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BATTERY LITERATURE SEARCH

BIBLIOGRAPHY AND ABSTRACTS

July 1976

Volume II

Prepared by

The Boeing Company
P.O. Box 3999
Seattle, Washington 98124

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For

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California 91103

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PREFACE

This comprehensive bibliography with abstracts, consisting of five volumes, was compiled to assist battery technologists to obtain information quickly on secondary aerospace battery cells and related technology. The subject index was extracted from The Battery Information Index prepared by the Battelle Memorial Institute, Columbus, Ohio, under Air Force Aero Propulsion Laboratory Contract No. AF33 (615)-3701. Index Citations B-1 through B-2189 (Vols. II through IV) were from the AFAPL sponsored work and includes references up to mid-1972. References TBC-3001 and on (Vol. V) were prepared by Boeing after reviewing computer searches from JPL's S.D.C. International Search Service, DDC, NTIS, Lockheed Information Retrieval Service, and Boeing Literature Search. References TBC-3301 and on cover the literature from 1972 to the end of 1975 and a few references prior to 1972 missed by the AFAPL work. Volume I consists of an extensive cross-referencing subject listing and an author index. An article covering several different subjects is referenced under each of the subject headings in the index. The index or author number refers to the referenced publications which are listed in a numerical sequence in Volumes II through V. Most citations contain an accession number which refers to the computer searches of the Defense Documentation Center, National Technical Information Service, etc. This number can be used to obtain a copy of the publication from the appropriate file source.

R. S. Bogner
Project Manager

ACKNOWLEDGEMENTS

This work was performed by D.D. Abbott and I.S. Mehdi, supervised by H. Ohman and approved by S.W. Silverman. JPL also wishes to acknowledge the cooperation of R. Marsh of AFAPL for supplying a large portion of the information used to compile this document.

CONTENTS

B-1

Paul J. Rappaport, U. S. Army Signal Research and Development Laboratory, "Performance Ratings of Secondary Batteries," Electronics, 33 (8) 60 + 62 (February 19, 1960).

Detailed charts present a wide range of characteristics for each battery type to help the designer choose a battery for a specific application. The curves of Fig. 1 compare batteries on the basis of their discharge characteristics. Table 1 relates the energy that can be obtained from each to the conditions under which the battery is discharged. Table 11 demonstrates a range of electrical and mechanical properties, as well as listing some battery manufacturers.

B-2

R. Sabapathy, P. V. Vasudeva Rao, and H.V.K. Udupa, Central Electrochemical Research Institute, Karaikudi, India, PPerformance Characteristics of Different Types of Nickel-Cadmium Batteries," Bull, India Sect. Electrochem. Soc. 11 (4), 92-99 (October 1962).

The performance characteristics of five types of nickel-cadmium alkaline cells belonging to the categories (1) pocket type, (2) sintered type, and (3) button cells have been studied. The discharge characteristics of these cells at different rates, the influence of temperature on the performance at one hour rate of discharge and the charge receiving capacity at different rates were studied.

The results indicate that the sintered plate cells in addition to exhibiting good efficiencies at high rates of discharge, show superior performance at low temperatures. The charge receiving capacity of the sintered cell is also superior to that of pocket type cell, especially at high rates of charging. Similarly, button cells with sintered elements perform better than the ones with pocket type elements.

B-3

David Linden and Arthur F. Daniel, U. S. Army Research and Development Lab., "New Batteries for the Space Age," Electronics, 31 (29), 59-65 (July 18, 1958).

Electrochemical batteries have a history of reliable service older than the science of electronics as we know it today. Under the rigorous demands of missile service, battery development has taken on new imoetus. In this article, the limitations and applications of some of the latest developments, including the still-secret thermal cell, are discussed. Here too, are data to aid in the selection of batteries for present and future missile applications.

B-4

Walter J. Hamer, National Bureau of Standards, "Modern Batteries," IRE Transactions on Component Parts, CP-4 (3), 86-96 (September 1957).

> This article gives an outline of the electric batteries in use today. Included are discussions of primary secondary, and reserve batteries with a section on batteries as component parts. Also included are discussions of special types of primary batteries, namely, solid-electrolyte batteries, waxy-type batteries, ion-exchange batteries, and nuclear cells.

B-5

E. J. Casey, P. L. Bourgault, and Phyllis E. Lake, Defense Research Chemical Laboratories, Ottawa, "Nickel-Cadmium Batteries I. Sintered Plates from a New Canadian Nickel Powder,"Canadian Journal of Technology, 34, (3), 95-103 (May 1956).

> Sintered plaques of high porosity and good mechanical strength have been made from a new domestic nickel powder. The plaques, when impregnated and given electrolytic oxidations and reductions in a test cell, gave electrical capacities at low rates of discharge equal to those of plates produced commercially from carbonyl nickel powder; and at extremely high rates gave 15-20% less than the commercial plates. Physical and electrical characteristics of the plates are interpreted in terms of the physical properties of the new powder and various factors in the processing. Certain problems which need detailed investigation are pointed out.

B-6

P. L. Bourgault, Phyllis E. Lake, E. J. Casey, and A. R. Dubois, Defense Research Chemical Laboratories, Ottawa, Canada, "Nickel-Cadmium Batteries. II. Impregnation of Positive Plates by Thermal Decomposition of Aqueous Nickel Nitrate," Canadian Journal of Technology, 34 (8), 495-502 (March 1957).

> A method is described for placing electrochemically-active material in the pores of sintered nickel plaques. The plaque is first immersed in acueous nickel nitrate; then the nickel nitrate in the pores is decomposed at high temperatures to an intermediate which converst rapidly to nickel hydroxide in caustic solutions. The effects of temperature and time of immersion and of thermal decomposition, and of the surrounding atmosphere, have been studied. Results on electrical behavior of the plates are presented, and a preliminary discussion of the mechanism of the impregnation process is offered.

B-7

C. K. Morehouse, R. Glicksman, and G. S. Lozier, RCA Laboratories, "Batteries", Proceedings of the IRE, 46 (8), 1462-1483 (August 1958).

A review is given of the chemical compositions, structures, performance characteristics, and applications of various primary and secondary batteries. Both batteries produced presently, and those in the development stages are included.

The following primary batteries have been discussed: dry, solid-electrolyte, wet, reserve, fuel, and EMF standards. The secondary battery section covers a review of lead-acid, nickel-iron, nickel-cadmium, zinc-silver oxide, and cadmium-silver oxide batteries.

Also included is a review of the various nuclear batteries and solar converters showing the relationship to each other and the electrochemical batteries.

B-8

R. C. Shair, G. Rampel, and E. Kantner, Gulton Industries, Inc., "Hermetically-Sealed Nickel-Cadmium and Silver-Cadmium Storage Batteries,"IRE Transactions on Military Electronics, MIL-6 (1), 67-71 (January 1962).

The galvanic battery is the most highly developed means of storing electrical energy today. In satellite and space-vehicle applications where auxillary electrical power is required for extended periods of time, it has been found that the most feasible power supply currently available consists of silicon solar cells used in conjunction with sealed nickel-cadmium storage batteries. They are capable of thousands of repeated cycles and have an energy output of about 12 watt-hours per pound. Sealed silver-cadmium cells are of interest, because of their higher output, 24 watt-hours per pound, but they are not as far developed, nor de they as yet have the cycle life of nickel-cadmium cells.

In the development of hermetically-sealed nickel-cadmium batteries, the following areas have received considerable attention: 1) Hermetic seal, 2) Continuous overcharge capability and low internal cell pressure, 3) Separator, and 4) Cycle Life.

B-9

Leonard M. Krugman, RCA, "Design Characteristics of Nonvented Nickel-Cadmium Cells," IRE Transactions on Component Parts, CP-7, (4), 129-131 (December 1960).

The properties and operating characteristics of non-vented, rechargeable, nickel-cadmium cells are determined and illustrated. The characteristics shown can be used to predict the performance of available sizes for circuit applications where a permanent, rechargeable dc power source is desired.

B-10

Norman D. Wheeler, General Electric Company, "Survey of Electrochemical Batteries, " Electro-Technology, 71 (6), 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 deivce that requires battery power.

B-11

Louis Wilson and Sterling E. Voltz, General Electric Company, "A Calorimetric Study of Nickel-Cadmium Cells", Journal of Chemical and Engineering Data, 8 (3), 414-416 (July 1963).

The amounts of heat evolved during the discharge of sealed nickel-cadmium cells were determined in a calorimeter. The heats liberated were a linear function of the percent of discharge. The heat losses during discharge were 14 to 20% of the total energies obtained from the cells. The molar enthalpy of the cell reaction was determined to be 64 kcal. per gram-mole.

B-12

Upton B. Thomas, Jr., Bell Telephone Laboratories, Batteries. Preceedings of the 3rd International Symposium held at Bournemouth, October 1962, Edited by D. H. Collins, Macmillan Company, New York (1963), "Kinetic Basis for the Operating Characteristics of Sealed Nickel-Cadmium Cells."

Some of the kinetic parameters important in determining the capabilities and the limitations of sealed nickel-cadmium storage cells are considered and examples are cited to show how they affect the practical application of such batteries.

The difference in properties between sealed and open cells are discussed in relation to these parameters.

B-13

Tomizo Hosono and Masayoshi Matsui, Honda-Electric Co., Ltd., Toky, Japan, "The difference in the Reaction Mechanism of the Positive and Negative Plate of the Nickel-Cadmium Alkaline Battery, and the Electrochemical Behavior of Electrodeposited Cadmium Electrode," Journal of the Electrochemical Society of Japan, 28 (7-9) E-170-E-173 (1960).

Measurements made on cadmium electrodes showed that the characteristic features of their polarization curves were consisted of smaller and steeper slopes, and on interrupting the current the potential reached rapidly a constant value and those discharged materials were made of Cd, $Cd(OH)_2$. It was assumed that on discharging at constant current an initial region of relatively small slope is in equilibrium of Cd, $Cd(OH)_2$ phases. The steeper slope of discharge curves is responsible for increasing of the overpotential. Our results indicated that overpotential depends on reaction processes of both solid and liquid phases. The former process was indicated by effects of layer thickness, current densities, concentration or stirring of electrolyte and X-ray diffraction pattern of (001) broad line of $Cd(OH)_2$. The latter was indicated by the discharge potential passed through the pronounced maximum before becoming constant in the particular conditions.

B-14

Tomizo Hosono and Masayoshi Matsui, Honda Denki K. K., Tokyo, "Studies on the Negative Plate or Nickel Cadmium Alkaline Batteries. III. The Overpotential in Solid Phase of the Cadmium Electrode in Alkaline Electrolyte,"Journal of the Electrochemical Society of Japan, 29 (1), E-37-E-41 (1961).

Our study on the mechanism of the discharge of cadmium electrode in alkaline electrolyte has shown that the reaction process may be considered as occurring in the slow and quick ones. In this paper consideration is given of the electrochemical aspects of the quick process. We suggest that the overpotential in the quick process is responsible for the primary reaction product accumulated on the electrode surface, and for the electrical resistance of the solid phase. Thus, the postulate applied is as follows: - The electrode reduced to metal is oxidized anodically according to the equation $Cd \rightarrow Cd^{2} + 2e$ and the primary product with OH^- in electrolyte is formed.

B-15

H. D. Wilson, "New SAE Test Shows How and Why Batteries Vary Greatly," SAE Journal, 69 (5), 56-57 (May 1961)

A test method and minimum-charge acceptance standards have been established by the Storage Battery Subcommittee of the SAE Electrical Equipment Committee. These new standards - which are in the 1961 SAE Handbook - are designed to benefit all those responsible for battery applications.

B-16

E. J. Casey, Defense Research Chemical Laboratories, Ottawa, Ont., "Some Chemistry of the Nickel-Cadmium Battery," Chemistry in Canada, 12 (10), 49-56 (October 1960).

This paper is intended to outline the results of some recent laboratory investigations which have resulted in a better understanding of the chemistry of this system, and to outline a few vexing problems which still await investigation.

Topics considered include: Stoichiometry (or Lack of It) of the Reactions; Formation of Solid Solutions and Soluble Complexes; Separator Problem; Negative Electrode; Positive Electrode; Costs and Future.

B-17

D.C. Bomberger and L. F. Moose, Bell Telephone Laboratories, "Nickel-Cadmium Cells for Spacecraft Battery," The Bell System Technical Journal, 42 (4), Part 3, 1687-1702 (July 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 percent discharge daily; this operation is far in excess of the expected duty cycle of satellite cells.

B-18

Arthur Fleischer, Nickel Cadmium Battery Corporation, "Sintered Plates for Nickel-Cadmium Batteries," Transactions of the Electrochemical Society, 94 (6), 289-299, 400-401 (December 1948).

Porous plaques are prepared by sintering carbonyl nickel powder of low apparent density. The plaques are impregnated with nickel or cadmium salt solutions and the heavy metal ions precipitated in the pores of the plaque by cathodic polarization in alkali hydroxide solution. Sintered plates made by this procedure have been assembled into experimental cells for study. A typical set of discharge curves is shown for a five plate experimental cell covering the range from the twenty hour rate to the three minute rate.

B-19

Anna P. Hauel, "The Cadmium-Nickel Storage Battery," Transactions of the Electrochemical Society, 76, 435-452 (1939).

The cadmium-nickel battery is widely used in Europe, but not in America. It is particularly applicable to severe service conditions since the active material does not shed readily and wide temperature fluctuations have but little effect. The active material of the positive plates is nickel hydroxide plus pure crystalline graphite. In place of graphite, metallic nickel flakes may be used. The active material of the negative plates is cadmium oxide or hydroxide. The effect of the presence of iron in the cadmium paste is discussed at length. Similarly the addition of lithium hydroxide to the KOH electrolyte is treated at length. On the basis of the author's experiments, the lithium appears superfluous in the positive electrodes containing graphite except that it counteracts the deleterious effects of traces of iron. The adsorption of CO_2 by the KOH electrolyte reduces the capacity of the battery, due to cadmium carbonate formation on the surface of the CdO grains. The new starting battery has very thin plates and very close spacing. It is replacing the lead storage battery in trucks and buses.

B-20

C. Berg, Nickel Cadmium Battery Corporation, "Nickel-Cadmium Batteries," Iron and Steel Engineer, 26 (9), 133-136 (September 1949).

Owing to the more expensive materials used and the mechanical design of the cell, the nickel cadmium battery cannot compete on a watt-hour basis with lead batteries on first cost. The economic justification for and explanation of the wide use of nickel cadmium batteries over a period of some 40 years is to be found in its long life, freedom from sulfation and corrosion troubles and low cost of maintenance. The chief appeal of nickel cadmium batteries is therefore to officials who have a public service or private operation to maintain at minimum costs, such as providing transportation, furnishing power, pumping of oil or making steel.

B-21

C. Berg, Nickel Cadmium Battery Corporation, "Characteristics of Nickel-Cadmium Batteries Produced by Powder Metallurgy," Precision Metal Molding, 10 (8), 49-50, 83 (August 1952).

The sintered plate battery differs from the conventional alkaline battery in that it has porous nickel plates which serve as the retainer of the active materials and as collectors and conductors of the current to the cell terminals.

The plaques are prepared by sintering carbonyl nickel powder. The plaques have a porosity of 75 to 80 percent of which about 40 to 50 percent is utilized to retain active material introduced into the pores by an impregnation process.

B-22

L. G. Hector, Sonotone Corporation, "Inside the New Nickel-Cadmium Battery, SAE Journal, 63, 36-38 (March 1955).

The unique construction and chemistry of the nickel cadmium battery makes it adaptable to extreme climate and service conditions where ruggedness, high amperage, and long life are prime consideration. Here is explained its design and operation.

The most important innovation in the new nickel cadmium battery is its plates. Each plate is a screen of nickel wire that has been converted into a sheet by sintering nickel powder into its meshes. Although the sheet is metal, it is relatively porous. Negative plates are made by electrochemically depositing cadmium hydroxide within the pores; positive plates by depositing nickel hydroxide.

B-23

Alkaline Batteries, Ltd. and C.A.V., Ltd., "Alkaline Batteries. Some Notes on the Production of C. A. V. - NIFE Cells," Automobile Engineer, 39 (512), 114-117 (March 1949).

Mechanical construction and plate manufacturing procedures are discussed.

B-24

"Nickel-Cadmium Batteries in the Spotlight," Diesel Power, 32, 40-43 (March 1954).

Topics discussed include: history, advantages of nickel-cadmium batteries, types, sintered plate developments and costs.

B-24

"Fundamentals of Storage Batteries," Product Engineering, 21, 133-137 (February 1950).

Topics discussed include: types of batteries; how batteries are rated; discharge characteristics; types of service; selection of proper battery for the job.

B-26

James E. Cassidy, University of New Hampshire, "Storage Batteries, Journal of Chemical Education, 27, 63-67 (February 1950).

This article compares the cell characteristics of nickel-cadmium, Edison, and lead storage batteries.

B-27

E. Rabkin, National Research Council, Ottawa, "The Nickel-Cadmium Storage Battery," National Research Council, Canada, T.I.S. Report No. 12 (October 1950).

Review and Bibliography.

B-28

"How American Bosch Makes Nickel Cadmium Batteries for Automotibe Equipment," Automotive Industries, 110 (4), 86 + 149 (February 15, 1954).

American Bosch is producing the new battery through a licensing agreement with Sonotone Corporation. Sintere plates provide an extensive surface area of active material and have good porosity qualities.

For the sintering process, very fine screen made of nickel wire is used as a base. Nickel powder is applied on both sides of the screen and is then tamped to form a plate. Plates are then sintered at 1700 F in a neutral atmosphere furnace.

After the sintering process, the plates are impregnated with nickel nitrate for the positive plate and cadmium nitrate for the negative plate.

B-29

Paul J. Rappaport and Arthur M. Frink Jr., U.S. Army Electronics R&D Laboratory "Sealed Nickel-Cadmium, Silver-Cadmium, and Silver-Zinc Batteries," Progress in Astronautics and Aeronautics, Volume 11. Power Systems for Space Flight. 1963, Edited by Morris A. Zipkin and R. N. Edwards, Academic Press, New York (1963), pp. 211-219.

This paper presents the latest "state of the art" on three hermetically sealed rechargeable battery systems and their application as energy storage devices in satellites, and other space vehicles. The areas covered include the following: 1) cell reactions, 2) theoretical and practical energy densities, 3) construction features, 4) performance data, and 5) further areas for investigation.

B-30

R. C. Shair, Gulton Industries, Inc. and W. Gray, Grumman Aircraft Engineering Corporation, "Hermetically Sealed Nickel-Cadmium Batteries for the Orbiting Astronomical Observatory Satellite," Progress in Astronautics and Aeronautics. Volume 11. Power Systems for Space Flight. 1963, Edited by Morris A. Zipkin and R. N. Edwards, Academic Press (1963), pp. 221-239.

A report is presented on the design considerations and the testing of the battery for this large NASA satellite scheduled to be orbited in 1964. The constructions of the cells and batteries is described. The electrical, thermal and mechanical aspectsof the battery are delineated. Life cycle testing is reported along with the reliability assessment based on the life test data.

B-31

Sidney M. Selis and Charles R. Russell, General Motors Corporation, "An Analytic Representation of the Discharge Characteristics of Commercial Secondary Batteries," Electrochemical Technology, 1 (3-4), 77-81 (March-April 1963).

The equation of Peukert has been applied to express discharge time and delivered capacity as a function of constant discharge current, Analytic relationships have been developed successfully for modern lead-acid batteries as well as for several secondary batteries with alkaline electrolytes.

Relationships also have been derived which relate mean terminal voltage to discharge current. It is therefore possible to express delivered energy as a function of current. The calculated values are in satisfactory agreement with the energy values as determined experimentally.

B-32

R. W. Schult, Aerospace Corporation, and W. T. Stafford, Space Technology Labs., "Electrochemical Energy Sources. Nickel-Cadmium Batteries, Electro-Technology, 68 (1), 87-91 (July 1961).

At their present state of development, nickel-cadmium batteries are capable of delivering about 10 watt-hour/lb and 0.8 watt-hour/in.^{3} for a single discharge of the 1-hr rate at room temperature.

This article describes the properties, reactions, design, operation and mechanism of damage of nickel-cadmium batteries.

B-33

Irwin M. Schulman, General Electric Company, "Secondary Batteries for Energy Storage in Space," Progress in Astronautics and Rocketry. Volume 3. Energy Conversion for Space Power, Edited by Nathan W. Snyder, Academic Press, New York (1961), pp. 479-496.

