HEAT PIPE FOR THE ADVANCED THERMAL CONTROL FLIGHT EXPERIMENT (ATFE)
B. Swerdling, R. Kosson, and M. Urkowitz (Grumman Aerospace Corporation, Bethpage, New York), and J. Kirkpatrick (NASA Ames Research Center, Moffett Field, California). AIAA 7th Thermophysics Conference, San Antonio, Texas, April 10-12, 1972. AIAA Paper No. 72-260. Avail: TAC

The analysis, design, fabrication, and test of the engineering model of the ATFE diode is presented. Included is a review of several diode concepts that led to selection of the liquid blockage technique for shut-off. The diode is made of stainless steel, 26 inces long, 0.375-inch nominal OD, with self-filling spiral artery wick and ammonia working fluid. In the normal heat pipe mode, at ambient temperatures, the diode capacity is 85 watts. For flight, the pipe will deliver 20 watts with a 9^{o}F temperature difference between the external evaporator and condenser surfaces. Reverse mode conduction is less than 1.5 watts with a 260^{o}F termperature difference. (Author)

72038 A TUNNEL WICK 100,000 WATT-INCH HEAT PIPE
R. Kosson, R. Hembach, F. Edelstein, and M. Tawil. Grumman Aerospace Corporation; Bethpage, New York, AIAA 7th Thermosphysics Conference, San Antonio, Texas, April 10-12, 1972. AIAA Paper No. 72-273. Avail: TAC

The tunnel wick is a new type of heat pipe artery which can prime in a gravity environment by temperature-induced pressure differences between interior and exterior. The paper discusses the concept and its application in the design of room-temperature high-transport-capacity heat pipes. The analytical model of the system is summarized; and performance data obtained with the aid of a related computer program is included. Test data verifying the concept is presented for several pipes, including an eight-foot-long, 0.9-inch ID pipe, using ammonia working fluid, with a transport capacity in excess of 150,000 watt-inches. A brief discussion of potential applications for this type of heat pipe includes a variable conductance device to serve as a radiator header and a high capacity heat transport system. (Author)

72039 DEVELOPMENT OF A SELF-PRIMING HIGH-CAPACITY HEAT PIPE FOR FLIGHT ON OAO-C

F. Edelstein, B. Swerdling, and R. Kosson (Goddard Aerospace Corporation, Bethpage, New York). AIAA 7th Thermophysics Conference, San Antonio, Texas, April 10-12, 1972. AIAA paper No. 72-258, Avail: TAC

This paper describes the development of a 0.500-inch OD heat pipe with a spiral artery designed to fill under surface tension forces in a one-g field. Capacities in excess of 12,000 watt-inches have been achieved with ammonia as the working fluid. The paper presents the analysis, design, and test of the three-foot-long development models. Also included are some design and fabrication details, along with qualification ground test data for a 12-foot-long spiral artery isothermalizer type heat pipe that is installed on the Orbiting Astronomical Observatory C Model scheduled for launch in 1972. (Author)

D. 2 WICKS

No citations in update, June 30, 1972

D. 3 MATERIALS

72040 ARC-CAST MOLYBDENUM-BASE TZM ALLOY PROPERTIES AND APPLICATIONS

J.Z. Briggs and R. Q. Barr (Climax Molybdenum Company, New York, New York). In: Plansee Seminar, 7th, Reutte, Austria, June 21-25, 1971, Vol. 1, 100 p., 175 refs., Avail: TAC

General survey of the properties and applications of vacuum-melted molybdenum-base TZM alloy. The various stages of production of TZM alloy are reviewed, methods of forming and machining this alloy are discussed, and the physical and mechanical properties of the alloy are summarized. Applications of arc-cast TZM alloy in die casting, turbine power plants, heat pipes, aerospace and rocket structures, pressure vessels, furnace parts, and bearings are noted.

72041 FABRICATION AND EVALUATION OF CHEMICALLY VAPOR DEPOSITED TUNGSTEN HEAT PIPE

Robert J. Bacigalupi, 1972, 8 pages, refs. Proposed for presentation at Third International Conference on Chemical Vapor Disposition, Salt Lake City, April 24-27, 1972. Sponsored by American Nuclear Society. (NASA-TM-X-67987; E-6723). Avail: TAC

A network of lithium-filled tungsten heat pipes is considered as a method of heat extraction from high temperature nuclear reactors. The need for material purity and shape versatility in these applications dictates the use of chemically vapor deposited (CVD) tungsten. Adaptability of CVD tungsten to complex heat pipe designs is shown. Deposition and welding techniques are described. Operation of two lithium-filled CVD tungsten heat pipes above 1800 K is discussed.

