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**DIRECT ENERGY CONVERSION
LITERATURE ABSTRACTS**

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DIRECT ENERGY CONVERSION LITERATURE ABSTRACTS

Introduction

This is the sixth 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.

Users who are primarily interested in thermoelectricity are referred to the four-part bibliography which preceded the present undertaking. Entitled Thermoelectricity Abstracts, it was issued May (PB 151657) and August (PB 151810) 1959, and March (PB 161301) and August (PB 161714) 1960. Copies may be obtained from the Office of Technical Services, U.S. Department of Commerce, Washington, D.C., 20235, by citing the PB numbers included above, following the dates.

The NRL Library does not have copies of the listed material available for outside loan. It is, therefore, suggested that those desiring access to material cited utilize their usual channels for loan or acquisition.

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Suggestions concerning this bibliography are encouraged by the compiler, Miss Eileen Pickenpaugh, Consultant in Research Information, U.S. Naval Research Laboratory, Code 2023, Washington, D.C., 20390.

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I. ENERGY CONVERSION
A. General Information

4639

Aerospace Corp., El Segundo, Calif.
ENERGY CONVERSION RESEARCH PROGRAM. ELECTRICAL PROPERTIES OF ORGANIC COMPOUNDS, January 1 - June 30, 1962, by H.H. Takimoto, and others. 10p., Jly.31,1962. (Semi-annual Tech.Rept.) (Rept. TDR 69(2220-20) TR-2) (Contract AF 04(695)69) (DCAS TDR 62-166) (AD-288 925)

The investigation concerned the mechanism of the electronic conduction process in organic compounds to provide data for development of new solid-state and energy conversion concepts. Several methods were studied for the preparation of organonitrile compounds whose derivatives may exhibit relatively high conductivities. This led to an interesting and unusual reaction involving anthrone, thionyl chloride and malononitrile resulting in formation of the heretofore unreported 10-dicyanomethylenanthrone. (TAB U63-1-4:19, Feb.15, 1963)

4640

AiResearch Manufacturing Co., Los Angeles, Calif.
THERMOKINETIC ION CONVERTER STUDY, by R. Parthasarathy, and A.L. Vodopia. 106p., June 1962. (Final Rept.) (ASD-TDR-62-285) (Contract AF 33(616)-7894)

This report presents an analytical as well as experimental study on extracting electrical power from an ionized gas stream. Included in this report are a literature survey on ion convection generators, principles of ionization with reference to effects of non-equilibrium conditions, space charge neutralization studies, one dimensional flow of an ionized gas and interaction of ions and neutrals. A description of the converter design and a detailed discussion of the experimental results are presented in this report.

4641

Baum, V.A. USE OF SOLAR ENERGY FOR ELECTRICITY PRODUCTION BY DIRECT CONVERSION BY MEANS OF THERMOELECTRIC CONVERTERS AND PHOTO-ELECTRIC CELLS. United Nations Conference on New Sources of Energy, Rome, June 1961, 31p., illus.

Three types of converters of solar energy into electricity are discussed (1) thermoelectric, (2) photoelectric and (3) thermionic. (Solar En., 7:81-82, Apr.-June 1963)

4642

Bialer, M. ADVANCES IN SOLID STATE ENERGY CONVERSION DEVICES. Proc. Nat. Aerospace Electron. Conf., 6-9, 1961.

Devices for converting heat, light, motion and radiation into electrical energy are briefly surveyed. (Instr. Abs., 17:8199, Dec. 1962)

4643

California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif. MARINER VENUS POWER-SUPPLY SYSTEM, by E.N. Costogoe. 21p., Mar. 30, 1963. (Tech. Rept. 32-424) (Contract NAS 7-100)

The report covers the design, development, and integration of the components and subsystems comprising the power supply for Mariner Venus spacecraft. Data on the performance of the power system from launch until the end of mission are also presented.

4644

California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif. SPACE PROGRAMS SUMMARY NO. 37-20, Volume IV. SUPPORTING RESEARCH AND ADVANCED DEVELOPMENT, February 1 - March 31, 1963. 230p., Apr. 30, 1963. (Contract NAS 7-100)

Research of interest reported includes: Solar energy thermionic (SET) electrical power supply by P. Rouklove, p. 7-11; Development of 5-ft D electroformed mirrors by Z. Brozdowicz, p. 11-12; Energy storage by G.M. Arcand, p. 13-14; Electrical conversion by R.L. Spencer, p. 14-16; and Power systems by E.L. Leventhal, p. 16.

4645

Chang, S.S.L. ENERGY CONVERSION. Englewood Cliffs, N.J., Prentice-Hall, 1963.

This book is a text on non-electromechanical energy conversion. It covers thermoelectric engines, thermionic converters, magnetohydrodynamic engines, photovoltaic effect and solar cells, and free energy and fuel cells.

4646

Cox, A.L. COLLOIDAL ELECTROHYDRODYNAMIC ENERGY CONVERTER. ARS Preprint no. 2559-62. New York, American Rocket Society, 1962. Prepublication Copy. 10p.

The colloidal electrohydrodynamic energy converter described changes the thermal energy of a slightly ionized superheated vapor to directed kinetic energy, then to high-voltage electric energy. High conversion efficiency is possible if neutral atoms can be made to condense on the ions, which are being pushed against a retarding electric field. Radiation and radiator requirements of the system are noted. The electric power output attainable should be better than 0.4 kw/lb at 500 kw. Use of

the system for propulsion and internal power for spacecraft is discussed. Performance of Hg, K, Na, and Li as working fluids is described. (Nuclear Sci.Abs., 17:9122, Mar.31,1963)

4647

Davis, W.K. ENERGY CONVERSION, ENGINEERS MAKE IT WORK. Mech. Eng., 85:38-39, Mar. 1963.

There's the theoretical device, sketched by the scientist, promising a new era in power generation. But then come engineering realities, problems for engineers who know costs and can integrate the new device into the overall plant.

4648

Debiesse, Jean, Klein, Siegfried and Taillet, Joseph. TEST OF THE PHYSICAL INTERPRETATION OF AN ENERGY CONVERSION PHENOMENON. Acad.Sci.Paris. Compt.Rend., 255:3144-3146, Dec.5,1962.

In French. The possibility of collecting the electrical power from electrodes plunged in a gas at pressure close to atmospheric pressure, propelled by a rotation movement or to great pressure variations, and exposed to x irradiation was recently shown experimentally (Compt. Rend., 254: 4151(1962)). The phenomenon is particularly sharp with argon. A possible explanation for this energy conversion is proposed. (Nuclear Sci.Abs., 17:17346, May 31,1963)

4649

Egli, P.H. HISTORY AND RECENT DEVELOPMENTS IN DIRECT ENERGY CONVERSION SYSTEMS. Materials Science and Technology for Advanced Applications., Englewood Cliffs, N.J., p.371-407, 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. Magneto-hydrodynamics 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. (Nuclear Sci.Abs., 17:6551, Mar.15,1963)

4650

Electro-Optical Systems, Inc., Pasadena, Calif. THERMAL RADIATION GUIDES FOR POWER TRANSMISSION, October 1 - December 31, 1962, by W.J. Swenson. 48p., illus., Jan.15, 1963. (Q.Tech.Prog.Rept.3) (EOS Rept. 3000-Q-3) (Contract AF 33(657)-8526) (AD-295 410)

Research progress is directed towards achieving a fundamental advance in the state of the art of energy transmission in spacecraft by a technique heretofore unexplored for this purpose. The technique discussed involves the transmission of radiant energy through a hollow, reflective tube from a heat source to some other location in a spacecraft without intermediate Carnot cycle limited conversion process. This technique is particularly useful for applications in which a significant portion of the total energy requirement is in the form of thermal energy. (TAB U63-2-3:72, May 1,1963)

4651

Euler, J. UNGEBRAEUCHLICHE METHODEN ZUR STROMERZEUGUNG. (UNUSUAL METHOD FOR ELECTRICAL CURRENT GENERATION). Chemie-Ingenieur-Technik, 34:567-571, Aug.1962.

In German. In recent years, numerous investigators have concerned themselves with thermionic diodes, magnetohydrodynamic converters, thermocouples and fuel cells; also considers a whole series of wrongly forgotten arrangements. These are the cesium-vapor jet generator, galvanic cells with liquid sodium-amalgam, electrokinetic current generators with porous plates through which flow takes place, thermocells of Weininger and ferro-electric arrangements. (Battelle Tech.Rev., 11: 504a, Dec.1962)

4652

Fortini, A. THERMO-PHOTOELECTRIC ENERGY CONVERSION. Onde Elect., 42:530-540, June 1962.

A simplified model is used to calculate the conversion efficiency of a cooled p-i-n structure irradiated by a local source. The operation of a practical device is considered and the potential advantages over the solar cell are noted. (Indust. Electron. Abs., 1:A193, Dec. 1962)

4653

Fuechsel, K.M. DIRECT CONVERSION OF NUCLEAR ENERGY INTO ELECTRICAL OR THRUST ENERGY. Am. Nuclear Soc. Trans., 4:335-336, Nov.1961.

Abstract of paper 32-7 given at winter meeting, November 7-9, 1961, Chicago.

A description is given showing how nuclear energy is converted directly into electrical or thrust energy.

4654

General Electric Co., Light Military Electronics Department, Advanced Electronics Center, Ithaca, N.Y.
SURVEY OF POWER SOURCES, by N. Wheeler. 57p., 1961.

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, thermo-electric power generation, thermionic cells, nuclear cells, primary and secondary cells, reserve or delayed action batteries, fuel cells, etc. (Eng.Index, p.40, Jly.1963)

4655

Great Britain, Royal Aircraft Establishment, Farnborough Hants.
VISIT TO A.R.S. SPACE POWER SYSTEMS CONFERENCE, SANTA MONICA, CALIFORNIA. SEPTEMBER 1960, by H.J.H. Sketch. 33p., June 1961. (TM G.W. 394)

This publication consists of abstracts of some of the papers given at the conference, written by an attendee. They are grouped under the following headings: power requirements; photovoltaic cells; fuel cells; secondary batteries; thermionics; thermo-electricity; heat engines, plasma generators; solar systems; and nuclear systems.

4656

Hoh, S.R. CONVERSION OF THERMAL TO ELECTRICAL ENERGY WITH FERROELECTRIC MATERIALS. Inst. Elec.& Electr.Engrs.Proc., 51:838-845, May 1963.

The subject is reviewed and recent experimental and theoretical results are presented. It is shown that materials with high polarization and high dielectric strength can yield good conversion efficiencies. Very high specific outputs are calculated for the conversion of uncollected solar radiation by a spinning space vehicle. Such high specific outputs require suitable thin ferroelectric films of high thermal shock resistance. These requirements can not be met in present experimental converters. Approaches for the improvement of insulation resistance and polarization are given.

4657

Hughes, W.L., Summers, C.S. and Allison, H.J. AN ENERGY SYSTEM FOR THE FUTURE. Inst. Elec.& Electr.Engrs.Trans., IE-10:108-111, May 1963.

A technique for the practical utilization of solar energy on a continuous basis to provide bulk power is described. The output of solar energy converters is used to produce hydrogen by pressure electrolysis of water. The energy stored in the hydrogen can be efficiently transformed into electrical energy by the use of hydrogen-oxygen fuel cells.

4658

ITT Federal Laboratories, Nutley, N.J. FERROELECTRIC ENERGY CONVERSION, April 1961- April 1962, by S.R. Hoh and F.E. Pirigyi. 51p., June 1962. (Final Rept.) (Contract AF 33(616)-7940) (ASD-TDR-62-398)

A study was conducted to explore the usefulness of ferroelectric energy conversion for flight vehicle power supplies. The development of barium titanate-based materials was encouraging and fruitful. Ceramic sheets with very high values of polarization, permittivity, and insulation resistance were prepared. A new approach for introducing low valency anions such as fluorine simultaneously with high valency cations such as uranium proved successful and practical. The conversion efficiency does not exceed 1% with BaTiO₃-based compositions, but good specific outputs can be calculated for very thin ferroelectric films. (STAR, 1:16-17, Jan.8, 1963)

4659

Jecht, K. and Gross, A.T. DIRECT USE OF RADIATION. Brennstoff-Warme-Kraft, 14: 337-347, Jly.1962.

In German. Gives a summary of the papers of the United Nations Conference on New Sources of Energy, Aug. 1961 in Rome. Solar energy collectors, heat exchangers etc. are considered for water-heating, refrigeration, room-heating, cooling and conditioning; costs are indicated. The papers cover experience in various parts of the world. (Elec.Eng.Abs., 65:13993, Dec. 1962)

4660

Jenny, E. SURVEY OF THE FOUR MOST IMPORTANT PROCESSES FOR THE DIRECT CONVERSION OF ENERGY (HEAT INTO ELECTRICITY). Soc.Roy. Belge Elect., Bull., 78:227-248, Jly.-Sept.1962.

In French. This survey considers methods based on chemical cells, thermoelectricity, thermionic generators, and magnetohydrodynamic generators. In each case, the

principles and the practical designs and developments are described. (Elec.Eng. Abs., 66:5618, June 1963)

4661
Kilbon, Kenyon. ENERGY CONVERSION. Radiotronics, 28:3-7, Jan.1963.

New electronic technology, founded upon pains-taking research, is preparing a future era of noiseless generators that function without moving parts to transform heat, light, and chemical energy directly and simply to abundant electric power - first in handy packages for use anywhere on earth or in space, and eventually in great central stations serving urban industrial complexes across the continent.

4662
Klein, S. THE DIRECT CONVERSION OF THERMAL ENERGY INTO ELECTRICAL ENERGY. "Ionization in Gases" Conference Paper, Munich, 1961, p.806-814.

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 electrical charges was obtained without applying an electrical or magnetic field in the vicinity 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. (Phys.Abs.,66:3996, Mar.1963)

4663
Klein, S. and Preve, J. A PROCESS FOR THE CONVERSION OF IONIZATION ENERGY TO ELECTRICITY. J.Phys.Radium, 23:588-589, Aug.-Sept.1962.

In French. Following proposals for a method of direct conversion of heat into electricity a device is described for directly converting atomic energy into electricity. An experimental device using X-rays as a source of ionization produced on open-circuit potential of 25 V and a short-circuit current of 22×10^{-9} A, and

had an internal resistance of about 10^8 ohms. (Elec.Eng.Abs., 66:3497, Apr.1963)

4664
Marks Polarized Corp., Whitestone, N.Y. THE CONVERSION OF HEAT TO ELECTRICAL POWER BY MEANS OF A CHARGED AEROSOL, April 1 - June 30, 1961. 66p., illus., Nov.14,1961. (Q.Rept.4) (Contract NOW 60-0831-c) (AD-284 662)

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. (TAB U63-1-1:85, Jan.1,1963)

4665
Massachusetts Institute of Technology, Cambridge, Mass. ANNUAL REPORT 1962-63, MATERIALS SCIENCE AND ENGINEERING. p.103-119, Apr.1963.

Section B, Chapter 6, covers semiconductors and semiconductor devices, thermoelectric processes and materials and energy conversion materials, processes, and devices.

4666
Massachusetts Institute of Technology, Energy Conversion Research, Cambridge, Mass. RESEARCH ON MATERIALS, PROCESSES, AND DEVICES RELATED TO ENERGY CONVERSION. 68p., Dec.31,1962. (Sci. Rept. 6) (Contract Nonr-1841(78))

Research Reports on: I. Superconducting Materials and Systems. II. Electrochemical Energy Conversion Research. III. Thermoelectric and Thermionic Materials Research. IV. Solid State Energy Converters. V. The Development of Thermionic Emitter Materials.

4667
National Aeronautics & Space Administration, Washington, D.C. POWER FOR SPACECRAFT, by N.D. Sanders, and others. 26p., Dec.1962.

The subject of this paper is the electric requirements for spacecraft. Certain aspects of the interrelation of power requirements, energy sources, and conversion techniques are discussed.

4668

Picquendar, J.E. DIFFERENTS SYSTEMS DE PRODUCTION D'ENERGIE A BORD DES SATELLITES. (DIFFERENT SYSTEMS FOR THE ENERGY PRODUCTION IN SATELLITES). International Scientific Radio Union (URSI), Symposium, Paris, France, Sept.18-22, 1961. In Space Radio Communication, New York, Elsevier Publishing Co., 1962. p. 224-238, Discussion, J.Maillard, p.238, 239.

In French. Examination of the problems created by the use of various power-generating systems in satellites and their association with solar and nuclear energy sources. The discussion covers energy requirements, energy sources, energy converters, and systems for the generation of electric power. (Intern.Aerospace Abs., 3:A63-14247, May 1,1963)

4669

Potter, J.A. and Tyler, J.S. SUPERCRITICAL CRYOGENIC HYDROGEN AND OXYGEN STORAGE SYSTEMS FOR DIRECT ENERGY CONVERTER REACTANT SUPPLY IN MANNED SPACECRAFT. ARS Preprint no. 2515-62. New York, American Rocket Society, 1962. Prepublication Copy. 24p.

An outline is given of the description and operation of supercritical cryogenic systems for storing gases in space vehicles. Considerations of weight, thermodynamics, insulation, delivery rates, materials of construction, fluid delivery rates, and heat leaks are discussed. Data are given for H₂, O₂, and N₂. (Nuclear Sci.Abs., 17: 9123, Mar.31,1963)

4670

Republic Aviation Corp., Missile Systems Division, Mineola, N.Y.
A SHORT REVIEW OF SPACE POWER SYSTEM TECHNOLOGY. 42p., May 18, 1962.(NP-12492)

A brief review is presented of various power systems currently available for space vehicles. The systems discussed are solar cells, primary batteries, secondary batteries, fuel cells, solar thermionic systems, nuclear power systems, chemical systems, and microwave power transmission. The pertinent characteristics of the available power systems for space application are summarized and compared with each other for specific power levels and missions. (Nuclear Sci.Abs.,17:12035, Apr.15,1963)

4671

Schulte, H.A., Jr., Tarter, J.H., and Roble, R.G. COMPARATIVE ANALYSIS OF FUEL CELL,

SOLAR CELL, AND CRYOGENIC CHEMICAL DYNAMIC SPACE POWER SYSTEMS FOR INTERMEDIATE DURATION MISSIONS. American Rocket Society, Space Power Systems Conf., September 25-28, 1962. Santa Monica, Calif., 1962. (ARS Paper 2524-62) 9p.

The operating characteristics, advantages, disadvantages, and problem areas of fuel cell systems, solar cell systems, and cryogenic chemical dynamic systems are discussed. System parameters are defined for power levels up to 5 kw and for space mission durations up to 14 days. The limitations of each system are discussed and the system characteristics compared. (Astron.Info.Abs., 7:70,502, Feb.1963)

4672

Spring, K.H. MATERIALS FOR USE IN NEW METHODS OF POWER CONVERSION. I. Eng.Mat.& Design, 5:482-485, Jly.1962.

Discussion of the principles of fuel cell, MHD, and thermionic power generation, and the environmental conditions they produce. The factors to be considered in diode construction and their interaction as they affect materials selection are described. (Intern. Aerospace Abs., 2:7764, Aug.1962)

4673

Sundstrand Aviation-Denver, Engineering and Testing Laboratory, Pacoima, Calif.
A FEASIBILITY STUDY OF A THIONINE PHOTO-GALVANIC POWER GENERATION SYSTEM, March 1961 - February 1962, by L.J. Miller. 234p., May 1962. (Tech. Documentary Rept.) (Contract AF 33(616)-7911) (ASD-TDR-62-373)

A feasibility study was made of the thionine photogalvanic system for converting solar energy to electrical energy. Theoretical and experimental investigations have been made to determine the maximum voltage and power available from the system. The effects of operating conditions as well as solution composition variables on cell performance have been studied. Cell voltages up to 220 mv and power levels up to 1.8μ watts were obtained. Estimates of the power, weight, and cost of a photogalvanic cell have been made on the basis of present knowledge. (STAR, 1:92-93, Jan.23,1963)

4674

Teodorovich, E.V. POSSIBLE METHOD FOR CONVERSION OF THERMAL ENERGY INTO ELECTRICITY. Zhurn. Tekh. Fiz., 32:1490-1492, Dec.1962.

In Russian. Transl. in Soviet Phys., Tech.Phys., 7:1101-1102, June 1963.

A technique for the direct conversion of thermal energy into electricity is

considered. It is based on the partial ordering of the random thermal motion of charged particles in a nonuniform magnetic field, which leads to the production of a current and an effective emf.

4675

U.S. Air Force, Aeronautical Systems Division, Wright-Patterson AFB, Ohio.
PROPERTIES OF INORGANIC ENERGY-CONVERSION AND HEAT-TRANSFER FLUIDS FOR SPACE APPLICATIONS, by W.D. Weatherford, J.C. Tyler, and P.M. Ku. (WADD TR 61-96) (AD-267 541)

Various inorganic fluids which may be of potential value for energy conversion or heat-transfer in space applications are examined. The fluids are presented in three distinct classes—liquid metals, nonmetals, and gases. Their characteristics are discussed, and their recommended property values are presented in tabular and graphical form, with detailed documentation of basis and source. In addition, background material is discussed, including thermodynamic cycle, heat transfer, compatibility, and working fluid considerations. Current research activities in this field are summarized. (Astronautics Information Abs., 5:5,593, June 1962)

4676

U.S. Atomic Energy Commission, Argonne National Laboratory, Washington, D.C.
CHEMICAL ENGINEERING DIVISION SUMMARY REPORT, July, August, September 1962. 218p., Sept. 1962. (ANL-6596)

Section V. Energy Conversion. Studies on regenerative emf cells are continuing with the object of converting nuclear energy into electricity. Research on thermoelectric materials for direct conversion of heat into electricity has continued. Seebeck coefficient measurements in the temperature range from 100 to 900 C have been made on a sintered uranium monosulfide ingot containing one percent by weight uranium oxysulfide.

4677

Wedlock, B.D. THERMO-PHOTO-VOLTAIC ENERGY CONVERSION. Inst. Elec. & Electr. Engrs. Proc., 51:694-698, May 1963.

The concept of a thermo-photo-voltaic (TPV) energy converter is introduced and the device compared with thermoelectric and thermionic converters. Features of the TPV converter are that the entire device is kept at room temperature; potential power densities on the order of 10 w/cm², and potential conversion efficiencies of 30 per cent are possible. Considerations for TPV converter design are presented and compared with solar cells. Use of geometry and thin-film optical filters to improve

efficiency is discussed. For a germanium converter operating with a hot source in the neighborhood of 1600°C a p-i-n structure with the absorption taking place in the intrinsic base region is shown to give maximum efficiency. A measured efficiency of 4.23 per cent on an experimental converter with 282 mw/cm² incident energy has been achieved.

4678

Westinghouse Electric Corp., Aerospace Electrical Division, Lima, Ohio.
SPACE ELECTRIC POWER SYSTEMS STUDY, November 8, 1961 - February 8, 1962, by F.X. Dobler, and others. 306p., Feb. 8, 1962. (Prog. Rept.-First Q.) (Contract NASS-1234)

Purpose of the contract is to develop parametric data for the generation, control, conversion and transmission of electric power for space systems. Ratings to be studied are between one and ten megawatts. This report presents the technical data developed during the first three months.

4679

Wilson, G.W. SMALL NON-CONVENTIONAL ELECTRICAL POWER SOURCES. Brit. Interplan. Soc. J., 19:81-86, May-June 1963.

The present status of each of three methods of conversion of heat or light into electrical power without the use of rotating machinery is surveyed: thermoelectricity, thermionic conversion, and photovoltaic converters. A comparison of practical devices indicates that for some time each method will find specialized applications.

B. Bibliographies

4680

Atomics International, Canoga Park, Calif.
A DISCUSSION AND BIBLIOGRAPHY OF CURRENT LITERATURE CONCERNING VAN ALLEN BELTS FOR USE IN SNAP ENVIRONMENTAL STUDIES, by V.E. Kistler. 47p., Feb. 15, 1963. (NAA-SR-78 49)

This report presents a bibliography of theoretical and experimental papers which concern the Van Allen trapped radiation belts. A general discussion of past history and conclusions from some experimental data are also presented.

4681

Autonetics, Downey, Calif.
ANNOTATED BIBLIOGRAPHY ON THERMOELECTRICITY-MATERIALS AND DEVICES, by B.H. Nagel. 225p., Jan. 28, 1960. (EM-5987)

4682

Avco-Everett Research Laboratory, Everett, Mass.
MAGNETOHYDRODYNAMIC POWER GENERATION. A BIBLIOGRAPHY, by B.A. Spence. 39p., June 1963. (AMP 110)

The bibliography was prepared to serve as a reference tool for scientists and engineers interested in the field of magnetohydrodynamic power generation. It was aimed to have a complete and all-inclusive listing of material in print anywhere in the world in the field of MHD power generation. Periodic addenda will be published.

4683

Great Britain, Department of Scientific and Industrial Research, National Engineering Laboratory, Edinburgh.
HEAT BIBLIOGRAPHY, 1961, by A.J. Ede. 325p., 1961.

Includes some references to thermoelectric powers.

4684

International Atomic Energy Agency, Vienna.
BIBLIOGRAPHY ON RESEARCH ON CONTROLLED THERMONUCLEAR FUSION. 260p., 1961.

The bibliography includes about 2900 references to works published between January 1955 and December 1960.

4685

Lockheed Aircraft Corp., Sunnyvale, Calif.
ELECTROCHEMICAL FUEL CELLS: AN ANNOTATED BIBLIOGRAPHY, by S.J. Buginas. 56p., Dec. 1962. (Special Bibliography SB-62-51) (Rept. 2-99-62-5) (Suppl. to AD-251 660 and AD-253 809) (AD-296 360)

This bibliography consists mostly of references dated late 1961 and the first 9 months of 1962. It is a supplement to the following LMSC Electrochemical Fuel Cell bibliographies: SRB-60-5 (AD-251 660) Nov. 1960, SRB-60-5 (AD-253 809) Feb. 1961, and SRB-62-2, Mar. 1962. Search completed October 1962. (TAB U63-2-4:16, May 15, 1963)

4686

North American Aviation, Inc., Downey, Calif.
AUXILIARY POWER SOURCES IN SPACE: TECHNICAL DOCUMENTATION. VOLUME I. FUEL CELLS. 156p., illus., Jly. 12, 1962. (Rept. SID 62-708) (AD-282 474)

This bibliographic search surveys the literature on fuel cells from 1950 to date, with special emphasis on hydrogen-oxygen, molten salt electrolytes, redox and ion membrane exchange types. (TAB U62-4-5:34, Dec. 1, 1962)

4687

Stanford Research Institute, Menlo Park, Calif.
VOLUME I. A BIBLIOGRAPHY OF BINARY I-VII COMPOUNDS. VOLUME II. A BIBLIOGRAPHY OF GROUP II-VI COMPOUNDS. VOLUME III. A BIBLIOGRAPHY OF GROUP III-V COMPOUNDS. VOLUME IV. A BIBLIOGRAPHY OF GROUP IV ELEMENTS AND THEIR COMPOUNDS, by W.J. Fredericks, F.J. Keneshea, and F. Craig.

4 vols., u.d. (SR 2) (AFCRL 62-917(I), (II), (III), & (IV)) (Contract AF 19(604)-7231)

This report provides a 1946-1961 bibliography of solid state research on I-VII compounds, II-VI compounds, III-V compounds and group IV elements and their compounds.

4688

U.S. Atomic Energy Commission, Washington, D.C.
DIRECT ENERGY CONVERSION AND SYSTEMS FOR NUCLEAR AUXILIARY POWER (SNAP), by S.F. Lanier, and H.D. Raleigh. 61p., Jan. 1963. (TID-3561 (Rev.3))

This search contains 552 references to publications on the SNAP program and related topics. The references were taken from Nuclear Science Abstracts and cover the issues through December 31, 1962.

C. Patents

4689

Ackerman, K. ALKALINE BATTERY ELECTRODES. Belg. 620,911, Jan. 31, 1963, Ger. Appl. Aug. 4, 1961, 5p. (to Badische Anilin- & Soda-Fabrik A.-G.)

Electrodes can be activated by treating a salt of a slightly basic metal in aqueous solution, followed by an alkaline treatment and water rinse. Salts are Zn, Cr, Al as $Al(NO_3)_3$. A single treatment by $Al(NO_3)_3$ yields better results than 4 deposits from $NiNO_3$. The activation is better in the presence of oxidizing anions. (Chem. Abs., 59:1291, Jly. 22, 1963)

4690

Andre, H.G. ELECTRODE ASSEMBLY FOR ELECTRIC BATTERIES OR ACCUMULATORS. U.S. Patent 3,075,032, Nov. 19, 1959. (to Yardney International Corp., New York, N.Y.)

An electrochemical cell, comprising a positive electrode, a negative electrode and electrolyte therebetween, said negative electrode comprising a layer of electrochemically active zinc material provided on one side only with a coating of copper. (U.S. Patent Off. Off. Gaz., 786:1224, Jan. 22, 1963)

4691

Boyarchuk, M.K. and Gil'manov, K.N. CHEMICAL DRY CELL BATTERY. USSR Patent 152,489, Feb. 12, 1963, Appl. June 5, 1961. (Byul. Izobret. i Tovarnykh Znakov, no. 1:16, 1963)

The battery is a can-type, Zn-Mn system. To increase efficiency, simplify construction, and improve the elec.-tech. parameters, a layer of lacquer containing $HgCl_2$, $ZnCl_2$, and a nitrobase is applied to the inner surface of the can. A layer of starch, forming a separating agent

through swelling, is applied to the lacquer, thus separating the electrodes. The positive electrode is composed of an agglomerate mass and cast immediately inside the negative electrode (the can itself). The latter is insulated by a layer of nondrying organic paste to prevent air from getting through to its working surface. (Chem.Abs.,59: 1291, Jly.22,1963)

4692

Casey, E.J. and Nagy, G.D. METHOD OF INCORPORATING AN ELECTRO-CHEMICALLY ACTIVE CADMIUM COMPOUND INTO A POROUS NICKEL PLAQUE. U.S. Patent 3,068,310, Dec.7,1959. (to Her Majesty the Queen in right of Canada as represented by the Minister of National Defence).

A method of incorporating an electro-chemically active cadmium compound into a porous sintered nickel plaque in the preparation of negative plates for nickel-cadmium storage batteries, which comprises soaking the plaque for at least about 10 minutes in molten $Cd(NO_3)_2 \cdot 4H_2O$ which has been heated to boiling at a sub-atmospheric pressure, removing the plaque and reducing the cadmium nitrate contained therein by heating the plate in a hydrogen filled container for about 1/2 hour to about 2 hours at a temperature of from about 200°C. to about 300°C. and allowing the plaque to cool in a hydrogen atmosphere. (U.S. Patent Off.Off.Gaz., 785:664, Dec.11,1962)

4693

Chambers, H.H. and Tantram, A.D.S. CONSTRUCTION OF FUEL ELEMENTS. German Patent 1,146,150, Mar.28,1963., Brit. Appl. Dec. 29,1955, 3p. (to National Research Development Corp.).

A fuel cell is composed of a fuel element with a gas such as water gas and an O electrode in a semifluid electrolyte. For example, a fuel element of a silvered ZnO electrode at 600° oxidizes CO to CO₂. The electrolyte of Li or Na carbonate is kept suspended in a semifluid melt kept at a few degrees below the eutectic melting temperature. The reaction at the O electrode, $1/2 O_2 + CO_2 + 2e = CO_3^{--}$, results in a current flow of 0.044 amp./sq.m. with a voltage drop of 0.7 v. (Chem.Abs., 59: 1291, Jly.22,1963)

4694

Chambers, H.H. and Tantram, A.D.S. FUEL CELLS. U.S. Patent 3,068,311, June 22,1959. (to National Research Development Corp., a corp. of Great Britain and Northern Ireland).

In a fuel cell for the production of electrical energy by the decomposition of a fuel gas an oxydising gas only, at least one non-consumable electrode composed of a

porous intimate mixture of zinc oxide and metallic silver, the said mixture containing at least 1% silver, the pore size of the electrode being such that flooding of the electrode is prevented by surface tension. (U.S. Patent Off.Off.Gaz., 785: 665, Dec.11,1962)

4695

Charland, T.L. and Moss, R.H. PROCESS FOR THE PREPARATION OF THERMOELECTRIC ELEMENTS. U.S. Patent 3,086,068, June 10,1959. (to Westinghouse Electric Corp., East Pittsburgh, Pa.).

A process for preparing a thermoelectric element comprised of a compacted homogeneous intermetallic compound selected from the group consisting of indium antimonide, indium arsenide, cadmium antimonide and zinc antimonide, comprising, admixing predetermined amounts of two finely powdered metals to form an intermetallic compound selected from the group consisting of indium antimonide, indium arsenide, cadmium antimonide and zinc antimonide, sintering the admixture in an inert atmosphere at a temperature 20°C. to 100°C. below the melting point of the intermetallic compound for from 2 to 15 hours, and compacting the sintered admixture under sufficient pressure and heat to form a compact of desired density and configuration. (U.S. Patent Off.Off.Gaz., 789: 809, Apr.16,1963)

4696

Daley, J.L.S. and Leger, E.E. SEALED GALVANIC CELL. U.S. Patent 3,068,312, Nov.19,1958. (to Union Carbide Corp., a corp. of New York).

A sealed galvanic cell comprising a cupped metallic container made of a rigid metal and having an electrolyte therein; said cell being sealed at the open end of said cupped container by a seal closure which comprises a cover made of a rigid metal and a seal ring made of a hard di-electric plastic-like material which is not readily wetted nor deleteriously affected by said electrolyte and is characterized by a resistance to cold-flow and a high compressive and shear strength; said cover and container having opposite electrical charges, said cover having a substantial horizontally disposed portion which terminates at the periphery of said cover in a vertical edge; said seal ring having an annular, generally upstanding portion having an inner vertical section which corresponds to said vertical edge of said cover and an outer vertical section which corresponds to a section of said cupped cylindrical container; said annular upstanding portion of said seal ring being interposed between said cover and the inner sidewall of said cupped container with said vertical portions in

juxtaposition with the corresponding vertical portions of said container sidewall and said cover; said annular upstanding portion being in a state of radial compression between said cover and said container sidewall and exerting a force which is normal to said vertical portions of said container sidewall, cover, and annular upstanding portion, and parallel to said substantial horizontally disposed portion of said cover; said force being substantially equivalent to, but not greater than the yield strength of the rigid metal of which said cupped container is formed; and said seal ring having another portion integral with said upstanding portion which physically and electrolytically separates said oppositely charged cover and container at the point of sealing from electrolyte carrying elements of said cell and provides an elongated electric current path between said oppositely charged cover and container when the surface of said another portion is wetted by electrolyte. (U.S. Patent Off.Off.Gaz.,785:665, Dec.11,1962)

4697

Dalton, H.R. SHEET-LIKE ELECTRODES FOR STORAGE BATTERIES. German Patent 1,136,387, Sept.13,1962. Appl. Jly.28,1958. 5p.

Elastic electrodes with smooth surfaces were manufactured by adding 40-80 wt. % finely divided C to a solution of a plastic resin containing softening agents, spreading this suspension on a carrier, evaporating the solvent and applying a 2nd similar layer containing less C on the former; the 2-layer film was separated from the carrier. Alternatively, a 3rd layer with higher C content was applied on the 2nd layer. C black or graphite were suitable for such preparations. For example: a 1st layer, consisting of 28g. vinylchloride-acetate copolymer, 100 g. C black, 3 g. dioctylphthalate, 0.5 g. basic lead carbonate, 0.5 g. stabilizer, 280 g. Me Et ketone, and 60 g. Me iso-Bu ketone, showed a special resistance -5 ohm/cm.; a 2nd similar layer containing 77 g. dioctylphthalate was spread, filling the pores of the 1st layer. The film (0.05 mm.) was separated from the paper carrier, the specific resistance was 6 ohm/cm. (Chem.Abs., 58:1130-1131, Jan.21, 1963)

4698

DETECTION DEVICE BY MEANS OF THERMOELECTRIC COUPLES. 13p., Nov.1960. MCL-732/2. Rough draft trans. of French Patent 1,035,691, gr. 7, cl. 3, by Detectif (Company with Limited Liability) and M. Marcel Simon, appl. 13 February 1951, released 22 April 1953. pub. 27 August 1953. OTS or SLA. OTS 61-19451.

4699

Dickfeldt, Siegfried, and Dieberg, Rolf.

BATTERY ARRANGEMENT. U.S. Patent 3,076,860, Dec.16, 1959. (to Accumulatoren Fabrik A.G., Hagen (Westphalia), Germany).

In an alkaline storage battery, in combination, a pair of electrodes of opposite polarity the positive electrode of said pair of electrodes including active nickel mass and the negative electrode of said pair of electrodes including active cadmium mass and the active masses of said positive and negative electrodes directly contacting each other; and an alkaline electrolyte fixed in the active masses of said electrodes, whereby upon charging of said battery an insulating layer will be formed in the area of contact of said positive and negative active masses, said insulating layer serving as separator between said electrodes of opposite polarity during operation of said battery. (U.S. Patent Off.Off.Gaz.,787:193, Feb.5,1963)

4700

Doyen, Jean. ACTIVATOR FOR DRY-CHARGED ELECTROCHEMICAL BATTERIES AND THE LIKE. U.S. Patent 3,075,034, June 5,1959. (to Yardney International Corp., New York).

A system for developing a sudden and sustained increase in gas pressure in a duct, comprising a cartridge adapted to discharge explosion gases into said duct upon being detonated, a container of fluid under pressure having a discharge port opening into said duct, frangible seal means initially blocking said port, and activator means responsive to said combustion gases for unblocking said port, said activator being provided with communicating axial and transverse bores for conducting said fluid from said container to said duct. (U.S. Patent Off.Off.Gaz., 786:1224, Jan.22,1963)

4701

Duddy, J.C. METHOD OF TREATING STORAGE BATTERY ELECTRODES. U.S. Patent 3,067,273, Dec.4,1959. (to The Electric Storage Battery Co., a Corp. of New Jersey).

A process for treating electrodes for lead-acid batteries of the pasted lead grid type which comprises the steps of rapidly applying pressure of from about 80 pounds per square inch to about 400 pounds per square inch to said electrodes with platens heated to a temperature of from about 225° F. to about 350° F., the faces of said platens forming a seal with said electrode grids which confines the steam generated within the paste to said grids, maintaining said pressure for a period of from about fifteen seconds to about five minutes, then slowly releasing said pressure to permit the gradual release of steam. (U.S. Patent Off.Off.Gaz.785:810,Dec.4,1962)

4702

Eaton, G.K. PHOTO-ELECTRIC CELL. U.S. Patent 3,072,796, Mar.22,1960. (to North American Philips Co., Inc., New York).

A high-sensitivity photocell comprising photoconductive indium antimonide sensitive to radiation over a given wavelength range and exhibiting a fatigue effect wherein its sensitivity is greatly reduced upon exposure to radiation of a wavelength shorter than about 0.7 micron, and means enclosing said photoconductive member and opaque to wavelengths shorter than about 0.7 micron but including a portion transparent to wavelengths shorter than about 0.7 micron but including a portion transparent to wavelengths greater than about 0.7 micron and within the said given range and allowing incident radiation of the latter character to impinge upon the indium antimonide, whereby the indium antimonide is prevented from exhibiting the fatigue effect and retains high sensitivity. (U.S. Patent Off.Off.Gaz.,786:572-573, Jan.8,1963)

4703

Elm, R.A. and Krawczak, W.G. THERMOELECTRIC GENERATOR. U.S. Patent 3,075,030, Dec.22, 1959. (to Minnesota Mining and Manufacturing Co., St. Paul, Minn.).

A thermoelectric generator comprising a thermally conductive annular heat dissipating and supporting member formed with a plurality of cylindrical radial bores, thermojunction means spaced from and centrally disposed within said annular member, a plurality of radially extending thermoelements spanning the annular space between said thermojunction means and said annular member and each in registration with one of said radial bores, a junction electrode at the outer end of each of said thermoelements, a separate cylindrical thermally conductive force applying member having a snug coaxial sliding fit within each radial bore with which a thermoelement is in registry, and biasing means cooperable with said annular member and with each of said force applying members for causing the latter to engage and exert radially inwardly directed forces on said junction electrodes to thereby place each of said thermoelements under longitudinal compression. (U.S. Patent Off.Off.Gaz., 786:1223, Jan.22,1963)

4704

Fafa, J.A. DRY CELLS. Belg. Patent 619,208, Oct.15,1962, France Appl. July 6,1961, 9p. (to Compagnie Industrielle Des Piles Electriques).

Improvement of a dry cell in a plastic case such that a porous element which conducts electricity, e.g. Cu or bronze, projects from the Zn lining of the cell and is closely joined to the plastic material of the

case, permitting the evacuation of the gas while rendering escape of liquid impossible. (Chem.Abs., 58:6453, Apr.1, 1963)

4705

Fawcett, S.L. and Anno, J.N. DIRECT CONVERSION OF NUCLEAR ENERGY TO ELECTRICAL ENERGY. Belg. Patent 613, 689, Feb.28, 1962; U.S. Appl. Feb.15,1961. 22p.

A nuclear reactor has fuel elements that constitute a series of cathodes. About each cathode is a barrier and about each barrier is an anode. Each cathode provides fission fragments which travel to the anode, where they give rise to a high positive potential. Electrons accompanying the fission fragments are repulsed by the negative potential of the semipermeable barrier. The layer containing the fissionable material (cathode) must be sufficiently thin to permit the fragments formed to escape into the environment; however, an external sheath of nonfissionable metal is applied to reduce metal evaporation and electron emission. The cathode, barrier, and anode must be isolated electrically from each other and maintained under a vacuum of 10^{-6} - 10^{-7} mm. Hg. The design is applicable to both breeder- and nonbreeder-type reactors. (Chem.Abs., 57:14678, Dec.10,1962)

4706

Frantti, E.W. THERMOELECTRIC AIR CONDITIONING APPARATUS FOR A PROTECTIVE GARMENT. U.S. Patent 3,085,405, Apr.6,1961. (to Westinghouse Electric Corp., East Pittsburgh, Pa.).

A portable device for providing conditioned air to a protective garment comprising a thermoelectric heat pumping panel of annular shape having an array of thermoelectric bodies disposed in an annular pattern and interposed between a pair of annular heat conducting plate members, said plate members being in good heat exchange relation with said array, a pair of wall members disposed in fixed spaced relation with said heat conducting plates and jointly therewith defining first and second annular air flow passages, a first blower centrally disposed in said first passage, a second blower centrally disposed in said second passage, a motor carried by one of said wall members, said motor having a drive shaft supporting said blowers for joint rotation, said drive shaft extending transversely through said heat pumping panel, means for supporting said drive shaft in rotatable relation with said panel, means for preventing flow of air from said first to said second passage, each of said wall members having a central aperture, said apertures

defining air intake openings for said first and second passages, and said blowers being arranged to draw air through said apertures and to pump the air in radially outward directions through said passages. (U.S. Patent Off. Off.Gaz., 789:632, Apr.16,1963)

4707

Henderson, C.M. and Harris, D.M. THERMO-ELECTRICITY. U.S. Patent 3,081,361, Mar. 12, 1963. (to Monsanto Chemical Co.).

A thermoelectric device which generates power at 110° to 925°C comprises a first element of boron in combination with 0.05 to 45% (wt) Ge, a second element in electrical and thermal contact comprised of C, Cu, Au, Ag, Ni, Co, Fe, Re, V, Hf, Nb, Ti, Ta, Be, and/or oxides, borides, carbides, silicides, or nitrides of Ni, Co, Fe, Re, V, Hf, Nb, Ti, Ta, or Be, and external leads connected to the elements. U.S. 3,081,362 - In a device which generates power at 110° to 1950°C, the first element comprises B and 0.05 to 17% Be, and the second element may contain Rh or Ru instead of Hf or Be. U.S. 3,081,363. - The first element comprises B with 0.05 to 45% Zr, and the second element may contain Si. U.S. 3,081,364. - The first element comprises B with 0.05 to 45% Sn. U.S. 3,081,365. - The first element comprises B with 0.05 to 45% Hf. (Am.Ceram.Soc.J., 46:194, Jly.21,1963)

4708

Herinckx, Claude, Offergeld, G.R. and Van Cakenberghe, J.L. THERMOELECTRIC MATERIALS. U.S. Patent 3,076,859, July 10,1961. (to Union Carbide Corp.).

A thermoelectric composition consisting essentially of the material characterized by the formula $\text{BiSb}_2\text{Te}_{1.49+1.47a}$ wherein a is between about 3.1 and about 4.3, and at least one doping element selected from the group consisting of copper, silver, gold, iodine, bromine, chlorine, potassium, sodium, and lithium, the doping material being present in an amount between about 0.3 and about 3.0 milligrams per gram of final composition. (U.S. Patent Off.Off. Gaz., 787:193, Feb.5,1963)

4709

Hill, D.E. and Epstein, A.S. THERMOELECTRICITY. U.S. Patent 3,077,506, Feb.12, 1963. (to Monsanto Chemical Co.).

A thermoelectric couple which generates electricity at 2000°C consists of a boron phosphide having a boron-to-phosphorus ratio of 6:1 together with a complementary electrical element and associated circuitry. (Am.Ceram.Soc.J., 46:166, June 1963)

4710

Hockings, E.F. and Mularz, W.L. LEAD TELLURIDE-TIN TELLURIDE THERMOELECTRIC COMPOSITIONS

AND DEVICES. U.S. Patent 3,075,031, July 28,1961. (to Radio Corp. of America)

An N-type thermoelectric alloy consisting essentially of 95 to 70 mol percent lead telluride and 5 to 30 mol percent tin telluride, said alloy containing 0.2 to 2.4 weight percent of a mixture of lead and lead bromide, said weight percent being a percent of the weight of said lead telluride and tin telluride, said mixture consisting of 35 to 65 mol percent lead, balance lead bromide. (U.S. Patent Off. Off.Gaz., 786:1223-1224, Jan.22,1963)

4711

Horn, Lutz and Philipp, Fritz. SEPARATOR FOR ELECTRIC BATTERIES. U.S. Patent 3,097,975, May 17,1960. (Varta Aktiengesellschaft, a Corp. of Germany)

In a storage battery of the type described, in combination, a separator consisting essentially of a plurality of superposed sheets consisting of crimped electrolyte-resistant polyamide fibers; and an ion-permeable fluid-impermeable foil interposed between and contacting at least two of said plurality of sheets. (U.S. Patent Off.Off.Gaz., 792:737, Jly.16,1963)

4712

Janko, Zofia and Appelt, Kazimierz. CELLS AND BATTERIES FOR WORK AT LOW TEMPERATURES. Polish Patent 43,433, Sept.20,1960, Appl. May 26,1956, 2p.

Cells capable of working at down to -40° are produced with the use of two electrolytes composed of the same ingredients but having different concentrations. The electrolyte surrounding the anode consists of NH_4Cl 1-2, ZnCl_2 5-8, $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ 9-13, and H_2O 7-8 parts, whereas that being in contact with the cathode comprises NH_4Cl 6-7, ZnCl_2 1-3, $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ 2-4, H_2O 22, HgCl_2 0.1, wheat flour 4.5, and potato flour 2.5 parts. Thus, very finely ground naturally occurring battery manganese 15 was mixed with activated MnO_2 15, graphite 5, and carbon black 4 parts. NH_4Cl (2 parts) was added and the whole treated with concentrated solution composed of NH_4Cl 2, ZnCl_2 8, $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ 13, and H_2O 8 parts. After careful mixing the mass was left standing for 24 hrs. at 20° and relative humidity 90%, and then pressed to obtain rod-shaped anodes. These were wrapped into a gauze, dipped for 3-5 minutes in the anode electrolyte, and then put into the cathode cylinders previously filled with the cathode electrolyte. The electrolyte mass sets within 15-30 minutes. (Chem.Abs., 58:1131, Jan.21,1963)

4713

Jones, L.E. SOLAR CELL. U.S. Patent

3,078,328, Feb.19,1963. (Texas Instruments, Inc.)

A photovoltaic cell for converting light radiation into electrical energy comprises a layer of silicon carbide formed on one face of a graphite base, a first layer of silicon of one-type conductivity formed on the layer of silicon carbide, and a second layer of silicon of opposite-type conductivity formed on the first layer to define a pn junction. (Am.Ceram.Soc.J., 46:166, June 1963).

4714

Justi, Eduard. THERMOELECTRIC COUPLES. U.S. Patent 2,685,608 and German Patent 872,210.

The components are coated with a solder in nonoxidizing ambient during ultrasonic pressure oscillation. (Semiconductor Abs., 7:3079, 1959).

4715

Kunz, H.R. FUEL CELLS. Belgium Patent 625,440, Mar.14,1963, (to United Aircraft Corp.) U.S. Appl. Nov.30,1961, 9p.

Fuel cells containing a combustible substance, e.g. H, and an oxidant, e.g. O, under pressure are provided with means for controlling the temperature and the pressure of the electrolyte in the cell so as to obtain the desired output of electrical energy. In Belgium 625,438 (same patentee; by George H. Davis); 11pp., the temperature of the liquid introduced into the cell is controlled by suitable means so as to maintain the desired temperature within the cell. (Chem.Abs., 59:1290, Jly.22,1963).

4716

Lane, D.H. and Feduska, William. THERMO-ELECTRIC ELEMENTS. U.S. Patent 3,082,277, Mar.19,1963, (to Westinghouse Electric Corp.).

The element comprises a shaped body of thermoelectric material (lead telluride, germanium telluride, or germanium bismuth telluride), a relatively thin unfused low electrical resistance diffusion barrier layer (Co, Cr, Fe, Mo, Si, Zr, and/or Ti) joined to both ends, and a relatively good electrically and thermally conductive metal contact (Cu, Al, Ag, or their alloys) joined to the barrier layers. (Am.Ceram. Soc.J., 46:194, Jly.21,1963).

4717

Lieb, H.C. and Wallack, Stanley. RADIOACTIVE BATTERY. U.S. Patent 3,069,571, Dec.18, 1962. (Filed Dec.16,1957) (to Leeson Corp.).

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. (Nuclear Sci.Abs., 17:9150, Mar.31,1963).

4718

Lucas, O.D. PRIMARY ELECTRIC BATTERIES. British Patent 740,497, 28.7, and 7.10.53.

The battery contains a series of cells each comprising a Cu anode, a Mg cathode, and a quantity of CuCl₂ (made into a paste with concentrated HCl) so disposed that the cell is normally inert and is only activated when water is admitted to the cell. (J.Appl.Chem.Abs., p.ii-183, 1956).

4719

Macauley, B.T. SOLAR ENERGY DEVICE. U.S. Patent 3,085,565, Mar.10,1961. (to Sundstrand Corp.)

A solar energy concentrating device comprising a primary parabolic mirror for forming at its focal plane a solar spot of decreasing intensity from the center to the edge of said spot, a secondary mirror located on the axis of the primary mirror and adjacent but inwardly spaced from the focal plane thereof, said secondary mirror being provided with an opening adapted to communicate with a solar furnace, said opening having a diameter less than the diameter of said solar spot, said secondary mirror being provided with a first reflective surface generally ellipsoidal in configuration and immediately surrounding the opening, and a second reflective surface in the form of a cone diverging from said first surface toward said primary mirror whereby to direct into said opening the rays forming the portion of the solar spot surrounding the opening. (U.S. Patent Off.Off.Gaz., 789:680, Apr.16, 1963).

4720

McEvoy, J.E. and Shalit, Harold. FUEL CELL ELECTRODE. U.S. Patent 3,097,974, Nov. 7,1960. (Air Products and Chemicals, Inc.).

The method for making a catalytic fuel cell which comprises the steps of: forming a water solution of a noble metal compound selected from the group consisting of palladium chloride and chloroplatinic acid, the metallic component thereof being present in the amount required in the finished electrode; combining with said solution a quantity of high surface area, activated carbon powder finer than 200 mesh so as to form a slurry; admixing the slurry-forming components for a time sufficient to effect maximum adsorption of said noble metal compound on said activated carbon; removing excess liquid from said slurry and further drying the activated carbon containing adsorbed noble metal

compound; forming a suspension of said activated carbon containing adsorbed noble metal; introducing said suspension by deposition into the pores of a thin porous electrode matrix having an average pore diameter substantially greater than the particle size range of said activated carbon powder; and drying said matrix. (U.S. Patent Off. Off. Gaz., 792:737, Jly.16,1963).

4721

Metzler, Otto and Kaus, Willy. POROUS ELECTRODE BODIES FOR PRIMARY AND SECONDARY CELLS. Belgium Patent 616,596, Aug.15,1962; German Appl. Apr.26,1961; 14p.

The electrode bodies according to invention should consist of porous resins produced by soldering together grains of resins, e.g. polyethylene; polymers of tetrafluoroethylene, trifluoroethylene, chloroethylene; polypropylene, and others. The desired porosity can be obtained by variation of the grain size and by addition of retarding agents, e.g. Ti oxide. The surfaces of the pores should be coated by colloidal graphite or by carbon black for assuring electrical condition and for protecting the resin against corrosion by the electrolytes. The active material should be introduced in the form of solutions, e.g. lead sulfate or acetate. (Chem. Abs., 58:6454, Apr.1,1963).

4722

Meyers, W.F. LIQUID AMMONIA CURRENT-PRODUCING CELL. U.S. Patent 3,083,252, Mar. 26,1963, Appl. Jan.12,1960, 7p. (to G. & W.H. Corson, Inc.).

Liquid NH_3 is used as the principal electrolyte solvent in the current-producing cell (CA 53, 7830i). In the present invention a sulfate of a heavy metal below Fe^{++} in the electrochemical series is employed as a depolarizer. The sulfate also serves to regenerate the electrolyte solute so that the present cell is not electrolyte-limited. Since liquid NH_3 by itself is not very conductive, a solute is used to raise the condition. Various solutes are discussed; the NH_4^+ and Li salts are particularly well suited for this use. The various factors involved in cell construction are discussed and illustrated. Examples of the preparation and operation of the cell system are given. (Chem. Abs., 59:1291, Jly.22,1963).

4723

Moos, A.M. FUEL-CELL ELECTROLYTES. U.S. Patent 3,083,251, Mar.26,1963, Appl. Sept.28,1960. (to Leeson Corp.).

Fuel-cell electrolytes containing alkanolamines, e.g. ethanolamine, aminoethylethanolamine, and their derivs., e.g. con-

taining OH, Co, N: groups, which contain <16C atoms provide efficient fuel-cell operation at 25-185°. Conductance of the electrolytes may be enhanced by the addition of materials of high dielectric constant such as urea, formamide, and dimethylformamide. A cell was successfully operated with a metallic Ag-activated C plate as the oxidizing electrode and a bi-porous Ni electrode as the fuel electrode, separated by a solution of ethanolamine. CO and air were passed into the cell, which operated at 100°. (Chem. Abs., 59:1291, Jly.22,1963).

4724

Nefedov, K.P. AN AUTOMATIC CHARGE CUT-OFF FOR SILVER-ZINC STORAGE BATTERIES. Izobretenii Byull. no. 15, p.32-34,1960.

In Russian. Patent 130547. Transl. of unedited rough draft available from OTS or SLA, no. FTD-TT-61-172, AD-268 071.

In order to avoid discharge of the electrodes during charging, and to cut-out fully-charged and faulty storage batteries from the charging circuit, triodes are used as the relays for the voltage which actuates the executive unit. (Tech. Trans., 7:648, May 15,1962).

4725

Rosi, F.D. THERMOELECTRIC ELEMENTS HAVING GRADED ENERGY GAP. U.S. Patent 3,050,574, Aug.21, 1962. (to Radio Corp. of America).

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. (Nuclear Sci. Abs., 17:9148, Mar.31,1963).

4726

Samulon, H.A. and Robison, P.C. ELECTROMAGNETIC RADIATION CONVERTER. U.S. Patent 3,076,861. June 30,1959. (to Space Technology Laboratories, Inc.).

A solar radiation converter comprising means for converting electromagnetic energy into electrical energy, said means adapted to receive electromagnetic radiation lying substantially within a wavelength band of .5 to 1.0 microns, said means including a photoresponsive semiconductive member having a spectral sensitivity to said defined wavelength band for directly converting electromagnetic energy to electrical energy, and an interference 787 U.G.-13 filter bonded directly on said photoresponsive semiconductive member with the filter being in surface engaging relationship with the member for transmitting electromagnetic radiation within

said wavelength band and reflecting substantially all other wavelengths of electromagnetic radiation not in said band. (U.S. Patent Off.Off.Gaz., 787:193, Feb.5, 1963).

4727

STORAGE-BATTERY ELECTRODES. Belgian Patent 611,248, Dec.29,1961.(to Electric Storage Battery Co.,) Appl. Dec.7,1961, 20p.

A first thermoplastic resin, e.g. polyethylene, polypropylene, polystyrene, or poly(vinyl chloride) is intimately mixed with a 2nd thermoplastic resin incompatible therewith, preferably in the wt. ratio 1:1/9-3, and with a powdered electrochemical active substance, e.g. and oxide of Cd, Pb, Zn, or Fe, or Ni hydroxide to obtain a plastic mass. The 2nd thermoplastic resin is preferably polyethylene glycol or poly(vinyl pyrrolidinone). The mass is then shaped into elements which are inserted in the respective conducting sheaths for the electrode, and the 2nd resin is washed out from the mixture so as to obtain a porous electrode in intimate contact with the sheath. (Chem.Abs., 57:12256, Nov.12, 1962).

4728

STORAGE BATTERY WITH AN INTERMEDIATE PLASTIC LAYER. Belgian Patent 621,305, Nov.30,1962, German Appl. Aug.25,1961, 9p. (to Accumulatoren-Fabrik, A.G.).

A storage battery is made with an intermediate plastic layer placed between the electrodes. To the plastic material is added 5-40 wt.% of a compound with an internal space surface area of 10 sq. m./g. These compounds are silica, diatomite, hard rubber powder, activated C, bentonite, vermiculite, clay, or microporous poly(vinyl chloride) or polyethylene. For example, a sheet of 0.6 mm. thickness is made from 25 g. poly(trifluoroethylene), 50 g. methylformamide, 25 g. Me cellulose, 25 g. ZnCl₂, 175 g. formamide, 225 g. water, and 105 g. Aerosil with a space surface area of 350 sq. m./g. The sheet is placed between a Ag anode and a Zn cathode. It is charged with 10 ma./sq.cm. with increase in voltage from 1.16 to 4.5 v. The discharge at 10 ma./sq. cm. lasts 58 minutes with a decrease in voltage from 0.91 to 0.4 v. (Chem.Abs., 59:1291-1292, Jly.22,1963).

4729

Varta, A.-G. FUEL CELL. Belgian Patent 621,308, Nov.30,1962, German Appl. Aug.11, 1961, 25p.

In a fuel cell, the fuel (H, CO, MeOH, HCOOH) and the oxidants (O, air, or halogens) are activated by a catalyst in suspension in the electrolyte which carries the electrical charges produced by the

reaction on the catalyst to the inert electrodes. The catalyst for the reducing agent is Pt or analogs, Ni, Raney Ni, or Ni alloys and for the oxidant Ag, Ag alloys, or activated C. The alkali electrolyte is a KOH solution or the acid electrolyte is H₂SO₄ and HClO₄. The anodic and cathodic compartment are separated by a semi-permeable membrane. (Chem.Abs.,59:1291, Jly.22,1963).

4730

Vul'fel'dt, I.K. A METHOD FOR THE DIRECT TRANSFORMATION OF HEAT ENERGY INTO ELECTRICAL ENERGY. Soviet Patent 140920 (689180/24), 4p., Dec.16,1960. (AD-295 456).

In Russian. Transl. FTD-TT-62-759, U.S. Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.

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. (TAB U63-2-3: 25, May 1,1963).

II. THERMOELECTRICITY

A. General Information

4731

Gramberg, G. and Plust, H.G. DEVELOPMENTS IN THE FIELD OF THERMO-ELECTRICITY. Brown Boveria Rev., 49:501-514, 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.

4732

Jaccard, C. THERMOELECTRIC EFFECTS IN ICE CRYSTALS. I. THEORY OF THE STEADY STATE. Phys. Kondens. Materie, 1:143-151, 1963.

Starting from the phenomenological equations which describe the currents of the four specific ice lattice defects (OH_2^+ , 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 ($1.8 \text{ mV}/^\circ\text{C}$) 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^-/D^0 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. (Phys.Abs., 66:10899, June 1963).

4733

Klein, H.E. INSIDE INDUSTRY. Duns Rev. & Mod. Indus., 79:127-129, Mar.1962.

This column, which is a regular feature of the magazine, is devoted to thermoelectricity, developments and applications. Many commercial devices are mentioned, most of them in the experimental stage.

4734

Koenigsberger, J. ÜBER DISKONTINUIERLICHE ÄNDERUNG DER THERMOKRAFT. Ann.Physik, 47: 563-565, 1915.

Discontinuity in thermoelectric power at melting point.

4735

Massachusetts Institute of Technology, Department of Electrical Engineering, Cambridge, Mass. THERMOELECTRIC PROCESSES AND MATERIALS. 14p., Jan.1,1963. (Semiannual Prog. Rept. 4 & 5) (Contract Nonr-1841(51))

This report is a combined report covering the period from January 1, 1962 to January 1,1963. The theme which connects the research reported is the relationship between basic properties of materials and their applications as energy converters. The experimental work has been mainly concerned with compound semiconductors. Investigations concerned with properties relevant to thermoelectric energy conversion have been continued and considerations of other types of energy conversion processes have recently been included.

4736

Morgan, K. THERMOELECTRICITY. Elec.Rev., 172:10-14, Jan.4,1963.

Principles of thermoelectric generation. Thomson effect, Seebeck effect, Peltier effect, principle of generation of thermoelectricity, cooling and material. Efficiency of the device and a brief note on application. (Brit. Non-Ferrous Metals Res.Assoc.Bull., 43:161, Apr.1963).

4737

Naval Research Laboratory, Washington, D.C. STATUS REPORT ON THERMOELECTRICITY. PART II - DEVICES, by J.W. Davisson, Joseph Pasternak, and B.B. Rosenbaum.(BuShips). 159p., Jan.1963. (Memo. Rept. 1361).

This second part of the ninth quarterly review on the state of the art on thermoelectricity, deals with thermoelectric devices including hardware and feasibility studies.

4738

Naval Research Laboratory, Washington, D.C. STATUS REPORT ON THERMOELECTRICITY, by J.W. Davisson, Joseph Pasternak and B.B. Rosenbaum (BuShips). 104p., Mar.1963. (Memo. Rept. 1404).

Data obtained on materials and equipment research and development are presented. This is the terminal report of the series.

4739

O'Connor, J.R. PELTIER COEFFICIENT AT A SOLID-LIQUID INTERFACE. J.Appl.Phys., 31: 1690-1691, Sept.1960.

If a current traverses a stationary liquid-solid interface, the Peltier heat causes a displacement of this interface. Expressions are given which relate the displacement and the initial displacement velocity to the Peltier and Thomson coefficients. (JPL Astron.Info.Search no. 392:223, Mar.1962).

4740

Tyco Laboratories, Inc., Waltham, Mass. POWER DENSE THERMOELECTRIC MODULE, July 3,1961 - November 2,1962. 65p., Nov.2,1962. (Interim Rept.) (Contract NObs-86015).

A technique which utilizes a SnTe braze, has been developed for bonding P and N-type PbTe to pure Fe electrodes. Contact resistances fall in the range 5-15 micro-ohm-cm². A bonding technique involving the interdiffusion of Fe and N-type PbTe at 850°C has been developed. Contact resistances fall in the range of 10 - 20 micro ohm-cm². N-type PbTe directionally solidified under the influence of ultrasonic oscillations has

been found to possess superior mechanical properties to presently available material. Bonded and unbonded PbTe (1/4" x 1/4") were found to be capable of sustaining, without any visible damage, a temperature gradient of 510° for over 250 hours.

4741

Wolfe, Raymond. THE PHYSICS OF THERMO-ELECTRICITY. Semiconductor Prod., 6: 23-28, Apr.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.

4742

Zemel, N.J. and Greene, R.F. SEMICONDUCTOR SURFACE TRANSPORT. Semiconductor Physics Conference, Prague, 1960, p.549-552.

Discusses what is known about surface transport, and in particular the authors' work on thermoelectric power. The origin, extent, dependence on initial treatment and temperature dependence of the surface scattering remain essentially unknown. (Phys.Abs., 66:2858, Feb.1963)

B. Theory

4743

Chadda, M.M. and Sinha, A.P.B. THEORY OF THERMOELECTRIC POWER IN LOW-MOBILITY SEMICONDUCTORS. Indian J.Pure Appl.Phys., 1:161-163, May 1963.

The thermoelectric properties of low-mobility semiconductors, in which the charge carriers are localized and the electrical conduction takes place through their hopping motion, have been investigated. The heat of transport (Q^*) and the energy lowering (ϕ) due to the polarization of lattice have been shown 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 has been shown that the contribution of Q^* to the thermoelectric power can be appreciable in some cases. The values of Q^*/ϕ have been theoretically evaluated for a face-centred cubic crystal for certain select directions of temperature gradient.

4744

Jaumot, F.E., Jr. THERMOELECTRICITY. In Advances in Electronics and Electron Physics, Vol.17, 207-243, New York, Academic Press, 1962.

Principles involved in thermoelectricity are reviewed. Any phenomenon involving the interchange of heat and electrical energy may be called a thermoelectric effect, however, the term is usually meant to imply the Peltier, the Thomson, and the Seebeck effects.

4745

Naval Research Laboratory, Washington, D.C. A BRIEF SURVEY OF ELEMENTARY THERMO-ELECTRIC THEORY, by W.H. Lucke. 15p., figs., May 3, 1963. (Rept. 5888).

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 to 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 very briefly described and some interesting ideas for improvement are mentioned along with criticisms concerning predictions of the maximum possible figure of merit.

4746

Office of Naval Research, Washington, D.C. PERSPECTIVES IN MATERIALS RESEARCH. 771p., 1961. (ACR-61)

Chapter 4, Section 4 by W.W. Scanlon is entitled Thermoelectricity. The author discusses the theory and experimental investigations of thermoelectric effects.

4747

Ohta, Tokio. PHONON-DRAG SEEBECK EFFECT IN A STRONG MAGNETIC FIELD. Phys.Soc., Japan J., 18:909, June 1963.

A quantum theory is developed for the phonon-drag thermoelectric power of pure semiconductor in a magnetic field which is so strong that the carriers are all in the lowest Landau level (the quantum limit). It is assumed that the phonon energy is negligible compared to the magnetic energy

of carrier and only the role of acoustic phonon is considered.

4748

Tavernier, J. SUR LA THEORIE DES PHENOMENES DE TRANSPORT DANS LES SOLIDES. J.Phys. et Radium, 24:99-102, Feb.1963.

In French. The author develops a generalization of the ((average energy gain)) method which permits a description of the phenomena caused by an applied electric field and a temperature gradient, in the presence of a magnetic field. One straightforward calculation gives the general expression for the electrical conductivity and thermoelectric-power tensors.

4749

Thouvenin, Yves. THEORETICAL CONSIDERATIONS WITH RESPECT TO THE DEFINITION OF THE ELECTROLYTIC PELTIER EFFECT. Acad.Sci. Paris, Compt. Rend., 255:674-676, Jly.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. (Phys.Abs., 65:23484, Dec.1962).

4750

Ure, R.W. THEORY OF MATERIALS FOR THERMOELECTRIC AND THERMOMAGNETIC DEVICES. Inst. Elec. & Electr. Engrs. Proc., 51:699-713, May 1963.

The relation between the thermoelectric figure of merit Z and the basic properties of the material such as carrier mobilities, band structure, thermal conductivity and minority carrier lifetime is discussed. For isotropic materials with parabolic bands it is shown that the figure of merit based on the Seebeck coefficient will increase when a magnetic field is applied, if acoustic-mode scattering is predominant. If optical-mode scattering is predominant, the figure of merit will increase if $ZT > 0.77$. Materials for devices based upon the Nernst or Etingshausen effects will have large figures of merit only if 1) $(m^*)^{3/2} v_u / K_L$ is large, 2) the energy gap is less than kT , and 3) the electron and hole mobilities are similar. Materials requirements for Nernst- and Seebeck-type devices are compared.