Secondary batteries have been used as electrical storage devices in satellites. It has been recognized that these batteries are in a critical area in the electrical power subsystem of space vehicles. Certain problems associated with the design of batteries for space application are discussed. Emphasis is placed on battery charging problems when using the solar array for energy conversion. A thermal analysis is made for a battery being discharged 75% of its full capacity, and which is used for a vehicle in a 24 hour equatorial orbit. A battery test program being run at MSVD, General Electric is briefly discussed.

B-34

A. S. Cherdak and R. C. Shair, Gulton Industries, "Determination of State of Charge of Nickel-Cadmium Batteries,"Proceedings of the 15th Annual Power Sources Conference (may 9-11), 1961), pp. 59-63.

The primary purpose of the work was to determine the accuracy of the USASRDL Tester and the optimum pulse rates for operation of the tester with several different sizes of batteries at different temperatures.

Accuracy is defined as the deviation of the indicated state of charge from the true state of charge at any given tester indication.

B-35

E. C. Kopper, Electric Storage Battery Company, "Design Characteristics of Nickel-Cadmium Batteries," Proceedings of the 15th Annual Power Source Conference (May 9-11, 1961), pp 63-66.

This paper is intended to summarize the development of a standard line of 6 sizes of high capacity, vented, sintered plate nickel-cadmium cells for military applications sponsored by the U. S. Army Signal Research and Development Laboratory. In addition to the development of this line of cells the contract stipulated the delivery of 300 cells of each size, or a total of 1800 cells. Consequently the program was divided into three phases as follows:

Phase I comprised a study of limited nature of the design parameters considered conducive to the achievement of the performance requirements, the design, construction and testing of experimental cells, and the evaluation of the test data; Phase II covered the design of the six sizes of cells based on results obtained under Phase I; and Phase III-the manufacture of 1800 cells.

B-36

Frank Alliegro and August B. Mundel, Sonotone Corporation, "High Capacity Sealed Nickel-Cadmium Batteries," Proceedings of the 15th Annual Power Sources Conference (May 9-11, 1961), pp. 67-69.

The purpose of this contract is the design and manufacture of 60 engineering test models of each of three sizes of sealed nickel cadmium cells. The cells are of 10 A.H., 50 A.H. and 100 A.H. capacity, when measured at the five hour discharge rate.

B-37

H. M. Seiger and R.C. Shair, Gulton Industries, "Studies on Sealed Nickel-Cadmium Batteries," Proceedings of the 15th Annual Power Sources Conference (May 9-11, 1961), pp 70-74.

Investigations in several areas have been undertaken to improve the sealed nickel-cadmium battery. These areas are namely: 1) the seal, 2) separators, 3) uniformity, and 4) stabilization of the positive electrode.

B-38

H. N. Seiger, P. B. Pinches, H.I. Cohen, and R.C. Shair, Gulton Industries, "Sealed Nickel-Cadmium Batteries," Proceedings of the 16th Annual Power Sources Conference (May 22-24, 1962), pp 96-99.

It has been found that good hermetically sealed cell operation is associated with materials that imbibe electrolytes to the extent of at least four reaction and influences the current density distribution in a cell, it is desirable for the materials to retain at least 90% of the absorbed electrolyte during acceleration. The only recently tested materials that meet our preliminary requirements are a nonwoven polyprepylene manufactured for experimental evaluation as battery separators, X611, an inorganic separator, RaMA 313, an asbestos material manufactured by Raybestos-Manhattan, and another non-woven polyamide by Pellon which is less spectacular than other of the polyamides reported upon previously.

B-39

Francis Alliegro, Louis Belove, and Peter Voyentzie, Sonotone, Corporation, "High Capacity Sealed Nickel-Cadmium Batteries," Proceedings of the 16th Annual Power Sources Conference (May 22-24, 1962), pp. 99-101.

The normal operating cycle of the sealed nickel-cadmium battery yields a working output of approximately 12 watt hours per pound. However, the "useful" capacity of a nickel-cadmium battery in satellite applications has been limited by factors other than the actual plate capacities. For reliability and extended cycle life the depth of discharge on most satellites has been limited to approximately 5-10% with peak discharges of 25%. Thus, the energy output is reduced from 12 watt hours/lb to an average of approximately 1.2 watt hours/lb.

The primary purpose of the present program is to increase the utilization of available watt hours per pound.

B-40

T. E. King, E. J. Casey, and H. S. Henderson, Defense Research Chemical Laboratories, "Canadian Research on Secondary Batteries," Proceedings of the 16th Annual Power Sources Conference (May 22-24, 1962), pp 108-112.

This paper is an attempt to interpret the results of recent research in terms of battery operation, maintenance or design. The investigations reported include not only those of this laboratory, but also those done at Canadian universities. Only the lead acid, nickel-cadmium, and zinc-silver oxide systems are reviewed.

B-41

C. Menard, Gould-National Batteries, Inc., "Sealed Nickel-Cadmium Batteries," Proceedings of the 14th Annual Power Sources Conference (May 17-19, 1960). pp. 78-80.

This type of construction has the ability to accept a charge quickly and give satisfactory performance at high rate discharges and low temperatures. From the number of cycles observed thus far on several of the regular cells, no indication is given of the maximum life of these cells, although it appears to be several hundreds to several thousands of useful cycles depending on the sequence used. The life of the cell will undoubtedly vary with the type of application. Furthermore, the cells are capable of accepting continuous overcharge at the recommended 10-hour rate for long periods of time and are also protected against overdischarge under reasonable discharge conditions.

B-42

August B. Mundel and Paul Ritterman, Sonotone Corporation, "Cadmium-Oxygen Study on Sealed Ni-Cd System," Proceedings of the 14th Annual Power Sources Conference (May 17-19, 1960), pp. 81-84.

A series of investigations of the mechanism of recombination during overcharge in the sealed nickel-cadmium cell have been conducted. These investigations were designed to yield information leading to the improvement of the sealed nickel-cadmium cell. This paper covers the initial phases of recent test programs of the reaction mechanism which investigated: 1) The effect of varying electrolyte concentration on the rate of oxygen consumption by a charged cadmium plate. 2) The effect of varying mole fraction of oxygen on the rate of oxygen consumption by a charged cadmium plate. 3) The effect of varying oxygen pressure on therate of oxygen consumption by a charged cadmium plate. 4) The internal pressure produced during charge and discharge of a two-plate nickel-cadmium cell initially containing the ambient atmosphere (1 atmosphere pressure $N_2/O_2 = 4/1$).

B-43

A Fleischer, Nickel-Cadmium Battery Corporation, "Vented Nickel-Cadmium Batteries," Proceedings of the 11th Annual Battery Research and Development Conference (May 22-23, 1957), pp. 83-86.

The effect of expanders on the negative active material is a subject of great importance in the electrochemistry of the storage battery. Results prove that cadmium-containing negative active material of the alkaline nickel-cadmium battery. Its use provides a means of achieving an improvement in battery performance and reliability. It will also provide a useful experimental tool in developing an insight to the electrochemistry of the negative electrode.

B-44

L. Belove and I. M. Schulman, Sonotone Corporation, "Sealed Sintered Plate Ni-Cd Batteries," Proceedings of the 11th Annual Battery Research and Development Conference (May 22-23, 1957), pp. 86-89.

Our experience indicates that a properly designed sealed sintered plate nickel-cadmium battery appears to be promising for certain rechargeable battery uses. While the performance of the sealed battery is not quite as good as that of the conventional nickel-cadmium battery at low temperatures, it is felt that further development will result in better low temperature performance and increase its value for applications which may require such performance.

B-45

Burton Resnic, U. S. Army Electronics R&D Laboratory, "Optimum Charge Procedures for Sealed Nickel-Cadmium Batteries," Proceedings of the 17th Annual Power Sources Conference (May 21-23, 1963), pp. 107-110.

> Under this program we plan to study the constant potential, constant current and pulse charging techniques. The relative importance of certain charging conditions and how these effect overall cell performance is to be determined. Included in the program are the effects of charging times of 1, to 16 hours, the effects of ambient temperatures of -40F to +125F, and the influence of initial battery states of charge of 0 to 66%. The effects of from 10 to 70% overcharge in the constant current method, effects of voltage level in the constant potential method and variations in pulsing in the pulse charging method are also included. Two cell types, the 3.5A.H. and 10 A.H. cells, and two discharge rates,the minute (15) and the 5 hour rates are other study parameters.

B-46

M. Lurie, H. N. Seiger and R. C. Shair, Gulton Industries, Inc., "State of Charge Methods for Nickel-Cadmium Batteries," Proceedings of the 17th Annual Power Sources Conference (May 21-23, 1963), pp. 110-114.

> Of the five electrical properties of Ni-Cd cells studied - phase shift, ohmic resistance, double layer capacitance, transient peak height and impedance at audio frequencies - the first two were found to depend on state of charge in a useful manner. The variations of phase shift and ohmic resistance with state of charge are measurable and reproducible enough to provide and indication of state of charge.

B-47

William G. Ingling and Walter W. Clark, Cook Electric Company, "Evaulation of Secondary Batteries," Proceedings of the 17th Annual Power Sources Conference (May 21-23, 1963), pp. 122-124.

> The primary objectives of this program were two-fold. First, a broad base of data on the performance characteristics of sealed, secondary batteries was desired to determine the probable useful life of these units when subjected to the various load conditions and many temperature environments that they may encounter in aerospace applications. Secondly, a chemical and physical analysis of cycled cells was desired in order to determine the nature and extent of failure mechanisms so that research efforts could be directed toward increasing the reliability, cycle life, and energy density.

B-48

Alvin J. Salkind and Paul F. Bruins, Polytechnic Institute of Brooklyn, "Nickel-Cadmium Cells. I. Thermodynamics and X-Ray Studies," Journal of the Electrochemical Society, 109 (5), 356-360 (May 1962).

Voltage decays of electrodes in sintered type nickel-cadmium cells were measured in cells stored at temperatures between -18 and 52 C. The heat of reaction of the cell was calculated to be - 64 kcal/g mole. The solid reaction products of the cell were studied, in situ, by x-ray techniques, in special cells designed to fit on an x-ray diffractometer.

B-49

Alvin L. Salkind and Joseph C. Duddy, The Electric Storage Battery Company, "The Thermal Runaway Condition in Nickel-Cadmium Cells and Performance Characteristics of Sealed Light Weight Cells," Journal of the Electrochemical Society, 109 (5), 360-364 (May 1962).

The thermal runaway condition, sometimes called the vicious cycle, can be caused in almost any type of cell under certain conditions. The underlying causes of the runaway condition are discussed with specific application to sealed nickel-cadmium cells on constant potential overcharge. The discharge and overcharge performance characteristics of sealed nickel-cadmium cells with plastic electrodes are presented. These cells operated at high energy density levels on both a weight and volume basis and were more difficult to put in the runaway condition.

B-50

J. C. Duddy and A. J. Salkind, The Electric Storage Battery Company, "High Energy: Weight Ratio, Nickel Cadmium Cells," Journal of the Electrochemical Society, 108 (8), 717-719 (August 1961).

Conventional nickel cadmium cells contain the active materials in either porous sintered nickel plaques or in nickel or nickel-plated steel pockets or tubes. A new process, adaptable to continuous methods of production, has been developed in which the active and conductive materials are dispersed in a microporous plastic structure. Cells with the high energy to weight ratio of 40 whe/kg have been constructed. Cell volumes are equal to those of the sintered plate design for equivalent capacities.

B-51

S. Uno Falk, Svenska Ackumulator AB Jungner, Stockholm, Sweden, "Invesgigations on the Reaction Mechanism of the Nickel-Cadmium Cell," Journal of the Electrochemical Society, 107 (8), 661-667 (August 1960).

X-Ray diffraction patterns from electrodes submerged in electrolyte have been obtained during charge and discharge by means of a special test cell, and the composition of the active materials has been determined. The question whether CdO or $Cd(OH)_2$ is formed during discharge has been subject to special attention. The low potential reaction of the positive plate has been studied. The emf and the dE/dT have been determined between -40 and +500 at various states of charge.

B-52

Sven Bergstrom, Nife, Inc., "Nickel-Cadmium Batteries - Pocket Type," Journal of the Electrochemical Society, <u>99</u> (9), 248C-a50C (September 1952).

The characteristics of nickel-cadmium pocket type storage batteries are discussed. Topics include: cell construction, engineering characteristics, electrolyte, self-discharge and usefulness.

B-53

G. B. Ellis, H. Mandel, and D. Linden, Signal Corps Engineering Laboratory, "Sintered Plate Nickel-Cadmium Batteries," Journal of the Electrochemical Society, <u>99</u> (9), 250C-252C (September 1952).

Performance measurements were made on a group of 5-cell batteries rated at 75 amp-hr. The average battery had a weight of 41.5 lb., and a volume, excluding the terminals, of 545 in.^{3} It actually delivered 415 whr at the 5-hr rate. This can be expressed as 10 whr/lb, 1311 whr/ft^3, and gives a density of 131 lb/ft^3.

The following characteristics are discussed: discharge curves; Relative capacities vs. temperature and discharge rate; relative watt-hour capacities vs. temperature and discharge rate; charging characteristics; self-discharge and life.

B-54

A. Fleischer, Nickel-Cadmium Battery Company, "Nickel-Cadmium Batteries," Proceedings of the 10th Annual Battery Research and Development Conference, (May 23, 1956), pp. 37-41.

Review of nickel-cadmium battery development in the United States. The following characteristics are discussed: thin plate batteries: low temperature performance; separators; negative plate studies.

B-55

F. Kornfeil, U. S. Army Signal Research and Development Laboratory, "The Charge-Discharge Process of the Nickel Oxide Electrode," Proceedings of the 10th Annual Battery Research and Development Conference (May 21-22, 1958), pp. 18-22.

The purpose of the present investigation was to obtain a quantitative elucidation of the electrode reaction. It is particularly important to determine the reference ion concentration with great precision, as will be shown in an analysis of the experimental error.

B-56

B. C. Bradshaw, U. S. Army Signal Research and Development Laboratory, "Absorption Measurements on Nickel Oxide Electrodes," Proceedings of the 12th Annual Battery Research and Development Conference (May 21-22, 1958). pp. 22-25.

The area of nickel oxide electrodes has been measured by the B.E. T. method and found to be about 50 m^2 per gram. Charged nickel oxide electrodes adsorb about 6 mg of KOH per gram from solutions that range in concentration from 0.05 to 3.0 normal inclusive, and their area as calculated from the amount of KOH that they adsorb is about 40 m^2 per gram. But the uncharged electrodes do not adsorb a measurable quantity of KOH from any solution that we used. The energy of adsorption of KOH on a charged nickel oxide plate is about 4×10^{-13} erg.

B-57

L. Belove and I. M. Schulman, Sonotone Corporation, "Charging Characteristics of a Sealed Sintered Plate Nickel-Cadmium Battery," Proceedings of the 12th Annual Battery Research and Development Conference (May 21-22, 1958), pp. 27-30.

We have presented charge data at three temperatures ranging from 0 to 125F. Cells of this type have a wide range of application due to their minimum maintenance requirements. These investigations are being expanded to include temperatures from -65 to +165F. Particular emphasis is being placed on applications which call for continual cycling at various temperatures.

B-58

Ernst G. Baars, "The Working Mechanism of Sealed Nickel-Cadmium Cells," Proceedings of the 12th Annual Battery Research and Development Conference (May 21-22, 1958), pp. 25-27.

As a result of the thorough analysis of patent specifications and experimental observations, I have come to the conclusion that the oxygen is "activated" on the surface of many metals, or carbon, or presumably any electronically conducting material immersed in an alkaline electrolyte.

B-59

P. V. Vasudeva Rao, S. Ghosh and H.V.K. Udupa, Central Electrochemical Research Institute, Karaikudi, "Fabrication of Sintered Plate Nickel-Cadmium

Batteries, Bull. India Sect., Electrochem.

The sintered-plate Ni-Cd battery differs from the flat-pocket and tubular-type batteries in the method of support of the active materials. Ni powder of suitable grade is sintered into plates which are highly porous. Ni nitrate or Cd-$(NO_3)_2$ soln. is then impregnated into the pores in vacuo. The plates are then formed electrolytically to the resp. active materials for the pos. and the neg. plates of the battery. The processes of sintering, impregnation, forming, and assembling are described. Graphs illustrating the performance of the cells assembled in the lab. are presented.

B-60

S. Januszkiewicz, Gould-National Batteries, Inc., "Addition of Cobalt to Nickel-Cadmium Batteries," Proceedings of the 13th Annual Power Sources Conference (April 28-30, 1959), pp. 75-77.

The use of cobalt as an agent to increase the coefficient of utilization of positive sintered plates has been substantiated. It has been further shown that the over addition of cobalt will cause the depression of the average voltage and consequent loss of capacity to high end voltages. It has been shown that cobalt has little effect on the charge retention of positive plates of nickel-cadmium sintered plate cells.

B-61

A Fleischer, Thomas A. Edison Research Laboratory, "Sealed Nickel Cadmium Batteries," Proceedings of the 13th Annual Power Sources Conference (April 28-30, 1959) pp. 78-82.

This paper concerns the overcharging mechanism of the sealed cell with its restriction of gas evolution to pure oxygen and the reconversion of oxygen to hydroxide ion.

B-62

L. Belove and I. M. Schulman, Sonotone Corporation, "The Hermetically Sealed Sintered Plate Nickel-Cadmium Cell," Proceedings of the 13th Annual Power Sources Conference (April 28-30, 1959), pp. 82-85.

The addition of lithia to potassium hydroxide electrolyte does not appear to offer significant improvement in the capacity performance of hermetically sealed sintered plate nickel-cadmium cells at high charging rates for any individual cycle. Neither did it appear to have any effect upon cell charging voltage levels.

Lithia as an additive to electrolyte appears to help maintain the cell voltage level in continuous cycling programs where no rest is permitted between cycles.

Higher concentrations of potassium hydroxide electrolyte give superior performance in hermetically sealed cells especially at -20F.

B-63

K. Dehmelt and H. von Dohren, Accumulatoren Fabrik A. G., "Cathodic Oxygen Reduction Under Conditions Effective in Hermetically Sealed Nickel-Cadmium Accumulators," Proceedings of the 13th Annual Power Sources Conference (April 28-30, 1959), pp. 85-89.

Experiments are described which demonstrate the effect of pressure upon the rate of cathodic reduction of oxygen gas at various cathode potentials. The range of oxygen pressure and potentials employed in the study correspond to those normally encountered in commercial nickel-cadmium cells. Under these conditions the reduction of oxygen gas occurs at a potential close to the equilibrium potential of the Cd $Cd(OH)_2$ electrode. The amount of oxygen liberated at the anode corresponds exactly with that consumed at the cathode, showing that no alternative mechanism for maintaining steady state pressure plays any significant role. In other electrochemical systems the O_2 reduction requires different potentials.

B-64

W. S. Herbert, The Electric Storage Battery Company, "Battery Research and Fuel Cells, SAE" Preprint No. S347 (March 19, 1962).

This paper is concerned with the conversion of chemical energy to electricity by the electrochemical method. It discusses various energy conversion devices, including batteries, fuel cells, and internal combustion engines. The author concludes that fuel cells offer many attractive features, but that further research and development work must be done to enable them to compete successfully with the other well-established systems.

B-65

C. G. Grimes and W. S. Herbert, The Electric Storage Battery Company, "The Choice of Battery Systems,"SAE Preprint No. 269D presented at the 1961 SAE International Congress and Exposition of Automotive Engineering, Detroit, Michigan (January 9-13, 1961).

In considering the choice of a battery system to best fulfill requirements of an application, many factors other than capacity must be weighed. Usually, it is a compromise of many characteristics, among which are weight, volume, availability, rechargeability, cycle life, stand life, cost and maintenance.

B-66

Paul L. Howard, Yardney Electric Corporation, "Wet-Cell Batteries for Power, Product Engineering, 31, 75-82 (February 15, 1960).

Rechargeable wet-cell batteries - Lead-acid, nickel-iron, nickel-cadmium, silver-zinc and silver-cadmium - fill the gap where the power source must be independent of electrical power lines, yet be available as often as needed. Here, for the first time, are tables comparing energy and size in consistent units.

B-67

A. M. Frink, U. S. Army Signal R&D Laboratory, "Sealed Cells for Satellites," Proceedings of the 13th Annual Power Sources Conference (April 28-30, 1959), pp. 89-92.