E. TESTING AND OPERATION

72042 PERFORMANCE OF A PRECISION THERMAL CONTROL SYSTEM USING VARIABLE CONDUCTANCE HEAT PIPES.
W.F. Ekern and M. P. Hollister (Lockheed Missiles and Space Company, Sunnyvale, California). AIAA 7th Thermophysics Conference, San Antonio, Texas, April 10-12, 1972. AIAA Paper No. 72-270, Avail: TAC

Presented is an experimental evaluation of an assembly representative of a general concept for precise control of a surface to which spacecraft equipment radiatively transfers time-varying thermal loads for rejection by a space radiator with time-varying temperature. Two acetone heat pipes, wicked nitrogen reservoirs, active electrical feedback control, and a radiation coupler are used. Transient tests demonstrate $\pm 1^{\circ}F$ control with thermal load changing from 10 to 100-watts and a $40^{\circ}F$ sinusoidal sink variation. Lab-support equipment constrained sink temperatures between 65 and $125^{\circ}F$. A transient computer-model is described for use in predicting assembly characteristics with space radiator temperatures appropriate for typical space missions. (Author)

72043 SOUNDING ROCKET HEAT PIPE EXPERIMENT
Roy McIntosh (NASA Goddard Space Flight Center, Greenbelt, Maryland), and Greg Knowles and Richard J. Hemback (Grumman Aerospace Corporation, Bethpage, New York). AIAA 7th Thermophysics Conference, San Antonio, Texas, April 10-12, 1972. AIAA Paper No. 72-259, Avail: TAC

An experiment was conducted during October 1971 aboard a sounding rocket to observe the operation of several heat pipes in a zero gravity environment. The pipe designs which were tested included a spiral artery, a pedestal artery, and a plain groove. Two control pipes without wicking were also flown. The two artery pipes were similar to those which will be used on the OAO-C satellite, while the groove pipe was similar to that used on the ATS-F spacecraft. The results of the experiment indicate that the heat pipes operated satisfactorily during the flight which included four minutes of zero gravity. (Author)

72044 HEAT TRANSFER LIMITS, LIFETESTS, AND DYNAMIC BEHAVIOR OF HEAT PIPES

M. Groll, O. Brost, H. Kreeb, K. P. Schubert, P. Zimmermann, Institut Fur Kernenergetik, Universitat Stuttgart, Germany, 28 pages. In English. Avail: TAC

Heat pipes are devices possessing a very high thermal conductance which utilize two phase flow for the transport of mass and the latent heat of vaporization. Today, there exists a variety of practical uses for heat pipes in the temperature range between 200 K and 2000 K. In this paper, the discussion is mainly restricted to low temperature heat pipes (200 K to 500 K) while the subject of mean and high temperature heat pipes is only touched. Special problems and the necessary technological background are described. Results of performance and lifetests are also included.

Besides general problems of heat pipe construction, fabrication, and operation, there is the important field of heat pipe dynamics. In general, small power variations around the operation point of a heat pipe present no special dynamic problems. However, the startup of heat pipes is much more complicated and there are applications which require that these difficulties be overcome. A theoretical model for describing heat pipe startup is also developed, and examples for normal startup and for startup failure are then subsequently presented.

72045 PERFORMANCE CHARACTERISTICS OF WATER HEAT PIPES OF ANNULAR WICK CONFIGURATION.

K. C. Sockalingam, V. E. Schrock. University of California, Berkeley. Trans. Amer. Nucl. Soc., 14; No. 2, 436-437. October 1971. Avail: TAC

An experimental study of an annular heat pipe was undertaken to evaluate the merits of using an annular design to reduce the resistance to capillary pumping.