4751

Wolfe, R. and Smith, G.E. EXPERIMENTAL VERIFICATION OF THE KELVIN RELATION OF

THERMOELECTRICITY IN A MAGNETIC FIELD. Phys.Rev., 129:1086-1087, 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 ("Umkehrereffekt"). The Peltier coefficient (II) 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, $II(B) = TS(-B)$.

C. Related Phenomena

4752

Godefroy, L.R. and Tavernier, J. CALCULATION OF MAGNETOELECTRIC AND THERMOMAGNETO ELECTRIC EFFECTS. "Semiconductor Physics" Conference, Prague 1960 (see Abs., 21113 of 1962) p.185-186.

In French. A comment on the calculation of the electrical conductivity of a crystal placed in a magnetic field. It is noted that measurements of conductivity, magneto resistance, thermoelectric power and Nernst effect provide insufficient data to determine the energy band structure of crystals of high symmetry. (Phys.Abs., 66:6565, Apr.1963)

4753

Sasaki, Kazuo. INITIAL ELECTROMOTIVE FORCE OF THERMOCELL. Nippon Kagaku Zasshi, 83:233-236, 1962.

Initial e.m.f.s. of thermocells of AgCl, AgBr, and AgI based on data in the literature differed for cells of common cations. The differences were due to differences in the reversible entropy change. This fact suggested that the heat transported by anions was nearly the same for Cl^- , Br^- , and I^- . For the cells of different cations with identical electrodes, the variation in the initial e.m.f. mainly came from the difference in the irreversible entropy change; the difference in the heat transported by cations was high in this case. The initial e.m.f. of a cell, AgI/HI, was estimated. (Chem.Abs., 58: 5255, Mar.18,1963).

4754

Shadrinova, A.P. THERMOELECTRIC METHOD FOR THE STUDY OF PROCESSES WHICH OCCUR IN AUSTENITIC STEELS. Izvest. Vysshikh Ucheb. Zavedenii. Chernaya Met., 5: 107-110, 1962.

The thermal e.m.f. was studied in steels Kh18N9, Kh18N9T, OKh18N9, and OKh18N9T during heating. The curves of thermal e.m.f. vs. temperature were plotted

from experimental data. (Chem.Abs., 58: 3144, Feb.18,1963).

D. Materials

1. Measurements

4755

Alfred University, State University of New York College of Ceramics, Alfred, N.Y. SEMICONDUCTING MATERIALS, November 30, 1961 - December 1, 1962. 36p., Dec.1,1962. (Annual Summary Rept.) (Contract Nonr-1503(01)).

p.1-4, Section I. THERMOELECTRIC PHENOMENA, by Lyle Slack. The thermoelectric investigations are continuing with the redesign and reconstruction of the apparatus for measuring thermal conductivity of semiconductors by the series comparative method.

4756

Armour Research Foundation, Chicago, Ill. METHODS OF PURIFICATION OF METALS AND INTERMETALLIC COMPOUNDS, June 15, 1959 - May 14, 1960, by Sherman Susman. 125p., illus. Aug. 1961. (Summary Tech.Rept.) (Rept. ARF 3133-23) (Contract AF 33(616)5895) (WADD TR 59-303, pt.2) (AD-267 777).

A study was made of impurity transport in thermal gradients and other fields in materials potentially useful for thermoelectric, thermionic or photovoltaic power generation at high temperatures. The general problem of impurity distributions in an intense thermal gradient was considered. The physical and chemical properties of SiC were considered in the context of diffusion phenomena and thermoelectric behavior at elevated temperatures. Single crystals and polycrystalline rods of SiC were studied. Both chemical and spectrographic analyses were used for the qualitative and quantitative estimation of impurity content. Electrical resistivity and thermoelectric power measurements were made up to 1000 C. Polycrystalline SiC rods were subjected to intense thermal gradients by direct inductive coupling at 5 mc. Impurity redistribution is followed by spectrographic analysis. (TAB U62-1-4:122, Feb.15,1962).

4757

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

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 2%. (Nuclear Sci.Abs.,17:11316, Apr.15,1963).

4758

Henry, W.G. THE ISOTHERMAL PELTIER COEFFICIENT AND PHONON-DRAG IN COPPER. Can.J.Phys., 41:1094-1101, Jly.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.

4759

Kennedy, W.L., Sidles, P.H. and Danielson, G.C. THERMAL DIFFUSIVITY MEASUREMENTS ON FINITE SAMPLES. Adv.Energy Conv., 2: 53-58, Jan.-June 1962.

A new technique has been developed for measuring the thermal diffusivity of small samples in which an IBM 650 computer has been used to perform the calculations. The samples were in the form of round rods of finite length, surrounded by a cylindrical guard fabricated from the same material. This method has been shown to give values of thermal diffusivity for Armco iron, from room temperature to 1100°C, which are in good agreement with those obtained by other methods. Preliminary measurements have also been made on a silicon single crystal over the same temperature range.

4760

McNeill, D.J. MEASUREMENT OF THERMAL CONDUCTIVITY USING THE PELTIER EFFECT. Brit.J.Appl.Phys., 14:113-116, Feb.1963.

A modification of the Harman 'Z-meter' technique for the measurement of the thermal conductivity of thermoelectric materials is described. Heat losses are taken into account in the thermal conductivity equation, and an experimental technique derived which enables the losses to be eliminated. The theory is tested by measurements on a specimen of FeSi₂-4%CoSi₂ alloy.

4761

Nettelbladt, H. MEASUREMENT OF FIGURE OF MERIT FOR THERMOELECTRIC MATERIALS. Elteknik, 6:13-15, 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. (Elec.Eng.Abs., 66:4694, May 1963).

4762

Rynn, N. MEASUREMENT OF THE THERMOELECTRIC POWER OF A FULLY IONIZED, LOW-TEMPERATURE PLASMA. Phys.Rev.Ltr., 10:465-467, June 1, 1963.

During the progress of an experiment on an alkali-metal plasma (the Q-1 device), it was found possible to measure the Seebeck coefficient, or the thermoelectric power, of the plasma. This note describes the measurement and compares the result with a calculation based upon an approximate theory.

4763

Timberlake, A.B., Davis, P.W. and Shilliday, T.S. THERMAL DIFFUSIVITY MEASUREMENTS ON SMALL SAMPLES. Adv.Energy Conv., 2: 45-51, Jan.-June 1962.

A method is described for the measurements of thermal diffusivities of small samples of semiconducting materials. Results of measurements on InSb and GaAs are given. It is shown that in some cases the simple theory of Angstrom's method must be modified to include some other mechanism of energy transfer, possibly that of ambipolar diffusion.

2. Properties

4764

Agavev, Ya. THERMOELECTRIC PROPERTIES OF SOLID SOLUTIONS OF INDIUM ANTIMONIDE-ALUMINUM ANTIMONIDE. Izvest.Akad.Nauk Turkm.Ser. Fiz.-Tekhn. Khim.i.Geol.Nauk., SSSR, no. 3: 115-117, 1962.

The Seebeck coefficient α , of InSb-AlSb, 25% InSb-75% AlSb, and pure InSb or AlSb (all p type) was determined at 90-700°K. For InSb-AlSb, α increased with temperature to a maximum of 450 $\mu\text{V}/\text{degree}$ at room temperature then decreased rapidly. The α of 25% InSb-75% AlSb was determined $\leq 460^\circ\text{K}$, where it approached maximum at $\approx 600 \mu\text{V}/\text{degree}$. From these data the possible limiting Fermi levels and the effective masses were calculated. The latter were $\approx 0.2m_0$ for InSb and $\approx 0.5m_0$ for the other computation. (Chem.Abs., 58:998, Jan.21, 1963).

4765

Arvin, M.J. ELECTRICAL CONDUCTIVITY AND THERMOELECTRIC POWER OF INDIUM OXIDE. Phys.& Chem.Solids, 23:1681-1683, Nov.1962.

Electrical conductivity and thermo-electric power of pressed samples of polycrystalline indium oxide (In_2O_3) powder were measured in air as a function of temperature from 180 to 460°C.

4766

Averkin, A.A., Kasimov, S. and Nensberg, E.D. PRESSURE DEPENDENCE OF THE ELECTRICAL PROPERTIES OF PbTe AND PbS. Fiz. Tverdogo Tela, 4:3667-3669, Dec.1962.

In Russian. Transl. in Soviet Phys., Solid State, 4:2681-2682, June 1963.

The variation of the thermoelectric power α and the electrical conductivity σ with uniform (omnidirectional) pressure up to 9000 kg/cm^2 applied at room temperature to single-crystal n- and p-type samples of PbTe and PbS was measured. Oil was used as the pressure-transmitting medium.

4767

Babb, S.E. and Scott, G.J. EFFECTS OF PRESSURE UPON THE THERMOELECTRIC PROPERTIES OF METALS. Am.Phys.Soc., Bull., 7:116(A), Feb.23, 1962.

The effects of pressure on the thermal EMF's of several metals commonly used in thermocouples have been measured over a range to 10,000 bars and 400°C. The method used is essentially that of Bridgman, where the correction is measured on a thermocouple composed of one leg of normal, and the other of compressed metal. By combining the results for the two legs of a thermocouple algebraically, one may obtain the correction to the readings of a thermocouple under pressure. Graphs and power series representations of the data for some common thermocouples were presented. (Solid State Abs., 3: 15,613, 1962).

4768

Baer, Y. and others. WAERMELEITFAEHIGKEIT, ELEKTRISCHE LEITFAEHIGKEIT, HALL-EFFEKT, THERMOSPANNUNG UND SPEZIFISCHE WAERME VON Ag_2Se . Z. Naturforsch., 17a:886-889, Oct.1962.

The thermal conductivity, electrical conductivity, Hall coefficient and thermo-electric power of Ag_2Se have been 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 has been calculated using the Price formula. Agreement with experiment is satisfactory. The specific heat has been measured between 30 and 200°C. For the

latent heat a value of (5.7 ± 0.5) cal/gr was determined in agreement with measurements of Bellati and Lussana. In addition to the transition at 133°C an unknown new transition has been found at about 90°C .

4769

Bartenbach, M., Tomczak, Z. and Kolodziejczak, J. IN-PILE THERMOELECTRIC POWER MEASUREMENTS OF GERMANIUM BOMBARDED BY FAST NEUTRONS. Acta Phys. Polon., 23:189-195, Feb. 1963.

The thermoelectric power and electrical conductivity of germanium bombarded by fast neutrons in the reactor at Swierk have been measured simultaneously as functions of the irradiation time in the neighbourhood of the intrinsic region of conductivity. vs. irradiation time, and using the theory of thermoelectric power, the dependence of the thermoelectric power vs. time of irradiation has been calculated and compared with experiment. A good agreement has been found indicating the internal consistency of the theory of thermoelectric power and conductivity. Some evidence has also been found to support four the number of minima in the conduction band of germanium.

4770

Beckman, O. and Bergvall, P. DOPING PROPERTIES OF $\text{Bi}_2\text{Te}_{2.7}\text{Se}_{0.3}$. Arkiv Fys., 24:113-122, 1963.

Thermoelectric properties of n-type $\text{Bi}_2\text{Te}_{2.7}\text{Se}_{0.3}$ doped with Cu, CuBr, CuBr₂, BiClO and BiI₃ are studied. The lattice thermal conductivity is 1.03 W/m deg K and $\nu_0 (\text{m}^*/\text{m})^{3/2}$ parallel to the cleavage plane ranges from 0.036 to $0.032 \text{ m}^2/\text{V sec}$ giving an optimum Z-value of $3.0 \times 10^{-1} (\text{K})^{-1}$. Galvanomagnetic studies give a band structure close to that of n-type Bi_2Te_3 . The effective mass m^* is $0.57m_0$ 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. (Phys. Abs., 66:10895, June 1963).

4771

Bergvall, P. and Beckman, O. THERMOELECTRIC PROPERTIES OF NON-STOICHIOMETRIC BISMUTH-ANTIMONY-TELLURIDE ALLOYS. Solid State Electron., 6:133-136, Mar.-Apr. 1963.

The thermoelectric properties of p-type alloys of the composition $\text{Bi}_{24}\text{Sb}_{60+x}\text{Te}_{150+x}\text{Se}_6$ have been 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 $\nu_0 (\text{m}^*/\text{m})^{3/2}$ is relatively constant. A maximum figure of merit $Z_p = 3.2 \times 10^{-3} (\text{K})^{-1}$ is found for $x = 8$.

4772

Black, J. and Banks, E. THE PREPARATION AND PROPERTIES OF AgTlTe : A NEW SEMICONDUCTOR. Semiconductor Physics, Conference, Prague, p.1007-1009, 1960. (see Abs. 21113 of 1962).

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. (Phys. Abs., 66:874, Jan. 1963).

4773

Brixner, L.H. X-RAY STUDY AND THERMOELECTRIC PROPERTIES OF THE $\text{W}_x\text{Ta}_{1-x}\text{Se}_2$ SYSTEM. Electrochem. Soc. J., 110:289-293, Apr. 1963.

A wide range of compositions of the title system have been 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 $0.5-0.9 \times 10^{-3} \text{ deg}^{-1}$ are experienced at elevated temperatures.

4774

Buras, Bronislaw, and others. RADIATION DAMAGE AS A METHOD FOR STUDY OF ELECTRICAL CONDUCTIVITY, HALL COEFFICIENT, AND THERMOELECTRIC POWER OF Ge AS FUNCTIONS OF CARRIER CONCENTRATION. Polish Acad. Sci., Inst. Nucl. Res., Rept. 314/I-B, 8p., 1962.

n-Type Ge may be transformed into p-type Ge by fast neutron bombardment. The dependence of the Hall coefficient and thermoelectrical power on the carrier concentration was measured. The results support the assumption that the number of minutes in the conduction band of Ge is 4. (Chem. Abs., 57:14552, Dec. 10, 1962).

4775

Centre d'Etude de l'Energie Nucleaire, Mol, Belgium. PHYSICAL PROPERTIES OF UO_2 SINGLE CRYSTALS, October 1 - December 31, 1962. 24p., Dec. 31, 1962. (Q.Rept. 5) (EURAE-524) (Contract 063-61-10RDB) Work Performed under United State-Euratom Joint Research and Development Program.

Several runs were made to prepare single

crystals of UO_2 for studies at CEN and for satisfying requests from other institutions. The gyration method for spheroidization of single crystals was improved. An equipment for the sintering experiments and for observation of the necks formed between the particles was constructed. The thermoelectric power of three single crystals of UO_2 was measured between $170^\circ K$ and $320^\circ K$ with a slightly modified apparatus. From the sign of the Seebeck coefficient, it follows that the conduction in UO_2 is of p-type in the temperature region investigated. The curves show a rather constant value for the thermoelectric power as a function of the temperature. (Nuclear Sci.Abs., 17:16642, May 31, 1963).

4776

Christenson, E.L. EFFECTS OF TRANSITION METAL SOLUTES ON THE THERMOELECTRIC POWER OF COPPER AND GOLD. J.Appl.Phys., 34: 1485-1491, 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 $1000^\circ K$. Similar alloys of gold have been measured between 4.2° and $100^\circ K$. The individual solutes produce comparable effects in either solvent.

4777

Christy, R.W., Hsueh, Y.W. and Mueller, R.C. THERMOELECTRIC POWER OF NaCl CONTAINING $CdCl_2$. J.Chem.Phys., 38:1647-1651, Apr.1, 1963.

The thermoelectric power of NaCl has been measured as a function of temperature between $550^\circ C$ 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.

4778

Cusack, N.E., Kendall, P.W. and Marwaha, A.S. ELECTRON TRANSPORT PROPERTIES IN LIQUID GALLIUM. Phil.Mag., 7:1745-1752, Oct.1962.

New measurements of the Hall coefficient and absolute thermoelectric power of liquid gallium are reported. The former has the 'free electron' value. All known electron transport properties of liquid Ga are collected and discussed in relation to the recent theory of Ziman. Previously unpublished x-ray diffraction observations are quoted and used.

4779

Cutler, M., Fitzpatrick, R.L. and Leavy, J.F. THE CONDUCTION BAND OF CERIUM SULFIDE $Ce_{3-x}S_4$. J.Phys.& Chem.Solids, 24: 319-327, Feb.1963.

A study of cerium sulfide, $Ce_{3-x}S_4$, over most of the range of composition, $0 < x < 1/3$, has led to information about the conduction band. The compositions, determined by accurate density measurements, permitted evaluation of the electron concentration, n . The room temperature values of the electrical conductivity σ , the thermoelectric power α , and the Hall coefficient R_H , were determined as a function of n over the range from $6 \times 10^{20} \text{ cm}^{-3}$ to $6 \times 10^{21} \text{ cm}^{-3}$. The mobility is relatively low ($2-3 \text{ cm}^2/\text{V-sec}$), but the thermoelectric power varies as $n^{-2/3}$, as required by conventional theory for degenerate systems, and this permitted estimates of the effective mass and width of the conduction band. On the other hand, the Hall coefficient decreases below the value $1/ne$ as n is increased, indicating warping of the Fermi surface as the conduction band is filled. These results, and the analogy to transition metal oxides, suggest the possibility that the conduction band arises primarily from overlapping 5d orbitals of the cerium ions.

4780

Cutler, M. and Mallon, C.E. THERMOELECTRIC STUDY OF LIQUID SEMICONDUCTOR SOLUTIONS OF TELLURIUM AND SELENIUM. J.Chem.Phys., 37:2677-2683, Dec.1, 1962.

The thermoelectric properties of liquid tellurium have been studied at temperatures ranging between 400° and $500^\circ C$ both for pure tellurium and for solutions containing up to 20% (by weight) of selenium. This included measurements of the electrical conductivity σ , the Seebeck coefficient α , and the dimensionless figure of merit $\gamma (= \alpha^2 \sigma T / \kappa)$ and from these the thermal conductivity κ was derived. The measurements were made entirely by electronic methods in a sealed Pyrex tube containing platinum and platinum-rhodium leads. The figure of merit was obtained by the small area contact method devised by one of the authors. For liquid tellurium, our results for α , σ , and κ agreed with values which have been obtained previously by other investigators. The unusually large value of κ observed in liquid tellurium is found to decrease upon addition of selenium. This, and the behavior of α and σ indicate that selenium tends to reduce the concentration of electrons in comparison to that of the holes. At higher concentrations of selenium, phenomena are observed which seem to be related to the motion of ions.

4781

Dolov, M.A. THERMAL ELECTROMOTIVE FORCE OF GLASS WITH ELECTRON CONDUCTIVITY. Uch. Zapiski Kabardino-Balkarsk.Univ., no.13: 31-34, 1961.

A study was made of the thermal e.m.f. of nonalkali glass containing Fe oxide. The thermal e.m.f. and the contact temperatures were measured with a compensation circuit by using a PPTB-1 potentiometer at $>300^{\circ}$. The thermal e.m.f. of nonalkali glass containing Fe oxide has a negative sign; i.e., it corresponds to electron diffusion. The thermal e.m.f. depends on the composition of the glass and varies from 0.55 to 0.17 mv./degree. The thermal e.m.f. tended to decrease with increase in the ferric oxide content. There was a considerable scattering of values for thermal e.m.f. of the same glass composition, depending on the history of the given specimen. (Chem.Abs.,57:14724, Dec.10,1962)

4782

Dugdale, J.S. and Mundy, J.N. THE PRESSURE DEPENDENCE OF THE THERMOELECTRIC POWER OF THE ALKALI METALS AT ROOM TEMPERATURE. Phil.Mag.,6:1463-1473, 1961.

The thermoelectric power S of the alkali metals was measured at ≤ 3000 atmospheres and room temperature. At -400 atmospheres S changes sign in Cs. The results are discussed in terms of the distortion of the Fermi surface under pressure. A relation between S and the pressure coefficient of electrical resistivity is noted.

4783

DuPont de Nemours, E.I., and Co., Inc., Experimental Station, Pigments Department, Wilmington, Del. THERMOELECTRIC PROPERTIES OF SELENIDES AND TELLURIDES OF GROUPS VB AND VIB METALS AND THEIR SOLID SOLUTIONS, July 1 - December 30, 1962, by W.T. Hicks and H. Valdsaar. 2 vols., Oct.31,1962, Feb.8,1963. (Q.Repts. 5 & 6) (Contract NObs-84824).

The study of the tantalum-doped solid solutions of the compounds WSe_2 , WTe_2 , $MoSe_2$ and $MoTe_2$ was continued during the fifth quarter. During the sixth quarter 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 $0.5 \times 10^{-3}/\text{deg}$ in the $500-1000^{\circ}\text{C}$ range. An apparatus for direct efficiency measurements is under construction.

4784

Edwards, A.R. THE THERMOELECTRIC ANOMALY AT 35°C IN CHROMIUM. Phil. Mag., 8:311-322, Feb.1963.

The thermoelectric power of chromium against copper has been investigated in the range $30-40^{\circ}\text{C}$ 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 $35.3 \pm 0.8^{\circ}\text{C}$. 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 anti-ferromagnetic ordering and the influence of internal stresses on domain structure.

4785

Epstein, Arnold and Wildi, Bernard. ELECTRICAL AND THERMAL PROPERTIES OF POLY (COPPER-PHTHALOCYANINE). Symp. Elec.Conductivity Org. Solids, Durham, N.C., 1960, 337-357, (Pub.1961).

Polymers of Cu-phthalocyanine were prepared and the electrical conductivity, thermal conductivity, Hall effect, and thermoelectric power were determined. Two forms of the polymer were studied; when the low-temperature polymer was heated to $250-350^{\circ}$ a new form arose. The low-temperature form had an activation energy of 0.26 e.v., p-type conductivity, thermoelectric power of $15 \mu\text{v./degree}$, and a thermal conductivity of $9 \times 10^4 \text{ cal. cm./sec. degree at } 25^{\circ}$. The heat-treated form had an activation energy of 0.12 e.v., p-type conductivity and thermoelectric power of $35 \mu\text{v./degree}$. (Chem.Abs., 57:14529, Dec.10,1962)

4786

Evans, W.G. CHARACTERISTICS OF THERMOELECTRIC MATERIALS. Semiconductor Prod., 6:34-39, Apr.1963.

This article 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.

4787

Fistul', V.I. and Cherkas, K.V. THE THERMO-EMF OF HEAVILY ALLOYED n-TYPE GERMANIUM. Fiz.Tverdogo Tela., 4: 3288-3292, Nov.1962.

In Russian. Transl. in Soviet Phys., Solid State, 4:2407-2410, May 1963.

The thermo-emf of germanium single crystals alloyed with arsenic, antimony, and phosphorus has been investigated over a wide range of impurity concentrations up to values approaching the solubility limit.

4788

Frant, M.S. and Eiss, Roger. CONDUCTIVITY AND THERMOELECTRIC POTENTIAL MEASUREMENTS ON PERYLENE: METAL HALIDE COMPLEXES. *Electrochem.Soc.J.*, 110:769-772, Jly.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 have been 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 $>10^{-5}$ mho/cm ($\text{InCl}_3, \text{PCl}_3, \text{FeCl}_3, \text{ICl}, \text{SbCl}_5, \text{I}_2$) were black in color; 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 reservoir 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.

4789

Gallo, C.F., Chandrasekhar, B.S. and Sutter, P.H. TRANSPORT PROPERTIES OF BISMUTH SINGLE CRYSTALS. *J.Appl.Phys.*, 34:144-152, Jan.1963.

The absolute Seebeck coefficient, electrical resistivity, and thermal resistivity were simultaneously measured on pure bismuth single crystals of various orientations between approximately 80° and 300°K . Using an overlapping two-band many-valley model, numerical values for the temperature dependence and anisotropy (where appropriate) of the following parameters have been calculated: (1) the overlap energy and the Fermi energy of the electrons and of the holes, (2) the density of states effective mass of the electrons and of the holes, (3) the separate electronic and lattice thermal conductivities, (4) the actual index of thermoelectric efficiency, and (5) the hypothetical "optimum" index of thermoelectric efficiency. The calculated electronic thermal conductivity includes a new term due to bipolar diffusion.

4790

General Atomic, San Diego, Calif. HIGH TEMPERATURE BROAD BAND SEMICONDUCTORS, by M. Cutler and others. v.p., Aug.31,1962. (GA-3450) (Final Rept.) (Contract NObs-77144).

A study of cerium sulfide has improved understanding of its metallurgy and basic electronic properties. Results indicate that cerium sulfide and related compounds have potential value as thermoelectric materials at temperatures between 500°C and 1200°C . A study of phase stability shows that pure cerium sulfide is unstable at the temperatures of potential application; however appropriate doping of pure cerium sulfide with alkaline earth elements can prevent conversion to other phases.

4791

General Telephone and Electronics Laboratories, Inc., Bayside, N.Y. HOT CARRIER PHENOMENA IN SEMICONDUCTORS AT MICROWAVE FREQUENCIES, November 15, 1962 - February 15, 1963, by E.M.Conwell and others. 23p., Feb.15,1963. (TR 63-303.3) (Q.Rept. 3) (Contracts DA 36-039-sc-89174 & DA 36-039-sc-87298).

A new technique was developed for the investigation of the thermoelectric power of hot carriers. A thermoelectric potential was observed in Ge due to the application of a high intensity pulse of 69 Gc power. A semi-quantitative theory was constructed for the analysis of the data.

4792

Gmoehling, Werner and Hagmann, Dieter. CONDUCTIVITY AND HALL CONSTANTS. XXIII. THE TEMPERATURE DEPENDENCE OF THE RESISTANCE AND THE HALL CONSTANT OF PALLADIUM MIXED CRYSTALS. *Z. Metallk.*, 53:459-465, Jly.1962.

In German. The temperature coefficient of resistivity and Hall constant at room temperature were measured on alloys of Pd with Ag, Cd, In, Rh, Ru, Mo, Nb, Zr, and V. Starting from pure Pd, the absolute temperature coefficient of resistivity $\Delta\rho/\Delta T$ is decreased by all alloying additions. This fact is mainly due to the filling up of the d-band by the electrons of the solute. The amount of the absolute temperature coefficient of the Hall constant $\Delta R/\Delta T$ also decreases in every case. This change is far more pronounced than that of the temperature coefficient of resistivity and leads to a change of sign for many alloys at additions of only 2 at.% alloying element to Pd. This effect is also connected with the d-band of Pd. Comparing it with the behavior of the thermoelectric power of

these alloys, however, suggests that this pronounced change is mainly caused by the scattering of the electrons at solute atoms. (Nuclear Sci.Abs.,17:580, Jan.15,1963).

4793

Gobrecht, H. and others. ELECTRICAL AND OPTICAL PROPERTIES OF MERCURY SELENIDE(HgSe). J.Appl.Phys., 32:2246-2250, Oct.1961, (Supplement).

The conductivity, Hall effect, and thermoelectric power of HgSe single crystals are measured between 90 and 500°K.

4794

Gorbatov, G.A. VARIABILITY OF THE THERMO-e.m.f. OF NATURAL SEMICONDUCTOR MINERALS. Mineral'n.Syr'e, Moscow, Sb. no.3:116-121, 1961.

To determine the nature of the variability in thermoelectric properties a previously described application was used to measure the thermo-e.m.f., E_t , of crystals of magnetite, magnesioferrite, jacobsonite, pyrrhotite, and molybdenite from various deposits of the U.S.S.R. and of certain varieties of crystals of cassiterite which had been previously considered as nonconductors of electricity. (Chem.Abs.,58: 3999-4000, Mar.4,1963).

4795

Grenier, C.G., Reynolds, J.M. and Zebouni, N.H. ELECTRON TRANSPORT PHENOMENA IN ZINC AT LIQUID-HELIUM TEMPERATURES. Phys.Rev., 129:1088-1104, Feb.1,1963.

The magnetic-field dependences of the electrical and thermal resistances, the thermoelectric power, the Hall, the Righi-Leduc, the Peltier, the Ettingshausen, and the Ettingshausen-Nernst effects at liquid-helium temperatures in magnetic fields up to 14 kG, have been investigated in a single crystal of zinc. The measurements were taken with either a constant heat current or a constant electric current flowing perpendicular to the hexagonal axis and with the magnetic field parallel to the hexagonal axis.

4796

Guenault, A.M. and MacDonald, D.K.C. ELECTRON AND PHONON SCATTERING. II. THERMOELECTRICITY IN RUBIDIUM, CAESIUM AND ALLOYS AT VERY LOW TEMPERATURES. Roy.Soc.London Proc., 274: 154-162, Jly.23,1963.

Following earlier measurements on pure potassium and alloys, the authors have now made a corresponding study 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 the 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.

4797

Gusev, S.M. and Rakin, G.V. THERMOELECTRIC PROPERTIES OF CADMIUM ANTIMONIDE ALLOYED WITH ELEMENTS OF GROUPS I, III, IV, AND VI. Fiz.Tverdogo Tela, 4:2328-2337, Sept.1962.

In Russian. Transl. in Soviet Phys., Solid State, 4:1704-1711, Mar.1963.

The temperature dependences of the electrical conductivity, Hall effect, thermoelectric power, and Nernst-Ettingshausen effect, as well as the magnetic field dependence of the resistance and Q^1 , were investigated for polycrystalline and single-crystal CdSb of stoichiometric composition or alloyed with copper, gallium, indium, germanium, tin, lead, selenium and tellurium. The forbidden bandwidth at absolute zero was deduced from the experimental results: It was $E_0 = 0.58$ eV. The temperature dependence of the mobility in the impurity region was deduced from the Hall effect and conductivity, but in the intrinsic region it was deduced from the temperature dependence of the Nernst-Ettingshausen effect. The ratio of the effective masses in the intrinsic region and the effective masses of holes and electrons in the impurity region at 100°K were also determined. It was established that the impurities affect the sign of conduction, carrier density, thermoelectric power and other properties of CdSb.

4798

Hanford Works, Richland, Wash. ELECTRICAL PROPERTIES OF PLUTONIUM OXIDES, by C.E. McNeilly. 16p., Sept.1962. (HW-75120) (Contract AT(45-1)-1350).

Preliminary measurements have been made on the electrical resistivity and thermoelectric power of plutonium oxide in the composition range of $PuO_{1.70}$ to $PuO_{2.00}$ from 20 to 1000 C. The normal PuO_{2-x} composition which results from the vacuum sintering of PuO_2 has been shown to exhibit α -type conductivity at room temperature. This changes on heating to

n-type which is characteristic of oxygen deficient PuO_{2-x} . Room temperature resistivity and low temperature activation energy varies directly with oxygen content. The activation energy for electronic conduction for PuO_{2-x} is 0.52 eV over a wide range of oxygen content, while the intrinsic activation energy for PuO_2 is 1.8 eV.

4799

Harman, T.C. EFFECT OF ZONE-REFINING VARIABLES ON THE SEGREGATION OF IMPURITIES IN INDIUM-ANTIMONIDE. *Electrochem.Soc.J.*, 103:128-132, figs., Feb.1956.

Upon zone-refining indium-antimonide, ultimate concentrations of two slowly segregating impurities are approached. The most slowly segregating impurity, identified as tellurium, was found to be n-type which lowers the melting point of indium-antimonide. The second most slowly segregating impurity, identified as zinc, was shown to be p-type which raises the melting point of indium-antimonide. Both impurities originated in the indium. Electrorefining is an effective technique for removal of zinc from indium. Zone-refining is an effective technique for removal of tellurium from indium. There are no indications that deviations from stoichiometry prevent the attainment of extrinsic carrier concentrations below $10^{14}/\text{cm}^3$ in indium-antimonide.

4800

Herkart, P.G. and Kurshan, J. THEORETICAL RESISTIVITY AND HALL COEFFICIENT OF IMPURE GERMANIUM NEAR ROOM TEMPERATURE. *RCA Rev.*, 14:427-440, Sept.1953.

The resistivity of high-quality single-crystal germanium is determined by its impurity content and, in turn, resistivity can be used as a measure of purity. The semiconductor device engineer will find it most convenient to specify germanium purity in electrical terms by its conductivity type (n or p) and its resistivity at some standard temperature such as 25°C. In this paper, the temperature variation of resistivity over the range -100°C to +140°C has been calculated and plotted for both n-type and p-type germanium with different impurity content, ranging from 0.1 ohm-centimeter to 60 ohm-centimeters at 25°C.

4801

Horne, R.A. CHEMICAL SUBSTITUTION IN VB-VIB THERMOELECTRIC MATERIALS. *Solid-State Electron.*, 5:55-57, Jan.-Feb.1962.

This Note describes some simple chemical properties of these thermoelectric materials relevant to their incorporation into practical devices.

4802

Huneidi, F. CRITERIA FOR SELECTING THERMOELEMENT MATERIALS FOR THERMOELECTRIC PELTIER DEVICES. *ASHRAE J.*, 5:80-82, Mar.1963.

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. (*Eng.Index*, p.188, June 1963).

4803

Irie, T., Takahama, T. and Ono, T. THE THERMOELECTRIC PROPERTIES OF AgSbTe_2 - AgBiTe_2 , AgSbTe_2 - PbTe AND $-\text{SnTe}$ SYSTEMS. *J.Appl.Phys.(Japan)*, 2:72-82, Feb.1963.

Thermoelectric properties of AgSbTe_2 - AgBiTe_2 , AgSbTe_2 - PbTe and $-\text{SnTe}$ 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 $-\text{PbTe}$ 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 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 at.% in the AgSbTe_2 - PbTe system. In AgSbTe_2 - SnTe the lattice thermal conductivity increases with increase of SnTe . (*Phys. Abs.*, 66:10900, June 1963).

4804

Jan, J.P. and Pearson, W.B. ANISOTROPIC THERMOELECTRIC POWER OF AuSn . *Phil.Mag.*, 8:911-917, June 1963.

The absolute thermoelectric power of single crystals of AuSn has been 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 .

4805

Jan, J.P. and Pearson, W.B. ELECTRICAL PROPERTIES OF AuAl₂, AuGa₂ AND AuIn₂. Phil. Mag., 8:279-284, Feb.1963.

Measurements of the electrical resistivity, absolute thermoelectric power and Hall coefficient of AuAl₂, AuGa₂ and AuIn₂ between liquid helium and room temperatures are reported and discussed. These metallic compounds have the cubic fluorite structure.

4806

Janninck, R.F. and Whitmore, D.H. THERMO-ELECTRIC POWER IN NONSTOICHIOMETRIC α -Nb₂O₅. J.Chem.Phys., 39:179-182, Jly.1, 1963.

Thermoelectric power measurements have been made on nonstoichiometric α -Nb₂O₅ over the temperature range from 300° to 1270°K. The measurements show that, for all compositions in the single-phase, α -Nb₂O₅-x region (0.0012 < x < 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 band with the conduction electrons being assigned an effective mass equal to four times that of the rest mass.

4807

Johnson, R.G.R. and Brown, J.T. PREPARATION AND PROPERTIES OF SILVER-ANTIMONY-TELLURIUM ALLOYS FOR THERMOELECTRIC POWER GENERATION. (Met.Soc.Conf.) Metallurgy of Semiconductor Materials, 15:285-299,1962.

The thermoelectric power, electrical resistivity, and thermal conductivity, between room temperature and -800°K, of the pseudo-binary system Ag₂Te-Sb₂Te₃ were measured, and the effect of heat-treatment studied. Results are presented graphically. (Met.Abs.,30:590, Apr.1963).

4808

Kelley, C.M. THERMOELECTRIC PROPERTIES OF A LIQUID SEMICONDUCTOR SYSTEM. Pacific Energy Conversion Conf. Proc., San Francisco, 26:1-26, 1962.

A preliminary report on some properties of Cu₂S and its alloys with Cu₂Te. The materials are Cu deficient, exhibit hole conduction, and melt between 900 and 1130°. They are semiconductors in the molten state. An alloy of 75% Cu₂Te and 25% Cu₂S was by far superior over other compositions tested. Thermal conductivity is lower in the liquids than in the corresponding solids. The liquid states will not be subject to mechanical failure. A disadvantage is the containment problem. (Chem.Abs., 58:2960, Feb.8,1963).

4809

Kishimoto, Shozo. THERMOELECTRIC FORCE AND

LATTICE DEFECTS AS ACTIVE CENTERS IN METALLIC CATALYSTS. J.Phys.Chem.,66: 2694-2696, 1962.

Changes in thermoelectric force (S) by annealing were measured for Cu and Ni cold-worked at room temperature. In the case of Cu (90 -15% compression), the changes in the region from 120-to 400° are attributed to the disappearance of dislocations (T_D). The changes for Ni (80% compression) occurred in two stages, one between 200 and 300° and the other above 400°. These are attributed to the disappearance of point defects (vacancies) (T_V) and dislocations (T_D), respectively. (Chem.Abs., 58:3945, Mar.4,1963).

4810

Korshunov, V.A. and Gel'd, P.V. ELECTRIC CONDUCTIVITY AND THERMO-e.m.f. OF MANGANESE SILICIDES. Trudy Ural. Politekh. Inst.Sb., no. 114:164-165, 1961.

The electric conductivity σ and thermo-e.m.f. α of Mn silicides were studied. From comparison of the values of σ and α (1500-10,000 ohm⁻¹cm.⁻¹ and from +15 to +20 meq./degree, respectively, for Mn₃Si, Mn₅Si₃, and MnSi and 200 - 600 ohm⁻¹cm.⁻¹ and from +70 to 110 meq./degree for the higher silicide MnSi_{1.67}-MnSi_{1.73}) it is concluded that the former has a metallic character and the latter a polymetallic character. (Chem.Abs., 57:14528, Dec.10,1962).

4811

Koster, Werner, Gmoehling, Werner and Hagemann, Dieter. LEITFAHIGKEIT UND HALLKONSTANTE 26. DIE MISCHKRYSTALLE DES PALLADIUMS MIT PLATIN, RHODIUM, MOLYBDAN UND VANADIUM. Z.Metallk., 54:325-330, June 1963.

In German. In solid solutions of palladium with platinum, rhodium, molybdenum and vanadium electrical resistivity, Hall constant and their temperature coefficients as well as the differential thermoelectric power have been measured at room temperature. Different properties vary in a similar way. These are susceptibility, electronic specific heat, and the temperature-coefficient of electrical resistivity, as well as Hall-constant, its temperature coefficient and thermoelectric force. This fact depends mainly on the exchange of electrons between the solute atoms and the conductivity bands of palladium. All additions to palladium lead to a change in sign of the temperature coefficient of the Hall constant. A comparison with palladium-gold alloys indicates, that this behaviour is not necessarily connected with the presence of two conductivity bands.

4812

Kurnick, S.W., Fitzpatrick, R.L. and Merriam, M.F. PHYSICAL PROPERTIES OF BARIUM-DOPED CERIUM SULFIDE. Chapter from "Rare Earth Research". Gordon and Breach, Science Publishers, Inc., 150 Fifth Ave., New York 11, N.Y., 248-260, 1962.

Investigation of the lattice parameters, electrical properties and thermoelectric performance of Ce_2S_3 -BaS solid solutions prepared by vacuum melting. (Rev. Metal Literature, 20:34, Jan.1963).

4813

LaBotz, R.J. and Mason, D.R. THE THERMAL CONDUCTIVITIES OF Mg_2Si AND Mg_2Ge . Electrochem.Soc.J., 110:121-126, Feb.1963.

The thermal conductivities of relatively large homogeneous samples of Mg_2Si and Mg_2Ge have been measured in a dynamic calorimeter from $0^\circ C$ to $300^\circ C$. In both samples, phonon scattering predominates, and the relationship, $\lambda T = \text{constant}$ was observed. For Mg_2Si , $\lambda T = 23.4$ watts/cm, and for Mg_2Ge , $\lambda T = 19.8$ watts/cm.

4814

LaBotz, R.J., Mason, D.R. and O'Kane, D.F. THE THERMOELECTRIC PROPERTIES OF MIXED CRYSTALS OF $Mg_2Ge_xSi_{1-x}$. Electrochem. Soc.J., 110:127-134, Feb.1963.

The purpose of this work was to determine the thermoelectric properties of the pseudobinary system Mg_2Si - Mg_2Ge . The compositions investigated were Mg_2Si , $Mg_2Ge_{0.2}Si_{0.8}$, $Mg_2Ge_{0.4}Si_{0.6}$, $Mg_2Ge_{0.6}Si_{0.4}$, $Mg_2Ge_{0.8}Si_{0.2}$, 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 $1070^\circ \pm 5^\circ C$, while that of Mg_2Ge was found to be $1102^\circ \pm 5^\circ C$. Electrical resistivity and Hall effect measurements indicated that at $300^\circ K$ the electron Hall mobility in the mixed crystals is essentially the same as that of the pure compounds. Maximum values obtained were slightly above $300 \text{ cm}^2/\text{volt sec}$. 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 $300^\circ K$. At this temperature the lattice thermal conductivity of $Mg_2Ge_{0.6}Si_{0.4}$ was found to be $0.0268 \text{ watt/cm}^2 \text{ }^\circ K$. 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.

4815

Lashkarev, G.V. and Samsonov, G.V. CHARACTERISTICS OF SOME HIGH-MELTING COMPOUNDS OF TRANSITION METALS AS MATERIALS FOR THERMOELECTRIC CONVERTERS. Atomnaya En., 13:187-188, Aug.1962.

In Russian. Transl. in Soviet J. Atomic Energy, 13:790-792, Mar.1963.

The article provides the results of approximate calculations of the z parameter of high-melting compounds ($z = \alpha^2 / \eta \rho$, where α is the thermo-emf coefficient, η is the thermal conductivity coefficient, and ρ is the electrical resistivity) and also the results obtained in calculating the efficiencies of thermoelectric generators made of these materials for the case where the hot junction temperature is $T_1 = 1200^\circ K$, and the temperature of the cold junction is $T_0 = 400^\circ K$.

4816

Lashkar'ov, G.V. and Samsonov, G.V. CHARACTERISTICS OF REFRACTORY COMPOUNDS OF TRANSITION METALS AS MATERIAL FOR THERMOELECTRIC GENERATORS. Dopovidi Akad.Nauk Ukr. RSR, no.9:1148-1151, 1961.

The quality factors and the corresponding efficiencies are calculated for $MoSi_2$, $CoSi$, $NbSi_2$, $ReSi$, CrN , NbB_2 , TiC , $MnSi$, $MnSi_2$, $ReSi_2$, and $CrSi_2$. Mn , Re , and Cr silicides and CrN have higher thermoelectric efficiencies and possibly may be used as materials for thermoelectric generators. (Chem.Abs., 57:187, Jly.9, 1962).

4817

Leroux-Hugon, Patrick. PROPERTIES OF SOME TERNARY SEMICONDUCTING COMPOUNDS. Acad. Sci.Paris Compt. Rend., 256:118-120, 1963.

Thermoelectric power, Hall constant, Hall mobility, thermal conductivity (k), and the lattice contribution to k (k_l), m.p., phase-instability temperature and other properties of $CdGeAs_2$, $CdSnAs_2$, $ZnGeAs_2$, and $ZnSnAs_2$ were determined. For all the compound, $k_1 \propto T^{-1}$ at $300^\circ K$, and its absolute value is less than in $InAs$. (Inst.Metals, J., 91:794, Jly.1963).

4818

Louisiana State University and Agricultural and Mechanical College, Baton Rouge, La. HALL EFFECT IN BISMUTH AND LIQUID HELIUM STUDIES, February 1, 1961 - January 31, 1963, by J.M. Reynolds. Sp., Jan.31, 1963. (Final Rept.) (Contract DA-ORD-31-124-61-G76).

An extensive study was completed on the electron transport phenomena in zinc at liquid helium temperatures. The magnetic field dependents of the electrical and thermal resistances, the thermoelectric power, the Hall, the Righi-Leduc, the Peltier, the Ettingshausen, and the Ettingshausen-Nernst effects were investigated in magnetic fields up to 14 kG. The different kinetic coefficients relating fluxes to affinities were computed and curve fitting of the conductivity coefficients to the Sondheimer - Wilson theory was made in terms of a four-band scheme.

4819

Lubell, M.S. and Mazelsky, R. CARRIER COMPENSATION IN GERMANIUM TELLURIDE. *Electrochem.Soc.J.*, 110:520-524, June 1963.

Changes in the Seebeck coefficient and Hall constant have been studied for the system $(1-x)M_{0.024} + (1-x)Ge_{0.976}Te + xBi_2Te_3$ where M stands for the metals, germanium, tin, indium, gallium, titanium, and silver. The solubility of these metals is shown to increase with the addition of "neutral vacancies" introduced via bismuth telluride. A linear relationship is obtained between the log of the carrier concentration and the amount of neutral vacancies. The initial solubility is determined only by the ion charge and radius of the solute metal, and the initial carrier concentration is inversely proportional to the charge/radius ratio. An expression satisfying the data is obtained for the solubility as a function of charge, radius, neutral vacancy, and known constants.

4820

Massachusetts Institute of Technology, Laboratory for Insulation Research, Cambridge, Mass. ELECTRIC AND MAGNETIC PROPERTIES OF V_2O_3 AND RELATED SESQUIOXIDES, by A.J. MacMillan. 32p., Oct.1962. (TR 172) (Contract AF 19(604)-5482) (Contract Nonr-1841(10)).

The study is concerned primarily with the electric and magnetic properties of V_2O_3 , both in the pure form and in solid solution with other related oxides. Results of thermoelectric power measurements are presented in tables.

4821

Maxim, I. and Ribco, L. THERMO-ELECTROMOTIVE FORCE OF VANADIUM PENTOXIDE EXPOSED TO THE ACTION OF NUCLEAR RADIATIONS. *Acad. Rep.Populare Romine, Studii Cercetari Fiz.*, 13:289-295, 1962.

In Rumanian. The variation of the thermo-electromotive force of V_2O_5 both during and after reactor irradiation was studied. During irradiation with a flux of

5×10^{12} n/sec cm^2 and a gamma dose of 10^4 r/sec, the thermo-electromotive force begins to increase, reaches a maximum value after 4 to 5 hrs of irradiation, and then returns to its initial value. After irradiation, the thermo-electromotive force keeps the same value as before irradiation. (*Nuclear Sci.Abs.*, 17:12724, Apr.30,1963).

4822

Minegishi, Takeharu. MAGNETO-THERMOELECTRIC POWER AND MAGNETOSTRICTION OF $FeNi_3$ SINGLE CRYSTALS. *J.Applied Phys.(Japan)*, 2:151-155, Mar.1963.

The change in thermoelectric power due to magnetization of ferromagnetic substance, i.e. the magneto-thermoelectric power, and linear magnetostriction at given temperatures are 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 are 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, have been determined. The magneto-thermoelectric power depends on the orientation of the crystal axes and is always negative. The numerical values obtained are as follows: $(E_m)_{100} = -0.84 \times 10^{-6}$ volt/degree, $(E_m)_{111} = -0.53 \times 10^{-6}$ volt/degree and $\lambda_{100} = 8.4 \times 10^{-6}$, $\lambda_{111} = 1.3 \times 10^{-6}$.

4823

National Lead Co., Titanium Alloy Manufacturing Division, Niagara Falls, N.Y. THERMOELECTRIC MATERIALS. v.p., Jan.31, 1963. (Contract NObs-78326).

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.

4824

Naval Radiological Defense Laboratory, 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. 85p., Sept.13,1962. (USNRDL-TR-581).

Two satisfactory laboratory methods for detecting and studying transient radiation effects on Seebeck coefficient, S, and electrical resistivity, p, of materials having large thermoelectric figures of merit, z, have been developed. The

transient effects of intense beams of 2 Mev electrons on z in commercially available, thermoelectric grade bismuth telluride, have been deduced from separate observations of S and σ , 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 $\pm 50\%$. However, 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.

4825

Northwestern University, Technological Institute, Department of Materials Science, Evanston, Ill.
THERMOELECTRIC POWER IN NONSTOICHIOMETRIC $\alpha\text{-Nb}_2\text{O}_5$, by R.F. Jannick and D.H. Whitmore. 9p., Mar.29,1963. (TR 4) (Contract Nonr-1228(16)).

Thermoelectric power measurements have been made on nonstoichiometric $\alpha\text{-Nb}_2\text{O}_5$ over the temperature range from 300° to 1270°K . The measurements show that, for all compositions in the single-phase, $\alpha\text{-Nb}_2\text{O}_5\text{-}x$ region ($0.0012 \leq x \leq 0.1545$), 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.

4826

Pollock, D.D. and Finch, D.I. EFFECT OF COLD WORKING ON THERMOELEMENTS. Temp., Meas. Control Sci.Ind., 3:237-241, 1962.

Wire specimens were cold drawn at 0° to various amounts of reduction of area and the thermoelectric shifts induced were measured. There are given (1) the variation in e.m.f. with time at 25° after a 20% reduction of area in thermocouple Fe, constantan, Cu, Chromel-P, Alumel, Pt, and 10% Rh-Pt; (2) the effect of 20% reduction of area as a function of temperature in Cu, Chromel-P, Alumel, Pt, and 10% Rh-Pt; and (3) the effect of temperature and of the amount of reduction of area in thermocouple Fe and in constantan. (Chem. Abs., 58:6515, Apr.1,1963).

4827

Pollock, D.D. and Conard, G.P. THE THERMOELECTRIC PROPERTIES OF SOME TRANSITION THERMOELEMENTS IN COMMON USE. AIME Met. Soc.Trans., 227:478-482, Apr.1963.

Equations of the form of the Mott and Jones equations for the absolute thermo-

electric powers of metals are derived primarily from a thermodynamic approach. The behaviors of transition thermoelements in common use are then examined and compared with this simple theory.

4828

Princeton University, Plastics Laboratory, Princeton, N.J.
PIEZO-RESISTIVE CHARACTERISTICS OF SOME ORGANIC SEMICONDUCTING POLYMERS, by A.W. Henry and C. Capps. 40p., Apr.15,1963. (Tech.Rept. 67A) (ONR 356-375) (Contract DA-31-124-ARO(D)-21).

A series of highly conjugated polymers with semiconducting characteristics, was examined to determine the piezo-resistive behavior. The resistivities ranging from 10^2 to 10^{11} ohm-cm at room temperature and 1840 atmospheres pressure, decreased 100, and for some polymers, 1000 fold as the pressure was increased to 35,000 atmospheres. An elemental polymeric semiconductor with high conductivity was also observed to have a decreasing thermoelectric power with increased pressure and a relatively constant activation energy, both due to the p-type TeO_2 impurity.

4829

Rajagopalan, N.S. and Ghosh, S.K. MEASUREMENTS OF SOME ELECTRICAL AND THERMOELECTRICAL PROPERTIES OF ANTIMONY TELLURIDE FILMS. Physica, 29:234-242, Mar.1963.

Measurements of Hall mobility and conductivity at room temperature and of the variation of resistance and thermoelectric power with temperature have been made on antimony telluride films prepared by vacuum evaporation. Results of the measurements show the presence of inter-crystallite 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 have been discussed.

4830

Rice, Warren and Flam, Eric. DESIGN DATA FOR SEMICONDUCTOR THERMOELECTRIC DEVICES. Electro-Tech., 71:132-133, Mar.,1963.

Sample descriptions, test conditions, and Resulting Thermal Conductances of Thermoelectric materials are presented.

4831

Rupprecht, J. $\text{Bi}_2\text{Te}_3\text{-Sb}_2\text{Te}_3$ ALLOYS WITH ADDED TELLURIUM AND SELENIUM. Z. Naturforsch., 17a:628-629, Jly.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 1/5 of the excess Te added were considered the most suitable.

4832

Sienko, M.J. and Weller, P.F. CARRIER CHARACTERISTICS IN COPPER-DOPED WO_3 FROM CONDUCTIVITY, HALL VOLTAGE, AND THERMAL EMF STUDIES. Inorg. Chem., 1: 324-331, 1962.

Single crystals of $\text{Cu}_0.076\text{WO}_3$, $\text{Cu}_0.094\text{WO}_3$, and $\text{Cu}_0.95\text{WO}_3+\delta$ were prepared by thermal decomposition of CuWO_4 and WO_3 . Potential-probe resistivity measurements in the range 120° to 770°K indicate complex semiconducting behavior. Measurements of the Hall voltage and of the thermoelectric power indicate that carriers are electrons. At 300°K representative carrier densities are 5×10^{18} , 15×10^{18} , and 1×10^{18} electrons per cubic centimeter with mobilities of 6, 10, and $0.4 \text{ cm}^2/\text{v-sec}$ for $\text{Cu}_0.076\text{WO}_3$, $\text{Cu}_0.094\text{WO}_3$, and $\text{Cu}_0.95\text{WO}_3+\delta$, respectively. Thermal emf values fall in the range -220 to -300 $\mu\text{V}/\text{deg}$. Results are interpreted in terms of a conduction band model with destruction of the band below room temperature due to a probable ferroelectric transition in the host lattice. Excess oxygen acceptor centers of appreciable ionization energy apparently are present in small concentration in the low-copper materials and in large concentration in the high-copper material. (Am. Ceram.Soc.J., 46:26, Jan.21,1963).

4833

Smirous, K., Hruby, A., and Stourac, L. THE INFLUENCE OF IMPURITIES ON THE ELECTRIC AND THERMOELECTRIC PROPERTIES OF CdSb SINGLE CRYSTALS. Czechoslov.J.Phys., 13: 350-357, 1963.

The influence of impurities on the electric and thermoelectric properties of 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.

4834

South Dakota School of Mines and Technology, Solid State Physics Project, Department of Physics, Rapid City, S.D. THE EFFECT OF A MAGNETIC FIELD ON THERMAL AND ELECTRICAL PROPERTIES OF MAGNESIUM STANNIDE AND INDIUM ANTIMONIDE, by R.J. Kosteletzky. 61p., Nov.1,1962. (TR 7) (Contract Nonr-2964(01)).

The measurements performed allowed the determination of (1) the value and the relative change in a magnetic field of the thermal conductivity of InSb and Mg_2Sn , (2) the relative change in a magnetic field of the Seebeck coefficient of InSb and Mg_2Sn , and (3) the relative change in a magnetic field of the electrical resistivity of InSb.

4835

Southern Research Institute, Birmingham, Ala. THE THERMAL PROPERTIES OF TWENTY-SIX SOLID MATERIALS TO 5000°F OR THEIR DESTRUCTION TEMPERATURES, May 1, 1960 - April 31,1962, by C.D. Pears and others. 420p., illus., Jan.1963. (ASD-TDR-62-765) (Contract AF 33(616)-7319).

The thermal expansion, heat capacity, thermal conductivity, total normal emittance, electric resistivity, and thermoelectric voltage were investigated for 26 refractory materials, including the borides, carbides, nitrides, oxides, ATJ graphite, tungsten, and alloys of molybdenum and columbium. The temperature range was from 500°F to 5000°F . In addition to these thermophysical properties, the density, chemical analysis before and after temperature exposure, and microscopic pictures before and after temperature exposure, are included to define the materials and assist in the analysis of the data.

4836

Stanford Research Inst., Menlo Park, Calif. THERMOELECTRIC MATERIALS, October 19,1958 - May 31,1961, by J.W. Johnson. 13p.,illus., Jly.1,1961. (Summary Rept.) (Contract NObS-77017) (AD-277 109).

Resistance measurements of pressed pellets of metal-free phthalocyanine ranged from 2×10 to the 11th power at room temperature to 8×10 to the 6th power ohm-cm at 225°C . An activation energy of 1.385 eV was calculated for conduction; the Seebeck coefficient was -1680 micro v/C at 220°C . Liquid semiconductors having thermoelectric properties comparable with Cu_2S were produced by addition to Cu_2S . The best material investigated to date contained 75% Cu_2Te -25% Cu_2S . The improvement in the thermoelectric properties of Cu_2S for

power generation apparently depends more on lowering the resistivity than by raising the Seebeck coefficient. The Cu-S ratio should be altered by increasing the S content rather than the Cu content. Ag-In tellurides prepared by heating equivalent amounts of the elements in an evacuated sealed quartz tube did not produce stoichiometric compositions. (TAB U62-4-1: 47, Oct.1,1962).

4837
Stanford Research Institute, Menlo Park, Calif.
THERMOELECTRIC MATERIALS, January 1 - March 1, 1962, May 1,1962 - March 1,1963, 6v., Mar.19, Jly.17, Sept.14, Nov.15,1962, Jan.16, Mar.15,1963. (Repts. 18,20,21, 22,23,24) (Bimonthly Prog. Repts.) (Contract NObs-77017).

The Progress Reports describe works performed under Contract NObs-77017 on thermoelectric material for the periods listed.

4838
Tantraporn, W. EFFECTS OF UNIDIRECTIONAL PRESSURE ON THE THERMAL EMF OF Bi_2Te_3 . Adv.Energy Convers., 1(Pt.I-IV):109-112, 1961.

The change of thermal emf in Bi_2Te_3 single crystals when unidirectional pressure is applied along the trigonal axis was measured at room temperature. The fractional change of the thermal emf along the trigonal axis under such pressure appears to approach a saturation value of a few per cent, and is positive for the p-type, negative for the n-type. The magnitude of the change varies with the carrier density, and may be explained qualitatively in terms of the change of the carrier density by the pressure.

4839
Taylor, P.L. THE THERMOELECTRIC POWER OF METALS. Phys.Ltrs., 3:245-246, Jan.15,1963.

The thermoelectric power of several monovalent metals is positive in sign. It is the purpose of this letter to point out that the form of the electron-phonon interaction leads naturally to an anomalous positive contribution to the thermopower of all metals, and that the magnitude of this contribution depends strongly on the topology of the Fermi surface.

4840
Timchenko, I.N. and Shalyt, S.S. THERMOELECTRIC PROPERTIES OF TELLURIUM AND THE EFFECTIVE MASS OF HOLE CARRIERS. Fiz. Tverdogo Tela, 4:3612-3617, Dec.1962.

In Russian. Transl. in Soviet Phys., Solid State, 4:2642-2645, June 1963.

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

4841
Ugai, Ya.A., Averbakh, E.M. and Lavrov, V.V. SOME ELECTRICAL PROPERTIES OF THE INTERMETALLIC COMPOUND $\beta\text{-Zn}_4\text{Sb}_3$. Fiz. Tverdogo Tela., 4:3270-3272, Nov.1962.

In Russian. Transl. in Soviet Phys., Solid State, 4:2393-2395, May 1963.

The authors have measured the temperature variation of the electrical conductivity and thermo-emf in single crystals and polycrystals of Zn_4Sb_3 to determine their semiconducting properties. The Hall constant was determined at room temperature. Some of the samples investigated were subjected to zone recrystallization.

4842
U.S. Atomic Energy Commission, Oak Ridge National Laboratory, Oak Ridge, Tenn. SOLID STATE DIVISION, ANNUAL PROGRESS REPORT FOR PERIOD ENDING AUGUST 31,1962. 213p., Nov.26,1962. (ORNL-3364).

p.89-90. THERMOELECTRIC POWER IN GERMANIUM. by O.E. Schow. Although 40% of the carriers were removed from a 2-ohm-cm n-type germanium sample by Co^{60} photon irradiation, the Seebeck coefficient remained relatively unchanged. A definitive experiment, using 0.2-ohm-cm n-type germanium, is in progress which will establish the validity of the premise that the Seebeck coefficient is less sensitive in antimony-doped germanium to Co^{60} photons than the theory predicts.

4843
U.S. Bureau Mines, Washington, D.C. THERMOELECTRIC PROPERTIES OF ENARGITE-TYPE COMPOUNDS, by R.L. Carpenter, J.S. Murray, and T.D. Roberts. 8p., 1963. (Rept. Investigations 6200).

Thermal conductivity, electrical resistivity, and Seebeck coefficient for 9 compounds, based on formula for enargite Cu_3AsS_3 , 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. (Eng.Index,p.188, June 1963).

4844

Uphoff, H.L. and Healy, J.H. THERMOELECTRIC PROPERTIES OF DIPHASAL SYSTEMS COMBINING As_2Te_3 AND Tl_2Se WITH Sb_2Te_3 , OR Sb_2Se_3 . J. Appl. Phys., 34:390-395, Feb. 1963.

Fourteen sample compositions, representing combinations of As_2Te_3 and Tl_2Se with Sb_2Te_3 , Bi_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 7.2×10^{-4} - 1.8×10^3 Ω -cm in resistivity, 3.1 - 1040 $\mu V/^\circ K$ in Seebeck coefficient magnitude, and 3.6 - 19.0 mW/cm -deg in thermal conductivity.

4845

van den Berg, G.J. and de Nobel, J. LES PROPRIETES A BASSES TEMPERATURES DES ALLIAGES DES METAUX "NORMAUX" AVEC DES SOLUTES DE TRANSITION. J. Phys. & Radium, 23:665-671, Oct. 1962.

In French. The low temperature anomalies of the resistivity, the electrical and thermal magnetoresistance, the Hall effect, the thermoelectric power and the specific heats in dilute alloys of transition elements in normal metals are reviewed. In particular the thermoelectric power may become larger than in the pure metals by several order of magnitude. The specific heat anomalies display the magnetic entropy due to the spin of the solutes. A tentative comparison between theory and experiment is presented.

4846

Warren, I.H. URANIUM COMPOUNDS AS THERMOELECTRIC MATERIALS. Canadian Mining and Metallurgical Bull., 56:288-298, Apr. 1963.

Properties required for a compound to form useful thermoelectric materials are described. Uranium compounds which might have these properties are reviewed. Several of these compounds were prepared and fabricated into compacts. The apparatus used for hot pressing, and for the measurement of thermoelectric power, electrical conductivity, and thermal conductivity, is described. Detailed attention is given to the properties of the nitrides. (Battelle Tech. Rev., 12:306a, Jly.-Aug. 1963).

4847

Westinghouse Electric Corp., Atomic Power Department, Pittsburgh, Pa. PREPARATION AND PRELIMINARY THERMOELECTRIC EVALUATION OF THE URANIUM CHALCOGENIDES, by W.P. Blankenship. 45p., Oct. 1961. (WCAP-1866) (Contract AT(30-3)-500).

Potential thermoelectric materials investigated were: US_x , USe_x , UTe_x , and

some ternary combinations of U with S, Se, and Te. Procedures were developed for preparation of the various compounds, fabrication of geometrically regular samples, and determination of the thermoelectric properties of these samples as a function of temperature. Uranium-sulfur and uranium-selenium binary compounds, and uranium-sulfur-tellurium ternary compositions were found to offer considerable promise as good thermoelectric materials. The uranium-selenium group probably has the highest range of useful operating temperatures. (Nuclear Sci. Abs., 17:14856, May 15, 1963).

4848

Wolfe, Raymond, and Smith, G.E. SEMIMETALS AS THERMOELECTRIC MATERIALS. Semiconductor Prod., 6:29-33, Apr. 1963.

Semimetals, which contain equal numbers of electrons and holes, have recently returned to the list of optimum thermoelectric materials. Values of the figure of merit as high as $6 \times 10^{-3}/^\circ K$ 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 $8.6 \times 10^{-3}/^\circ K$ have been measured in a field of 1000 gauss at $100^\circ K$. These results are discussed in terms of the cooperative behavior of equal numbers of high-mobility, anisotropic electrons and holes.

4849

Yaroshenko, V. EFFECT OF IMPURITIES ON THE THERMOELECTRIC PROPERTIES OF METALS. Trudy. Tbilisk. Gos. Pedag. Inst., 14: 59-74, 1959.

In Russian. A review. Theoretical and experimental data on the thermoelectric properties of metals and alloys are generalized. It is concluded that during the formation of solid solution in a binary system consisting of thermoelectrically positive metals, the dependence of the absolute thermo-e.m.f. on the composition is represented by a smooth curve with a minimum (Ag-Au). This shifts the point of the zero thermo-e.m.f. towards the right at a junction with transitional metals. During the formation of solid solution in a binary system consisting of thermoelectrically negative metals, the dependence of the thermo-e.m.f. on the composition changes along a smooth curve with a maximum (Pt-Pd). This shifts the point of the zero thermo-e.m.f. towards the right at a junction with Cu. The formation of solid solution in a

binary system consisting of metals with thermoelectrically different signs produces a decrease in the thermo-e.m.f. and accordingly produces a displacement of the point of the zero thermo-e.m.f. to the right at a junction with Cu. (USSR Abs., J. of Metallurgy, no.9/10(Part A):31,1961).

4850

Zalar, S.M. THERMOELECTRIC BEHAVIOUR OF THE SEMICONDUCTING SYSTEM $Cu_xAg_{1-x}InTe_2$. (Met.Soc.Conf.) Metallurgy of Semiconductor Materials, 15:263-283, 1962.

Thermal, X-ray-diffraction, microscope, and thermoelectric methods were used and the system $Cu_xAg_{1-x}InTe_2$ was shown to be a continuous series of metastable solid solution at temperature $> 650^\circ C$, and to be unstable and supersaturated $< 650^\circ C$, from which secondary phases, e.g. Ag_2Te and $InTe$, are precipitated. Annealing increases both thermoelectric power and resistivity, but the former increases faster than the latter. In some compounds e.g., if $x=2/3$, resistivity decreases with annealing time. (Met.Abs.,30:587-588, Apr.1963).

E. Design, Principles of

4851

Atomic International, Division of North American Aviation, Inc., Canoga Park, Calif. STATISTICAL ANALYSIS OF SNAP 10A THERMOELECTRIC CONVERTER ELEMENT PROCESS DEVELOPMENT VARIABLES, by S.H. Fitch and J.W. Morris. 41p., Dec.15,1962. (NAA-SR-7288) (Contract AT-11-1-GEN-8).

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. (Nuclear Sci.Abs.,17:11314, Apr.15,1963).

F. Applications

4852

Brickley, R.L. THE OUTLOOK FOR THERMOELECTRIC DEVICES. Electron.Indus., 22:D6-D9, June 1963.

Thermoelectrics are introducing significant new trends in heating and cooling. These

include infrared detection and cold-probe electronic measurements. Other devices in the field are shown and their effect on future products is predicted.

4853

Egli, P.H. THERMOELECTRICITY FOR SPACE APPLICATIONS. ARS, Space Flight Report to the Nation, New York, N.Y., 4p., Oct.9-15, 1961, Preprint 2122-61.

Survey of the current status of thermoelectricity, and of its space applications. Developments in thermoelectric materials are discussed, and the characteristics of the most promising materials are outlined. It is shown that valid design concepts of thermoelectric converters are now available with (1) isotope or reactor heat sources, (2) unfocused solar energy, or focused energy from large or small collectors, and (3) either battery or thermal storage. In each case, the converter is shown to be lighter, less expensive, and of longer lasting reliability than other existing systems, but to have limitations in regard to size and efficiency. The use of thermoelectric units as heat pumps and refrigerators is discussed. (Intern.Aerospace Abs., 2:52-10786, Nov. 1962).

1. Power Generation

4854

Bartlett, C.M. THE SEMI-CONDUCTOR THERMOELECTRIC ELEMENT AS A LOW-VOLTAGE POWER GENERATOR. Solid-State Des., 4:16-19, Apr.1963.

The phenomenon of voltage generation by means of heat applied to junctions of different metals has been known for many years, and the advent of semiconductors which have properties superior to metals has given increased impetus to this field. Numerous practical applications have already developed and still others seem feasible. This note describes one such application of thermoelectric elements to provide a very low voltage direct-current supply.

4855

Battelle Memorial Institute, Columbus, Ohio. MULTIFUELED THERMAL-ENERGY-CONVERSION SYSTEMS, July 1 - December 30, 1962, by H.R. Hazard and others. 2v., Sept.30, & Dec.30, 1962. (Q.Prog.Repts. 1 & 2) (Contract DA 36-039-sc-90838).

The object is to investigate the feasibility of utilizing wood, coal, charcoal, or other locally available fuel found in world-wide areas as a heat source, for a thermoelectric generator or small engine-driven generator capable of producing 150 watts of electric power.

4856
DESIGN OF THERMOELECTRONIC 300-KW GENERATOR.
Przeгляд Techniczny, no.27:11, Jly.5,1961.

In Polish. Transl. in FTD-TT 62-1824,
by Air Force Systems Command, Foreign
Technology Division.

Manufacture of several types of thermo-
electronic generators with power rating
of 30 to 300 kw was proposed. It is
contemplated to build first a 30-kw
generator; other generators with a higher
power rating will be built after a
thorough testing of the prototype. Heat
energy will be supplied by a small nuclear
reactor.

4857
Fritts, R.W. THE DEVELOPMENT OF THERMO-
ELECTRIC POWER GENERATORS. Inst.Elec.&
Electr.Engrs.Proc., 51:713-721, May 1963.