A consideration of the overall effort to date leads to a number of conclusions concerning the use of sealed nickel-cadmium cells teamed with a charging source in a 100 minute orbit satellite application, in which percent voltage difference from the end of charge to end of discharge is not be exceed 20%: (1) Constant potential charging or the use of silicon solar converters, are preferable to constant current charging; (2) Sintered plate cells give better performance than pressed plate cells; (3) Temperatures as high as 120 F and as low as 20 F should be avoided where possible, if good cycle life and narrow percent voltage difference is to be maintained. An estimate of a desirable working temperature range may be taken between 50 to 90 F; (4) Shallow discharge is conducive to long cycle life and closer voltage tolerance; (5) Failure of cells generally seems attributable to loss of water from the cells; (6) The use of sealed cells having true hermetic closure, e.g., a welded seam, in place of a grommet type seal should result in longer cycle life by reducing moisture loss.

B-68

Paul Ruetschi and Boris D. Cahan, The Elctric Storage Battery Company, "Storage Battery," U. S. Patent 3,080,440 (March 5, 1963).

A hermetically sealed storage battery of the nickel-cadmium type containing an electrolyte, a gas chamber above said electrolyte, and a positive electrode and a negative electrode in said electrolyte, an auxiliary gas consuming electrode connected to said positive electrode by voltage regulating means comprising the forward voltage drop of a semi-conductor diode adapted to maintain the potential of said auxiliary electrode between -1.2 and -0.2 volts with respect to said positive electrode, said auxiliary electrode being partly immersed in said electrolyte, and extending partly into said gas space, said auxiliary electrode comprising porous conductive water-proofed matrix impregnated with a metal of the platinum group, said positive electrode being characterized by having an excess of uncharged active materials with respect to the active material of said negative electrode to promote the evolution of hydrogen from the negative electrode on overcharge.

B-69

F. B. Pipal, Union Carbide Consumer Products Co., Charles Carr, Electric Storage Battery Company, and Charles Grun and Martin Sulkes, Yardney Electric Corp., "Batteries - A Survey of All Types - A Guide to Their Selection for Portable and Mobile Electric Power," Machine Design, 35 (9), 190-218 (April 11, 1963).

This article discusses the performance characteristics of the following batteries: Dry Batteries (carbon-zinc, alkaline-manganese, mercury, silver-oxide, and nickel-cadmium), Wet Batteries (lead-acid, nickel-iron, and nickel-cadmium), and High-Energy Reserve Batteries (silver-zinc, silver-cadmium, and reserve).

B-70

H. A. Hancock, D. J. I. Evans and V. N. Mackiw, Sherritt Gordon Mines Limited, "Sintered Plates from Low Density Nickel Powder," Paper presented at the Annual General Meeting of the Canadian Institute of Mining and Metallurgy (April 13-15, 1964), Montreal, Quebec. Published Int. J. of Powder Metallurgy, 1, #2 (1965) pp. 42-55.

Special low density nickel powders suitable for the production of porous matrices are described with particular reference to nickel-cadmium battery plates. The results of gravity sintering tests are given to show the relationship between the physical characteristics of the powders and their sintering behaviour. The variables investigated include apparent density, Fisher number, particle size, surface area, sintering time and sintering temperature. The plaques made from these powders by gravity sintering were evaluated for porosity, electrical resistivity, shrinkage, and strength. Powders with apparent densities as low as 0.5 gm./cc. gave plaques with up to 90% porosity and very low shrinkage.

B-71

Department of the Army, Signal Corps Logistics Evaluation Group, "Military Application of Sealed, Sintered Plate, Rechargeable Nickel-Cadmium Batteries, Report No. SC Log Gp 60-149, SIGSU-A8 (June 1960). AD 246 317.

Sealed, sintered plate nickel-cadmium cells offer cold weather and cost advantages over zinc cells justifying the placing of additional development contracts and procurement of battery packs for testing.

B-72

Howard T. Francis, Armour Research Foundation of Illinois Institute of Technology, "Space Bettery Handbook," prepared under NASA Contract NASw-401 (April 15, 1963).

This book is concerned with three secondary battery types: nickel-cadmium, and silver-zinc. After a brief discussion of the requirements of space batteries in general, the characteristics of each system will be reviewed, pointing out some of the remaining problems. Finally, suggestions are offered on the mechanics of developing a power system, including exchange of test data with other groups.

B-73

Tomizo Hosono and Masayoshi Matsui, Honda Electric Company, Ltd., Tokyo, "Studies on the Negative Plate of Nickel Cadmium Alkaline Batteries. IV. The Mecahnism for the Formation and the Formula of the Primary Product Fromed on a Cadmium Electrode During the Discharge Reaction," Journal of the Electrochemical Society of Japan, 30 (2), E-108 (1962).

The discharge mechanism for a cadmium electrode has been investigated by us on the basis of the postulate that a primary product is formed. Furthermore, in this work the mechanism of the formation and the formula of this primary product were studied in detail.

B-74

Tomizo Hosono and Masayoshi Matsui, Honda Electric Co., Ltd., Tokyo, "Studies on the Negative Plate of Nickel Cadmium Alkaline Batteries. V. The Influence of Impurities on Cadmium Plate of Alkaline Cell," Journal of the Electrochemical Society of Japan, 30 (2), E-109 (1962).

The effects of impurities are considered to be roughly classified as described below.

Group of Fe, Co, Ni and group of Ag, In, Tl - The coefficient of utilization for active material involving former group tends to be higher with increasing amount of impurity. In the case of addition of the latter group the variation in the coefficient is similar to the former, but the electrochemical behavior of the plate seems to be more complicated. These results are suggested to indicate a decrease of either accumulation or ionic resistance of the primary product.

Group of Ca, Mg, Si - Hydrogen is easily liberated at an initial stage of charge by adding a little amount of these impurities. Therefore these are the most harmful to the plate, probably because of colloidal film deposition on active material.

B-75

Tomizo Hosono and Masayoshi Matsui, Honda Electric Co., Ltd., Tokyo, "Studies on the Negative Plate of Nickel Cadmium Alkaline Batteries. VI. The Effect of Impurities on the Reaction Process during the Discharge of Cadmium Electrode, Journal of the Electrochemical Society of Japan, 30 (2), E-109-E-110 (1962).

Oxides of silver, indium, thallium and gallium were used to study the effect of the reaction process of solid phases while nickel, iron, and cobalt were studied as the impurities of liquid phases.

B-76

Tomizo Hosono and Masayoshi Matsui, Honda Electric Co., Ltd., Tokyo, "Studies on the Negative Plate of Nickel Cadmium Alkaline Batteries. VII. The Effectos of Some Impurities on the Performance of Practical Alkaline Cell," Journal of the Electrochemical Society of Japan, 30 (3), E-154 (1962)

For the sintered plate type which used indium saturated in electrolyte, watt hour efficiency at low temperature (-20C) increased by about 20% of that of the normal. In the presence of gallium in electrolyte a little reduction was observed.

The negative plates (pocket type) which contained the cadmium-iron active material mixed with respective 1,2, 0.9, 0.6 or 0.3 per cent of nickel were examined. The coeffieient of utilization of active material was found to become higher as the amounts of nickel increased. For the plate involving 1 per cent of nickel a gain in capacity of about 25 per cent compared with the original one was got.

B-77

Arthur Fleischer, Nickel-Cadmium Battery Corporation, "Investigations on the Improvement in the Performance Characteristics of the Nickel-Cadmium Battery," Seventh Quarterly Progress Report (September 1 - November 30, 1955), U. S. Army Signal Corps Engineering Laboratories Contract DA 36-039-SC-56728

Studies are reported on the positive plates, negative plates, separators and electrolyte leading to an improvement in performance characteristcs.

B-78

Arther Fleischer, Nickel-Cadmium Battery Corporation, "Laboratory Investigations and Reserach Toward the Development of Nickel Cadmium Alkaline Storage Batteryes," Quarterly Progress Report (December 31, 1947), Contract W-36-039-SC-32271

This report gives a resume of the work in sintering light carbonyl nickel powder to produce porous plaques, the impregnation of the porous plaques with nickel or cadmium nitrate solutions to produce positive or negative plates, and on the testing of such plates in cells to determine capacity and behaviour.

B-79

Heiman W. Koren and George Baumstark, Sonotone Corporation, "Electric Storage Battery," U. S. Patent 2,696,515 (December 7, 1954)

Methods by which the sintered electrode plates for nickel-cadmium batteries may be produced to obtain highly effective sintered electrode plates of consistent quality and characteristics on a large scale production basis.

A novel electrode spacer is provided which permits the construction of compact batteries.

B-80

Saul Padwo, Yardney Electric Company, "Power for Underwater Vehicles and Systems," Undersea Technology, 19-21 (May-June 1962).

Development of the latest undersea equipment has helped introduce large scale use of post-World War II batteries, such as the compact high-energy silver-zinc and silver-cadmium alkaline batteries, and the silver chloride-magnesium water-activated type, which also offers high energy density per unit of weight and volume. The lead-acid, nickel-cadmium and cuprous chloride-magnesium types, which provide a much lower energy density, are still used in many applications. In most cases, however, the selection of a battery is dictated by the paramount need for large amounts of power and the urgent requirement for minimum size and weight.

B-81

Hans Winkler, "The Phenomena in Sealed Nickel-Cadmium Batteries," Proceedings of the International Committee of Electrochemical Thermodynamics and Kinetics 9th Meeting, Paris, 1957. Butterworths Scientific Publications, London (1959) pp 320-325. In German

The voltage-time curve for the discharge of a sealed Ni-Cd battery does not differ from that of an ordinary Ni-Cd battery, but during charge there are differences: a series of comparative diagrams is presented. Gassing occurs much later in the sealed cells. Both H and O are absorbed by the Cd electrode with the resulting formation of water. The effect of addns. of antipolar masses (Cd powder, CdO, or $Cd(OH)_2$ added to the $Ni(OH)_2$ and vice-versa) was examined. CA 54:11750f

B-82

The Electric Storage Battery Company, "Improvements in Alkaline Type Electric Batteries," British Patent 873,403 (July 26, 1961)

In accordance with the present invention, there is provided a sealed nickel-cadmium battery which is adapted to be operated with an excess of electrolyte and which employs a new and improved negative plate having plaques impregnated and polarized to form cadmium electrodes and the non-wetting, gas permeable member may be a non-wetting microporous thermoplastic resin such as a sheet of microporous tetrafluoroethylene.

B-83

The Electric Storage Battery Company, "Improvements in or Relating to Electric Batteries," British Patent 870,697 (June 14, 1961)

An alkaline electrolyte for a nickel-cadmium battery containing a salt of a halogen selected from the group of chlorine, bromine, and fluorine in an amount ranging from 1 to 10 molar percent by weight of the electrolyte.

B-84

H. N. Seiger, E. Kantner, A. Lyall, et al., Gulton Industries, Inc., "The Oxygen Reduction Process at the Cadmium Electrode. Part I. Characteristics of Sealed Cells Due to the Oxygen Reduction Reaction," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1963), Abstract No. 1, 1-2, Extended Abstracts Publication

This work deals with the characteristics of sealed nickel-cadmium and sealed silver-cadmium secondary alkaline storage batteries which utilize the cadmium bielectrode. The cadmium bielectrode consists of the $Cd/Cd(OH)_2$ half cell situated in the pores of an "inert" metal electrode. The "inert" metal used in this work is sintered nickel having an original porosity of approximately 80%.

B-85

H. N. Seiger, Gulton Industries, Inc., "The Oxygen Reduction Process at the Cadmium Bielectrode. Part II. Mechanisms of Oxygen Transport and Reduction," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1963), Abs. Tract No. 2, pp 3-5, Extended Abstracts Publication.

This work will deal with the mechanisms by which oxygen is reduced at the bielectrode, and with the mode of transport of oxygen during overcharge from the anode (where it is generated from OH^-) to the cathode.

B-86

J. F. Laurent and J. P. Harivel, Societe des Accumulateurs Fixes et de Traction, "Studies of the Consumption of the Electrolysis Products on Porous Sintered Nickel Electrodes in Sealed Cells," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1963), Extended Abstracts Publication, Abstract No. 3, pp 6-9.

B-87

I.H.S. Henderson and S.G. Ladan, Defence Research Chemical Laboratories, "Coulometric Charging of Sealed Nickel-Cadmium Cells," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1963), Abstract No. 4, pp 10-13, Extended Abstracts Publication.

> When coulometric charging control is employed, sealed nickel-cadmium satellite cells can be recharged efficiently and rapidly following discharge of 75% of the cell capacity. The coulometer itself, which can be hermetically sealed, is rugged, simple to construct and easily incorporated in satellite charging systems.

B-88

P. Bauer, Space Technology Labs, Inc., "Pressure Characteristics of Nickel-Cadmium Cells," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1963), Abstract No. 5, pp. 14-17, Extended Abstracts Publication.

> An electro-hydraulic test system was developed to measure the internal pressure of nickel-cadmium cells without disturbing the hermetic seal, based upon the principle of sensing the differential in pressure between inside and outside and balancing the internal pressure with an equal external hydraulic pressure. Pressure differentials were sensed by mounting elements of a strain gauge bridge on the cell wall. The equipment was calibrated to 180 psi, with an accuracy of ± 2 psi.

B-89

R. C. Shair, J. Wartell, A. Lyall, and H. Seiger, Gulton Industries, Inc., "Electrical Parameters of Hermetically Sealed Nickel-Cadmium Cells," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1963), Abstract No. 6, pp 18-21, Extended Abstracts Publication.

Hermetically sealed nickel-cadmium cells are widely used in many space applications where extremely reliable completely automatic operation is essential. Since these cells are relatively new, their performance characteristics are still in the process of being delineated. Not only are the prosaic characteristics, such as charge and discharge being studied, but data is also being collected on overcharge capability, charge efficiency, changes in electrical properties with time and the necessary electrical control parameters which must be exercised to operate hermetically sealed cells successfully for thousands of cycles.

B-90

W. N. Carson, Jr., and J. M. McQuade, General Electric Company, "The Use of Auxiliary Electrodes in Sealed Cells," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1963), Abstract No. 10, pp 32-33, Extended Abstract Publication.

A large part of our effort on the use of auxiliary electrodes is concentrated on the use of the auxiliary and its associated circuitry for charge control in sealed nickel-cadmium cells. During charging, the auxiliary electrode voltage (compared to cadmium) is about 0.1 volt at the start of charging and remains constant until the onset of overcharging whereupon the potential rises rapidly to over 0.8 volt. Pressure measurements during charging show that the rise in voltage coincides with a rise in gas pressure of less than 5 mm. The relatively large signal is easily used in voltage control circuits. With this type of control, charging of the cell can be performed at rates up to 2C with less than 1 psi pressure rise at any time.

B-91

Paul C. Milner, Bell Telephone Laboratories, Inc., "Concentration Polarization Within Porous Nickel Oxide Electrodes During Oxygen Evolution," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1963), Abstract No. 12, pp 37-38, Extended Abstracts Publication.

The behavior of nickel oxide-impregnated sintered nickel electrodes during overcharge is of interest both because of their practical importance as positive electrodes in alkaline battery systems and because of their large surface areas, which permit the extension of measurements of oxygen evolution to very low current densities. In addition, non-uniformities in electrolyte concentration and current distribution within such porous electrodes are reflected in the steady-state current-voltage measurements, so that these can provide information pertinent to more complicated phenomena which may occur during transients as charge and discharge.

B-92

J. L. Weininger and M. W. Breiter, General Electric Research Laboratory, "Hydrogen Evolution and Surface Oxidation on Nickel Electrodes in Alkaline Solution," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1963), Abstract No. 13, pp 39-41, Extended Abstract Publication.

A recent study of the anodic formation of $Ni(OH)_2$ and NiOOH in alkaline solution was continued in the present work. Greater emphasis was placed on the potential range of -300 to -800 mv in order to obtain information about the adsorbed species and reactions which occur at these potentials.

Hydrogen evolution and anodic formation of $Ni(OH)_2$ were studied on polycrystalline and crystal electrodes of nickel in 4 N KOH with A.C. as well as D.C. measurements.

B-93

J. B. Andelman, Bell Telephone Labs, Inc., "Hydrogen Evolution on Nickel-Based Porous Cadmium Plates," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1963), Abstract No. 13A, p. 42, Extended Abstract Publication.

Hydrogen evoluation was studied on nickel-based porous cadmium plates in 7M potassium hydroxide. The overvoltage on fully charged plates indicated varying and changeable amounts of exposed nickel. Cathodic overvoltages were simililarly measured with different amounts of the cadmium present as cadmium hydroxide. Even though the latter is being electrochemically reduced, hydrogen simultaneously be evolved, its rate being dependent on the state of charge, the previous history of the electrode and the amount of exposed nickel.

B-94

D. R. Turner, Bell Telephone Labs., Inc., "The Effect of State of Charge of the Cadmium Electrode on Oxygen Recombination in Sealed Nickel-Cadmium Cells." Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1963), Abstract No. 13B, p. 43, Extended Abstract Publication.

The steady-state oxygen pressure on overcharge has been found to be inversely proportional to the state of charge of the negative electrode in sealed rechargeable nickel-cadmium cells. It is possible to condition a Ni-Cd cell, if it has sufficient excess cadmium ampere-hour charge capacity, so that the maximum overcharge oxygen pressure never exceeds a few atmospheres even at very high rates of overcharge.

B-95

M. H. Gottlieb, V. T. Murphy, M. L. Cassota and G. A. Caffoni, Bell Telephone Labs., Inc. "Effects of Prolonged Cycling of Sealed Nickel-Cadmium Cells," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1963), Abstract No. 13C, p. 44, Extended Abstract Publication.

The behavior of nickel-cadmium cells of the type used in the Telstar satellites was studied under simulated orbital cycling conditions, as well as in cycle regimes ranging from complete discharging of the cells to shallow cycling and continuous overcharge. Loss of cell capacity and ability to accept overcharge, as evidenced by development of high pressures, were encountered under certain types of cycle. The mechanism of the loss of overcharge capability was investigated.

B-96

H. H. Kroger, General Electric Company, Schenectady, New York, "Electrochemical Studies of Positive and Negative Electrodes for Nickel-Cadmium Batteries," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1963), Abstract No. 14, pp 45-46, Extended Abstracts Publication

The experiments were conducted as single electrode tests with an excess of liquid potassium hydroxide electrolyte, using sintered porous electrodes for nickel-cadmium batteries. Positive sintered electrodes in a charged state served as reference electrodes; no separators were used. The necessary spacing for the electrodes was provided by slits in the walls of the cell containers. The variation of charge and discharge rates and the influence of contaminants on the electrode performance were studied.

B-97

Paul C. Donnelly, NASA/Goddard Space Flight Center, "NASA/Goddard Battery Evaluation Programs," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 1, 1963), Abstract No. 22, pp 65-67, Extended Abstracts Publication.

Goddard is presently monitoring two nickel-cadmium satellite battery test programs.

The primary purpose of these tests is to obtain data useful in the designing of power systems for satellites. This paper describes the test set-up, current results, and the analysis of the data obtained from these formal evaluation programs.

B-98

Ferdinand J. John, U.S. Army Electronics R&D Laboratory, "Non-Destructive State-Of-Charge Tests for Batteries," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1963), Abstract No. 23, pp 68-73, Extended Abstracts Publication.

> Some of the more recent attempts at achieving non-destructive state-of-charge condition indicators will be reported here. For nickel-cadmium batteries: (a) double layer capacitance technique; (b) height of transient peak technique; (c) audio frequency impedance technique; (d) the Kordesch technique; (e) effective internal resistance technique; (f) phase shift technique; (g) resonant frequency technique; and (h) colorimetric indicator technique.

B-99

M. Lurie, R. C. Shair, and H. N. Seiger, Gulton Industries, Inc., "Observations on the A.C. Characteristics of Nickel-Cadmium Cells," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1961), Abstract No. 24, pp 74-75, Extended Abstracts Publication

> An equivalent circuit was synthesized which has the impedance and transient behavior outlined in the paper. A circuit was also developed by considering the physical structure of a cell. Electrically, a cell consists of resistance and inductance due to terminals, plates, electrolyte and separator; capacitance due to the parallel sets of plates and the electrochemical double layer; and, a source of emf. By following the path of current through a cell, an appropriate configuration for these components was found. The circuit thus developed is the same as that synthesized electrically. Values for the circuit components were found by matching the magnitude of the impedance of the circuit to that of a cell. These values were used to predict the frequency for zero phase shift.