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00002 WHITFIELD M G
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00003 CORMAN J C KELLY P E
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00009 ZERKLE R D
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00005	# INTERNAL	CONFIGURATION FOR A RADIAL HEAT PIPE
00003	HEAT PIPE	COOLED CAPACITOR#
00002	SUPER-	COOLED DISK BRAKE#
00001	PLATE#	COOLED ELECTRONIC EQUIPMENT MOUNTING
00004	FIBROUS VAPOR	COOLING MEANS#
00009	THE LIKE#	COOLING SYSTEM FOR CUTTING TOOL AND
00009	COOLING SYSTEM FOR	CUTTING TOOL AND THE LIKE#
00007	VING HEAT PIPES INCORPORATED IN THE	DISCONNECTING STRUCTURES AND POWER C
00002	SUPER-COOLED	DISK BRAKE#
00001	COOLED	ELECTRONIC EQUIPMENT MOUNTING PLATE#
00008		ENGINE EXHAUST GAS HEATER#
00001	COOLED ELECTRONIC	EQUIPMENT MOUNTING PLATE#
00008	ENGINE	EXHAUST GAS HEATER#
00013	AR REACTOR WITH HEAT PIPES FOR HEAT	EXTRACTION# NUCLE
00010	METHOD OF	FABRICATING A HEAT PIPE#
00004		FIBROUS VAPOR COOLING MEANS#
		'FOR ' NOT INDEXED
00008	ENGINE EXHAUST	GAS HEATER#
00012	THERMALLY CASCADED THERMOELECTRIC	GENERATOR#
00007	E DISCONNECTING STRUCTU/ SWITCHGEAR	HAVING HEAT PIPES INCORPORATED IN TH
00013	NUCLEAR REACTOR WITH HEAT PIPES FOR	HEAT EXTRACTION#
00003		HEAT PIPE COOLED CAPACITOR#
00011	SEGMENTED	HEAT PIPE#
00010	METHOD OF FABRICATING A	HEAT PIPE#
00005	INTERNAL CONFIGURATION FOR A RADIAL	HEAT PIPE#
00013	NUCLEAR REACTOR WITH	HEAT PIPES FOR HEAT EXTRACTION#
00007	NNECTING STRUCTU/ SWITCHGEAR HAVING	HEAT PIPES INCORPORATED IN THE DISCO
00006	D HEAT TRANSFER SURFACE#	HEAT TRANSFER APPARATUS WITH IMPROVE
00006	AT TRANSFER APPARATUS WITH IMPROVED	HEAT TRANSFER SURFACE# HE
00008	ENGINE EXHAUST GAS	HEATER#
00006	HEAT TRANSFER APPARATUS WITH	IMPROVED HEAT TRANSFER SURFACE#
		'IN ' NOT INDEXED
00007	RUCTU/ SWITCHGEAR HAVING HEAT PIPES	INCORPORATED IN THE DISCONNECTING ST
00005	HEAT PIPE#	INTERNAL CONFIGURATION FOR A RADIAL
00009	ING SYSTEM FOR CUTTING TOOL AND THE	LIKE# COOL
00004	FIBROUS VAPOR COOLING	MEANS#
00010		METHOD OF FABRICATING A HEAT PIPE#
00001	COOLED ELECTRONIC EQUIPMENT	MOUNTING PLATE#
00013	HEAT EXTRACTION#	NUCLEAR REACTOR WITH HEAT PIPES FOR
		'OF ' NOT INDEXED
00003	HEAT	PIPE COOLED CAPACITOR#
00011	SEGMENTED HEAT	PIPE#
00010	METHOD OF FABRICATING A HEAT	PIPE#
00005	NAL CONFIGURATION FOR A RADIAL HEAT	PIPE# INTER
00013	NUCLEAR REACTOR WITH HEAT	PIPES FOR HEAT EXTRACTION#
00007	ING STRUCTU/ SWITCHGEAR HAVING HEAT	PIPES INCORPORATED IN THE DISCONNECT
00001	OOLED ELECTRONIC EQUIPMENT MOUNTING	PLATE# C

00007 IN THE DISCONNECTING STRUCTURES AND POWER CONDUCTORS# /PES INCORPORATED
00005 INTERNAL CONFIGURATICN FOR A RADIAL HEAT PIPE#
00013 RACTION# NUCLEAR REACTOR WITH HEAT PIPES FOR HEAT EXT
00011 SEGMENTED HEAT PIPE#
00007 S INCORPORATED IN THE DISCONNECTING STRUCTURES AND POWER CONDUCTORS# /PE
00002 SUPER-COOLED DISK BRAKE#
00006 PARATUS WITH IMPROVED HEAT TRANSFER SURFACE# HEAT TRANSFER AP
00007 RATED IN THE DISCONNECTING STRUCTU/ SWITCHGEAR HAVING HEAT PIPES INCORPO
00009 # COOLING SYSTEM FOR CUTTING TOOL AND THE LIKE
'THE ' NOT INDEXED
00012 NERATOR# THERMALLY CASCADED THERMOELECTRIC GE
00012 THERMALLY CASCADED THERMOELECTRIC GENERATOR#
00009 COOLING SYSTEM FOR CUTTING TOOL AND THE LIKE#
00006 T TRANSFER SURFACE# HEAT TRANSFER APPARATUS WITH IMPROVED HEA
00006 ANSFER APPARATUS WITH IMPROVED HEAT TRANSFER SURFACE# HEAT TR
00004 FIBROUS VAPOR COOLING MEANS#
'WITH ' NOT INDEXED

G.3 AUTHOR INDEX

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00010	ALEXANDER E E
00007	CLEAVELAND C M
00010	COMSTOCK I J
00003	CORMAN J C
00001	FELDMANIS C J
00013	FIEBELMANN P
00005	FREGGENS R A
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00009	ZERKLE R D

G.4 PATENT NUMBER INDEX

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HEAT PIPE RELATED PATENTS JUNE 30, 1972 UPDATE

00001	U.S. PATENT 3651865#
00002	U.S. PATENT 3651895#
00003	U.S. PATENT 3656035#
00004	U.S. PATENT 3656545#
00005	U.S. PATENT 3658125#
00006	U.S. PATENT 3661202#
00007	U.S. PATENT 3662137#
00008	U.S. PATENT 3662542#
00009	U.S. PATENT 3664412#
00010	U.S. PATENT 3665573#
00011	U.S. PATENT 3666005#
00012	U.S. PATENT 3666566#
00013	U.S. PATENT 3668070#