This work is a review of the technical
developments that have led from early
semiconductor research to the emergence
of the thermoelectric generator as a
rapidly growing power source of high
reliability.

4858
General Electric Co., Syracuse, N.Y.
RESEARCH ON POWER SUPPLY (ADVANCED SOLID
STATE), May 1961 - July 1962, by W.J.
van der Grinten and others. 60p., illus.,
Oct.24,1962. (ASD-TDR-62-745) (Rept.
R62-ELS-69) (Contract AF 33(616)-8256).

The report covers the first phase of a
program, the objective of which is the
development of a self-contained thermo-
electric power supply. The use of a
radioactive source of heat incorporated
in everyone of 36 thermoelectric components
will be considered towards the end of the
second phase. Only non-radioactive heat
sources have been used during Phase I.

4859
General Instrument Corp., Thermoelectric
Division, Newark, N.J.
CHEMICAL FUELED THERMOELECTRIC GENERATOR.
v.p., Nov.30,1962. (Final Rept.)
(Contract NObs-78656).

A proof-of-principle, thermoelectric device
is described which is fueled with a high
energy (1875 calories per gram) high
density (1.8 grams per cubic centimeter)
fuel slurry. Handling and storing the
fuel for periods up to one year offered
little difficulty; however, operating
problems, such as fuel feed to the burner
and ash removal from the burner, were
not fully solved. Two fuel feed systems
were designed and tested; a gravity drop
system which is suited to low power output
devices of up to 5 watt electrical output

and a pressurized, continuous fuel feed
system which is suited to devices about
5 watts electrical output.

4860
General Instrument Corp., Newark, N.J.
ECONOMIC FACTORS OF MFP THERMOELECTRIC
GENERATORS, by E.J. Lemanski. v.p., n.d.
(Final Rept.) (Contract AT(30-1)-2605).

The report describes the results of a
study on the economic aspects of mixed
fission product type generators, in which
a cost comparison with a pure radio-
isotope-fueled thermoelectric generator
of the SNAP 7 type is made. Cost of the
radioisotope fuel, potting the fuel
source, special materials of construction,
biological shield materials and attendant
fabrication and transportation costs are
considered. In addition, problems
involving the handling and emplacement
of the larger size thermoelectric
generators are discussed.

4861
Glassburn, C.W. FLAT PLATE SOLAR THERMO-
ELECTRIC GENERATOR SYSTEM CONCEPT. ARS
Preprint, no.2573-62. Prepublication Copy.
7p.

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 estab-
lished. (Nuclear Sci.Abs., 17:9132, Mar.
31,1963).

4862
Great Britain, Atomic Energy Research
Establishment, Harwell, Berkshire.
AN EXPERIMENTAL THERMOELECTRIC GENERATOR,
by S.M. Third and G.E. Hare. 75p., figs.,
Nov.1962. (AERE-R 4188).

A low power device, simulating a section
from a megawatt output generator, has
been built to test a new idea for the
arrangement of thermoelements around a
cylindrical pipe. The device uses
bismuth telluride type thermoelements and
operates between a condensing vapor
source at 250°C and a sink of cooling
water at about 20°C. The maximum
measured efficiency was 2% at 13 watts
output.

4863
Gritton, D.G. and Tang, Y.S. COOLING
DEVICES FOR THERMOELECTRIC GENERATOR.
Chem.Eng.Progress Symposium Ser., 59:
18-24, 1963.

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. (Eng.Index, p.190, May 1963).

4864

Katz, Kurt. THERMOELECTRIC GENERATORS FOR THE CONVERSION OF SOLAR ENERGY TO PRODUCE ELECTRICAL AND MECHANICAL POWER. United Nations Conference on New Sources of Energy, Rome, 1961, 32p., illus.

The design and performance capability of thermoelectric generators for the conversion of solar energy and relative system economics are the scope of this paper. A brief review of the equations and parameters of importance in predicting performance of a thermoelectric generator, and the status of materials for this mode of energy conversion are presented. As a best estimate at this time 7 to 10 cents per kwh for the cost of electrical energy from a solar-thermoelectric generator appears plausible in the size ranges discussed (50 to 1000 watts). With time, the efficiency of thermoelectric probability reduce the cost of electric power per kilowatt hour further. However, even at the present cost range, solar-thermoelectric power generation appears attractive for many areas of the world. (Solar En., 7: 82, Apr.-June 1963).

4865

Lang, Ronald and Lubin, Barry. A MODULAR SOLAR THERMOELECTRIC POWER SUPPLY SYSTEM. ARS Preprint no. 2574. New York, American Rocket Society, 1962. Prepublication Copy, 6p.

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. (Nuclear Sci.Abs., 17:9128, Mar.31,1963).

4866

Martin Marietta Co., Nuclear Division, Baltimore, Md.
SNAP 7 PROGRAM, TASK 8-STRONTIUM-90 FUELED THERMOELECTRIC GENERATOR DEVELOPMENT, November 1,1961 - July 31,1962, by W.A. McDonald. 3v., Jan.31, Apr.30, & Jly.31,1962. (Q.Prog.Repts. 5,6,&7) (MND-P-2483-5,6, & 7) (Contract AT(30-3)-217).

Design, fabrication, and progress in achievement are reported for SNAP 7A,7B,7C, and 7D generators .

4867

Martin Marietta Corp., Nuclear Division, Baltimore, Md.
SNAP 7D. STRONTIUM-90 FUELED THERMOELECTRIC GENERATOR POWER SOURCE THIRTY-WATT U.S. NAVY FLOATING WEATHER STATION, by C.N. Young. 95p., Mar.15,1963. (MND-P-2835) (Final Rept.) (Contract AT(30-3)-217).

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. This report describes the sixty-watt strontium-90 thermoelectric generator, the relay panel, the batteries, and the installation of the system in a boat-type buoy.

4868

Monsanto Research Corp., Dayton Laboratories, Dayton, Ohio.
HIGH TEMPERATURE THERMOELECTRIC GENERATOR, October 1 - December 31,1962, by C.M. Henderson, and others. 52p., Dec.31,1962. (Q.Prog.Rept.4) (NP-12477) (Contract AF33(657)-7387).

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. (Nuclear Sci.Abs.,17:8944, Mar.31,1963).

4869

Schmerzler, L.J. THERMOELECTRIC GENERATORS-STATUS 1963. Semiconductor Prod., 6:39-44, Apr.,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 watts per pound and costs of \$30-\$100 per watt. Thermoelectric material costs have dropped from \$1500 to \$100 per pound 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 watts per pound of system are projected.

4870

Schuh, N.F. THERMOELECTRIC POWER SYSTEMS.
Astron. and Aerospace Eng., 1:80-83,
May 1963.

Against a background of several years of basic studies, and recent progress with available materials, emphasis shifts to the design of practical devices for space systems.

4871

Shalyt, S.S. CHARGE AND HEAT TRANSPORT IN
n-TYPE INDIUM ARSENIDE AT LOW TEMPERATURES.
Fiz.Tverdogo Tela, 4:1915-1927, Jly.1962.

In Russian. Transl. in Soviet Phys.,
Solid State, 4:1403-1411, Jan.1963.

In order to make a study of the electron scattering mechanism in indium arsenide at $T=77^{\circ}\text{K}$, one sample of the semiconductor with a current carrier concentration of $3 \cdot 10^{16} \text{ cm}^{-3}$ was used in a combined investigation of the following kinetic phenomena: 1) electrical conductivity, 2) Hall effect, 3) magnetoresistance, 4) thermal emf, 5 and 6) the two Nernst-Ettingshausen thermomagnetic effects. The heat conductivity and thermal emf were investigated over the temperature range from 2- 5 to 100°K . A comparative study was made to find what role the geometric effect plays in the magnetoresistance and the magnetothermal emf.

4872

Verie, C. CONVERSION DIRECTE D'ENERGIE
THERMIQUE EN MOUVEMENT. J.Phys.et Radium,
23:166A-168A, Dec.1962.

In French. A method is proposed for directly converting thermal energy into mechanical energy by means of thermoelements. As an example, a simple device is described. The first experimental results show that this technique has many advantages in the case of low energies.

4873

Westinghouse Electric Corp., Central Research
Laboratories, Pittsburgh, Pa.
MODULE IMPROVEMENT PROGRAM. v.p., Aug.31,
1962. (Fina. Rept.) (Contract NObs-
84329).

The objective of the program has been to improve the life-performance of thermoelectric generator modules by means of engineering development and evaluation in the areas of insulation, material processing, and contacting. This final report presents additional data primarily related to the continued testing of materials for use in power generator modules.

4874

Westinghouse Electric Co., Lima, Ohio.
SOLAR THERMOELECTRIC GENERATOR SYSTEM
CONCEPT AND FEASIBILITY STUDY, May 15-
August 15, 1962, by A.J. Krause, J.L.
McCabria and D.A. Naumer. 8p., illus.,
Aug.15,1962. (Q.Rept.2) (Contract
AF33(675)-8089) (AD-283 435).

A constant speed drive mechanism has been incorporated into the collector concentrator and operates as planned. A ten-couple module has been extensively tested and the results indicate the feasibility model can produce 18.3 w. The waste heat radiator test rig is being assembled. Problem areas are still being encountered in the thermal energy storage system. A preliminary system design has been completed. A test specification is included. (TAB U62-4-6:30, Dec.15,1962).

4875

Westinghouse Electric Corp., Lima, Ohio.
SOLAR THERMOELECTRIC GENERATOR SYSTEM
CONCEPT AND FEASIBILITY STUDY, August 15 -
November 15,1962, by A.J. Krause and J.L.
McCabria. 33p., illus., Nov.15,1962.
(Q.Rept.3) (Contract AF33(657)8089)
(AD-291 432).

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. (TAB U63-1-6:10-11, Mar.15,1963).

2. Heat Pumps

4876

Allison, D.K. COOLING MICROMODULES INTERNALLY
WITH PELTIER JUNCTIONS. Electronics
Reliability and Microminiaturization, 1:
359-363, 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. (Elec. Eng.Abs.,66:3842, Apr.1963).

4877

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. Iv., illus., Dec.31,1961. (Rept. TR-24-61-1) (Contract DA 44-009-eng-4643) (AD-295 596).

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. (TAB U63-2-3:43, May 1,1963).

4878

Bannister, W.J. and Kay, R.H. A CIRCUIT TO OPERATE A THERMOELECTRIC "COLD" STIMULATOR. J.Sci.Instrum., 40:83, Feb.1963.

A transistor circuit to control the operation of a thermoelectric "cold" stimulator is described. Rectangular current pulses are available of amplitude 0-10A. duration 1-4 sec., either singly, or repetitively at pulse intervals 5-15 sec. (Elec.Eng.Abs., 66:5001, May 1963).

4879

Bean, J.E. APPLICATIONS OF THERMOELECTRIC COOLING. Indust.Electron., 1:132-134, Dec.1962.

The advantages and applications of thermoelectric cooling devices are discussed.

4890

Bean, J.E. THERMOELECTRIC COOLING. Indust. Electron., 1:110-113, Nov.1962.

The Peltier effect has become a practicable

method of small-scale refrigeration. This is a consequence of the development of semiconductors, and very compact units are now available; one of volume about 0.03 cubic inch will give a heat transference of about 0.1 calorie per second.

4881

Bendix Corp., Research Laboratories Division, Southfield, Mich.
DEVELOPMENT OF A DEWPOINT HYGROMETER FOR ATMOSPHERIC SOUNDING, by H.R. Farrah, A.A. Vitale, and H.R. Young. v.p., June 1962. (Rept. 2055) (Contract AF 33(600)-4182).

This report describes the development of a thermoelectric-cooled, mirror-type dewpoint hygrometer for use in measuring dewpoint in the range of -80°C to -50°C in altitudes between 100K feet and sea level.

4882

Cox, C.D. and Edwards, W.D. ICE POINT MAINTAINED THERMOELECTRICALLY AND REGULATED BY CHANGE OF STATE. Rev.Sci. Instr., 34:704-705, June 1963.

This note describes a method of maintaining an ice point to provide a 0°C reference temperature for a thermocouple junction. Two thermoelectric refrigerating elements are used to cool a small container of water until it is partially frozen. The volume change of the water on freezing is used to control the power to the cooling elements so that the volume of ice remains constant.

4883

Crawley, J.C.W. A COOLED MICROSCOPE STAGE USING SEMICONDUCTOR THERMOELECTRIC COOLING. J.Sci.Instr., 40:330, June 1963.

The design of a microscope stage cooled by a thermoelectric device is discussed. The temperature was stabilized near 0°C using the latent heat of fusion of ice.

4884

Eichhorn, R.L. A REVIEW OF THERMOELECTRIC REFRIGERATION. Inst.Elec.& Electr.Engrs. Proc.,51:721-725, May 1963.

The advantages of thermoelectric refrigeration, some of its possible applications and its principles of operation are briefly presented. The current state of the art in thermoelectric materials is discussed. The design problems in developing thermoelectric devices and some of the current techniques used to solve them are reviewed. Some information is provided on devices that have been built for the U.S. Navy and for commercial application.

4885

Goldsmid, H.J. THERMOELECTRIC AND THERMO-

MAGNETIC COOLING. *Indust. Electron.*, 1: 441-444, May 1963.

Only recently materials have been developed which have enabled the Peltier effect to be of practical use. The article discusses the requirements and considers the possibilities of another effect-the little-known Ettingshausen effect.

4886

Goldsmid, H.J. THERMOELECTRIC AND THERMO-MAGNETIC COOLING. *Indus. Electron.*, 1: 467-470, June 1963.

Some applications of thermoelectric cooling are discussed and then the possibilities of thermomagnetic cooling are considered. This form of cooling depends on the Ettingshauser effect and has certain advantages, but is most effective at very low temperatures.

4887

Merritts, T.D. and Taylor, J.C. THERMO-ELECTRIC TEMPERATURE CONTROL. *Westinghouse Engr.*, 23:120-124, July 1963.

This temperature control method is extremely flexible because it can be used in systems that have to operate in various ambient temperatures and deliver various controlled temperatures. It can provide temperature control requiring only cooling, only heating, or both cooling and heating. This article deals with devices that provide both heating and cooling because most applications require that ability and also because such devices most fully illustrate the principles involved.

4888

OFF-THE-SHELF THERMOELECTRICITY BOOSTS LAMP OUTPUT. *Mach. Design*, 32:10, Nov. 10, 1960.

A brief description plus illustration is given for thermoelectric spot coolers which let four fluorescent tubes do the work of seven. By chilling each tube to maintain mercury-vapor pressure at an optimum value, the coolers increase lamp output by 72 per cent.

4889

Phillips, A.F. THERMOELECTRIC AIR CONDITIONING AND REFRIGERATION FOR SUBMARINES. *Inst. Int. du Froid-Annexe au Bul-Commissions* 2,3,4,6A, Washington, D.C., Aug. 20-29, 1962, p.163-177.

Several thermoelectric devices to provide refrigeration for air conditioning and food storage aboard submarines have been developed under US Navy program by different contractors; these include 1/6-ton cooling capacity chilled water to seawater units, 1-ton air to fresh water unit, and

refrigerated food units; all use bismuth telluride as thermoelectric material. (*Eng. Index*, p.167, Jly. 1963).

4890

Poganski, S. THERMOELECTRIC REFRIGERATION AND ITS TECHNICAL APPLICATIONS. *AEG Mitt.*, 51:259-265, Jly.-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. (*Elec. Eng. Abs.*, 66:540, Jan. 1963).

4891

Pomazanov, I.N. and Tikhomirov, P.L. THERMO-ELECTRIC REFRIGERATOR OPERATING ON HEAT ENERGY. *Kholod. Tekh.*, 38:24-27, 1961. In Russian. *Transl. AEC-tr-5105*.

The combination of a thermoelectric refrigerator and thermoelectric generator in one installation to generate cold without external sources of electric power is discussed. The possibility of creating a refrigerator for quick cooling and freezing of water and operating with the heat from an ordinary gas burner was investigated. Such a refrigerator consists of a cylindrical copper or aluminum tank at the bottom of which are installed semiconductor plates forming the individual elements of the electronic refrigerator. It was found that the refrigerating capacity of the device is sufficient for cooling by $\Delta T = 20^\circ$ and freezing of approximately 0.70 kg of water per hour. (*Res. Devlpmt. Abs.*, 2:356, Apr.-June 1962).

4892

Rice, L.R. THERMOELECTRIC COOLING AND ITS USE. *Solid State Des.*, 4:32-37, May 1963.

A new and unique solution to the cooling problem lies in the application of thermoelectric cooling. Thermoelectricity derives its heat pumping capability from the difference in the electron energy level in the p and n-type materials that are used to construct the thermocouple. As an electron traverses the p-n junctions, heat is absorbed from the load and evolved at the heat sink. Therefore, to utilize this system, the designer need only to control the magnitude of the thermoelectric device current to achieve cooling action.

4893

Rollinger, C.N. and Sunderland, J.E. THE PERFORMANCE OF A THERMOELECTRIC HEAT PUMP WITH SURFACE HEAT TRANSFER. Solid-state Electron., 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.

4894

Steiger, O. PERFORMANCE OF THERMOELECTRIC COOLING ELEMENTS. Kaltetechnik, 14: 69-75, 1962.

In German. The refrigerating capacity of a single element is discussed. A survey is given on the obtainable efficiencies on the basis of which interesting performance conditions and refrigerating capacities are described. Questions concerning the determination of element dimensions are answered. (Appl.Mech.Rev.,16:553, Jly.1963).

4895

U.S. Air Force. Rome Air Development Center, Griffiss Air Force Base, N.Y. INVESTIGATION OF UNCONVENTIONAL COOLING TECHNIQUES, by J.B. McCormick and T.W. Walsh. 43p., Nov.1962. (TM RAS-TM-62-6).

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.

4896

U.S. Army Electronics Research and Development Laboratory, Fort Monmouth, N.J. DESIGN AND EVALUATION OF THERMOELECTRIC THERMAL BARRIER FOR MICRO-MODULES, by R.D. Fitzgerald and H.C. Frankel. 37p., illus., Sept.1962. (USAEIRD Tech.Rept.2308).

This report covers internal work on the 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. Test results on a simulated binary divider micro-module indicate the feasibility of the thermoelectric thermal barrier approach.

4897

Westinghouse Electric Corp., Aerospace Electrical Division, Lima, Ohio. FEASIBILITY STUDY AND INVESTIGATION OF THERMOELECTRIC POWER GENERATION AND COOLING FOR FLIGHT VEHICLES, March 1 - April 1, 1962. 16p., Apr.1,1962. (Interim Rept. 7) (Contract NOW 61-0921-d).

A computer program was established to investigate various design parameters of thermoelectric coolers. A discussion of this program and the results obtained for various designs are presented.

4898

Westinghouse Electric Corp., Semiconductor Division, Youngwood, Pa. THERMOELECTRIC TEMPERATURE CONTROL FOR QUARTZ CRYSTALS AND CRYSTAL OSCILLATORS, April 1, 1961 - March 31, 1962. 124p., Mar.31,1962. (Final Rept.) (Contract DA-36-039-sc-87190).

An approximate design procedure on a thermoelectric single couple is presented using average values of material parameters. It is shown that a thermoelectric chamber is a low voltage, high current and low ripple device. A-c to d-c power conversion using fundamental silicon rectifier circuits is discussed. Theoretical operation of a static d-c to d-c power converter is described. Emphasis is placed on circuit losses and important transistor ratings. It is shown that a simulation of the principal elements in a thermoelectric chamber temperature control system can be made and evaluated on an analog computer. Experimental investigations on best pumping performance and temperature control are given for several chamber designs. An investigation on chamber design criteria is presented with respect to various parameters.

4899

Whirlpool Corp., St. Joseph, Mich. THERMOELECTRIC TEMPERATURE CONTROL IN AN/URQ-9 FREQUENCY STANDARD, January 1- April 30, 1962, by R.G. Sickert and A.F. Martz. 32p., illus., May 24, 1962. (Interim Dev.Rept.4) (Contract NObSR-85314) (AD-283 663).

Modified ovens have been installed in one AN/URQ-9 Frequency Standard. The performance of the modified ovens is such that in an ambient temperature from 0 C to 45 C the crystal is maintained at a temperature from 20C to 28C regulated to accuracy of at least ± 0.01 C. (TAB U62-4-6:40, Dec.15, 1962).

4900

Zito, Ralph. DYNAMIC BEHAVIOR OF A THERMO-ELECTRIC HEAT PUMP. *Electro-Technology*, 71:64-69, Feb.1963.

One important characteristic in the consideration of a heat pump is its coefficient of performance, defined as the ratio of the heat removed by the refrigerant to the work performed on the refrigerant. In the case of a thermoelectric device, the refrigerant is the electrical current that flows through the circuit. The thermoelectric power involves, the thermal and electrical conductivities of the materials, and the operating temperatures of the junctions are therefore important in determining the dynamic behavior and overall efficiency of the refrigerator.

3. Thermocouples

4901

General Electric Co., Nuclear Materials and Propulsion Operation, Evendale, Ohio. RESEARCH AND EVALUATION OF MATERIALS FOR THERMOCOUPLE APPLICATION SUITABLE FOR TEMPERATURE MEASUREMENTS UP TO 4500°F ON THE SURFACE OF GLIDE RE-ENTRY VEHICLES, March 15,1962 - March 15,1963, by W.C. Kuhlman. 75p., illus., May 1963. (ASD-TDR-63-233) (Contract AF 33(657)-8472).

The thermoelectric output versus temperature of a W/W - 26Re thermocouple was measured to 5800°F. Thermoelectric sensitivity was relatively high over the entire temperature range. Thermoelectric output on new thermocouple systems versus temperature was also measured with respect to W - 26Re commercial wire for Re, Re-6W, Re-9W, Re-12W, Re-15W, Re-10Ru, Re-5Ru, Re-10Rh, Re-20Rh, Re-10Pt, Re-30Ir, Re-5Mo, Re-10Os, Re-20 Os, Mo, Mo-10W, Mo-20W, Mo-10Re, Ir-20Re alloy materials. Of the alloys studied, Re-10Ru and Re-12W show the greatest potential for high-temperature thermocouple application.

4902

Northeastern University, Boston, Mass. CALCULATION OF THERMOPOWER FACTORS FOR A PLASMA AND A METAL, by J.Davis and G. Lanza. 14p., Nov.1,1962. (SR 3) (AFCL-62-1047) (Contracts AF 19(604)-7358 & AF 19(604)-8462).

The authors develop the classical theory of transport phenomena, as applied to thermocouples, using the Boltzmann transport equation.

4903

Sirs, J.A. MEASUREMENT OF RAPID TEMPERATURE CHANGES BY THERMOCOUPLES. *J.Sci.Instr.*, 38: 489-490, Dec.1961.

An experiment is described in which the

response of a thermocouple to an instantaneous change of temperature was measured directly. A simple circuit is described to permit observation of changes occurring within a few ms with a mechanically robust junction. (*Instr. Abs.*,38:489-490, Dec.1961).

4904

Smart, D. and Smart E. ON THE RELATIONSHIP BETWEEN RESISTIVITY AND THERMO-e.m.f. *Phil.Mag.*,8:643-650, Apr.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. 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.

4905

Stanford Research Institute, Menlo Park, Calif. SURFACE TEMPERATURE MEASUREMENTS WITH THERMOELECTRIC MATERIALS, June 1,1960-May 31,1961. 109p., illus., Aug.1962. (Final Rept.) (Contract AF 33(616)-7377) (ASD TR 61-373) (AD-286 098).

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. (TAB U63-1-2:138, Jan.15,1963).

4906

Weiss, H. APPARATUS FOR MEASURING TEMPERATURES BY THERMOELECTRIC COUPLES ON MACHINES RUNNING AT VERY HIGH RATES OF ROTATION. *Elect.Traction Railways (Internat.Railway Congr.Assoc.)*, 13:332-340, Jly.1962.

In the apparatus described, the measuring thermocouple is connected in opposition to a reference thermocouple which is kept at constant temperature, the differential output being used to excite a revolving electromagnet which in turn induces pulses proportional to temperature, in a stationary inductive pick-up. The magnetic fields are balanced by passing a balancing current through the pickup winding. The design of the magnetic circuit is discussed and an experimental set-up described. The circuit used to make the device self-balancing is described, and attention is given to errors and to calibration procedure. A range of 40°C-450°C, and of 190-18 000 rev/min and even higher, can be covered with an accuracy of 2%. (*Elec.Eng.Abs.*, 66:428, Jan.1963).

4907

Wormser, A.F. and Pfuntner, R.A. THERMO-COUPLE TELLS TEMPERATURES ABOVE ITS MELTING POINT. *Soc.Automotive Engrs.J.*, 70:57-58, May 1962.

New pulse technique alternately heats and cools thermocouple junction. Based on Paper 524A.

4908

Zhilo, N.L. TEMPERATURE MEASUREMENT BY A RHODIUM PLATINUM-RHODIUM THERMOCOUPLE. Symposium: Nauchno-tekh. Trud.Nauchno-issled.Inst.Metallurg.Chelyab.Sovnarkhoza, no.2:178-179, 1960.

In Russian. A Rh (80% Pt + 20% Rh) thermocouple with a maximum practical temperature of 1800° and a thermal e.m.f. of 7.5 mV at this temperature is described, together with an account of tests of this instrument. (*USSR Abs., J. of Metallurgy*, no.7(Pt.B):103, 1961).

4. Miscellaneous

4909

Ambach, W. and Habicht, H.L. EIN THERMO-ELEKTRISCHER STRAHLUNGSBILANZMESSER ZUR BESTIMMUNG DER IN OBERFLAECHENNAHEN EISSCHICHTEN EINES GLETSCHERS ABSORBIERTEN STRAHLUNGSENERGIE. (A THERMOELECTRIC RADIATION BALANCE METER FOR DETERMINATION OF ABSORBED RADIATION ENERGY IN ICE LAYERS NEAR THE SURFACE OF A GLACIER). *Archiv fuer Meteorologie, Geophysik und Bioklimatologie, Ser.B, Vienna*, 11:241-250, 1961.

A thermoelectric instrument was built to

investigate the drop of radiation balance in the top ice layers of a glacier. The radiation sensitive area of the instrument has a diameter of no more than 7.5 mm and allows nearly undisturbed measurement of the radiation balance. The data obtained permit a direct calculation of the energy transformations taking place in these layers. Calculations are given of the optimum wire size for the thermoelectric elements between the two receiver plates. Measurements were made in pure glacier ice. The average extinction coefficient in the layers from 0 to 20 cm depth was found to be 0.14 cm⁻¹. Below that depth the extinction coefficient assumes a constant value of 0.018 cm⁻¹. Half of the incident energy is absorbed in the first 1 or 2 cm. At a depth of 10 cm only 10 percent of the energy remains. Thus the radiation balance decreases somewhat more sharply than the short wave radiation measured with a spherical receiver. (*Meteorol. Geostrophys.Abs.*, 13:547, Sept.1962).

4910

Boivinet, P., Bros, J.P. and Calvet, E. THERMOELECTRIC CALIBRATION OF A MICRO-CALORIMETER OF THE E. CALVET TYPE. *J. Chim. Phys.*, 59:805-807, Jly.-Aug. 1962.

In French. The microcalorimeter fitted with multiple thermocouples is calibrated by means of the Peltier effect. In order to calculate the heat flux it is necessary that all the thermocouples be used alternately as generators and detectors. The appropriate circuit arrangements are described. (*Phys.Abs.*, 66:3916, Mar.1963).

4911

Geiseler, G. and Ratzsch, M. UBER EIN ROTATIONS-METALLBLOCK-KALORIMETER HOHER EMPFINDLICHKEIT. *Z.Naturforsch.*, 18a: 473-481, Apr.1963.

A rotatable metal-block-calorimeter with thermoelectrical measurement of temperature is described. The platinum-lined combustion block is made of electrolytic copper. The zero-blocks, set up symmetrically on both sides of it, are of pure aluminum. Eight thermo-piles, with 50 elements each, are used for measuring. The small combustion-shell, also of platinum, is freely suspended so that its contents are never spilled during rotation. The whole calorimeter, is mounted on bearings, and is housed in a high-vacuum container, which can be evacuated down to a pressure of 10⁻⁵mm Hg. A multi-jacket thermostat is used for thermal isolation. In the outer jacket the temperature constancy is better than 10⁻³°C. The sensitivity of the calorimeter has been tested by the burning of some typical substances.

4912

Kashmiry, M.A. HERMACH-ENGELHARD TRANSFER STANDARD. Instr. & Contr.Sys.,36:79-81, Jan.1963.

The Model C Hermach-Engelhard standard is a thermoelectric transfer instrument utilizing a thermal converter as a transfer element. The instrument is capable of measuring dc and ac voltage over the range 0.2 to 1500 volts, and current over the range 3 ma to 25 amp. The instruments accuracy of better than 0.05%, without correction factors, can be certified over the frequency range 5 cps to 50 kcps, on voltage ranges to 600 volts and current ranges to 5 amperes. All higher ranges possess this certified accuracy over the frequency range 5 cps to 20 kcps; dc currents and voltages can be measured with the same accuracy over the entire ranges of the instrument.

4913

Maevskaya, V.M. and Morozov, A.D. THERMOELECTRIC ANEMOMETER FOR MEASURING AIR FLOW SPEEDS. Izmeritel. Tekh., no.7:18-20, Jly.1962.

In Russian. Transl. in Meas.Tech., no.7: 556-558, Jly.1962.

A miniature portable thermoelectric anemometer ATE-1 for measuring air speeds over a wide range from 0.001 to 20 m/sec. has been developed.

4914

Usiskin, C.W. THERMOELECTRIC CONTROL IN SATELLITES. In Proceedings of the First Space Vehicle Thermal and Atmospheric Control Symposium, Wright-Patterson Air Force Base, Ohio, February 1963. 561-580, April 1963. (ASD-TDR-63-260).

The paper analyzes several common satellite component control problems and establishes the usefulness of thermoelectric control. In addition, the experiments carried out to demonstrate the feasibility of using thermoelectric modules as a thermal switch are discussed in detail.

G. Thermomagnetic Phenomena

4915

Angrist, S.W. A NERNST EFFECT POWER GENERATOR. J.Heat Transfer, 85:41-48, 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. (Nuclear Sci.Abs.,17:16187, May 31,1963).

4916

Angrist, S.W. ON THE BOUNDEDNESS OF THE DIMENSIONLESS INDEX OF PERFORMANCE OF A NERNST EFFECT GENERATOR. J.Appl.Mech., 30:291-294, June 1963.

The author, in an earlier paper, analyzed a Nernst effect generator by the usual thermodynamic methods and found that a bound of unity arises on the dimensionless quantity θ 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.

4917

Cuff, K.F. and others. THE THERMOMAGNETIC FIGURE OF MERIT AND ETtingshausen COOLING IN Bi-Sb ALLOYS. Appl.Phys.Ltr., 2:145-146, Apr.15,1963.

A large figure of merit, for a device operating in the transverse mode, is obtained in an intrinsic system which has large and approximately equal electron and hole mobilities.

4918

Davidenko, N.I. ANISOTROPY OF EVEN EFFECTS IN CRYSTALS WITH ORTHORHOMBIC AND RHOMBOHEDRAL LATTICES. Fiz.Tverdogo Tela, 4:3396-3402, Dec.1962.

In Russian. Transl. in Soviet Phys., Solid State, 4:2486-2490, June 1963.

A calculation is made of the anisotropy of the even effects in crystals with orthorhombic and rhombohedral lattices. It is shown that the anisotropy in the longitudinal Nernst-Ettingshausen thermomagnetic effect in a magnetic substance, in the temperature range below its low-temperature transformation, is described by the equation obtained for the anisotropy of the even effects in crystals with orthorhombic symmetry.

4919

El-Saden, M.R. THE NERNST GENERATOR, A SOLID-STATE, THERMOMAGNETIC, DIRECT-ENERGY CONVERTER. ASME Preprint Paper no.62-WA-26. New York, American Society of Mechanical Engineers 1962. Prepublication Copy. 9p.

The thermomagnetic and galvanomagnetic effects present some new potentialities in the field of direct conversion of heat to electrical power. A device referred to as the "Nernst generator" operating on the Nernst and Ettingshausen effects is studied. The thermodynamic performance of the device is analyzed. The results show that there exists a dimensionless grouping of the properties of the material, called the "thermomagnetic number," which governs the suitability of a material for this application. The present-day knowledge of the properties of the material, relevant to this application, are discussed. From this discussion, it appears that, contrary to the case in thermoelectric applications, intrinsic semiconductors, within a certain range of temperature, are more promising than extrinsic semiconductors. This would permit the device to operate at higher temperatures. (Nuclear Sci.Abs.,17:9101, Mar.31,1963).

4920

El-Saden, M.R. NERNST GENERATOR LOOKS GOOD FOR DIRECT-ENERGY CONVERSION. Space/Aero., 39:110, Apr.1963.

The Nernst generator looks fairly promising for converting heat directly to electric power. Basically a solid-state MHD generator, it operates on the principle that a thermal current through a conducting block in a uniform magnetic field produces a potential across the block's faces. The better the thermomagnetic properties of the block, the more efficient the conversion.

4921

Harman, T.C. and Honig, J.M. NERNST-ETTINGSHAUSEN (TRANSVERSE) ENERGY CONVERSION. Semiconductor Prod., 6:19-24, Jly.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.

4922

Lockheed Missiles and Space Co., Palo Alto, Calif.

SOLID STATE CRYOGENICS, by C.F. Kooi, and others. 15p., illus., Mar.1963. (Final Rept.) (ASD-TDR-62-1100) (Contract AF 33(616)-8490).

The prospects for cooling by means of the Ettingshausen effect were determined theoretically and experimentally. It was shown that Ettingshausen cooling is very promising in the range of 50° to 200°K. For a semimetal with equal numbers of holes and electrons and for $\mu, \nu_B \gg 1$, transport theory shows that Ettingshausen cooling can be 6 to 12 times better than Peltier cooling. Measurements on the Bi-Sb alloy system confirm this prediction. Good agreement with theory was obtained between 100° and 200°K. In the middle of the range, cooling of up to 35°K was obtained with a rectangular nonstaged cooler. Ettingshausen cooling device theory was put on a sound basis with recognition that the Ettingshausen cooler is essentially a constant electric field device, rather than a constant current density device.

4923

Louisiana State University, Department of Physics, Baton Rouge, La. EFFECT OF PRESSURE ON THE OSCILLATION'S PERIOD IN THE ETTINGSHAUSEN -NERNST EFFECT IN ZINC AT HELIUM TEMPERATURE, by R.J. Deck, C.G. Grenier, and J.M. Reynolds. 62p., Jan.1963. (Interim Tech.Rept.3) (Contract DA-ord-31-124-61-G76).

A piston and cylinder combination using solid hydrogen as a pressure transmitting medium was constructed for the purpose of studying pressure dependence of the Ettingshausen-Nernst effect and the thermoelectric power in zinc. The apparatus was designed to produce a maximum of 5,000 atmospheres of hydrostatic pressure at helium temperatures in a .25 inch diameter cylinder. The oscillatory potential was recorded as a function of magnetic field at different pressures, while pressure was being increased in steps, and also while pressure was being decreased in steps.

4924

Norwood, M.H. THEORY OF NERNST GENERATORS AND REFRIGERATORS. J.Appl.Phys.,34: 594-599, Mar.1963.

The Nernst coefficient, the Hall coefficient, the electrical resistivity,

and the Seebeck coefficient have been 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.

4925

Silverman, S.J., Carlson, R.O. and Ehrenreich, H. NERNST EFFECT IN n-TYPE GaSb. *J. Appl. Phys.*, 34:456-459, Mar. 1963.

Formulas for efficiency and coefficient of performance are derived for devices based on the Nernst and Ettingshausen effects. The equations reduce to those of Harman and Honig in the limits of small figure of merit and refrigerator current, but they do not approach the Carnot limits. To obtain a better device theory, one must solve a two-dimensional partial differential equation in which the current density is allowed to vary with position. A crude maximization procedure for the figure of merit is shown for a one-band nondegenerate semiconductor in a weak magnetic field. Experimental data indicate that $Hg_xCd_{1-x}Te$ alloys are perhaps the best materials for such devices at present.

III. THERMIONIC EMISSION

A. General Information

4926

Atomics International, Division of North American Aviation, Inc., Canoga Park, Calif. SECOND ANNUAL TECHNICAL SUMMARY REPORT FOR BASIC RESEARCH IN THERMIONIC ENERGY CONVERSION, November 1, 1961 - October 31, 1962, by C. Warner, and others. 133p., Oct. 31, 1962. (AI-7979) (Contract Nonr-3192(00)).

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 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.

4927

Chupakhin, M.S. EVAPORATION AND THERMIONIC EMISSION BY MEANS OF A THREE-FILAMENT ION SOURCE. *Zh. Analit. Khim.*, 17:665-669, 1962.

The effect of directed ion formation was

studied depending on which of the 3 filament sources the evaporation took place. The original cause for the generation of smaller or greater ion currents seems to be the evaporation of the sample from different metallic surfaces. When the surface of a W vaporizer was increased by placing on it some W powder, the intensity of the ion beam for samples of the same weight increased many times. The mechanism of the directed ion formation is discussed and the reasons for the differences between ion currents relative to the material of the vaporizer surface are considered. (*Chem. Abs.*, 58:6288, Apr. 1, 1963).

4928

Ettinger, K.W. and Moscicki, W. OBSERVATION OF THERMOELECTRONS BY MEANS OF GEIGER-MULLER COUNTERS. *Acta Phys. Polon.*, 22: 129-132, 1962.

The detection and measurement of thermo-electron currents from W and a Cu-Ni alloy are described. The metal whose thermoemission current is to be measured is used as the cathode in a G-M tube, and Ar and Ar-ethanol mixtures are used as the filler gases. Voltage pulses are applied to the cathodes, which are at 500 to 1100°K, and the currents are measured as functions of the cathode temperature and the pulse duration. (*Nuclear Sci. Abs.*, 17:3583, Feb. 15, 1963).

4929

General Electric Co., Special Purpose Nuclear Systems Operation, Atomic Products Division, Pleasanton, Calif. DEVELOPMENT OF A NUCLEAR THERMIONIC FUEL ELEMENT, September 1 - November 30, 1962. 35p., Nov. 30, 1962. (GESR-2006) (Q. Prog. Rept. 2) (Contract AT(04-3)-189).

The program includes work on materials development, converter development, and reactor and system analysis.

4930

General Electric Co., Schenectady, N.Y. EXPLORATORY ENERGY CONVERSION STUDY OF PHOTON THERMIONICS, by W.J. Kearns. 20p., illus., Nov. 1962. (Q. Tech. Prog. Rept. 1) (Rept. R-635 Q-1) (Contract AF 33(657)-9202) (AD-289 801).

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. (TAB U63-1-5:84, Mar.1,1963).

4931

General Electric Co., Syracuse, N.Y.
EXPLORATORY STATIC ENERGY CONVERSION STUDY-MULTILAYER THERMIONICS, July 1 - September 30,1962, by V.A. Russell, W. Tantraporn, and W.J. van der Griten. 41p., illus., Sept.30,1962. (Q.Tech.Prog.Rept.1) (Contract AF 33(657)-9204) (AD-289 355).

A new static heat-to-electricity conversion principle is described 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. (TAB U63-1-4:46, Feb.15,1963).

4932

General Motors Corp., Allison Division, Indianapolis, Ind.
INVESTIGATION OF THE MONOCAPILLARY THERMIONIC EMITTER AS A DUAL SOURCE OF IONS AND ELECTRONS, May 15 - August 15,1962, by D.L. Dresser and W. Laurita. 32p.,illus., Aug.15,1962. (Q.Tech.Prog.Rept.3) (Rept. EDR 2978) (Contract AF33(616)-8299) (AD-283 262).

Theoretical work is reported to describe a model of a capillary thermionic emitter in which the neutral cesium density varies from some high value at the entrance to some low value at the exit. As a consequence of this model, the plasma density, the sheath potential, and the sheath thickness vary along the capillary. From this model, electron emission is predicted and compared with experimental results obtained on a monocapillary structure. (TAB U62-4-6:109, Dec.15,1962).

4933

General Motors Corp., Allison Division, Indianapolis, Ind.
INVESTIGATION OF THE MONOCAPILLARY THERMIONIC EMITTER AS A DUAL SOURCE OF

IONS AND ELECTRONS, August 15,1962 - February 15,1963, by D.L. Dresser and W. Laurita. 120p., Feb.15,1963. (Q.Tech. Prog.Rept.4) (Contract AF33(616)-8299) (EDR-3207).

Theoretical work is reported on a random current model of the capillary emitter-in this model the ion and electron emission currents are dependent upon the atom density at the capillary exit, and the emitter temperature. A solution of the cesium flow through a multicapillary converter was obtained in order to estimate the interelectrode pressure. Experimental data on three multicapillary converters are reviewed. (Nuclear Sci. Abs.,17:16773, May 31,1963).

4934

General Motors Research Laboratories, Warren, Mich.
INVESTIGATIONS ON THE DIRECT CONVERSION OF NUCLEAR FISSION ENERGY TO ELECTRICAL ENERGY IN A PLASMA DIODE, February 1 - October 31,1962, by F.E. Jamerson, and others. 121p., Oct.31,1962. (Annual Rept.) (Contract Nonr 3109(00)).

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 in individual reports.

4935

Gingrich, J.E., Warner, C. and Weeks, C.C.
EXPERIMENTAL MEASUREMENT AND INTERPRETATION OF VOLT-AMPERE CURVES. Adv. Energy Convers., 2:325-333, Jly.-Sept.1962.

Volt-ampere curves have been obtained 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. 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.

4936

Giori, F., MacKenzie, L.A. and McKinney, E.J.
LASER-INDUCED THERMIONIC EMISSION. Appl.
Phys.Ltr.,3:25-27, Jly.15,1963.

Thermionic emission of electrons at very high emission densities was observed from a tungsten cathode when the surface was impulse-heated with a sharply focused laser light beam.

4937

Great Britain, Atomic Energy Research
Establishment, Harwell, Berkshire.
MATERIAL PROBLEMS ASSOCIATED WITH A
CATHODE OF AN IN-PILE THERMIONIC CONVERTER,
by R.J. Hill. 17p., Nov.1962. (AERE-R 4117).

The materials problems most likely to hinder rapid development of a feasible power producing in-pile thermionic direct conversion diode are reviewed. A research program is suggested which should provide answers to these problems.

4938

Hatsopoulos, G.N. and Welsh, J.A.
THERMIONISCHE KONVERTER FUER DIE
DIREKTERZEUGUNG VON ELEKTRIZITAET AUS GaS.
Gas - u Wasserfach, 103:1042-1047,
Sept.28,1962.

In German. 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. (Eng.Index, p.55, May 1963).

4939

Houston, J.M. and Webster, H.F. THERMIONIC
ENERGY CONVERSION. In Advances in
Electronics and Electron Physics, vol.17;
125-206, New York, Academic Press, 1962.

This paper surveys the state of thermionic converters as of mid-1961. These devices convert heat energy into electrical energy by utilizing the thermionic emission of electrons. In the last five years the power output and efficiency of such devices have reached around 5 watt/cm² at 15% efficiency.

4940

Jarvis, T. A PRELIMINARY ANALYSIS OF THE
ARC MODE CESIUM CONVERTER. Adv.Energy
Convers., 2:437-446, Jly.-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.

4941

Kaplan, Coleman. MATERIALS FOR THERMIONIC
CONVERTERS. Materials Science and
Technology for Advanced Applications.,
Englewood Cliffs, N.J., p.453-466,
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. (Nuclear Sci.Abs.,17:6553, Mar.15,1963).

4942

Kuhn, E. NOISE IN THERMIONIC CONVERTERS.

Adv. Energy Convers., 2:637-638,
Jly.-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; (c) the level of space charge limited noise; can give indications of activity and patchiness at different times of emitter life. Using these characteristics shot noise 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.

4943

Martini, W.R. and McKisson, R.L. PROGRESS IN THE DEVELOPMENT OF FLAME-HEATED THERMIONIC POWER SOURCES. Adv. Energy Convers., 3: 123-136, 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. ID molybdenum thimble with an 34 cm² 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 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.

4944

National Aeronautics and Space Administration,

Washington, D.C.

EXPERIMENTAL INVESTIGATION OF CHEMICAL REGENERATION OF SURFACES IN SIMULATED THERMIONIC DIODES, by H.F. Butze and A.L. Smith. 20p., Jly. 1963. (NASA Tech. Note 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.

4945

Slivka, M.J. A STUDY OF CESIUM VAPOR ATTACK ON THERMIONIC CONVERTER CONSTRUCTION MATERIALS. Adv. Energy Convers., 3: 157-166, Jan.-Mar. 1963.

Results are reported on a study of 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. The main objectives in this study were two-fold: (1) to obtain data on which to select attack resistant materials for use in current thermionic converter work, (2) to determine where concerted effort was needed and should be placed in more extensive attack rate experiments to follow.

4946

SYMPOSIUM ON THERMIONIC POWER CONVERSION, SESSIONS I-III, COLORADO SPRINGS, COLORADO, 1962. Adv. Energy Convers., 2: Jly.-Sept. 1962.

Papers presented can be found under the following authors: Weeks, C.C., Gingrich, J.E., Wilson, V.C., Lawrence, J., Ogle, H.M., Ingold, J.H., Garvin, H.L., Haas, G.A., Blue, E., McIntyre, R.G., Leffert, C.B., Jarvis, T., Talaat, M.E., Warner, C., Nottingham, W.B., Steele, H.L., Stenzel, W., Bullis, R.H., Gibbons, M.D., Rasor, N.S., Kitrilakis, Sotiris., Hernqvist, K.G., Richards, H.K., Devin, B., Zollweg, R.J., Kuhn, E., and Bloss, W.

4947

Tower, L.K. ANALYSES OF THE CHEMICAL REGENERATION OF SUBLIMATING THERMIONIC COMPONENTS. Adv. Energy Convers., 3: 185-198, Jan.-Mar. 1963.

This paper discusses the process of chemical regeneration of hot metallic

surfaces, which may find application in very high temperature thermionic devices. 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. The paper consists of an analysis of chemical regeneration under conditions of free molecule flow (Knudsen conditions) in which particles are assumed not to interact in the interspace. Partial or complete equilibration is assumed at the walls, the degree of equilibration being expressed by a recombination coefficient, γ .

4948

Weinberg, A.F. and Yang, L. INTERDIFFUSION BETWEEN URANIUM-BEARING REACTOR FUELS AND REFRACTORY-METAL THERMIONIC EMITTERS. Adv. Energy Convers., 3:101-111, 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, UC₂, UC-ZrC, and UO₂, are studied in combination with tungsten, molybdenum, tantalum, and niobium over the temperature range 1200°-2000°C. A technique has been developed for simultaneously studying the interdiffusion between a given uranium-bearing material and each of the four refractory metals.

4949

Westinghouse Electric Corp., Pittsburgh, Pa. HEAT DIODE CONVERTER, May 1 - July 31, 1962. Iv., illus., Aug.20, 1962. (Contract AF 33(616)-8262) (AD-287 519).

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. (TAB U63-1-3: 20, Feb.1, 1963).

4950

Zollweg, R.J. and Gottlieb, M. RADIO-FREQUENCY OSCILLATIONS IN THERMIONIC DIODES. Inst. Elec. & Electr. Engrs., Proc., 51:754-759, 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.

B. Theory

4951

Blue, E., Ingold, J.H. and Ozeroff, W.J.

DIFFUSION OF ELECTRONS AND IONS IN A NEUTRAL GAS. Adv. Energy Convers., 2: 395-403, Jly.-Sept. 1962.

The migration of electrons and ions in a scattering gas is described in terms of the diffusion approximation to transport theory. A discussion of the range of validity of the diffusion theory and the conditions required for constant transport coefficients is presented. The theory is used to analyse a planar high pressure thermionic converter. It is assumed that the electrons and ions originate from the surface of electrodes as a result of thermionic emission and surface ionization respectively.

4952

California University, Lawrence Radiation Laboratory, Livermore, Calif. THE EFFECT OF BAND STRUCTURE ON THERMIONIC EMISSION, by W.E. Spicer. 21p., Mar.13, 1962. (UCRL-6820) (Contract W-7405-eng-48).

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 $A=120 \text{ amp/cm}^2 (\text{°K})^2$; 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. (Nuclear Sci. Abs., 17: 11336, Apr.15, 1963).

4953

Hatsopoulos, G.N. TRANSPORT EFFECTS IN CESIUM THERMIONIC CONVERTERS. Inst. Elec. & Electr. Engrs. Proc., 51:725-733, 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 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.

1. Emission Phenomena

4954

Aerospace Corp., El Segundo, Calif.

EFFECT OF SCHOTTKY EMISSION ON THERMIONIC CONVERTER CURRENTS IN IGNITED MODE, by G.L. Johnston. Aug.15,1962. (TDR.69(2220-50)TR-3, DCAS TDR 62-149) (AD-288 092).

A theoretical model of a cesium thermionic converter, operating in the ignited mode, is investigated in order 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 integration employs expressions for charged particle densities derived from the Bohm analysis of a stable positive ion sheath. The interelectrode plasma is considered to be uniform. Simultaneous solution of relationships expressing (1) continuity of electron flow, (2) conservation of energy for electrons, and (3) balance of ion production and loss mechanisms in the plasma with the sheath field relationship, permits generation of current-voltage characteristics. It is concluded that the Schottky effect contributes substantially to the production of observed high currents. (Astron.Info.Abs., 6:61,566, Nov.1962).

4955

Buyers, A.G. CALCULATION OF WORK FUNCTIONS FOR SURFACES COMPOSED OF IONIC CRYSTALS. J.Phys. & Chem.Solids, 24:431-435, Mar.1963.

Values for the work functions of thermionic emitter surfaces composed of alkaline earth oxides have been approximated by means of a closed energy balance cycle which is a modification of the Born-Haber Method ordinarily used to estimate lattice energies or electron affinities. Comparison of calculated surface potentials with reported work functions for alkaline earth oxides disclosed reasonable agreement. The modified Born-Haber cycle includes, among other terms, the lattice energy, the heat

of sublimation, and the molecular electron affinity of the gaseous, neutral, diatomic molecules under consideration. Justification for the incorporation of these quantities into the energy balance, together with the general implications of this method of estimating work functions, is discussed.

4956

Galagali, R.J. THERMIONIC ANALOGUE OF JOSHI EFFECT IN MAZE TYPE COUNTER IN ARGON. Phys.Soc.Japan J., 18:825-830, June 1963.

Experiments are carried out to explain the occurrence of Joshi Effect in a "free electron" gas such as argon. The influence of increased thermionic emission on the discharge current is also studied.

4957

General Motors Research Laboratories, Warren, Mich.

DEVELOPMENT OF BARIUM OXIDE-URANIUM OXIDE - TUNGSTEN AND BARIUM OXIDE - URANIUM OXIDE - RHENIUM EMITTERS FOR USE IN NUCLEAR HEATED THERMIONIC CONVERTERS, June 1,1962 - June 30,1963, by F.E. Gifford and R.F. Hill. 78p., Jly.1,1963. (Annual Rept.) (Contract Nonr 3870(00)).

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 containing 60 m/o BaO and 40 m/o 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.

4958

Gibbons, M.D. EXPERIMENTAL STUDIES OF THE EMISSION AND DISCHARGE CHARACTERISTICS OF THE Ta-Cs SYSTEM. Adv.Energy Convers., 2:527-543, Jly.-Sept.1962.

This paper describes emission and discharge measurements made on a Cs-Ta emitter in a tube with parallel electrode geometry and with an adjustable emitter-collector spacing. 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.

4959

Haas, G.A. ACTIVATION PHENOMENA IN URANIUM-BEARING EMITTERS. *Adv. Energy Convers.*, 2: 389-390, Jly.-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.

4960

Hansen, L.A. and Rasor, N.S. EVALUATION OF METAL EMITTERS FOR THERMIONIC CONVERTERS. (Met.Soc.Conf.) *Metallurgy of Semiconductor Materials*, 15:381-390, 1962.

A review of the factors affecting the operation of emitters in thermionic energy-converters. It is considered that refractory metals using adsorbed Cs offer considerable advantages. (*Met.Abs.*, 30:586, Apr. 1963).

4961

Hernqvist, K.G. ANALYSIS OF THE ARC MODE OPERATION OF THE CESIUM VAPOR THERMIONIC ENERGY CONVERTER. *Inst. Elec. & Electr. Engrs. Proc.*, 51:748-754, 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.

4962

Kaganovich, M.V. and Makarova, R.A. EMISSION CHARACTERISTICS OF THORIUM AND YTTRIUM

OXIDES ON SUBSTRATES OF RHENIUM AND NIOBIUM. *Radiotekh. i Elektronika*, 7: 1579-1584, Sept. 1962.

In Russian: Transl. in *Radio Eng. & Electron. Phys. (USSR)*, 7:1475-1479, Sept. 1962.

The thermal activation, the thermionic and secondary emission properties, and the poisoning of cathodes of thorium and yttrium oxides on niobium and rhenium substrates has been investigated; the data are compared with the data obtained by using cathodes on tantalum and molybdenum substrates.

4963

Los Alamos Scientific Laboratory, N. Mexico. THERMIONIC EMISSION CHARACTERISTICS OF CERTAIN ACTINIDE COMPOUNDS, by F.P. Cranston, Jr. and J.W. Barger. 17p., 1960. (Contract W-7405-eng-36) (LADC-5128).

Thermionic emission constants of UC, UMoC₂, Pu₂O₃, Pu₂O₃ + PuC, UWC₂, and Np₂C₃ were measured. A cylindrical diode geometry was used. The emitter consisted of a 0.030-in. W wire coated electrochemically with the desired substance. (*Nuclear Sci. Abs.*, 17: 16783, May 31, 1963).

4964

Laubenstein, R.A. and others. SOURCES OF POSITIVE IONS FOR SPACE CHARGE NEUTRALIZATION AT LOW TEMPERATURES. *Adv. Energy Convers.*, 3:351-361, Jan.-Mar. 1963.

In order to operate a thermionic power converter from a heat source which utilizes fossil fuels burned in air, it is desired to have a converter which operates at a temperature of 1200°C or lower. At these low temperatures, it is difficult to obtain an adequate source of positive ions for space charge neutralization. Surface ionization of cesium, which is the most common source of positive ions in a thermionic converter, is not effective at these low temperatures. Two methods for providing positive ions have been investigated experimentally: (1) The thermionic emission of positive ions from solid compounds or mixtures of compounds, and (2) The application of repeated short pulses of electric power to the converter to ionize the cesium vapor in the inter-electrode space.

4965

Matskevich, T.L., Kazantsev, A.P. and Krachino, T.V. THE THERMIONIC EMISSION OF HfB₂, HfC, HfO₂, VC AND A SOLID SOLUTION OF (UC)₁(ZrC)₄. *Zhurn. Tekh. Fiz.*, 32:1266-1274, Oct. 1962.

In Russian. Transl. in *Sov. Phys., Tech. Phys.*, 7:934-940, Apr. 1963.

This article gives the work functions of HfC, HfO₂, VC and (UC)₁(ZrC)₄, calculated from the total current extrapolated to zero field. We have shown how the work function of these substances changes with increase in the temperature. For HfB₂ and HfC we give data for emission in the presence of cesium.

4966

McIntyre, R.G. ANALYSIS AND NUMERICAL SOLUTIONS TO THE SPACE-CHARGE POTENTIAL PROBLEM IN LOW-PRESSURE THERMIONIC CONVERTERS. Adv.Energy Convers., 2:405-416, Jly.-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.

4967

McIntyre, R.G. EFFECT OF ANODE EMISSION OF ELECTRONS ON SPACE-CHARGE THEORY OF THE PLASMA THERMIONIC CONVERTER. Inst.Elec. & Electr.Engrs.Proc., 51:760-768, 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 by P.L. Auer and by the author reporting first integrations of Poisson's equation without anode emission appears as a special case in this paper. In addition, in each of the ten first-order differential equations there appears a term giving the contribution of anode emission.

4968

Minnesota University, Institute of Technology, Minneapolis, Minn.
STUDIES OF PRIMARY ELECTRON SOURCES, December 1, 1961 - March 1, 1962, by D.E. Anderson. 68p., illus., Sept.1962.

(SR 4) (AFCRL-63-5) (Contract AF 19 (604)-8381).

Radiotracer studies of the reaction of (BaSr)O cathodes with partial pressure of H₂ are described. The operation of oxide cathodes under heavy pulse current drain shows that the slump in emission is a consequence of anode contaminants and that impulse heating occurs in the absence of anode effects. An analysis of impulse heating is presented. Photoelectric studies of oxide cathodes and thickness dependence are described. Studies of Al-Al₂O₃-M and Ta-Ta₂O₅-M thin film tunnel emission devices are described. An upper bound on the ratio of emission current to tunnel current of 1.37×10^{-11} was established for Ta-Ta₂O₅-M systems. An improved measuring technique is described for studies of enhanced electron emission from superconducting field emitters.

4969

Missman, R.A. and Gehman, B.L. EXPERIMENTAL STUDIES OF LOW-WORK-FUNCTION COLLECTORS. Adv.Energy Convers., 3:229-233, Jan.-Mar. 1963.

Thermionic emission from a cesium-covered molybdenum surface is increased by the introduction of hydrogen. Emission in the presence of cesium hydride is about two orders of magnitude larger at 500°K than is obtained with cesium alone. The lower work function collecting surface in a thermionic converter if means can be found to retain the required amounts of cesium, cesium hydride, and hydrogen under operating conditions.

4970

Myatt, J. THERMIONIC EMISSION FROM ZIRCONIUM CARBIDE WITH CAESIUM VAPOUR PRESENT. Adv.Energy Convers., 3:279-285, Jan.-Mar.1963.

Measurements of electron emission from ZrC, both under high vacuum conditions and in an atmosphere of caesium vapour, are presented. Under vacuum conditions emission constants were determined.

4971

Ranken, W.A. and others. EXPERIMENTAL STUDIES OF Cs-CsF-Mo AND Cs-CsF-W PLASMA DIODE EMITTERS. Adv.Energy Convers., 3:235-244, Jan.Mar.1963.

Measurements are presented which demonstrate that the electron emission of molybdenum in cesium vapor is greatly enhanced by the addition of cesium fluoride. This enhancement amounts to a factor of about 340 at the maxima of the respective Langmuir S-curves for a cesium pressure of 10^{-2} mm Hg.

4972

Rasor, N.S. THE CESIUM VAPOR THERMIONIC CONVERTER: I-LIMITATIONS IMPOSED BY EMISSION PROCESSES. Adv.Energy Convers., 2:545-567, Jly.-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 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.

4973

Rasor, N.S., Hatsopoulos, G.N. and Kitrilakis, S. THE CESIUM VAPOR THERMIONIC CONVERTER: II. PATCH AND TRANSPORT EFFECTS. Adv.Energy Convers., 2:569-581, Jly.-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 semi-quantitative 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.

4974

Rasor, N.S. EMISSION PHYSICS OF THE THERMIONIC ENERGY CONVERTER. Inst.Elec.& Electr. Engrs.Proc., 51:733-747, May 1963.

Emission processes establish the upper limit of the performance obtainable in the thermionic converter. This paper briefly introduces the basic factors which must be considered to achieve this limit and outlines recent developments in the related technology. 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.

4975

Scherbakov, G.P. and Skol'skaya, I.L. EXPERIMENTAL INVESTIGATION OF THE ENERGY DISTRIBUTION OF FIELD-EMITTER ELECTRONS FROM CdS SINGLE CRYSTALS. Fiz.Tverdogo Tela, 4:3526-3536, Dec.1962.

In Russian. Transl. in Soviet Phys., Solid State, 4:2581-2588, June 1963.

Investigation of the energy spectra of field-emitted electrons and thermionic electrons in the case of tungsten has demonstrated the suitability of the experimental apparatus employed for investigating the energy spectra of field-emitted electrons in the case of semiconductors. It is shown that increase in the internal field in the emitter leads to heating of the electron gas, and carrier generation commences when the total width of the field-emitted energy spectrum approximately coincides with the energy gap in CdS. Increase in the temperature of the emitter leads to a broadening of the energy spectrum and to a shift of the distribution maximum in the direction of higher energy electrons.

4976

Surplice, N.A. and Jones, R.P. THE THERMOELECTRIC POWER OF OXIDE CATHODES ON PLATINUM CORES. Brit.J.Appl.Phys., 14: 444-448, Jly.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 degc⁻¹ at low temperatures, (ii) thermoelectric power increasing rapidly from 180 to 300°C, (iii) constant at more than 2 mv degc⁻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 thermo-electric 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.

4977

Texas Instruments, Inc., Dallas, Texas.
BASIC RESEARCH IN THERMIONICS. Part I. CESIUM PERMEATION THROUGH TANTALUM, November 1, 1961 - October 31, 1962, by R.A. Chapman and others. 73p., Jan. 1963. (SR 1) (Contract Nonr-3705(00)).

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.

4978

Thermo Electron Engineering Corp., Waltham, Mass.
THERMIONIC EMITTER MATERIALS RESEARCH PROGRAM, July 1 - December 31, 1962, by S.S. Kitrilakis, N.S. Rasor and L. van Someren. 62p., Dec. 31, 1962. (Rept. 20-63) (TEE 4015-3) (Semi-Annual Tech. Summary Rept.) (Contract Nonr-3563(00)).

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. In addition to the above emitter surface studies, work has continued on the current-voltage characteristics of converters.

4979

Zollweg, R.J. ELECTRON AND ION EMISSION FROM CESIUM-COATED REFRACTORY METALS IN ELECTRIC

FIELDS. Appl. Phys. Ltr., 2:27-29, Jan. 15, 1963.

Attention is called to the dependence of cesium coverage of refractory metal emitters on electric field as well as upon cesium arrival rate (pressure) and upon emitter temperature.

2. Related Phenomena

4980

Daly, G.J. and Gumnick, J.L. EXPERIMENTAL EVIDENCE FOR CYCLIC AND SPONTANEOUS MIGRATION OF CESIUM ON RHENIUM AND TUNGSTEN. Adv. Energy Convers., 3:223-227, Jan.-Mar. 1963.

Studies have been made of the effect of cesium on the field emission characteristics of rhenium and tungsten. These studies were made using a field emission microscope. Cesium was deposited on the emitters after measurements were made on them in their clean state. The work function of each changed from that associated with the clean metal to that of metallic cesium when several monolayers of cesium were allowed to contaminate the emitting surface. For both rhenium and tungsten there was no radical change in the symmetry of the emission pattern due to cesium adsorption. There was, however, evidence for build up at low work function planes and at plane edges. When voltages in the range of 1500-3800 V were applied, a spontaneous initial migration of cesium was observed starting at the low work function regions of the emitter. The minimum starting voltage for this migration was lower for tungsten than for rhenium and was dependent upon cesium pressure in the tube. The migration was very roughly circular moving toward the edge of the emission pattern. After a time lapse of several seconds, migration proceeded from the pattern periphery back toward the center. The effect was like a contracting ring of brightness which stopped at a certain minimum size then reversed moving again to the periphery of the pattern. The expansion and contraction of this ring repeated itself in cycles with periods of the order of ten seconds. Associated with this migration were fluctuations of emission current at constant voltage ranging from two to ten times the base current on which they were superimposed. The shapes of current versus time wave forms of the cyclic activity were almost identical over periods of several minutes but showed slight continuous changes over longer periods of time. Motion picture studies of these effects have been taken and will be shown. A proposed mechanism for the cyclic migration will be described.

4981

Gottlieb, Milton. and Zollweg, R.J. THERMAL CONDUCTIVITY OF CESIUM VAPOR. Adv. Energy Convers., 3:37-48, Jan.-Mar.1963.

The thermal conductivity of cesium vapor has been measured as a function of pressure at spacings which correspond to a range from a fraction of a cesium mean free path to several mean free paths. The gas conduction was measured as the increase in power necessary to maintain a hot ribbon filament at a fixed temperature with increasing cesium pressure. A differential measurement with two filaments of different lengths was used to cancel end errors, so that a high degree of accuracy was achieved. The thermal conductivity is independent of spacing at low cesium pressures and is a constant, independent of pressure at high pressure, as expected from kinetic theory. A value of 1.7×10^{-5} W/cm²-°K was obtained for this high pressure limit.

4982

ITT Federal Laboratories, Nutley, N.J. POWER CONVERSION BY ELECTRON CONVECTION, by S.R. Hoh, and W.L. Harries. 32p., illus., Oct.1962. (ASD-TDR-62-693) (Final Rept.) (Contract AF33(616)-7941) (AD-291683).

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.

4983

Kitrilakis, S. and Meeker, M. EXPERIMENTAL DETERMINATION OF THE HEAT CONDUCTION OF CESIUM GAS. Adv. Energy Convers., 3:59-68, Jan.-Mar.1963.

The heat conduction of a cesium gas in a thermionic diode was found by measuring under open circuit conditions the difference in heat flux rejected from the diode collector in the presence and absence of cesium vapor. Different emitter materials and emitter temperatures were employed, as well as different spacings.

4984

Martini, W.R. THEORETICAL CALCULATION OF THE THERMAL CONDUCTIVITY OF CESIUM VAPOR AT THERMIONIC TEMPERATURES. Adv. Energy Convers., 3:49-58, Jan.-Mar.1963.

The heat conducted between the emitter and

the collector of a thermionic diode by cesium vapor is an important fraction of the total heat transport. Equations were developed for the thermal conductivity of cesium vapor based upon the kinetic theory of gases for high, very low and intermediate pressures. In order to apply these equations one must know from experiment the molecular diameter and the accommodation coefficient. The possible ranges for these quantities are given. Since at the conditions existing in a thermionic diode cesium is a monatomic gas, the possibility of additional heat transport in the very low pressure (Knudsen) region by association to Cs₂ at the cold surface, or by emission of excited atoms or ions from the hot surface, was investigated. In most cases the thermal effect of association and of excited atom or ion emission was found to be very small. A simple procedure is described for measuring the thermal conductivity of cesium vapor in a functioning thermionic diode. Data obtained by the author are compared with kinetic theory and with results from other laboratories. Agreement between experiments and theory is within an order of magnitude and shows that the phenomenon of heat transport through cesium gas requires additional investigation.

4985

Zollweg, R.J. ELECTRON REFLECTION FROM CESIUM COATED SURFACES. Adv. Energy Convers., 2:631-636, Jly.-Sept.1962.

The a.c. retarding potential difference technique has been applied to the study of the reflection of low energy electrons at surfaces partially coated with cesium. The technique is described and results for polycrystalline copper coated with cesium are given. For primary electron energy of 0.5 eV about 20 per cent of the incident electrons are reflected while at 1.0eV about 30 per cent are reflected.

C. Electrode Properties

4986

Aracon Laboratories, Concord, Mass. STUDY OF MATERIALS FOR THERMIONIC CONVERTERS, by H. Homonoff, and S. Ruby. 83p., Dec.31,1962. (Summary Rept. 2) (ARA-T-9159-2) (Contract Nonr-3385(00)).

A summary is presented in this second report of the theoretical study concerning materials for use in thermionic converters. Of those properties required for satisfactory long-lived performance of a material as either the emitter or collector; it was considered that the work function was most critical. Factors relating to the

crystalline structure, surface, and adsorption phenomena, and the electronic nature of interatomic interactions, are discussed for the following classes of materials. A. Metals, B. Ionic Solids, C. Semiconductors.

4987

Armour Research Foundation, Chicago, Ill.
STRESS DEPENDENT INTERACTIONS BETWEEN CESIUM AND OTHER MATERIALS, February 15, 1962 - February 15, 1963, by D.W. Levinson. 61p., illus., Mar.22,1963. (Summary Rept.) (ARF-B215-12) (Contract Nonr 3441(00)).

Metals and alloys germane to thermionic energy converter usage have been 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.

4988

Atomics International, Canoga Park, Calif.
UNIFORM WORK FUNCTION CATHODE STUDIES FOR THERMIONIC CONVERTERS, October 12,1962 - January 12,1963, by M.N. Huberman. 33p., illus., Jan.1963. (Q.Rept.2) (Contract AF 33(657)-8726) (AD-296 458).