B-100

W. E. Howden, Bell Telephone Labs., Inc. "Automated Test Facility for Cycling Nickel-Cadmium Cells," Abstract of paper presented at the Electrochemical Society Fall Meeting, Battery Division, New York (September 30 - October 3, 1961), Abstract No. 26A, p. 81, Extended Abstracts Publication.

> An automated test facility for charge-discharge cycling of nickel-cadmium cells has been designed. This facility provides reliable and accurate cycle control for 50 cells. Cells can be individually charged and discharged to time, voltage, temperature or pressure end-points according to programs punched on paper tape. Cell cycle programs are easily shared

among the 50 cells. The scanning rate is about 20 cells/min, but both scanning rate and scanning order can be varied. Data collection is synchronized with the system control scan so that the correspondence between parameter readings (voltage, pressure, temperature) and cell state (charge, discharge, open circuit) can be easily and definitely established. Data output is on punched cards; the format is single entry, giving time, cell location, cell number, cell state, and readings of up to eight parameters. Internal comparison of readings is used to limit the data output to significant information.

B-101

Michael L. Yaffee, "Space Power Systems - Part 2: Battery Reliability Ensures Continued Use," Aviation Week and Space Technology, 80 (22), 49-57 (June 1, 1964).

Review

B-102

D. Feldman and U. B. Thomas, Bell Telephone Laboratories, Inc., "Current Status of Sealed Nickel-Cadmium Storage Cells," American Institute of Electrical Engineers Pre-Conference Publication of the Pacific Energy Conversion Conference (July 13, 1962), pp 18-1 through 18-9.

This paper provides a discussion of the current status of sealed nickel-cadmium storage cells. The material presented stresses technical characteristics of sealed cells and illustrates their application in systems such as communications satellites.

Information about the overcharge characteristics and recharge efficiency of sealed cells as a function of charge rate and temperature is presented along with recent experience in deep and shallow discharge cycling. Effects such as fading capacity are described. Battery arrangements and methods of charging and overcharging are described along with a discussion of sealed nickel-cadmium cell storage characteristics.

B-103

Harry Cross Hubbell, Hubbell-Fuller Battery Company, "Storage-Battery Electrode and Process of Making Same," U.S. Patent 1,373,733 (April 5, 1921)

The process which comprises tableting a nickel oxide with finely divided cadmium, assemblying the tablets in a perforated metal container for an electrode, piercing the sides of the container with holes so that the burs extend into the tablets, and heating the tablets and the container in a substantially non-oxidizing atmosphere to bring about a reaction between the tableted materials.

B-104

H. N. Seiger, Gulton Industries, Inc., "Cycling Behavior of Sealed Nickel-Cadmium Cells," American Institute of Electrical Engineers Pre-Conference Publication of the Pacific Energy Conversion Conference (July 13, 1962), pp 22-1 through 22-3.

The hermetically sealed nickel-cadmium cell is in a corrosion-resistant stainless steel container. Ceramic-to-metal seals isolate the terminals of the case. The seals have a leakage rate of less than 10^{-8} cm^3 per sec. of helium.

The cells are capable of prolonged overcharge up to about C/5 at 77°F. The overcharge capability is greater at higher temperatures and somewhat less at lower temperatures. Optimum discharge capacity is also obtained at room ambient temperatures. Optimum discharge capacity is also obtained at room ambient with a derating of about 60% at 5°F. There is only a moderate derating of capacity at 120°F.

Cycle life studies to date are given for a continuous 100 minute charge-discharge cycle at various depths of discharge at several temperatures ranging from 48° to 120°F.

B-105

D.W.T. Kirkman and F.W. Mann, "Alkaline Accumulators: the Nickel-Cadmium Type," Colliery Guardian, 148, 1053-1055 (1934)

The positive-plate active material consists of Ni hydroxide and the electrolyte of 1.19 sp.gr. KOH. Finely divided Cd comprises the negative plate. The resistance of the positive plate is much less than in the Edison plate. A very small amount of Fe is mixed with the CdO to prevent caking. No gases are evolved upon discharge; this makes possible unspillable cells by fitting solid stoppers. No self-discharge of these cells is evident while idle. The charging voltage of the Ni-Cd cells is 1.35 - 1.50 v. Charging may proceed at very low rates. These cells can give practically their full rated capacity at high rates of discharge. The comparative watt-hr. efficiencies at 10-hr discharge rate are: Pb storage battery 75%, Ni-Cd 65% and Ni-Fe (Edison) 58%. The efficiencies for a 1-hour discharge rate are Pb 68%, Ni-Cd 58%. and Ni-Fe cell 36%. Freezing has no permanent effect on either of the alkaline cells but is disastrous to Pb accumulators. The percentage capacities available at normal discharge rates based upon 100% at 15° are at +5°; Pb 84%, Ni-Cd 96.5%; Ni-Fe 79.0%; at -5°, Pb 65%, Ni-Cd 92% and Ni-Fe 52.5%; at -15°, Pb 43%, Ni-Cd 74.5% and Ni-Fe 15.8%.

B-106

F. W. Mann, "Nickel-Cadmium Alkaline Battery," Mining Elec. Engr., 11, 329-337 (1931)

In these batteries the active material in the positive plates is Ni hydroxide and in the negative plates a mixture of Cd and Fe. On discharge, the Cd oxide which is formed has a comparatively high cond., and the Fe maintains the porosity of the mixture. The active material is contained in steel pockets. The electrolyte is a 20-25% solution of KOH. A full description of the cells is given, and also of their behavior on charge and discharge. The internal resistance is about one-half that of the Ni-Fe battery. Charge and discharge curves are given, and these are compared with those of the Ni-Fe and Pb cells. The special type of battery developed for miners' lamps is fully described.

B-107

Howard J. Strauss, Electric Storage Battery Company, "Storage Batteries," German Patent 1,154,160 (September 12, 1963)

Storage batteries are manufactured by cleaning the cell with O, satg. the alk. electrolyte with O, and closing the cell vacuum-tight. The negative electrode (Cd) is put into the cell in an uncharged condition while the positive electrode ($Nk(OH)_2$) is inserted in a fully charged state. The electrolyte is KOH. The negative electrode is larger than the positive electrode and the gas space above the electrolyte is kept small. During charging of the cell, the following reactions occur: at the positive electrode $Ni(OH)_2 + OH^- \rightarrow Ni(OH)_3 + e^-$ (1) and at the negative electrode $Cd(OH)_2 + 2e^- \rightarrow Cd + 2OH^-$ (2). When the charging action is fast or when the cell reaches the maximum charge, the following reactions may take place: at the positive electrode $4\ OH^- \longrightarrow 2\ H_2O + O_2 + 4e^-$ (3) and at the negative electrode $2\ H_2O + 2e^- \longrightarrow H_2 + 2OH^-$ (4). Due to the liberation of the O and 3 and H of 4 an increase in the gas pressure may occur. However, O being very sol. in the electrolyte, diffuses to the negative electrode and is eliminated according to the reaction $O_2 + H_2O + 4e^- \rightarrow 4\ OH^-$ (5). Due to the small soly. of H in the electrolyte, little H diffuses to the positive electrode, and the reaction is H_2 _ 2 $OH^- \longrightarrow 2e^-$ _ 2 H20 does not occur and does not eliminate the H. The conditions described in manufacturing the cell prevent reaction 4 and stimulate reaction 5, so O is eliminated and the production of H is prevented. The cell can be used at higher temperatures than those containing a considerable amount of H.

B-108

John L. S. Daley, Union Carbide Corporation, "Sealed Nickel Cadmium Cell," U.S. Patent 2,980,747 (April 18, 1961)

An anti-polar mass is placed within a Ni-Cd cell in the form of two auxiliary electrodes of a cathodic reducible oxide, such as CdO or preferably $Cd(OH)_2$, separated by a spacer screen of sufficient thickness and of proper structure to allow gas circulation between them, all of which are disposed between 2 semicylindrical pieces of $Ni(OH)_2$ mix which make up the positive electrode.

B-109

Freimut Peters, Accumulatoren-Fabrik A.G., "Permanently Sealed Gas-Tight Accumulator," U.S. Patent 3,031,517 (April 24, 1962)

The formation of H during charging cycles is prevented by initially overcharging before sealing. O produced in subsequent charging cycles is rapidly removed by electrochem. reaction at the negative Cd electrode, a portion of which is in contact with the gas. A NiOH positive electrode and aq. KOH electrolyte (d. - 1.2), which is immobilized in the porous separators, are employed.

B-110

Freimut Peters, Accumulatoren-Fabrik A.G., "Hermetically Sealed Alkaline Storage Battery," U.S. Patent 2,988,585 (June 13, 1961)

To improve the efficiency of the consumption of O in sealed batteries, compressed electrodes composed of an active Cd mass and Ni powder in a ratio of from 1:1 to 1:4 by volume are employed.

B-111

Louis Belove, Sonotone Corporation, "Fusion-Sealed Metal-Encased Rechargeable Alkaline Battery Cell," U.S. Patent 3,064,065 (November 13, 1962)

Rechargeable alkaline cells constructed by a crimping process tended to lose electrolyte by alkaline creeping between joints but were rendered gas and liquid tight by a process of fusion sealing. Thus, a typical cell (e.g., Ni-Cd electrodes and 20-35 wt.% KOH electrolyte) was assembled so that the rim edge of the thick metallic top wall and the surrounding upper edge of the tubular cell casing were jointed by high-temperature fusion. An inorg. collar of glass (Corning 9010) was used. The glass insulator was fused into previously oxidized metal surface. The completed cell had an integrated metal casing enclosing the electrode assembly with a relatively thin tubular casing wall. The end walls were relatively thicker; one of these consisted of an insulating section containing a gas-tight feed through for one terminal. The whole construction was such as to repress mechanical deformation produced by excess internal gas pressure.

B-112

Jean Piroux, "Sealed Alkaline Accumulator," U.S. Patent 2,980,748 (April 18, 1961)

The pressure of gas evolution in a Ni-Cd battery is reduced from 1300 to 0.650 kg/cm^2 during charging by lowering the KOH electrolyte concentration from 24 to 15^0 Be'. Thus, the container can be hermetically sealed safely.

B-113

Howard J. Strauss, the Electric Storage Battery Company, "Gas Permeable Negative Electrode," U.S. Patent 3,057,943 (October 9, 1962).

The negative plates can be two thin, sintered nickel plaques impregnated and polarized to form cadmium electrodes and the non-setting gas permeable member may be a non-wetting microporous thermoplastic resin such as a sheet of microporous tetrafluoroethylene. The gas permeable member is sandwiched between and held in close contact with the sections of the negative plate. Cells using this negative plate may be operated with an excess of electrolyte in the manner of conventional unsealed cells.

B-114

Edmund J. Casey, Phyllis E. Lake and Gerard D. Nagy, "Method of Incorporating an Electrochemically Active Cadmium Compound into a Porous Nickel Plawue," U.S. Patent 3,068,310 (December 11, 1962).

A method of incorporating an electrochemically active cadmium compound into a porous sintered nickel plaque which comprises soaking the plaque in a bath of $Cd(NO_3)_2.4H_2O$ which has been heated to boiling at a subatmospheric pressure, removing the plaque and reducing the cadmium nitrate contained therein by heating the plate in a hydrogen filled container for at least about 1/2 hour at a temperature of from about 200^0C to about 300^0C and allowing the plaque to cool in a hydrogen atmosphere.

B-115

Myron A. Coler and Sidney A. Corren, "Flexible Battery," U.S. Patent 3,023,259 (February 27, 1962)

Ni-Cd alk. batteries, which could be bent and deformed in use were made in the form of thin ribbons or sheets. Two thin, flat electrodes, a microporous separator, and at 25% aq. KOH solution were sealed with protruding leads, in a plastic film envelope. The flexible electrodes were made of Ni screen coated with a mixture containing at least 75% of electrochem. active material, such as $Ni(OH)_2$, powdered Cd-CdO, powdered Fe-CdO, and 25% of an elec. conducting plastic binder, such as a graphite mixture of poly(vinyl chloride) or of a vinyl acetate-vinyl chloride co-polymer. A model Ni-Cd battery, 0.085 in. thick, had a theoretical capacity of 1.1 amp-hr/cu.in.

B-116

Arnold S. Louis and Myron A. Coler, "Monolithic Electrode-Separator Structure for Electrochemical Cells," U.S. Patent 3,023,261 (February 27, 1962)

The flexible microporous separator was formed as a coating on battery electrodes. An electrode was dipped into a slurry of vinyl chloride-acrylonitrile copolymer (I) 67, $HCONMe_2$ (II) 540, and poly(vinyl alc.) of mol. wt. 1500 (III) 200 g. The coating was set by rinsing in H_2O to wash out the II. Poly(vinyl chloride), poly (vinyl butyral), poly (vinylidene chloride), and cellulose acetate were used alternately with I, and starch, carboxyethylcellulose, and zein were used in place of III.

B-117

Kenneth C. McLennan, Burndept Limited, London, England, "Layer Type Voltaic Cells," U.S. Patent 3,064,067 (November 13, 1962)

A miniature or "button-type" voltaic cell, primary or secondary, 2 cm. in diameter and 0.5 cm. thick, that is capable of being stacked like coins in series, is shown. A small sheet-metal box, whose lid is insulated from the body, carries two thin sheet electrodes of pressed Ni powder, sintered at 900^o. Their pore space carries the electrolyte. The positive electrode is formed by immersing such a pressed form in $Ni(NO_3)_2$ or other Ni salt solution, under reduced pressure (10-20 mm. Hg), for 5 minutes, then at restored atmospheric pressure 5 minutes. It is then made cathode in boiling 25% KOH solution at a voltage sufficient to produce 1 amp./sq. in. This is repeated 5 times. The negative electrode is made in the same way but is immersed in a Cd solution. Each electrode has a central hole to admit a single rivet of polystyrene plastic, as in the thin bilbulous spacer between the electrodes, made of any suitable nonconducting material. This rivet is the sole support of the cell structure. The assembly is immersed in a 25-35% KOH solution and fully charged, removed, washed free of KOH, dried at 60^o, and stored in dry air, ready for placement in the above sheet metal box, using a thin sheet metal plate at top and bottom of the stack to act as connector to the above-mentioned insulated halves of the box and keep the assembly pressed together. The electrolyte, such as KOH solution, is stored mainly in the Ni pressings but a small indentation in the lower electrode also carries a few drops of KOH solution. Since an alkaline solution is used as electrolyte, it is well to make metal parts of the cell of Mg.

B-118

Howard G. McEntee, "Packaged Power Packs New Punch," Popular Science 80-83, 170 + 172 (June 1964)

With small batteries powering everything from toothbrushes to drills, you need a guide to know which is best for what.

B-119

Ronald M. Benrey, "Inside Those Tiny New Speedlights," Popular Science 130-132, 186 (June 1964)

Here's the lowdown on the new breed of tiny electronic flashes - potent, portable, and pretty.

B-120

M. I. Gillibrand and B. E. Wilde, "Thermodynamic Properties of Electrochemical Storage Cells," Electrochemica Acta, 9, 401-411 (April 1964)
In German

In the study reported, the heat evolved when lead-acid storage cells and nickel-cadmium alkaline cells are charged and discharged in an adiabatic calorimeter was determined, and the heat content change and the free-energy change for the reactions which account for the electrical-storage capacity of the cells were calculated from the data obtained.

B-121

Burgess Battery Company, Burgess Engineering Manual, Complete Battery Data for the Design Engineer, "Burgess Rechargeable, Sealed Nickel-Cadmium Batteries," pp 117-125. 1961 Edition.

The following characteristics are discussed: Operation of the Sealed Nickel-Cadmium Battery; Battery Sizes; Service Life Rating; Methods of Expressing Rate of Discharge; Discharge Characteristics; Recharging; Retention of Charge; Temperature Characteristics; Normal Life; and Estimating Service Life.

B-122

Union Carbide Consumer Products Company, Portable Power Handbook. The Inside Story of Dry Batteries. "Eveready Sealed Nickel-Cadmium Rechargeable Batteries," Chapter 10, pp 47-50 (1961)

The following topics are discussed: Operation of the Sealed Nickel-Cadmium Battery; Button Cells; Cylindrical Cells; and Rectangular-Cells.

B-123

H. N. Seiger, Avco, RAD, "Sealed Nickel-Cadmium Cells Containing Palladium," paper presented at the Electrochemical Society Fall Meeting, Columbus (October 19-21, 1959), Abstract No. 28, pp 62-63

One of the major problems encountered with hermetically sealed nickel-cadmium cells is that of catastrophic failure during overcharge and discharge. The use of catalysts to accelerate the recombination of gaseous products has been suggested often. Dr. A. Fleischer prepared palladium surfaces for this purpose which were placed in the core during the assembly of the cells.

B-124

C. M. Shepherd and H. C. Langelan, U.S. Naval Research Laboratory, "Formation of Porous Metal Plates by Electrolytic Reduction Under Controlled Pressures," paper presented at the Electrochemical Society Fall Meeting, Houston (October 10-12, 1960), Abstract No. 31, pp 93-95

A thick mixture of a suitable metal compound was pasted on a thin wire screen grid, made into a flat assembly with inert anodes and placed in a thin, flexible polyethylene bag which served as a cell case. By pressing between two plates, controlled mechanical pressure was applied to this assembly and transmitted to the pasted compound. This pressure was maintained throughout electrolysis. The metal electrodes formed by cathodic reduction in this manner, are porous, adherent and have high surface areas and a considerable degree of mechanical strength. This is the type of physical structure that is often desirable in battery anodes.

B-125

Donald Tuomi, McGraw-Edison Company, "The Forming Process in Nickel-Positive Electrodes," paper presented at the Electrochemical Society Fall Meeting, Houston (October 10-12, 1960) Abstract No. 32, pp 96-98

The assembled electrodes of storage batteries are generally given a particular electrolytic processing to bring the active materials into a stable state of electrochemical activity. This process of improving the electrical capacity of the battery is described as "forming". Several facets of this art are illustrated by data from a microscopic and x-ray diffraction examination of experimental nickel positive electrodes at various stages of formation.

B-126

B. E. Conway and P. L. Bourgault, University of Ottawa, Canada, "Electrochemical Behaviour of the Semi-Charged Nickel Oxide Electrode," paper presented at the Electrochemical Society Fall Meeting, Houston (October 10 - 12, 1960), Abstract No. 33, pp 99-100

> Kinetic studies have been made on nickel oxide electrodes oxidised to a controlled state of charge corresponding to the formal degree of oxidation $NiO_{1.25}$. Emf decay and recovery measurements as a function of time have been made following anodic and cathodic polarisations of the semi-charged electrodes, respectively.

B-127

A. A. Menodruk and L. L. Kuz'min, Chem.-Technological Inst., Ivanovo "Behavior of a Positively Pressurized Electrode in a Cadmium-Nickel Accumulator," Izv. Vysshikh Uchebn Zavedenii, Khim. i. Khim. Teknol. 7 (2), 263-268 (1964)

> The behavior of a pressurized NiO electrode in a Cd-Ni battery was studied. The decreased current output due to a loss in capacity at the positive electrode was shown to be related to a decrease in pressure. To lengthen battery service life by pressurization, it is recommended that the applied pressure be in the range 0.2-1.0 Kg/cm^2, that separators resistant to alkaline solutions be used, that an elastic material be used for the battery case, and that the deposit on the plates be capable of withstanding pressures.

B-128

Ernst Waldemar Jungner, "Process of Making Active Material for Accumulator - Plates," U.S. Patent 670,024 (March 19, 1901)

> The process of producing active material for accumulator-plates which consists in mixing cadmium oxide with the salt of a metal capable of forming with a basic double salt, causing the formation of the double salt by double decomposition with a solution of ammonium chloride, and electrolytically reduced the double salt in an alkali-bath.

B-129

E. Jost and F. Rufenacht, Metals and Controls, Inc., Division of Texas Instruments Inc., "Polarization Studies on Sintered Plate Electrodes Containing Various Amounts of $Ni(OH)_2$," paper presented at the Electrochemical Fall Meeting, Battery Division, Washington, D.C. (October 11-15, 1964), Abstract No. 38, pp 103-107.

The polarization behavior of porous sintered carbonyl-nickel plates impregnated with $Ni(OH)_2$ in a manner as described by Fleischer was investigated at different current densities. The plaques were 0.1 cm. thick, had identical internal surface areas and porosities, and contained 0.375, 0.24, 0.10, and 0.035 grams of $Ni(OH)_2$ per gram of plaque, resulting from six, three, one, and "one-third" impregnated cycles with standard $Ni(NO_3)_2$ solution.