Chemical vapor deposition techniques are being studied as a possible means of producing nonplanar 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. (TAB U63-2-4:23, May 15,1963).

4989

Bainton, K.F. THERMIONIC PROPERTIES OF UC, UC-ZrC AND Ta. Adv.Energy Convers., 3: 273-277, Jan.-Mar.1963.

Using planar diode geometry and long pulse measuring techniques, a study has been 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.

4990

Bondarenko, B.V. and Yermakov, S.V.
THERMIONIC PROPERTIES OF METAL CARBIDES OF GROUPS IV AND V. Radio Eng. & Electron.(USSR), no.12:1953-1956, Dec.1962.

The authors investigated the thermionic emission of carbides of metals of groups IV and V over a wide range of temperatures.

4991

Branstetter, J.R. SPECTRAL EMISSIVITIES OF ELECTRODE MATERIALS. Adv.Energy Convers., 3:295-303, Jan.-Mar.1963.

Many of the high temperature metals and carbides being considered as electrodes in thermionic converters 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 25 per cent greater than the gray-body flux when both computational procedures were based on the same emissivity data. The present paper discusses current progress towards obtaining spectral emissivity data on other materials (such as tantalum); the amount of emissivity data required for any given material in order to calculate summed net heat flows having good accuracy; the extent to which simple equations can be made to fit these heat flow data.

4992

Denver University, Denver Research Institute, Denver, Colo.
INVESTIGATION OF THE CHARACTERISTICS OF INTERMETALLIC COMPOUNDS AS THERMIONIC EMITTERS, November 1,1961 - October 31, 1962, by C.B. Magee, and others. 43p., Dec.31,1962. (DRI 2079) (Annual Tech. Summary Rept.1) (Contract Nonr 3361(01)).

Equipment has been designed and fabricated for the determination of evaporation rates of intermetallic compounds by means of the Langmuir free evaporation technique. Evaporation rate data have been obtained in the temperature range from 900 to 1200°C for metallic beryllium and for ZrBe₁₃, NbBe₁₂ and Nb₂Be₁₇.

4993

DeSteele, J.G. THERMIONIC EMISSION CHARACTERISTICS OF RHENIUM WITH LOW CESIUM COVERAGE. Appl.Phys.Ltr.,2:25-27, Jan.15,1963.

The purpose of this Letter is to report

the appearance of a discontinuity in field-enhanced emission.

4994

Devin, B. and others. STUDY OF THERMO-EMISSIVE PROPERTIES OF URANIUM CARBIDES BY AN EMISSION ELECTRON MICROSCOPE. Adv. Energy Convers., 3:287-294, 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.: O₂, UO₂) and to observe the evolution of grains boundaries during heating.

4995

Druzhinin, A.V. ELECTRON OPTICAL INVESTIGATION OF EFFECTIVE THERMIONIC CATHODES. Radiotekh. i Elektron., 7:1446-1453, Sept.1962.

In Russian. Transl. in Radio Eng. & Electron.Phys.(USSR), 7:1446-1453, Sept.1962.

With the aid of a high-vacuum emission microscope, an investigation was made of the distribution of emission and work functions over the emission surface of an L cathode of pressed tungsten impregnated with aluminates.

4996

Dyubua, B.Ch. and Popov, B.N. METALS WITH HIGH OXYGEN STABILITY OF THERMIONIC EMISSION AGAINST THE ACTION OF OXYGEN. Radiotekh. i Elektron., 7:1556-1565, Sept.1962.

In Russian. Transl. in Radio Eng. & Electron.Phys.(USSR), 7:1454-1458, Sept.1962.

An experimental investigation was made of the stability of thermionic emission of pure metals and those coated with an absorbed film of barium relative to the action of oxygen. The investigated metals, rhodium, iridium, platinum, rhenium, titanium, zirconium and hafnium in comparison with tungsten possess enhanced stability against the action of oxygen. A theoretical treatment of the problem of the increase in stability of emission of thermal cathodes against the action of oxygen was undertaken.

4997

Dyubua, B.Ch. and others. THERMIONIC EMISSION OF W-Ti AND W-Hf ALLOYS AND ITS DEPENDENCE ON OXYGEN PRESSURE.

Radiotekh. i Elektron., 7:1566-1574, Sept.1962.

In Russian. Transl. in Radio Eng. & Electron.Phys.(USSR), 7:1463-1470, Sept.1962.

The dependence of the work function of W-Ti and alloys on their composition is examined. It is shown that the work function of the solid solutions is less than that of pure metals. The solid solutions and chemical compounds should be considered as new emitters whose properties differ from those of pure metals. The influence of oxygen on the emission of alloys is considered.

4998

Elcombe, A.D. and Wright, D.A. URANIUM CARBIDE AS A THERMIONIC EMITTER. Adv. Energy Convers., 3:199-202, Jan.-Mar.1963.

The properties of uranium carbide as a thermionic emitter have been 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/cm², the emission fell to half this value, leading to a state with $\phi=4.6$ eV, A greater than 105. It is probable therefore that there is little if any uranium carbide remaining on the cathode at this stage.

4999

Electro-Optical Systems, Inc., Pasadena, Calif. RESEARCH PROGRAM RELATED TO VAPOR THERMIONIC CONVERTERS FOR NUCLEAR APPLICATION, September 27 - December 27, 1962, by A.O. Jensen. 40p., Jan.16,1963. (Rept.3410-Q-1) (Q.Prog.Rept.) (Contract NAS 3-2529).

The major objective of this research program is to study the effects of long time at temperature on the surface crystal structure of poly-crystalline 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 applications. The investigations are primarily limited to molybdenum and/or vapor deposited coatings on molybdenum as a starting point.

5000

Fogel', Ya.M., Rekova, L.P. and Kolot, V.Ya.
THE THERMIONIC EMISSION OF METALS IN AN
ATMOSPHERE OF VARIOUS GASES. Zhurn.Tekh.
Fiz., 32:1259-1265, Oct.1962.

In Russian. Transl. in Sov.Phys.,Tech.Phys.,
7:929-933, Apr.1963.

The effect of various gases (O₂, H₂, CCl₄, NH₃, air) on thermionic emission of nickel and platinum was studied. Experiments on the action of CCl₄ vapors 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 evacuating the 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 behavior of the total thermionic emission current and individual components of 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.

5001

Ford Instrument Co., Long Island City, N.Y.
THERMIONIC ENERGY CONVERTERS. EMITTER
MATERIALS STUDY, by M. Silverberg, and
L.L. Haring. 73p., illus., Dec.31,1962.
(Final Tech.Rept.) (Contract Nonr-3696(00)).

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.

5002

Garvin, H.L. RESEARCH ON CESIUM-VAPOR CELLS
EMPLOYING CARBIDE CATHODES. Adv.Energy
Convers.,2:375-387, Jly.-Sept.1962.

This paper reports the status of a research program 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.

5003

General Atomic, San Diego, Calif.
CARBIDE CATHODE STUDIES PHYSICAL AND
CHEMICAL REDEPOSITION, by L. Yang, and
others. 42p., Jan.30,1963. (GA-3642)
(Contract NAS 3-2301).

The purpose of the work was to investigate the possibility of utilizing physical and chemical methods for reducing the vaporization loss of UC-ZrC cathodes in a thermionic cell. The physical method consisted of the proper selection of anode temperature, anode material, and interelectrode spacing so that the condensation of the vapor of the cathode materials on the anode would be reduced or suppressed. The chemical method involved the use of chemical additives to transport the vaporized materials back to the cathode.

5004

General Atomic, San Diego, Calif.
RESEARCH ON CESIUM-VAPOR CELLS EMPLOYING
CARBIDE EMITTERS, February 1 - October 31,
1962, by G. Cheney and F. Carpenter. 37p.,
illus., Oct.1962. (GA-3593) (Tech.
Summary Rept.) (Contract Nonr-3193(00)).

This report describes the status of a research program, to study the performance of cesium-vapor thermionic cells employing carbide emitters. It has been established that emission poisoning can result when a UC-ZrC emitter is exposed to air after being heated to a high temperature. Also, the thermionic emission of UC-ZrC emitters was found to be independent of composition; however emitters with a low percentage of UC are more easily poisoned. Data taken during the operation of the Mark I-D cell show that cesium vapor causes a substantial modification of the thermionic work function of a carbide.

5005

General Electric Co., Research Laboratory,
Schenectady, N.Y.
THERMIONIC EMISSION FROM METAL CRYSTALS IN
ALKALI METAL VAPORS, by H.F. Webster, and
P.L. Read. 54p., illus., May 1963
(SR 2) (AFCL-63-451) (Contract
AF 19(604)-8424).

Thermionic emission microscopes have been used to evaluate the emission density from tungsten, molybdenum, tantalum, niobium, nickel, rhenium, and niobium carbide in cesium, rubidium, and potassium vapors as a function of alkali vapor pressure, emitter temperature, and

emitter crystal face. It was found that when the emitter surface had less than a monolayer coverage of alkali metal, it was the atomically closest packed plane of the emitter which yielded the highest thermionic emission density. The effects of surface contaminants were studied and evidence was obtained suggesting that the high work function of the 112 plane of tungsten and molybdenum may be caused by a contaminant.

5006

General Electric Co., Vallecitos Atomic Laboratory, Pleasanton, Calif.
TECHNICAL SUMMARY REPORT. THERMIONIC EMITTER MATERIAL PROPERTIES, September 15, 1961 - September 15, 1962, by L.N. Grossman and others. 208p., Oct.15,1962. (GEST-2009) (Contract NObs-86289).

To meet the needs of nuclear thermionic applications, fuel-emitter materials must possess a combination of specific chemical, nuclear, physical, and mechanical properties. Uranium and thorium-bearing carbides and two selected rare earth hexaborides, EuB_6 and YB_6 , have been studied to establish some degree of quantitative knowledge of these materials and the properties most likely to be employed in thermionic applications.

5007

General Telephone and Electronics Laboratories, Inc., Bayside, N.Y.
STUDIES OF ELECTRON TUBE MATERIALS AND THERMIONIC EMISSION PROCESSES, July 1, - September 30, 1962, by J.V. Florio, and T.G. Polanyi. 17p., Sept.30,1962. (TR 62-704-104-204-208.21, SR 10) (AFCRL-62-905) (Contract AF19(604)-7286).

One phase of this contract has been thermionic emission microscopy of cathodes. In order to gain new insights into thermionic emission mechanisms and phenomena, and to verify existing hypotheses on various factors influencing thermionic emission, including materials, processes, thermal treatment, etc., a systematic study of cathodes has been made by means of an emission microscope that incorporates many of the advances in electron optics and cathode-ray tube technology of the past twenty years.

5008

Hill, R.F. and Keller, D.L. THE DEVELOPMENT OF EMITTER MATERIALS FOR USE IN THE NOBLE GAS PLASMA DIODE. Adv. Energy Convers., 3: 113-121, 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 have been 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.

5009

Hopkins, B.J., Ross, K.J. and Blott, B.H.
WORK FUNCTION MEASUREMENTS IN EXPERIMENTAL TUBES CONTAINING CATHODES OF URANIUM AND ZIRCONIUM CARBIDES. Adv. Energy Convers., 3:265-271, Jan.-Mar.1963.

Work function measurements are reported for carburized tantalum cathodes coated electrochemically with uranium and zirconium carbides. Thermionic methods for the determination of work function have been used together with the Zisman modification of the Kelvin technique. The poor agreement found between the two sets of results is thought to indicate that thermionic emission takes place from only a fraction of the total cathode area. Work function measurements have also been made on the thin films that evaporate from these cathodes during their operation at high temperatures on to fixed anodes. When the cathode is uranium carbide, our measurements can be interpreted in terms of an evaporated film of uranium metal and uranium monoxide on the anode surface. All of this work has been performed under ultra-high vacuum conditions.

5010

Ingold, J.H., Blue, E. and Ozeroff, W.J.
THERMIONIC CONVERTER EXPERIMENTS. Adv. Energy Convers., 2:363-373, Jly.-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 A/cm²deg² 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/cm² was obtained for a planar Cs-on-Ta converter at an emitter temperature of 2250°K and a collector temperature of 1725°K.

5011

Kaznoff, A.I., Hoyt, E.W. and Grossman, L.N. PHYSICOCHEMICAL PROPERTIES OF BORIDE THERMIONIC CATHODE MATERIALS. Adv.Energy Convers.,3:167-173, 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. It is the object of this paper to discuss the materials problems encountered in working with these emitter materials. The materials studied were YB₆ and EuB₆, 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. 1. Synthesis of the hexaborides. 2. Fabrication of the hexaborides. 3. Bonding of the hexaborides to refractory metal substrates. 4. Sublimation behavior at high temperatures and decomposition products. 5. Compatibility of the hexaborides with cesium. 6. Summary of physicochemical properties of YB₆ and EuB₆.

5012

Kennedy, A.J. CESIUM ADSORPTION ON REFRACTORY METALS. Adv.Energy Convers., 3:207-221, Jan.-Mar.1963.

The measurement of the effective work function of a cesium-covered emitter as a function of emitter temperature and cesium pressure provides an important insight into the adsorption phenomena. In this paper, experimental data on the work function of tantalum, molybdenum, rhenium, iridium and other refractory metals, over a range of emitter temperature (1500-2000°K) and cesium pressures (0.01-3 mm Hg), is presented. A model of the adsorption process, in good agreement with the trends shown by the data, is also given. A useful manner of presenting the experimental data is provided by the fact that curves of constant work function are straight lines when plotted on a plane of logarithm of the pressure vs. reciprocal temperature.

5013

McKisson, R.L. EMITTER CORROSION IN THERMIONIC

CONVERTERS. Adv.Energy Convers.,3: 137-156, Jan.-Mar.1963.

It has been observed that under certain circumstances a relatively large amount of material has been 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 has been 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.

5014

Missouri University, Department of Physics, Columbia, Mo. PROGRESS REPORT, by E.B. Hensley. 11p., Sept.1,1963. (Contract Nonr-2296(01)).

Two investigations were completed during this quarter. They were Thermionic emission from barium telluride and Optical absorption and reflectivity of BaTe.

5015

Radio Corp. of America, Electron Tube Division, Lancaster, Pa. THE DEVELOPMENT OF A LOW-WORK-FUNCTION COLLECTOR FOR THERMIONIC ENERGY CONVERTERS, December 15,1962 - February 15, 1963, by W.B. Hall, R.J. Hill, and J.J. O'Grady. 8p., Feb.15,1963. (Bi-Monthly Status Rept. 1) (Contract Nonr-4012(00)).

5016

Richardson, L.S., Gottlieb, Milton, and Zollweg, R.J. THE EVAPORATION OF MOLYBDENUM IN THE PRESENCE OF CESIUM VAPOR. Adv.Energy Convers., 3:175-184, Jan.-Mar.1963.

Initial measurements use deposition of molybdenum from a molybdenum cathode onto a nickel anode in the presence of cesium vapor showed a significant reduction over that for vacuum evaporation. The ribbon filament in these experiments was heated electrically and the quantity of deposited molybdenum determined by spectro-chemical analysis. Four cathode-anode spacings were provided to determine the dependence of the deposit on spacing. These initial results have been refined and extended to cover a larger range of emitter temperatures and cesium pressures.

5017

Ulrich, A.J. THERMIONIC ENERGY CONVERSION

DIODE USING A FILM BOILING LIQUID METAL ELECTRON COLLECTOR. *Adv. Energy Convers.*, 3:397-405, Jan.-Mar. 1963.

The conventional plasma thermocouple or thermionic energy conversion diode has a solid metal electron collector. Cesium vapor at a pressure of a few millibars or less is widely used to provide ions for electron space charge neutralization. Usually conditions are such that a monolayer of cesium coats the collector, so that electrically the collector appears to be cesium. This suggests the use of a diode with a liquid metal collector material such as cesium, rubidium, or potassium and their alloys. Recent experiments at this Laboratory 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 which covers the film boiling liquid. If conditions in the film are appropriate for production of plasma a thermionic energy conversion plasma diode results.

5018

Yang, Ling and others. EXPERIMENTAL RESULTS ON SELECTION OF THERMIONIC CATHODES FOR REACTOR APPLICATION. *American Rocket Society Space Power Systems Conf.*, Sept. 25-28, 1962., 15p., Santa Monica, Calif., 1962. (ARS Paper 2550-62) (NASA Contract NASS-1253; Contract AT(04-3)-167).

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) refractory 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. This paper discusses these aspects on the basis of existing experimental data. (STAR, 1: 15, Jan. 8, 1963).

5019

Yang, L. and others. SOME CRITICAL MATERIALS PROBLEMS OF THERMIONIC CATHODE SYSTEMS FOR FISSION-HEAT CONVERSION. *Adv. Energy Convers.*, 3:93-99, Jan.-Mar. 1963.

Two types of thermionic emitters have been suggested for the direct conversion of fission heat to electrical energy: (1) uranium-bearing carbides which also function as the nuclear fuels, and (2) refractory metals fueled with uranium containing oxides or carbides. Irrespective of what happens in a reactor, there are certain conditions which have to be met before these emitter systems can be of any practical value. For the carbide emitters, the rate of material loss by vaporization should satisfy the designed life expectancy at temperatures where useful performance is obtainable. For the refractory-metal emitters, the diffusion of the components of the fuels into the metals should not impair their electron-emission characteristics. The purpose of this paper is to analyze these aspects on the basis of existing experimental data and to discuss the current status and problem areas with regard to the feasibility of these two emitter systems.

D. Plasma Properties

5020

Bullis, R.H. ELECTROSTATIC PROBE MEASUREMENTS IN A CESIUM PLASMA. *Adv. Energy Convers.*, 2:523-526, Jly.-Sept. 1962.

Electrostatic probe measurements have been made in a cesium plasma with an electron number density of $10^9/\text{cm}^3$ which is 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.

5021

Ford Instrument Co., Long Island City, N.Y. LO-TEMP THERMIONICS PLASMA STUDY. 80p., figs., Jan. 31, 1963. (Final Rept.) (Contract Nonr-3416(00)).

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 consistent 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.

5022

Fraser, D.A. THE RESISTANCE OF A PLASMA FOR A THERMIONIC CONVERTER. "Ionization in Gases" Conference Paper, Munich, 1961, p.819-824.

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. (Phys.Abs.,66:4155, Mar.1963).

5023

Gabor, D. THE THEORY OF GAS DISCHARGES WITH EXTRANEIOUS ION SUPPLY. Adv.Energy Convers., 3:307-314, Jan.-Mar.1963.

It was suspected for some time that the ion current J_i required for establishing a cathode sheath and drawing out an electron current J_e is less than the value $(m/M)^{1/2} J_e$ required by Langmuir's theory. This has now been proved experimentally. In the experimental device the main discharge space between emitter and collector was supplied with ions through the meshes of a metal gauze, from an auxiliary glow discharge. Probe measurements indicate electron temperatures of the order of 0.15-0.25 V in an argon discharge, confirming that all ions are introduced through the gauze. By multiple collisions almost perfect temperature equilibrium is established between ions and neutrals. The small ion drift current could be calculated from the measured electric and density gradients, with known values for ion mobility, and was found, in an example, about 100 times smaller than required by Langmuir's theory. The average energy of the ions at the emitter was calculated as about 0.5 V. This leads to the conclusion that ions of

such low energy are not absorbed by the emitter, as was hitherto assumed, but are reflected with a high probability. The ion space charge in the cathode sheath is in fact very nearly as required by Langmuir's theory, but it is produced by ions which are reflected about 50 times at the emitter before they are absorbed.

5024

Hernqvist, K.G. and Johnson, F.M. SPACE CHARGE ANALYSIS OF A PLASMA DIODE. Adv. Energy Convers., 2:601-611, Jly.-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.

5025

Hughes Research Laboratories, Malibu, Calif. CESIUM PLASMA STUDIES FOR THERMIONIC ENERGY CONVERSION, PHASE II, by J.Y. Wada and R.C. Knechtli. 2lp., illus., Dec.1962. (Semi-Annual Tech.Summary Rept.) (Contract Nonr-3501(00)).

The thermalization of an electron stream injected at a controlled energy (up to 7 eV) into a quiescent cesium plasma has been observed. The plasma heating associated with the thermalization of the injected electrons has been measured and was found to be in general agreement with theoretical expectations. The resistivity of a highly ionized quiescent cesium plasma has been measured for small current densities (negligible ohmic heating of the plasma), at temperatures between 2000 and 2500°K. The measured values of resistivity were found to be in good agreement with those theoretically predicted by Spitzer.

5026

Hughes Research Laboratories, Malibu, Calif. CESIUM PLASMA STUDIES FOR THERMIONIC ENERGY CONVERSION, PHASE II, by R.C. Knechtli. 2v., 1962, 1963. (Q. Ltr. Repts. 2 & 3) (Contract Nonr-3501(00)).

Measurements of the resistivity of a

ionized cesium plasma for small current densities have been completed. The experimental values of resistivity of initial measurements and subsequent results were found to be in good agreement with those theoretically predicted for a highly ionized plasma in which Coulomb electron-electron and electron-ion collisions are predominant.

5027

Jamerson, F.E. and others. NUCLEAR GENERATED PLASMAS IN NOBLE GAS THERMIONIC CONVERTERS. Adv. Energy Convers., 3:363-383, 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:A (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.

5028

Kihara, M. and others. SOME CHARACTERISTICS OF A CESIUM PLASMA CELL. Inst. Elec. & Electr. Engrs. Proc., 51:769-773, May 1963.

Many studies about cesium plasma cells have been reported, but it seemed to the authors 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.

5029

Kucherov, R.Ya. and Rikenglaz, L.E. KINETIC THEORY OF THE LOW-DENSITY PLASMA DIODE. Zhurn. Tekh. Fiz., 32:1275-1284, Oct. 1962.

In Russian. Transl. in Sov. Phys., Tech. Phys., 7:941-946, Apr. 1963.

The potential distribution in a diode filled with low-density plasma under the assumption that the potential between electrodes is nonmonotonic is considered. Under these conditions it is necessary to take account of particles that are trapped in the potential wells produced near the extrema of the potential. A complete solution is given of the problem for several cases in which the distribution of trapped particles is a Boltzmann distribu-

tion. The corresponding portions of the voltage-current characteristics and the voltage drop across the diode are obtained.

5030

Leffert, C.B. A PLASMA-SHEATH THEORY FOR NOBLE GAS THERMIONIC CONVERTERS. Adv. Energy Convers., 2:417-436, Jly.-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 inpile 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 inpile thermionic converters are analyzed by adjusting plasma parameters to fit the theoretical to the experimental voltage-current characteristics.

5031

Massachusetts Institute of Technology, Research Laboratory of Electronics, Cambridge, Mass. INVESTIGATION OF ELECTRON-BEAM INTERACTION WITH A BEAM-GENERATED PLASMA, by W.D. Getty. 110p., Jan. 19, 1963. (TR 407) (Contract DA 36-039-sc-78108).

Recent research has demonstrated that the flow of an electron beam through a plasma is unstable. Specifically thermal fluctuations of the beam and plasma particles are amplified by an interaction between the electron beam and the plasma electrons. This interaction can result in the extraction of power from the electron beam. This report is concerned with the study of the beam-plasma interaction and the consideration of it as a possible mechanism for the heating of plasma electrons.

5032

Nottingham, W.B. THE ENERGY DISTRIBUTION FOR ELECTRONS IN A THERMIONIC DIODE. PLASMA CANNOT BE TRULY MAXWELLIAN. Adv. Energy Convers., 2:467-479, Jly.-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 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.

5033

Northingham, W.B. IONIZATION OF CESIUM AT SURFACES. *Adv. Energy Convers.*, 3:245-253, Jan.-Mar.1963.

Indications from voltage-current curves of thermionic power converters suggest enhanced ionization at, or very near, cesium-coated surfaces. Experiments are now being conducted to study this phenomenon quantitatively. The tube contains three indirectly-heated tantalum surfaces surrounded by a shield. These heated surfaces are tantalum tubes located at the three corners of an equilateral triangle. The extension of a line from the corner E1 perpendicular to the base of the triangle formed by the line E2 and E3 serves to locate the position of a fine-wire ion collector. Electrons are accelerated from surfaces E2 and E3 to bombard E1. Ions produced at or near E1 are then accelerated toward the ion collector to serve as a measure of the ion production. Results of this experiment will be discussed in detail.

5034

Robinson, L.B. THERMODYNAMIC AND TRANSPORT PROPERTIES OF A CESIUM PLASMA. *Adv. Energy Convers.*, 3:19-36, Jan.-Mar.1963.

Very little information is available regarding the properties of a cesium plasma. In this report, thermodynamic and transport properties of partially ionized cesium vapor, or plasma, are determined from theory (supplemented by available experimental results). Such information is essential in predicting efficiencies of the cesium plasma diode converter. Emphasis is placed upon the transport properties of electrons and the effects of neutral atoms on the thermodynamic and transport properties. Cesium vapor, in the region of small fractional ionization, is considered as a non-ideal gas obeying the virial equation of state.

5035

Roehling, Duane. THE ELECTRICAL RESISTIVITY OF A PARTIALLY IONIZED CESIUM PLASMA. *Adv. Energy Convers.*, 3:69-76, Jan.-Mar.1963.

The electrical resistivity of a partially ionized cesium plasma has been measured by direct current methods at temperatures ranging from 1100°K to 1900°K and for cesium equilibrium temperatures of 250°C ($p=0.5$ mm Hg), 275°C ($p=1.0$ mm Hg), and 340°C ($p=5.0$ mm Hg). The measurements were made in a cell consisting of two parallel tungsten plates, one of which was guard ringed to avoid edge effects. By measuring total resistance versus separation distance the plasma resistance was separated from the sheath resistance and a plasma resistivity obtained. The resistivity ranged from approximately one ohm-cm at the high temperature to a few thousand ohm-cm at the low temperatures. Scattering cross sections for electron-neutral atom collisions were calculated from the resistivity measurements. These cross sections are valid for a cesium plasma having electrons with a Maxwellian velocity distribution. The values of the cross section range from approximately 7×10^{-15} cm² at 1100°K to approximately 15×10^{-15} cm² at 1870°K with an accuracy of about 50 per cent.

5036

Stenzel, W. and Bernstein, M. LOW TEMPERATURE CESIUM PLASMA CONVERTER. *Adv. Energy Convers.*, 2:499-521, Jly.-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.

5037

Talaat, M.E. THE SURFACE IONIZATION AND VOLUME IONIZATION MODES OF OPERATION IN THE THERMIONIC PLASMA ENERGY CONVERTER. *Adv. Energy Convers.*, 2:447-458, Jly.-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. 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 which 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 which is approximately an order of magnitude higher than the surface ionization current density.

5038

Warner, C. SPACE CHARGE ANALYSIS OF THE CESIUM-FILLED THERMIONIC DIODE. Adv. Energy Convers., 2:459-465, Jly.-Sept.1962.

The space charge problem for a plane diode whose hot cathode emits both ions and electron 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. These authors describe the variety of potential distributions that can arise, but give few numerical results. The present paper systematizes and discusses the numerical results of machine calculations for potential distributions with various ratios of emitted electron to emitted ion density, electrode spacings, and applied potentials. 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.

5039

Waymouth, J.F. ELECTRICAL ENERGY FROM HIGH-TEMPERATURE PLASMAS. Inst. Elec.Engrs.J., 9:380-383, Aug.1962.

Theoretical calculations and experimental data are given for a hot- and cold-electrode convertor for extracting electrical energy from a high-temperature plasma. Unlike other plasma convertors, this can be a high-voltage generator. An efficiency of 36% has been obtained at a power level of 25w, and an efficiency of 67% may be possible at thermonuclear temperatures.

E. Design Parameters

5040

Devin, Bernard and Vandevyver, Michel. RENDEMENT THEORIQUE MAXIMUM DES CONVERTISSEURS D'ENERGIE A EMISSION THERMOELECTRONIQUE. (THEORETICAL MAXIMUM EFFICIENCY OF THERMOELECTRONIC EMISSION ENERGY CONVERTERS). J.Phys. et Radium (Supple), 23:73A-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. (Battelle Tech.Rev.,11:534a, Dec.1962).

5041

General Atomic, San Diego, Calif. A DIGITAL-COMPUTER CODE FOR THE ANALYSIS OF THERMIONIC NETWORKS, by J.H. Broido, C.W. Savery, and W.B. Wright. 75p., May 22,1963. (GA-4147) (Contract NObs-86221).

A digital-computer code which describes the performance of thermionic diodes has been developed. Detailed data derived from physics research on operating thermionic diodes are incorporated in the library of this code. With the data now available, semiquantitative estimates can be made of these diodes in a reactor environment. These estimates are useful in the initial evaluation of the feasibility of thermionic systems.

5042

General Electric Co., Research Laboratory, Schenectady, N.Y. OPTIMUM DESIGN OF CYLINDRICAL ELECTRON BOMBARDMENT HEATERS, by J.M. Houston, T.A. Howlett, and H.F. Webster. 6p., illus., May 1963. (Sci.Rept. 4) (AFCRL-63-453) (Contract AF 19(604)-8424).

It is shown that an optimum geometry exists for a cylindrical electron bombardment heater in which maximum thermal flux is to be delivered with stable operation and long life of the bombardment heater coil. The procedure for finding the stable operating condition is illustrated, and the optimum heater size is evaluated.

5043

A SEARCH FOR EMITTERS SUITABLE FOR THERMIONIC DIRECT CONVERTERS. Soviet J.Atomic En., 13:902-903, June 1963.

Attempts to work out practical designs for thermionic direct converters capable of converting heat energy to electrical energy have the problem of finding suitable emitter materials. Sonic thermionic properties of several potential emitters are listed.

F. Devices

5044

Atomics International, Canoga Park, Calif. FLAME HEATED THERMIONIC CONVERTER RESEARCH, July 1 - December 31, 1962, by W.R. Martini, and E.V. Clark. 2v., illus.,

Sept.30,1962 & Apr.15,1963. (AI-7841 & AI-8124) (Q.Repts. 5 & 6) (Contract DA 36-039-sc-88982).

The purpose of this research is to develop the technology required for portable, flame-heated thermionic power sources. Active development in thermionic diodes, heat sources and materials is underway.

5045

Atomics International, Canoga Park, Calif.
UNIFORM WORK FUNCTION CATHODE STUDIES FOR THERMIONIC CONVERTERS, July 12-October 12,1962, by M.N. Huberman. 25p., illus., Oct.1962. (Q.Rept.1) (Contract AF 33(657)-8726) (AD-286 693).

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. (TAB U63-1-2:39, Jan.15, 1963).

5046

Block, F.G. THE DEVELOPMENT STATUS OF THERMIONIC ENERGY CONVERSION IN INDUSTRY. Soc.Automotive Engrs.J., 71:113, June 1963.

"State-of-the-Art" of thermionic energy conversion is briefly covered in this paper. Basic operating principles of thermionic energy conversion are outlined. The problem areas of cesium attack, emitter and collector and converter fabrication techniques are discussed. Application of thermionic converters to solar, nuclear and fossil fuel heat sources is covered. Data on efficiency, power density, weight and life results with various sources are presented.

5047

Bloss, W. INVESTIGATIONS ON NOBLE GAS FILLED THERMIONIC CONVERTERS. Adv.Energy Convers., 3:315-321, Jan.-Mar.1963.

This paper deals with a method for space charge compensation in noble gases and with the performance of a special thermionic converter with operating temperatures not exceeding 1300°K. Low work function collector materials ($\phi \approx 1$ 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/cm².

5048

Bloss, W. A NEW GAS FILLED THERMIONIC CONVERTOR. "Ionization in Gases" Conference Paper, Munich, 1961, p.815-818.

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 auxiliary 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. (Phys.Abs.,66: 3997, Mar.1963).

5049

Boyer, Pierre. DIRECT TRANSFORMATION OF HEAT INTO ELECTRICITY WITH THE AID OF THERMIONIC CONVERTERS WITH CESIUM ATMOSPHERE. Rev.Gen.Elec., 16:17-22, 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. (Nuclear Sci.Abs.,17:2113, Jan.31,1963).

5050

Brosens, P.J. and Kitrilakis, S.S. CESIUM THERMIONIC CONVERTERS AND GENERATORS FOR SOLAR SPACE POWER SYSTEMS. American Rocket Society Space Power Systems Conf., Sept.25-28, 1962., 10p., Santa Monica, Calif. 1962. (ARS Paper 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. Where

pertinent, references to the original publications are given. 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 done at Thermo Electron on cylindrical monodiode and cubical multidiode generators is described. 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. (STAR, 1:16, Jan.8,1963).

5051

Brosens, P. and Hatsopoulos, G.N. THERMIONIC ENERGY CONVERTER WITH A LIQUID COLLECTOR. Adv. Energy Convers., 3:387-396, 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.

5052

California University, Lawrence Radiation Laboratory, Livermore, Calif. DESIGN AND CONSTRUCTION FEATURES OF A VARIABLE GAP THERMIONIC CONVERTER TUBE, by W.H. Gust and E.S. McKee. 14p., Sept.27, 1962. (Contract W-7405-eng-48) (UCRL-7031).

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 6 inches. (STAR, 1:17, Jan.8,1963).

5053

California University, Lawrence Radiation Laboratory, Livermore, Calif. HEAT-SHIELDED MAGNETICALLY CHANNELED PLASMA HEAT CONVERTER, by Raymond Fox. 27p., Aug.5,1961. (UCRL-6553) (Contract W-7405-eng-48).

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 homogeneous 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. (Nuclear Sci.Abs., 17:5643, Feb.28,1963).

5054

Cook, K.G., Fraser, D.A. and Isaacs, G.G. A THERMIONIC GENERATOR WITH ION INJECTION. Adv. Energy Convers., 3:323-331, Jan.-Mar. 1963.

Thermionic generators have been described where the space charge is neutralized by ions generated in an auxiliary discharge. During the past two years work has been carried out at the Hirst Research Centre on a generator of this type. 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: (1) The electron energy can be adjusted to a value significantly above the ionization potential, to give optimum conditions for efficient ion production. (2) The interelectrode space between emitter and collector is free of obstacles which would provide an ion drain. (3) Ions are generated at the point where space charge neutralization is required, rather than having to diffuse from adjacent regions. An experimental generator of this type is

described. 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.

5055

Devin, B., McElroy, J.D. and Klein, S.
CESIUM PLASMA TRIODE. Adv.Energy Convers.,
2:623-630, Jly.-Sept.1962.

Experiments with Cs plasma triodes have shown three distinct types of oscillations which may be of interest in energy conversion work. One mode of operation is analogous to conventional vacuum triode operation, another is a low frequency mode which exhibits several interesting features, and the third is a way of coupling to the spontaneous plasma oscillations. These modes are presented and are discussed in terms of the ionized medium conditions.

5056

Dobretsov, L.N. THERMIONIC ENERGY CONVERTER.
Cesk.Casopis Fys., 12:428-438, Apr.1962.

In Czechoslovakia. 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. (Nuclear Sci.Abs.,17: 20649, June 30,1963).

5057

Electro-Optical Systems, Inc., Pasadena, Calif.
RESEARCH PROGRAM RELATED TO VAPOR
THERMIONIC CONVERTERS FOR NUCLEAR APPLICATION,
December 27,1962 - March 27,1963, by
A.O. Jensen. 48p., Apr.24,1963. (EOC
3410-Q-2) (Q.Prog.Rept.) (Contract
NAS 3-2529).

Information is presented on the status and results obtained in the following 4 areas: (1) sample processing investigations, (2) grain growth experiments in vacuum and cesium vapor environments, (3) long term cesiated emission tests from such substrates which are undergoing surface crystal changes and (4) electron emission microscope examinations of initially polycrystalline materials which are operated long times at high temperatures.

5058

General Atomic, San Diego, Calif.
HIGH-TEMPERATURE, VAPOR-FILLED THERMIONIC
CONVERTER, August 1,1961 - January 31,
1962, by A.E. Campbell and others. 112p.,
illus., June 1962. (Final Rept.) (Rept.
GA-2911) (Contract AF 33(616)-7422)
(ASD-TR-61-513, vol.2) (AD-284 410).

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. (TAB U62-4-6:32, Dec.15,1962).

5059

General Electric Co., Missile & Space Division,
Philadelphia, Pa.
CAVITY VAPOR GENERATOR PROGRAM, June 1961-
September 1962, by D.L. Purdy and others.
140p., illus., Dec.1962. (ASD-TDR-62-
899) (Contract AF 33(616)-8394)
(AD-295 490).

A description 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 are discussed.

5060

General Electric Co., Power Tube Dept.,
Schenectady, N.Y.
EVALUATION OF A MOLYBDENUM EMITTER, LOW
VOLTAGE ARC THERMIONIC POWER CONVERTER,
June 15 - September 15, 1962, by E.A. Baum.
24p., figs., Oct.1962. (Q.Tech.Prog.
Rept.2) (Contract AF 33(657)-8323)
(AD 286-711).

The effort during this second quarter of the program has been directed toward the completion of the life test equipment, initiation

of life tests, and the acquisition of operational data.

5061

General Electric Co., Schenectady, N.Y.
EVALUATION OF A MOLYBDENUM EMITTER, LOW VOLTAGE ARC THERMIONIC POWER CONVERTER, by E.A. Baum. 100p., illus., Feb.1963. (Final Rept.) (ASD-TDR-63-183) (Contract AF33(657)-8323).

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.

5062

General Electric Co., Research Laboratory, 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. 36p., illus., May 1963. (SR 1) (AFCRL-63-450) (Contract AF 19(604)-8424).

Measurements made on a Cs-vapor thermionic converter having a 13.3 cm^2 Th-W emitter indicate that in the retarding range of the converter the emission cooling is just what simple theory would predict. However, for collector-to-emitter voltages more positive than approximately -1.3 volts, the emission cooling fell far below that predicted by simple electron emission from the emitter, indicating that large amounts of power (as much as 20 watts/cm^2 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 radiation, excited atoms, and ions returning to the emitter. These originate in a region of high electron temperature adjacent to the emitter.

5063

General Electric Co., Research Laboratory, Schenectady, N.Y.
SINGLE-CRYSTAL THERMIONIC CONVERTER STUDIES, by H.F. Webster. 12p., illus., May 1963. (SR 3) (AFCRL-63-452) (Contract AF 19(604)-8424).

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.

5064

General Motors Corp., Allison Division, Indianapolis, Ind.
INVESTIGATION OF THE MONOCAPILLARY THERMIONIC EMITTER AS A DUAL SOURCE OF IONS AND ELECTRONS, by D.L. Dresser and W. Laurita. 166p., Feb.15,1962. (Q.Tech. Prog.Rept.1) (EDR-2617) (Contract AF 33(616)-8299).

The capillary emitter is a new approach to thermionic energy conversion-in this concept, cesium flows through a refractory emitter structure so that the emitter becomes a dual source of ions and electrons. To determine the fundamental performance characteristics of the capillary emitter, a theoretical and experimental study was conducted on a monicapillary configuration. This report summarizes the results of the investigation. (STAR, 1:N63-16307, Jly.8,1963).

5065

HEAT GIVES ELECTRICITY DIRECTLY: THERMO-ELECTRON ENGINE. Elec.World, 150:70, diags., Jly.21,1958.

Thermo-electron engine developed by MIT professors G.N. Hatsopoulos and Joseph Kaye produces small quantities of electricity with 12% efficiency.

5066

ITT Industrial Laboratories, Fort Wayne, Ind.
INVESTIGATION OF CLOSE-SPACED THERMIONIC CONVERTER, December 15,1960 - June 25, 1962, by D.K. Coles. 77p., illus., Oct.1962. (Final Rept.) (ASD-TDR-62-687) (Contract AF 33(616)-7683) (AD-291 677).

Difficulties in realizing a very small anode-cathode spacing, due to uneven thermal expansion and warping, have led to a feasibility study of a subliming anode surface that automatically maintains the proper spacing from the cathode. Barium was chosen as a subliming metal since it serves also to activate the cathode. This required that all parts of the vacuum enclosure be held above 500 degrees C. Effects of barium corrosion at high temperatures were studied. (TAB U63-1-6:26, Mar.15,1963).

5067

Kitrilakis, Sotiris and Hatsopoulos, G.N.
THE CESIUM VAPOR THERMIONIC CONVERTER: III. OBSERVED DEPENDANCE OF PERFORMANCE ON CESIUM PRESSURE, SPACING, EMITTER TEMPERATURE AND EMITTER MATERIAL. Adv. Energy Convers.,2:583-600, Jly.-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.

5068

Knechtli, R.C. and Fox, Marvin. THEORY AND PERFORMANCE OF AUXILIARY DISCHARGE THERMIONIC ENERGY CONVERTERS. *Adv. Energy Convers.*, 3:333-349, 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.

5069

Kramar, J. THERMIONIC CONVERTOR OF HEAT INTO ELECTRICITY. *Elektrotech. Obzor*, 51: 64-69, 1963.

In Czechoslovakia. Explains the basic properties of this convertor and calculates its efficiency, assuming perfect charge compensation in the space between the electrodes. Results of these calculations are applied both to a device with a tantalum cathode and to one with an impregnated barium cathode supported by porous tungsten. (*Elec. Eng. Abs.*, 66:6233, June 1963).

5070

Lawrence, J. and Wilson, V.C. CHARACTERISTICS AND LIFE TESTS OF CYLINDRICAL THERMIONIC CONVERTERS. *Adv. Energy Convers.*, 2: 341-351, Jly.-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.

5071

Leovic, W.J., Mueller, M.W. and Stevenson, C.G. PERFORMANCE TEST OF A CUBICAL CAVITY SOLAR THERMIONIC GENERATOR. *ARS Preprint no. 2554-62*. New York, American Rocket Society, 1962. Prepublication Copy., 11p.

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. (*Nuclear Sci. Abs.*, 17:9134, Mar. 31, 1963).

5072

Marquardt Corp., Van Nuys, Calif. THERMIONIC CONVERTER RESEARCH, January 1, - March 31, 1963, by W.E. Beyermann and R.A. Laubenstein. 29p., illus., Mar. 31, 1963. (Rept. 25,082) (Rept. 7) (Q.Rept. 3) (Contract DA36-039-sc-90751).

Continuing studies are described on the operation of thermionic energy converters in the low-voltage arc mode at emitter temperatures of 1070°C to 1400°C. Additional data have been obtained on the degradation in performance of a thermionic

converter with molybdenum emitter after the converter is processed. Large changes in output power are observed before stable performance characteristics are achieved. No significant difference has been obtained between the performance of molybdenum emitter converters with stainless steel or molybdenum collectors. The ignition potential of a molybdenum electrode converter operating at low emitter temperatures was found to change in the direction of positive power output as the emitter temperature was increased or as the collector temperature was decreased. Operating conditions for optimum power output from a converter do not correspond to the conditions for the optimum positive ignition potential. Qualitative data are presented on the discharges observed in a converter for different cesium vapor pressures.

5073

Martin Marietta Co., Nuclear Division, Baltimore, Md.
A STUDY PROGRAM ON CESIUM VAPOR-FILLED THERMIONIC CONVERTERS HAVING IRIIDIUM EMITTERS, November 1, 1961 - October 31, 1962, by M.E. Talaat, D.S. Trimmer, and A.J. Kennedy. 87p., figs., Dec. 1962. (Yearly Summary Rept.) (Contract Nonr-3639(00)).

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 .030". 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.

5074

Martin Marietta Corp., Aerospace Division, Baltimore, Md.
DEVELOPMENT OF AN ENCAPSULATED THERMIONIC POWER GENERATOR, November 1 - January 31, 1963. 15p., Feb. 15, 1963. (Q.Tech.Prog. Rept.) (MND-2945-1) (Contract AF33(657)-10077).

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. (Nuclear Sci.Abs., 17:11313, Apr. 15, 1963).

5075

Morgulis, N.D. and Korchevoi, Yu.P. EFFECT OF AN INTERELECTRODE CESIUM PLASMA ON THE CHARACTERISTICS OF A THERMIONIC ENERGY CONVERTER. Zhurn.Tekh.Fiz., 32: 1487-1489, Dec. 1962.

In Russian. Transl. in Soviet Phys., Tech.Phys., 7:1099-1101, June 1963.

The behavior of a thermionic energy converter filled with cesium vapor was studied.

5076

National Aeronautics and Space Administration, Washington, D.C.
EXPERIMENTAL INVESTIGATION OF A 90° FLAT-PLATE MAGNETIC TRIODE FOR DIRECT ENERGY CONVERSION, by R.R. Cullom. 13p., Nov. 1962. (NASA Tech.Note D-1532).

An approach to decreasing the inter-electrode space charge of a magnetic triode was tested by using a shaped magnetic field to improve triode performance. The shaped field was designed to restrict the electrons to circular orbits and thus to decrease electron-electron collisions and/or electron scattering. A percentagewise improvement in the triode output power was observed with the shaped magnetic field. This improvement in the performance, however, was not of sufficient magnitude to make this particular triode a practical energy converter because the grid power loss was of greater magnitude than the power output.

5077

Ogle, H.M., Samstad, G.I. and von Damm, C.A. NUCLEAR THERMIONIC FUEL ELEMENT EXPERIMENTS. Adv.Energy Convers., 2:353-361, Jly.-Sept. 1962.

Several in-reactor tests of plasma diodes have been performed at the Valeclitos 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 which are required for in-pile operation; and (3) Test facility requirements for adequate control of converter parameters.

5078

Purdy, D.L. THERMIONIC CAVITY GENERATOR DEVELOPMENT. ARS Preprint no. 2572-62. New York, American Rocket Society, 1962. Prepublication Copy. 49p.

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. (Nuclear Sci.Abs.,17:9130, Mar.31,1963).

5079

Radio Corp. of America, Industrial Tube Products, Lancaster, Pa.
THE DEVELOPMENT OF AN AUXILIARY ELECTRODE THERMIONIC CONVERTER, June 15 - December 15, 1962, by W.B. Hall and J.J. O'Grady. 2v., illus., Oct.1962 & Jan.1963. (Q. Tech.Rept. 3 & 4) (Contract AF 33(657)-8005) (AD-286 324 & AD-295 052).

Progress is reported on research conducted to improve the efficiency and life expectancy of thermionic energy converters for space applications. (TAB U63-1-2:35, Jan.15,1963 & TAB U63-2-3:16, May 1,1963).

5080

Radio Corp. of America, Princeton, N.J.
VAPOR-FILLED THERMIONIC CONVERTERS, October 1 - December 31, 1962, by K.G. Hernqvist and J.R. Fendley. 19p., illus., Jan.20,1963. (Q.Rept. 1) (Contract NAS 3-2531).

An analysis of the cesium vapor arc discharge is described. A duo-emitter diode for microwave studies of a cesium plasma and its application in a circuit are described. A test station for the monitoring and control of the gas environment in an operating cesium diode is described.

5081

Radio Corp. of America, Princeton, N.J.
VAPOR-FILLED THERMIONIC CONVERTERS, January 1 - March 31, 1963, by K.G. Hernqvist and J.R. Fendley. 20p., illus., Apr.20,1963. (Q.Rept.2) (Contract NAS 3-2531).

Studies of the plasma density variation with discharge current are described both for a synthesized cesium plasma and for a cesium

arc discharge. Preliminary experiments with a gas-analysis, gas-dosing system are described. The experimental verification for ball-of-fire analysis of the cesium arc discharge is summarized.

5082

Republic Aviation Corp., Farmingdale, L.I., N.Y.
MAGNETIC FIELD EFFECTS IN THERMIONIC PLASMA DIODES, by A. Schock and others. 43p., illus., Jan.1963. (Final Tech.Rept.) (RAC-1102) (Contract Nonr-3285(00)).

Experiments to determine the effect 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.

5083

Steele, H.L. and Gillette, R.B. THE TRANSITION TO THE ARC MODE AND ITS INFLUENCE ON THERMIONIC CONVERTER PERFORMANCE. Adv.Energy Convers., 2: 483-497, Jly.-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.

5084

U.S. Atomic Energy Commission, Argonne National Laboratory, Lemont, Ill.
RF OSCILLATIONS AND POWER OUTPUT IN ALKALINE THERMIONIC CONVERTERS, by H.K.

Richards. 18p., Apr.1962. (TID-16215)
(Contract W-31-109-eng-38) (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. (Nuclear Sci.Abs.,17:11837, Apr.15,1963).

5085

Webster, H.F. THERMIONIC CONVERTER RESEARCH.
Pacific Energy Conversion Conf. Proc.,
San Francisco, 4/14-16, 1962.

A brief survey of basic research on thermionic converters refers to the work function of various materials and to the physics of low-voltage Cs plasmas. A brief description of device research contains information on converter tubes using Ta, Mo, and Nb as emitters, respectively. The tubes were operated in air for fairly long periods (>2500 hrs. continuously, in one case). Power yield varied from 2.5 to 4.55 w./sq.cm. for the different tubes operated at emitter temperatures 1950-2080°K., and at collector temperatures 875-1000°K. Tube construction is illustrated with a cross-sectional drawing. (Chem. Abs.,58:2928, Feb.18,1963).

5086

Weeks, C.C., Dahleen, R.C. and Gingrich, J.E.
EXPERIMENTAL OPTIMIZATION OF CESIUM VAPOR
THERMIONIC CONVERTERS WITH METAL EMITTERS.
Adv.Energy Convers., 2:315-323, Jly.-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.

5087

Wilson, V.C. and Lawrence, J. DESIGN AND
OPERATION OF LABORATORY TYPE PARALLEL
PLANE CESIUM THERMIONIC CONVERTERS. Adv.
Energy Convers., 2:335-340, Jly.-Sept.1962.

Two parallel plane converters are described. Evidence is presented that suggests that an auxiliary discharge to a guard ring increases the output power of these converters. While driving one tube with a 60 c/s transformer, a current of 110 A/cm² was drawn at an emitter temperature of 2000°K and with the collector 1.5V positive.

5088

Wilson, V.C. and Hamilton, R.C. THERMIONIC
CONVERTERS FOR SPACE POWER. Astron. and
Aerospace Eng., 1:62-67, May 1963.

No longer merely "interesting" as back-up devices, converters today warrant serious consideration for space vehicles. A solar-heated system could be ready for test flights within the next two years.

G. Systems

5089

Aerojet-General Nucleonics, San Ramon, Calif.
FEASIBILITY DETERMINATION OF A NUCLEAR
THERMIONIC SPACE POWER PLANT, May 1 -
July 31,1962. 12p., illus., Jly.31,1962.
(Q.Tech.Prog.Rept.) (Rept. AN-693)
(Contract AF 33(657)-8977) (AD-282 179).

Work is described which is directed toward demonstration of the feasibility of the Nuclear Thermionic Radiator Space Power System. The specific objectives of the current program are: (1) to demonstrate operation of a minimum of three thermionic converters in a series array using heat from a liquid metal loop to heat the cathodes; and, (2) to demonstrate 1000 hours of thermionic operation using liquid metal heating. (TAB U62-4-5:114, Dec.1,1962).

5090

Aerojet-General Nucleonics, San Ramon, Calif.
FEASIBILITY DETERMINATION OF A NUCLEAR
THERMIONIC SPACE POWER PLANT, by K.E.
Buck, C.R. Fisher, and I.M. Rehn. 150p.,
illus., Nov.1962. (Final Rept.) (ASD-
TDR-62-827) (Contract AF 33(616)-8119).

This report describes the first phase of a program to determine the feasibility of a nuclear space-power system that utilizes a thermionic radiator. 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.

5091

Aerojet-General Nucleonics, San Ramon, Calif.
FEASIBILITY DETERMINATION OF A NUCLEAR
THERMIONIC SPACE POWER PLANT, November 1,
1962 - January 31,1963. 39p., illus.,
Jan.31,1963. (Q.Tech.Prog.Rept.) (Rept.
AN-856) (Contract AF 33(657)-8977)
(AD-296 862).

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. (TAB U63-2-4:17, May 15, 1963).

5092

Atomics International, Canoga Park, Calif.
PERFORMANCE OF CESIUM THERMIONIC DIODES OPERATED IN SERIES - PARALLEL CIRCUITS, by J.W. Holland. 33p., Feb.1, 1963. (NAA-SR-7661) (Contract AT(11-1)-GEN-8).

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.

5093

Beller, William. THERMIONIC CELL GENERATES A-C POWER. Missiles and Rockets, 12: 18-19, Feb.11, 1963.

Ford Instrument device exploits internal pulsing, hence needs no inverters and may be step to space solar-thermionic system.

5094

Dunn, P.D. THERMIONIC GENERATION TO AID NUCLEAR POWER. New Scientist, 15:80-82, Jly.12, 1962.

Development and design of a multi-element reactor system using thermionic diodes to emit electrons from a hot surface to generate electricity. Methods for neutralizing the space charge are included.

5095

General Atomic, San Diego, Calif.
PARAMETRIC STUDY OF DIRECT CONVERSION REACTOR POWER SYSTEMS, by W.B. Wright. 133p., illus., Oct.31, 1962. (GA-3540) (Final Tech.Rept.) (Contract Nonr-3371(00)).

This work is composed of four major sections. In the section entitled "Models of Thermionic-cell Behavior in Reactor Systems," mathematical formulations of thermionic-cell dynamics are discussed. Energy transfer mechanisms are considered in detail and cesium vapor effects are incorporated into the analytical description. In particular, an empirical correlation of cesium wetting phenomena is provided. The resulting analytical models provide methods for determining the effects of the

neutronics and heat-transfer aspects of a reactor on the performance of thermionic-cell networks. In the section entitled "Nuclear Design Aspects of Water-moderated Thermionic Reactors," two of the major neutronics problems that arise in the design of in-pile thermionic systems are examined--power flattening and lattice heterogeneity. Parametric studies of the lattice heterogeneity problem were made with multigroup transport theory. In addition, an extensive study of power-flattening methods in water-moderated high-power-density systems is discussed. In the section entitled "The Conceptual Design of a 1-Mw(e) Thermionic Reactor System," a complete design study was made of an in-pile thermionic reactor. The interrelated thermionic-neutronic-heat-transfer characteristics of this specific system were studied using the analytical models of thermionic-network behavior. Comparison of this type of reactor with a conventional power plant is discussed. In the section entitled "Analysis of Thermionic Reactor System Performance," the kinetic behavior of thermionic reactor systems is considered. A complete mathematical formulation of the kinetics of an entire thermionic plant is developed. The resulting set of equations and the linearization of these equations are discussed.

5096

Getler, Michael. SOLAR SPACE POWER, THERMIONIC FLIGHT EXPERIMENT STUDIED. Missiles and Rockets, 12:38,42-43, Apr.29, 1963.

A study made here by General Electric Co. scientists indicates that an experimental solar thermionic power system, operating at about 5% efficiency with a 55-watt output, could be placed in orbit within two to two and one-half years.

5097

Gyftopoulos, E.P. and Hatsopoulos, G.N. THERMIONIC NUCLEAR REACTORS. Elec.Eng. 82:108-116, Feb.1963.

A unique power system for space, submarine propulsion, and applications in remote areas should result from the successful coupling of nuclear reactors with thermionic converters. Three conceptual designs of thermionic nuclear reactors are reviewed to establish requirements for performance characteristics and materials and to pinpoint some of the problem areas.

5098

Martin Marietta Corp., Baltimore, Md.
FEASIBILITY STUDY OF WATER-COOLED THERMIONIC NUCLEAR POWER PLANT. 199p., Nov.1962. (MND-2903 (Vol. I)).

This volume contains a justification, description, and evaluation of a water-cooled thermionic plant. A series of appendices is included which describes in detail fuel element geometry, thermionic diode analysis, system control analysis, reliability and maintainability of this plant, and transportability of this plant.

5099

Martin Marietta Corp., Aerospace Division, Baltimore, Md.
THERMIONIC ISOTOPIC POWER SYSTEM, September 30, 1961, by W.E. Kortier and T.S. Bustard. 243p., Sept. 30, 1961. (Final Summary Rept.) (Contract AT(30-3)-217) (MND-P-2679).

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. (Nuclear Sci. Abs., 17:4357, Feb. 15, 1963).

5100

Menetrey, W.R. and Smith A. SOLAR ENERGY THERMIONIC CONVERSION SYSTEM, American Rocket Society Space Power Systems Conf., Sept. 25-28, 1962, 106p., Santa Monica, Calif., 1962. (ARS Paper 2499-62).

A discussion is presented of the fabrication and performance of a 5-ft solar concentrator, fabrication and test of 40 SET thermionic converters, and the fabrication of 2 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. (STAR 1:13, Jan. 8, 1963).

5101

Morgulis, N.D., Levitskiy, C.M. and Groshev, I.N. CURRENT OSCILLATIONS IN THE SYSTEM OF A THERMIONIC ENERGY CONVERTER WITH CESIUM VAPOR. Radiotekh. i Elektron., 7: 352-353, Feb. 1962.

In Russian. Transl. Radio Eng. & Electron. (USSR), no. 2:330-332, Feb. 1962.

The investigation was performed by means of an experimental tube filled with cesium vapors and containing a Ta strip cathode and a similar cesium-coated Ta anode with screening electrodes, the distance between which could be varied. The investigated oscillations were recorded by an oscillogram. The variable parameters of the investigation were: cathode temperature, cesium vapor saturation temperature and interelectrode distance. The data presented give a characterization of certain new aspects of a thermoelectronic energy converter with cesium vapor.

5102

Pratt and Whitney Aircraft, East Hartford, Conn.
ADVANCED NUCLEAR ELECTRIC POWER GENERATOR SYSTEM STUDY. THERMIONIC NUCLEAR SPACE POWERPLANT, October 1, 1962 - March 31, 1963, by P. Bolan and W.J. Lueckel. 2v., Dec. 31, 1962 & Mar. 31, 1963. (PWA-2157 & 2212, (vol. II)) (Contract NASW-360).

Parametric system studies of a thermionic reactor space powerplant with an output of one megawatt electric and an operational lifetime of 10,000 full power hours, have been completed. System specific weight has been found to minimize at a particular cathode temperature for a given fuel evaporation rate limit. Minimum system weights are defined at cathode temperatures of 3200 > 3500°F for evaporation rates of 0.002 > 0.020 inch per year in vacuum, respectively. Corresponding system specific weights for lithium-cooled systems with a beryllium radiator are 10.5 and 3.9 pounds per kilowatt.

5103

Thompson Ramo Wooldridge Inc., Cleveland, Ohio.
ADVANCED SOLAR THERMIONIC POWER SYSTEMS, June 1960 - August 1962. 239p., illus., Dec. 1962. (Final Rept.) (ASD-TDR-62-877) (Contract AF33(616)-7411).

This report contains 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. The results of the survey and development program were used in a comprehensive parametric study 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 thermionic converters and generators built during the program are presented.

5104

Thompson Ramo Wooldridge, Inc., Cleveland, Ohio.

LONG-LIFE THERMIONIC CONVERTERS FOR SOLAR POWER SYSTEMS, March 1961 - October 1962. 82p., illus., Feb. 1963. (Final Rept.) (ASD-TDR-62-1069) (Contract AF33(616)-8114).

This report describes the work accomplished under an applied research program directed toward increasing the cycle life of thermionic converters which can be used in solar thermionic generators. The results of cycle life tests of five thermionic converters, and the results of a solar test of a cavity-type thermionic generator which used five converters identical to the life test converters, are presented. A complete discussion of all specialized equipment and techniques is also included along with design details.

5105

Voorhees, B.G. PROGRESS TOWARD NUCLEAR THERMIONIC SPACE POWER. American Rocket Society Space Power Systems Conf., September 25-28, 1962. Santa Monica, Calif., 1962. (ARS Paper 2577-62).

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. (Astron. Info. Abs., 7:70,477, Feb. 1963).

IV. PHOTOELECTRIC PROCESSES

A. Photovoltaic

1. Theory

5106

Andreichin, R. and Ivanova, H. POSITIVE AND NEGATIVE PHOTOVOLTAIC EFFECT IN SILVER SULFIDE LAYERS. Acad. Bulg. Sci. Compt. Rend., 15:245-248, 1962.

In English. A photoelement $Au|Ag_2S|Al$ was made from a thin Ag_2S layer on a glass sheet. Au and Al electrodes were evaporated in vacuum onto the Ag_2S layer. The resistance of the element was 6×10^4 to 10^5 ohms, the e.m.f. was 80-250 mv. in the darkness, and the current 0.01-0.1 μ amp., with Al as anode. In light, the e.m.f. initially dropped and then rose slowly to maximum 300 mv., restoring its original value obtained in darkness. These effects were more pronounced with infrared light than with light of shorter wavelengths. In darkness a galvanic e.m.f. was produced to which a photo-e.m.f. was added in the light. (Chem. Abs., 58:1018, Jan. 21, 1963).

5107

Baicker, J.A. and Faughnan, B.W. RADIATION-INDUCED CHANGES IN SILICON PHOTOVOLTAIC CELLS. J. Appl. Phys., 33:3271-3280, Nov. 1962.

The effect of both electron and proton irradiation of silicon photovoltaic cells is given in terms of the loss of photovoltaic response and the decrease in the lifetime. Analysis of the spectral response shows that a simple carrier diffusion model provides an adequate description of the behavior of the shallow-diffused junctions that were investigated, and yields values for the minority carrier diffusion length before and after irradiation. Most of the photovoltaic response is shown to occur in the base region of the cells, rather than in the surface layer, and virtually all of the loss of response is caused by defects introduced in the base. The reciprocal of the lifetime is linear with the cumulative irradiation flux, and is consistent with the loss of photovoltaic response. There are significant differences between p on n and n on p cells under electron bombardment; the former damaging roughly 100 times as rapidly as the latter. Under proton bombardment the difference is roughly a factor of three. A comparison of electron, proton, and neutron irradiation suggests that the individual lattice displacements produced in electron irradiation are no more effective in producing recombination than the displacements produced in high concentration in neutron and proton irradiation.

5108

Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio. TRANSIENT RADIATION EFFECTS ON ELECTRONIC COMPONENTS AND SEMICONDUCTOR DEVICES, by D.C. Jones and others. 106p., Apr. 19, 1963. (REIC Rept. 26) (Contract AF 33(657)-10085).

This report summarizes the information that was available before 1962 concerning the effects of nuclear weapon-burst and simulated-burst radiation on electronic components and semiconductor devices. This work reports only the effects observed in components that are due to gamma rays and/or neutrons of a transient radiation environment.

5109

Desvignes, F. VELLULES SOLAIRES PHOTOVOLTAIQUES: NOUVEAUX RESULTATS THEORIQUES ET EXPERIMENTAUX (PHOTOVOLTAIC SOLAR CELLS: NEW THEORETICAL AND EXPERIMENTAL RESULTS). International Scientific Radio Union (URSI), Symposium, Paris, France, Sept. 18-22, 1961. In Space Radio Communication. New York, Elsevier Publishing Co., 1962, p. 240-256;

Discussion, J. Maillard, p. 256.
In French.

Analysis of the energy conversion in solar cells, from the incident light to power consumed in the external load. The process is split into three independent phases: (1) energy transfer from photons to hole-electron pairs; (2) photoelectric minority carrier collection at the depletion layer; and (3) energy transfer from the collected minority carriers to the external load. In addition, the most important properties of silicon cells are reviewed from the viewpoint of space communications applications. (Intern. Aerospace Abs., 3:A63-14248, May 1, 1963).

5110
Evans, J. SOLAR CELLS. Brit. Interplan. Soc. J., 19:62-67, May-June 1963.

The basic principles of conversion of sunlight into electrical energy in a semiconductor p-n junction are described. From the theory, prediction of the expected performance as a function of external and internal parameters is made, and the maximum efficiency for a number of likely semiconductors quoted. Practical results are given for typical arrangements, including space projects already successful and proposed for the future. The effects of the space environment on performance and life are discussed. Finally, the direction and promise of future developments are indicated.

5111
Kamiyama, Masahide, Haradome, Miyoshi, and Kukimoto, Hiroshi. HIGH-VOLTAGE PHOTO-VOLTAIC EFFECT IN EVAPORATED CdTe FILMS. J. Appl. Phys. (Japan), 1:202-209, Oct. 1962.

The properties of CdTe films vacuum-evaporated at an oblique angle of incidence onto a substrate of glass, which are known to exhibit unusually high photovoltages, are experimentally studied. (1) The angular distribution of the intensity of light scattered by the film is asymmetric. (2) The (111) planes of the crystallites do not lie parallel to the substrate surface, as they do in the case of normal incidence. The incline of the (111) planes is determined in the main by the angle of incidence of vapor θ . (3) The photovoltage V exhibits a peculiar dependence on θ . It changes its sign at a certain value of θ , which in turn is determined by the substrate temperature. A model is proposed for the structure of the film, which will explain the experimental results.

5112
Koltun, M. SOLAR BATTERIES OF THE FUTURE.

Nauka i Zhizn', pp.63-64, Oct. 10, 1961.
Transl. FTD-TT-62-972. (AD-286 578).

The conversion of helioenergetics into an independent and important technological field is discussed. Outstanding scientists of the world, including Frederic Joliot-Curie, feel that helioenergetics will be put on an equal footing with the study of atomic energy. In this connection scientists await further research. (TAB U63-1-2:26, Jan. 15, 1963).

5113
Lockheed Aircraft Corp., Missiles and Space Co., Sunnyvale, Calif.
ON THE ORIGIN OF THE ANOMALOUS PHOTO-VOLTAIC EFFECT IN ZINC SULFIDE, by F.A. Junga. 82p., May 1, 1963. (Tech. Rept.: Physics. 6-90-63-20) (Contract Nonr-222(57)).

Certain crystals of ZnS generate voltages greater than the band gap voltage when illuminated with ultraviolet light. This phenomenon is called the anomalous photovoltaic effect. The purpose of this study was to devise and justify a model (semi-quantitative) to account for the general features of the anomalous photovoltaic effect.

5114
Michigan University, Institute of Science and Technology, Ann Arbor, Mich.
EFFECT OF CHEMISORBED OXYGEN OF PHOTO-VOLTAIC AND PHOTOCONDUCTIVE PROCESSES IN RUTILE, by R. Keezer. 8p., May 1963. (Rept. 2900-400-R) (Contract DA 36-039-sc-78801).

It has been found that the presence of adsorbed oxygen increases both the response and the response time for the photovoltaic effect in rutile. The model for the effect of chemisorbed oxygen on the photoconductivity has been modified to take into consideration the effect of oxygen pressure. The conductance of rutile has been measured as a function of oxygen pressure. The results agree with the modified model. The increase in photovoltaic response and response time with exposure to oxygen has been explained in terms of the barrier layer formed by chemisorbed oxygen.

5115
Michigan University, Institute of Science and Technology, Ann Arbor, Mich.
PHOTOVOLTAIC EFFECTS IN RUTILE, by R. Keezer, J. Mudar, and D.E. Brown. 7p., May 1963. (Rept. 2900-398-R) (Contracts DA 36-039-sc-78801 & AF 33 (616)-8410).

The ultraviolet photovoltaic response of

barrier-layer cells formed from single-crystal rutile has been investigated. Typical samples have response maxima at 3200 Å, a D^* of 10^9 cm cps $^{1/2}$ /w, and time constants of 100 usec. Variations in time constant over several orders of magnitude have been observed; they depend largely on preparation techniques. The effect of surface treatment on cell characteristics is discussed.

- 5116
Momin, A.U. and Sinha, A.P.B. A THEORETICAL STUDY OF THE EFFECT OF p-LAYER RESISTANCE ON THE EFFICIENCY OF PHOTOVOLTAIC SOLAR ENERGY CONVERTERS. J. Electron. & Contr., 14:425-436, Apr. 1963.

A theoretical investigation has been made to determine the exact role which the internal series resistance and the surface layer (p or n layer) resistance play in determining the conversion efficiency in solar energy converters using p-n junction photovoltaic cells. An equivalent circuit of the photovoltaic solar cell which is represented by a network consisting of a large number of current sources interconnected through series resistors, simulating the effect of sheet resistance of the surface layer, is assumed.

- 5117
Setton, R. and Bazin, J. PHOTOELECTRIC EFFECTS IN GRAPHITE-CAESIUM COMPOUNDS. Acad. Sci. Paris. Compt. Rend., 254:2150-2152, Mar. 19, 1962.

Caesium is evaporated on to a graphite plate in vacuo to form an "interstitial" compound. Illumination of the graphite on the face obscured from the cell anode still gives a photocurrent and with a more elaborate cell it is found that electrons produced by illumination pass through the graphite before being emitted and collected at the anode. (Phys. Abs., 65:12546, July 1962).