B-130

S. F. Pensabene and A. J. Catotti, General Electric Company, "The Effect of Nitrates on Self-Discharge of Nickel-Cadmium Batteries," paper presented at the Electrochemical Society Fall Meeting, Battery Division, Washington, D.C. (October 11-15, 1964), Abstract No. 43, p 119

Nitrates were introduced into nickel-cadmium laboratory-type test cells by adding KNO_3 to the electrolyte prior to its addition to the cells. Several levels of added nitrates were investigated. Results of this investigation show that in general the fraction of initial capacity decreases with time as expected, and that this loss in capacity increases as the level of nitrates increases.

B-131

Yu.M. Pozin, O.I. Bondarenko and V.I. Fishman, Accumulator Research Institute, Moscow, "Preparation of Highly Porous Metal Powder Products for the Accumulator Industry," Poroshkovaya Metallurgiya, No. 3, 80-85 (1962) Abstract Only

The authors describe the preparation of plates consisting of a nickel or nickel-plated iron network to which is bounded a porous layer of metal.

B-132

D. K. Worn and R. P. Perks, International Nickel Company (Mond) Ltd., "Sintered Nickel Electrodes," British Patent 937,548 (September 25, 1963) Abstract Only

In the method of the invention, a mixture of Ni powder with 10-60 parts by volume of a fugitive spacing agent such as methyl cellulose powder is rolled into a compact, which is heated slowly to decompose and volatilize the spacing agent, without disrupting the compact, and sintered to form a porous strip. The amount of the spacing agent, the thickness of the compact, and the conditions of sintering must be correlated so as to ensure a minimum porosity of 60%.

B-133

Accumulatoren-Fabrik A.G., "Negative Electrodes for Alkaline Accumulators," British Patent 751,725 (July 4, 1956). Abstract Only

Self-supporting electrodes are produced by cold compacting of a powdered metallic component which normally does not take part in the electrochemical reactions during operation of the accumulator, a metallic oxide component which is the effectively active electrochemical constituent, and a second, and different chemically inactive metal powder, for example Ni or Ni alloy. 50-40 parts Cd+50-60 parts CdO+150 parts Ni, moulded at 700-1500 kg./cm^2, is suggested.

B-134

Paul D. Payne, "Manufacture of Electric Storage Cells," U.S. Patent 2,379,374 (June 26, 1945)

In a method of manufacturing an electrical storage cell, the procedure of clamping together a laminated assembly of electrode elements including a plurality of parallel resilient metallic plates having exteriorly projecting edge portions and forcing said clamped assembly into an interiorly conductive container having an inside cross-section smaller than that of said plates, thereby forcibly bending the projecting portions against the interior of the container, to secure the assembly therein and to provide electrical connection to the plates.

B-135

Wilhelm Garten, Klaus Dehmelt, Hans v. Doren, and Freimut Peters, Varta Pertrix-Union GmbH, "Hermetically Sealed Alkaline Storage Battery," U.S. Patent 3,089,913 (May 13, 1963), Abstract Only

A storage battery with a number of cells connected in series is described which can be operated in a hermetically sealed conditions without forming excessive overpressure under conditions of supercharge and deep discharge. In a Ni-Cd battery, in the case of deep-discharge of the storage battery cell with concurrent reversal of its polarity, the capacity of the battery will be limited by its negative electrode whereby the voltage will drop only slightly below 0 v. since the positive electrode, because of its discharge reserve, maintains its original potential. The negative electrode whose polarity has been reserved does not yet evolve any O since the antipolar mass is included in or connected with the negative electrode, consisting of $Ni(OH)_2$, must first be charged, i.e., oxidized to $Ni(OH)_3$. After exhaustion of the discharge reserve of the positive electrode, the polarity of the electrode is reversed, after which redn. of the antipolar mass of the positive electrode to metallic Cd will start without producing H gas. The voltage is finally reversed to a potential corresponding inversely to the charge potential of a Ni-Cd cell. Before all of the antipolar mass of the positive electrode, $Cd(OH)_2$, is reduced to Cd, O gas formation of the oxidized antipolar mass of the negative electrode will start. The resulting O gas will oxidize the already formed metallic Cd surface areas at the positive electrode so that upon deep-discharge of the cell an equil. will be established between O gas formation and consumption. During super-charging, formation of H gas will be prevented since the negative electrode possesses a charge reserve. The O gas generated at the positive electrode will be bound by the metallic Cd mass of the negative electrode as an oxide or hydroxide. Thus, equil. between O gas formation will be established at a very low O gas pressure.

B-136

Henry Reginald Milnes, "Alkaline Storage Battery," U.S. Patent 2,527,888 (October 31, 1950)

In an alkaline electric storage cell, a plurality of positive and negative electrodes each formed of two finely perforated metal plates each embossed to provide a series of alternate parallel, depressed portions and narrow, hollow, V-shaped ribs, the depressed portions being completely filled with active material up to and over the top of said ribs and being smooth to form a continuously extending external layer of active materials, said plates being placed back-to-back so that the continuous layers of active material are outermost and so that the hollow portions of said V-shaped ribs are in register to form gas escape channels, pervious insulating sheets for separating the unlike electrodes, and resilient means for exerting end pressure on the assembled electrodes.

B-137

Eric Maurice O'Conor Honey and Charles Rupert, The Electric Storage Battery Company, "Process of Producing Microporous Material," U.S. Patent 2,542,527 (February 20, 1951)

A process of the production of microporous material comprising the steps of mixing approximately one part by weight of dry, finely divided particles of polyvinyl chloride, approximately five parts by weight of dry finely divided starch, and approximately two parts by weight of a solvent of the group consisting of cyclohexanone, methyl cyclohexanone and chlorobenzene, and thereby forming a dough in which said solvent acts as a temporary plasticizer for the coating of the starch particles, extruding the dough as a sheet, removing the plasticizer by evaporation, passing the extruded sheet through water at approximately boiling temperature to swell the starch particles thereby to increase the dimensions of the sheet, passing the swollen sheet through hot acid to digest the starch and to shrink the sheet to approximately its original dimensions, and then washing and drying the sheet.

B-138

Georg Neumann and Uscha Gottesmann, "Bureau Technique Gautrat," S.A.R.L., Paris, France, "Electrolyte Cell and, in Particular, Alkaline Cells, U.S. Patent 2,571,927 (October 16, 1951)

An electrolytic cell of the type described comprising a sealed vessel capable of confining under pressure the gases generated therein, and in said vessel a negative electrode, a positive electrode, an immobilization liquid electrolyte between limited areas of the surface of one electrode and the surface of the other electrode, free gas passages through electrolyte-free gas spaces between other areas of opposite surfaces of said electrodes, and a film of the electrolyte on said latter areas, said latter film-covered areas on either electrode causing thereon depolarization and recombination of a substantial amount of the gas developed at the electrode of the opposite polarity.

B-139

Joseph Donald Moulton, Thomas A. Edison, Inc., "Storage Battery," U.S. Patent 2,634,303 (April 7, 1953)

An alkaline battery comprising a positive electrode, a negative electrode including active cadmium material, an alkaline electrolyte and a tin material in effective contact with said electrolyte and in a form capable of depositing onto the negative electrode when the battery is charged.

Tin is added to cadmium in the ratio of 1 to 4 parts to 585 parts of cadmium.

B-140

Georg Neumann, "Bureau Technique Gautrat," S.A.R.L., Paris, France, "Gastight Storage Battery and Method of Manufacturing Same," U.S. Patent 2,636,058 (April 21, 1953)

In the method of making a gastight storage battery cell the steps of placing in a container an electrolyte, a positive electrode and a negative electrode having a higher capacity than the positive electrode, the condition of said negative electrode corresponding, prior to sealing, to a higher charged state than the condition of the positive electrode, the difference between the charged states of said electrodes being at most equal to the difference between their capacities, and hermetically closing the container.

B-141

Wright W. Gary, Jr., "Alkaline Battery," U.S. Patent 2,642,469 (June 16, 1953)

A battery cell construction of the alkaline type comprising a plurality of interposed positive and negative plates, said positive plates including an individually sealed envelope of porous membrane, thin layers of nickel hydroxide hydrogel in a soft plastic mass covering substantially the entire surface of said membrane, a foil conductor between said hydrogel layers and extending externally of said envelope, said negative plates being interposed between said positive plates and including an individually sealed envelope of porous membrane, thin layers of cadmium oxide covering substantially the entire internal surface of said membrane, and a thin foil between said cadmium oxide layers and extending externally of said envelope, the outer surfaces of said membranes of said positive plates being in contact with the outer surfaces of said negative plates.

B-142

Victor Herold, Societe des Accumulateurs Fixes & de Traction, "Process for the Manufacture of Battery Electrodes and the Resulting Electrodes," U.S. Patent 2,646,454 (July 21, 1953)

An electrode for an electric battery having alkaline electrolyte comprising an electrolytically inactive electro-conductive support impregnated with precipitates consisting of ternary mixtures of hydroxides of iron, of cadmium and of a metal selected from the group consisting of mercury and titanium.

B-143

Pierre A.C. Jacquier, Societe des Accumulators Fixes & de Traction, "Fabrication of Storage Battery Plates," U.S. Patent 2,646,456 (July 21, 1953)

The method of making highly porous metallic plates for use as electrodes for alkaline storage batteries comprising reducing iron oxides to produce non-pyrophoric, finely-divided porous iron powder, immersing determined quantities of said powder for a determined time in a solution of nickel salts for chemical exchange between the iron of the iron powder and the nickel of the solution so that the metallic nickel of the solution replaces iron forming nickel-coated iron particles, separating the nickel-coated particles from the solution, molding the latter particles with a minimum or compacting into the configuration of a storage battery plate and thereafter sintering the molded particles to form a porous storage battery plate.

B-144

Pierre A.C. Jacquier, Societe des Accumulateurs Fixes & de Traction, "Electrode for Alkaline Batteries," U.S. Patent 2,646,457 (July 21, 1953)

> A process for the production of a porous carrier body for an electrode for an alkaline storage battery, comprising the steps of molding without compression into the form of an electrode and then sintering without compression at a temperature between about 800°C and about 1050°C ho ogeneous powdery metallic products whose physical texture and composition is such that after sintering the metal constituting the porous body is a homogeneous alloy of iron-nickel containing at least 20% nickel.

B-145

Georg Neumann, Bureau Technique Gautrat, S.A.R.L., Paris, France, "Hermetically Sealed Storage Battery," U.S. Patent 2,651,669 (September 8, 1953)

> In a hermetically sealed storage battery cell at least one electrode of one polarity and at least one electrode of the opposite polarity, a first terminal, means for connecting said first terminal to one of said electrodes, two other terminals, means for connecting said two latter terminals in parallel to the electrode of the opposite polarity, a switch for opening and closing the connecting means between one of said latter terminals arranged for charging the battery cell and the electrode of the opposite polarity, and pressure responsive means associated with the battery cell and adapted to open the switch under the pressure of gases generated during the charging operation.

B-146

Joseph B. Brennan, "Battery Separator," U.S. Patent 2,673,230 (March 23, 1954)

> In combination, an electrolyte cell electrode carrying active material, and a dielectric support and spacer layer of plastic material integrally bonded to and extending in substantially continuous relation over a portion of said electrode sufficient to substantially support and envelop the same, said layer comprising spray deposited particles of said plastic material welded together at adjacent points on the surface of the particles with interstices between the particles rendering the layer porous and electrolytically permeable.

B-147

Leo Schlecht and Ernest Oestreicher, Badische Anilin- & Soda-Fabrik A.G., "Porous Sintered Metal Bodies for a Storage Battery," U.S. Patent 2,699,458 (January 11, 1955)

A process for the production of a porous carrier body for an electrode for an alkaline storage battery comprising the steps of thermally decomposing a vaporous mixture of metal carbonyls to produce a metallic powder consisting essentially of an intimate mixture of the metals having a piled weight of less than 2 kilograms per liter, and sintering the mixture in the desired shape of the carrier body in a hydrogen atmosphere to produce a porous metal alloy carrier body.

B-148

Heiman W. Koren and George Baumstark, Sonotone Corporation, "Electric Storage Batteries and Their Production," U.S. Patent 2,708,211 (May 10, 1955)

In the process of producing electrode plates for alkaline storage battery cells out of self-supporting sheet formations, each comprising a porous layer of sintered nickel powder particles, the steps comprising providing a sheet formation containing a supporting member having on at least one side thereof a porous layer of sintered powder particles of a metal selected from the group consisting of nickel and iron, compacting said sheet formation along narrow separation zones to change said separation zones to zones of low porosity having a thickness of at most half the original thickness thereof, said separation zones separating said sheet formation into several sections of areas corresponding to the areas of the several desired electrode plates, subjecting the integral sheet formation to treatments wherein the pores of the several sheet sections are loaded with desired active electrode material which is modified when charging or discharging a cell thereafter subjecting the sheet formation to at least one electric charging and discharging cycle while immersed in a electrolyte and thereafter cutting the so treated sheet formation along said separation zones to provide individual electrode plates loaded with at least partially active electrode material.

B-149

Heiman W. Koren and George Baumstark, Sonotone Corporation, "Electric Storage Batteries," U.S. Patent 2,708,212 (May 10, 1955)

In an electrode plate for use in an electric storage battery operating with an alkaline electrolyte, a thin sheet structure comprising a layer of sintered nickel powder particles of substantial porosity having united thereto a thin, substantially planar backing layer made up of a plurality of continuous metal elements extending in a direction of at least one major dimension of said sheet structure, the powder particles along the edges of said sheet structure being compacted against said backing layer to provide thin edge regions of a thickness at most about half the thickness of the major area of said sheet structure and free of any continuous metal elements other than said backing layer a metallic terminal strip having a portion electrically and mechanically affixed to a compacted region of said sheet structure adjoining a portion of the compacted thin edge region of said sheet structure.

B-150

Heiman W. Koren, Sonotone Corporation, "Electric Storage Batteries," U.S. Patent 2,708,213 (May 10, 1955)

In an electric battery, a plurality of battery cells having generally rectangular cell casings with the side walls of adjacent cell casings abutting each other over at least parts of their areas, said abutting side walls being recessed along their facing upper regions to provide between extended adjacent facing side wall areas discharge passages through which liquid overflowing the top regions of said cells will flow downwardly and laterally to the edges of said side walls between adjacent side walls, adjacent side walls of said casings being also spaced along downwardly extending corner wall regions to provide between them discharge channels for discharging liquid flowing through said passages beyond the bottom of said cell casings, the top wall of each cell having an opening through which electrolyte liquid may flow between the interior of said casing and the exterior of said top wall having an upwardly projecting hollow retainer structure for retaining liquid overflowing through said opening, upper wall portions of said retainer structure being shaped for discharging liquid tending to overflow said retainer structure into at least one said discharge passage.

B-151

Grenville B. Ellis, U.S. Army, "Battery Separator" U.S. Patent 2,729,694 (January 3, 1956)

A composite ionically permeable barrier to be inserted between the electrodes of primary cells comprising a porous polyvinyl chloride acting as a mechanical support, the pores of said supporting material containing a mixture of ultra micro-porous cellophane and polyvinyl alcohol of high ionic conductivity and low electric resistance.

B-152

Freimut Press, Accumulatoren-Fabrik A.G., "Oxidizable Electrode for Sealed Alkaline Storage Cells," U.S. Patent 2,798,110 (July 2, 1957) Reissued May 23, 1961, RE 24,989

An accumulator of the hermetically sealed alkaline type having two composite electrodes comprising a porous skeleton structure of sintered nickel and active mass, said skeleton of sintered nickel having one surface uncovered by the active mass, a porous separator closely bound between the respective electrodes, and an electrolyte substantially completely absorbed within said separator, whereby oxygen freed by electrolysis is substantially completely absorbed by said uncovered surface.

B-153

Freimut Peters, Accumulatoren-Fabrik A.G., "Method of Forming Cold-Welded Negative Electrodes for Alkaline Accumulators," U.S. Patent 2,830,108 (April 8, 1958)

> The method of producing a negative electrode for an alkaline type accumulator which comprises the steps of pressing a homogeneous mixture comprising pulverized cold-weldable negative electrode metal, pulverized active oxide which is reducible upon charging of the accumulator and pulverized metallic material which is substantially inert during charge and discharge at the accumulator, said pressing of said mixture being performed at room temperature in a mold providing a desired shape for the finished electrode and within a pressure in the range from 700 to 1400 kilograms per square centimeter, the particles of said pulverized electrode metal and said inert metal becoming cold-welded together under said pressure so as to form a self-supporting porous electrode structure having said oxide uniformly distributed therethrough and being accessible to the electrolyte of said battery, said electrode being present in a proportion sufficiently great to provide an excess which remains inert upon charge and discharge of said accumulator, thereby acting so as to preserve and maintain said cold-welded self-supporting structure, the mixture of metal and the oxide thereof comprising 5 to 30% of oxide and 95 to 70% of metal, and the inert metallic material ranging from a minimum significant quantity to one and one-half times the weight of the mixture of active metal and oxide thereof.

B-154

Pierre L. Bourgault, Phyllis E. Lake and Edmund J. Casey, "Method of Impregnation of Positive Plates by Thermal Decomposition of Aqueous Nickel Nitrate," U.S. Patent 2,831,044 (April 15, 1958)

> A method of impregnating a porous sintered nickel plaque with nickel hydroxide which comprises immersing the plaque in a molten bath of $Ni(NO_3)_2.6H_2O$, roasting the plaque which has been subjected to said immersion, at a temperature of from about 180°C to about 250°C for a period of at least about 10 minutes, whereby to decompose the nickel nitrate into a product intermediate between nickel nitrate and nickel hydroxide, and converting said intermediate product into nickel hydroxide by immersing the plaque in hot concentrated caustic solution, prior to washing and drying the thus-treated plaque.

B-155

Freimut Peters, Accumulatoren-Fabrik A.G., "Electrode for an Alkali Storage Cell and a Process of Manufacturing Same," U.S. Patent 2,832,813 (April 29, 1958)

A negative electrode of an alkaline storage cell which electrode comprises a highly compressed body, said compressed body consisting of a conductive metal and a negative active material containing a metal compound selected from the group consisting of the oxides and hydroxides of zinc, iron, and cadmium and of mixtures thereof, said electrode body obtained by compressing a mixture of said conductive metal and said active material in finely powdered form at a pressure between about 700 kg./sq. cm. and about 1400kg./sq.cm and by solidifying said compressed body into a porous metal electrode structure by cathodic treatment in an alkaline electrolyte subsequent to said pressure treatment, said metal compound being present in said compressed electrode body before said cathodic treatment in an amount between about 50% and about 150% of said conductive metal powder.

B-156

Witold Nagorski, Burndept Limited, "Voltaic Cells," U.S. Patent 2,847,495 (August 12, 1958)

A unit for an electric dry battery of the layer type, consisting of the electrical components of a cell, all of flat form and substantially rectangular shape, assembled in register, and seamless tube of an elastic plastic material which is dielectric and resists the electrolyte but permits the diffusion of gases produced in the cell tightly enclosing said components, the axis of said tube being parallel with the flat faces of the components and the ends of the tube sealed by welding so as to leave pockets adapted to accommodate gases and/or liquid produced in the storage and operation of the cell, and a conductive tongue electrically connected with one end component and protruding through one welded end of the tube, the weld being sealed to the tongue.

B-157

Harold P. Murphy and Abraham L. Levine, The Electric Storage Battery Company, "Alkaline Storage Battery," U.S. Patent 2,880,257 (March 31, 1959)

A method of producing battery electrodes comprising the steps of impregnating a porous matrix selected from a group consisting of sintered nickel and graphite with a solution of a metal nitrate, reacting said metal nitrate with a solution of reactant selected from the group consisting of formaldehyde and formic acid to form a metal formate, and thermally decomposing said metal formate in an oxidizing atmosphere to form electrochemically active material within said matrix.

B-158

Howard J. Strauss, The Electric Storage Battery Company, "Storage Battery Separator," U.S. Patent 2,880,260 (March 31, 1959)

In a sealed storage battery of the alkaline type, including positive plates and negative plates, a separator interposed between adjacent plates, said separator consisting of a highly microporous thermoplastic resin having a plurality of macroscopic openings therethrough, the size of said microscopic openings being from approximately one-sixteenth of an inch to about one-quarter of an inch in the narrowest dimension, said openings being arranged in a vertical overlapping manner so that gas passing upwardly between said plates will encounter at least one of said openings prior to reaching the top of said plates, and electrolyte absorbed within and saturating the microporous portions of said separator, the macroscopic openings being substantially free of electrolyte.