2. Silicon Cells

- 5118
Baicker, J.A. and Rappaport, P. RADIATION DAMAGE TO SOLAR CELLS. In Atomic Energy Commission. Division of Technology Information, Washington, D.C. Protection Against Radiation Hazards in Space Proceedings of the Symposium at Gatlinburg, Tenn., Nov. 5-7, 1962, p. 118-135.

The construction, operation, and performance characteristics of solar cells are described. The radiation-damage process is discussed, and details of proton and electron damage to silicon cells presented. The degradation of the photovoltaic current-voltage characteristics and the spectral response is shown, and a comparison made of various types of solar cells,

including silicon, gallium arsenide, and cadmium sulfide. Differences between p/n and n/p silicon cells are discussed and explained in terms of basic properties of the radiation defects. (Sci. & Tech. Aerospace Rept., 1:N63-15123, June 8, 1963).

- 5119
Denney, J.M., Downing, R.G. and Simon, G.W. EFFECT OF SPACE ENVIRONMENT ON PHOTOVOLTAIC CELLS. American Rocket Society Space Power Systems Conf., Sept. 25-28, 1962, 8p., Santa Monica, Calif., 1962. (ARS Paper 2536-62).

A series of theoretical calculations have been performed concerning inelastic nuclear interactions between incident high energy protons and silicon. The results of these calculations, indicate that, above incident proton energies of about 20 Mev, the primary defect production mechanism is inelastic nuclear interactions. Additional evidence is presented which indicates that the defect structures produced by these inelastic nuclear interactions are significantly more complicated than those produced by electron and lower energy proton induced elastic nuclear interactions. Based on these phenomena, it is shown that high energy proton experimental damage data on silicon photovoltaic devices obtained at low illumination intensities cannot be applied directly to spacecraft photovoltaic power supply systems designed to operate at the illumination levels existing in space. (STAR, 1:14, Jan. 8, 1963).

- 5120
Electro-Optical Systems, Inc., Pasadena, Calif. FEASIBILITY STUDY TOWARD DEVELOPMENT OF RADIATION RESISTANT SOLAR CELL, July 1-October 31, 1962, by S. Kaye. 44p., Nov. 30, 1962. (Interim Eng. Rept.) (Contract NAS7-92) (EOS-2080-IR-2).

The feasibility of producing radiation-resistant silicon solar cells by the use of a graded base structure is being studied. Methods of fabrication of both n on p and p on n graded base cells are discussed and the results of efficiency measurements at sea level and on Table Mountain are presented. The results of bombarding the cells with 1-Mev electrons are shown and compared with the results obtained by bombarding n on p cells having a uniform base region of 25 ohm cm resistivity. The results of experiments designed to measure the presence of an electric field in the base region of the graded base cells by carrier transient time measurements are given. The results indicated that the graded base structure affects the transport properties of minority carriers injected

into the base region of the cells. The electron irradiation experiments also indicated that the performance of the cells when subjected to 1-Mev electron bombardment is at least as good and may be superior to that reported on other silicon cells. (Nuclear Sci.Abs.,17: 6795, Mar.15,1963).

5121

Electro-Optical Systems, Inc., Pasadena, Calif.
FEASIBILITY STUDY TOWARD DEVELOPMENT OF RADIATION RESISTANT SOLAR CELL, October 1 - December 31,1962, by M.D. Cheslow and S. Kaye. 3v., Nov.15, Dec.15,1962 & Jan.15, 1963. (EOS Rept. 2080-ML-12, 13, & 14) (Monthly Repts) (Contract NAS7-92).

Reports present information on cell measurement and fabrication.

5122

Electro-Optical Systems, Inc., Pasadena, Calif.
FEASIBILITY STUDY TOWARD DEVELOPMENT OF RADIATION RESISTANT SOLAR CELL, November 1, 1961 - January 31,1963, by M.D. Cheslow and S. Kaye. 5op., Feb.28,1963. (Final Rept.) (EOS-2080) (Contract NAS7-92).

The results of a feasibility program to develop radiation resistant solar cells are described. An electric field in the base region which was produced by means of a graded base structure increased the collection efficiency of light produced carriers from the base region. Comparative results of radiation damage tests with both 1 Mev electrons and 95 Mev protons are presented. The cells were found to be 20 times more radiation resistant than n-on-p cells having 1 ohm cm base region.

5123

General Atomic, San Diego, Calif.
RADIATION EFFECTS ON SILICON SOLAR CELLS, December 1,1961 - August 31,1962, by D.M.J. Compton and others. 4v., Mar.7, June 14, Sept.18,1962 & Feb.15,1963. (GACD-3001, 3223, 3511, & GA-3872) (Q. Prog. Repts. 1,2,3 & Final Rept.) (Contract NAS7-91).

Experiments have been performed to study the defects introduced into silicon by high energy (-30 Mev) electron irradiation. These defects are expected to be similar to those produced by high-energy protons. The diagnostic tools used include measurements of galvanomagnetic coefficients, excess carrier lifetime, electron-spin resonance, and infrared absorption. The results indicate that the A center in quartz-crucible-grown silicon is not the primary excess-carrier recombination center. Instead recombination in quartz-crucible-grown and floating-zone refined silicon appears to be dominated by the same center.

5124

Hayashi, K. DISTRIBUTED-CONSTANT THEORY OF THE SILICON SOLAR BATTERY. J.Inst. Elect.Commun.Engrs.Japan,45:23-28, Jan.1962.

In Japanese. In the case of Si batteries of large area, the flow of the generated current through the thin P-type layer causes voltage drop and power loss before reaching the terminal electrode, so that a distributed-constant equivalent circuit is required for analysis. Discussion of such a circuit leads to a nonlinear differential equation for the potential distribution of the solar cell, a solution of which has been obtained by use of a computer and an approximated equation. Expressions are thus derived for the potential distribution on the P layer, the generated power, the internal power loss caused by the series resistance, and the output power of both rectangular and circular Si solar cells. (Elec.Eng.Abs., 65:14673, Dec.1962).

5125

Heliotek, Division of Textron Electronics, Inc., Sylmar, Calif.
HIGH EFFICIENCY SILICON SOLAR CELLS, June 15, - December 15,1962, by P.A. Berman, R.J. Handy, and G.P. Rolik. 2v., Oct.15,1962 & Jan.15,1963. (Rept. 1 & 2) (Q.Prog.Rept. 1 & 2) (Contract DA 36-039-sc-90777).

The purpose of the contract is the development of high efficiency, lower cost silicon solar cells. Both N+ on P and P+ on N cell structures are to be studied and the cells optimized for use in terrestrial environment with and without utilization of solar concentrators.

5126

Kaye, S., Weiman, I. and Wright, W.V. A NEW RADIATION DAMAGE RESISTANT SOLAR CELL. American Rocket Society Space Power Systems Conf., Sept.25-28,1962., 24p., Santa Monica, Calif., 1962. (ARS Paper 2567-62) (NASA Contract NAS7-92).

The design and performance of an experimental silicon p-n junction solar cell intended for space application is described. The cell has an n-type surface layer and has an impurity gradient in the p-type base region. The gradient is such as to provide an electric field in the base region which will accelerate photoelectrons into the vicinity of the p-n junction. By this means, the dependence of the short circuit current upon the minority carrier lifetime is reduced. Since this latter parameter is the one most affected by bombardment of the cell by energetic charged particles, the tolerance of the cell to damage by such

particles is considerably enhanced.
(STAR, 1:16, Jan.8,1963).

5127

Madey, Richard. SOLAR CELL DEGRADATION BY PROTONS IN SPACE. In Atomic Energy Commission., Division of Technology Information, Washington, D.C. Protection Against Radiation Hazards in Space Proceedings of the Symposium at Gatlinburg, Tenn., Nov.5-7, 1962, p.243-259.

An analytic expression for the decrease in efficiency of a solar cell, behind a protective cover glass, exposed to a spectral distribution of protons is formulated on the basis that the time rate of decrease in output power is proportional to the proton dose rate absorbed at the surface of the solar cell. The decrease in the maximum power output of an n-on-p silicon solar cell exposed to the solar flare of 12 November 1960 is calculated as a function of the thickness of protective cover glass for a power-law representation of the differential flux spectrum of the incident protons. (Sci.& Tech. Aerospace Rept., 1:N63-15128, June 8,1963).

5128

Minneapolis-Honeywell Regulator Co.,
Research Center, Hopkins, Minn.
THIN LAYER LARGE AREA SILICON SOLAR CELLS,
January 1 - March 31,1963, by J.D. Heaps
and J. Pone', 26p., Mar.31,1963. (Q.
Prog.Rept. 1) (Contract DA 36-039-AMC-
00115(E)).

The objectives of the contract are to further investigate the possibilities of solar energy conversion utilizing the photovoltaic effect in polycrystalline silicon layers and to apply the results of the investigation by devising methods and techniques applicable to the fabrication of low cost, large area solar cells.

5129

Muller, R.S. SURFACE PHOTOVOLTAGE STUDIES OF SILICON-ELECTROLYTE SYSTEMS. Electrochem.Soc.J., 109:1195-1197, Dec.1962.

Surface photovoltage measurements were employed to test the effects of electrolytic environment on both n- and p-type silicon having a range of resistivity values. The electrolytes chosen were those used in various phases of the chemical processing of silicon for commercial use.

5130

Naval Research Laboratory, Washington, D.C.
IN-PILE HALL COEFFICIENT AND CONDUCTIVITY MEASUREMENTS ON ZONE-REFINED P-TYPE SILICON, by G.C. Bailey and C.M. Williams. 12p., figs., May 13,1963. (Rept. 5930).

The Hall coefficient and conductivity have been measured during pile irradiation for a number of zone-refined p-type silicon crystals with initial resistivities of 1, 8, and 100 ohm-cm. To supply the magnetic field (500 oersteds) for the Hall measurements in the reactor, a small electromagnet was used. The conductivity of zone-refined silicon shows much faster changes with irradiation than pulled silicon samples of equivalent resistivity. The 100-ohm-cm samples exhibit a monotonic nonlinear decrease of $\ln \sigma$ (conductivity) vs ϕ_f (integrated fast flux), whereas the other samples with initial Fermi levels closer to the valence band have one or two regions of linear decrease in $\ln \sigma$ vs ϕ_f before the nonlinear decrease region is observed. The Hall mobility for the 100-ohm-cm samples decreases and becomes negative as a result of the carrier density decreasing with irradiation. In the case of the 8-ohm-cm sample, the Hall mobility decreases with irradiation, whereas the 1-ohm-cm sample shows no change in Hall mobility with irradiation up to the maximum integrated flux used in the present experiment. The origins of the dependence of $\ln \sigma$ on ϕ_f as well as the behavior of the Hall coefficient and Hall mobility with irradiation are discussed.

5131

Pieper, G.F. THE ARTIFICIAL RADIATION BELT. APL Tech.Dig.,2:3-13, Nov.-Dec.1962.

As a result of the high-altitude nuclear explosion over Johnston Island, an intense electron radiation belt has been trapped in the earth's magnetic field. This belt can cause silicon solar cells to deteriorate at a much greater rate than was previously expected as a result of protons in the natural Van Allen Radiation belt. At the altitudes of instrumented satellites, the electron radiation belt does not appear to be diminishing at a rate fast enough to offer relief from this new environment in the near future. To provide a satellite solar-cell power-system with a long-life capability, it will be necessary to provide a large margin of over-design in the initial power-generating capability of the solar power system. The use of N-on-P solar cells will have a significant effect in increasing the life of the satellite's power-generating system. The use of thick cover slides for the solar cells will result in a decrease in the rate of degradation. The extent of this protection cannot be accurately determined until the energy spectrum of the trapped particles is better defined. Direct measurements of the effectiveness of various shield thicknesses are being obtained from the ANNA satellite.

5132

Radio Corp. of America, Princeton, N.J.
RADIATION DAMAGE TO SILICON, July 16, 1962 -
March 15, 1963, by J.A. Baicker, B.W.
Faughnan, and J.J. Wysocki. 51p., illus.,
Apr. 15, 1963. (Semiannual Rept. 3)
(Contract NAS 5-457).

Results are presented of a study of various radiation-induced changes in the electrical, optical, and magnetic properties of n- and p-type silicon. Lifetime measurements show a number of different radiation-induced recombination levels. Trapping measurements show a large number of minority carrier traps produced by bombardment. A summary of observations of thermally stimulated conductivity in normal and neutron-irradiated silicon is given. A number of solar cells of both Si and GaAs were irradiated with electrons and protons. The damage rate with electron energy between 0.8 and 5.6 MeV is reported for p-type silicon (n/p solar cells).

5133

Rosenzweig, W., Gummel, H.K. and Smits, F.M.
SOLAR CELL DEGRADATION UNDER 1-Mev
ELECTRON BOMBARDMENT. Bell Sys.Tech.J.,
42:399-414, Mar. 1963.

The effect of radiation damage on the important parameters of solar cells has been evaluated for groups of blue-sensitive n-on-p, normal p-on-n, and blue-sensitive p-on-n cells using 1-Mev electrons. The outer space short circuit current, maximum power, junction characteristic, and spectral response are presented quantitatively as a function of radiation flux along with the bulk minority-carrier diffusion length.

5134

Ross, Bernd. SOLAR ENERGY CONVERTERS.
Materials Science and Technology for
Advanced Applications., Englewood Cliffs,
N.J., p.431-452, Prentice-Hall, Inc., 1962.

A short discussion of semiconductor P-N junctions is given. This will be related to the operation of a photovoltaic device. A method of fabricating a silicon photovoltaic energy conversion device is discussed. Considerations of spectral response and optimization to solar radiation resulting in the development of a solar simulator are described. Special requirements of solar cells operating in earth space are mentioned. (Nuclear Sci.Abs., 17:6552, Mar. 15, 1963).

5135

Sandia Corp., Albuquerque, N.Mex.
RADIATION DAMAGE TO SEMICONDUCTOR DEVICES,
by J.W. Hasley. 36p., Jly. 1962. (SCR-532)

Radiation damage to solar cells is discussed.

5136

Schoffer, P. and Pfeiffer, C. PERFORMANCE
OF PHOTOVOLTAIC CELLS AT HIGH RADIATION
LEVELS. Am.Soc.Mech.Engrs.Trans., 85A:
208-212, Jly. 1963.

The performance of p-n gridded, water-cooled silicon photovoltaic cells was measured at radiation levels of up to 250 Langley per min. Outputs exceeded 1/4 watt per sq cm. An analysis of cell operation at high fluxes permits computation of the performance over a wide range of radiation intensities from a single high-radiation voltage-current curve. An array of eight p-n cells and an optical system used with the array is described. Characteristics of n-p cells were measured, and their peculiar V-I curves are noted. Methods of improving cell performance at high fluxes are discussed.

5137

SILICON SOLAR CELLS DETECT RADIATION.
Electromech. Design, 6:44, Jly. 1962.

This brief article is based on a report by Dr. Walter Rosenzweig of Bell Telephone Laboratories.

5138

Treble, F.C. THE EFFECTS OF RADIATION
DAMAGE IN SOLAR CELLS. Electronics
Reliability and Microminiaturization (GB),
1:299-309, Oct.-Dec. 1962.

An account is given of proton bombardment tests on samples of silicon and gallium arsenide solar cells at energies ranging from 25 to 140 MeV. The effects of radiation damage on the performance parameters of such cells are discussed, with particular reference to the influence of factors such as absorption characteristic, junction depth, minority carrier lifetime, type of cell (p-on-n or n-on-p) and proton energy. The results indicate that at the most damaging energy levels silicon cells lose about 75 per cent of their initial output after 10^{13} protons/cm². Gallium arsenide cells are much more resistant to radiation. (Elec.Eng.Abs., 66:3020, Mar. 1963).

5139

U.S. Air Force, Institute of Technology,
Wright-Patterson AFB, Ohio.
RADIATION EFFECTS ON SOLAR CELLS(thesis),
by J.W. Diebold. 63p., May 1962.
(GNE/Phys/62-6) (AD-283 955).

Gallium arsenide and Si solar cells were irradiated with protons and deuterons at 195 to 2 Mev. The electrical characteristics of the solar cells were measured before and after irradiation using a space solar simulator. The space

solar simulator provides a light source similar to the sun and a space environment for testing solar cells. Measurements were also made during irradiation using floodlamps as a light source. The results indicate that deuterons are more damaging than proton by a factor of 3 to 5, and gallium arsenide cells are more resistant to radiation than Si solar cells. (Nuclear Sci.Abs.,17:11263, Apr.15,1963).

5140

Weller, J.F. PROTON DAMAGE TO SILICON SOLAR CELLS. Report of NRL Progress, 1-6, Jan.1963.

Several types of silicon solar cells have been irradiated with approximately 4.8 Mev protons. Variations in the cells irradiated in the experiment were bulk material, impurity concentration, and oxygen concentration. Changes in diffusion length, spectral response, and current-voltage characteristics show that the n/p cell is more radiation resistant than the p/n. No difference in radiation resistance is seen by varying the oxygen concentration, but there is a trend toward increased radiation resistance as the resistivity of the bulk is increased.

3. Compound Semiconductors

5141

Electro-Optical Systems, Inc., Pasadena, Calif. RESEARCH ON MATERIALS EXHIBITING PHOTO-VOLTAIC PHENOMENA, by J.W. Burns. 160p., illus., Jan.1963. (ASD-TDR-62-841) (Contract AF33(616)-7482).

This report summarizes two years of effort directed toward the development of new materials for photovoltaic solar energy conversion. A brief review is given of the factors governing the selection of materials for efficient solar cells.

5142

General Electric Co., Schenectady, N.Y. CdTe RESEARCH FOR SOLAR ENERGY CONVERSION APPLICATION, May 15,1961 - May 15,1962, by D.A. Cusano, R.E. Halsted, and M.R. Lorenz. 24p., illus., Jan.1963. (Final Rept.) (ASD-TDR-62-966) (Contract AF33(616)-8308).

Substantial contract effort was devoted to improving the conversion efficiency and learning as much as possible about the variations in the fabrication and the overall performance of polycrystalline vapor reacted thin film solar cells. Solar conversion efficiencies up to 6% have been achieved in polycrystalline film cells with some samples exhibiting open circuit voltages up to .55 volts and other samples showing short circuit current densities about 18 ma/cm², these values at

room temperature under 80 mw/cm² solar irradiation. Various performance data on polycrystalline film cells are presented in this report. Included are spectral response, load characteristics, illumination dependence, temperature dependence, etc. The single crystal results which are also presented offer considerable encouragement for the applicability and general utility of the solar cell fabrication technique developed during this year's program with vapor reacted films.

5143

Grimmeiss, H.G., Kischio, W. and Koelmans, H. p-n-JUNCTION PHOTOVOLTAIC EFFECT IN ZINC-DOPED GaP. Solid-State Electron., 5:155-159, May-June 1962.

The p-n-junction photovoltaic effect in Zn-doped GaP was studied as a function of various parameters. The spectral sensitivity, the temperature dependence of the short-circuit current and the open-circuit voltage are discussed. In addition to the intrinsic effect an extrinsic photovoltaic effect was found. Arguments are given to show that the extrinsic response is not an electrode effect, but is clearly correlated with the specific dope introduced into the GaP bulk.

5144

Gutkin, A.A. and others. A GaAs PHOTOELECTRIC CONVERTER OF SOLAR ENERGY. Radiotekh. i Elektron., 7:2095-2096, Dec.1962.

In Russian. Transl. in Electron.Express, 5:#9, 8-9, 1963.

Gallium arsenide photoelements are described that have an efficiency of -7% and do not require a coating that reduces reflection.

5145

Gutkin, A.A. and others. GaAs SOLAR CELL. Radio Eng. & Electron. (USSR), no.12: 1947-1948, Dec.1962.

Gallium arsenide photocells with efficiencies of approximately 7%, not requiring the use of antireflection coating, are described.

5146

Gutkin, A.A. and others. PHOTOELECTRIC PROPERTIES OF GaAs p-n JUNCTIONS. Fiz.Tverdogo Tela, 4:2338-2348, Sept.1962.

In Russian. Transl. in Soviet Phys., Solid State, 4:1712-1719, Mar.1963.

The method of preparing GaAs photocells is briefly described. The following properties are reported and analyzed:

spectra of photocells and current-voltage characteristics of p-n junctions under photocell and diode operating conditions at various temperatures; temperature dependences of the short-circuit photocurrent and photo-emf at various intensities of illumination; and the relaxation characteristics of p-n junctions under photocell and photodiode conditions for various intensities of light and various temperatures.

5147

Harshaw Chemical Co., Cleveland, Ohio.
LARGE AREA THIN FILM CADMIUM SULFIDE SOLAR CELL ARRAY INVESTIGATION, by F.A. Shirland and others. 2v., Jan.4, & Mar. 21, 1963. (Q.Tech.Prog.Rept. 1 & 2) (Contract AF 33(657)-9975).

As the result of Contract AF33(616)-7528, the CdS front wall evaporated film solar cell progressed to the point where large area cells of 9 square inches could be made in the range of 2 to 3% conversion efficiency with reasonable reproducibility. Testing of the CdS film cell under the conditions of space and the conditions that would be encountered in getting arrays into space is the principal objective of the present contract. Secondary objectives are to improve the performance of the CdS film cell and to obtain a better understanding of the fundamentals governing the operation of this cell.

5148

Harshaw Chemical Co., Cleveland, Ohio.
RESEARCH AND DEVELOPMENT IN CdS PHOTO-VOLTAIC FILM CELLS, December 1, 1962 - February 28, 1963, by T.A. Griffin, and J.C. Schaefer. 17p., Feb. 28, 1963. (Q. Prog.Rept. 3) (Contract NAS 3-2493).

During this period an evaporator was tooled for the purpose of evaporating uniform CdS films on 6" x 6" substrates. Several large area films were made, some of which were completed as front wall photovoltaic cells. Two hundred fifty-eight cells were produced on the pilot line with an average efficiency of 2.06% and a maximum efficiency of 3.5%.

5149

Harshaw Chemical Co., Cleveland, Ohio.
RESEARCH ON PHOTOVOLTAIC CELLS, November 1, 1962 - January 31, 1963, by N.E. Heyerdahl. 27p., Feb. 1963. (Q.Prog.Rept.3) (Contract AF33(657)-7916).

During the past quarter Cu_3Se_2 and Cu_2S have been synthesized and examined. Large CdTe crystals have been grown by vapor phase deposition and found to have unusual metallic precipitate on them. Films of CdTe containing various dopants

have been prepared by coevaporation and examined for resistivity as a function of temperature. The recrystallization of CdTe by dendritic growth during film formation by coevaporation has been observed. The effect of polytypism upon the etching behavior of II-VI compounds has been examined. CdSe solar cells have been prepared from CdSe films containing various dopants.

5150

Harshaw Chemical Co., Cleveland, Ohio.
RESEARCH ON SOLAR-ENERGY CONVERSION EMPLOYING CADMIUM SULFIDE. VOLUME II, January - August 1962, by F.A. Shirland and others. 63p., illus., Dec. 1962. (Final Rept.) (Contract AF 33(616)-7528) (ASD-TDR 62-69, vol.2) (AD-295 485).

Continued development of a thin-film solar cell using vacuum-evaporated layers of CdS is summarized. Primary emphasis was on the front wall CdS film cell using molybdenum foil substrates. Efficiencies of large-area (up to 9 sq. in.) front wall cells were increased to the range of 2 to 3%. The major factor in this increase was the reduction of sheet resistance by the use of a fine-mesh metallic grid laminated to the barrier surface. Improved vacuum evaporation techniques made possible a reduction in CdS film thickness and in molybdenum foil substrate thickness, each to about 0.001 in. With these improvements, power-to-weight ratios for CdS thin film front wall solar cell arrays, that may be suitable for space applications, of 20 to 30 watts/lb seem assured. Some tests of CdS front wall film cells and arrays indicate that they should be stable in the high vacuum of space, and possibly fairly resistant to radiation of the Van Allen types. Research studies on the structure of CdS single crystals and polycrystalline films continued regarding grain growth, orientation and polarity effects, etching, and grain boundary studies. There are indications of a correlation between crystallite orientation and photovoltaic response. (TAB U63-2-3:17, May 1, 1963).

5151

Lyubin, V.M. and Fedorova, G.A. HIGH-VOLTAGE PHOTO-EMF'S IN LAYERS OF ANTIMONY TRISELENIDE. Fiz.Tverdogo Tela. 4:2026-2030, Aug. 1962.

In Russian. Transl. in Soviet Phys., Solid State, 4:1486-1489, Feb. 1963.

The results of a study of electrical and photoelectric properties are reported for sublimated crystalline layers of antimony triselenide, in which photo-emf's up to 50-80 V/cm were generated on

illumination. In addition parameters are given for layers of some chalcogenides of antimony and bismuth in which high-voltage photo-emf's were also observed.

5152

National Cash Register Co., Dayton, Ohio.
FEASIBILITY INVESTIGATION OF CHEMICALLY SPRAYED THIN FILM PHOTOVOLTAIC CONVERTERS, August 1 - October 31, 1962, by R.R. Chamberlin. 35p., illus., Oct. 31, 1962. (Q.Rept.3) (Contract AF 33(657)-7919) (AD-289 278).

Studies included: possible variations in the physical structure (crystallinity and crystallite orientation) of the semiconducting layer (CdS and CdSe) due to changes in the deposition parameters; the effect on different orientations due to heat treatment; changes in resistivity due to heat treat and doping; improvement of the deposition of the barrier layer; investigation of a barrier layer using copper selenide; search for a flexible (metal foil) substrate compatible with the film deposition conditions; investigation of the possible correlation between crystallite orientation and crystallinity to photovoltaic response; and the spectral characteristics of the CdSe, CdS, and CdSe-CdS photovoltaic cells. (TAB U63-1-4:29-30, Feb. 15, 1963).

5153

Radio Corp. America, Defense Electronic Products, Princeton, N.J.
APPLIED RESEARCH PROGRAM ON HIGH-TEMPERATURE RADIATION-RESISTANT SOLAR-CELL ARRAY, May - October 1962. 2v., Aug. 15, & Oct. 31, 1962. (Q.Tech.Prog.Rept. 1 & 2) (Repts. AED-1558 & AED-1668) (Contract AF 33(657)-8490) (AD-282 219 & AD-287 570).

Effort was made to determine the technology necessary for the application of a high-temperature, radiation-resistant array of solar cells in a configuration suitable to aerospace vehicles. Toward this end, gallium arsenide solar cells are being fabricated for temperature and radiation tests, and experimental studies are being conducted to determine techniques for fabricating modules and arrays. In the second report, Progress is reported on GaAs cell development and fabrication for temperature, radiation, and array configuration testing. (TAB U62-4-5:131, Dec. 1, 1962. & TAB U63-1-3:20-21, Feb. 1, 1963).

5154

Radio Corp. America, Semiconductor and Materials Division, Somerville, N.J.
DEVELOPMENT OF IMPROVED SOLAR ENERGY CONVERTERS FROM GALLIUM ARSENIDE, April 1959 - May 1962, by M.F. Lamorte and G.W. McIver. 213p., illus., Sept. 1962.

(Final Rept.) (ASD-TDR-62-639)
(Contract AF 33(616)-6615).

A discussion of solar cell fabrication is presented; the discussion includes commentary on: (1) crystal used and crystal properties; (2) diffusion techniques used; (3) surface treatments used; (4) a comparison of Polystyrene and silicon oxide antireflecting coatings; (5) data for n on p cells; (6) diffusion techniques for formation of gallium phosphide on gallium arsenide substrates; (7) methods for growing large area gallium arsenide single crystals; and (8) methods for epitaxial growing of gallium arsenide layers from the vapor phase. Experimental procedures employed are outlined and several analytical investigations are presented concerning optimum grid structure, solar cells with cascaded energy gaps, the effect of the built-in field, surface recombination, the optimum antireflecting coating, and the determination of short-circuit current from the spectral response curve.

5155

Radio Corp. of America, Somerville, N.J.
GALLIUM ARSENIDE SOLAR CELL PRODUCTION PROCESSES AND TECHNIQUES, July 15 - September 15, 1962, by R.D. Gold. 28p., illus., Sept. 15, 1962. (Interim Tech. Documentary Prog. Rept. 1) (Contract AF 33(657)-8921) (AD-286 648).

In order to facilitate fabrication of solar cells for initial process experiments, the fabrication process developed under contract NASS-457 and presently in use for contract AF 33(657)-8490 was adopted. The present process resulted in typical efficiencies between 6 and 8% with maximum efficiencies near 10%. Cells now being made with GaAs are doped with either Ge or Si. An experiment performed to evaluate fabrication procedures indicates that the use of a tungsten light for optimization of cell efficiency by etching will result in an optimized cell for sunlight. (TAB U63-1-2:23, Jan. 15, 1963).

5156

Shirland, F.A., Griffin, T.A. and Dierssen, G.H. THIN FILM CdS FRONT WALL SOLAR CELLS. American Rocket Society Space Power Systems Conf., Sept. 25-28, 1962., 8p., Santa Monica, Calif. 1962. (ARS Paper 2566-62).

A new photovoltaic cell made from a film of CdS vacuum evaporated onto a metal foil substrate is described. Such cells are being made in sizes up to 3-in x 3-in, at conversion efficiencies of 2 to 3%. They can be laminated in plastic envelopes

to form arrays delivering 10 to 15 watts per pound. It is estimated that these cells can be made very economically. Typical I-V characteristic, spectral response, and temperature performance curves are given. Data on the stability of these front wall CdS cells, including resistance to radiation damage, are also presented. Possibilities for larger area, lighter weight, higher efficiency cells of this design are discussed. (STAR, 1:16, Jan.8,1963).

5157

Sidorov, V.I. and Lifshits, T.M. PHOTO-ELECTRIC PROPERTIES OF GERMANIUM ALLOYED WITH GOLD AND ZINC. Radio Eng. & Electron. (USSR), no.12:1927-1935, Dec.1962.

The dependence of the spectral characteristics of the photovoltaic and photocurrent effects on the concentration of impurity centers and the degree of their compensation was studied in specimens of Ge:Au:Sb and Ge:Zn:Sb. The temperature dependence of the photosensitivity was also studied. It is shown that the photovoltaic effect is independent of the impurity concentration and the degree of compensation while the photocurrent effect depends on the ratio N_d/N_a . For each specimen with a specific type of impurity center there is a limiting temperature above which the photosensitivity drops abruptly.

5158

Williams, R. SURFACE PHOTOVOLTAGE MEASUREMENTS ON CADMIUM SULFIDE. Phys. & Chem. Solids, J., 23:1057-1066, Aug.1962.

Surface photovoltaic measurements on conducting crystals of cadmium sulphide show that, at equilibrium, there is a difference in potential between the surface and the bulk of 0.2 to 0.3 eV. This is due to adsorbed oxygen which forms charged acceptor states on the surface. The adsorption is a reversible process, and the oxygen may be removed by replacing the air ambient with an inert gas such as nitrogen. The density of charged surface states on typical conducting crystals is 1×10^{11} per cm^2 . On high-resistance photoconducting crystals there is no detectable density of charged surface states. There is, however, a measurable photovoltage which is apparently due to the Dember effect. A model is proposed for the surface states which accounts for the observed behaviour. (Phys.Abs.,65:21190, Nov.1962).

4. Devices

5159

Athens, A.S. USING SOLAR CELLS TO READ HOLES. Electron. Design, 10:78-81, Feb.15,1962.

Standard switching circuitry as well as a new gating circuit for solar-cell hole readers are described. Both are treated in terms of the movement of their operating points on the solar-cell characteristic curves. The typical circuit for a solar cell controlling a transistor in a card reading operation is shown. When the cell is off, the transistor is biased "on" through a resistance. When the light comes through a hole to turn the solar cell on, the cell generates enough opposite polarity voltage to remove the "on" bias from the base of the transistor. Often the output of these transistor amplifiers must be gated. For each solar cell circuit two additional diodes are usually required. A better method for gating solar cells employing a resistor and common gate transistor driver which minimizes the cost of such gating is described. (Info. Processing J.,1:2084, 1962).

5160

Clevite Corp., Electronic Research Division, Cleveland, Ohio.
STUDY OF THIN FILM LARGE AREA PHOTO-VOLTAIC SOLAR ENERGY CONVERTER, October 1, 1962 - March 31,1963, by W.J. Deshotels, Frank Augustine and Allan Carlson. 2v., Jan.11, & Apr.5,1963. (Q.Rept. 1 & 2) (Contract NAS 7-203).

The first report gives a description of work done on cadmium sulfide solar cells prior to the present contract by the Electronic Research Division of Clevite Corporation. This is followed by a discussion of the necessary requirements for "scaling-up" equipment and processes in order to accommodate the larger solar cells to be investigated under the present contract. Then specific experiments to determine optimum parameters are described followed by a brief discussion of alternate methods of producing cadmium sulfide solar cells. Finally, the present status of semiconductor photovoltaic theory applicable to cadmium sulfide solar cells is discussed. The second reports that a total of twenty-two evaporations have been performed, twelve being completed in the second quarter and yielding a total of 146 film samples ranging in size from 4 x 4 inches to 1 x 1 inch. Improvements in processing of samples are described and data are tabulated to show how the average conversion efficiency has been raised from one-half percent to two percent as more parameters are identified and controlled. Spectral transmission curves are given for evaporated CdS films showing the effect on optical transmission of the barrier layer formed by the cuprous oxide slurry.

5161
Cobbold, R.S.C. and Jackson, N.J. A SIMPLE SOLAR-CELL X-RAY MONITOR. J.Appl.Physiol., 18:209-210, Jan.1963.

An x-ray detector in which the basis of operation is a p-n junction, silicon solar cell is described. When such a cell is bombarded by x-rays, hole-electron pairs are liberated, some of which become separated by the electric field existing at the junction and are responsible for the generation of a voltage at the terminals of the device. The power available from the cell is proportional to the junction area, so that by using a large area cell the degree of subsequent amplification required can be minimized. The radiation damage threshold for silicon is ~ 0.3 Mev, so that deterioration of the cell characteristics for normal diagnostic operation of the x-ray tube presents no problem. Measurements of the cell characteristics before and after being subjected to a total radiation dose of 6000 r (at 100 kv) showed no detectable change. Since output from the cell used was inadequate, a transistor differential preamplifier was used. The x-ray monitor enables an output to be obtained that is a measure of the x-ray voltage and current. However, if an output is required that is independent of these factors, the amplifier can be followed by a simple transistor limiter to yield a constant output. The complete device can be assembled for less than \$25. (Nuclear Sci.Abs.,17:22025, Jly.15,1963).

5162
Columbia University, School of Engineering and Applied Science, New York, N.Y.
RADIATION MEASUREMENTS AND ENERGY CONVERSION, by M. Mitchner and R.A. Gross. 128p., Aug.1962. (NSF Grant 17701).

Theory, experimental apparatus, and experimental results are described for radiation measurements from the ultraviolet to the infrared (2000 A to 14,000 A), and energy conversion using semiconductor solar cells. This work is part of the National Science Foundation new laboratory-equipment-development project to improve laboratory demonstration experiments. (Sci.& Tech. Aerospace Rept., 1:N63-14942, June 8,1963).

5163
Eagle-Picher Co., Chemicals and Metals Division, Miami, Oklahoma.
VARIABLE ENERGY GAP DEVICE, May 1 - November 1, 1962, by L.E. Stone, G.N. Webb, and J.R. Musgrave. 2v., Aug.31, & Nov.30, 1962. (Q.Tech.Repts. 1 & 2) (Contract DA 36-039-sc-89106).

The general objective of this Contract is to investigate the variable band gap structure $\text{GaAs}_x\text{-GaP}_{1-x}$, having a gallium

phosphide surface grading to lower energy gap GaAs below the surface and containing a single junction.

5164
Great Britain, Royal Aircraft Establishment, Farnborough.
SOME FACTORS AFFECTING THE POWER AVAILABLE FROM A PANEL OF SOLAR CELLS, by R.R. Allan. 12p., Aug.1962. (Tech.Memo. SPACE 7).

Various possible ways of increasing the output power are examined, all of which involve accepting less incident radiation. The only practical scheme is to reflect quanta of wavelengths longer than the threshold for silicon (1.1μ) which might increase the output power by about 10%. Some further, but very small, increase might be achieved by reflecting high energy quanta of wavelengths shorter than about 0.35μ .

5165
Gummel, H.K., Smits, F.M. and Froiland, A.R.
A METHOD FOR TERRESTRIAL DETERMINATION OF SOLAR CELL SHORT CIRCUIT CURRENT UNDER OUTER SPACE SOLAR ILLUMINATION. IRE Wescon Convention Record, v.5, paper 7/3, 1961.

A procedure for predicting the outer space short circuit current of solar cells is presented. This procedure is similar to, and utilizes, the well established method of the Smithsonian Institution for the determination of the solar constant. The only absolute calibration used is that of a current meter. It is demonstrated that accuracies of 2% can be achieved with relative ease.

5166
Hanson, K.L. A SURVEY OF TECHNIQUES FOR PREDICTING THE SPACE OUTPUT OF PHOTO-VOLTAIC DEVICES. ASME Preprint Paper no. 62-WA-194. New York, American Society of Mechanical Engineers 1962. Prepublication Copy. 8p.

Major problem areas in predicting the output of photovoltaic power supplies for space vehicles are identified. The accuracy requirements are defined, and present methods of prediction are described and evaluated with respect to the requirements. It is concluded that refinement of present methods will be sufficient for future needs, but correlation and additional high-altitude experimentation are needed. (Nuclear Sci.Abs.,17:9104, Mar.31, 1963).

5167
Hoffman Electronics Corp., Hoffman Semiconductor Division, El Monte, Calif.
SOLAR ENERGY MEASUREMENT TECHNIQUES,

March 1961 - August 31, 1962, by Bernd Ross and D.B. Bickler. 165p., Jan. 1963. (Final Rept.) (ASD-TDR-62-882) (Contract AF 33(616)-7946).

This report describes a broad investigation which has been made of the subject of solar-cell measurements. A portable tester has been designed and built which will enable an operator to determine the output of a solar-cell power supply in space by analyzing output under conditions existing at either laboratory or field test sites. (STAR, 1:N63-16269, Jly.8, 1963).

5168

Kobayashi, M., Ishikawa, Y., and Hayashi, K. SOLAR BATTERIES FOR THE USE AS THE POWER SOURCE OF UNATTENDED U.H.F. REPEATERS. NEC Res. Devlpmt. no. 1, p.20-25, Oct. 1960.

The transmitter-receiver equipment, which has an average consumption of 4.5 W, is supplied by NiCd cells charged from solar batteries with a peak output of 70 W. (Electron. Tech. 39:A97, June 1962).

5169

Lamorte, M.F. SOLAR CELLS DESIGNED FOR OPERATION IN THE INNER REGIONS OF THE SOLAR SYSTEM. ARS Preprint no. 2568-62. New York, American Rocket Society, 1962. Prepublication Copy Sp.

Resistive losses in solar cells become quite large for high incident flux levels. A method is described, consisting in the addition of a grid-structure contact to the top surface of the cell, for reducing these losses in regions where the incident intensity is 1 w/cm² or more. The grid dimensions are determined by the anticipated flux level. This method is shown to be capable of increasing the efficiency of a solar cell, at 1 w/cm² incident intensity, from about 50% to about 97% of the theoretical power output. (Nuclear Sci. Abs., 17:9115, Mar. 31, 1963).

5170

Loferski, J.J. RECENT RESEARCH ON PHOTO-VOLTAIC SOLAR ENERGY CONVERTERS. Inst. Elec. & Electr. Engrs. Proc., 51:667-674, May 1963.

This paper contains a review of recent work on photovoltaic cells fabricated from semiconductors other than silicon; the effects of radiation on silicon n/p and p/n cells, and gallium arsenide p/n cells; and thin film photovoltaic cells.

5171

McClelland, D.H. DEVELOPMENT OF A CON-CENTRATING PHOTOVOLTAIC POWER GENERATOR. ARS Preprint no. 2497-62. New York, American Rocket Society, 1962. Pre-publication Copy. 13p.

The power output of a solar cell panel can be increased by the use of auxiliary reflectors or other types of optical concentrating devices. The use of concentration with solar cell systems is discussed and is contrasted with the situation for high temperature solar power converters involving heat engines. Theoretical performance and weight estimates are given for various configurations of concentrating photovoltaic systems. Design and selection of components and materials are discussed, including cells, cell panels, concentrators, filters, and coatings. A 50-watt ground test model is described and experimental performance results are given. (Nuclear Sci. Abs., 17:9125, Mar. 31, 1963).

5172

North, N.B. PREDICTING THE PERFORMANCE OF SOLAR CELLS IN SPACE. Space/Aero. 37: 77-79, 81, 83, June 1962.

Relationships are reviewed between the essential parameters of solar-cell performance and the changes in cell temperature, incident illumination, and solar-energy spectrum as one goes from lab conditions to space. A method is given for constructing nomographs for conversions from sea level characteristics to determine cell performance in space-craft.

5173

Motorola Semiconductor Products, Inc., Phoenix, Ariz. RESEARCH AND DEVELOPMENT FOR SURFACE PROTECTION FOR SILICON DEVICES, June 15 - September 14, 1962, by H.W. Cooner, and others. 33p., Oct. 1962. (SR 3) (AFCRL-63-21) (Contract AF 19(604)-8358).

Work during the quarter was directed toward chemical surface treatments and their effects on breakdown voltages, studies on the formation of thermal oxides of silicon, and the electrical evaluation of passivating coatings on silicon.

5174

Radio Corp. of America, Defense Electronic Products, Princeton, N.J. SOLAR CELL ARRAY OPTIMIZATION, October 1961 - June 1962 on Photostatic Energy Conversion Techniques. 94p., illus., Dec. 1962. (Rept. 3 (final)) (Contract AF 33(616)-7415) (ASD-TR 61-11, vol. 3) (AD-295 558).

Research of photovoltaic materials has shown the feasibility of fabricating cells with the p-n junction far removed from the surface by means of heterogeneous cell formation, of fabricating cells by

the silk-screen technique of applying the active material, and also has shown that CdS polycrystalline cells are more resistant to 1.5 Mev protons and to 0.8 Mev electrons than are n-on-p silicon cells. Five cells of small area were fabricated and demonstrated the feasibility of making cells from converted CdS layers. The maximum efficiency of these cells was about 0.7%. (TAB U63-2-3:17-18, May 1, 1963).

5175

Radio Corp. of America, David Sarnoff Research Center, Princeton, N.J.
THIN FILM LARGE AREA PHOTOVOLTAIC SOLAR ENERGY CONVERTER, October 1, 1962 - March 31, 1963, by S.G. Ellis and others. 2v., Dec. 31, 1962 & March 31, 1963. (Q. Repts. 1 & 2) (Contract NAS7-202).

In the first report methods are described for the production of n-type and p-type films of gallium arsenide on tungsten and molybdenum sheet. During the second quarter work was concentrated on the improvement and understanding of junction structures in gallium arsenide films. Open-circuit voltages of up to 0.7 volts have been achieved on small areas. Short circuit-currents of 1 ma have been observed on larger area units. Better control of the growth of gallium phosphide films has been achieved. They show semiconducting properties, but continue to be n-type.

5176

Rappaport, P., Loferski, J.J., and Linder, E.G.
THE ELECTRON-VOLTAIC EFFECT IN GERMANIUM AND SILICON P-N JUNCTIONS. RCA Review, 17:100-128, Mar. 1956.

The electron voltaic effect is analyzed to show how the properties of the semiconductor (energy gap, minority carrier diffusion length, surface recombination velocity and the temperature) and of the impinging electrons (average energy, density, maximum energy) affect the usefulness of the electron-voltaic effect as a means of converting the energy of beta rays into electricity. Experiments on germanium and silicon p-n junctions are described.

5177

Spectrolab, North Hollywood, Calif.
INVESTIGATION OF OPTICAL COATINGS FOR SOLAR CELLS, January 1 - May 30, 1961, by A.E. Mann. 216p., illus., May 30, 1961. (Final Rept.) (Contract DA 36-039-sc-85284).

This report is concerned with the study of spectrally selective filters for silicon solar cells used in auxiliary power systems for space vehicles. The effect of filters on array efficiency is

evaluated and optimum specifications are determined for the various classes of coatings. A survey is made of state-of-the-art coatings with respect to physical properties and performance under various environmental conditions.

5178

Spectrolab, North Hollywood, Calif.
INVESTIGATION OF OPTICAL COATINGS FOR SOLAR CELLS, July 1 - December 31, 1961, by F.E. Fuller and R.J. Romagnoli. 2v., Jan. 1962 & Sept. 10, 1962. (Tech. Summary Rept. 2 & Final Rept.) (Contract DA-36-039-sc-87449).

Performance analyses are made of silicon cell solar power systems using radiation concentration and filtering. The elementary conditions of system design for optimum performance of such systems are established and a plan is outlined for construction of a prototype system. Specifications for suitable mirror filters are formulated. Experimental mirror filters are fabricated and data obtained to evaluate the effect of such filters on solar power system performance.

5179

Tallent, R.J. and Oman, H. SOLAR-CELL PERFORMANCE WITH CONCENTRATED SUNLIGHT. Appl. & Indus. (AIEE Trans. Pt. II) no. 59, p. 30-33, Mar. 1962.

A system employing an Archimedes array of six flat plate-glass mirrors was adopted as a concentrator to test the performance of solar cells in high intensity sunlight. Test results are given. (JPL Astron. Info. Survey 5:50, 889, Apr. 1962).

5180

Wayne State University, Detroit, Mich.
THE PROPERTIES OF ELECTROLYTICALLY PREPARED CUPROUS OXIDE AND THE EFFECT OF SULFIDING ON THE PROPERTIES OF CUPROUS OXIDE PHOTOVOLTAIC CELLS, by R.S. Toth, Nicolaos Economou, and Dan Trivich. 46p., illus., Apr. 30, 1960. (Tech. Rept. 3) (AFOSR TN 60-725) (Contract AF 18(600)-481) (AD-240 470).

A method of preparing thin films of Cu_2O by an electrodeposition technique has been developed for the study of these films. The basic properties of these films differ only slightly from results on thermally prepared Cu_2O except that water has been found to be incorporated in the deposit. This can be eliminated by annealing at a proper temperature. The sulfide treatment of the Cu_2O surface of a copper oxide photovoltaic cell has been found to affect only slightly the output of thermally prepared cells.

Sulfiding on electrolytically prepared cells was found to increase the power output by a factor of 10^2 to 10^3 . The reason for the increased output is the lowering of the series resistance of the cells by the sulfide layer and a consequent increase in the efficiency of collection of the carriers produced at the photosensitive junction. This effect is larger for high resistance electrolytic Cu_2O than for the lower resistance thermal Cu_2O . The effect of the sulfiding treatment on the photovoltaic output can be maximized by proper selection of sulfide layer thickness and geometry of the top contact.

5181

Wolf, M. DRIFT FIELDS IN PHOTOVOLTAIC SOLAR ENERGY CONVERTER CELLS. Inst.Elec.& Electr.Engrs.Proc., 51:674-693, May 1963.

A theoretical investigation into the effects of electrostatic drift fields in the diffused region and in the base region of photovoltaic solar energy converter cells has been carried out. Expressions for a single-layer and a two-layer model for each of the two regions have been evolved. These expressions have been applied to the study of the semiconductor parameters in the diffused region with and without drift field. The applicability of surface recombination velocities in the normal expected range has been established, and the introduction of a drift field in the diffused region has been found to necessitate only a decrease of the minority carrier lifetime by a factor of 4.4 compared to the field free case. Further, a study of the effect of drift fields in the base region can considerably reduce the radiation damage rate and increase the useful life of solar cells in the Van Allen belt environments by about an order of magnitude over that of present "n on p" radiation resistant silicon solar cells. Various configurations of the drift fields in the base layer, including arrangement in one and two layers with drift field, were investigated in order to find the most promising layout for the achievement of the slowest degradation rates, and to lay the groundwork for future device design work. Data for the more promising configurations are given.

5. Systems

5182

Anderson, R.E.D., Meszaros, C.W. and Ciccolella, D.F. THE SATELLITE POWER SYSTEM. Bell Labs.Rec., 41:143-150, Apr.1963.

The power system of the Telstar satellite combines the energy-converting feature of solar cells with the energy-storing capability of rechargeable batteries.

5183

Anderson, R.E.D., Hake, E.A. and Feldman, David. TELSTAR SATELLITE POWER SYSTEM. ARS Preprint no. 2503-62. New York, American Rocket Society, 1962. 21p.

In addition to the communications receiver and transmitter, Telstar contains several radiation experiments and a number of subsystems for acquisition and control. The power drains for the various loads are operated on different duty cycles, reaching a peak load of about 24 watts. The satellite power system design is severely constrained by requirements of long life (one to two years), minimum size and weight, and extreme radiation exposure. A solar cell, nickel-cadmium battery power system is selected, utilizing silicon n-on-p solar cells and special nickel-cadmium cells. Power conversion circuitry is designed to perform at maximum possible efficiency. The battery bus voltage variations are regulated to a common minus 16-volt bus by means of a solid-state regulator. High voltages for the traveling wave tube are obtained from this bus by means of a solid-state converter circuit. In view of the space and weight limitations, emphasis is placed on extremely reliable components and circuitry rather than on redundant systems. (Nuclear Sci.Abs.,17:9118, Mar.31,1963).

5184

Armour Research Foundation, Chicago, Ill. A NUCLEAR-PHOTON ENERGY CONVERSION STUDY, July 1 - December 31, 1962, by H.V. Watts and S. Nudelman. 2v., Oct.9, 1962 & Jan.15, 1963. (Q.Tech.Repts. 2 & 3) (Rept. ARF 1214-TR 2 & 3) (Contract AF 33(657)-8527) (AD-286 024).

During the second quarter the characteristics of silicon p-n junction photovoltaic cells were experimentally studied to determine their operational properties for use in a nuclear-photon energy conversion system. During the third quarter the temperature dependence and phosphor thickness dependence on the luminescence output was studied for several phosphors which appear promising for use in a nuclear-photon energy conversion system. (TAB U63-1-2:96, Jan.15, 1963 & TAB U63-2-3:60, May 1, 1963).

5185

Bomberger, D.C. and others. THE SPACECRAFT POWER SUPPLY SYSTEM. Bell Sys.Tech.J., 42:943-972, Jly.1963.

The power supply system in the Telstar spacecraft consists of a solar cell plant to convert solar radiation to electrical

energy when the satellite is illuminated by the sun, a 19-cell nickel-cadmium battery to store energy, and a regulation circuit to supply constant output voltages over a wide variation in input voltages. Additionally, the power supply system provides switching to conserve power and allow battery recharging during periods between communications experiments.

5186

Brown, W.L. and others. THE SPACECRAFT RADIATION EXPERIMENTS. Bell Sys.Tech.J., 42:899-941, Jly.1963.

The radiation experiments on the Telstar spacecraft were designed to measure the electron and proton particle distributions in the region of space explored by the satellite orbit and to give information on the integral semiconductor radiation damage produced by these particles. A solar aspect experiment is included with the radiation experiments because of its direct importance to solar cell damage results. The design and the hardware for these experiments are described in the present paper. Results of the experiments are included in a companion paper in this issue.

5187

Chance Vought Aircraft, Inc., Dallas, Texas. APOLLO SOLAR PHOTOVOLTAIC POWER SYSTEM. Jly.10,1962. (Tech.Rept. 00.63).

The feasibility of using solar cells for supplying power for the Apollo vehicle was studied and the results indicate that solar cells are the lightest and most reliable method (within the present or near-future state of the art) of producing electrical power for the anticipated Apollo mission. A preliminary design of a photovoltaic power system is presented. Structures, thermal characteristics, and electrical power are discussed in detail. The system is designed to produce an average power of 2.2 kw. The solar array consists of 276,480 cells which are mounted on 16 separate petals attached to the service module. Orientation is achieved by positioning the entire vehicle. The estimated weight is 647 lb. (Astron. Info.Abs.,6:61,258, Nov.1962).

5188

Cherry, W.R. SOLAR CELLS AND THE APPLICATIONS ENGINEER. Astron. and Aerospace Eng., 1:54-57, May 1963.

Knowledge of cell characteristics and performance having recently become much more precise, the engineer can now treat system designs with greater skill and efficiency.

5189

Doshay, I. and Emrich, W.F. RELIABLE SOLAR POWER SUPPLY DESIGN. SAE Preprint 580C. New York, Society of Automotive Engineers, Inc. 1962. Prepublication Copy. 7p.

An analysis is made of a power supply system design for an orbiting spacecraft. Two designs are developed for a highly reliable solar power supply, both of which encompass redundant components. Reliability estimates are developed. Conclusions are reached on the alternative with the most advantageous performance and reliability characteristics. Details of the improvement in reliability resulting from various techniques in design are given, as are the calculations involved. The number of solar cell modules required to satisfy power-usage requirements at a given reliability level is also developed; this includes consideration of the effects of meteoroid bombardment and Van Allen Radiation. (Nuclear Sci.Abs.,17:9105, Mar.31,1963).

5190

Smith, K.D. and others. THE SOLAR CELLS AND THEIR MOUNTING. Bell Sys.Tech.J., 42:1765-1816, Jly.1963.

Objectives in development of the solar plant for the Telstar spacecraft were to provide a power source which would withstand launching stresses and the expected space environment, with optimum end-of-life performance. The spacecraft solar cells use the n-on-p structure, in preference to conventional p-on-n structure, to obtain a factor of 3 to 10 increased life expectancy. Response to light in the 0.4 to 0.7 micron range is enhanced by using a thin n-layer (about 0.5 micron) and an antireflection coating with minimum reflectance at 0.55 micron wavelength. Early estimates of electron and proton fluxes in the satellite orbit showed that even the best cells would not give sufficient life without radiation shielding. Therefore the cells are protected against electrons of energy up to 1 Mev by 0.3 gm/cm² sapphire cover plates. The cell mountings are designed to withstand peak vibration stresses of 200 g and repeated temperature cycles from +65°C to -100°C. The 3600-cell solar power plant is composed of 300 twelve-cell groups of cm X 2 cm cells, yielding a nominal initial power of 14 watts at 28 volts for any spin-axis orientation relative to the sun. Telemetry information on performance of the solar plant indicates degradation of the shielded solar cells equal to that measured in the laboratory on unshielded cells with a

1-Mev normal incidence flux of 6×10^{12} electrons/(cm² day). From this comparison it is estimated that the plant will degrade to 68 per cent of its initial output after two years in orbit.

5191

Yagerhofer, F.C. THE DESIGN OF THE UNITED KINGDOM SCIENTIFIC SATELLITE SOLAR POWER SYSTEM. American Rocket Society, Space Power Systems Conf., Sept. 25-28, 1962, 27p., Santa Monica, Calif., 1962. (ARS Paper 2498-62).

A description is presented of the electrical power system used in the International Ionospheric Satellite, S-51, jointly sponsored by the United Kingdom and the United States. For this cooperative effort, the British supplied the scientific experimental equipment while the Goddard Space Flight Center contributed the payload electronic instrumentation, the power supply, the satellite structure, and the ground station equipment. The satellite employs a flat solar cell configuration rather than the conventional shingled-modular type and utilizes an electrochemical cell as a one-year payload cutoff timer. Of particular note are the techniques used to obtain proper charge rate into the rechargeable nickel-cadmium batteries, the novel standby battery with automatic switching circuitry and the precision static dc to dc conversion equipment. (STAR, 1: 13, Jan. 8, 1963).

5192

Zoutendyk, J.A. SOLAR-CELL POWER SYSTEMS TESTING. American Rocket Society Space Power Systems Conf., Sept. 25-28, 1962, 45p., Santa Monica, Calif. 1962. (ARS Paper 2504-62).

The use of high-altitude balloon flights in determining the earth space short-circuit current of solar cells is discussed. The application of balloon flight measurements to the determination of solar-cell spectral correction factors is outlined. (STAR, 1:13, Jan. 8, 1963).

B. Photoemissive

5193

Ames, I. and Christensen, R.L. ANOMALOUS PHOTOELECTRIC EMISSION FROM NICKEL. IBM J. Res. & Devlpmt., 7:34-39, Jan. 1963.

The photoelectric emission from a nickel ribbon has been observed as a function of temperature from 25° to 760°C, over a wavelength range from 2250 to 2530 Å, qualitatively confirming and extending Cardwell's earlier work. The yield increases with temperature at all wavelengths, with an upward bulge near the Curie point. Fowler-Dubridge analyses of the emission

from the front face of the ribbon, which is found to contain mainly (111) facets after extensive outgassing, yield values of the work function ranging from about 5.07 eV at 25°C to about 5.20 eV at 760°C. Behavior below the Curie point may be consistent with the magnetization-squared dependence recently suggested by Wonsowski, et al.

5194

Blet-Talbot, Dhetty. THERMODYNAMIC STUDY OF SELENIUM PHOTOCELLS BY DIFFERENTIAL THERMAL ANALYSIS. Publ. Sci. Techn. Minist. Air (France), 65p., 1962. (TN 106).

Differential thermal analysis of a Se photocell was carried out with an apparatus comprising two identical photocells, one acting as control, with thermocouples connected in opposition to a circuit of varying external resistance. The temperature difference between the cells was thus measured, using an amplifying galvanometer. It was found that there is a critical value of the external circuit resistance, above which, the photocell cooled to a temperature equilibrium, and, below which, its temperature increases. It is concluded that the action of light (from which infra-red radiation has been eliminated) has three effects, (1) to heat the cell, (2) to produce the photo-electric current, and (3) to modify the structure of the barrier-layer. (Inst. Metals J., 91:76, Oct. 1962 & Metallurgical Abs., 30:76, 1962).

5195

Jeppesen, M.A. PHOTOELECTRIC EMITTANCE FROM GOLD FILMS AS A FUNCTION OF FILM THICKNESS. JOSA, 52:1081, Sept. 1962.

The note presents measurements of the photoelectric emittance from different thicknesses of evaporated gold films.

5196

Minnesota University, Minneapolis, Minn. RESEARCH ON PHOTOEMISSION, December 16, 1961 - December 15, 1962, by W.T. Peria. 112p., illus., Mar. 1963. (ASD-TDR-63-340) (Final Rept.) (Contract AF 33(657)-8041).

Techniques used to obtain high vacua, to provide clean surfaces, to deposit Na on these surfaces and to measure their work functions are described. A method used to fabricate hemispherical grids is also included. Work function, electron diffraction and secondary emission studies of sodium-covered germanium are presented. Preparations for a field-emission study of the same system are described. In the study of the compound Na₃Sb, preliminary data on the details of film

formation have been obtained and the inert atmosphere facility for the preparation of the bulk material has been completed. A brief description of the apparatus to be used in the study of anomalous photo-voltaic effects in Ge films is given.

5197

National Research Corp., Cambridge, Mass.
DEVELOPMENT OF A PHOTOEMISSIVE SOLAR ENERGY CONVERTER, June 1961 - May 1962, by Peter Fowler, L.R. Koller, and M.P. Schrank. (Tech. Documentary Rept. (Final)) (Contract AF 33(616)-8415) (ASD-TDR-62-600) (AD-288 650).

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 on one side with a photoemitter and on the other with a low work function conductor. 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 used 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. The observed power conversion efficiency was of the order of $10^{-4}\%$. There was no correlation between converter efficiency and geometrical parameters. Measurements of spectral response showed good agreement with published values for Cs_3Sb . Life tests did not show any deleterious effects due to the evaporation which would be expected to occur in space. Calculation of rates of evaporation indicated a life of 0.8 year at $27^\circ C$ and 70 years at $0^\circ C$. The effect of oblique incidence was found by experiment to be a decrease in output at a lower rate with respect to angle of incidence than would be predicted by the cosine law. It was found that $Cs-Sb$ surfaces can be formed at temperatures considerably below $120^\circ C$ by a co-deposition of cesium and antimony. (STAR, 1:92, Jan. 23, 1963).

5198

Semiletov, S.A. CONCERNING THE HIGH VOLTAGE PHOTO-EMF IN THIN FILMS OF CADMIUM TELLURIDE. Fiz. Tverdogo Tela, 4: 1241-1246, May 1962.

In Russian. Transl. in Soviet Phys. Solid State, 4:909-913, November 1962.

As a result of an electron-diffraction investigation of vacuum-deposited thin films of cadmium telluride, the following structural properties have been established: 1) well defined crystallite orientation associated with material in the molecular

beam arriving at the growing crystal from a single direction; 2) the formation in the film of crystallites of variable structure - cubic and hexagonal (12H poly-type); 3) the formation within the crystallites of the hexagonal phase of a large number of stacking faults. An attempt is made to associate the generation of the high voltage emf, which is produced when the CdTe film is illuminated, with these structural properties.

5199

U.S. Air Force, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio.
PHOTOEMISSION STUDIES, by W.T. Peria. 72p., illus., Mar. 1962. (ASD-TDR-62-231) (Contract AF 33(616)-6455).

Experimental results dealing with the influence of Na overlayers on the photoemission and work function of Ge and Si crystals are presented. For Ge a model is presented which predicts the observed dependence of photoelectric threshold on coverage. For Si the simultaneous measurement of photoelectric threshold and work function has allowed inferences regarding the source of photoelectrons in the surface region, and the nature and degree of surface band bending. Methods of preparing bulk Na_3Sb are discussed, and a glovebox facility required for further study is described. Progress on the study of Na_3Sb films is summarized, and a tube for film composition control is described. A calculation of the potential variation in the surface space-charge region of an intrinsic semiconductor is given.

5200

Westinghouse Electric Corp., Electronic Tube Division, Elmira, N.Y.
HIGH TEMPERATURE PHOTOELECTRIC TECHNIQUES AND MATERIALS, by V.J. Santilli, H. Shabanowitz, and Z. Szepesi. 60p., figs., Jly. 1962. (Contract N0bsr-77556).

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 $120^\circ C$. A bi-alkali (Na-K-Sl) photoemissive cathode was developed which can withstand elevated temperatures in excess of $120^\circ C$ for an extended period of time combined with high sensitivity and uniformity over the useful photocathode area. Photoconductor cells were prepared and measured for sensitivity spectral response and resistivity.

V. MAGNETOHYDRODYNAMICS

A. General Information

5201

Bienstock, D. and others. EXPERIMENTAL UNIT FOR STUDY OF HIGH-TEMPERATURE COMBUSTION OF COAL FOR MHD POWER GENERATION. ASME Preprint Paper No. 62-WA-147. New York, American Society of Mechanical Engineers, 8p., Prepublication copy. 1962.

An experimental cyclone furnace for studying high-temperature combustion of pulverized coal with oxygen-enriched air and seeded with alkaline salts is described. Temperatures of 4000°F and higher will be attempted. The objectives of the study are to determine the nature and disposition of the slag deposits downstream from the furnace, extent of corrosion of various boiler-tube materials at wall temperatures of 300 to 1700°F on exposure to the highly alkaline products of combustion, and the distribution and possible recovery of the seeding material. (Nuclear Sci. Abs., 17:8302, Mar. 31, 1963).

5202

Brogan, T.R. and others. PROGRESS IN MHD POWER GENERATION. Symposium on the Engineering Aspects of Magnetohydrodynamics, 2nd, Proceedings, Philadelphia, Pa., Mar. 9, 10, 1961. In Engineering Aspects of Magnetohydrodynamics, New York, Columbia University Press, 1962, p. 147-165.

Review of progress in MHD power generation at the Avco-Everett Research Laboratory. The work is part of a program to determine the suitability of MHD for central-station power generation. Detailed consideration is given to the oxygen cycle and the electrical conductivity of seeded combustion products. (Intern. Aerospace Abs., 3: A63-14033, May 19, 1963).

5203

Brown, J.J.W. SOME ASPECTS OF MHD POWER PLANT ECONOMICS. Presented at Third Symposium on the Engineering Aspects of Magnetohydrodynamics, University of Rochester, N.Y., Mar. 28-29, 1962, 23p.

The results of recent research and engineering, including a high-strength superconducting magnet, have been utilized to design a 500-megawatt MHD-steam turbine combined-cycle electric-power generating plant. Wherever possible, presently available materials and standard practices have been utilized to give close approximation to such a plant as it might be designed and constructed in the near future. Performance calculations show the incentive behind the present efforts being expended in anticipation of the solution of the remaining problems. The capital

costs presented for such a plant, while not discouraging, include areas of appreciable ignorance. The actual costs in these areas require better definition to confirm the attractiveness of the MHD principle for the central station application. The overall economics of MHD-steam turbine combined-cycle power-generating plants is compared with the moving target of today's cycles: fossil-fueled steam turbine, fossil-fueled steam and gas turbine combined cycle, and finally, nuclear-fueled steam turbine. This comparison emphasizes the urgency of successfully solving the present MHD problem areas if the MHD Principle is to find wide use in electric utility central stations. (Sci. & Tech. Aerospace Rept., 1:N63-14318, May 23, 1963).

5204

Clark, R.B., Swift-Hook, D.T. and Wright, J.K. THE PROSPECTS FOR ALTERNATING CURRENT MAGNETOHYDRODYNAMIC POWER GENERATION. Brit. J. Appl. Phys., 14:10-15, Jan. 1963).

The various possible systems of a.c. magnetohydrodynamic power generation using electrodes or inductive coupling with stationary or alternating magnetic fields are examined and compared with the d.c. case. It is shown that with gas temperatures below 3000°K and an alternating magnetic field the cost of coil driving equipment is likely to be prohibitive, whilst theoretical and experimental evidence suggests that with inductive coupling and a steady magnetic field the power densities are probably too low to be of interest. The only possibility remaining is the generator with pulsed conductivity where the current is collected on electrodes and the considerable difficulties peculiar to this method are discussed.

5205

Dzung, L.S. HALL EFFECT AND END LOOP LOSSES OF MAGNETOHYDRODYNAMIC GENERATORS. Preprint Paper 2, Session IV. Prepublication Copy. 12p. (Brown Boveri and Co. Ltd., Baden, Switzerland).

Eddy-current or end-loop losses in a magnetohydrodynamic generator are studied, taking the Hall effect into consideration. Equations are derived for a steady two-dimensional electric field in a plane perpendicular to the applied magnetic field of a constant-area duct, assuming that the magnetic Reynolds number is small. By use of the derived equations, the region around the electrode ends of the MHD generator channel is investigated. The end losses are found to increase very rapidly with β , the ratio of the Hall voltage to the ohmic voltage, if continuous electrodes are used. Electrode

segmentation increases the power density and reduces the relative end losses. Graphs of current paths and potential lines are presented for continuous electrodes with and without Hall effects. (Nuclear Sci. Abs., 17:9087, Mar. 31, 1963).

5206

General Electric Co., Space Sciences Laboratory, Philadelphia, Pa.
RESEARCH IN MHD POWER GENERATION, June 15, 1962 - October 31, 1963, by G.W. Sutton. 4p., June 30, 1963. (Q.Rept.4) (Contract Nonr-3867(00)).

The major progress made during the last quarter was the verification of magnetically induced ionization by means of the cinespectrograph, the calibration of the conductivity probe and the initiation of low temperature experiments in Neon-Argon mixtures. In addition a study was initiated to determine the effect of the Lorentz body force on magnetically induced ionization.

5207

General Electric Co., Space Sciences Laboratory, Missile and Space Division, Philadelphia, Pa.
THE TRANSIENT INTERACTION OF A TRANSVERSE MAGNETIC FIELD WITH FLUID IN COUETTE FLOW, by F.H. Shair. 43p., figs., Feb. 1963. (Rept. R63SD16) (Contract AF 49(638)-1092).

Solutions are given to MHD Couette flow systems with increasing complexity. Finally the problem of Couette flow with an oscillating transverse magnetic field is solved. The solution is obtained by means of a transformation which demonstrates the similarity between a set of transient MHD systems and a set of transient heat conduction systems. Under various conditions, the solution of the oscillating MHD system reduces to various solutions of simpler systems. Although the Couette flow system was chosen for simplicity, the results of analysis are useful for the determination of: 1) The start-up time interval for both MHD-AC and MHD DC systems. 2) The steady state distortion in the alternating current output for MHD-AC systems.

5208

George, D.W. and Messerle, H.K. POWER GENERATION FROM IONIZED GASES. Elect.Mech. Engng.Trans., Australia, 4:1-6, May 1962.