B-159

Franz Bronstert, Accumulatoren-Fabrik A.G., "Annular Permanently Sealed Alkaline Accumulator," U.S. Patent 2,915,577 (December 1, 1959)

An annular, permanently sealed alkaline storage battery comprising an annular tubular container of flexible material having two open ends adjacent one another, mermetic sealing means permanently closing each open end of said container, two annular, flexible electrodes - mounted in the annular tubular container, each electrode extending longitudinally through said tubular container and having one end near a respective one of said sealing means inside the container and another end forming a battery terminal leading outside the container through the sealing means in an opposite one of said open container ends, and an annular separator means disposed in the container between the said electrodes.

B-160

Francis T. Bonner and Henry B. Linford, Koehler Manufacturing Company, "Sealed Electrolytic Cell with Auxiliary Electrode," U.S. Patent 2,928,889 (March 15, 196

A hermetically sealed nickel-cadmium galvanic cell containing alternate positive and negative plates spaced apart and arranged parallel to each other, and separators filling the spaces between said plates, means defining a reservoir contiguous to the ends of said plates and separators electrolyte completely filling said reservoir and saturating said separators an auxiliary negative electrode in contact with the electrolyte in said reservoir, said auxiliary electrode being spaced apart from the positive plates in said cell and forming substantially a part of said reservoir - defining means, and being electrically directly connected in parallel with the negative plates therein, and being in contact with said electrolyte throughout its exposed surface area, a foraminous auxiliary positive electrode within said reservoir in electrical contact with the positive elemects of said cell and insulated from the negative elements thereof and positioned between the auxiliary negative electrode and said plates and separators, said electrolyte filling the entire free space within said cell.

B-161

George Neumann, "Bureau Technique Gautrat," Paris, France, "Electrolytic Cell, Particularly Accumulator Cell," U.S. Patent 2,934,580 (April 26, 1960)

An alkaline storage battery cell comprising a positive electrode, a negative electrode having a greater charge capacity than said positive electrode, a form-stable layer intermediate of, and in electrically conductive contact with, said electrodes, said layer being impregnated with an alkaline electrolyte containing a reducible cadmium compound selected from the group consisting of cadmium oxide and cadmium hydroxide vs contiguous particles forming electrically conducting bridge-like connections between said electrodes when their polarities are reversed, and electrical resistance means supplementing during recharge of the cell the resistance of said intermediate layer to produce an oxidizing potential at said positive electrode, said electrically conducting connections between the electrodes being broken by reoxidation of the cadmium when the original polarity of the electrodes is restored.

B-162

Rodolphe A. Herold, Societe des Accumulateurs Fixes et de Traction, "Electrodes for Alkaline Storage Batteries," U.S. Patent 3,108,910 (October 29, 1963) Abstract Only

The alkaline storage batteries have as electrodes envelopes of tubular or rectangular pockets of perforated sheet metal (Ni or Fe) filled with finely divided Ni in porous grains, as carrier for the active material, $Ni(OH)_2$ coating the grains. Being a poor conductor these coatings should be $< 10\mu$ thick. The grains are clumps of more finely divided metal and can be closely sized to permit penetration of vapor or liquid, such as solution of $Hi\text{-}(NO_3)_2$ and the NaOH of the electrolyte, forming the film of $Ni(OH)_2$. The thinner the film, the more efficient is the battery. Any contamination by $Co(OH)_2$ is permissible. The envelopes of sheet metal should have $<20\%$ of their total area in small perforations. The suspension may contain Ni carbonyl in a carboxy-methyl-cellulose solution.

B-163

Societe des Accumulateurs Fixes et de Traction, "Alkaline Storage Battery Cells," French Patent 1,321,504 (March 22, 1963) English Abstract Only

Porous metallic supports are impregnated by pptn. of metal hydrates from a weakly acidic solution of the nitrates of Cd, Ni, and (or) Co., esp. in the manufacture of alkaline Cd-Ni storage battery cells having a sintered Ni support. Corrosive attack of the porous metal during the impregnation process is inhibited by inhibiting the redn. of NO_3^- by addition of a negative catalyst, e.g. $Cu(NO_3)_2$. The impregnating solution is a $Ni(NO_3)_2$ solution containing 300 g. Ni/l., having an acidity corresponding to ~3 g. HNO_3/l. and containing 150 mg. Cu^{++}/l.

B-164

Freimut Peters, Accumulatoren-Fabrik A.G., "Counterelectromotive-Force Cell," U.S. Patent 2,980,745 (April 18, 1961)

A hermetically sealed, electrolytic counter cell, comprising, in combination, a housing; means for hermetically sealing said housing; two metal electrodes of potentially different polarity and substantially free of active material located in said housing; separator means between and in contact with adjacent surface portions of said electrodes of potentially different polarity, at least one of said electrodes having free surface portions partically defining a gas space within said housing. An electrolyte capillarily fixed in said separator means and forming a thin film on said free surface portion of said electrode; and a gas atmosphere in said housing consisting at least primarily of oxygen at the time the cell is hermetically sealed, whereby gases evolved during operation of said counter cell will reach said gas space and will be consumed in contact with said electrolyte film-covered surface portion of said electrode.

B-165

Tsutomu Iwaki, Taketsugu Hirai and Masataro Kikuda, Centeral Research Lab., Matsushita, Japan, "Sintered Plate Nickel Cadmium Alkaline Batteries, I. Thermal Decomposition of Nickel Nitrate in Steam," Denki Kagaku, 32 (8) 604-610 (1964). English Abstract Tract Only

The products of the termal decomposition of nickel nitrate was examined with x-ray diffraction, infrared absorption, and others. The compn. of the product is $0.3\ Ni(NO_3)_2.0.7\ Ni\ (OH)_2$ for the decomposition at 220-245°C in water steam. The nitrate content is appreciably lower compared with what in the product of thermal decomposition in air. The remaining nitrate ions can be replaced nearly completely with OH by treating the decomposition product with KOH ac. solution (s.w. 1.24) for 1.5 hours at 60°C.

B-166

Union Carbide Consumer Products Division, "'Eveready' Battery Applications and Engineering Data," no publishing information given, received October 22, 1964

This reference manual provides basic data on more than 350 batteries. There are five battery systems described in the data book including: carbon-zinc, alkaline (primary), alkaline (secondary), nickel-cadmium, mercury and silver.

B-167

U.S. Department of Commerce, "Specification for Dry Cells and Batteries," National Bureau of Standards Handbook 71 (December 1959)

The seventh edition of the American Standard Specification for Dry Cells and Batteries contained in this Handbook was approved as American Standard on March 25, 1959. It supersedes the previous specification, which was approved August 19, 1954, and published in Circular 559 of the National Bureau of Standards.

B-168

Alfons Erich Lange, Erich Langguth et al., Accumulatoren-Fabrik A.G., "Electric Battery, Particularly Secondary Battery, and Method of Operating the Same," U.S. Patent 2,131,592 (September 27, 1938)

The method herein described of removing evolved gas from the chamber of a secondary battery of alkaline type which consists in effecting the charging of the battery while the electrodes are submerged in the electrolyte, and effecting under pressure changes incident to the establishment of open circuit and of discharging conditions, a recession of the electrolyte and emergence of an electrode surface with consequent chemical reaction between evolved gas and the substance of the electrode over surfaces so exposed.

B-169

Paul Bauer, TRW Space Technology Laboratories, "Characteristics of Three-Electrode, Sealed, Nickel-Cadmium Cells," Transactions on Aerospace, 2 (2), 784-788 (April 1964)

The chemical and electrical characteristics of the nickel-cadmium cell are related to the characteristics of the oxygen electrode, and the qualitative behavior of the three-electrode cell is predicted. Measurements are made on a three-electrode cell and show substantial agreement with predicted behavior.

Measurement of the magnitude and threshold of appearance of the third electrode signal and the cell temperature shows that the state of charge at which the full charge signal appears is dependent upon cell temperature and varies from 115 percent of rated capacity at 40°F to 25 percent of rated capacity at 140°F.

B-170

Adolf Dassler, "Galvanic Battery," U.S. Patent 2,104,973 (January 11, 1938)

In a galvanic battery comprising a receptacle containing an electrolyte with a gas chamber above the surface of the electrolyte and main electrodes in contact with the electrolyte, said main electrodes being capable of producing electrical energy in an external circuit connected therewith, means for preventing the accumulation of gas within the chamber above the electrolyte, such means consisting of a subsidiary electrode of gas-absorbing and -ionizing metal extending at one end into the gas chamber of the battery and at the opposite end into the electrolyte, and connected when the battery is in service to a source of electrical potential, relatively to the electrolyte.

B-171

Edmond F. Webb, Chrysler Corporation, "Spirally Wound Storage Cell," U.S. Patent 2,487,499 (November 8, 1949)

A storage battery cell including a casing comprising insulating material and having a floor provided with an upstanding insulating support element, a generally cylindrical battery plate unit comprising spaced spirally wound elongated positive and negative plates having a plurality of turns and being offset axially relative to each other, edge portions of said positive plate protruding axially in one direction from an end of said unit and edge portions of said negative plate protruding axially in the opposite direction from the other end of said unit, a spirally wound insulator between said positive and negative plates, first terminal means extending across one end of_said unit comprising a rigid metal strap fused to said protruding portions of said positive plate, second terminal means extending across the other end of said unit comprising a metal strap fused to said protruding portions of said negative plate, said first and second terminal means rigidifying said battery plate unit by tying together the adjacent convolutions thereof and one of said terminal means being seated upon said upstanding support elements.

B-172

Karl Ackermann, Badische Anilin-& Soda-Fabrik A.G., "Electrodes for Alkaline Storage Battery Cells," German Patent 1,160,043 (December 27, 1963)

The porous electrode skeleton which was made by sintering powdered Ni is impregnated at elevated temperatures with a solution which contains metal salts with oxidizing anions, e.g., $Ni(NO_3)_2$ or $Co(NO_3)2$, optionally other metal salts, and one or more weak acids, AcOH and (or) NH_2CH_2COOH. The electrode skeleton is impregnated at $> 50^{0}$ and in an atmosphere of satd. steam.

B-173

Societe des Accumulateurs Fixes et de Traction, "Alkaline Storage Battery Cell," French Patent Addition 82,314 to French Patent 1,301,369 (January 24, 1964).

In an alkaline Cd-Ni storage battery cell, the closed container is so constructed that it is resistant against internal pressure up to 10 kg./sq. cm. for a charging current of C/10-C/8 for continuous operation or up to C/5 for a limited period, C being the capacity of the cell in ampere hours.

B-174

Societe des Accumulateurs Fixes et de Traction, "Perfection of Electrolyte Cells, Especially of Sealed Storage Batteries Working Without Formation of Gases," French Patent 1,301,369 (August 17, 1962)

The distance between the electrodes is 0.1-0.2 mm., which gives a fast depolarization of dissolved O at the cathode, preventing any formation of H_2 since the products of electrolysis recombine. The speed of depolarization is increased by increasing the partial pressure of the O_2 in the storage battery, higher than the partial pressure of O_2 in the air, before the storage battery is sealed. This increased pressure is obtained by renewal of the atm. of the storage battery several times with pure O_2 before the storage is sealed.

B-175

J. P. Harivel and J. F. Laurent, Societe des Accumulateurs Fixes et de Traction, "Kinetic Study of the Decomposition of the Active Materials of the Positive Electrode of the Nickel-Cadmium Battery," Electrochimica Acta, 9 (6), 703-710 (June 1964). In French

B-176

Freimut Peters, Varta Petrix-Union GmbH, "Permanently Gas-Tight Alkaline Nickel-Cadmium Storage Battery," German Patent 1,173,155 (July 2, 1964) English Abstract Only

The formation of higher Ni oxides is avoided by addition of Fe compounds to the positive electrode. This can be done (1) by mechanical addition of powdered Fe or Fe compounds to the positive mass, (2) by simultaneous pptn. of the Fe addition together with the positive active mass from Fe solutions, (3) by impregnation the positive active mass with a Fe solution and subsequent treatment with caustic solutions.

B-177

Freimut Peters, Varta Pertrix-Union GmbH, "Gas and Liquid-Tight Alkaline Storage Battery," German Patent 1,175,302 (August 6, 1964). English Abstract Only

Sealed alkaline storage batteries are subject to generation of dangerous internal gas pressure on complete discharge. This is prevented by adding an antipolar material to one or both electrodes. Anti-polar material for the positive electrode is the usual active material of the negative electrode. The capacity of the regular material of the positive electrode is always greater than that of the regular active material of the negative electrode. The presence of anti-polar materials in the amount of 5-30% of the active mass, $Ni(OH)_2$ in the negative electrode and $Cd(OH)_2$ in the positive electrode, restricts evolution of O and H on heavy discharge with possible polarity reversal. The electrodes are metallic and porous; the active material may be applied in the pores by chem. or electrochem. means, or metal and active material may be pressed together as discs, multiple sections or as a porous sheet which is rolled into a cylindrical form with suitable spacers. Spacers may be porous sheets of natural or synthetic fibers semi-permeable regenerated cellulose, mircoporous membrane or combinations of these. Electrodes must be coated with thin film of electrolyte and present large surface area to remove gases efficiently. Ratios of antipolar to regular active material, and antipolar materials in each electrode may be varied. For example, the anode may contain the equivalent of 5 amp-hrs of antipolar material and the cathode 3 amp-hrs.

B-178

A. A. Nemodruk, "Active Mass for Alkaline Iron-Nickel and Cadmium-Nickel Storage Batteries," U.S.S.R. Patent 149,480 (August 28, 1962). English Abstract Only

The positive active mass is produced by treating $NiSO_4$ with NaOH followed by filtration of the suspension, drying, washing from Na_2SO_4, and finally grinding and mixing of the resulting $Ni(OH)_2$ with graphite. To simplify the process, increase the activity of the mass and the effectiveness of the Ni, and to reduce the cost of the batteries, a 0.25-0.5% solution of polyacrylamide is added to the $Ni(OH)_2$ ppt. in an amount of 1.5-3%, based on the Ni. The coagulated $Ni(OH)_2$ is washed and separated from Na_2SO_4 in a centrifuge or suction or vacuum filter, and the ppt. is dried at 100-50°.

B-179

Shiro Yoshizawa and Zenichiro Takehara, Kyoto University, "Studies on the Cadmium Electrode. III. An Intermediate Product at the Discharge of the Cadmium Electrode," Denki-Kagaku, 32, 203 (1964). English Abstract Only

> Changes in the surface structure of the cadmium electrode during discharge in alkali-batteries were examined by means of X-rays, electron diffraction, and the electron microscope. The following results were obtained. Cadmium seems to be transformed into cadmium hydroxide through an intermediate product. This intermediate product is probably cadmium oxide (produced by electron microdiffraction after discharge at low temperature in dilute potassium hydroxide). This intermediate product is very unstable in solution, so that, it dissolves rapidly and is finally decomposed into cadmium hydroxide.

B-180

Arthur Fleischer, Nickel Cadmium Battery Corporation, "Investigations on the Improvement in the Performance Characteristics of the Nickel-Cadmium Battery," First Quarterly Progress Report (May 15, 1956 to August 14, 1956), U.S. Army Signal Corps Engineering Laboratories Contract DA-36-039-SC-72138.

> Positive and negative sintered plates were prepared by impregnation of 5 sq. in. plaques prepared from 10 carbonyl nickel powders and two soln.-pptd. Ni powders. Weight gains were independent of plaque thickness from 40 to 100 mils. Weight gain of positive plates appeared to correlate with surface reactivity. Studies on the determination of nickel and nickel hydroxide in positive plates by reaction with iodine were initiated.

B-181

Joseph C. Duddy, The Electric Storage Battery Company, "Electrodes and Method of Making the Same," U.S. Patent 3,121,029 (February 11, 1964)

> An electrode material comprising a battery active material in powdered form homogeneously dispersed in a continuous phase throughout and bound in a binder comprising a first thermoplastic resin homogeneously and intimately mixed with a second thermoplastic resin, said second thermoplastic resin being present in a ratio based upon parts by weight of said first thermoplastic resin of between 1 to 3 and 3 to 1, said second thermoplastic resin being substantially insoluble in said first thermoplastic resin and soluble in a solvent in which said first theremoplastic resin and said battery active material are substantially insoluble and inert.

B-182

P. Ritterman, Gulton Industries, Inc., "Investigation of Battery Active Nickel Oxides", First Quarterly Report, NASA CR-54196 (June 11 to September 11, 1964), NASA Contract NAS 3-4178

A literature review of recent articles dealing with the chemical structure and composition of the nickel oxide electrode is presented. The entire program for this project is outlined, and the work completed during the first quarter is discussed. Sintered plate nickel oxide electrodes completed all formation cycling. Initial data for self-discharge stand is given for 10, 25 and 50 C. X-ray diffraction patterns of the charged nickel oxide electrodes are given.

B-183

P. Ritterman, Gulton Industries, Inc., "Investigation of Battery Active Nickel Oxides," Second Quarterly Report, NASA CR-54295 (September 12 to December 12, 1964), NASA Contract NAS 3-4178.

The study of the effect of stand at various temperatures on the sintered plate and graphite nickel oxide electrodes were continued. Results indicate that the two types of positive electrodes differ considerably with respect to electrochemical and chemical characteristics.

The investigation into the effect of overcharge on the composition of the sintered plate and nickel oxide electrode has been initiated. The X-ray diffraction patterns of the positive electrode of a two plate Ni-Cd cell, under conditions of dynamic overcharge have many lines which cannot be attributed to NiOOH, $Ni(OH)_2$, or $Ni_2)_3 \cdot H_2O$.

The study concerned with the effect of state-of-charge on composition of sintered plate nickel oxide electrodes, at the C and C/10 rate, has been started.

B-184

P. Ritterman, Gulton Industries, Inc., "Investigation of Battery Active Nickel Oxides," Third Quarterly Report, NASA CR-54402 (December 13, 1964 to March 13, 1965), NASA Contract NASA 3-4178

The study of the effect of stand, at various temperatures, on the tubular graphitic nickel oxide electrode was concluded. With this Phase I was brought to an end.

The investigation into the effect of overcharge on the composition of the sintered nickel oxide electrode was continued. The positive electrode of a two plate cell was continually monitored by X-ray equipment during charge, overcharge and stand. Diffraction patterns were taken between the angles of $2\theta = 12^{\circ}$ to 14.5°. The growth during charge and overcharge, and decline on stand, of a peak between these two angles were noted. In a separate experiment, it was shown that no "strange" lines occurred because of crystallization of KOH during overcharge.

The study concerned with the effect of state-of-charge on the composition of sintered plate nickel oxide electrodes was continued. The study was made by means of X-ray diffraction patterns obtained from positive electrodes charged and discharged to various degrees at the C and C/10 rates. The analysis of positive electrodes at various states of charge, by means of differential thermal analysis and chemical analysis has been started.

Positive electrodes discharged to the "graphitic" level were also analyzed by means of X-ray and D.T.A.

B-185

P. Ritterman and H.N. Seiger, Gulton Industries, Inc., "Investigation of Battery Active Nickel Oxides," Final Report, NASA CR-54654 (June 11, 1965) NASA Contract NAS 3-4178

A study of the compounds formed on a nickel oxide electrode with respect to charged stand, charge rate, state of charge, and during overcharge, has been made. This was done using X-ray diffraction, differential thermal analysis, chemical analysis, and spectography. Most of the work was done by means of X-ray diffraction.

It was found that the active compounds of the electrode are essentially γNiOOH and Ni(OH)$_2$ during ordinary conditions of charge and discharge. During overcharge, an unstable compound is found having the X-ray patterns listed by ASTM files for γNiOOH. These patterns were obtained by means of X-ray monitoring a two plate cell during overcharge. Data for decay of this compound during open circuit stand are also presented. In some cases, the lines of the compound disappear completely. One case is shown where after extended stand, γ NiOOH seems to decay into a compound whose X-ray patterns fit 4Ni(OH)$_{2}$.NiOOH.

Differential thermal analysis has indicated the existence of a compound of nickel at the "graphitic" level which differs from both NiOOH and Ni(OH)$_2$.

Initial cycling data and testing are also presented for sintered plate nickel and tubular graphite types of positive plates.

An experiment for stabilizing the sintered plate nickel oxide electrode by means of formation at various rates and temperatures has been started.

B-186

R. E. Amsterdam, P. R. Mallory and Company, Inc., "Cell Equalization Techniques", Technical Progress Report dated June 1965, Contract AF 33(615)-2491.