Authors briefly review problems associated with direct conversion of kinetic energy of an ionized gas into electrical power in a magnetogasdynamic (MGD) generator. These include choking, ionized gas production, losses, and materials. The Hall effect and its suppression or utilization and non-equilibrium, low temperature, ionization are only noted in passing. Discussion following paper contains interesting

description of microscopic behavior of gas during conversion. (Appl.Mech.Rev., 16:404, May 1963).

5209

Great Britain, Aeronautical Research Council, London.
COMBUSTION PROBLEMS IN MHD POWER GENERATION, by I.A. McGrath. 11p., Sept. 13, 1962. (A.R.C. 24,016).

Adiabatic expansion through a converging-diverging nozzle causes a temperature drop with increase in gas velocity and as initial temperature is limited by combustion the temperature falls too low for appreciable ionization thus presenting a problem in the open, classical cycle MHD system. Three methods for overcoming the difficulty are outlined: (1) use of a striated layer system requiring two fluids, (2) a pulsating combustion system making use of the fact that combustion at constant volume gives a pressure rise which can be converted directly into velocity, and (3) a continuous shock tube system.

5210

Gunson, W.E. and others. MHD POWER CONVERSION. Nucleonics, 21:43-47, Jly. 1963.

Although still far from being a reality, the direct conversion of heat into electricity through interaction of the working fluid with a magnetic field now, because of recent developments, warrants serious attention.

5211

Hamilton, Stuart. MHD FOR POWER STATIONS. Symposium on the Engineering Aspects of Magnetohydrodynamics, 2nd, Proceedings, Philadelphia, Pa., Mar. 9, 10, 1961. In Engineering Aspects of Magnetohydrodynamics, New York, Columbia University Press, 1962, p.211-227, USAF-supported research.

Discussion of methods of applying MHD to smaller power plants, particularly to peak-load stations. An approach toward optimizing a combined MHD and gas-turbine power plant and a method of generating alternating current are presented. An analytic method is proposed for establishing the values of total pressure level and other flow variables which result in maximum MHD generator output per unit size. Several gas-turbine cycles are proposed to reduce cost of the MHD power plants for peak-load operations. (Intern. Aerospace Abs., 3:A63-14036, May 1, 1963).

5212

Hepworth, M.A. and Arthur, G. CERAMIC MATERIALS FOR M.P.D. POWER GENERATION. Preprint Paper 39, Session I, Pre-

publication Copy. 12p. (Thermal Syndicate Ltd., Wallsend, Eng.).

Various oxides were heated in Ta and W crucibles at temperatures up to 2,200°C, and the weight losses were measured. From these results and published data, it was concluded that W electrodes and HfO₂ or ThO₂ insulators could be used in a closed-cycle magnetoplasmadynamic generator. For an open-cycle generator, electrodes of "doped" ZrO₂ and insulators of SrO.ZrO₂, HfO₂, or ThO₂ would be possible. (Nuclear Sci.Abs.,17:9073, Mar.31,1963).

5213

LeBouc, F. and Ricateau, P. PRODUCTION OF ELECTRICITY USING MAGNETOHYDRODYNAMIC METHODS. Onde Elec., 42:482-495, June 1962.

In French. Presents a review paper, which starts with the fundamental equations, and develops the concept of conductivity in a plasma. A number of different methods of utilizing a moving plasma in the generation of electricity, including the use of the Hall effect are considered, and the use of small additions of alkali metals to increase the conductivity is discussed. The specific power produced as a function of temperature is one of the main factors with which the designer is concerned. Using established techniques, a temperature of 2500°K is required in order to attain attractively high efficiencies, but this imposes requirements on the materials for the combustion chamber which can barely be met at the present time. However some improvements in ceramic materials are confidently anticipated, to lead to higher plasma conductivities at lower temperatures, eventually possibly as low as 1500°K. (Elec.Eng.Abs.,66:73, Jan.1963).

5214

McCune, J.E. MAGNETOHYDRODYNAMIC ENERGY CONVERSION. Phys.Today, 16:44-54, Apr.1963.

This paper discusses the techniques, advantages, and future prospects of generating electrical power by magnetohydrodynamical means.

5215

Marquis, D.H. POTENTIAL INDUSTRIAL APPLICATIONS OF MAGNETOHYDRODYNAMICS. Inst.Elec.& Electr.Engrs.Trans., IE-10: 85-90, May 1963.

Magnetohydrodynamic power generation has been presented as limited in application to large generating stations but offering the promise of reduced power cost to be achieved through heat rate improvement. The potential for industrial application will be broadened if generators can be made attractive in smaller ratings, if generating cost can be reduced, and if the generator

can be made lighter and more compact. The scaling considerations which make large output more favorable will be reviewed and the possibility of devising attractive MID generators in smaller ratings will be explored.

5216

Massachusetts Institute of Technology, Research Laboratory of Electronics, Cambridge, Mass. QUARTERLY PROGRESS REPORT NO. 67. 283p., Oct.15,1962. (p.95-114) (Contracts DA36-039-sc-78108, DA-SIG-36-039-G14, AF 19(604)-5992, and AF 33(616)-7624).

Chapter IX reports research on plasma magnetohydrodynamics and energy conversion.

5217

Massachusetts Institute of Technology, Research Laboratory of Electronics, Cambridge, Mass. QUARTERLY PROGRESS REPORT NO. 69. 265p., Apr.15,1963. (Contract DA 36-039-sc-78108).

Chapter 8 considers research on plasma magnetohydrodynamics and energy conversion.

5218

Massachusetts Institute of Technology, Aerophysics Laboratory, Cambridge, Mass. THE USE OF AN ELECTROLYTE IN MODEL MID POWER GENERATORS, by E.E. Covert and D.T. Nowlan. 18p., illus., May 1962. (Tech.Rept. 37) (Contract AF 49(638)-900) (AD-289 688).

The problems associated with the use of electrolytes in scale models for tests of MID Generators are discussed. It is concluded that the Hartmann number and fluid Reynolds number must be matched between the model and the full scale device. (TAB U63-1-5:22, Mar.1,1963).

5219

Milewski, J. and Smigielski, J. SOME EXPERIMENTAL RESULTS CONCERNING THE POSSIBILITY OF DIRECT CONVERSION OF THERMAL ENERGY INTO ELECTRICITY WITH M-G-D METHODS. Acad.Polon.Sci.Bull. Ser.Sci.Techniques, 10:429-434, 1962.

Brief outline of a research program the objective of which is the designing and constructing of MGD devices for direct conversion of heat into electricity. The P.1 plasmatron, initially developed from this program, and its improved version, the P.3, are described, as are the MGD generators, G.1 and G.2, designed to supplement these plasmatrons. Photographs and design diagrams of these devices are presented. Experimental research aimed at the analysis of generator operation is noted, as well as the investigation of the conductance

of thermally ionized gases, the flow of a conducting fluid in a magnetic field, and the various phenomena associated with the use of electrodes. (Intern. Aerospace Abs.,3:A63-13916, May 1,1963).

5220

Picquendar, J.E., Dieulesaint, Eugene and Defranould, Philippe. CHARACTERISTICS OF SPACE-CHARGE THERMOELECTRIC CONVERTERS COMPENSATED BY A CESIUM PLASMA. Acad. Sci.Paris. Compt.Rend., 256:103-105, 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. (Nuclear Sci.Abs.,17:16186, May 31,1963).

5221

Raytheon Co., Super-Power Programs Laboratory, Burlington, Mass.
INVESTIGATION OF MHD POWER GENERATION Vol. II. INTEGRATION WITH CROSSED-FIELD MICROWAVE DEVICES, by W.C. Brown. 147p., June 30,1962. (PT-335) (RADC-TDR-62-464) (Contract AF 30(602)-2487).

A study of crossed-field microwave devices for the generation of very large amounts of microwave power in conjunction with the use of a magnetohydrodynamic generator as a source of primary power has been important in establishing better understanding of the power potentialities of the Electromagnetic Amplifying Lens.

5222

Virginia University, Department of Aerospace Engineering, School of Engineering and Applied Science, Charlottesville, Va.
MAGNETOHYDRODYNAMIC POWER GENERATION - ITS PRINCIPLES AND PROBLEMS, by W.C. Moffatt. 24p., Jan.1963. (Project Squid, TR) (MIT-29-P) (Contract Nonr-3623(00)).

The increasing reliance on thermal plants for the production of electrical power has prompted a growing interest in unconventional power generation techniques. One of the most promising of these, and one which is the focus of a considerable research and development effort, is magnetohydrodynamics. This scheme envisions the generation of power by passing an electrically conducting fluid, usually a high temperature gas, through transverse electric and magnetic fields. In its simplest form, this type of machine is exactly analogous to the conventional generator except that a moving fluid conductor is substituted for a rotating wire-wound armature. In this paper the

basic operating principles of an MHD generator are presented, and some of the major problems yet to be overcome before such devices become practical realities are described. Typical power plant arrangements incorporating MHD channels are set forth, and estimates of the relative costs of plants and power production for a number of configurations are presented.

B. Principles

5223

Brzozowski, Wojciech. THE MAGNETOHYDRO-DYNAMIC GENERATORS. PART II. Nukleonika, 7:287-309, 1962.

In Polish. A study is made of thermodynamic and gasdynamic phenomena occurring in so-called magnetohydrodynamic generators. The derived formulas are based upon simplifying assumptions relating to the working medium. Changes of state are presented in heat diagrams (T-s) and work diagrams (P-v). (Nuclear Sci.Abs., 17:634, Jan.15,1963).

5224

Buergel, B. A GRAPHICAL METHOD FOR THE INVESTIGATION OF MAGNETOHYDRODYNAMIC GENERATORS. Brown Boveri Rev.,49: 493-500, Nov./Dec.1962.

A graphical process is outlined, which presents a clear survey of certain properties exhibited by various types of magnetohydrodynamic (MHD) generators. For this purpose a diagram is devised which contains the curves for constant electrical and brake outputs and for constant efficiency. Every generator corresponds to a well-defined section of the diagram. As an example, the output characteristics of various types of generators are investigated.

5225

C.E.A. Groupe De Recherches Sur La Fusion Controlee, Gif-sur-Yvette, France. Association Euratom.
MICROSTRICTION I ET II, by M. Alidieres, and others. 53p., 1961. (C.E.A. Rept. 2050)..

A certain quantity of gas is enclosed between two co-axial glass tubes (diameters 67 and 87 mm). In this annular space thus formed exists a permanent magnetic configuration, whose lines of force are perpendicular to the surface of the tubes (0-500 gauss). An electric field is then produced by induction such that its lines of force are circles whose axis coincides with that of the tubes (200 V/cm). The electric field lasts for 0, 5 μ s. This field ionises the gas and causes an electric

current to flow perpendicularly to the magnetic field. The corresponding Laplacian force accelerates the plasma along the axis of the tubes.

5226

Celinski, Z. PRINCIPLES OF THE MHD GENERATOR THEORY. *Przeglad Elektrotech.*, 37:353-358, Sept.1961.

In Polish. D.C. energy is produced in an electrically conducting gas passing through a magnetic field which is normal to the gas flow. The electrical energy produced is equal to the total enthalpy drop in the gas. Only the working chamber is discussed. The basic equations are derived and then three special cases are described: (i) constant velocity; (ii) constant cross-section; and (iii) constant pressure. Some conclusions are presented in the form of graphs. (*Elec. Eng.Abs.*, 66:4205, Apr.1963).

5227

Dahlberg, Erling. AN ATTEMPT AT A ONE-DIMENSIONAL TREATMENT OF THE FLOW IN A HALL-EFFECT MHD-GENERATOR CHANNEL. *Roy. Inst.Tech.Trans.*, no.208:1-21, 1963.

Steady flow of a conducting gas in crossed, longitudinal electric and transverse magnetic fields is treated. The conductivity is taken as the scalar conductivity multiplied by a Hall-effect tensor. Owing to the complexity of the two-dimensional problem, a one-dimensional treatment is considered worth developing. In this, the invariance along the channel of mass flow and longitudinal current are taken into account.

5228

Fabre, J. and Pericart J. SOME PRELIMINARY STUDIES WITH RESPECT TO THE MAGNETO-HYDRODYNAMIC GENERATION OF ELECTRICAL ENERGY. *La Mecanique des Fluides et la Magneto-hydrodynamique*, p.135-156, Paris, Eyrolles, 1962.

The principle of the procedure (expansion in a magnetic field of a high-temperature gas made sufficiently conducting by a convenient apparatus) is described. The admissible temperature limits are defined. The conductivity of the gas is determined, and expressions for the yield and power density are derived. The optimum shape for an acceptable yield is investigated. (*Nuclear Sci.Abs.*,17:5527, Feb.28,1963).

5229

Fanucci, J.B. THEORETICAL INVESTIGATIONS OF AN A.C. MHD POWER GENERATOR. Preprint Paper 29, Session I. Prepublication Copy. 14p., (Radio Corp. of America, Moorestown, N.J.).

The electric impedance of an a-c generator is calculated for infinite-length generators and semi-infinite generators using a small perturbation expansion. The power factor and the power extracted from the generator are then determined. It is concluded that the plasma conductivity must be large if a-c magnetohydrodynamic power generation is to be economically feasible. For low-frequency operation, fringing losses must be kept to a minimum. High magnetic fields are necessary to obtain reasonable power densities at low plasma velocities. (*Nuclear Sci.Abs.*,17:9077, Mar.31,1963).

5230

General Electric Co., Space Sciences Laboratory, Philadelphia, Pa. INVESTIGATION OF NON-THERMAL IONIZATION FOR MHD ENERGY CONVERSION, June 15 - September 15, 1962. 60p., illus., Sept.15,1962. (Q.Rept.2) (Contract AF 33(657)-8298) (AD-286 278).

Results of two groups of experiments performed in cold cathode cesium diodes are given. The first group of experiments covered cesium-helium discharge phenomena in a diode configuration and were made to verify theoretical non-equilibrium concepts and formulations. The second group of experiments covered pure cesium discharges in a similar geometry and were conducted to answer questions concerning plasma conductivity, uniformity of discharge, and gradients produced in the positive column and the effect of wall conduction on the discharge. (TAB U63-1-2:113, Jan.15,1963).

5231

General Electric Co., Space Sciences Laboratory, Valley Forge, Pa. THE THEORY OF MAGNETO-HYDRODYNAMIC POWER GENERATORS, by G.W. Sutton. 205p., Dec.1962. (Tech.Information Series, R62SD990) (Contract AF 49(638)-914).

Magnetohydrodynamic power generation has now been under active development for over four years, but there has not yet appeared any complete description of the theory. This report is intended to close this gap. Most of the theory presented was developed by the author and personnel at the General Electric Company. The topics covered are: electrical conductivity in MHD generators, optimum "speed" ratio, local analysis of the continuous and segmented electrode geometries; Hall geometry, helical flow geometry; magnetically induced ionization; polytropic efficiencies; compressible analyses of the constant velocity, temperature, Mach number, pressure and cross-sectional area flows; end losses;

AC generation; cycle efficiencies; and a summary of generating experiments at the General Electric Company and other places. Geometries other than linear are not considered herein; the most important of those omitted is the vortex generator.

5232

General Electric Co., Space Sciences Laboratory, Valley Forge, Pa.
THERMODYNAMIC CONSIDERATIONS FOR MHD SPACE POWER SYSTEMS, by S.I. Freedman. 90p., Sept. 1962. (Tech. Information Series R62SD83) (Contract Nonr 3867(00)).

Thermodynamic efficiencies and radiator sizes of Brayton Cycle MHD generator systems with and without regenerators, were obtained. A new gas cycle, the Tri-Cycle, was synthesized. The Tri-Cycle has a radiator size as small as the regenerative Brayton Cycle, but a higher pressure ratio. A new cycle was discovered which operates on a dissociating chemical reaction and combines the advantages of a dry gas expansion, a liquid compression, and a Rankine Cycle size radiator. Entropy generation in supersonic MHD generators was analyzed, the polytropic efficiency was related to the generator operating parameters. Transient boil-off and active refrigeration techniques were examined. Multiple radiation shield insulation thicknesses were computed. An optimum temperature ratio for heat rejection from an active refrigeration system was found.

5233

Iantovskii, E.I. and Tolmach, I.M. ON THE THEORY OF AN ASYNCHRONOUS MAGNETOHYDRODYNAMIC GENERATOR WITH A ROTATING FIELD. Akad.Nauk.SSSR Otdel. Tekh.Nauk. Energetika i Avtomatika. Izvest., no.3:32-41, May-June 1962.

Equations have been cited which describe the flow of conducting gas in a magnetohydrodynamic generator (MHDG) with a rotating field. In this paper these equations are generalized a) by taking into account the dependence of the gas conductivity on the temperature and density, b) by not averaging with respect to the transverse coordinate and time, and c) by taking into account the voltage drop across the stator winding and the winding properties. A system of equations is derived for a specific asynchronous MHDG scheme. The concept of vector diagrams for a MHDG is introduced. The process of directly converting a portion of the kinetic energy of a gas into electrical energy and the delivery of that energy to a power net is illustrated using local and over-all vector diagrams. (Phys.Express 2:30-37, 1962).

5234

Japan Atomic Energy Research Inst., Tokyo.
THEORY OF THE APPLICATION OF ELECTRICAL IONIZATION TO THE MID POWER GENERATOR, by Syukuro Yano and Tatsumi Hiramoto. 56p., 1962. (JAERI-1037).

In Japanese. A method of increasing the ionization in MID power generators by applying momentary electric fields to rare gases at 1000 to 2000°K seeded with low-ionization-potential gases was investigated theoretically. It was found to be theoretically possible to design and construct such generators using the non-equilibrium ionization state that is created by the initial stage of the electric discharge in the short interval between initiation of electric field application to the seeded rare gases and ionization saturation. (Nuclear Sci.Abs., 17:8922, Mar.31,1963).

5235

Levy, R.H. A SIMPLE MHD FLOW WITH HALL EFFECT. AIAA J., 1:698-699, Mar.1963.

This note describes a simple flow in which the Hall current can be calculated exactly and the results compared with those that follow from the usual simplifying assumptions of reducing in fixed ratios the conductivities parallel and perpendicular to the field lines.

5236

Messerle, H.K. and Morrison, I.F. PERFORMANCE RELATIONS FOR A MAGNETOHYDRODYNAMIC ENERGY CONVERTER. Elect.Mech.Engng.Trans., Australia, 4:21-27, May 1962.

Contribution of this paper to the expanding literature on the direct conversion of kinetic energy of a flowing gas into electrical energy is a closed form solution of the linearized set of one-dimensional steady flow equations and Ohm's law. Basis for this solution is assumption that results obtained using a one-step numerical integration from inlet to exit closely approximate results obtained using many steps on a digital computer. However, a detailed comparison is not presented to fully justify this assumption. Solution in terms of non-dimensionalized velocity and static pressure is used to derive an expression for conversion effectiveness, defined as the ratio of electrical power output to inlet stagnation enthalpy. This is plotted against load parameter, interaction parameter, and inlet Mach number for a monatomic working fluid. These curves peak at load parameters near one-half. While conversion effectiveness appears to increase indefinitely with interaction parameter for subsonic flow,

a finite limit is approached for supersonic flow. While the subsonic result appears to contradict the basic definition, the authors show that choking limits the possible values of interaction parameter to those yielding effectiveness in the vicinity of twenty percent. (Appl.Mech. Rev., 16:404, May 1963).

5237

MHD Research, Inc., Newport Beach, Calif. RESEARCH ON THE PHYSICS OF CONTINUOUS AND PULSED MHD GENERATORS, by M.S. Jones and others. 84p., Feb.1963. (Rept. 632) (Contract Nonr-3859(00)).

Short duration electrical pulses of 1.8 MW peak power have been produced from 10 grams of seeded condensed explosives by MHD principles. The pulse length is about 10 microseconds. Low ionization potential materials are applied either as surface seeding or mixed into the bulk explosive. The effect upon power output of the geometry of the explosion tube, the size, geometry and composition of the explosive charge, and magnetic field intensity and electrode geometry are discussed.

5238

Rivkin, S.L. and Zuperman, D.A. THE MAGNETOHYDRODYNAMIC METHOD OF DIRECTLY CONVERTING THERMAL ENERGY INTO ELECTRICAL ENERGY. Energetik(USSR), no.10:1-6, Oct.1962.

In Russian. Describes the basic principles of magnetohydrodynamic (MHD) generation, in which ionized gas at high temperature and speed is passed through a nozzle containing electrodes sited in a magnetic field. Gives equations relating the parameters of such systems and describes American investigations into MHD generation. The investigations are considered to be promising and it is hoped that conversion efficiency up to 55% may be obtained, but considerable work still remains to be done. (Elec.Eng.Abs., 66:2099, Feb.1963).

5239

Sheindlin, A.E. and others. ON THE PROBLEM OF OPTIMIZING THE OPERATING MODES OF MAGNETOHYDRODYNAMIC GENERATORS. Izvestia Akad.Nauk, Otdel. Tekh.Nauk, Energetika i Avtomatika, no.6:34-38, Nov.-Dec.1962.

The paper investigates the problem of finding the flow mode in the channel of a magnetohydrodynamic generator; this optimal mode assures the maximum removal of power per unit length of the channel or per unit of the channel. It is demonstrated that for any dependence of the gas conductivity on temperature and pressure and for a specified internal efficiency of the magnetohydrodynamic generator it is possible to find the optimal stream

velocity and optimal dependence of the local electrical efficiency on temperature which assure the minimal length or minimal volume of the channel. (Power Express, 2:12-15, 1963).

5240

Szendy, C. BASIC EQUATIONS OF THE M.H.D. GENERATOR. Acta Tech.Hungar., 40: 431-439, 1962.

A formula relating complex quantities of the electric and magnetic field strengths, the current density and the gas velocity, is introduced, which can be used for determination of power output and losses. (Elec.Eng.Abs., 66:4145, Apr.1963).

5241

Yantovskiy, Ye. I. and Tolmach, I.M. ON THE THEORY OF AN ASYNCHRONOUS MAGNETO-HYDRODYNAMIC GENERATOR WITH A ROTATING FIELD. Izvestia Akad. Nauk, Otdel.Tekh. Nauk, Energetika i Avtomatika, no. 3: 32-41, 1962.

In Russian. Transl. FTD-TT-62-1797, Foreign Tech.Div., Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.

Equations which describe the flow of a conducting gas in a magnetohydrodynamic generator with a rotating field are generalized by taking into account the dependence of the conductivity of the gas on the temperature and density, by not averaging with respect to the transverse coordinate and time, and also by taking into account the voltage drop across the stator winding and the characteristics of the winding. A system of equations for an actual scheme of an asynchronous MHDG is obtained. The concept of vector diagrams of an a-c MHDG is introduced. The process of the direct conversion of a part of the kinetic energy of the gas to electrical energy and its entry into the network is illustrated with the aid of local and over-all vector diagrams.

C. Plasma Properties

5242

Agnew, Lewis. and Summers, C. EXPERIMENTAL CESIUM LINE SHAPES. Adv.Energy Convers., 3:79-87, Jan.-Mar.1963.

The widths of some of the spectral lines emitted from a dense plasma are sensitive to the ion density but insensitive to the electron temperature. In partially-ionized cesium plasmas with number densities greater than 10^{13} ions-cm⁻³ these plasma-broadened lines are easily measured and can be used as a simple diagnostic method for the determination of ion density,

once the width versus ion density relationship is established either theoretically or experimentally. The authors present measured line widths and compare results with theoretical widths.

5243

Brocher, E.F. ON THE ELEVATION OF ELECTRON TEMPERATURE IN MHD GENERATORS AND ITS EFFECT ON THE GAS CONDUCTIVITY. Preprint Paper 8, Session IV. Prepublication Copy. 11p., (Battelle Memorial Inst., Geneva).

The elevation of the electron temperature is given as a function of a parameter, α , which depends on the nature of the gas, the total temperature and gas pressure, and the strength of the magnetic field. An expression for electric conductivity is also derived. Graphs of the elevation of electron temperature as a function of α and electric conductivity, with and without elevated electron temperatures, as a function of α are presented. Electron temperature and electric conductivity in constant-velocity magnetohydrodynamic generators are studied, and the results are shown in graphs. It is concluded that much higher conductivities, electric currents, and power densities can be achieved if the upstream value of α is sufficiently large. Since α is proportional to the square of the magnetic field, the use of high magnetic fields in MHD generators is indicated. It was found that the downstream value of the electron temperature may be higher than at the entrance of the generator under certain conditions, and the electric conductivity shows an increase along the length. (Nuclear Sci.Abs.,17:9095, Mar.31,1963).

5244

Dibelius, N.R., Luebke, E.A. and Mullaney, G.J. ELECTRICAL CONDUCTIVITY OF FLAME GASES SEEDED WITH ALKALI METALS AND APPLICATION TO MHD POWER PLANT DESIGN. Symposium on the Engineering Aspects of Magnetohydrodynamics, 2nd, Proc., Philadelphia, Pa. Mar.9,10,1961. In Engineering Aspects of Magnetohydrodynamics. New York, Columbia University Press, 1962, p.307-326.

Determination of the electrical conductivity of propane-oxygen flame gases with K_2CO_3 , KOH, and CsCl as additives, flame temperatures at 1,800°-2,400°K, and pressure at 1 atm. The results of potassium measurements are applied to the calculation of MHD-generator designs for central-station power-plant applications. Variations in several cycle parameters are explored, and the effect of varying pressure ratio across the MHD duct is evaluated. The reduction in performance with lower inlet temperatures to the MHD duct is appraised. (Intern. Aerospace Abs.,3:A63-14041, May 1,1963).

5245

General Atomic, San Diego, Calif. INSTABILITY OF A PARTIALLY IONIZED PLASMA IN CROSSED ELECTRIC AND MAGNETIC FIELDS, by A. Simon. 27p., Oct.23,1962. (GA-3604).

A weakly ionized plasma in a uniform magnetic field is considered. Application of a potential across the magnetic field results in a steady current flow, owing to the finite conductivity. It is shown that this steady state is unstable if the plasma density is non-uniform in the direction of the applied electric field and if the applied potential is large enough. It is necessary that the sign of the product of the electric field and the density gradient be positive.

5246

General Electric Co., Space Sciences Laboratory, Missile and Space Division, Philadelphia, Pa. RESEARCH IN MHD POWER GENERATION, December 31,1962, by G.W. Sutton. 73p., 1963. (Semiannual Rept. 1) (Contract Nonr-3867(00)).

Preparation of the shock tube for testing nonequilibrium ionization in MHD generators was completed. Tests were conducted using Argon and Xenon as the driven gas in the shock tube. The Argon tests were conducted at gas temperatures of 3000°K and no current flow as observed in the MHD test section. The Xenon tests were conducted at 5000°K, where the shock heated gas has a conductivity of about 100 Mho/M. Current measurements in the test channel were obtained which could be due to a nonequilibrium effect.

5247

General Electric Co., Missile and Space Vehicle Department, Philadelphia, Pa. RESEARCH IN MHD POWER GENERATION, by G.W. Sutton. 3v., Sept.30, Dec.30,1962 and Mar.30,1963. (Q.Repts. 1,2, & 3) (Contract Nonr-3867(00)).

The purpose of the contract is to demonstrate magnetically induced non-thermal ionization in gases and vapors which will be suitable for use in closed-cycle nuclear MHD generators. Non-thermal ionization is necessary because the allowable temperatures for materials for heterogeneous nuclear reactors is below that at which sufficient ionization of the gas may be obtained.

5248

General Electric Co., Space Sciences Laboratory, Philadelphia, Pa. THEORETICAL PERFORMANCE FOR MHD GENERATORS UTILIZING NON-EQUILIBRIUM IONIZATION IN PURE ALKALI METAL VAPOR SYSTEMS, by F.II.

Shair, and F. Cristinzio. 4lp., figs., Jan.1963. (Tech.Information Series R62SD94) (Contract AF 33(657)-8298).

Each member of the alkali metal series has been investigated to determine the best system for a closed cycle MID generator utilizing magnetically induced non-equilibrium ionization. MID generator performances have been calculated for one-dimensional steady state flows with constant mach number in which the dimer concentration is neglected. The calculations are for a generator with segmented electrodes. Potassium appears to be the best choice among the alkali metal series for a 1 megawatt generator operating at total temperatures near 1600°K and total pressures around 20 psia. The calculations show that the performance of an MID generator utilizing a non-equilibrium condition of the electrons is primarily dominated by the elastic electron-neutral collision cross section.

5249
Gourdine, M.C. NON-EQUILIBRIUM R.F. PLASMAS FOR MAGNETOGASDYNAMIC ENERGY CONVERSION. Preprint Paper 35, Session III. Pre-publication Copy. 19p. (Curtiss-Wright Corp., Wood-Ridge, N.J.).

A nonequilibrium plasma is defined as a gaseous mixture of electrons, ions, and neutrals, each having a different temperature. It is useful in magnetogasdynamic energy conversion, since the desired electrical conductivity can be obtained at a lower mean temperature than with an equilibrium plasma. The production of highly nonequilibrium plasmas using the r-f electric field of an electrodeless discharge is described, and a theoretical analysis is presented. It was found to be difficult to use r-f excited plasma for MGD energy conversion because of the low density of the plasma, high diffusion and recombination losses, and reduction of effective conductivity by the Hall effect. Experiments to take advantage of the Hall and Klein effects are described, and graphs of the results are presented. The advantages of using r-f excited plasma for MGD energy conversion indicate that further research should be performed. (Nuclear Sci.Abs.,17: 9090, Mar.31,1963).

250
Toshi, G.H. ENERGY CONVERSION MECHANISM IN A MAGNETIZED CURRENT-CARRYING PLASMA. "Ionization in gases" Conference Paper, Vol.II, p.1699-1717.

A linear macroscopic electrodynamic analysis of a fully ionized collisionless magnetized electron-ion drifting plasma interacting with an ambient plasma suggests two possible energy conversion mechanisms. The

first mechanism is based on the coupling between the quasi-longitudinal space charge waves and the quasi-transverse electro-magnetic waves. Here the coupling between the two classes of waves is due to the scalloping of the finite current carrying plasma which drifts along the magnetic field. The mechanism is restricted to frequencies which are slightly below the ion cyclotron frequency. The other mechanism involves the interaction among the individual transverse hydromagnetic waves which are supported by an infinite plasma drifting along the ambient magnetic field through an ambient plasma. The two mechanisms might find an application (a) to the heating of the thermonuclear plasma and (b) to plasma propulsion. The analysis might also enable an explanation to be given to some of the whistler-type low-frequency radio noise and the enhancement of the solar radio-frequency radiation due to solar outbursts. (Elec.Eng.Abs., 66:4170, Apr.1963).

5251
Koch, Werner and Menke, Helmut. TECHNISCHE ASPEKTE DER MODERNEN PLASMAFORSCHUNG. (TECHNICAL ASPECTS OF MODERN PLASMA RESEARCH). ETZ, 84:65-75, Feb.11,1963.

In German. Plasma physics, due to the intensive efforts to perfect controlled nuclear fusion, and to research on space flight, has developed into a large, independent, technical field of research. Beginning with nuclear fusion research, a number of other new fields of application of the fourth state of aggregation of matter were found for technical purposes. These are mainly magnetohydrodynamic generators for the generation of electricity from thermal energy without the intervention of a mechanical stage, and electrical space flight drive systems with particularly good methods of control. For electrical engineering this field of plasma technique presents a number of problems, and several special ones are discussed in more detail.

5252
LA SITUAZIONE ATTUALE DELLA CONVERSIONE DIRETTA DEL CALORE IN ENERGIA ELETTRICA PER VIA MAGNETOPLASMA DINAMICA COME SI E PRESENTATA AL CONGRESSO DI NEWCASTLE UPON TYNE. (PRESENT STATUS OF DIRECT CONVERSION OF HEAT INTO ELECTRICITY BY MAGNETOPLASMA DYNAMICS). Com.Naz.Ener.Nucl.Not., 9:100-110, Apr.1963.

A discussion of the current status of research on the conversion of heat into electricity by the magnetoplasma dynamic way, as it appeared at the Newcastle upon Tyne.

5253
Lindley, B.C. MAGNETOPLASMA DYNAMIC ELECTRICAL POWER GENERATION.

Power Eng. (Gt. Brit.), 3:30-37,
Oct.1961.

A review of recent American development work is given. (Elec.Eng.Abs.,65:3485, May 1962).

5254

Lindlev, B.C. MID POWER RESEARCH IN THE UNITED KINGDOM. Symposium on the Engineering Aspects of Magnetohydrodynamics, 2nd, Proceedings, Philadelphia, Pa., Mar.9,10, 1961. In Engineering Aspects of Magnetohydrodynamics, New York, Columbia University Press, 1962. p.127-146.

Review of research on MID power generation in the U.K. It is observed that this research is at an early stage, the experimental effort being mainly devoted to the demonstration of effects and to the development of measurement techniques suitable for future work. The exception is the investigation by Pain and Smy at Imperial College. More ambitious experiments are being planned or constructed, and there is interest both in the open-cycle system using combustion gases and in the closed-cycle system using inert gases. Emphasis is placed upon gaining an understanding of ionization phenomena and the physical processes which occur in the extraction of electric power from a plasma rather than upon the engineering problems of a prototype generator. (Intern. Aerospace Abs., 3:A63-14032, May 1,1963).

5255

Martin Marietta Corp., Nuclear Division, Baltimore, Md.
RESEARCH PROGRAM ON CLOSED-CYCLE MAGNETO-PLASMA DYNAMIC ELECTRICAL POWER GENERATION WITH NON-EQUILIBRIUM IONIZATION, by M.E. Talaat. 3v., Dec.15,1962, Mar.15, & June 15,1963. (MND-2866-4) (Q.Repts. 2,3, & 4) (Contract Nonr-3866(00)).

The objectives of this program are to experimentally demonstrate the principle of non-equilibrium ionization under actual closed-cycle magnetoplasma dynamic generator operation conditions, to verify the basic phenomena underlying the behavior of moving ionized gases in the non-equilibrium state when interacting with a magnetic field by correlation of the experimental results with the theory of non-equilibrium ionization and to investigate the potential performance of the MID power generator with non-equilibrium ionization in closed-cycle systems having a reactor heat source.

5256

Martin Marietta Corp., Baltimore, Md.
RESEARCH PROGRAM ON CLOSED-CYCLE MAGNETO-PLASMA DYNAMIC ELECTRICAL POWER GENERATION WITH NON-EQUILIBRIUM IONIZATION, June 15 - Dec.15,1962, by M.E. Talaat and W.B. Bienert. v.p., Jan.1963.

(Semi-Annual Tech.Summary Rept. MND-2939) (Contract Nonr-3866(00)).

In the first part of the program, an experimental, closed cycle, electrically heated MPD electrical power generator has been designed and is currently under fabrication. In the second part a theoretical program contributed to the understanding of the basic factors necessary for the success of non-equilibrium ionization in the MPD generator using seeded noble gases. Supporting the theoretical investigation is the third part which is an experimental measurement program on gas-filled discharge tubes containing seeded noble gases.

5257

MHD Research, Inc., Newport Beach, Calif.
NON-EQUILIBRIUM IONIZATION EFFECTS IN A MAGNETIC DIFFUSER, January 1, - December 31, 1962, by V.H. Blackman and J.R. Hamer. v.p., Dec.1962. (Final Rept.) (Contract Nonr-3689(00)).

Experimental evidence of non-equilibrium ionization effects in the flow of unseeded argon gas through a magnetic field (diffuser) has been obtained. The voltage-current characteristics of the induced discharge using a heated tantalum cathode were determined for low total currents (less than 10^{-3} amperes). The V-I characteristic curve appears to follow that of the normal and abnormal glow discharges.

5258

Moore, G.E. EXPERIMENTAL STUDIES OF SOME ELECTRICAL PROPERTIES OF SEEDED FLAME GASES. ARS Preprint 2590-62. New York, American Rocket Society, 1962. Prepublication Copy. 34p. (General Electric Co., Schenectady, N.Y.).

Three experimental programs and some of their results are described. The conductivity of potassium-seeded, propane-oxygen flame gases was determined by simple resistance measurements, using concentric graphite electrodes in a small furnace. Experiments were carried out with 2- by 4-inch MHD channels, using K-seeded H₂-air combustion gases at ~730 m/sec and 2100°K static temperature; the operating characteristics for both Faraday and Hall generators were measured in B-fields of 3 to 12 kgauss. Values of electron mobility were obtained in three ways and compared: from the variation of internal resistance with B for both types of generator, from the ratio of their open-circuit voltages, and from ordinary resistance measurements on the gas. Some materials problems in the operation of these generators are briefly

discussed. An experimental survey was made of the electrical conductivity of flame gases resulting from seeding with various other materials; in all, 26 elements were tried, 10 of which are known to have been studied elsewhere. (Nuclear Sci.Abs.,17:9099, Mar.31,1963).

5259

Nagamatsu, H.T., Sheer, R.E.Jr., and Weil, J.A. NON-LINEAR ELECTRICAL CONDUCTIVITY OF PLASMA FOR MAGNETOHYDRODYNAMIC POWER GENERATION. 17th Annual Meeting and Space Flight Exposition, Los Angeles, Nov. 1962. Preprint 2632-62. 8p., New York, American Rocket Society, 1962.

The interaction of high-velocity air plasma with a transverse magnetic field is investigated in a hypersonic shock tube. Shock Mach numbers vary from 15 to 31 and the corresponding equilibrium temperature range is 5500 to 10,000°K. At high Mach numbers the induced electromotive force across the probes, for open circuit conditions, agrees with theoretical prediction. For the plasma produced by a Mach-30 shock wave, the voltage across the electrodes with different external loads decreases nonlinearly with increasing current flow. The plasma resistance across the electrodes decreases drastically at high current flows. With two copper electrodes at room temperature, area of 3.94 cm², it is possible to extract 447 amp from the plasma. The electrical conductivity increases with the current flow, and is found to be greater than the theoretical value. With an average magnetic field strength of 6500 gauss, a power as high as 155 kw is extracted from the moving air plasma. Because of the nonlinear increase in the conductivity, the extractable power from the plasma is much greater than the theoretical prediction. (Nuclear Sci.Abs., 17:7491, Mar.15,1963).

5260

Princeton University, Plasma Physics Laboratory, Princeton, N.J. SEMI-ANNUAL REPORT, July 1, - December 31, 1962. 225p., Mar.13, 1963. (MATT-Q-20) (Contract AT(30-1)-1238).

Research at the Plasma Physics Laboratory continues to be directed partly towards achieving hot confined plasmas, and partly towards enhancing basic knowledge in plasma physics.

5261

Rosa, R.J. NONEQUILIBRIUM IONIZATION IN MID GENERATORS. Inst.Elec.& Electr. Engrs.Proc., 51:774-784, May 1963.

In this paper a brief review is given of the basic principles of MID power generation and its current status. The remainder of

the paper will discuss the problem of obtaining the level of gas ionization required for MID generation.

5262

Southern California University, Engineering Center, Los Angeles, Calif. RESEARCH IN PLASMA AND MAGNETOHYDRODYNAMICS, by Zohrab Kaprielian. 19p., Dec.1961. (Final Rept.) (Rept. 70-101) (AFOSR-1998) (Contract AF 49(638)-522) (AD-272 808).

Theoretical and experimental work in four major areas are presented: (1) electromagnetic wave propagation in ionized media; (2) plasma diagnostics; (3) electromagnetic scattering properties of a plasma; and (4) amplification of plasma waves. The results of these investigations were discussed in publications and technical reports and are reviewed briefly.

D. Devices

5263

Abramov, B. PLASMA PRODUCES ELECTRIC ENERGY. Ekonomicheskaya Gazeta, Moscow, #33:p.13, Aug.11,1962.

In Russian. Transl. JPRS 16010. p.24-26.

Russian scientists have recently designed and built the first low-capacity installation of the machineless magnetohydrodynamic type. Heat energy is transformed directly into electric energy and a great saving in fuel is achieved.

5264

Aerospace Corp., Los Angeles, Calif. ENERGY CONVERSION PROGRAM. MAGNETOHYDRODYNAMIC GENERATOR, January 1 - June 30, 1962, by W.R. Grabowsky and K.E. Starner. 28p., illus., Aug.31, 1962. (Semiannual Tech.Rept.) (Rept. TDR-69(2220-40) (TR-2) (Contract AF 04(695)-69) (DCAS TDR 62-171) (AD-291 076).

Progress in the materials studies of interest in the design and study of a magnetohydrodynamic (MHD) vortex generator for use in a closed-cycle power conversion system is described. Experimental results of tests to determine the tensile strength properties of tantalum to its melting point are presented. Measurements of temperature creep and stress deformation definitely indicate that creep rate will rule out use of tantalum as the sole structural material at design stresses greater than 600 psi. Fabrication difficulties in the use of tungsten possibly may be overcome or alleviated by wire-wrapped construction. Design of an electron bombardment heated test facility to determine the electrical

resistivity of high-temperature (2500 K) insulating materials is covered in detail. (TAB U63-1-5:20, Mar.1,1963).

5265

AiResearch Manufacturing Co., Los Angeles, Calif.
VORTEX MAGNETOHYDRODYNAMIC GENERATOR
EXPERIMENTAL TEST PROGRAM, August 1, 1961 -
April 6, 1962, by H.G. Starck and others.
75p., June 1962. (Final Rept.) (ASD-TDR-
62-459; SS-708-R) (Contract AF 33(616)-
7808).

A vortex-type magnetohydrodynamic generator was designed and fabricated on the basis of currently available materials, and was tested to determine the feasibility of obtaining electric power from a seeded combustion gas. The combustion gas was oxygen-hydrogen, seeded with potassium hydroxide solution. A power output of 0.15 watts was obtained from a vortex channel which was 4 inches wide with a magnetic field strength of 4000 gauss. The gas flow rate varied from 0.4 to 0.7 pounds per minute. This result compares with a theoretical output of 29 to 60 watts which was calculated by digital-computer methods. The low output was due to material failures throughout the unit and particularly of the combustion chamber and the center electrode. The study program indicated that the small vortex MHD generator has a significant potential provided that the material problems can be solved. (STAR, 1:N63-16303, Jly.8,1963).

5266

Ailer, R.C. FEASIBILITY STUDY OF 300-MWE
MHD POWER PLANT. Proc.Am.Power Conf.,
24:382-391, 1962.

Component designs for a 300 Mwe magnetohydrodynamic (MHD) power plant are prepared and assembled into an overall plant complex. The plant is coal burning with air for combustion and the MHD generator operates in the peak temperature range. The MHD generator produces 80% of the gross electric output and a coupled conventional steam boiler generates the remaining 20% from steam power. Brief descriptions are given of the MHD generator, integrated MHD and steam generating plant cycle, combustion and air preheat system, d-c to a-c conversion system, operating cycle temperature-entropy diagram, heat rates and efficiencies, and the overall plant layout. Theoretical energy production costs show a substantial improvement over conventional steam plants. Future MHD applications and the major developmental problems to be solved are discussed. (Nuclear Sci.Abs.,17:5629, Feb.28,1963).

5267

Avco Everett Research Laboratory,
Everett, Mass.

DESIGN, DEVELOPMENT, AND TEST OF A
PROTOTYPE SELF-EXCITED MHD GENERATOR.
24p., illus., Sept.1962. (Semi-annual
Tech.Summary Rept.) (Contract AF 33(657)-
8380) (AD-289 674).

Effort was devoted to the design, construction, and test of a self-excited MHD generator with a net power output of 20 mw after deduction of the power for excitation. Estimates of the performance of the Mark V generator indicated that to achieve an output power of 20 mw would require a gross power of about 40 mw. With the completion of the performance analysis, it was possible to begin the design of the generator channel. In the construction of this channel, requirements of local heat transfer rate and cooling water demand were considered along with the properties demanded by the insulating side walls and the electrode walls in different portions of the generator. Design and procurement of materials for the magnet of the generator were completed. This work involved the study of field distributions in model magnets, assessment of magnetic stresses, and determination of methods of construction, and a matching of the magnet characteristics to those of the generator. The requirements of the auxiliary system, such as fuel supply, oxygen supply, and water storage, were determined; and the design of the systems to supply these materials to the generator begun. (TAB U63-1-5:146-147, Mar.1,1963).

5268

Avco-Everett Research Laboratory,
Everett, Mass.
MHD GENERATOR PERFORMANCE UNDER NON-
UNIFORM AND TIME VARYING LOAD, by J.F.
Louis, and R. Decher. 21p., Mar.1963.
(Res.Rept.148).

An MHD generator with segmented electrodes is idealized as a one-dimensional channel with infinite segmenting. Transient and steady state effects due to local non-uniformities on the remainder of the channel are investigated.

5269

Barnes, J.F. SOME CONSIDERATIONS INFLUENCING
THE USE OF AN OPEN CYCLE MHD DEVICE
FOR THE GENERATION OF BASE LOAD ELECTRIC
POWER. Preprint Paper 6, Session I.
Prepublication Copy. 8p. (National Gas
Turbine Establishment, Pyestock,
Farnborough, Eng.).

5270

de Montardy, A. MHD GENERATOR WITH SERIES-
CONNECTED ELECTRODES. Preprint Paper 19,
Session I. Prepublication Copy. 8p.
(Electricite de France, Paris).

A magnetohydrodynamic "series generator" or "constant field direction generator" is described in which power is extracted through segmented series-connected electrodes to a single load. The characteristics of this type of MHD generator are analyzed and compared to those of a similar generator in which the power is extracted through segmented electrodes into separate loads. It is concluded that the "series generator" delivers the same power density under load with less complexity than the generator with separate loads and is better suited for working at low values of the load factor. (Nuclear Sci.Abs.,17: 9085, Mar.31,1963).

5271

Donaldson, C. duP. THE MAGNETOHYDRODYNAMIC VORTEX POWER GENERATOR: BASIC PRINCIPLES AND PRACTICAL PROBLEMS. Symposium on the Engineering Aspects of Magnetohydrodynamics, 2nd, Proceedings, Philadelphia, Pa., Mar.9,10,1961. In Engineering Aspects of Magnetohydrodynamics, New York, Columbia University Press, 1962, p.228-254. Thompson Ramo Wooldridge, Inc., supported research.

Brief review of the basic theory of laminar, vortex power generators, and discussion of the general characteristics of the solutions. Some of the major assumptions on which the laminar theory is based are indicated. Those assumptions which are largely hydrodynamic in character, and hence can be checked experimentally in simulated vortex chambers driven by compressed air, are discussed in the light of such experimental work. The inevitable conclusion is that the flow in practical vortex power generators will be turbulent in nature, and that these turbulent profiles will differ markedly from those obtained with the laminar theory using a constant effective eddy viscosity. The development of a theory for the velocity distribution in incompressible, turbulent conducting vortices is attempted. Although no actual velocity profiles computed by the method developed are as yet available, it appears that the new theory is capable of describing properly the velocity distributions in turbulent vortices. (Intern.Aerospace Abs., 3:A63-14037, May 1,1963).

5272

Emmerich, W.S. and others. A CLOSED LOOP MHD DEVICE WITH CESIUM SEEDED HELIUM. Preprint Paper 33, Session III. Prepublication Copy. 17p. (Westinghouse Electric Corp., Pittsburgh).

The design and construction of a closed-loop magnetohydrodynamic device, consisting of motor and generator sections connected to end plenum passages, are described.

Helium seeded with Cs will circulate in the loop, and power may be extracted from the generator section while the gas is circulating. A theoretical analysis of the loop operation is presented. When completed, the device will be used to study MHD duct processes, plasma characteristics and properties, and materials and structures for MHD systems. (Nuclear Sci.Abs.,17:9091, Mar.31,1963).

5273

EXPERIMENTAL MHD GENERATOR PASSES 1 MILLION-WATT MARK IN RECENT TEST. Elec.Eng.,81: 978-979, Dec.1962.

A power output of 1,350 kw has been achieved by an experimental magnetohydrodynamic generator at the Avco-Everett Research Laboratory.

5274

Gilbey, D.M. THE MHD GENERATION OF D.C. POWER. Preprint Paper 13, Session I. Prepublication Copy. 24p. (Royal Aircraft Establishment, Farnborough, Eng.).

The problems involved in the design of power stations using a magnetohydrodynamic generator are discussed in detail. A thermodynamic analysis is performed on one scheme for a MHD generator topping a steam cycle, and data are presented. Depending upon the gas pressure of the cycle and duct gas entropy, the cycle efficiency, for the system studied, was found to be between 48% and 58%, where the steam cycle without the MHD generator would have an efficiency of 40.4% using the same assumptions. The performance of an MHD generator is studied using the equations for flow of gas in a duct. The effects of gas conductivity and ion slip are discussed, and the heat-transfer loss is calculated. Magnet design and materials for the duct and electrodes are also discussed, and the major areas for further study are listed. (Nuclear Sci. Abs.,17:9083, Mar.31,1963).

5275

Jackson, W.D., Pierson, E.S. and East, D.A. A MAGNETOHYDRODYNAMIC POWER CONVERTER. Symposium on the Engineering Aspects of Magnetohydrodynamics, 2nd, Proceedings, Philadelphia, Pa., Mar.9,10,1961. In Engineering Aspects of Magnetohydrodynamics, New York, Columbia University Press, 1962. p.294-306, USAF-Army-Navy-NSF-supported research; (Contract AF 33 (616)-7624).

Proposal of an MHD power-conversion method which uses a channeled, electrically conducting fluid, an electromagnetic pump, and an MHD generator. These are to replace, respectively, the mechanical coupling, drive motor, and generator of

a conventional rotating machine converter set. Consideration is restricted to the case of voltage transformation in dc systems, and to MID converters in which a liquid metal serves as the working fluid. It is concluded that the velocities attainable in a practical device using liquid metal (mercury) as the working fluid, together with presently available magnetic-flux densities, limit operating voltages to the range below 10 volts when the interelectrode distances are on the order of 1 m. Improvements in the fluid design and substitution of NaK as the working fluid would make the liquid-metal converter of practical interest in low-voltage, high-current systems. (Intern. Aerospace Abs., 3:A63-14040, May 1, 1963).

5276

Litton Industries, Electron Tube Division, San Carlos, Calif.
 INVESTIGATION OF MID POWER GENERATION. VOLUME III - INTEGRATION WITH CROSSED-FIELD AND LINEAR BEAM MICROWAVE DEVICES, by G.E. Pokorny and A.J. Prommer. 21p., Jly.9, 1962. (Final Eng. Rept.) (RADC-TDR-62-464) (Contract AF 30(602)-2487).

The results of this study show that an MID power source is compatible with present day microwave generators, and that a system combining these two devices is technically and economically feasible and constitutes a very attractive package for super power microwave generation.

5277

Radio Corp. of America. Missile and Surface Radar Division, Morrestown, N.J.
 ELECTRODELESS MID GENERATOR RESEARCH. Part I. THEORETICAL ANALYSIS, by J.B. Fanucci and others. 216p., Oct. 1962. (Final Rept.) (ASD-TDR-62-411. Pt. 1) (Contract AF 33(616)-7913).

The theoretical investigation encompassed both the electrodynamic and gasdynamic aspects of the a.c. MID generator and their relationship to each other. This report includes the following areas of investigation: generator impedance, side losses, fringing effects, channel flow, heat transfer, plasma viscosity, operating conditions, and starting transients. Parametric studies are included for several of these topics. The result of the above studies has led to the design of an experimental generator. Results indicate that the addition of a ferromagnetic material external to the generator improves the power factor characteristics. Power factors up to 0.4 are possible at low frequencies. Supersonic rather than subsonic operation of the generator yields the higher power densities. Fringing effects indicate the need for shading magnetic fields analogous to d.c.

generators. Heat protection of the a.c. MID generator walls by transpiration cooling is feasible. (STAR, 1:N63-16115, Jly.8, 1963).

5278

Sherman, A. A HIGH PERFORMANCE, SHORT TIME DURATION, MID GENERATOR SYSTEM. ARS Preprint no. 2558-62. New York, American Rocket Society 1962. Prepublication Copy. 14p.

The potential performance of a chemically fueled MID generator operating on an open cycle is considered. Chemical fuels other than fossil are considered. By appropriately selecting ultra-high-temperature fuels, extraordinarily high power densities can be achieved. A theoretical inviscid analysis is carried out of the channel flow for such a generator in order to determine its size, geometry, and weight. Calculations show that relatively modest magnetic fields are permissible so that appropriate configurations of permanent magnets are considered for this application. Some estimates are made of the weight of such a permanent magnet system. Consideration is also given to the heat transfer caused by the extraordinarily high gas temperatures. Tentative conclusions are that the heat loss in such generators can be handled by a combination of regenerative and radiative cooling. From theoretical calculations and estimates the fuel-plus-oxidizer flow rate for such an MID generator seems to be in the range of 3 kg/kwh, while the specific weights range from 6 to 3 kg/kw for the larger sizes. A number of potential applications for such an MID generator system are discussed. (Nuclear Sci.Abs., 17:9124, Mar.31, 1963).

5279

Sternglass, E.J. and others. MID POWER GENERATION BY NON-THERMAL IONIZATION AND ITS APPLICATION TO NUCLEAR ENERGY CONVERSION. Nuclear En., 60-66, Mar. 1963.

One of the most severe limitations of MID power generation is the high temperatures required for thermal ionization. Two alternative, nonthermal ionization methods are considered: electron-beam injection and fission-product radiation. Electron-beam injection appears to be the most promising method. The thermodynamic cycle of a power plant incorporating a MID generator and a reactor is considered. The design of a MID generator with nonthermal ionization and the use of MID compressors are discussed. (Nuclear Sci.Abs., 17:16188, May 31, 1963).

5280

Sutton, G.W. END LOSSES IN MAGNETOHYDRO-

DYNAMIC CHANNELS WITH TENSOR ELECTRICAL CONDUCTIVITY AND SEGMENTED ELECTRODES. J. Appl. Phys., 34:396-403, Feb. 1963.

End losses of an inviscid magnetohydrodynamic channel having tensor conductivity and segmented electrodes have been calculated for a magnetohydrodynamic power generator of this geometry. It was found that the constant-current configuration is more efficient than the constant potential difference case. The efficiencies increase with increasing Hall effect, but constant magnitude extensions to the magnetic field have very little effect. The theoretical efficiency for an aspect ratio of 10 and $\omega\tau=2$ is only 74%.

5281

Swift-Hook, D.T. and Wright, J.K. THE CONSTANT-MACH-NUMBER MHD GENERATOR. J. Fluid Mech., 15:97-110, Jan. 1963.

It is shown that the optimum design of duct in a magnetohydrodynamic generator is close to the one in which the flow Mach number remains constant. This constant-Mach-number generator is analysed in some detail and it is shown that the optimum Mach number can be defined to within a few percent. For a γ of 1.25, this optimum is near 0.85. For very short ducts, the maximum power output is obtained near matched-load conditions but for rather longer ones maximum total power output is obtained by working as close to short-circuit conditions as is practicable. Against this, the minimum compressor requirements are found by working as close to open-circuit conditions as is practicable, and so a compromise must be reached for optimum overall generator design as far as load conditions are concerned. This will probably give an internal ohmic loss in the fluid of about one-third of the total output. Curves are presented which enable the optimum Mach number to be determined with greater precision when the optimum load conditions have been selected.

5282

Swift-Hook, D.T. LARGE-SCALE MAGNETOHYDRODYNAMIC POWER GENERATION. Brit. J. Phys., 14:69-76, Feb. 1963.

The basic physical principles of magnetohydrodynamic generation are described and the electro-dynamics and thermodynamics discussed. The interaction is controlled by the plasma conductivity, which is low, and methods of increasing it are mentioned. The quasi-one-dimensional flow equations are presented and methods of solution outlined. The practical problems are discussed and a survey is made of experimental work to date. The immediate prospects for open cycle fossil fuel

devices give grounds for cautious optimism and possible future developments include superconducting electromagnets, closed cycles for nuclear applications and a.c. generation.

5283

Thompson Ramo Wooldridge, Inc., TAPCO Division, Cleveland, Ohio. RESEARCH AND DEVELOPMENT ON A VORTEX MHD POWER GENERATOR, September 21, 1960 - December 8, 1961. 52p., Dec. 1961. (Final Rept.) (Contract NAS5-703) (ER-4737).

An experimental and theoretical program was conducted in order to investigate the performance of a continuous-flow crossed-field MHD (magnetohydrodynamic) power generator within which the working fluid has a vortex motion. The experimental effort involved construction and operational test of small vortex and linear channel generators as well as cold-gas vortex chambers. The primary emphasis of the theoretical study was concerned with improving the understanding of turbulence in two-dimensional vortices and in defining optimum methods of attaining the desired velocity profiles. During this effort a theory of turbulence in a vortex, based on the concepts of mixing length, was evolved. (Nuclear Sci. Abs., 17:20562, June 30, 1963).

5284

Thompson Ramo Wooldridge Inc., Cleveland, Ohio. RESEARCH ON THE VORTEX MHD POWER GENERATOR, by W.C. Davis and R.T. Craig. 21p., Oct. 1962. (Q. Prog. Rept. 2) (Contract NAS3-2526).

Fabrication of the experimental model of the vortex magnetohydrodynamic generator was completed and appears to be satisfactory in its conceptual design. A gas dilution calorimeter was constructed for determining the enthalpy of the driving jets under conditions simulating those within the generator. The calorimeter will also be used for determining local heat transfer coefficients within the vortex generator and generator conversion efficiency. The vortex chamber installation was completed and soon will be providing more comprehensive and accurate data for the determination of velocity fields within vortex cavities supplied with and without center bodies. Further study of the application of pseudo-laminar boundary layer analysis to the prediction of velocity profiles within a turbulent vortex confirmed the earlier expectations of its successful employment. (Nuclear Sci. Abs., 17:2363, Jan. 31, 1963).

5285

Thompson Ramo Wooldridge Inc., TAPCO Division,

Cleveland, Ohio.
RESEARCH ON THE VORTEX MHD POWER
GENERATOR, 17p., Jan.1963. (Q.Prog.
Rept. 3) (Contract NAS3-2526).

Efforts toward providing instrumentation for the vortex MHD generator tests and for the vortex chamber apparatus to be used in turbulent vortex flow studies are reported. (Nuclear Sci.Abs.,17:13623, Apr.30,1963).

5286

Way, S. COMPARISON OF THEORETICAL AND EXPERIMENTAL RESULTS IN AN MHD GENERATOR. Symposium on the Engineering Aspects of Magnetohydrodynamics, 2nd, Proceedings, Philadelphia, Pa., Mar.9,10, 1961. In Engineering Aspects of Magnetohydrodynamics. New York, Columbia University Press, 1962. p.166-179.

Discussion of experiments involving the determination of the importance and extent of the effects of loss factors such as leakage currents, thermal losses, and electrode drops in the evaluation of the MHD power-generation scheme. Comparisons are made with theoretical findings. It is concluded that (1) it is possible to build MHD generators with open-circuit voltages closely approaching the theoretical value; (2) theoretical conductivities for combustion products tend to run about 25% higher than experimental values; (3) actual power is appreciably lower than the theoretical generated power for the actual gas conductivity when leakage currents are present; (4) thermal losses ahead of the generator must be prevented to assure good fuel economy in an actual MHD plant; and (5) realization of the full potential of MHD power generation requires close attention to thermal insulation and appropriate design measures to prevent internal leakage currents. (Intern. Aerospace Abs.,3:A63-14034, May 1,1963).

5287

Woodson, H.H. and Lewis, A.T. SOME REQUIREMENTS FOR THE OPERATION OF MAGNETOHYDRODYNAMIC INDUCTION GENERATORS. Symposium on the Engineering Aspects of Magnetohydrodynamics 2nd, Proceedings, Philadelphia Pa., Mar.9,10,1961. In Engineering Aspects of Magnetohydrodynamics. New York, Columbia University Press, 1962, p.277-293, (USAF-Army-Navy-supported research; Contract no. AF 33(616)-3984).

Consideration of an MHD machine that is analogous to a conventional reluctance machine or induction generator. The starting point is the assumption that single-frequency ac power is to be generated, which leads to an equivalent circuit that is necessary to satisfy this assumption. Analysis of the equivalent

circuit shows some general properties of the system in terms of circuit parameters, which in turn are related to gas properties by using experimental results obtained with magnetically driven shock tubes. This process yields an unambiguous specification of the gas properties that must be achieved to obtain certain performance characteristics. It is indicated that more exact data on gas behavior are needed to make the analysis accurate enough for engineering design. The physical model considered consists of a cylindrical, nonconducting channel with a concentric coil. Slugs of conducting material are assumed to traverse the region of the coil periodically. (Intern. Aerospace Abs., 3:A63-14039, May 1,1963).

VI. ELECTROCHEMICAL PROCESSES

A. Fuel Cells

1. General Information

5288

Engelhard Industries, Inc., Newark, N.J. HYDROGEN GENERATION FOR FUEL CELLS, November 1, 1962 - January 31,1963, by E.J. Emerson, L. Kantrowitz and H.H. Geissler. 22p., illus., Jan.31,1963. (Q.Rept. 3) (Contract DA36-039-sc-89077).

A research project is carried out to develop a method of generating hydrogen from primary fuels in such a manner that the generation of hydrogen and its separation from other reaction products can be accomplished in the field on a portable basis. Successful operations continued on a portable hydrogen generator utilizing ammonia feed at a pressure of 35 psig. The waste stack gas was utilized successfully as the source of heat of vaporization to the liquid ammonia to maintain the ammonia vapor at the necessary operating pressure. Suitable mixtures of water and JP-4 have been emulsified by simple shaking with an emulsifying agent.

5289

FUEL CELLS GENERATE INTENSE INTEREST. Chem. Eng., 70:54-56, June 24, 1963.

A review of Advances in the technology of fuel cells, plus a close scrutiny of their future uses are presented from a recent Army-sponsored conference on power sources.

5290

Hart, A.B. FUEL CELLS. Brit. Interplan. Soc.J., 19:58-61, May-June 1963.

Fuel cells will be needed in the next decade as primary electric generators of intermediate power, i.e., 100 W. and

10 kw., for spaceflights lasting from a few hours to several days or weeks. Principles of their operation, particularly in relation to the factors and processes which control power yield and heat loss, are discussed. At the present time the most reliable device available is basically a hydrogen/oxygen cell working at 100-200°C. with concentrated potassium hydroxide or an ion exchange resin as the electrolyte. The gases may be carried cryogenically or in chemical form. Brief reference is made to other types of fuel cell.

5291

Hentschel, K. REVIEW OF THE POSSIBILITIES OF APPLYING FUEL CELLS AS VOLTAGE SOURCES FOR ELECTRICAL VEHICLES INDEPENDENT OF SUPPLY CABLE. Tech., 17:553-558, Aug.1962.

In German. The first part of a review article discusses the electrochemistry of various types of fuel cell and indicates the kind of voltage-current characteristic that is obtainable. (Elec. Eng.Abs.,66:528, Jan.1963).

5292

Jenny, E. THE FOUR MOST IMPORTANT METHODS OF DIRECT ENERGY-CONVERSION. Part 4. Schweiz. Bauztg., 79:448-454, 1961.

In German. The fourth method, discussed here, is the use of the fuel cell, in which gaseous fuels are fed to an electrolyte where by electrochemical action they are transformed into the production of electrical power. The process is continuous while current is drawn and fuel supplied. There is no stored energy as in a battery. The thermodynamic theory of the cell is outlined and several proposed models described (those of Bacon, Union Carbide, Justi), operating for low temperature or high temperature. Constructional problems and some practical results are discussed. Life characteristics are briefly compared with those of solar cells and isotope cells. (Index Aero. 17:53, Oct.1961).

5293

Justi, E.W. FUEL CELL RESEARCH IN EUROPE. Inst.Elec.& Electr.Engrs.Proc., 51: 784-795, May 1963.

This report on fuel cell research on the European continent deals with the main lines of present activities, i.e., high temperature cells with semi-solid electrolytes, the Bacon HYDROX cell operating at medium temperatures and high pressures and the electrochemical energy converters operating at ambient temperature and pressure. The author devotes the main part of his report to these low temperature types including the Double Skeleton

Catalyst ("DSK") system of the German Fuel Cell Consortium, the Swiss Mono-skeleton ("MSK") system and the German system of dissolving a liquid carbonaceous fuel such as methanol in a cell with catalytically different electrodes. In addition, various applications of such cells, e.g., for storage of electrical energy by electrolysis of water and subsequent recombination of hydrogen and oxygen are reviewed.

5294

Ketelaar, J.A.A. DIRECT GENERATION OF ELECTRICAL ENERGY BY MEANS OF ELECTRO-CHEMICAL FUEL CELLS. Ing., 66:E85-E91, Aug.20,1954.

The efficiencies obtainable with a primary electric cell, utilizing the reaction of a gaseous or solid fuel with oxygen, are considered in relation to the change in entropy determined by the change in the number of gas molecules. Recent types of fuel cells are discussed, especially the H₂-O₂ cell with an aqueous electrolyte and the Davtyan cell with a so-called solid electrolyte consisting essentially of a porous solid phase impregnated with molten salt. Performance data are given for these and more recently constructed cells subjected to duration tests. It is shown that the combination of a fuel cell and a water-gas generator as proposed by Forin offers no increase in electrical energy produced. (J.Appl.Chem.Abs., p.i-494,1955).

5295

Kirkland, T.J. and Jasinski, R. FUEL CELLS - STATE OF THE ART. Inst.Elec.& Electr. Engrs. Trans., IE-10:112-124, May 1963.

The current intensive effort on fuel cell research and development is justified by the potential uses and advantages. Many industrial laboratories are investigating some form of mobile power in which high efficiency, low manufacturing cost, and low maintenance are the most important factors. Another potential large application for fuel cells and the one that is receiving the most attention at this time is in aerospace vehicles where this form of power satisfies many special needs.

5296

Kordes, K.V. LOW TEMPERATURE FUEL CELLS. Inst.Elec.& Electr.Engrs.Proc., 51: 806-812, May 1963.

Fuel cells have emerged from the research laboratories and are now in the state of being actively developed for various military and commercial purposes. The paper tries to describe the principal problems which had to be overcome to build reliably operating, relatively inexpensive

- cells. The different systems presently used are compared with each other and the possibility of the use of cheap hydrocarbon fuels in low temperature cells is discussed.
- 5297
Peattie, C.G. and others. FACTORS INVOLVED IN THE USE OF A HIGH-TEMPERATURE FUEL CELL AS A SPACE POWER SOURCE. American Rocket Society, Space Power Systems Conference, September 25-28, 1962. Santa Monica, Calif., 1962. (ARS Paper 2565-62).
- Potential advantages of using a high-temperature, molten-electrolyte fuel cell as a space power source are discussed. (Astron.Info.Abs., 7:70,413, Feb.1963).
- 5298
Peattie, C.G. A SUMMARY OF PRACTICAL FUEL CELL TECHNOLOGY TO 1963. Inst. Elec. & Electr.Engrs.Proc., 51:795-806, May 1963.
- A survey is made of three types of primary fuel cell systems now in battery engineering phases. The three cell types are: 1) those using aqueous electrolytes; 2) those using molten electrolytes; and 3) those with solid electrolytes. Ten aqueous-electrolyte cell systems, six molten-electrolyte cell systems, and three solid-electrolyte cell systems are reviewed. Seventy-eight references are cited.
- 5299
THE PROMISE OF FUEL CELLS AS A SOURCE OF ELECTRIC POWER. Sci.Horizons, no.33: 3-4, Apr.1963.
- In theory, fuel cells are 100 per cent efficient and so should be superior to batteries and conventional engines as soon as cheaper electrodes are developed. These adaptable devices are likely to be used in small power stations, motor vehicles and in spacecraft.
- 5300
Sale, B. LES PERSPECTIVES D'APPLICATION INDUSTRIELLE DES PILES A COMBUSTIBLES. (PROSPECTS OF INDUSTRIAL APPLICATION OF FUEL CELLS). Inst.Franc.Petrole & Ann. Combust. Liquides, Rev.,17:1181-1198, Sept.1962.
- Investigates from an engineer's point of view, some of the expected applications of fuel cells in the main industrial areas, i.e., output of electric power and "direct" output of mechanical work. (Battelle Tech.Rev., 12:17a, Jan.1963).
- 5301
Schanz, J.L. & Bullock, E.K. GEMINI FUEL CELL POWER SOURCE-FIRST SPACECRAFT APPLICATION. American Rocket Society, Space Power Systems Conference, September 25-28, 1962, Santa Monica, Calif. 1962. (ARS Paper 2561-62).
- An ion-exchange membrane fuel cell was chosen to furnish electrical power for the Gemini. The solid electrolyte fuel cell design, its developmental status, and key results to date are described briefly. Extensive testing experience has been favorable and substantiates the technical feasibility of the ion-exchange membrane fuel cell and its ability to perform its intended Gemini duty. (Astron.Info.Abs.,7:70,411, Feb.1963).
- 5302
SYMPOSIUM ON FUEL CELLS, DETROIT, OCTOBER 1961. Electrochemical Soc.Detroit, The Society, 1961. 161p., Brit.Non-Ferrous. Met.Assoc.Bull., no.389, p.504, Dec.1961.
- Abstracts (116, and some several pages in length) are given of sessions on primary and secondary batteries and their properties, fuel electrodes, oxygen electrodes, fuel cells, fused-salt corrosion and high-temperature fuel cells. The existence of these abstracts is no guarantee that longer corresponding communications will necessarily appear. (Fuel Abs. & Current Titles 3:1241, Feb.1962).
- 5303
Szego, G.C. and Cohn, E.M. FUEL CELLS FOR AEROSPACE APPLICATION. Astron. and Aerospace Eng., 1:107-111, May 1963.
- Studies are beginning on pulsed operation of fuel cells and space-biocell experiments.
2. Theory
- 5304
Aerospace Corp., El Segundo, Calif. EQUIVALENT CIRCUITS AND EFFICIENCIES OF FUEL CELLS, by J.I. Slaughter. 31p., May 17,1962. (Contract AF 04(647)-930).
- By introducing an equivalent thermal potential fixed in terms of the heat of reduction, a thermodynamic equivalent circuit is determined for a fuel cell which yields the correct current-potential curve of the cell for low current by formal application of Ohm's law. The thermodynamic power balance and the result of debethune for the thermodynamic efficiency also are given correctly. A linear electrical equivalent circuit is constructed which represents closely the electrical performance of the cell over a wide range of current (not approaching zero). The effect of polarization processes on the electrical power and efficiency is taken into

account through a single constant parameter. Introduction of the equivalent thermal potential into the circuit yields a thermodynamic equivalent circuit whose output computed by formal use of Ohm's law coincides exactly with that given by the electrical equivalent circuit. The correct electrical properties, thermodynamic power balance, and thermodynamic efficiency follow directly from the circuit. A general theorem is formulated, independently of the validity of an equivalent circuit, connecting the thermodynamic and electrical efficiencies of a fuel cell. Confirmatory experimental results based on hydrogen-oxygen cells are presented. The experimental results underline the large reduction in available power brought about by polarization processes in a fuel cell, in addition to that produced by the entropy change in the chemical reaction.

5305

Williams, K.R. and Gregory, D.P. ELECTROLYTES FOR LOW-TEMPERATURE FUEL CELLS. *Electrochem.Soc.J.*, 110:209-213, Mar.1963.

It is suggested that because of concentration polarization only strong acids or strong bases are suitable as electrolytes for commercially acceptable low-temperature fuel cells. If carbonaceous fuels are employed, acid electrolytes must be used, since alkaline electrolytes would react with the carbon dioxide produced. Experimental results are quoted to show that high performance oxygen and hydrogen electrodes can be made which operate satisfactorily in acid electrolytes.

5306

Winkle, J.V. and Carson, W.N. OPTIMIZATION CALCULATIONS FOR FUEL CELL SYSTEMS. *Electrochem.Tech.*, 1:18-22, Jan.-Feb.1963.

Many fuel cell applications require the minimization of the weight, volume or cost of the fuel cell system. This paper provides the method for combining the characteristics of the application, the fuel supply and the fuel cell itself to determine the design point for the desired minimum. The procedure consists of formulating the total system size in terms of the cell operating voltage and determining the value of the cell voltage which makes the total a minimum. The procedure is entirely general for fuel cell systems regardless of their specific characteristics or of the fuel and oxidant combination used. It provides the theoretical derivation for the figure of merit for the total fuel cell system in a particular application.

3. Electrode Processes

5307

Astropower, Inc., Newport Beach, Calif. INVESTIGATION OF ZEOLITE MEMBRANE ELECTROLYTES FOR FUEL CELLS, by A.D. Kelmers and others. 3v., Sept.18, Dec. 18,1962 & Mar.18,1963. (Repts. 108-Q1, Q2, & Q3) (Contract NAS 7-150).

The experimental program is designed to evaluate the potential applicability of various synthetic zeolites as hydrated solid electrolytes by investigating their physical and electrochemical properties.

5308

Austin, L.G. ELECTRODE KINETICS AND FUEL CELLS. *Inst.Elec.& Electr.Engrs.Proc.*, 51:820-837, May 1963.

This paper is a presentation of some of those aspects of electrode kinetics which pertain to fuel cells. It is intended as an introduction to the relevant theory of electrode kinetics. It does not give details of testing circuitry, nor does it review papers on electrode kinetics or fuel cell investigations. A brief mention is made of the application of the basic concepts to porous electrode structures.

5309

Florida University, Engineering and Industrial Experiment Station, Gainesville. A FEASIBILITY STUDY OF PALLADIUM AS A HYDROGEN DIFFUSION ELECTRODE MATERIAL FOR FUEL CELLS, by L.L. Chiu. 30p., illus., Oct.1,1962. (Summary Rept.5) (Contract DA 49-186-502-ORD-860) (AD-287 055).

Pd films as H diffusion electrodes in fuel cells were investigated and found to possess very interesting possibilities when the thickness is of the order of 100 Angstrom - or at temperatures above 200 C. Above 400 C, H transport through Pd films is found to follow a semi-logarithmic relationship, with an activation energy for diffusion of about 5.5 kcal/g-mole. At approximately 200 C, a low temperature phase having the approximate composition Pd₂H forms with a heat of dissociation of about 8.5 kcal/g-mole. At temperatures below 150 C, the current density supportable by mass transport is too low to make Pd films suitable for gas diffusion electrodes in fuel cells. Additional experimental work is suggested to clarify the possibilities of using Pd as a fuel cell electrode under conditions other than those indicated above. (TAB U63-1-3:19, Feb.1,1963).

5310

Massachusetts Institute of Technology,
Research Laboratory of Electronics,
Cambridge, Mass.
RATE-LIMITING STEPS ON FUEL-CELL
ELECTRODES, by A.R. Reti. 84p., illus.,
Jan.1963. (ASD-TDR-63-118) (Final Rept.)
(Contract AF 33(616)-7624).

The purpose of this investigation was to identify and to study the step or steps that limit fuel-cell electrode performance. The electrodes considered were the typical porous, gaseous-diffusion type, and most of the effort was directed toward acquiring a more quantitative understanding of the effect of the different variables governing electrode performance.

5311

Pennsylvania State University, Mineral
Industries Experiment Station,
University Park.
A DISCUSSION OF SOME ASPECTS OF ELECTRODE
KINETICS RELEVANT TO FUEL CELL STUDIES,
by L.G. Austin. 66p., illus., June 1962.
(Rept. 1) (Contract DA 49-186-502-
ORD-917) (AD-282 548).

Some aspects of electrode kinetics which would be of use to scientists and engineers working on fuel cells are presented. The report is intended as an introduction to the relevant theory of electrode kinetics and it does not give details of testing circuitry, nor does it review papers on electrode kinetics or fuel cell investigations. (TAB U62-4-5:34, Dec.1,1962).

5312

Pennsylvania University, Electrochemistry
Laboratory, Philadelphia, Pa.
REVERSIBLE OXYGEN ELECTRODES, August 1 -
October 31,1962, by A. Damjanovic, M.L.
Bhaskara Rao and M. Genshaw. 26p.,
Dec.31,1962. (Q.Rept. 4) (Contract
DA 36-039-sc-88921).

Adsorption of oxygen on oxide free platinum electrode has been studied in pure 1 N H₂SO₄ solutions. Coverage of electrodes with oxygen has been evaluated for various partial pressures of oxygen and temperatures. Heat of adsorption was obtained at different coverages. Dependence of rest potentials on coverage and on the temperature was determined. Preliminary work on the study of oxygen electrode reactions is described.

5313

Pennsylvania University, Electrochemistry
Laboratory, Philadelphia, Pa.
STUDIES OF THE FUNDAMENTAL CHEMISTRY
PROPERTIES AND BEHAVIOR OF FUEL CELLS,
October 1,1962 - March 31,1963, by J.O'M,
Bockris. 55p., Mar.31,1963. (Semi-Annual

Progress Rept. 1) (Contract
NASA Nsg 325).

The studies reported on are: potentials of zero charge, deactivation of catalysts: adsorption, nature of catalysts, mechanism of electro-catalysis, studies of the mechanism of porous electrodes, and the theory of electric double layers.

5314

Rensselaer Polytechnic Institute, Troy, N.Y.
ELECTROCHEMICAL BEHAVIOR OF A PALLADIUM
HYDROGEN DIFFUSION ELECTRODE, by L.
Lederer and N.D. Greene. 12p., Sept.25,
1962. (SR 2) (Contract AF 19(604)-8377).

Electrochemical studies on palladium hydrogen diffusion electrodes indicate that sufficiently high current densities can be achieved to make their use as hydrogen electrodes in fuel cell applications practically feasible. Using a palladium oxide catalyst, formed by heating the electrode in air at 600°C, maximum current densities of 75 ma/cm² at a solution temperature of 24°C and 140 ma/cm² at 43.5°C were achieved.

5315

Schwabe, K. RADIATION ACTIVATION OF OXYGEN
ELECTRODES IN A FUEL CELL. Am.Chem.Soc.,
Div.Petrol.Chem., Preprints 6, 61-68, 1961.

The influence of β- and γ-emitters on the O electrode and on its capacity were measured. A number of emitters, mostly deposited electrolytically on the electrode, were tried. Since all behaved similarly, the work was concentrated on Tl²⁰⁴ and Ru¹⁰⁶. The radiation accelerated the approach to the stationary potential; and the potential value reached was closer to the reversible potential if the radiation source was situated on the electrode itself. A lower potential drop also occurred during load. Tl²⁰⁴ had a greater effect than Ru¹⁰⁶ at a lower level of radioactivity per cm². (Chem. Abs., 59:1271, Jly.22,1963).

5316

Speer Carbon Co., Research Laboratory,
Niagara Falls, N.Y.
FUEL CELL ELECTRODE MATERIALS, June 1 -
November 30,1962, by W.E. Parker, R.W.
Marek, and E.A. Heintz. 2v., Aug.31, &
Nov.30,1962. (Q.Rept. 2 & 3) (SCC-
15 & 16) (Contract DA 36-039-sc-88954).

During the second quarter the effects of raw materials selection of the electrochemical performance of carbon fuel cell electrodes were determined by preparing two series of samples in which raw materials and proportions were held constant while processing conditions were altered. In this manner, a broad

range of physical properties was produced within each series. During the third quarter a series of electrodes possessing two and three zones of porosity were prepared. It was observed, for a given electrode material, that the reaction at the oxygen electrode is predominantly reduction to oxide when the coarse side of the electrode faces the electrolyte. When the fine side of the same electrode faces the electrolyte reduction to peroxide or perhydroxyl occurs. These observations were valid only for a given electrode material as no over-all correlation between electron change values and pore size could be made.

5317
Thompson Ramo Wooldridge, Inc., Cleveland, Ohio.
ELECTRODE DEVELOPMENT PROGRAM, S.S.
Carlton. 43p., June 1962. (Final Rept.)
(ASD-TDR 63-241) (Contract AF 33(600)-42449).

This report covers the third phase of a program relating to the development of a thermally-regenerative lithium hydrogen fuel cell. Emphasis is placed on improvement of the solid columbium hydrogen diffusion electrode and methods for improving its performance. Various procedures are examined for purification of the operating media and for testing their purity. An all-columbium fuel cell is described, and the result of a successful test run embodying the data developed during the purification studies is presented. Data are included for the various test steps, and the information is analyzed and discussed.

4. Primary

a. Hydrogen-Oxygen

5318
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
DESIGN OF 400 WATT HYDROGEN OXYGEN
CAPILLARY TYPE FUEL CELL, May 15 - October
31, 1962, by N.P. Bannerton, and others.
2v., Aug. 15, & Nov. 15, 1962. (Q.Tech.
Prog.Repts. 1 & 2) (Contract AF 33(657)-
8970) (AD-282 178 & AD-288 645).

The design of a hydrogen-oxygen fuel cell system was undertaken. The fuel cell module design was finalized and space oriented components were fabricated for feasibility tests. Two laboratory models of a 50 watt orbital fuel cell package were assembled. The method selected to reject the heat burden produced by the fuel cell package operating in space is evaporative cooling using water. (TAB U62-4-5:32, Dec.1, 1962 and TAB U63-1-4:28, Feb.15, 1963).

5319
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
FUEL CELL POWER PACK, December 11, 1961 -
June 30, 1962. 19p., illus., Jly. 30,
1962. (Engr.Res.Study Rept. on Phase 1)
(Contract DA 49-186-502-ORD 1057)
(AD-282 294).

A 1.5 kw experimental fuel cell system was designed and constructed. The hydrogen-oxygen fuel cell is an air cooled unit rated at 500 w at 12 v. It consists of 15 individual cells connected in series with each cell having an area of 0.489 sq. ft. (TAB U62-4-5:33, Dec.1, 1962).

5320
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
RESEARCH AND DEVELOPMENT OF AN OPEN-
CYCLE FUEL CELL SYSTEM, May 14, 1962 -
March 31, 1963, by R. Opperthausen, and
others. 3v., Sept. 30, Dec. 31, 1962 and
Mar. 31, 1963. (Q.Repts. 1, 2 & 3)
(TP 2-831321) (Contract NAS 8-2696).

Theoretical and experimental studies have been directed toward the development of the Vapor Pressure Control technique for the removal of by-product water from hydrogen-oxygen fuel cells.

5321
Brooklyn Polytechnic Institute, Brooklyn, N.Y.
FUEL CELL MATERIALS, September 1, 1960 -
February 28, 1962, by H.P. Gregor and
R.M. Danziger. 44p., illus., Feb. 28,
1962. (Q.Prog.Rept. 6 (Final)) (Contract
DA 36-039-sc-85384) (AD-283 651).

Measurement of the functional behavior of catalyst-impregnated ion-exchange membrane electrolytes in a modified H₂-O₂ fuel cell was made. An improved imprinting technique (the hot press method) was developed for membranes. New membrane electrolytes were prepared, including films with a fluorinated matrix polymer and films containing cross-linking resins for enhanced mechanical strength. Significant improvements were also made on the water-retaining properties of membrane electrolytes. (TAB U62-4-6:179, Dec. 15, 1962).

5322
Davtyan, O.K., Izmailova-Ratushnaya, D.N.
and Manakin, B.A. AN OXYGEN ELECTRODE
ON A CHROMIUM-NICKEL CARRIER. Nauch.
Ezhegodnik Odessk.Gos.Univ., Khim.Fak.,
no.2:120-123, 1961.

The O-electrode carriers were prepared from porous Ni skeletons filled with Cr-Ni active masses prepared by different methods; the most active was prepared from CrCl₃ and Ni(NO₃)₂. With increase in the temperature at which the electrode carriers were oxidized, both the electrode

potential and the amount of electrochemical active O, adsorbed by the electrode, increased. The Cr-Ni active mass may be a good depolarizer for the O-electrode in a H-O cell, particularly at high temperature. (Chem.Abs.,58: 225-226, Jan.7,1963).

5323

Frank, H.A. ELECTRICALLY-REGENERATIVE HYDROGEN-OXYGEN FUEL CELL. American Rocket Society Space Power Systems Conf., Sept. 25-28, 1962, Sp., Santa Monica, Calif., 1962. (ARS Paper 2563-62).

A description is presented of the status of electro-optical systems in the development of an electrically regenerative hydrogen-oxygen fuel cell for space application. The system performs the same function as a secondary battery in spacecraft, and shows potential advantages over batteries from standpoints of energy-to-weight ratio, cycle life, and operating temperature range. (STAR, 1: 15, Jan.8,1963).

5324

General Electric Co., Direct Energy Conversion Operation, Lynn, Mass. FUEL CELL RESEARCH AND DEVELOPMENT ION EXCHANGE MEMBRANE FUEL CELL FOR NAVAL PROPULSION, August 1 - October 11,1962. 67p., Oct.11,1962. (Q.Prog.Rept.4) (Contract NObs-86380).

While the objective of 4000 hours of operation at duty cycle power densities was not realized during this reporting period, cells of "Polymer A" Series A and Series D both exceeded 4000 hours at power densities higher than the average power density for duty cycle conditions. In addition, duty cycle operation for a period of approximately 1000 hours was achieved. During this reporting period a program was initiated to determine the causes of premature failures during duty cycle operation.

5325

General Electric Co., Philadelphia, Pa. HYDROGEN-OXYGEN PRIMARY EXTRATERRESTRIAL (HOPE) FUEL CELL PROGRAM, PHASE I AND APPENDICES, April 1961 - June 1962. 2v., Sept.1962. (Final Rept.) (Contract AF 33(616)-8159) (ASD-TDR-62-522, Append.) (AD-291 621).

Phase I of this program resulted in the development and test of a 35-cell 25-watt/28 volt space configuration fuel-cell module. The HOPE spacecraft, fuel supply tanks, pneumatics, and thermal systems have been designed and fabricated to provide operating capability in orbit for 7 days at 50 watts, compatible with the Blue Scout launch vehicle. A series of

development tests were conducted to verify water removal, thermal design, and 30-day shelf-life of the fuel cell. The 35-cell module was subjected to a series of performance tests. During the last test, it performed continuously for 7 days at an average 27 watts/29.5 volts. Following this test, the module delivered rated power without interruption during vibration tests simulating Blue Scout booster environment. (TAB U63-1-6: 11, Mar.15,1963 and Sci.& Tech.Aerospace Rept., 1:N63-15188, June 8,1963).

5326

General Electric Co., Space Sciences Laboratory, Philadelphia, Pa. HYDROGEN-OXYGEN PRIMARY EXTRATERRESTRIAL (HOPE) FUEL CELL PROGRAM, May 1 - August 1,1962, by R.J. Barchet. 62p., illus., Aug.1,1962. (Q.Tech.Prog.Rept. on Phase 1-a) (Contract AF 33(657)-9860) (AD-282 423).

Fuel cell development tests were conducted with 4, 5, and 6 cell stacks, and with Module No.2. (TAB U62-4-5: 33-34, Dec.1,1962).

5327

General Electric Co., Spacecraft Department, Philadelphia, Pa. HYDROGEN-OXYGEN PRIMARY EXTRATERRESTRIAL (HOPE) FUEL CELL PROGRAM, June - October 1962, by L.E. Chapman and others. 549p., Jan.1963. (Final Rept. on Phase 1-a) (Contract AF 33(657)-8960).

The activities conducted on the HOPE (hydrogen-oxygen primary extraterrestrial fuel system) Phase Ia program are described. Included are: research on electrochemical reactions, hydrogen ion diffusion through polymeric membranes, internal mass transport of water through capillary action, and mass transport of water vapor through an ambient of diatomic oxygen gas at 1 atm. pressure. Project HOPE's ultimate objective was the design of a 500-watt fuel-cell power-system, including cryogenic fuel supply, for orbital applications. (Sci.& Tech. Aerospace Rept., 1:N63-15187, June 8,1963).

5328

General Electric Co., Direct Energy Conversion Operation, Lynn, Mass. ION EXCHANGE FUEL CELL, January 1 - June 30,1962. 277p., illus., June 30,1962. (Semi-Annual Tech.Summary Rept. 2) (Contract DA 36-039-sc-89140).

Experimental electrochemical techniques related to chronopotentiometric, galvanostatic, potentiostatic and double-layer capacity measurements have been successfully applied to the ion-exchange membrane fuel cells. Different

types of reference electrodes have been developed. Physical and chemical properties of membranes have been investigated and related to fuel cell performance. Air-operated electrodes have been studied in single and multi-cell systems.

5329

General Electric Co., Direct Energy Conversion Operation, Lynn, Mass.
ION EXCHANGE FUEL CELL, October 1, 1961 - September 30, 1962, by H.J.R. Maget. 137p., Sept. 30, 1962. (Final Tech. Summary Rept. 3) (Contract DA 36-039-sc-89140).

Experimental electrochemical techniques related to chronopotentiometric, galvanostatic, potentiostatic measurements have been successfully applied to the ion-exchange membrane fuel cells. Different types of reference electrodes have been developed. Physical and chemical properties of membranes have been investigated and related to fuel cell performance. Air-operated electrodes have been characterized and studied in single and multi-cell systems.

5330

Gregor, Harry P., Leonia, N.J.
FUEL CELL MATERIALS, December 1, 1961 - February 28, 1962, Final Report, September 1, 1960 - February 28, 1962, by H.P. Gregor and R.M. Danziger. 44p., Feb. 28, 1962. (Rept. 6) (Contract DA 36-039-sc-85384).

Measurement of the functional behavior of catalyst-impregnated ion-exchange membrane electrolytes in a modified hydrogen-oxygen fuel cell was made. An improved imprinting technique (the hot press method was developed for membranes prepared in the laboratory. Additional, new membrane electrolytes were prepared, including films with a fluorinated matrix polymer and films containing cross-linking resins for enhanced mechanical strength. Improvements were also made on the water-retaining properties of membrane electrolytes.

5331

Gregor, Harry P., Leonia, N.J.
ION-EXCHANGE MEMBRANE ELECTROLYTES, March 1 - November 30, 1962, by H.P. Gregor and others. 3v., May 31, Aug. 31, & Nov. 30, 1962. (Q. Prog. Rept. 1, 2, & 3) (Contract DA 36-039-sc-89197).

The general objective of this investigation is the development of membrane electrolytes which permit higher power per unit of weight and volume, as well as long operational life in fuel cells.

5332

Shaw, R.H. and Thompson, R.A. HYDROGEN-

OXYGEN FUEL CELL SYSTEM FOR SPACE VEHICLES. American Rocket Society, Space Power Systems Conf., Sept. 25-28, 1962. Santa Monica, Calif., 1962. (ARS Paper 2560-62).

An attempt is made to show how hydrogen-oxygen fuel cells are integrated into an optimum powerplant for a space mission. Cell performance parameters are also discussed. The Hydrox cell, which employs hydrogen and oxygen reactants, dual porosity nickel-nickel oxide electrodes, and aqueous potassium hydroxide electrolyte, is considered. (Astron. Info. Abs., 7:70, 503, Feb. 1963).

b. Carbonaceous

5333

Beller, William. TEN YEARS HENCE HYDRO-CARBON FUEL CELLS MAY POWER TRACKING SITES. Missiles and Rockets, 12:26, 29, Apr. 29, 1963.

Chief advantage of such a cell is that its fuel is cheaply obtained, easily stored and shipped. Other advantages fuel cells have over competitors: Efficient conversion of fuel to electricity. Reliability because of no moving parts. Noiseless operation. No electromagnetic signal.

5334

Engelhard Industries, Inc., Research and Development Division, Newark, N.J.
FUEL CELL CATALYSTS, July 1 - December 31, 1962, by O.J. Adhart. 2v., Sept. 30, & Dec. 31, 1962. (Q. Repts. 1 & 2) (Contract DA 36-039-sc-90691).

A research program is carried out on electrode catalysts for fuel cells employing liquid organic fuels. Complete oxidation of the fuel to carbon dioxide and water is required under expulsion of these products from the fuel cell. The electrolyte of the cell, therefore, must be of sufficient acidity to avoid retention of carbon dioxide.

5335

ESSO Research & Engineering Co., Products Research Division, Linden, N.J.
SOLUBLE CARBONACEOUS FUEL-AIR FUEL CELL, January 1 - December 31, 1962, by B.L. Tarmy. 107p., Dec. 31, 1962. (Rept. 2, RL-60M-62) (Contract DA 36-039-sc-89156).

Research on the soluble carbonaceous fuel-air fuel cell has continued to concentrate on improving the performance of individual cell components and on translating these results into compatible electrode-electrolyte systems. These efforts encompass work carried out in three areas, namely the development of

the fuel electrode, the development of the air electrode, and their combination into a total cell.

5336
HYDROCARBON FUEL CELL. Eng., 215:1055-1058, June 7, 1963.

On April 23 the General Electric Company, of Schenectady, New York, presented the first public demonstration of a remarkable new type of fuel cell, which operates on a wide variety of common hydrocarbon fuels, including ordinary diesel oil. Fuel cells, convert chemical energy directly into electrical energy. They use common fuels and oxygen, but without combustion or moving parts. Because the fuel cell does not employ a heat cycle, the efficiency is inherently more than twice that of the best conventional power generators. Of all the several so-called "unique" energy conversion methods principally useful as portable power sources, the firm is presently most optimistic about fuel cells, and a large number of space, military and marine uses await their further development.

5337
MacDonald, Donald. HYDROCARBONS HIGHLIGHT FUEL CELL PROGRESS. Product Eng., 34:52, May 27, 1962.

Fuel cells that run on inexpensive and readily available hydrocarbons, are a potential source of energy. Laboratory models have been developed. They will probably be used first by the military as portable power sources in field applications.

5338
NATURAL GAS-POWERED FUEL CELL DEVELOPED. Am. Gas J., 190:38-39, Feb. 1963.

A new natural gas cell which operates at high temperatures and incorporates novel features for self-starting and for maintaining itself at about 2000 F without the use of externally applied heat. (Battelle Tech. Rev., 12:196a, May 1963).

5339
RANEY-TYPE PLATINUM METAL CATALYSTS. EXTENDED-SURFACE ELECTRODES IN FUEL CELLS. Platinum Metals Rev., 6:136-137, Oct. 1962.

When formaldehyde and formic acid were investigated as possible fuels, large current densities were obtained with polarizations comparable with those observed for methanol. Similar results were found in alkaline and acid electrolytes, although somewhat higher fuel conversion efficiencies were obtained in the latter. (Battelle Tech. Rev., 12:17a, Jan. 1963).

5340
Union Carbide Consumer Products Co., Cleveland, Ohio. CARBON ELECTRODE FUEL CELL. 92p., illus., Mar. 1963. (ASD-TDR 62-1044) (Interim Rept.) (Contract AF 33(616)-7256 SA/5) (AD-403 890).

Experimental studies are conducted on components of a carbon electrode fuel cell system, with emphasis on problems of operation in a space environment. A 500 watt (net electrical output) fuel cell system has been operated for 25 days continuously on fully automatic control in the laboratory. The performance is analyzed and related to the design of future flyable power systems.

c. Miscellaneous Fuels

5341
Aerospace Corp., Los Angeles, Calif. ENERGY CONVERSION RESEARCH PROGRAM. DIRECT CONVERSION OF CHEMICAL ENERGY TO ELECTRICAL ENERGY, January 1 - June 30, 1962, by F.D. Hess and S.W. Mayer. 8p., illus., Aug. 1, 1962. (Semiannual Tech. Rept.) (Rept. TDR-69(2220-30)TR-2) (Contract AF 04(695)-69) (DCAS TDR 62-164) (AD-285 084).

Prototype fuel cells were operated employing chlorine as oxidant, phosphorus trichloride as fuel, and methyl thiocyanate as solvent. Studies were made of pyrolytic processes for regeneration of reaction products and means of separating products. Other systems were investigated by chronopotentiometric techniques. Tungsten and antimony chlorides were found to have characteristics of special interest. (TAB U63-1-1:21, Jan. 1, 1963).

5342
General Motors Corp., Allison Division, Indianapolis, Ind. DESIGN AND DEVELOPMENT OF A LIQUID METAL FUEL CELL, by B. Agruss, H.R. Karas, and V.L. Decker. 143p., illus., Dec. 1962. (Final Rept.) (Contract AF 33(657)-7847) (ASD-TDR 62-1045) (AD-296 861).

Substantial progress has been made in the study and operation of potassium-mercury cells and in pointing up problem areas requiring solution. Six different types of cells were run, some utilizing a ceramic matrix while others operated on a differential density principle. Certain cells were operated with flowing cathode metal, so that steadiness of operation and regenerative capability could be studied. Results confirmed this regenerative capability up to 60 mw/sq. cm, the operating level of the experiment. Liquid metal cell

life was extended to as long as 550 hours to date. Current densities of 227 ma/sq. cm and power densities of 91 mw/sq. cm were achieved. Composite matrices composed of 6-micron MgO particles were produced, and electrical conductivities of discs of various electrolyte/MgO ratios were measured. Results conform to requirements of liquid metal cell systems. (TAB U63-2-4: 17, May 15, 1963).

5343

General Motors Corp., Allison Division, Engineering Department, Indianapolis, Ind. DEVELOPMENT AND TESTING OF ELECTROLYTE MATRIX COMBINATIONS FOR MERCURY-POTASSIUM FUEL CELL, December 12, 1962 - March 12, 1963. 33p., Apr. 10, 1963. (Rept. 3277) (QTPR 1) (Contract NASw-476).

Progress has been made in the following areas: 1) small differential density cell (DDC)-resistivity cell studies; 2) conductivity measurements of coarse grain composites; 3) strength measurements of coarse grain composites; 4) development of a preparation technique for fine grain composites; and 5) design of a small LMC and test rig.

5344

Monsanto Research Corp., Everett, Mass. COMPACT POWER FUEL CELL, December 10, 1960 - December 9, 1961, by J.O. Smith and others. 88p., June 1962. (Final Rept.) (ASD-TDR-62-42) (Contract AF 33(616)-7735).

A fuel-cell battery was built which generates 15 watts at 5 amperes for 8 hours, utilizing hydrazine (5M in 1.4 KOH) as fuel and nitric acid (10M) as oxidant. The battery consisted of 3 cells, each having an electrode area of 120 cm². The open-circuit voltage was 5.95 volts. Over the 8-hour period, the total current was just over 5 amperes at an operating voltage of about 4 volts. The battery produced 35 watt-hours/pound. Pentaborane and hydrogen peroxide were also tested as fuel and oxidant, respectively, with each other and with hydrazine and nitric acid. (STAR, 1:1963-16114, July 8, 1963).

5345

Peattie, C.G. and others. PERFORMANCE OF HIGH-TEMPERATURE FUEL CELLS. Pacific Energy Conversion Conf. Proc., San Francisco, 17:1-17, 1962.

Data are presented that were obtained with Baur-Broers cells having a MgO matrix that carries molten LiNaCO₃ electrolyte in its pores. H₂, reformed hydrocarbons, and higher paraffin hydrocarbons were used as fuels. The latter dehydrogenate in the cell at operating temperature (600-650°). (Chem. Abs., 58:3094, Feb. 18, 1963).

5346

Weaver, R.D., Smith, S.W. and Willmann, N.L. THE SODIUM/TIN LIQUID-METAL CELL. Electrochem. Soc. J., 109:653-657, Aug. 1962.

Preliminary studies of the liquid-metal cell have shown it to possess promising characteristics for application to the conversion of thermal energy. Polarization effects commonly associated with electrochemical cells are essentially absent: charge-discharge curves are straight lines passing through the open-circuit intercept. The conductivity of the fused electrolyte, 2.3 mhos, provides for low internal losses. Nongalvanic losses occur causing an apparent loss of reactants to the extent of 0.018 amp/cm². It is shown that a cell constructed of the materials and electrolyte employed in the study should allow operation at 0.7 amp/cm² at maximum power and that the coulombic efficiency would be 95% when continuously operated at this current density during balanced charge and discharge periods.

5. Regenerative

5347

California Institute of Technology. Jet Propulsion Laboratory, Pasadena, Calif. FUEL CELL ASSEMBLIES, January - March 1963, by Harvey Frank. 64p., Mar. 25, 1963. (JPL 950258) (EOS Rept. 3070-Final).

The objective of this program was to design, develop, and deliver multicell regenerative hydrogen-oxygen fuel cell assemblies. The final units contain 38 series connected cells and the prototype contains 36 cells. The cell stack of each unit is counted in a nickel plated aluminum tank which also serves as the hydrogen storage chamber. Another nickel plated aluminum tank serves as the oxygen storage chamber and is an integral part of the assembly. The nominal output of the unit is 30 volts at 4 amps for continuous operation. The maximum discharge output that has been attained with these units is 22 amp-hrs at 30 volts or 660 watt-hrs.

5348

Eisenberg, M. DESIGN AND SCALE-UP CONSIDERATIONS FOR ELECTROCHEMICAL FUEL CELLS. Adv. Electrochemistry & Electrochem. Eng., 2:235-291, 1962.

Article deals with regenerative-type fuel cells in which continuous supply of anodic fuel and of cathodic oxidizer is provided; kinetic principles, concepts, and definitions; transport processes in fuel cell systems; efficiency and material balance; scale-up of fuel cells; design

optimization study; calculations of pressure drop. (Eng.Index, p.65, May 1963).

5349

Electro-Optical Systems, Inc., Pasadena, Calif.
FUEL CELL ASSEMBLIES, April 10, 1962 - January 10, 1963, by Harvey Frank. 3v., Jly.10, Oct.15, 1962 & Jan.15, 1963. (EOS Rept. 3070-Q-1, 2, & 3) (Q.Repts. 1,2, & 3) (Contract NAS7-100).

The objective of the program is to develop and deliver three multi-cell regenerative hydrogen oxygen fuel cell assemblies to the Jet Propulsion Laboratory.

5350

Lockheed Missiles and Space Co., Sunnyvale, Calif.
U.S. Army Electronics Research Development Laboratory, Fort Monmouth, N.J.
SOLAR REGENERATIVE CHEMICAL SYSTEM, September 4, 1959 - September 30, 1962, by L.B. Anderson, E.V. Ballou, and S.A. Greenberg. 24lp., illus., Sept.30, 1962. (Rept. 7) (Rept. OST 76-08-000-61) (Final Rept.) (Contract DA 36-039-sc-85245).

A study of photochemical and thermochemical approaches to the conversion of solar energy to electrical energy is reported. A closed-cycle photo-regenerative system was operated for 90 days at conversion efficiencies approaching 0.2%. Methods of thermal regeneration which were studied include thermal dissociation, electrolysis at elevated temperatures and electrolysis into low pressure regions. Thermal regeneration appeared completely inapplicable to the systems studied. Although the electrolysis methods were feasible in principle, their application awaits the solution of materials handling problems. Fused salt thermocells employing regeneration by mass transfer were also investigated. Elementary thermocell devices were constructed and tested.

5351

Mayer, S.W. and Brown, W.E., Jr. ELECTRODE KINETICS FOR CHLORIDES OF TUNGSTEN, ANTIMONY, AND PHOSPHORUS. Electrochem. Soc., J., 110:306-311, Apr.1963.

Chronopotentiometry has been utilized to measure the rate constants for the first electroreduction step at platinum in dimethylformamide solution of several chlorine compounds of interest for regenerable fuel cell systems. The chronopotentiometric curves were also used to determine the diffusion coefficients and the products of the transfer coefficients with the number of electrons involved in the rate-determining steps. Tungsten hexachloride obeyed the chronopotentiometric equation of reversible reactions, with an $E_{1/4}$ of -0.159v (vs. a gold reference electrode)

for its one-electron first reduction step. The reduction of $SbCl_5$ to $SbCl_4$ was irreversible and occurred in two steps, suggesting the intermediate formation of $SbCl_4$. The reductions of phosphorus chlorides and several group IV A chlorides were also found to be irreversible. Some correlation was noted between bond energies and the reciprocals of the rate constants. The electrode surface-area requirements for minimizing activation polarization for PCl_5 and $SbCl_5$ were calculated from the rate constants and chronopotentiometric data. Using Latimer's method, it was estimated that the WCl_6 fuel cell could produce 40% higher open-circuit voltage than the PCl_5 fuel cell.

5352

Pennsylvania State University, Mineral Industries Experiment Station, University Park, Pa.
REDOX FUEL CELLS: THE FUEL REGENERATOR, by L.G. Austin, R.D. Chamberlin, and A.R. Schleicher. 27p., Aug.1962. (Contract DA 49-186-502-ORD-917) (AD-289 559).

An essential feature of a redox fuel cell employing a cheap hydrocarbon fuel is that the fuel must reduce the metallic ion (produced from the cell) at a reasonable rate. A large number of tests on the titanyl-titanous system and the stannic-stannous system, at temperatures up to 200 C, indicate that formic acid, formaldehyde and methanol will not reduce the higher valent ion to the lower at a feasible rate. Considerations of thermodynamic equilibrium, solubility and mass transport predict that regeneration by hydrocarbons will be even less feasible. (TAB U63-1-4:31, Feb.15, 1963).

5353

Thompson Ramo Wooldridge, Inc., Cleveland, Ohio.
ZERO GRAVITY SEPARATOR DEVELOPMENT FOR REGENERATIVE FUEL CELL, by A.J. Stromquist. 58p., illus, June 1962. (Final Rept.) (ASD-TDR-62-240) (Contract AF 33(600)-42449) (AD-284 474).

The separators tested in project were designed to show variance in separation between ground operation (+1.0G) and zero gravity operation as simulated by KC135 aircraft flying zero gravity trajectory. These separators, when sufficiently developed, are to be used in conjunction with the regenerative fuel cell. Because of safety precautions aboard aircraft, simulated fluids were used instead of actual fuel cell fluids. Design procedure for zero G separators is outlined in conclusion of report.

6. Biochemical

5354

Colichman, F.L. PRELIMINARY BIOCHEMICAL FUEL CELL INVESTIGATIONS. Inst.Elec.& Electr. Engrs.Proc., 51:812-819, May 1963.

The action of *Desulfovibrio* bacteria has been observed in a prototype biochemical fuel cell. The catabolic action of this microorganism in a properly balanced system, i.e., containing proper electrolyte-nutrient and bio-fuel combination, shows promise of yielding a practical, low-power biochemical fuel cell generator. Best results to date have been obtained with fresh mushroom as the bio-fuel where power levels of 1540 μ w per square inch have been achieved. Further experimentation planned in this laboratory will be directed at improving the power constancy at the higher current-voltage drainage rates.

5355

General Electric Co., Space Sciences Laboratory, Philadelphia, Pa.
RESULTS OF SOME EXPERIMENTS IN BIOCHEMICAL ELECTRICITY, by J.J. Konikoff and L.W. Reynolds. 25p., illus., Jan.1963. (Rept. R63SD8) (AD-296 045).

A Biochemical Fuel Cell system consisting of algae and fecal bacteria produced 0.3V at 1.4 to 2.0 ma/sq ft. The biological mechanism was studied by using a simplified system which contained only one organism, Fleischmann's yeast. Electrical properties were evaluated by analyzing polarization curves. These curves show a power density of 0.66 w/sq ft and a current density of 2.2 amps/sq ft at 0.3 volts. Finally, the catalytic action of the platinum-black was investigated. Bioelectric Potential has been measured in rats by placing electrodes in different parts of the body. The electrical output has been evaluated as above and indicates a power output of 90 microwatts at a current of 300 microamperes. For this study the electrode geometric area was about 75 sq mm. A 500 kc sine wave oscillator was designed and constructed and has been operated from the energy obtained from Bioelectric Potential of a 200 gram rat with implanted electrode. (TAB U63-2-4:44-45, May 15,1963).

5356

Magna Corp., Anaheim, Calif.
BIOCHEMICAL FUEL CELLS, July 1 - December 31, 1962, by H.P. Silverman, W.R. Momyer and J.M. Brake. 2v., ept.30, & Dec.31, 1962. (Q.Prog.Rept. 1 & 2) (Contract DA 36-039-sc-90866).

Studies of the biochemical influence on electrochemical phenomena were initiated as part of a program leading towards the development of biochemical fuel cells. Five biochemical systems were selected for study. Cultural and physiological studies of the *Clostridium butyricum* and *Escherichia coli* were started. The effects of pH, temperature, substrate concentration and salt content on gas evolution by the *Clostridium butyricum* are reported.

5357

Melpar, Inc., Falls Church, Va.
BIOCHEMICAL FUEL CELL, July 1 - December 31,1962, by R.T. Foley, G.C. Blanchard, and P.S. May. 2v., Sept.30, & Dec.31,1962. (Q.Prog.Rept. 1 & 2) (Contract DA 36-039-sc-90878).

In the first report the initial experimental results and the planned course of action on this program are described in the second report experimental investigation of microorganisms capable of producing hydrogen for fuel cell use is described.

5358

Ohio State University Research Foundation, Columbus, Ohio.
STUDY OF BIOELECTRIC ENERGY SOURCES, December 1,1960 - December 31,1961, by Quentin Van Winkle. 166p., June 1962. (ASD-TDR-62-377) (Contract AF 33(616)-7693) (AD-284 881).

A comprehensive literature review has been made on the subject of Bioelectricity. The review includes the following topics: 1) Survey of species which produce Bioelectricity, 2) Mechanism of production of Bioelectricity, 3) Electrochemistry of membrane phenomena, 4) Preparation and properties of synthetic ion-selective membranes, and 5) Production of electricity by ion diffusion. The electric discharge characteristics were determined for two species of knifefish and for the electric eel. A cell was designed and constructed for the study of the impedance of single living cells from the electric organs of Electrophorus Electricus.

5359

Potter, M.C. ELECTRICAL EFFECTS ACCOMPANYING THE DECOMPOSITION OF ORGANIC COMPOUNDS. Roy.Soc.London. Proc., 84B:260-276, 1911.

A description is given of a battery of 6 yeast cells with carbon electrodes connected in parallel which gave 1.25 ma.

5360

Scott, W.R., Rohrback, G.H. and del Duca, M.G.
BIOCHEMICAL FUEL CELL POTENTIALITIES FOR

SPACE FLIGHT. Space Power Systems Conference, Santa Monica, Calif., Sept. 1962. Preprint Paper #2562-62, 16p., New York, American Rocket Society, 1962.

An introduction of biochemical fuel cells is presented, including the special characteristics of these cells, useful types of catalysts, and mechanism of reactions. A number of bioelectrodes are discussed in detail with performance data. The general application of bioelectrochemical devices to space vehicle operation is considered, including disposal of solid, liquid, and gaseous human waste products. Present and future capabilities are discussed. The point is made that as a result of their low power density biochemical fuel cells do not appear promising as power supplies. (Nuclear Sci. Abs., 17: 5663, Mar. 15, 1963).

B. Primary Batteries

5361
BATTERIES. Radiotronics, 28:54-61, Mar. 1963.

This article discusses the history, basic types, construction, characteristics, testing, recharging and selection of batteries.

5362
Calvin College, Grand Rapids, Mich.
SILVER MIGRATION AND TRANSPORT MECHANISM STUDIES IN SILVER OXIDE ZINC BATTERIES, August 1 - November 1, 1962, by T.P. Dirkse and L.A. Vander Lugt. 15p., illus., Nov. 1, 1962. (Q. Tech. Prog. Rept. 2) (Contract AF 33(657)-8689) (AD-289 062).

Thirteen different materials were checked for their reaction towards silver oxide dissolved in potassium hydroxide solutions. Of these, the polyethylenes appear to have most promise as separator materials. Several attempts were made to trace the migration of silver in a silver-cadmium cell by the use of radioactive silver. A method of counting the radioactivity is being developed. The main difficulty encountered in this study is the take-up of radioactive silver by the electrodes. This has obscured the interpretation of the results obtained to date. (TAB U63-1-4:29, Feb. 15, 1963).

5363
Calvin Collage, Grand Rapids, Mich.
SILVER MIGRATION AND TRANSPORT MECHANISM STUDIES IN SILVER OXIDE-ZINC BATTERIES, November 1, 1962 - February 1, 1963, by T.P. Dirkse and L.A. Vander Lugt. 8p., illus., Feb. 1, 1963. (Q. Tech. Prog. Rept. 3) (Contract AF 33(675)-8689) (AD-296 894).

A study was made of three methods whereby radioactive silver can be used to determine

quantitatively the concentration of small amounts of silver dissolved in potassium hydroxide solutions. Good results were obtained by precipitating the dissolved silver as silver iodide and collecting this on a filter paper of sufficiently small pore size. The precipitated silver iodide was then counted. (TAB U63-2-4: 17, May 15, 1963).

5364
Catalyst Research Corp., Baltimore, Md.
CHEMICALLY HEATED ZINC SILVER OXIDE BATTERY, July 1 - September 30, 1962, by J.J. Holechek, and others. 27p., Sept. 30, 1962. (Q. Prog. Rept. 1) (Contract DA 36-039-sc-90812).

An investigation has been initiated for the purpose of developing an automatically activated zinc-silver oxide battery, with a chemical heating device. The technical efforts are being directed toward meeting the general requirements of the standard BA-485/U, that is, 1.5 second activation throughout the temperature range of -40 to 165°F while maintaining close voltage regulation. During the quarter, a study was undertaken to determine the theoretical heat requirements to promote rapid activation, particularly at the -40°F ambient temperature. Approaches to meeting the overall objectives were also evaluated. Preliminary heating devices (heat exchangers) were also designed on the basis of the theoretical requirements.

5365
Davtyan, O.K., Kuskova, M.S. and Manakin, B.A.
STUDY OF A CELL HAVING HYDROGEN PEROXIDE AS DEPOLARIZER. Nauch. Ezhegodnik, Odessk. Gos. Univ., Khim. Fak., no. 2: 117-120, 1961.

The chemical polarization of the cell $C(O_2)/NaOH(40\%)/Zn$, the e.m.f. of which is 1.41 v., was determined in relation to the current strength and rate of feeding H_2O_2 dropwise inside the porous C electrode. With increase in the H_2O_2 feed rate, the generated current increased up to a limiting value when the rate was 100 drops/min. The working voltage of the cell, at constant generated current, increased with increase in the H_2O_2 feed rate. When the H_2O_2 feed rate was 20 drops/min, and the generated current was kept constant at 0.2 amp., the cell operated continuously for 54 hours, when the Zn has still not completely dissolved, the voltage dropping stepwise. The first step corresponded to complete conversion of the NaOH in the electrolyte into zincate, in a solution of which Zn has a different potential than in NaOH solution; the second step corresponded to almost complete dissolution of the Zn electrode. H_2O_2 is a good depolarizer for the $C(O_2)$ electrode. (Chem. Abs., 58:225, Jan. 7, 1963).

5366
Drotschmann, C. MnO₂ DEPOLARIZATION IN
LECLANCHE-TYPE DRY CELLS. Batterien, 16:
384-392, 1962.

A review is given of the facts about the MnO₂ deposits which proved to be reproducible: e.g. $\Delta E/\Delta pH$, solubility of Mn⁴⁺, potential of MnO_{1.5} oxides, ion exchange on Mn⁴⁺ oxides and hydroxides, etc. From these facts it was deduced that during electrolytic reduction of MnO₂, Mn⁴⁺ forms. These ions can (a) go into solution, (b) readsorb on Mn⁴⁺ hydroxide, or (c) react chemically with MnO₂. The depolarization reactions are different for these 3 cases. The E₀ values of lower Mn oxides increase with time in contact with electrolyte because a disproportionation of these oxides to Mn⁴⁺ and Mn²⁺ is observed. The rapid decrease of the MnO₂ potential at the start of discharge is due to the formation of OH⁻ around the cathode. X-ray diagrams of different reaction products are given. (Chem.Abs.,58:5255, Mar.18,1963).

5367
Herbert, W.S. RECHARGING OF LECLANCHE DRY
CELLS. Electrochem.Tech., 1:148-151,
May-June 1963.

Previous efforts toward recharging dry cells were chiefly concerned with the electrical results obtained. In this work, the recharging of Leclanche dry cells was studied more from the standpoint of the effects occurring in the cell during both the discharge and charging operations. It was found that fixed potential charging in the range of 1.7-1.9v was most satisfactory. Constant current charging can result in damage to the cells and is to be avoided, especially for cells arranged in series. A suitable fixed-potential charging circuit was developed. Typical performance characteristics of dry cells during charge and discharge are presented for various stages of cycling. Some of the factors limiting cycle life are described. It is concluded that recharging can extend the useful life of dry cells under carefully selected conditions.

5368
Hirai, Taketsugu, Manabe, Haruo, and Fukuda,
Masataro. ELECTROLYTE COMPOSITION IN
THE BOBBIN OF DRY CELLS. (Chemistry of
manganese dioxide dry cells. -16) Natl.
Tech.Rept. (Japan), 7:129-133, June 1961.

The compositions of the electrolyte in the bobbins of D size dry cells were estimated from chemical analysis and electrochemical data, e.g., pH and zinc electrode potential. It was confirmed that zinc chloride concentration in liquid phase of NH₄Cl-ZnCl₂-H₂O system was about 10-20%, the content of Ni₄Cl crystal was below 5 g. and the

content of ZnCl₂·2NH₃ was below 3% of the total electrolyte. It is concluded that the electrolyte composition differed very much from sample to sample by types of discharge. (JSR Mech. & Elec.,8: 214, Aug.1961).

5369
Hirai, Taketsugu, Manabe, Haruo, and Fukuda,
Masataro. HARDNESS CHANGE OF BOBBIN
SURFACE OF DRY CELLS DURING DISCHARGE.
(Chemistry of manganese dioxide dry
cells.-15). Natl. Tech.Rept.(Japan), 7:
125-128, June 1961.

Change of hardness on the outer layer of the bobbin of D size dry cells was measured with a penetration tester during continuous and intermittent (30 min/day) discharge through 4 ohm load. In the continuous discharge the outer layer temporarily softens in the middle of the discharge process, while in the intermittent discharge it tends to gradually become hard. These variations in hardness are attributed to the chemical change of the electrolyte in the very thin outer layer of the bobbin. (JSR Mech.& Elec., 8:214, Aug.1961).

5370
Hirai, Taketsugu.,Fukuda, Masataro. and
Amano, Yasushi. METHODS FOR MEASURING
THE INTERNAL RESISTANCE OF DRY CELLS AND
THE SIGNIFICANCE. Natl. Tech.Rept.(Japan),
8:160-170, 1962.

Two routine methods for measuring the internal resistance of dry cells, internal resistance drop method and a.c. compensation method, were studied and compared. Significance of the measured values was discussed with an improved model for internal network of dry cells. The values obtained by the former method varied with the discharge current, but remained unchanged after some duration of discharge. These values were generally nonohmic, but had practical meaning, whereas the values obtained by the latter method were ohmic, but had no practical meaning. The dynamic change in a dry cell due to discharge could be successfully explained by the analysis of the relative change of the 2 values during discharge. (Chem.Abs.,57:10910, Oct.29, 1962).

5371
Hirai, Taketsugu., Manabe, Haruo, and
Fukuda, Masataro. RELATION BETWEEN
EVALUATED VALUE OF DEPOLARIZING ACTIVITY
OF MANGANESE DIOXIDE AND DISCHARGE
CAPACITY OF EXPERIMENTAL CELLS. Natl.
Tech.Rept.(Japan), 7:11-15, Mar.1961.

Investigates the relation between the value of depolarizing activity of manganese dioxide evaluated by alkalified hydrazine sulphate method and expressed

in terms of the rate of hydrazine consumption, and also the continuous discharge period of D size dry cells through a 4 ohm load or a load equivalent to 4 ohm. The evaluated values for natural manganese ores - samples of -150 and +200 mesh sizes and of ordinary particle size distribution for dry cell use - were found to be related to the discharge period down to a final test voltage of 0.9-0.75 V with a significance level of 5%. Particularly, in the continuous discharge through a load equivalent to 4 ohm, correlation was observed with a significance level of 1% overvoltages of 0.85-0.75 V. (JSR Mech. & Elec., 8:65, May 1961).

5372

Korver, M.P., Johnson, R.S. and Cahoon, N.C.
RECUOPERATION REACTION IN THE LECLANCHE
DRY CELL. Electrochem.Soc.J., 107:587-591,
1960.

The first of two steps in the cathodic reaction in the Leclanche dry cell is electrochemical reduction of Mn^{IV} to Mn^{II}. The 2nd step is the chemical reaction of Mn^{III} produced in the 1st step with unreacted Mn^{IV} to form an insoluble Mn^{III} compound. Two chemical reactions can occur producing MnOOH and ZnO.Mn₂O₃, manganite and hetaerolite, respectively. The latter reactions, termed recuperation reactions, are slow enough to limit dry cell operation under certain conditions. The more active depolarizers, such as electrolytic MnO₂, show more rapid recuperation reaction than the natural MnO₂ ore. The basic concepts of heterogeneous chemical kinetics were applied to this problem, and a simple mathematical equation was found which was applicable to all the data. (Chem. Abs., 57:9569, Oct.15,1962).

5373

Mallory Battery Co., North Tarrytown, N.Y.
TESTING AND EVALUATION OF PRIMARY ALKALINE
CELLS AND BATTERIES, September 1, 1961 -
July 31, 1962, by Roger Goodman. 63p., illus.,
Jly.31,1962. (Semi-annual Rept.4)
(Contract DA 36-039-sc-78320) (AD-289 330).

Testing of cells was performed under the revised Signal Corps Technical Requirement, SCL-6274A. Work continued on cell types 12R, 42R and 64OR. In addition, cell types 1R, 502R, 625R, 1438R and 1450R were started in the program. The relative dispersion of cell test groups was used to limit testing to areas where useful data for battery application would be obtained. (TAB U63-1-4:30, Feb.15,1963).

5374

Naval Ordnance Laboratory, Corona, Calif.
FEASIBILITY STUDY OF RESERVE LIQUID
AMMONIA BATTERIES FOR GUIDED MISSILE
FUZING, by W.C. Spindler. 36p., illus.,

Nov. 1, 1962. (NAVWEPS Rept. 7240)
(AD-288 531).

A liquid NH₃ battery is being developed to estimate its feasibility for short-life, reserve, primary applications. (TAB U63-1-4:60, Feb.15,1963).

5375

Naval Research Laboratory, Washington, D.C.
THEORETICAL DESIGN OF PRIMARY AND
SECONDARY CELLS. PART III - BATTERY
DISCHARGE EQUATION, by C.M. Shepherd.
15p., figs., May 2,1963.

An equation has been derived describing a complete battery discharge for the case when the current density distribution is uniform. The battery potential during discharge is given as a function of time, current density, polarization, internal resistance, and other factors. This equation will be used as a base for deriving the more general case where the current density over the face of the electrodes is uneven. This equation has a number of practical applications. It can be used to describe battery charges and discharges, capacities, power evolution, and predict capacities on the basis of limited data. The equation can be applied to the charging of batteries by changing the signs of some of the terms in the equation.

5376

Pipal, F.B. and others. BATTERIES.
Mach.Design, 35:189-218, Apr.11,1963.

A survey of all types and a guide to their selection for portable and mobile electric power are presented.

5377

PRIMARY CELLS AND BATTERIES. General Int.
Electrotechnical Commission Publ., 86-1,
1962, 15p.

Recommendation is presented that covers dry primary cells and batteries with object of enumerating types corresponding to most current needs, defining their characteristics, ensuring their interchangeability and limiting their number; recommendation specifies terminology and designations, dimensions, terminal arrangements and marking, and tests to be applied to determine performance. (Eng. Index, p.40, Jly.1963).

5378

Radio Corp. of America, Semiconductor and
Materials Division, Somerville, N.J.
HIGH-CAPACITY MAGNESIUM BATTERIES,
March 1 - November 30,1962, by G.S.
Lozier, R.J. Ryan, and T.R. Krebs. 3v.,
May 31, Aug.31, & Nov.30,1962. (Q.Prog.
Rept. 8, 9 & 10)

(Final Rept.) (Contract DA 336-039-sc-85340).

Characteristic data are presented for magnesium/magnesium-perchlorate reserve cells discharged at temperatures as low as -40°F . Cathode efficiency data as a function of temperature and current drain are also presented. Factors affecting the performance of dry cell batteries were investigated. Cathode efficiencies, storage characteristics, and electrode surface phenomena were evaluated. Data are also presented for a newly developed magnesium/mercuric-oxide meteorological battery, including discharge data for temperatures as low as -58°F .

5379

Radio Corp. of America, Semiconductor and Materials Division, Somerville, N.J. ORGANIC DEPOLARIZED PRIMARY BATTERIES, September 15, 1961 - December 14, 1962, by J.B. Eisen, G.S. Lozier, and R.J. Ryan. Sv., Dec. 14, 1961, Mar. 15, June 15, Sept. 15, Dec. 14, 1962. (Q.Prog.Repts. 2, 3, 4, 5, & Final Rept.) (Contract DA 36-039-sc-87243).

A survey is presented of experimental and commercial carbon blacks as used with m-dinitrobenzene in magnesium cells. The specification evolved lists low density, large surface area, high electrical conductivity and a maximum volume of voids in the compressed carbon black. This demands a fluffy carbon black which, in the presence of electrolyte, retains a measure of structure adequate for massive material transfer and diffusion processes. No commercial carbon black was found ideally suited for this cathode system. One available pure acetylene carbon black can be adapted, however, by means of an intensive mechanical "opening" process, especially with simultaneous introduction of a small quantity of V_2O_5 .

5380

Shimizu, Toshio. STARCHES AS THE ELECTROLYTE HOLDER IN DRY CELLS. III. SWELLING OF STARCHES CROSS-LINKED BY EPICHLOROHYDRIN. IV. INHIBITION OF THE CORROSION OF ZINC IN A DRY-CELL ELECTROLYTE BY STARCH. V. EFFECT OF STARCHES ON THE CATHODE POTENTIAL OF DRY CELLS. VI. ELECTRIC RESISTANCE OF STARCH CELLS FOR THE DRY CELL. Kogyo Kagaku Zasshi, 64:1241-1255, 1961.

Com. corn starch and potato starch were cross-linked by epichlorohydrin in alkaline solution. The degree of swelling of the cross-linked starch granules was measured by centrifugal precipitation, and the resistivity to acid or ZnCl_2 was investigated. The inhibiting properties of native and modified starches against the corrosion of the Zn electrode in dry-cell electrolyte were investigated. The effects of various types

of starches and organic impurities on the potential of MnO_2 electrodes were studied. Starch gel was used as the electrolyte holder in a Leclanche-type dry cell because of its inhibiting property against the corrosion of the Zn anode and its low electric resistance. (Chem.Abs., 57:10908-10909, Oct. 29, 1962).

5381

Union Carbide Consumer Products Co., Development Division, Cleveland, Ohio. ALKALINE- MnO_2 BATTERY, May 1 - July 30, 1962, by J. Winger, and P.B. Doll. 47p., figs., Aug. 27, 1962. (Q.Rept. 1) (Contract DA 36-039-sc-89098) (AD-295 976).

Examination of present factory product E-95 "D" size alkaline- MnO_2 cell at low temperatures with goal of optimizing said cell for low temperature, heavy drain use. Discusses improvements in electrode formulations which improve -40°F . service through higher carbon phase cathodes and higher area zinc anodes. Relates problems of Lot-Lot service uniformity with modified cathode formulation.

5382

Union Carbide Consumer Products Co., Electrochemical Product Development Laboratory, Cleveland, Ohio. ALKALINE - MnO_2 BATTERY, August 1 - October 31, 1962, by J. Winger, and P.B. Doll. 27p., figs., Nov. 21, 1962. (Q.Rept. 2) (Contract DA 36-039-sc-89098).

Finalization of improved cathode formulation for "D" size Alkaline- MnO_2 -Zinc cell for use at low temperatures. Analysis of energy losses at low temperatures. Definition of sources affecting uniformity of service levels at low temperature from lot to lot manufacture. Discusses results from use of various separator materials. Further investigation of anode contribution at low temperatures.

5383

Union Carbide Consumer Products Co., Cleveland, Ohio. INDUSTRIAL PREPAREDNESS STUDY OF SYNTHETIC MANGANESE DIOXIDE IN MASS PRODUCTION OF MILITARY DRY BATTERIES, June 28, 1957 - November 30, 1961, by H.K. Bishop. 56p., illus., Nov. 30, 1961. (Final Rept.) (Contract DA 36-039-sc-75946) (AD-291 171).

Two chemically prepared depolarizers were evaluated in BA-30, BA-270/U and BA-279/U batteries for ability to meet Mil-B-18b requirements. Following a preliminary mix formulation study, preproduction samples and pilot line quantities of the above types were prepared. Every effort was made to use present production equipment and techniques since experience gained would permit rapid conversion during time of

emergency. Both materials were nearly equivalent in output, although difficulty was experienced in meeting some of the specifications. It may be possible to overcome these shortcomings by redesign of components. (TAB U63-1-5:21, Mar.1,1963).

5384

Union Carbide Consumer Products Co.,
Development Division, New York, N.Y.
LOW TEMPERATURE BA-2270/U BATTERIES,
November 1, 1956 - May 31,1962, by D.G.
Soltis, and E.J. Zeitz. 55p., May 31,1962.
(Final Rept.) (Contract DA 36-039-sc-73092).

The BA-2270/U battery in the Cathodic Envelope construction will give an actual initial low temperature service level equivalent to 3 to 4 times that obtained under other contracts using conventional constructions. Increased electrode area and more intimate contact between materials of construction over the entire operating temperature range have been the prime factors giving this higher service level. High electrolyte solution volumes, higher concentrations of active ore and positive sealing of cells have also contributed to the service advantage.

5385

Wheeler, N.D. SURVEY OF ELECTROCHEMICAL BATTERIES. Electro-Tech., 71:68-73, June 1963.

This article presents a survey of data on presently available electrochemical cells. It is intended to aid the reader in selecting an optimum energy source for any device that requires battery power.

C. Storage Cells

5386

Allievi, G. THE USE OF PLASTIC MATERIALS IN ELECTRICAL ACCUMULATORS. Industr.Ital. Elettrotec, 15:335-342, May 31,1962.

In Italian. Reviews uses of plastics in the manufacture of lead, nickel-cadmium and silver/zinc batteries. Nine basic plastics are compared regarding their abilities to withstand strong acids and strong bases. PVC, Polyester and Polyethylene appear as most suitable. Resins are compared in mechanical and thermal respects which are tabulated for those favoured industrially. ABS made from Acrylonitrile-Butadiene-Styrene being particularly suitable. Fibres in conjunction with resins used for making plate-tubes are best represented by high density PE (polyester), specific weight 0.94-0.96 non-hygroscopic, minimum contraction on cooling. Proprietary applications of the above mentioned plastics have established themselves as successful alternatives to glass, ebonite, cellulose and steel in Pb, Ni-Cd and AgZn cells.

Specific examples of successful developments in USA, Germany, England and Italy are cited. (Elec.Eng.Abs.,66:530, Jan.1963).

5387

Boeing Co., Seattle, Wash.
EVALUATION OF SILVER-CADMIUM BATTERIES FOR SATELLITE APPLICATIONS, by C.B. Whitney and R.P. Phillips. 77p., illus., Aug.22,1961. (Document D2-90023) (IDEP Rept. 102.80.00.20-C6-01) (AD-281 980).

Tests were conducted to demonstrate the feasibility and to evaluate the capabilities of silver-cadmium batteries for satellite applications. (TAB U62-4-5:309, Dec.1,1962).

5388

Bomberger, D.C. and Moose, L.F. NICKEL-CADMIUM CELLS FOR THE SPACECRAFT BATTERY. Bell Sys.Tech.J., 42:1687-1702, Jly.1963.

The storage battery for the Telstar satellite must undergo frequent charge-discharge cycles; in addition, it is subject to overcharge during a substantial portion of its life. Nickel-cadmium cells were chosen as best capable of satisfactory long-time operation under these conditions. A design and selection program was undertaken to ensure that Ni-Cd cores would meet objectives imposed by battery service conditions, and the cell enclosure was designed to minimize electrolyte leakage. Selection, qualification, and life tests indicated that a storage battery using the cell design would perform satisfactorily. To date, the only failures occurring during continuing life tests have been among cells subjected to 100 per cent discharge daily; this operation is far in excess of the expected duty cycle of satellite cells.

5389

Bonnier, Etienne and Durand, Francis. DETERMINATION DE L'ACTIVITE DU CADMIUM DANS LES SYSTEMS LIQUIDES Cd-Sn-Cu ET Cd-Sn-Au. (DETERMINING THE ACTIVITY OF CADMIUM IN THE MOLTEN SYSTEMS Cd-Sn-Cu and Cd-Sn-Au). Acad.Sci.Paris. Compt.Rend., 256:1772-1775, Feb.18,1963.

In French. By measuring the electromotive force of concentration batteries, the activity of Cd between 350 and 650 C in these systems is determined. The Van Laar model faithfully represents the progressive evolution of the deviation from the ideal condition of Cd-Sn-Au in proportion as Au is substituted for Sn. (Battelle Tech.Rev., 12:306a, Jly.-Aug.1963).

5390

Cook Electric Co., Inland Testing Laboratories, Dayton, Ohio.
ALKALINE BATTERY EVALUATION, PART I AND II, April 15 - September 1, 1962, by W.W.

Clark, and others. Pt. I-146p., Pt. II-43p., Oct.1962. (Semi-annual Rept. 4) (Final Rept.) (ASD-TDR-62-893) (Contracts AF33(616)-7529, and AF33(657)-8450) (AD-291 477).

The alkaline battery applied research and failure analysis program is to establish a broad base of battery test data for use in the design of the electrical system of future vehicles and to determine the actual failure mechanism of all battery systems under varying environmental and cycle-life conditions so that improved space batteries can be developed. Another objective is to determine techniques and/or materials to prevent these failures, while at the same time increase the usable watt-hours-per-pound capability and cycle life of the battery.

5391

Cook Electric Co., Inland Testing Laboratories, Dayton, Ohio.
IMPROVEMENT OF NICKEL-CADMIUM BATTERIES, July 20 - August 20, 1962, by I.F. Luke. 14p., Aug.22, 1962. (Tech.Prog.Rept.16) (Contract NASS-1048).

The object of this study was to improve nickel-cadmium batteries through testing and analysis of failures. Vibration and acceleration tests were completed on samples of the Gulton VO-6HS cells with no evidence of failures. Capacity measurements were completed on all the Gulton cells. Optimum capacity tests were completed on the Sonotone and the Gould-National cells. Data on the capacity measurements of the cells of each manufacturer and the optimum capacity of the Sonotone and Gould-National are presented. (STAR, 1:182, Feb.8, 1963).

5392

Cook Electric Co., Inland Testing Laboratories, Dayton, Ohio.
INVESTIGATIONS LEADING TO THE DEVELOPMENT OF THE OPTIMUM METHOD(S) FOR CHARGING SEALED NICKEL-CADMIUM BATTERIES, October 1 - December 31, 1962, by I.F. Luke and R.L. Koesters. 72p., illus., Dec.31, 1962. (Q.Prog.Rept. 1) (Contract DA 36-039-sc-90823).

Experiment designs, test data, analyses and results for investigation of constant current charging at 75°F, 125°F, -10°F, and -40°F for fully discharged cells of Types BB412 and BB440 are presented. Since only one method has been investigated, no conclusions are drawn pertaining to charging methods, but analysis of the data shows that temperature, discharge rate, and cell type are the main factors controlling capacity obtained over the selected levels of the test variables.

5393

Dittmann, J.F. THE CAPABILITY OF THE CADMIUM-SILVER OXIDE SYSTEM. American Rocket Society Space Power Systems Conf., Sept.25-28, 1962, 6p., Santa Monica, Calif., 1962. (ARS Paper 2564-62).

Investigative studies conducted on the cadmium-silver oxide system have demonstrated the feasibility of operating both sealed and vented batteries at the two capacity levels of the positive plate. Operation of a sealed cell at its maximum positive plate capacity over a period of long cycle life is presently limited by the inability of maintaining the silver dioxide level without experiencing excessive internal pressures at practical charging rates. Operating the sealed cadmium-silver oxide cell at the lower capacity level of the positive plate offers several important advantages in achieving extremely long cycle life. However, it is realized that to attain long cycle life by this method, a sacrifice must be made in energy output per unit weight and volume. By subjecting sealed cells to various conditions of cycling, it has been demonstrated that the cadmium-silver oxide system has a potential of attaining greater energy output in watt-hours per pound for longer periods of cycling than other systems currently in use. (STAR, 1:15, Jan.8, 1963).

5394

Eagle-Picher Co., Joplin, Mo.
INVESTIGATIONS LEADING TO THE DESIGN OF A RELIABLE SEALED NICKEL-CADMIUM CELL, May 1 - July 31, 1962, by E.B. Cupp. 37p., illus., Aug.31, 1962. (Q.Prog.Rept. 1) (Contract DA 36-039-sc-89084).