The stabistor as a charge control device is particularly adapted to situations where high rate charging is required for recharge and where serious cell overcharge conditions may occur. These conditions are projected as being of special significance for space batteries where operation is designed at high depths of discharge. Exploratory continuous overcharge tests on 1.25 AH cells at 75°F have been initiated. Results to date indicate a shunting of 90% of the current through the stabistors with a maintenance of cell voltage of 1.45 - 1.46 volts.

Temperature studies made on the stabistor-cell combination indicate that although the temperature coefficients of both devices are negative, the relationship between them is not linear. However, the stabistor offers maximum protection at temperatures where cells gas most readily.

Exploratory end of charge voltages for Ag-Cd cells at various charge rates and temperatures have been determined. The significance of the maximum end of charge voltage is that the cell potential must be maintained below this voltage level (at a specific charge rate) to prevent gassing.

Two 3.9 V zener diodes in series operating in the forward direction were employed as stabistors. The purpose of utilizing this device was to circumvent the fabrication of stabistors having optimum fabrication characteristics. It was found that the reduction in leakage current at 1.30 volts was of a magnitude below that required to meet the contract goal.

An anti-reversal transistor circuit designed to prevent cell reversal during discharge was designed and constructed. The transistor base drive was obtained from an adjacent cell in the battery and was not sufficient to turn on the transistor to the required degree.

B-187

Richard E. Amsterdam, P. R. Mallory and Company, Inc., Cell Equalization Techniques", Second Quarterly Technical Progress Report (May 1 to August 1, 1965), Contract AF 33(615)-2491.

The ideal charge control device must be capable of cell protection under conditions of varying charge-discharge cycles and long periods of constant charge in a vacuum environment under conditions of extreme temperature. The work performed this quarter was designed to illustrate the stabistors capability to meet these requirements.

Continuous charging of stabistor protected Ni-Cd sealed space cells has demonstrated the ability of the diode to permit cells to be fully charged in a minimum amount of time by the use of relatively high charge rates, and at the same time protect the cells from the damaging conditions of overcharge and consequent gassing. The results of the test was not as successful as was expected due to internal shorting within five of the six cells at various points during the thirty day test. This internal shorting was due to the previous history of the cells and the protection afforded the cells was still demonstrated.

Initial tests made with stabistors in a vacuum environment prove the feasibility of designing and operating stabistors in an atmosphere where the only thermal path for cooling is afforded by conduction rather than convection. Further work on the vacuum chamber had to be performed in order to more closely control the temperature of the chambers wall when the stabistors are dissipating full power.

Significant improvement in stabistor strength, uniformity and reliability was achieved by the use of carbon boats in the assembly of the diode.

Electrical and thermal evaluation of the stabistor was begun in order to collect information that would be useful in properly designing stabistor protection systems that will operate under a wide temperature range and in vacuum environments. Graphs that were plotted include curves showing typical stabistor forward characteristics and case temperature vs. power dissipated.

Experimental planar stabistors were designed and constructed in an attempt to improve the stabistor leakage current during open circuit stand. A slight reduction in leakage current was observed at 1.30 volts but the forward voltage drop was too high. Additional units will be constructed of lower resistivity material in order to improve the forward characteristics.

Three circuits consisting of two transistors were constructed with the object of clamping the reverse voltage of a cell when it is forced into reversal. One of the circuits achieved the desired objective of clamping the voltage of a reversed cell to a potential more positive than -0.2 volts, at a current of C/1 (1 amp). Two major problems prevent the circuit from being fully successful. The circuit cannot protect the first and last cell in a battery due to a biasing problem. In addition, the anti-reversal circuit shunts a large percentage of the current during the charge cycle.

An investigation into the possible use of low energy gap semiconductors (e.g., indium-antimonide and indium arsenide) as anti-reversal diodes resulted in the conclusion that they would not be suitable devices. This is due to the excessive leakage current in the reverse direction that would prevent the stabistors from satisfactorily protecting the cells. They would cause excessive leakage current through the anti-reversal diode on open circuit stand.

Exploratory end of charge voltages for Ag-Cd cells at rates of charge of C/50, C/25, C/10, C/4, C/2 and C/1 at temperatures of -10°C, 25°C and 50°C have been determined. Further tests to determine safe end of charge voltages of nickel-free Ag-Cd cells will be conducted.

B-188

Richard E. Amsterdam, P. R. Mallory and Company, Inc., "Cell Equalization Techniques", Third Quarterly Technical Progress Report (August 1 to November 1, 1965), Contract AF 33(615)-2491.

Experimentation carried out under this contract during this quarter had as a goal the illustration of the stabistor as a practical device for secondary battery charge control permitting rapid recharge at relatively high rates with full protection given to the cells under conditions of simulated space environment.

6 AH Ni-Cd sealed space cells have successfully undergone more than 30 days in a continuous overcharge test in a cell-stabistor combination permitting a continuous current equivalent to the C/1 rate at 75°F. The stabistors shunted a minimum of 90% of the total current during the entire test. No decrease in cell capacity was observed.

5 AH Ag-Cd space cells have been found to gas excessively at continuous charge rates below those recommended by the cell manufacturer. Therefore it will not be possible to put the Ag-Cd cells procured under this contract on a 30 day tests similar to that performed with the Ni-Cd cells.

The cell-stabistor charge control system has been demonstrated as a workable design when operated under conditions simulating conditions of satellite application. The problem remaining is that the stabistor conducts current a few minutes too soon during the charge cycle, shunting current around the cell slightly before the cell has been fully recharged. The problem is mainly centered on the thermal capacity of the heat sink. New heat sinks are being developed to correct this condition.

A reed switch anti-reversal protection system has been designed, constructed and tested. Initial tests of the device with sealed Ni-Cd cells have resulted in successful operation of the cells under conditions of deep reversal.

Specially manufactured cells that have been delivered by the vendor during this quarter were tested to determine if they meet the manufacturer's claims. These cells were fabricated to withstand severe reversals without gassing. The cells appeared to operate as expected, according to the manufacturer's specifications. These cells will be delivered under the contract with the end of contract cells.

A small group of stabistors was designed, constructed and tested to demonstrate a redundancy capability. Two stabistors operated in parallel with slightly different characteristics have illustrated the ability of the stabistor charge control system to insure maximum reliability in critical applications.

The planar fabrication technique applied to the manufacture of stabistor has led to the development of units with reduced leakage currents in the forward direction. It is this leakage current which is important in the reduction of charge through a stabistor during open circuit stand.

End of charge voltages for sealed 5 AH Ag-Cd cells have been determined at 25°C for over a range of charging rates.

B-189

W. W. Clark, W. G. Ingling, I. F. Luke, and E. A. Roeger, Jr., Cook Electric Company, Inland Testing Laboratories, "Alkaline Battery Evaluation", Technical Documentary Report No. APL-TDR-64-65 (May 1964), Wright-Patterson Air Force Base Contract AF 33(657)-8450. AD 602 258.

This report covers the first four semi-annual periods of an alkaline battery applied research and failure analysis program. The purpose of this program is to establish a broadbase of battery test data for use in the design of the electrical system of future space vehicles, and to determine the actual failure mechanism of new 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 increasing the usable watt-hours-per-pound capability and cycle lift of the battery.

This program, to date, includes the cycle-life performance evaluation and failure analysis of the following types of sealed, secondary, alkaline cells: two types of 25 ampere-hour silver-zinc cells; one type of 15 and one type of 20 ampere-hour silver-cadmium cells; and one type of 20 ampere-hour nickel-cadmium cell. The program also includes a study of the effects of radiation upon each type of alkaline cell (see Appendix V). This study covers the three following general areas of interest.

1. The extraterrestrial space radiation environment.
2. The expected results of space radiation on alkaline storage cells and cell components.
3. The formulation of a radiation test program on alkaline storage cells using, as a basis, the information gained in items 1 and 2.

B-190

W. W. Clark, W. G. Ingling, I. F. Luke, and E. A. Roeger, Jr., Cook Electric Company, Inland Testing Laboratories, "Alkaline Battery Evaluation", Technical Documentary Report No. APL-TDR-64-76 (June 1964), Wright-Patterson Air Force Base Contract AF 33(616)-7529. AD 602 676.

This report covers an alkaline battery applied research and failure analysis program. The purpose of this program was to establish a broadbase of battery test data for use in the design of the electrical system of future space vehicles, and to determine the actual failure mechanism of new battery systems under varying environmental and cycle-life conditions so that improved space batteries can be developed. Another objective was to determine techniques and/or materials to prevent these failures, while at the same time increasing the usable watt-hours-per-pound capability and cycle life of the battery.

This program includes the cycle-life performance evaluation and failure analysis of the following types of sealed, secondary, alkaline cells: one type of 12 ampere-hour nickel-cadmium cells; one type of 20 ampere-hour nickel-cadmium cells; one type of 15 ampere-hour silver-cadmium cells; and one type of 25 ampere-hour silver-zinc cells.

This report includes the final results of cycle-life performance tests on 240 12 ampere-hour nickel-cadmium cells in groups of 10 cells and batteries of 20 cells, and 150 20 ampere-hour nickel-cadmium cells in groups of 10 cells. The 12 ampere-hour cells were cycled in four temperature environments with four depths of discharge in each environment while the 20 ampere-hour cells were cycled in five temperature environments with three depths of discharge in each environment. All cell groups and batteries were cycled in 90 minute periods consisting of 55 minutes of charge and 35 minutes of discharge. Also included in this report are the results of cycle-life performance tests conducted on 192 25 ampere-hour silver-zinc cells and 192 20 ampere-hour silver-cadmium cells separated into eight cell groups. Both types of cells were cycled in four temperature environments with three depths of discharge in each environment. One half of both types of cells was cycled in 2 hour periods consisting of 85 minutes of charge and 35 minutes of discharge, while the other half was cycled in 24 hour periods consisting of 22 hours and 48 minutes of charge and 72 minutes of discharge.

The results obtained from the cycle-life performance tests on these four types of cells show that: (1) cell cycle-life with shallow discharges is considerably longer than cycle-life at deep discharges and (2) cycle-life is reduced by high and low ambient temperatures.

B-191

Otto C. Wagner and Robert F. Enters, Yardney Electric Corporation, "Development of Manufacturing Methods and Techniques for the Production of Improved Alkaline Batteries", Interim Engineering Progress Report, IR-8-253(I), (April 1 to June 30, 1965), Wright-Patterson Air Force Base Contract AF 33(615)-2578.

A development program directed at the problem of producing improved alkaline batteries with identical cell capacities ± 1% of nominal ampere hour rating is described. The required properties of cell components are reviewed, and methods of fabrication along with cell designs are discussed.

A comprehensive literature survey has been conducted. Included are factors of interest with respect to prior research and development efforts directed towards fabricating alkaline Ni/Cd and Ag/Cd batteries to the best state-of-the-art. A summary of this survey, a report of which has been sent to Wright-Patterson Air Force Base, is presented in this report.

A study of electrode fabrication processes, separators and cell designs has been initiated. Of interest are the excellent uniformities, on the basis of weight distribution and performance, of a) silver positives produced by sintering fine silver powder plus grid in a rolling mill and b) supported cadmium negatives fabricated by the thermal decomposition of cadmium acetate.

Commercially available non-woven felts (known as Pellon), that are commonly employed in Ni/Cd and Ag/Cd cells, are relatively non-uniform with respect to weight and density distributions.

Sausage casing and C-19 membranes which are employed in Ag/Cd cells are very uniform in weight and thickness in both the wet and dry conditions (wet after soaking in alkali).

Preliminary designs of sealed Ni/Cd and Ag/Cd cells are presented. Utilizing a squat closure, with a volume of 11.2 cubic inches, the nominal capacity rating of the Ni/Cd cells should vary from 12 to 15 ampere-hours, depending on whether supported or sponge cadmium negatives are employed - the higher capacity rating being with cells containing the sponge negatives. The nominal capacity rating of the Ag/Cd cell, with sponge negatives, will be 15 ampere-hours.

B-192

P. Ritterman and H. N. Seiger, Gulton Industries, Inc., "Investigation of Battery Active Nickel Oxides", First Quarterly Report, NASA CR-54832 (September 12, 1965), NASA Lewis Research Center Contract NAS 3-7620.

X-ray patterns are presented indicating the interference of polyethylene covering. The removal of such a cover yields patterns which are more meaningful, with respect to their relation to state of charge.

Chemical methods have been developed which will make possible the determination of the formula weight of a particular state of charge of the positive electrode.

Superior materials, with respect to capacity and charge retention, by formation at 10 C - 35 ma and 80 C - 100 ma, have been produced.

B-193

R. C. Shair, Gulton Industries, Inc., "Sealed Secondary Cells for Space Power Systems", Journal of Spacecraft and Rockets, 3 (1), 68-70 (January 1966).

This paper presents the recent state of the art for sealed nickel-cadmium, silver-cadmium, and silver-zinc cells, and a forecast for the future. The mechanical construction, charge-discharge characteristics, overcharge capability, and charge efficiency are discussed, as well as methods of charge control. Recently, auxiliary electrodes, either a fuel cell electrode or an Adhydrode, have been incorporated into both nickel-cadmium and silver-cadmium cells for charge control and for increasing the overcharge capability. Over 1,000 cycles of 100 min each (50% depth of discharge) have been achieved at 77 F with a single Adhydrode cell controlling a series of five cells.

B-194

Societe des Accumulators Fixes et de Traction, "Improvements in or Relating to Electrical Storage Cells", British Patent 1,015,914 (January 5, 1966).

A storage cell comprising a gas tight casing provided with two or more electrodes, the distance between adjacent electrodes of opposite polarity being from 0.1 mm to 0.3 mm, and there being provided in the free space of the cell, before the cell is charged, an amount of gaseous oxygen sufficient to raise the partial pressure of oxygen in the free space of the cell to a value greater than the partial pressure of oxygen in the atmosphere at the same pressure as the pressure prevailing in the free space of the cell.

A cell as claimed wherein the cell is a nickel-cadmium alkaline cell.

B-195

Societe des Accumulateurs Fixes et de Traction, "Improvements in or Relating to Electrical Storage Cells", British Patent 1,015,915 (January 1966).

A method of manufacturing a sealed storage cell comprising a gas-tight casing containing at least two positive electrodes and at least one negative electrode, in which cell the total capacity of the negative electrode(s) is greater than the total capacity of the positive electrodes and the distance between adjacent electrodes of opposite polarity is from 0.1 to 0.3 mm, which method comprises placing the negative electrode or electrodes and at least one but not all of the positive electrodes in the casing in a discharged state and placing the remaining positive electrode(s) in the casing in a completely charged state, sealing the casing, and thereafter charging the cell.

A sealed storage cell wherein the storage cell is a nickel-cadmium alkaline cell.

B-196

M. G. Gandel and R. H. Kinsey, Lockheed Missiles and Space Company, "Heat Dissipation of Primary and Secondary Batteries", Journal of Spacecraft and Rockets, 2 (6), 996-998 (November-December 1965).

This note presents a method for determining thermal data using an inexpensive calorimeter, the calculations employed, and the results for 30-amp-hr, 25-v Ni-Cd and 360-amp-hr, 25-v Ag-Zn batteries tested. The results have been verified by measuring heat gain of thermally isolated batteries in a vacuum chamber.

B-197

Benjamin C. Bradshaw, U. S. Army Electronics Command, "A Study of Electrodes and Electrode Reactions: 1. The Energy Necessary to Remove an Oxygen Molecule From a Charged Nickel Oxide Electrode in a Vacuum", Technical Report ECOM-2637 (October 1965).

The energies that are necessary to remove oxygen from the crystals that are on the surface of charged nickel oxide electrodes have been calculated from the rates of evolution of oxygen from their surfaces into a vacuum. These energies increase in steps of about three kilo calories: this rate of increase is nearly the same as Bradshaw & Shuttleworth (1954)[1] found for the physisorption of inert gases on the surface of various crystals.

The energies of attachment of the oxygen to the nickel oxide crystals have been used to calculate the half lives of the oxides on the surface of the charged nickel oxide electrodes.

B-198

M. Jurie, H. N. Seiger, and R. C. Shair, Gulton Industries, Inc., "State of Charge Indicators for Nickel Cadmium Batteries", Technical Documentary Report ASD-TDR-63-191 (February 1963), Wright-Patterson Air Force Base Contract AF 33(657)-8130.

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 ± 10%. Ohmic resistance measured under correct conditions showed a closer correlation to state of charge but is difficult to measure.

B-199

Otto C. Wagner and Robert F. Enters, Yardney Electric Corporation, "Development of Manufacturing Methods and Techniques for the Production of Improved Alkaline Batteries", Interim Engineering Progress Report, IR-8-253(III), October 1, 1965 to December 31, 1965, Wright-Patterson Air Force Base Contract AF 33(615)-2578.

A development program directed at the problem of producing improved sealed alkaline batteries with matched cell capacities of ± 1% of nominal ampere-hour rating is described. The required properties of cell components are reviewed, and methods of fabrication along with cell designs are presented.

Single electrode studies have been completed. Of interest are a) the high energy density of supported over sponge cadmium negatives in Ni/Cd cells, b) the higher energy density of sponge over supported cadmium negatives in Ag/Cd cells and c) the relative constancy in cadmium utilization of impregnated sintered-nickel plaques within a loading range of 20 to 30 percent (as Cd metal in the void space of the plaque).

A statistical analysis of single versus grouped characterization cycling of nickel-hydroxide positives shows that there is a constancy in active material utilization and that the grouped method of formation is an excellent one for producing electrodes with closely matched electrical capacities, provided the weight of active material (weight gain) is closely controlled.

Short orbit cycling data of sealed 15 AH, - Ag/Cd five-cell batteries are presented and discussed. The batteries will deliver a minimum capacity of 7.5 AH, at -10 F, at the rates employed at the 75% depth of discharge and a maximum of 19.9 AH, at 150 F, at the rates employed at 25% depth. Overcharge gas recombination data are also presented.

Pilot line flow sheets for the phase II manufacture of sealed 14 AH-Ni/Cd and 15 AH - Ag/Cd batteries are presented. Outstanding control features are: a) uniform multi-step impregnations of Ni/Cd electrodes from relatively dilute nitrate solutions, b) characterization cycling of Ni/Cd electrodes, c) precise weighing of the Ni/Cd and Ag/Cd electrodes, d) batch utilization tests of silver and cadmium oxide powders for Ag/Cd batteries, e) constant input-output cycling of Ni/Cd and Ag/Cd batteries-cells (which are designed to operate on the oxygen cycle) and f) helium leak detection of metal closures and terminal seals.

B-200

P. Ritterman and H. N. Seiger, Gulton Industries, Inc., "Investigation of Battery Active Nickel Oxides", Second Quarterly Report, NASA CR-54903 (December 12, 1965), NASA Lewis Research Center Contract NAS 3-7620.

X-ray studies of sintered plate nickel oxide electrodes indicated that no noticeable structure change occurs until the electrode is at least 75% charged. This was true for both the C/2 and C/10 rate.

Electrodes impregnated with nickel nitrate containing 20 metal atom percent of cobalt have been tested. These appear to have better charge retention characteristics at elevated temperatures. The utilization of active material (based on weight gain) is also quite high.

Three groups of positive electrodes have been given three formation cycles, with the following conditions: (1) 10 C at C/30, (2) 80 C at C/10, and (3) 25 C at C/10, the first two groups having previously been shown superior on stand; the last group serving as a control.

B-201

P. Ritterman, S. Lerner, and H. Seiger, Gulton Industries, Inc., "Investigation of Battery Active Niclel Oxides", Third Quarterly Report, NASA CR-54957 (March 12, 1966), NASA Lewis Research Center Contract NAS 3-7620.

X-ray diffraction patterns are shown which indicate no structural differences between discharged and up to 90% charged plates.

X-ray patterns of fully charged and overcharged electrodes show amorphous and γ NiOOH structures.

A pictorial view of the $Ni(OH)_2$ structure is presented.

X-ray patterns of plates after initial stands at 10°C, 25°C and 50°C are shown.

Plates formed at C/30, 10°C; C/10, 25°C; and C/10, 80°C were compared for charge retention at room and elevated temperatures, and no significant differences were found.

Cobalt doped positives were shown to be superior to pure $Ni(OH)_2$ controls on charged stand tests.

B-202

W. N. Carson, Jr., General Electric Company, Schenectady, New York, "A Study of Nickel-Cadmium Spacecraft Battery Charge Control Methods", Final Report, NASA CR-62029 (April 1966), NASA Goddard Space Flight Center Contract NAS 5-9193.