Studies of various cell and electrolyte characteristics are recorded. Charge retention studies indicated that the major capacity losses found in previous studies were actually wattage losses rather than ampere-hour capacity losses, and were due to the lowering of the single electrode potentials during storage. Electrolyte decomposition potentials were measured for 31% potassium hydroxide under varying charge rates. The measurement of charge efficiencies and the effects of additives were initiated, but the data is inconclusive and further study is needed.

5395

Eagle-Picher Co., Joplin, Mo.
INVESTIGATIONS LEADING TO THE DESIGN OF A RELIABLE SEALED NICKEL-CADMIUM CELL, August 1 - October 31, 1962, by E.B. Cupp. 51p., illus., Oct.31, 1962. (Q.Prog.Rept.2) (Contract DA 36-039-sc-89084).

Results of investigations on plate parameters and electrolyte characteristics.

5396

Eagle-Picher Co., Joplin, Mo.

RESEARCH INVESTIGATIONS LEADING TO THE DEVELOPMENT AND EVALUATION OF A CADMIUM - SILVER OXIDE BATTERY HAVING A HERMETICALLY SEALED CONSTRUCTION, July 1, 1960 - June 30, 1962, by J. Wilson. 50p., illus., June 30, 1962. (Final Prog. Rept.) (Contract DA 36-039-sc-85370).

Development work has been directed toward the attainment of a reliable sealed cadmium - silver oxide battery. Among the areas investigated and discussed are improvements in separation, capacity efficiency, overcharge characteristics, and hermetic seals. In addition, the voltage, capacity, self-discharge, charge efficiency and life characteristics of cells utilizing the positive plate at both its divalent and monovalent oxide capacity levels are discussed. Although the ultimate in performance has not been attained, sufficient data have been accumulated to allow the construction of sealed cadmium - silver oxide cells with reliable performance characteristics.

5397

Eagle-Picher Co., Joplin, Mo.

RESEARCH INVESTIGATIONS LEADING TO THE DEVELOPMENT AND EVALUATION OF A CADMIUM - SILVER OXIDE BATTERY HAVING A HERMETICALLY SEALED CONSTRUCTION, July 1 - September 30, 1962, by J.K. Wilson. 2v., Oct. 30, 1962 & Jan. 31, 1963. (Repts. 9 & 10) (Q. Prog. Rept. 1 & 2) (Contract DA 36-039-sc-89605).

Development work is being directed toward the attainment of a reliable, sealed cadmium - silver oxide battery.

5398

Eagle-Picher Co., Joplin, Mo.

RESEARCH ON AMMONIA BATTERY SYSTEM, July 1 - September 30, 1962, by D.J. Doan, and L.R. Wood. 34p., illus., Oct. 30, 1962. (Rept. 9) (Q. Prog. Rept. 1) (Contract DA 36-039-sc-89188).

A better understanding has been obtained of the factors contributing to the previously observed slower practical activation of the -53°C batteries as compared to single cells under ideal conditions. Tests indicate a larger percentage of the batteries activate in less than 3 seconds, with several about 1 second. A new high-rate cathode possibility (silver sulfate) has been found. Permion 300 separator has been found much better than cellophane for limiting the silver diffusion in the low-rate, long-duration application.

5399

Eagle-Picher Co., Joplin, Mo.

RESEARCH ON AMMONIA BATTERY SYSTEM,

October 1 - December 31, 1962, by D.J. Doan and L.R. Wood. 60p., illus., Dec. 31, 1962. (Rept. 10) (Q. Prog. Rept. 2) (Contract DA 36-039-sc-89188).

From continued investigation into the defining factors involved on cold activation, the conclusion is reached that cathode electrode fabrication and processing variables are causing the variance of 0.5 second to about 3 seconds. Separator development has resulted in increasing capacity and permitting use of thinner cells, both of which result in approximately doubling the energy per unit weight to a maximum of 4.51 watt-hours per pound.

5400

Electric Storage Battery Co., Carl F.

Norberg Research Center, Yardley, Pa. ALKALINE BATTERY SEPARATOR STUDY, December 28, 1962 - March 28, 1963, by C.G. Oberholzer and E. Weiss. 25p., Apr. 11, 1963. (Q. Rept. 3) (Contract NAS 5-2860).

This report presents tensile strength measurements of various membranes as well as experimental oxidation studies made during the reporting period.

5401

Electric Storage Battery Co., Carl F.

Norberg Research Center, Yardley, Pa. ALKALINE BATTERY SEPARATOR STUDY, March 28 - June 28, 1963, by C.G. Oberholzer, A.J. Salkind and E. Weiss. 26p., July 11, 1963. (ESB Rept. 7054.4) (Q. Rept. 4) (Contract NAS 5-2860).

Twenty-six different separator materials were compared. Conclusions resulting from the experimental data covering electrical resistance, electrolyte absorption and retention, tensile strength, dimensional stability and oxidation resistance in the battery environment are presented.

5402

Electric Storage Battery Co., Missile Battery Division, Raleigh, N. Carolina.

DESIGN, DEVELOPMENT, AND TESTING OF A STANDARD LINE OF LOW RATE, HIGH ENERGY DENSITY, SEALED, SECONDARY SILVER OXIDE-ZINC CELLS FOR NASA, GODDARD. SPACE FLIGHT CENTER, by D.B. Colbeck. v.p., Mar. 21, 1963. (Final Rept.) (ESB Rept. E-6-63) (Contract NAS 5-1607).

Experimental work resolving the effects of plate thickness, sealing techniques, and various separator systems led to the design of a standard line on nonmagnetic, sealed, low rate silver-oxide-zinc cells for space applications. Three cell sizes

with nominal ratings of 20, 50, and 100 ampere-hours were constructed and tested. Contract objectives of 65 to 75 watt-hours per pound and 5 to 6 watt-hours per cubic inch have been met by the 20 ampere-hour cells and exceeded by the two larger sizes at discharge rates between 20 and 1000 hours in the temperature range 10°C to 50°C. Discharges at the 2000-hour rate are in progress with no serious degradation in performance expected.

5403

General Motors Corp., Delco-Remy Division, Anderson, Ind.
DEVELOPMENT OF SEALED SILVER OXIDE-ZINC SECONDARY BATTERIES, by J.J. Lander and J.A. Keralla. 142p., illus., Oct.1962. (ASD-TDR 62-668) (Final Rept.) (Contract AF 33(600)-41600).

Research and development program was conducted to provide an hermetically sealed silver oxide-zinc battery for use in satellite applications. Problem areas considered were: silver migration in cell, battery voltage regulation, zinc particle size and displacement during cycling, gas evolution, and terminal sealing. Sealed cells were designed, constructed, and tested electrically and environmentally.

5404

General Motors Corp., Delco-Remy Division, Anderson, Ind.
SILVER ZINC SECONDARY BATTERY INVESTIGATION, July 1 - October 1,1962, by J.J. Lander and J.A. Keralla. 20p., illus., Oct.1,1962. (Q.Tech.Prog.Rept. 1) (Contract AF 33(657)-8943) (AD-286 355).

Pd additions to the Ag positive plates of 0.2, 0.5, and 1% were tested in 25 amp/hr cells on the 2-hr cycle period. It was found that 1% Pd addition produces the maximum monovalent charge capacity of 50% and retains this level for approximately 200 cycles. Ag powders of different particle size were incorporated into 2 amp/hr cells and preliminary cycle data was obtained. Negative plates containing polyethylene oxide and polyvinyl alcohol are on the 2-hr cycle program. Five hundred cycles at 25% depth of discharge have been reached to date. Hydrogen evolution data was obtained from zinc negative plates containing 1, 2, and 4% HgO in various concentrations of KOH for a 2-wk period.

5405

General Motors Corp., Delco-Remy Division, Anderson, Ind.
TEST REPORT ON SEALED SILVER OXIDE-ZINC SECONDARY CELLS, by J.A. Keralla. 85p., illus., Feb.1962. (ASD-TR 61-636) (Contract AF 33(600)-41600).

Sixty-five AgO-Zn cells, constructed with hand-fabricated lucite containers and equipped with pressure gauges, were used to determine cycle life.

5406

Gould-National Batteries, Inc., Minneapolis, Minn.
RESEARCH PROGRAM ON SEALED CELLS, by William Jakobi. 84p., May 7,1963. (Final Rept.) (Contract NAS 5-1045).

The program involved 3 areas of study on the sealed nickel cadmium system: (1) separator materials; (2) cell closure and improvement in the performance of the glass-to-metal seal; and (3) a high vacuum method of testing cell seal.

5407

Gulton Industries, Inc., Alkaline Battery Division, Metuchen, N.J.
INVESTIGATION OF METHODS LEADING TO THE DETERMINATION OF THE STATE OF CHARGE OF NICKEL-CADMIUM BATTERIES, January 1 - March 30,1963, by M. Lurie, H.N. Seiger, and R.C. Shair. 32p., illus., Mar.30,1963. (Rept. 1) (Contract DA 36-039-AMC-00109(E)).

A method for determining changes in a nickel-cadmium cell's electrical properties is discussed. The purpose of this work is to isolate those properties that vary with state of charge, the final goal being to develop a method for determining the residual capacity in nickel-cadmium batteries. The approach used is to determine the values of the elements in an equivalent circuit believed to be a good analog to a nickel-cadmium cell. These values are determined by balancing the equivalent circuit against a cell in a bridge. Designs for such a bridge are discussed. The operation of one bridge is described and equivalent circuit values for several cells are given. It appears even at this early stage, that at least one component, a resistor shunting the cell capacitance, increases with decreasing residual capacity in a cell.

5408

Gulton Industries, Inc., Metuchen, N.J.
SILVER-CADMIUM BATTERY PROGRAM, by G.Rampel, J.Liska, and R.C. Shair. 106p., illus., Mar.1963. (WADD TR 61-131, Part II) (Final Rept.) (Contract AF 33(600)-42397).

This report covers the second phase of a research and development program leading to improved, long life, sealed silver-cadmium batteries for aerospace applications. A silver electrode was utilized which yielded up to 50% of its capacity at the Ag^{II} oxide voltage plateau and the balance at the Ag^I oxide voltage plateau. Several separator systems were tested with regard to obtaining maximum cycle life.

The best separator combination consisted of single layers of Dynel-Polypor WA (coarse nylon base) - Fibrous sausage casing - V, each enclosing the positive electrodes in the order listed.

5409

Gulton Industries, Inc., Metuchen, N.J.
STATE OF CHARGE INDICATORS FOR ALKALINE BATTERIES, by M. Lurie and H.N. Seiger. 38p., illus., Aug.15,1962. (Q.Tech.Prog. Rept.2) (Contract AF 33(657)-8130) (AD-282 390).

The work described has been divided into two major categories: Pulse Techniques and Phase Techniques. For the pulse techniques, a load was connected to a test cell through an appropriate switch so that the current was suddenly increased from zero to the required value. These values changed from C/2 to 100C on 4 Amp-Hr cells. The phase techniques rely on the measurement of the shift in phase between the cell voltage and current. (TAB U62-4-5:33, Dec.1,1962).

5410

Gulton Industries, Inc., Metuchen, N.J.
STATE OF CHARGE INDICATORS FOR ALKALINE BATTERIES, by M. Lurie and H.N. Seiger. 45p., illus., Nov.15,1962. (Q.Tech.Prog. Rept. 3) (Contract AF 33(657)-8130) (AD-289 541).

A system was developed to measure the residual capacity of Nickel-Cadmium batteries by measuring the phase shift produced by the cell. The system was calibrated for three sizes of batteries. An average deviation of $\pm 9\%$ is reported for manually cycled batteries. Results of the first stages of tests on batteries with various histories are given. Data is presented indicating a high correlation between residual capacity and resistance measured during a short high current pulse. A device was designed to measure resistance during the first few msec. of a pulse of several hundred amperes. This device will provide a means of measuring current when a load of about 1/2 milliohm is connected across a cell for a short time. (TAB U63-1-4:31, Feb.15,1963).

5411

Gulton Industries, Inc., Metuchen, N.J.
STATE OF CHARGE INDICATORS FOR NICKEL CADMIUM BATTERIES, January 1962 - January 1963, by M. Lurie, H.N. Seiger, and R.C. Shair. 95p., illus., Feb.1963. (Final Rept.) (ASD-TDR-63-191) (Contract AF 33(657)-8130) (AD-406 134).

The variations of several electrical properties of nickel cadmium cells with state of charge were studied to determine the suitability of any of these for

measuring state of charge. Three methods were originally proposed: measurements of ohmic resistance, microsecond transients and double layer capacitance. During the investigations two additional parameters were measured, a.c. impedance and phase shift. Double layer capacitance and a.c. impedance and transient behavior are not useful properties for determining state of charge. A phase shift system is described which when properly calibrated predicted state of charge with an average deviation of $\pm 10\%$. Ohmic resistance measured under correct conditions showed a closer correlation to state of charge but is difficult to measure.

5412

Hennigan, T.J. and Apelt, A.O. USE OF A SEALED SILVER CADMIUM BATTERY ON EXPLORER XII. American Rocket Society Space Power Systems Conf., Sept.25-28, 1962., 6p., Santa Monica, Calif., 1962. (ARS Paper 2509-62).

Due to the fact that silver cadmium cells could be constructed entirely free of magnetic materials, a secondary silver cadmium battery was used on Explorer XII, a satellite launched in 1961 to study radiation and magnetic fields. A program was carried out at Goddard Space Center to determine the feasibility of using the battery in this space application. Major points of interest of this program are presented. The operation of the power system on Explorer XII is outlined and cycling data, telemetered from the satellite, are presented. The first application of a silver cadmium battery on a satellite was very satisfactory. While in flight, no deterioration of the battery power supply was observed. (STAR, 1:13, Jan.8,1963).

5413

Khramov, N.Ya. ON FORMING AN ACCUMULATOR BATTERY. Elekt.Stantsii (USSR), no.6: 79, June 1962.

In Russian. Describes an arrangement for "forming" (i.e., subjecting to charge-discharge cycles) a station battery which has been in storage, using the normal motor-generator type of charger. (Elec.Eng.Abs.,66:1820, Feb.1963).

5414

Kipp, E.W., Schlotter, W.J. and Cahill, J.E. APPLICATION OF BATTERY POWER SUPPLIES IN RE-ENTRY AND RECOVERY VEHICLES. American Rocket Society Space Power Systems Conf., Sept., 25-28, 1962. Santa Monica, Calif., 1962. (ARS Paper 2507-62).

The Missile and Space Division of the General Electric Company maintains a functional group which is responsible for

development of battery power supplies for space vehicle application. This group has developed battery power supplies for numerous space programs such as Thor, Atlas, and Titan nose cones, and for various experimental re-entry vehicles. The types of batteries used are described. Specific battery types were selected for use in order to satisfy the systems power requirements in R&D and operational re-entry vehicles, orbiting re-entry vehicles, and satellite vehicles of one- to ten-day orbit duration. (Astron.Infor.Abs., 7:70,498, Feb.1963).

5415

Kubes, J. THE STORAGE BATTERY INDUSTRY TODAY. Elektrotech.Obzor, 51:639-642, 1962.

In Czechoslovakian. A critical discussion of the state of the storage battery industry in Czechoslovakia, in which shortcomings due to the shortage of special literature and due to the empirical approach in manufacture are disclosed. Principal developments abroad are described. (Elec.Eng.Abs.,66:4866, May 1963).

5416

Little, Arthur D., Inc., Cambridge, Mass. LOW TEMPERATURE OPERATION OF BATTERIES, August 15,1962 - February 14,1963. 2v., Nov.14,1962 & Jan.14,1963. (Q.Prog. Repts. 2 & 3) (Contract DA 36-039-sc-90706).

Studies to determine the most satisfactory methods for achieving low temperature operation of batteries.

5417

Lockheed Missiles and Space Co., Sunnyvale, Calif. NEW CATHODE-ANODE COUPLES USING NON-AQUEOUS ELECTROLYTES, by J.E. Chilton and G.M. Cook. 48p., illus., Dec.1962. (Final Rept.) (ASD-TDR-62-837) (Contract AF 33(616)-7957). (AD-286 889).

New cathode-anode couples using non-aqueous electrolytes are investigated for use as possible secondary batteries. A lithium anode is used with either a silver chloride or nickel chloride cathode in an electrolyte consisting of propylene carbonate, aluminum chloride and lithium chloride. Electrode reactions are studied in detail.

5418

Mallory, P.R., and Co., Indianapolis, Ind. MERCURY CELL BATTERY INVESTIGATION, June 16 - September 15, 1962, by J.M. Booe and R.E. Ralston. 22p., illus., Sept.15, 1962. (Q.Tech.Prog.Rept.3) (Contract AF 33(657)-7706) (AD-285 568).

Chemical reactivity rate determination was directed toward improving precision and reliability. Data are presented showing the effects of several variables studied during this period. A plastic version of the exploratory research cell which will accommodate the compartmented liquid anode retainer was fabricated. (TAB U63-1-1:22, Jan.1,1963).

5419

Mallory, P.R. and Co., Indianapolis, Ind. MERCURY CELL BATTERY INVESTIGATION, by J.M. Booe and R.E. Ralston. 59p., illus., Jan.1963. (Final Rept.) (ASD-TDR-62-1112) (Contract AF 33(657)-7706).

The rechargeable electrochemical system Zn/KOH/HgO-Ag has been investigated from the viewpoint of aero space requirements. Individual study phases were used to evaluate cell components. Exploratory research cells were used during positive and negative electrode charge-discharge experiments.

5420

Melpar, Inc., Falls Church, Va. A THIN-PLATE BATTERY, November 15,1962 - February 15, 1963, by R.T. Foley and others. 27p., illus., (Suppl. to Q.Rept.11) (Contract NOW 60-0362-c) (AD-296 426).

A program directed toward demonstrating the feasibility of miniaturizing the liquid ammonia activated cell is reported. The liquid ammonia activated cell, utilizing a reducible organic compound at the cathode and a light, active metal anode has the theoretical capability of meeting the energy requirement. The solvent for the system, liquid ammonia, satisfies the temperature requirement. (TAB U63-2-4:16, May 15,1963).

5421

National Aeronautics and Space Administration, Washington, D.C. USE OF A SEALED SILVER-CADMIUM BATTERY ON EXPLORER XII, by T.J. Hennigan and A.O. Apelt. 6p., Jan.1963. (NASA Tech. Note D-1543)

Since silver-cadmium cells may be constructed entirely free of magnetic materials, a secondary silver-cadmium battery was used on Explorer XII satellite, launched in 1961 to study radiation and magnetic fields. A program has been carried out at Goddard Space Flight Center to determine the feasibility of using the battery in this space application. The operation of the power system on Explorer XII is outlined and cycling data, telemetered from the satellite, are presented. The first application of a silver-cadmium

battery on a satellite was very satisfactory; in flight, no deterioration of the battery power supply was observed.

5422

Palagyi, T. EXPERIENCES OBTAINED WHILE STORING SILVER-ZINC STORAGE CELLS USING Zn^{65} AND Ag^{110} . Acta Chim.Acad.Sci. Hung., 31:473-483, 1962.

One Ag electrode containing Ag^{110} and 3 other nonlabeled Ag electrodes were used as the positive plates in a cell. Cells were stored in charged and in discharged states. Cells with 5 negative plates, one of which contained Zn^{65} , were also prepared. During storage, the non-labeled electrodes of the cells stored in the discharged state became contaminated with isotopes to a higher degree. (Chem.Abs.,58:225, Jan.7,1963).

5423

Radio Corp. of America, Semiconductor and Materials Division, Somerville, N.J. INVESTIGATION OF NEW CATHODE-ANODE COUPLES FOR SECONDARY BATTERIES USING MOLTEN SALT ELECTROLYTES, by E.F. Uhler, and others. 71p., illus., Jan.1963. (Final Rept.) (ASD-TDR-63-115) (Contract AF 33(657)-7758).

A final report is presented covering an investigation of the most direct and systematic approach in selecting the most promising materials for the development of secondary batteries for space applications with higher capacities.

5424

Rao, M.L.B., Anantharaman, P.N. and Mathur, P.B. PRODUCTION OF POSITIVE PLATES FOR SILVER OXIDE-ZINC BATTERIES. Indus.Eng. Chem., 2:155-157, June 1963.

Starting from silver oxide, a method of preparing positive plates without any grid has been worked out for a silver-oxide-zinc battery. The method is based on the fact that, on heating, silver oxide decomposes at a relatively low temperature to form silver which sinters to form a porous skeleton. The procedure thus eliminates one step (production of powder) in the conventional technique of production of anode plates using silver powder. The merits and demerits of the new procedure and the practical aspects of production are presented.

5425

Rappaport, P.J. and Frink, A.M., Jr. SEALED NICKEL-CADMIUM, SILVER-CADMIUM, AND SILVER-ZINC BATTERIES. American Rocket Society, Space Power Systems Conf., Sept. 25-28, 1962. Santa Monica, Calif., 1962. (ARS Paper 2511-62).

The latest state of the art of three hermetically sealed rechargeable battery systems (nickel-cadmium, silver-cadmium, and silver-zinc) is presented. The use of these system energy storage devices in satellites and other space vehicles is discussed. Subjects covered include (1) cell reactions, (2) theoretical and practical energy densities, (3) construction features, (4) performance data, and (5) further areas for investigation. (Astron. Info.Abs., 7:70,501, Feb.1963).

5426

Romanov, V.V. THE POSSIBILITY OF REDUCING THE GROWTH OF ZINC DENDRITES IN NICKEL-ZINC AND SILVER-ZINC ACCUMULATORS. Zhur. Prikl. Khim., 34:2692-2699, 1961.

In Russian. Transl. (DSIR)NLL M. 3637. order from OTS or SLA.

In an investigation of the effect of different current forms on the electrolysis of zincate solutions it was shown that no zinc dendrites are formed during electrolysis with asymmetrical alternating and pulsating single-half-cycle currents under appropriate conditions. It is shown that the charging of nickel-zinc accumulators should only be performed with a pulsating single-half-cycle current at a frequency of 50 c./s. The possibility of employing the electrolysis of zincate solutions with pulsating currents in the electroplating and electrometallurgy of zinc is noted. (Tech.Transl., 9:265, Feb.15,1963).

5427

Sandia Corp., Albuquerque, N.Mex. SELF-LIMITING CHARGER FOR NICKEL-CADMIUM BATTERIES, by E.B. Pearson. 7p., Aug.11, 1955. (Tech. Memo 170-55-55).

A prototype unit of the self-limiting battery charger was completed and has operated satisfactorily.

5428

Shair, R.C. and Gray, W. HERMETICALLY SEALED NICKEL-CADMIUM BATTERIES FOR THE ORBITING ASTRONOMICAL OBSERVATORY SATELLITE. American Rocket Society Space Power Systems Conf., Sept.25-28, 1962., 9p., Santa Monica, Calif., 1962. (ARS Paper 2508-62).

Nickel-cadmium batteries are described for use in the Orbiting Astronomical Observatory satellite. The electrical design of the battery package consists of three strings of 22 cells each. One string will operate the equipment while the two redundant strings are available as standby batteries, which increases the reliability of the total battery package. When the operating battery falls below 22.0 volts,

one of the standby batteries is switched into operation. Electrical and environmental tests of the battery package indicate a probability in excess of 99% that the battery will perform its function for the prescribed 7000 cycles. (STAR, 1: 13, Jan.8,1963).

5429

Skalozubov, M.F. WORKING SURFACE OF ELECTRODES IN A LEAD BATTERY. Zhurn. Priklad Khim., 35:1812-1814, 1962.

The specific surface, S , of the electrodes in a Pb battery was evaluated with the aid of S^{35} : $S = 1.52 \times 10^3 (1 - P_1/P_0)$, where P_1 and P_0 are the radioactivity of the $PbSO_4$ solution at the end and at the beginning of the experiment respectively. (Chem.Abs.,58:225, Jan.7,1963).

5430

Sonotone Corp., Elmsford, N.Y. DESIGN AND MANUFACTURE OF SEALED NICKEL-CADMIUM CELLS OF CYLINDRICAL DESIGN, December 1, 1959 - March 31,1963, by F. Alliegro, and others. 79p., illus., Mar.31,1963. (Final Rept.) (Rept. 4) (Contract DA 36-039-sc-84496).

The sixty cells of each of three sizes (10 A.H., 50 A.H. and 100 A.H.) have been manufactured. The qualification tests of SCL-7504A have been successfully passed and all cells have been delivered.

5431

Sonotone Corp., Elmsford, N.Y. IMPROVING PERFORMANCE AND RELIABILITY OF SEALED SECONDARY TYPE NICKEL CADMIUM STORAGE BATTERIES FOR SATELLITE AND SPACE APPLICATION, January 10,1961 - January 11, 1963, by P.R. Voyentzie. 54p., Jan.11,1963. (Final Rept.) (Contract NAS 5-977).

Results of the assignments to develop and improve the hermetic seal and the operational temperature range of the nickel cadmium "space battery" are discussed.

5432

Sprague Electric Co., North Adams, Mass. INDUSTRIAL PREPAREDNESS MEASURES ON SOLID ELECTROLYTE BATTERY BA-388()/U, January 1,1959 - December 31,1961, by W.F. Bell and A.G. Ceely. 1v., illus., Dec.31,1961. (Final Rept.) (Contract DA 36-039-sc-81251) (AD-277 108).

Technical and operational problems encountered in achieving the purposes of the contract are described. In particular, problems of low production yields and their eventual solutions are discussed. A major step in improvement of finished battery yields was the replacement of the brass outer case by an epoxy resin covering that

enhanced the ease of assembly and reduced the danger of shorting. Other problems encountered included determining the design of the silver shell to serve as container for the individual cells, determining the design of the seal and lead assembly for the cells, and accelerating, and improving the control of, the cathode extrusion step of the process. Results of preproduction qualification tests are presented. The process and process control steps in manufacturing the battery are described. (TAB U62-4-1: 13, Oct.1,1962).

5433

Stauder, B.S. GAS GENERATORS FOR AUTOMATICALLY ACTIVATED BATTERIES. Electromechanical Components & Systems Design, 7:54-56, Mar.1963.

Discussion of generators, or pressure cartridges, that supply gas which forces stored electrolyte from sealed container into battery proper; details on system in which gas pressure developed breaks diaphragm and pushes directly upon electrolyte normally stored in coiled copper tube; propellant and battery systems developed by Unidynamics Div, Universal Match Corp are discussed. (Eng.Index, p.46, June 1963).

5434

Stroup, E.R. THE BATTERY FOR THE INTERNATIONAL IONOSPHERE SATELLITE ARIEL I. American Rocket Society Space Power Systems Conf., Sept.25-28, 1962., 21p., Santa Monica, Calif., 1962. (ARS Paper 2510-62).

This paper describes the development of an improved rechargeable, nickel-cadmium battery for spacecraft. It was designed for the S-51 International Ionospheric Satellite, also known as the UK-1 or Ariel 1. Innovations including a ceramic-to-metal hermetically sealed case and pellon-plate separators are discussed. The six-ampere-hour, secondary battery selected for this satellite was an early product of the joint research and development program for battery improvement sponsored by NASA and industry. This battery incorporated the latest advancements in the state-of-the-art for spacecraft secondary batteries at the time of launch on April 26,1962. (STAR, 1:14, Jan.8,1963).

5435

Westinghouse Electric Corp., Lima, Ohio. THERMALLY ACTIVATED CERAMIC-METAL CELLS, May 1961 - February 1962. 83p., illus., June 1962. (Final Rept.) (Contract AF 33(616)-8231) (ASD TDR-62-397) (AD-284 891).

Investigations were made of the energy conversion mechanism in thermally activated ceramic-metal cells. Research was focused upon the Fe anode, Li borosilicate enamel-electrolyte and Ag cathode cell configuration. The cell operation temperature range was 450 to 700 C with 600 C being the most satisfactory. The Ag cathode functioned as a gas electrode which absorbed O. The enamel's ionic conductivity increased with temperature and transferred O(--) from the cathode to the anode. Electric power generation resulted from the free energy of anode oxidation reaction. Chemical analyses of discharged cells indicated Li migrated in the electrolyte to the cell cathode. Recharging of cells was not successful due to the iron oxide stability; however, anomalous charge storage was noted at 450 C. Cells made of more reactive anode materials were studied. (TAB U63-1-1:21, Jan.1,1963).

5436

Zaromb, Solomon, and Foust, R.A. FEASIBILITY OF ELECTROLYTE REGENERATION IN AL BATTERIES. *Electrochem. Soc.J.*, 109: 1191-1192, Dec.1962.

The feasibility of electrolyte regeneration was proved by a continuous current-drain experiment of more than 100-hr duration. The initial electrolyte consisted of 120 cc 3.0M KOH solution. The total current-drain amounted to more than 80 amp-hr (at around 1.5v and 20 ma/cm²), which is equivalent to more than 3 times the discharge expected without electrolyte regeneration.

VII. ENERGY STORAGE

A. General Information

5437

Batutis, E.F. STORING THERMAL ENERGY. *Astron. and Aerospace Eng.*, 1:102-103, May 1963.

Materials have been tested which, in terms of weight basis, have storage capability five times greater than batteries.

5438

Batutis, E.F. and Purdy, D.L. THERMAL ENERGY STORAGE FOR THERMIONIC CONVERSION. *American Rocket Society Space Power Systems Conf.*, Sept.25-28, 1962., 78p., Santa Monica, Calif., 1962. (ARS Paper 2505-62).

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 were conducted and 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 uncovered which had heats of fusion near or better than silicon. Fabrication and sealing problems of the silicon container materials have 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-Al₂O₃ 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 earlier. (STAR, 1:13, Jan.8,1963).

5439

Callery Chemical Co., Callery, Pa. DETERMINATION AND ANALYSIS OF THE POTENTIALITIES OF THERMAL ENERGY STORAGE MATERIALS, by K.W. Beahm and H.W. Wilson. 102p., Jan.1963. (ASD-TR 61-187, Part II) (Contract AF 33(616)-7224).

The results of a program to determine and analyze the potentialities of three candidate thermal energy storage materials are presented. The program consisted basically of three major tasks: (1) a materials compatibility study; (2) an experimental program to determine the physical and thermodynamic properties of energy storage materials; and (3) the design, construction and operation of a unit to measure the heat release rates and movement of the fusion front in thermal energy storage materials utilizing latent heat of fusion.

5440

Chandler, W.A. CRYOGENIC STORAGE FOR SPACE ELECTRICAL POWER. *Astron. and Aerospace Eng.*, 1:97-101, May 1963.

Supercritical storage offers most simplicity in operation, with inherent reliability and availability of system components.

5441

Langlie, H.J. A TEST-TO-FAILURE PROGRAM FOR THERMAL BATTERIES. In *Power Sources Conf.*, Proceedings, 16th, 1962, 117-120, Red Bank, N.J., PSC Publications Committee, 1962.

The Aeronutronic Division of Ford Motor Co., has developed a testing technique for obtaining "test-to-failure" data on thermal batteries and other one-shot items

included in the Shillelagh missile system.

5442

Wiederhold, P.R. ENERGY STORAGE FOR HIGH-POWER DISCHARGES. Astron. and Aerospace Eng., 1:104-106, May 1963.

Capacitive devices are more attractive in general, but superconductive magnetic designs show promise in megajoule region.

B. Chemical

5443

ENERGY STORAGE. Brennstoff-Warme-Kraft, 14: 347-348, Jly.1962.

In German. The papers, on energy storage problems, given to the United Nations Conference on New Sources of Energy, Rome, 1961, are reviewed. Many aspects of the subject are discussed: comparisons between the costs of storing energy in batteries and in fuel cells; the use, efficiency and expected improvement of fuel cells; the principles involved in the chemical conversion of solar energy to chemical energy; the use of metal hydride fuel cells; the chemical conversion and storage of concentrated solar energy for which the solar furnace is used for photochemical reactions. Finally, the general costs of storing energy in any form and delivering it are analysed with particular reference to storage batteries and fuel cells. (Elec.Eng.Abs.,66:529, Jan.1963).

5444

Hietbrink, E.H. and Karas, H.R. ANALYSIS OF A THEORETICAL LIQUID METAL CELL FOR ENERGY STORAGE IN SPACE. Gen.Motors Eng. J., 10:21-25, 1st Quarter 1963.

Discussion of a method of evaluating a proposed energy source system. The study is based on the use of a theoretical liquid-metal-fuel system incorporating a potassium-bismuth cell and solar cells. The equations necessary to permit optimum cell operating parameters with respect to system weight are derived. The liquid-metal cell is compared with a conventional storage-battery system for the same application by plotting minimum specific weight as a function of orbit altitude for each system. The comparison reveals that the liquid cell is potentially superior as an energy source for satellite applications where the orbit period is less than 24 hr. (Intern.Aerospace Abs.,3:A63-14217, May 1, 1963).

C. Electromagnetic

5445

Hassel, W.F. ENERGY STORAGE IN SUPERCONDUCTING MAGNETIC COILS. ARS Preprint no.

2506-62. New York, American Rocket Society, 1962. Prepublication Copy. 8p.

An inductance coil made of superconducting wire, maintained at the temperature of liquid helium, is considered as a means of electrical energy storage. A method is described for obtaining an effective d-c output from discharge of such a coil. Optimization of the coil design for maximum energy storage yields energy-per-unit-volume figures in the range of 2×10^8 to 2×10^9 joules/m³. The energy-per-unit-weight is comparable to that of batteries. The chief advantage of inductive energy storage is the capability of providing a power output greatly exceeding that of a battery of the same weight. (Nuclear Sci.Abs.,17:9112, Mar.31,1963).

VIII. ENERGY SOURCES

A. General Information

5446

Stanford Research Institute, Menlo Park, Calif. THE EFFECT OF CONCENTRATED LIGHT ON PHOTOCHEMICAL ENERGY CONVERSION BY NITROSYL CHLORIDE SOLUTIONS, by R.J. Marcus and F.M. Church. 16p., illus., Feb.7,1962. (Sci.Rept. 3) (Rept. 9) (Contract AF 19(604)-7302) (AFCL 62-256) (AD-273 662).

Experiments on the photolysis of nitrosyl chloride in CCl₄ solution with unconcentrated sunlight showed that quantum yields and amount of energy stored with unconcentrated light were only 1/10 of that stored with concentrated light. Therefore, it has been shown that concentrated light considerably increases the output of a photochemical reaction. The results obtained with unconcentrated sunlight may be expressed in terms of the photodissociation of nitrosyl chloride and of the recombination of the photoproducts, NO and Cl. The pressure rise upon exposure to light rapidly approached a steady state. The location of the steady state was governed by the speed of the back reaction. Once the steady state is established, the gas is generated only as fast as it is consumed by the back reaction. On the other hand, if the gas were withdrawn continuously to feed a nitrosyl chloride fuel cell, the steady state would be upset and the gas would be generated at the rate at which it is generated in the approach to the steady state in experiments. (TAB, U62-2-6:16, June 1962).

B. Nuclear

1. General Information

5447

Beller, William. PROBE OF SNAP PROGRAM UNDER WAY. Missiles and Rockets,11:21-22,Dec. 10,1962.

The Atomic Energy Commission is reviewing the SNAP program because of anticipation of rapid growth in the nuclear space effort and in reaction to complaints of sluggishness in developing space nuclear power.

5448

Kolcum, E.H. NUCLEAR POWERPLANT FOR MOON OUTLINED. Aviat.Wk. & Space Tech., 75: 50-53, Jly.31,1961.

The Argonne National Laboratory nuclear lunar powerplant is discussed in detail. (JPL Astron. Info.Search no. 392:272, Mar.1962).

5449

Lindley, B.C. THE APPLICATION OF NUCLEAR ENERGY FOR LARGE-SCALE SPACE POWER. Brit. Interplan.Soc.J., 19:92-98, May-June 1963.

Possible types of nuclear reactors and energy convertor suitable for the generation of power in space are surveyed. Estimates of probable performance are given.

5450

Martin Marietta Co., Nuclear Division, Baltimore, Md. SNAP PROGRAMS-UPPER ATMOSPHERE EXPERIMENTAL RE-ENTRY STUDY, by W. Hagis. v.p., Apr.1963. (MND-P-2953) (Final Summary Rept.).

An experimental flight test program was conducted as part of a program of safety analyses of SNAP generators designed for space use. This report covers the analyses concerning the re-entry of the telemetry capsule, location of downrange aircraft, type and function of instruments and optical data reduction techniques.

5451

Raab, Bernard. SECONDARY SPACE POWER FROM NUCLEAR RADIATION. IAS Natl.Summer Meeting, Los Angeles, Calif., Paper 62-121, June 19-22, 1962.

Description of techniques for the direct static conversion of the intrinsic energy losses of a reactor to electricity. The physical processes involved in the conversion of gamma photons, thermal neutrons, and fast neutrons are discussed, as is a technique for the production of additional power by replacement of a reactor passive shield by an active shield. Possible emitter materials for neutron conversion are tabulated. (Intern.Aerospace Abs., 2:62-8867, Sept.1962).

5452

Schulman, Fred. THE NASA NUCLEAR ELECTRIC POWER PROGRAM. American Rocket Society Space Power Systems Conf., Sept.25-28,

1962., 12p., Santa Monica, Calif., 1962. (ARS Paper 2522-62).

The nuclear electric power plants now in use or in development are described to indicate the current capabilities and project future requirements. The Snap-2 and the Snap-8 power sources are discussed along with the possible effects of the space environment on these systems. The estimated power requirements through 1967 are given, and the possibility of fulfilling these requirements with advanced systems, such as thermionic converters, is considered. (STAR, 1:14, Jan.8,1963).

5453

SYSTEMS FOR NUCLEAR AUXILIARY POWER. Atomic, 16:18-23, May-June 1963.

Two entirely different types of systems are being developed with SNAP designations. One type involves using power produced by small nuclear reactors, the other applies power produced by the heat from radio-isotope decay.

5454

U.S. Atomic Energy Commission, Argonne National Laboratory, Lemont, Ill. ENERGY CONVERSION, by C.E. Crouthamel and others. (ANL-6596(p.201-210)).

Research concerning the conversion of nuclear energy to electricity by use of regenerative emf cells and by thermo-electricity is reported. (Nuclear Sci. Abs.,17:14120, May 15,1963).

5455

U.S. Atomic Energy Commission, Washington,D.C. FUNDAMENTAL NUCLEAR ENERGY RESEARCH, 1962. 405p., Dec.1962.

One part of the research program is concerned with research and development into methods for using the energy of fission and nuclear radiation to produce electricity directly, rather than through the heating of gases or steam to power a turbogenerator. Much of this work is directed toward compact power generators for the nation's space exploration effort.

2. Isotopes

5456

Carpenter, R.T. SPACE ISOTOPIC POWER SYSTEMS. Astron. and Aerospace Eng., 1:68-72, May 1963.

With the technology sound and growing, and units already built for missions ranging from 120 days to 5 years, the designer can plan space application of isotopic systems.

5457

Chance Vought Corp., Dallas, Texas.

FEASIBILITY STUDY OF A RADIOISOTOPIC POWER SOURCE FOR REMOTE AREA HEATING, by W.H. Barnes, L.E. Light, and A.A. Totah. 178p., Jan.1962. (Final Rept.) (AER-E1R-13623) (Contract NBy-37602) (AD-276 451).

A technical and economic feasibility study was made in order to investigate the use of radioisotopic power as an energy source for remote area heating. Consideration was given to units for a rated output of 50,000 and 300,000 Btu/hr. Designs are presented for a number of feasible systems. The economic study revealed that a Nuclide Heat unit can compete with conventional heaters in remote locations where conventional fuel logistics add measurably to the over-all heating costs and where long lifetime, highly reliable units are required. (Nuclear Sci.Abs., 17:3256, Feb.15,1963).

5458

Davis, H.L. POWER REQUIREMENTS FOR DIRECT-BROADCAST SATELLITES. Nucleonics, 21: 53-56, January 1963.

Improved estimates indicate that the power needed for satellite-to-home receiver broadcasting is lower than previously believed - we are now confident a SNAP-8-powered satellite could cover an area seven times the size of the U.S.A.

5459

Gajewski, J. EXPERIMENTAL THERMOELECTRIC GENERATOR SNAP-3. Przegląd Elektron., 38: 252-254, 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) 69W, 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. (Elec.Eng. Abs., 66:2790, Mar.1963).

5460

ISOTOPE POWERS THERMO CONVERTER. Electron. 32:80-81, Feb.13,1959.

This is a brief announcement and description of the SNAP III thermoelectric conversion device, the energy for which is derived from radioactive polonium 210.

5461

Morse, J.G. ENERGY FOR REMOTE AREAS.

Science, 139: 1175-1180, Mar. 22, 1963.

Generators fueled with radionuclides are supplying power in small terrestrial and space systems.

5462

Morse, J.G. RADIONUCLIDE POWER SOURCES. Brit.Interplan.Soc.J., 19:87-92, May-June 1963.

Reviews 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.

5463

OAK RIDGE DETAILS Sr^{90} PRODUCTION: STRONTIUM 90 HEAT SOURCES FOR REMOTE POWER PLANTS. Chem. & Eng. News, 39:62-64, Dec.11,1961.

Some general details are given concerning the production of strontium 90, also the uses to which it is put.

5464

Sandia Corp., Albuquerque, N.Mex. A METHOD FOR DETERMINING THE CURIE LOADING OF Kr^{85} IN NUCLEAR BATTERIES, by Alex Thom. 19p., Jan.8,1960. (Tech. Memo 381-59 (16)).

This report describes a calorimeter which is used to determine the amount of Krypton 85 (in curies) in a nuclear battery. The construction of the calorimeter is described, and a sample measurement is included.

5465

Sandia Corp., Albuquerque, N.Mex. NUCLEAR BATTERY POWERED TIMERS, by R.L. Des Jardin. 12p., Sept.19,1958. (Tech. Memo 330-58-14).

The nuclear battery is a low-current, high-voltage, one-cell device with a shelf life of more than 10 years. The battery makes use of a radioactive, beta-emitting isotope to supply currents of the order of 10^{-10} amperes and voltages of the order of thousands of volts. The nuclear battery is essentially a constant current device and will maintain approximately the same current either shorted or at thousands of volts.

5466

U.S. Air Force Special Weapons Center,

Kirtland AF Base, New Mexico.
HIGH-TEMPERATURE DESTRUCTIVE TESTING OF PLUTONIUM-FUELED CAPSULES FOR A THERMOELECTRIC CONVERTER, by J.C. Clifford. 49p., illus., May 1963. (AFSWC-TDR-62-121).

Plutonium fuel capsules, designed for use in a thermoelectric SNAP device, were exposed to high-temperature oxidizing environments to evaluate the effects on capsule integrity and to determine the quantity and characteristics of alpha activity released during destruction of capsules.

5467

Wenzel, P. PRODUCTION OF ELECTRICAL ENERGY FROM RADIOACTIVE ISOTOPES. Isotopen-technik, 2:85-92, Mar.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. (Elec.Eng.Abs., 66:2509, Mar.1963).

3. Fission Reactors

5468

Anderson, G.M. NUCLEAR REACTOR SYSTEMS. Astron. and Aerospace Eng., 1:27-36, May 1963.

Combining Snap systems will offer the designer various building blocks, with power to 43 kwe.

5469

Heindl, C.J., Krieve, W.F. and Meghreblian, R.V. FISSION-FRAGMENT CONVERSION REACTORS FOR SPACE. Nucleonics, 21:80-85, 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. (Nuclear Sci.Abs., 17:16189, May 31, 1963).

5470

Martin, A.R. AUXILIARY POWER UNITS FOR SPACE APPLICATIONS. International Astronomical

Union-Douglas Aircraft Co., Inc., International Symposium on Space Age Astronomy, Pasadena, Calif., Aug.7-9, 1961. In Space Age Astronomy. New York, Academic Press, Inc., 1962, p.323-331; Discussion p.331.

Description of the operation and specifications of nuclear-powered electric generators that are at present under development to provide auxiliary power for space vehicles. A table of space power requirements is included, and the various SNAP reactor power units are discussed and illustrated. (Intern.Aerospace Abs., 3:A63-14364, May 1, 1963).

4. Fusion

5471

Colgate, S.A. and Furth, H.P. THERMONUCLEAR PLASMAS. Intern.Sci.Tech., #2:34-41, Feb.1962. (UCRL-6670-T).

To get power from nuclear fusion reactions a low pressure gas of heavy hydrogen needs to be heated to temperatures in excess of 100,000,000°K and held in place by magnetic forces for at least a tenth of a second or so. Reaching the required temperature seems not as difficult as containing the resultant plasma for a sufficient time. Plasma instabilities, however, permit it to escape from magnetic confinement. These instabilities fall into two classes, hydromagnetic instabilities and microinstabilities. The first class arises from the electrical and fluid properties of a plasma, without considering its detailed structure; the second class is caused by anisotropies in the distribution of the velocities of the particles in a plasma. Although no fusion device is completely free of such instabilities, considerable experience can be gained on how to control them. One guideline seems to be to keep the plasma pressure small compared with the pressure exerted on it by the confining magnetic field; another is to keep the particle-velocity distribution close to thermal equilibrium. Toy Top, an experimental fusion device of the mirror-machine type, which comes close to satisfying these criteria, can achieve ion temperatures close to the thermonuclear range, for only 0.1 millisecond because of residual instabilities. (Nuclear Sci.Abs., 17:7448, Mar.15, 1963).

5472

General Electric Co., Research Laboratory, Schenectady, N.Y.
ELECTRICAL POWER PROBLEMS IN FUSION RESEARCH, by H. Hurwitz, Jr. 20p., Sept. 1958. (NP-12054) (GP-96).

Although fusion power has not yet reached the stage of proven technical feasibility,

it represents a challenging research opportunity for the electrical industry. After the primary goal of a self-sustained and controlled thermonuclear reaction has been achieved, there will remain the equally difficult task of progressing from laboratory demonstrations to practical and economical power plants. The electrical approach to thermonuclear power which is based upon the ideas of magnetic containment and electrical heating is attractive. Several ingenious embodiments of this concept show considerable promise. It may, however, be necessary to obtain a more complete understanding of the properties of high-temperature plasmas before a self-sustained reaction can be achieved. A fundamental problem in fusion research is that of handling the large quantities of electrical energy needed in the experiments. Recent progress in the design of mechanical switches, capacitors, and ignitrons is discussed. Capacitor banks being used for fusion experimentation at the General Electric Research Laboratory are also described. (Nuclear Sci.Abs.,16:32481, Dec.15,1962).

5473

Green, T.S. THERMONUCLEAR POWER. A Newnes Technical Survey. London, George Newnes Limited, 1963. 174p.

A survey of the work on the controlled release of thermonuclear power is presented. The fundamentals of thermonuclear fusion and plasma physics are discussed, and the various approaches to the design of thermonuclear reactors are described. Simple physical models are used in the mathematical formulation of the problems. (Nuclear Sci.Abs.,17:21194, June 30,1963).

5474

Jephcott, D.F. THE SALZBURG CONFERENCE ON PLASMA PHYSICS AND CONTROLLED NUCLEAR FUSION RESEARCH (4th to 9th September,1961). Contemp.Phys., 4:49-54, Oct.1962.

The Conference was sponsored by the International Atomic Energy Agency and attended by over 500 delegates representing 30 countries; it was the first major international conference on controlled fusion research to be held since the 1958 Geneva Conference. This review describes some of the new aspects of a subject in which considerable progress has been made during these last three years, chiefly in the heating of plasmas and their containment by magnetic fields, since it is along these lines that it is hoped to solve the problem of obtaining useful power from the fusion of light nuclei.

5475

Meyer, K. METHODS FOR DIRECT CONVERSION OF

NUCLEAR FUSION ENERGY INTO ELECTRICAL ENERGY. 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 examples from the literature, and the prospects for application are discussed. (Nuclear Sci. Abs.,17:20681, June 30,1963).

5476

Mills, R.G. THERMONUCLEAR POWER AND SUPER-CONDUCTIVITY. Symposium on the Engineering Aspects of Magnetohydrodynamics, 2nd, Proceedings, Philadelphia, Pa., Mar.9,10, 1961. In Engineering Aspects of Magnetohydrodynamics, New York, Columbia University Press, 1962, p.515-520. (Contract AT(30-1)-1238).

Consideration of a class of hypothetical fusion reactors which makes use of an externally applied confining magnetic field. The problem of large output, possible methods for reducing the economic power output, implications of super-conductivity, and the pilot-plant question are covered. (Intern.Aerospace Abs., 3:A63-14052, May 1,1963).

5477

Post, R.F. SOME ASPECTS OF THE ECONOMICS OF FUSION REACTORS. Symposium on the Engineering Aspects of Magnetohydrodynamics, 2nd, Proceedings, Philadelphia, Pa., Mar. 9,10,1961. In Engineering Aspects of Magnetohydrodynamics, New York, Columbia University Press, 1962, p.469-514, (Contract W-7405-eng-48).

Discussion of some aspects of the power balance and the eventual economics of fusion reactors. Specifically covered is a deuterium-tritium (DT) mirror-machine type of reactor, although wider applicability is indicated. Based on present theory, DT mirror machines can be envisaged which would produce a positive balance against known energy-loss mechanisms. The following conditions must be met: (1) the plasma must be stably confined in a mirror machine of large aspect ratio; (2) the several transport coefficients which determine the rate of particle loss by collisions, and the rate of energy transfer between energetic ions and colder electrons, must not deviate seriously from the presently accepted theoretical values; and (3) particle-

injection methods of high energetic efficiency must be perfected. (Intern. Aerospace Abs., 3:A63-14051, May 1, 1963).

5478

Princeton University, Plasma Physics Laboratory, Princeton, N.J.
FOUR LECTURES ON FUSION POWER, by R.G. Mills. 60p., Sept. 21, 1962. (Contract AT(30-1)-1962) (MATT-145).

Lectures are presented on the interest in thermonuclear power production, various considerations concerning fusion reactors, and power production estimates. (Nuclear Sci. Abs., 17:955, Jan. 15, 1963).

D. Solar Collection and Concentration

5479

Bagby, J.P., Erdmann, R.C. and Biblarz, Oscar. LARGE, LOW-COST THERMIONIC SOLAR CONCENTRATION ANALYSIS AND DEVELOPMENT. ARS Preprint no. 2534-62. New York, American Rocket Society, 1962. 56p.

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. (Nuclear Sci. Abs., 17:9129, Mar. 31, 1963).

5480

Barber, R.E., Mullaney, J.E. and Bailey, R.N. PRELIMINARY DESIGN ANALYSIS OF SOLAR-POWERED, LONG DURATION SPACE POWER SYSTEMS FOR A POWER RANGE OF 1 TO 25 KW. American Rocket Society, Space Power Systems Conf., Sept. 25-28, 1962. Santa Monica, Calif., 1962. (ARS Paper 2569-62).

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. (Astron. Info. Abs., 7:70, 560, Feb. 1963).

5481

Blake, F.A. CALIBRATION OF SOLAR CONCENTRATOR FOR USE IN POWER SYSTEM RESEARCH. ARS Preprint no. 2528-62. New York, American Rocket Society, 1962. 27p.

Experimental calibration of a rigid solar collector is described. Evaluation of the geometry by optical inspection, of energy collection by calorimeter measurements, and of energy intensity by radiometer tests, is discussed. The effect of necessary accessories on the concentrator performance is presented. These accessories include the tracking system, vacuum-chamber window, and focal-plane mounting hardware. The effects discussed include: determination of collection efficiency as a function of misorientation angle, from 0 to 24 minutes misoriented; transmissivity losses and focused-energy distortion introduced by vacuum-chamber windows; and efficiency as a function of axial position. Flux distribution results, in planes perpendicular to the optical axis and on cylinders around the optical axis, are discussed. Two methods of flux distribution determination are utilized and compared. These are the incremental-energy method using a water calorimeter, and a point-by-point method using a radiometer. (Nuclear Sci. Abs., 17:9131, Mar. 31, 1963).

5482

Boston University, Department of Chemistry, Boston, Mass.
CRYSTAL STRUCTURE STUDIES OF MATERIALS FOR POTENTIAL USE IN SOLAR ENERGY CONVERSION, by Klaas Eriks. 10p., Apr. 30, 1963. (Final Rept.) (AFRL-63-606) (Contract AF 19(604)-5995).

The report describes X-ray structural studies of six different substances: Aluminum dodecaboride, AlB_{12} ; ammonium 12-tungstocobaltocobaltate, $(NH_4)_7(Co^{+2}Co^{+3}W_{12}O_{42})$; puridine-boron trichloride, $C_5H_5N_3BCl_3$; trimethylphosphine borane, $(H_3C)_3P.BH_3$; pararosanol perchlorate, $(H_2NC_6H_4)_3C.ClO_4$; cobaltous chloride-dimethylsulfoxide, $CoCl_2((CH_3)_2SO)_3$.

5483

Cobble, M.H. ANALYSIS OF A CONICAL SOLAR CONCENTRATOR. Solar En., 7:75-78, Apr.-June 1963.

The concentration that a conical mirror can theoretically attain is developed for two types of targets; a circular cylindrical target and a conical target. Under the assumption of a one-dimensional sun, the optimum mirror cone 1/2-angle is determined

for both types of targets. At the optimum mirror cone $1/2$ -angle, the concentration, assuming a two-dimensional sun, is determined, and the optimum concentration in terms of mirror radii is found for both types of mirrors.

5484

Cobble, M.H. HEAT EXCHANGERS FOR SOLAR CONCENTRATORS. Solar Energy, 7:18-21, Jan.-Mar.1963.

The theoretical analysis of three types of heat exchangers for use with solar concentrators is developed. Under the assumptions of an incompressible inviscid fluid, constant energy rate input per unit area, and losses to the surroundings, an expression for the temperature field, and average exit temperature is given. An expression for a dimensionless temperature modulus, to aid in the determination of a fluid exit temperature, is derived and plotted for the three types of heat exchangers.

5485

Cobble, M.H. TEMPERATURE FIELDS OF SOLIDS HEATED BY SOLAR CONCENTRATORS. Solar En., 7:134-137, Jly.-Sept.1963.

The steady-state temperature distribution is solved for four target solids under the assumptions that the energy rate per unit area at the target surface is coordinate dependent, and that there are losses to the surroundings at the exposed target surface. The analysis includes a cylindrical slab and a sphere heated at the focus of a paraboloidal mirror, and a rectangular slab and a cylinder heated at the focus of a parabolic cylinder mirror. The general solution for each target solid is given for any type of distribution of target energy rate per unit area. In addition, an experimental target energy rate per unit area is assumed, and the exact temperature field is shown. A dimensionless external temperature modulus is plotted vs. a dimensionless coordinate for various Nusselt numbers, using the assumed target energy rate per unit area.

5486

Duffie, J.A. and Lof, G.O.G. FOCUSING SOLAR COLLECTORS FOR POWER GENERATION. World Power Conf., Paper 207 III.7/5, 27p., Melbourne, 1962.

The current interest in economic development of the arid, "under-developed areas", and the consideration of natural resources for meeting the energy needs of these areas, have led to new interest in possible processes for conversion of solar energy to electrical or mechanical energy. Developments of processes for this conversion (by low-pressure turbines, by thermoelectric,

thermionic and photovoltaic convertors, and by Stirling engines) received emphasis in recent years, in part because of possible applications in space. The results of these developments have been improved prospects for application of these several processes to terrestrial power generation problems. These conversion processes require that energy be delivered to them at various temperatures and energy fluxes. Focusing solar collectors can be designed to deliver solar energy over a wide range of conditions to meet these needs. Focusing solar collectors are described and their performance noted, with particular emphasis on the inter-relationship between the major design parameters: type of collector, temperature, concentration ratio, and reflector contour accuracy. Materials of construction are also discussed, with particular reference to the effects of materials properties on collector performance. Concludes with a commentary on the economics of power generation from solar energy, noting that the most likely applications are to small-scale power problems (i.e., up to 10kW), and that the prospects for power costs in the range of 5 to 10 cents per kWh are good. (Elec.Eng.Abs.,66:1337, Feb.1963).

5487

Electro-Optical Systems, Inc., Pasadena, Calif. ANALYSIS, FABRICATION AND TEST OF LARGE SOLAR CONCENTRATORS, by L.M. Springer. 22p., Mar.10,1963. (Q.Prog.Rept.4) (EOS-1860-Q-4) (Contract AF 33(616)-8402).

The current program is devoted to the design, fabrication, and preliminary testing of an all-metal petal of a 44 $1/2$ -foot-diameter mirror. During this period, plating facilities were completed and checked for leaks with water and plating solution. The reflective inserts in the front-face master were completed. The polishable plastic surface of the large petal master has been proven experimentally by the model front-face reflective master which showed the practicality of such a system. A front-face skin was plated on the front-face master. It is now in the process of having the backing structure mold attached. A backing structure mold of plastic block foam was fabricated during this contract. The optical testing gear has been designed and is now in the process of assembly. A physical testing fixture has been designed and built. (STAR, 1:N63-15971, Jly.8,1963).

5488

Goodyear Aircraft Corp., Akron, Ohio. SOLAR ORIENTATION DEVICE FOR EXPANDABLE FLAT-PANEL ARRAY, July 1 - December 31,1962. 2v., Oct.30,1962 & Jan.30,1963. (GER-10871 & 10990) (Q.Prog.Repts. 5 & 6) (Contract DA 36-039-sc-88913).

Progress is reported on the investigation of various types and methods of orienting systems to determine their limits and suitability for use with expandable flat-panel solar cell arrays in ground applications.

5489

Heath, A.R. STATUS OF SOLAR ENERGY COLLECTOR TECHNOLOGY. American Rocket Society Space Power Systems Conf., Sept. 25-28, 1962., 11p., Santa Monica, Calif., 1962. (ARS Paper 2531-62).

A survey of solar energy collector technology is presented to point out the major areas of accomplishment. One-piece electroformed nickel collectors that closely approach the theoretical concentrating ability have been fabricated. The unit weights of these collectors fall in the range of 0.90 to 1.00 lb/ft² and, while their delivered energy per pound is low, they are capable of attaining higher absorber temperatures (over 4,000°R) than lighter collectors. The concentrating ability of the lighter reflectors, such as petal, Frensel, inflatable, and inflatable-rigidized, falls in the range of 500 to 5000, which makes them suitable for lower temperature requirements (around 2000°R). The unit weights range from 0.03 lb/ft² for the inflatable to 0.46 lb/ft² for the Frensel. The inflatable type delivers 1200 watts/lb at 2000°R while the petal models yield around 375 watts/lb. (STAR, 1:14, Jan. 8, 1963).

5490

Loeffler, I.J., Lieblein, Seymour and Clough, Nestor. METEOROID PROTECTION FOR SPACE RADIATORS. American Rocket Society Space Power Systems Conf., Sept. 25-28, 1962., 56p. Santa Monica, Calif., 1962. (ARS Paper 2543-62).

The meteoroid damage problem for space radiators is reviewed to point out possible approaches to the problem. Relations for predicting required thickness of armor protection are given for isotropic incident flux, and a uniform calculation procedure for design studies is proposed. The advantages of controlled radiator orientation to take advantage of the directional properties of meteoroids are also analyzed. (STAR, 1:15, Jan. 8, 1963).

5491

Löf, G.O.G. and Duffie, J.A. OPTIMIZATION OF FOCUSING SOLAR-COLLECTOR DESIGN. Am.Soc. Mech.Engrs.Trans., 85A:221-228, Jly.1963.

A set of general graphical relationships has been developed for establishing the receiver-reflector area ratio which will provide the maximum useful heat delivery from a focusing collector. The method,

applied to paraboloids and parabolic cylinders, gives the optimum area ratio in terms of incident radiation intensity, optical properties (including precision of reflector), and thermal loss rate. Use of the method for design and for evaluation of existing reflectors is illustrated; its use in economic optimization will be dependent on availability of adequate cost data.

5492

National Aeronautics and Space Administration, Washington, D.C. EARTH REFLECTED SOLAR RADIATION INCIDENT UPON AN ARBITRARILY ORIENTED SPINNING FLAT PLATE, by F.G. Cunningham. 45p., Jly.1963. (NASA Tech.Note D-1842).

A general derivation is given for the earth reflected solar radiation input to a flat plate - a solar cell paddle, for example - which is spinning about an axis coincident with the axis of symmetry of the satellite to which it is affixed. The resulting equations are written for the general case so that arbitrary orientations of the spin axis with respect to the earth-satellite line and arbitrary orientations of the normal to the plate with respect to the spin axis can be treated.

5493

NEW PANEL DESIGN CUTS SOLAR-CELL WEIGHT AND COST. Astro.Info.Abs., 6:61, 185, Oct. 1962.

A new technique for concentrating sunlight on the panel is described. An alteration in the panel design in conjunction with this new technique should result in a weight and cost reduction.

5494

Nichols, K.E. 15 KW ADVANCED SOLAR TURBO-ELECTRIC CONCEPT. ARS Preprint no.2501-62. New York, American Rocket Society, 1962. 44p.

Development work carried out on various components and subsystems of a 15-kilowatt solar dynamic power system designed for continuous operation for at least one year in earth orbit is described. Also included is a brief summary of future development plans. (Nuclear Sci.Abs., 17:9110, Mar. 31, 1963).

5495

Pratt and Whitney Aircraft, East Hartford, Conn. DETERMINATION OF THE EMISSIVITY OF MATERIALS, October 1 - December 31, 1962. 88p., Dec. 31, 1962. (Rept. PWA-2163) (Contract NASw-104).

During the three month period covered by this report, work was continued in support of NASA space power systems.

An aluminum phosphate bonded mixture of nickel-chrome spinel and silicon dioxide completed 10,720 hours of endurance testing on a SNAP-8 finned-tube radiator segment. Flame-sprayed coatings of titania on SNAP-8 and Sunflower I sections completed 9870 and 9830 hours respectively. A fourth rig containing a SNAP-8 section with an aluminum phosphate-bonded mixture of silicon carbide and silicon dioxide completed 8600 hours of testing.

5496

Rosenblatt, A. SOLAR CONVERTER, AMPLIFIER USE THIN FILMS. *Electron.Design*, 10: 4-7, Mar.15,1962.

Two new thin-film devices were described at a symposium at the Scientific Laboratory of Philco Corp., U.S.A. One shows transistor-like properties and is called an "edge-effect device", the other can be used for solar-energy conversion. (*Instrument Abs.*,17:3500, June 1962).

5497

Tabor, H. SOLAR UTILISATION AND DEVELOPMENT IN ISRAEL. *World Power Conf.*, Paper 183 III.7/4, 19p., Melbourne, 1962.

Apart from solar evaporation of Dead Sea brines, water heating is the major present practical use of solar energy in Israel and economics show it to be competitive with electric water heating. Solar research is concentrated on power production. Small units- up to 10kW-using inflated plastic collectors and a new organic vapour turbine of high efficiency are under development whilst an extensive research on solar ponds-as large scale collectors for megawatt power productions-is being pursued. (*Elec.Eng.Abs.*,66: 1336, Feb.1963).

5498

Thompson Ramo Wooldridge Inc., TAPCO Division, Cleveland, Ohio.
SUNFLOWER BOILER/HEAT STORAGE. v.p., Apr.1963. (ER-4869) (Topical Rept.) (Contract NAS5-462).

The component development program of the Sunflower (solar energy conversion system) boiler/heat storage unit is presented. The design analysis conducted and the small-scale experimental investigations performed are described and their results given. The performance obtained on tests of full-scale demonstration units is discussed. Design considerations and weight estimates for the flight-weight unit are presented.

5499

United Aircraft Corp., Hamilton Standard Division, Electronics Department, Broad Brook, Conn.

MODULAR DESIGN OF IMPROVED SOLAR CONVERTERS, September 1 - November 30, 1962, by W.J. Moriarty. 36p., illus., Nov.30,1962. (HSER 2650) (Q.Prog.Rept.6) (Contract DA 36-039-sc-87461).

Solar cell shingle specification defining mechanical and electrical requirements. Design considerations for moded shingle assembly. Wiring schematic which provides for output of 7.75, 15 1/2 and 31 volts. Investigation of material, module and array concepts continued for special warfare type solar array.

5500

von Cube, H.I. UTILIZATION OF SOLAR ENERGY FOR HEAT PUMPS. *Naturwissenschaften*, 9: 246-248, 1957.

In German. Some basic American results in the field of utilization of solar energy are discussed with a description of an experimental plant; consideration is given to the seasonal and climatic factors involved in the construction of such a plant. (*J.Appl.Chem.Abs.*, p.i-118, 1958).

IX. REGULATION AND CONTROL

5501

Brownell, H.R. THERMOELEMENT TRANSFER. *Inst.&Contr. Sys.*, 36:74-77, Jan.1963.

Factors which affect the accuracy of thermoelement AC-DC transfer devices are discussed, and the limits for accurate use are evaluated both for low and high frequencies. Technique for high-accuracy transfers, using reversals, is described.

5502

Electro-Optical Systems, Inc., Pasadena, Calif.
LOW INPUT CONVERTER STUDY, by P. Ramirez. v.p., Aug.31,1962. (EOS Rept.3210) (Final Prog.Rept.) (Contract JPL P.O. 950253).

The report is concerned with the solution to the problem of utilizing power from unconventional sources. The method considered would utilize only one low-voltage high-current source, switch the current, pass it through a step-up transformer and utilize the output either in ac form or rectify it for dc applications.

5503

General Electric Co., West Lynn, Mass.
VOLTAGE REGULATION AND POWER STABILITY IN UNCONVENTIONAL ELECTRICAL GENERATOR SYSTEMS, December 31,1960- March 31,1961. 139p., illus., Mar.31,1961. (Q.Tech. Prog.Rept.3) (Contract Now 60-0824-c) (AD-282 718).

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. (TAB U62-4-5: 35, Dec.1,1962).

5504

Jensen, J.L. OVERLOAD PROTECTION IN SOLID STATE POWER SUPPLIES. In Power Sources Conf., Proceedings, 16th, 1962, 159-162, Red Bank, N.J., PSC Publications Committee, 1962.

This paper assesses the problems of specifying and providing overload protection for solid state power supplies, with particular emphasis on military applications.

5505

Minneapolis-Honeywell Regulator Co.,
Honeywell Ordnance Division, Hopkins, Minn.
LOW INPUT VOLTAGE CONVERSION, July 1 -
September 30, 1962, by J.T. Lingle and
others. 219p., illus., Sept. 1962.
(Q.Prog.Rept. 1) (Contract DA 36-039-sc-
90808).

The purpose of this contract is to investigate all known approaches and to determine the optimum methods of converting low voltage d-c power to higher voltage more useable d-c or a-c power for operating military electronic equipment. The most feasible methods of converting the low output voltages of thermoelectric, thermionic, solar cells, fuel cells or other source voltages in the range of 0.1 volt to 1.5 volts will be determined.

5506

U.S. Naval Research Laboratory, Washington, D.C.
THREE-PHASE STATIC INVERTER WITH
WAVEFORM SYNTHESIS, by D.J. Hanrahan and
W.K. Gardner. 5p., figs., Jan. 21, 1963.
(Rept. 5879).

The principle of a new, three-phase, static inverter is demonstrated by means of a model circuit. Static inverters are replacing rotary inverters for dc to ac conversion in aircraft, missile, and satellite electrical power systems. Where sinusoidal output is required, there is a design conflict between efficiency and waveform. The new circuit retains the efficiency of switching, but switched portions of the input are combined so as to approximate a sinusoidal output, thereby minimizing filter requirements. Controlled rectifiers are used because they are available in higher power ratings than transistors. The evolution of the new circuit from the basic parallel inverter circuits is traced. A multiwinding transformer (suggested by Toffolo of NRL) is used to obtain a three-step approximation to a sine wave. Primary turns in the ratio $\sqrt{3}:3 + \sqrt{3}:3 + 2\sqrt{3}$ theoretically eliminate all harmonics up to the eleventh. The model circuit, constructed with turns in the ratio 1:3:4, exhibits even better waveform because of the filtering effect of the commutating capacitors. A simple criterion for successful commutation is established: the dc bus voltage must be greater than zero when each gate signal is applied. The main advantage of the new circuit is the reduction of filtering necessary for acceptable waveform. The principle may be employed with more switching elements to obtain even better waveform, but the increased complexity is not considered worth the gain. Another advantage of the circuit is that it is inherently a three-phase circuit, rather than three single-phase circuits, which promises construction economies and better performance under unbalanced load.

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