This study was made to evaluate the various methods for charge control of spacecraft nickel-cadmium batteries. The methods evaluated include constant current, constant voltage, voltage cut off, thermal cut off, pressure cut off auxiliary electrode cut off, coulometer cut off, stabistor, and limited charge systems. An evaluation for 5, 50 and 500 watt power supplies is made for 90-minute and 24-hour orbits. The electrochemical basis for sealed cell design and the related phenomena are discussed in terms of their influence on charge control design. The recommended charge control system varies with the orbit and size of the power supply. For short orbits and small (<10 - 15 watt) size, a constant current method is recommended; for short orbits and larger (>15 watt) sizes, a modified constant voltage-coulometer cut off system using cells with passive auxiliary electrodes is recommended. For long orbits, a modified constant voltage-dual coulometer cut off system, using cells with passive auxiliary electrodes, is recommended.

B-203

R. Amsterdam and J. Ball, P. R. Mallory and Company, Inc., "Cell Equalization Techniques", Technical Report AFAPL-TR-66-23 (April 25, 1966), Wright-Patterson Air Force Base Contract AF 33(615)-2491.

The purpose of work conducted under this contract was to develop and improve the techniques for charge and discharge control of nickel-cadmium and silver-cadmium secondary cells under simulated space conditions.

Charge control of Ni-Cd cells was accomplished by means of a stabistor constructed of forward-biased diodes, which through the use of careful heat sink design bypasses most of the charge current around a cell when it becomes charged.

One of the tasks, therefore, was to develop a heat sink, which unlike previous designs, would operate in a vacuum. Such a conduction-type heat sink was designed and applied to the fabrication of 60 end-of-contract cells of 6, 12 and 20 AH capacity designed to meet a cycle of 35 minutes, 75 percent discharge followed by 55 minutes charge over a range of -10°C to 50°C.

When the stabistor is operating, it shunts nearly all charging current around a cell, resulting in individual charge control of each cell. It was demonstrated under this contract that a battery of secondary cells with stabistor charge control can be subjected to C/1 charge for 30 days without harmful effects.

The effects of changes in ambient temperature on the operation of a stabistor/cell combination were investigated. It was discovered that the stabistor tends to compensate, to a large extent, for the decrease in cell charging efficiency with increasing temperature.

Low-energy gap diodes, transistor and reed switch circuits were investigated for clamping the reverse voltage of reversed cells in a battery to a value less than -0.2 volts. Both the diodes and transistor circuits were found to have excessive forward leakage, causing rapid discharge of the cell. The reed switch circuit was satisfactory, but limited in current to less than 8 amps discharge current.

Stabistor charge control of silver cadmium cells was studied. It was found that some silver-cadmium cells cannot accept a continuous overcharge even at very low rates, so would be unsuitable for stabistor charge control. However, some cells can accept a continuous overcharge current and, with this in mind, a test was conducted which demonstrated that the voltage characteristic of a charging silver-cadmium cell will cause proper operation of the stabistor.

As part of the study of the silver-cadmium cells, the end-of-charge voltage for different charge rates and different temperatures was determined.

Stabistor fabrication was improved through assembly in carbon boats. Evaluation of the stabistors for stability revealed that a one-week burn-in at 95°C improved the consistency of the lot. A one-week thermal fatigue test, however, caused a high proportion to fail.

Experiments to determine means of reducing the tendency of the stabistor to discharge cells on open circuit stand showed that the planar fabrication technique offers the most promise.

B-204

Floyd E. Ford and Piotr P. M. Liwski, U. S. Navy Marine Engineering Laboratory, "Shunt Voltage Regulator Circuit for Nickel-Cadmium Cells With Auxiliary Electrodes", MEL R&D Report 93/66 (April 1966), NASA Goddard Space Flight Center Contract S-12730-G.

A circuit to control charge current entering nickel-cadmium cells with auxiliary electrodes ("three-terminal" cells) using a shunt method of control has been developed by MEL for use in satellite power systems requiring minimum weight and space with optimum control and temperature compensation. Reduction in charge current is caused when the set limits of either the total battery terminal voltage, or the potential of an auxiliary electrode of any individual cell, is exceeded.

B-205

Inland Testing Laboratories, Cook Electric Company, "Alkaline Battery Evaluation. General Report. Failure Analysis of 20 AH Nickel-Cadmium Sealed Secondary Cells. Eagle-Picher Type RSN-20", report prepared under Wright-Patterson Air Force Base Contract AF 33(657)-8450. APIP-2. No date on report, received during July, 1966.

This report covers the general information relative to the evaluation of fifteen ten-cell groups of 20-ampere-hour, sealed, nickel-cadmium cells, Eagle-Picher Type RSN-20. The detailed performance data, analyses, conclusions and recommendations for the individual cell groups evaluated are included in separate reports for each group.

This report includes a detailed description of the cells, a discussion of the procedures and results of the electrical performance before, during, and after cycle-life tests, and the procedures and results of detailed teardown analysis of the cells after cycling. In this report particular emphasis is placed on the failure analysis, which is the primary objective of the program. Details of the entire program including instrumentation and facilities, data collection and processing, preliminary tests and cycle-life tests for the Eagle-Picher RSN-20 cells as well as other types evaluated under this program can be found in the Final Technical Report for the contract.

B-206

D. E. Mains (Author), H. M. Schultz, E. C. Bruess, and C. M. Austin (Editors), and V. Yeager (Reviewer), United States Naval Ammunition Depot, Quality Evaluation Laboratory, Crane, Indiana, "Evaluation Program for Secondary Spacecraft Cells. Second Annual Report of Cycle Life Test", Report QE/C 66-304 (May 13, 1966), NASA Purchase Order W11,252B for NASA Goddard Space Flight Center.

The cycle life test program began with sealed nickel-cadmium cells. A total of 51 of the original 84 packs have failed. The remaining 33 packs have completed from 516.6 to 738.5 days (a maximum of 11,816 1.5-hour cycles) of continuous cycling as of December 31, 1965. It was found that 50 C was in general, an unsatisfactory ambient temperature, for the specified currents and orbit periods, due to inefficient charge acceptance and accelerated separator deterioration.

Other cells added to the cycle life test program include silver-zinc and silver-cadmium types.

B-207

R. F. Chireau, Yardney Electric Corporation, "Silver-Zinc Missile Power Supply", First Quarterly Technical Progress Report (October 1965), Wright-Patterson Air Force Base Contract AF 33(615)-2663.

A compilation and analysis of weight and volume for automatically activated Silver-Zinc primary batteries has been made.

The design of a battery system to meet the Power Supply requirements has been initiated.

Paper designs for two types of unit cells to be used in the "all battery" approach to the Power Supply were prepared.

Initial screening tests on 0.2 Ampere-hour unit cells were performed. Additional cells are being fabricated to verify the validity of the preliminary design.

Techniques for fabricating thin (foil) cell positive and negative electrodes were investigated.

A Statement of Work defining the requirements for a solid state DC to DC converter to be used in conjunction with a Silver-Zinc battery in the Missile Power Supply has been drawn up.

B-208

Douglas Aircraft Company, Astropower, Inc., "Inorganic Separator for High Temperature Silver-Zinc Battery", Final Report, SM-46220-F (September 1965), NASA Contract NAS 3-6007. NASA CR-54749

The experimental work done under Contract NAS 3-6007 resulted in the development of silver-zinc test cells using Astroset Type 5-036-011 inorganic separators and novel electrode configurations which met or exceeded all work statement requirements and goals. It has been demonstrated that:

1. Silver-zinc test cells of this type are capable of long cycle life at both 100° and 25°C. Test cells have completed as many as 2286 cycles at 100°C and 2704 cycles at 25°C on a 1/2 hour discharge- 1 hour charge test schedule at a depth of about 17%. Several other test cells exceeded 1500 cycles at both temperatures.

2. The test cells developed in this program also demonstrated capability for operation at 150° and 125°C.

3. Experimental silver-zinc cells built with commercial electrodes and an Astroset Type 5-036-011 inorganic separator ran for more than 200 cycles. Voltage performance was comparable to commercial cells at the same current density at 25°. Cycle test failures of these cells using commercial electrodes were related to electrode changes, not the separators.

4. The gassing characteristics of Astropower Laboratory silver-zinc electrodes were determined to be superior to electrodes removed from a commercial cell and tested with an Astroset Type 5-036-011 inorganic separator at both 25° and 100°C.

5. Astroset Type 5-036-011 inorganic separators are capable of more than 2200 cycles at 100°C and 25°C at practical drain rates. They are also capable of operation at 125° and 150°C.

6. Paste type silver electrodes, as described in this report, are capable of as many as 2280 cycles at 100°C and 25°C and of operation at 125° and 150°C.

7. Paste type zinc electrodes as described in this report are capable of more than 2280 cycles at 100°C and 25°C. They are also capable of operation at 125° and 150°C. However, zinc electrode deterioration does occur after prolonged cycling and at high temperature. As the results herein reported indicate that the present zinc electrode system is a limiting factor as to cycle life, improvements in zinc electrode performance should be made in order to take full advantage of the overall capabilities of this design approach.

B-209

R. S. Bogner, General Motors Corporation, Delco-Remy Division, "Report of an Evaluation of Delco-Remy Design of Sealed, Secondary, Silver-Zinc Electrolytic Cells for Heat Sterilization", Technical Report (June 10, 1962), Jet Propulsion Laboratory Contract No. 950177, Subcontract under NASA Contract NASw-6.

A total of 71 cells was used in this study, and three combinations of separators were evaluated. A separator combination of Dynel and FSC was regarded as best suited to use in heat treated cells. The performance of the Permion 300 separator was poor, even in the control cells. Cells containing separators of Permion 600 gave excellent electrical performances, but indications were that it caused excess pressures to be developed during the temperature soak.

Thirty-six cells were put through the temperature soak in the following states: dry, wet-unformed, formed, and formed-discharged. None of the 27 cells containing electrolyte survived the temperature soak, but it was determined that wet-unformed cells were most likely to survive.

Thirteen cells with separators of FSC and Dynel were reinforced with fiberglass cloth and potted individually in reinforced epoxy. Pressure gauges were put on four of the cells. These cells reached a maximum pressure of 50 psig after 36 hours at 125°C. All of the 13 cells survived the temperature soak.

Electrical performances of the 13 temperature soaked cells were compared to 13 control cells. Cycle life tests indicated the temperature soak had no detrimental effect up to eleven cycles. The cells still had over 100% of their rated capacity after ten cycles. Cycle life tests are continuing.

Voltage characteristics and capacities were not appreciably affected at low discharge rates at room temperature and 120°F. At high rates, 30 amperes, and a temperature of 30°F, there was a significant loss in energy of the temperature soaked cells; they yielded only 61% of the energy produced by the control cell.

B-210

R. S. Bogner, General Motors Corporation, Delco-Remy Division, "Evaluation of Delco-Remy Design Sealed, Secondary, Silver-Zinc Electrolytic Cells for Heat Sterilization", Final Report (October 15, 1962), Jet Propulsion Laboratory Contract No. 950177, Subcontract under NASA Contract NASw-6.

This report contains, in part, a continuation of cycle life studies of cells subjected to the 125°C environment. Cells 7-C, 8-C, 14, 19 and 25 were cycled at the 3.5 ampere rate followed by a 1.25 ampere charge. Only cell 7-C is still cycling at the end of 63 cycles. Cell 8-C failed at 22 cycles, and cells 14, 19 and 25 failed at 28, 55, 52 cycles, respectively.

Cells 1-C, 2-C, 3-C, 13, 15 and 16 were cycled at the 9-ampere rate followed by a 1.25 ampere charge. Cells 13, 15, and 16 are still cycling after 90 cycles. Controls 3-C and 2-C failed at 21 and 29 cycles, respectively. Control 1-C blew apart when it was inadvertently reverse charged on the 60th cycle.

Cells 17, 18 and 20 were cycled automatically on a two-hour cycle consisting of a 9-ampere discharge for 35 minutes followed by a 2.0 volt constant potential charge. One cell failed at 600 cycles and the other two cells failed at 850 cycles.

Four cells out of 22 were successfully put through the 36-hour temperature soak at 145°C. The cause of failure of the new case design was traced to leaks or breaks in the case at the seal and was corrected. The cells yielded about 50% of their rated capacity when discharged at the 9-ampere rate at room temperature.

B-211

Paul L. Howard, Yardney Electric Corporation, "Novel Technique for Predicting Battery Performance", Product Engineering, <u>35</u> (22), 85-92 (October 26, 1964).

Now there is a quick way of predicting with reasonable accuracy (± 15%) how big the battery - any kind - must be to power your product. It may not solve the problems of some missile batteries that discharge the entire battery capacity in seconds, nor completely predict the size of a battery to operate five years in space without recharge. But it will solve most problems in between. Data from dozens of manufacturers were analyzed to produce this short cut calculation for all rechargeable wet-cell batteries.

B-212

Howard J. Strauss, Burgess Battery Company, "Alkaline Batteries", Electronics World, <u>74</u> (4), 49-52 (October 1965).

Operation and characteristics of alkaline-manganese, silver oxide-zinc, silver oxide-cadmium, and air-depolarized types.

B-213

R. F. Chireau, Yardney Electric Corporation, "Silver-Zinc Missile Power Supply", Second Quarterly Technical Progress Report (January 1966), Wright-Patterson Air Force Base Contract AF 33(615)-2663.

The study of an "all-battery" approach to the design of the Missile Power Supply was continued.

Unit cells and modules representing the conventional (individual) cell battery approach were constructed and design verification tests performed on 0.2 ampere-hour and 0.06 ampere-hour cells.

The design concept for a battery system utilizing individual cells in series has been established.

Experimental work on thin electrode fabrication techniques for both positive and negative electrodes was continued. The preparation of thin, foil type duplex electrodes using various constructional methods was investigated. Electrode electrical performance was checked to establish voltage level as a function of current density of discharge.

The design of a battery system utilizing the pile (duplex electrode) construction was initiated.

Multiple cell duplex electrode modules representing the projected design were tested at various discharge loads.

The study of the battery section of the battery-converter approach to the Missile Power Supply was initiated.

Yardney Electric document #596-65 (Request for Proposal for a solid state DC to DC converter to be used in conjunction with a silver-zinc battery in the Missile Power Supply) was released to prospective bidders in December. Target date for award of the subcontract is February 1966.

B-214

Sintered plate type nickel cadmium alkaline batteries.II. Preparation procedures of positive plate for sintered plate type alkaline batteries using thermal decomposition in steam. Tsutomu Iwaki and Masataro Fukuda (Matsushita Denkisangyo Co., Osaka, Japan). Denki Kagaku 33(10), 737-43(1965) (Japan); of. CA 61,14180d.

Simplified procedures of the chem. treatment of a sintered Ni plate for an alk. battery are described. The sintered Ni plate with a porosity of 82 or 86% and 0.6 mm. thick was treated repeatedly with the $Ni(NO_3)_2$ soln. and the thermal decompn. of $Ni(NO_3)_2$ by steam, then $NI(OH)_2$ was formed in the KOH soln. The recommended conditions are; the concn. of $Ni(NO_3)_2$ soln. = 211 g. Ni^{2+}/l. (d. = 1.55 at 20°), 8 times repetition of immersing in the soln. at room temperature and the thermal decompn. by steam at 220° in 20 min., the d. of the KOH soln. = 1.24, the formation of $Ni(OH)_2$ was carried out in the KOH soln. at 60° in 1.5 hrs. The pos. plate obtained by this treatment showed good charging-discharging characteristics.

B-215

Separation of galvanic elements. VEB Grubenlampenwerke (by Roland Ackermann and Karlheinz Christian). Fr. 1,411 - 905 (Cl.
September 24, 1965, Appl. Aug. 17, 1964; 6 pp.

Fibrous materials which possess a high porosity and aspiration capacity are used to sep. galvanic elements with a preferably alk. electrolyte, such as in gas-tight Ni-Cd batteries.

B-216

Positive active masses for alkaline storage battery cells. Varta Pertrix-Union G.m.b.H. (By Lutz Horn, Rudolf Dieberg, Fritz Philipp, and Siegfried Dickfeldt), Ger. 1,204,203 (Cl. II 01m), Nov. 4, 1965, Appl. Dec. 16, 1960; 3 pp.

Pos. active masses based on NiO or the hydrate thereof, or of similar hydroxides, and graphite as conducting component are prepared by intimately mixing the Ni hydroxide or similar hydroxides, or mixed hydroxides, e.g., Co hydroxide, or antipolar addns., e.g. Cd or Cd hydroxide, having a grain size of 10-100 μ, with a conducting substance esp. graphite having a grain size of $< 10\ \mu$, homogenizing the mixture in a hollow mill at 14,000-18,000 r.p.m., and processing the homogenized product on friction rolls with a gap width of <0.5 mm. and a friction ratio of 1:1-1.3 to coarse-rolled granules which are then worked up to fine granules having a grain size range of 60 μ 1 mm., the fine dust being removed by air sifting and re-cycled into the process.

B-217

Production of porous Ni for alkaline battery and fuel cell electrodes: practical and economic considerations. V. A. Tracey (Intern. Nickel, Ltd., Birminghan, Engl.). Powder Met. No. 8(16), 241-55(1965) (Eng.)

Electrodes for Ni/Cd alk. batteries having 70-90% porosity are made from carbonyl Ni powder. Sintering is accomplished at $\approx 900^0$ for ≈ 15 min. Flat plates are generally 0.03 - 0.16 in. thick and the Swiss-roll wound configuration is ≈ 0.010 in. thick. The porous battery plates, made by packing a central mesh support with the powder, can be produced by loose sintering, slurry techniques, roll compaction, die pressing, or a combination of methods. Activation is effected by incorporating $Ni(OH)_2$ in the pos. plate and Cd $(OH)_2$ in the neg. plate. Extra fine pore structure is difficult to impregnate and extra large pore structure permits the impregnant to fall out. Low to medium temp. double skeleton catalyst (D.S.K.) fuel-cell electrodes are made by pressing and sintering a mixture of Ni powder and Rancy alloy (Ni-Al) powder, and subsequently leaching out the Al with KOH. The pores should be uniform and "Conical", the larger dia to be used on the gas side. The "Conical" effect is produced by using multiple layer electrodes with different pore sizes, the largest pore plate on one side of the pack and the smallest pore plate on the other side. Formulas for prepn. of the fuel-cell dual-pore electrodes for H and O_2 are given, also the D.S.K. II and O electrodes.

B-218

A precision constant current/voltage load for battery studies. S. Barnartt, P. R. Malmberg, and R. B. Gosser (Westinghouse Elec. Corp., Pittsburgh, Pa.). Electrochem, Technal. 3(11-12), 327-31(1965)(Eng).

Transistorized circuitry is described which permits const. voltage control to ±0.1 mv. or better, during either charging or discharging of a galvanic cell. Continuous correction for ohmic errors due to internal resistance is provided by use of a virtual neg. resistance. The circuit also permits precise const. current charge or discharge, measurement of internal resistance and measurement of open-circuit voltage. It is limited, however, to relatively low resistance cells. Studies of Ni-Cd secondary cells are presented, including initial const. voltage discharge curves, const. voltage charging curves with imposed limiting current, and internal resistance variations during charging and discharging.

B-219

Method for preparing positive nickel-containing electrodes. Gustav A. Mueller (to Union Carbide Corp.). U. S. 3,203,879 (Cl. 204-56) Aug. 31, 1965, Appl. Jan. 17, 1961; 2 pp.

A sintered nickel plaque is made cathodic in a molten $Ni(NO_3)_2$, hydrate bath at pH 0-1.5 near 100° at 0.06-5.0 amp./ft.^{2} The anode is a sheet of Ni or Ni alloy. The active Ni deposit on the plaque renders it suitable for use as a pos. electrode in a Mi-Cd galvanic cell.

B-220

Formation of negative electrodes. Gustav A. Mueller (to Union Carbide Corp.). U. S. 3,184,338 (Cl. 136-75), May 18, 1965, Appl. Jan. 31, 1962; 2 pp.

A neg. electrode for use in alk. cells was conveniently formed by electrodepositing a coating of $Cd(OH)_2$ onto a porous Ni matrix. Thus, a matrix of 40 x 40 mesh of Ni (0.007 in.) wire 1.131 in. x 7.5 in. was made a cathode in a plating bath of 50 wt. % aq. $Cd(NO_3)_2$ at 20°. By use of an anode of Cd rods and a current of 10 amp. for 22 min., the plating produced a matrix 0.06 in. thick, as the pH was kept between 1.0-1.5 with HNO_3. The deposited $Cd(OH)_2$ in the complex was converted to Cd in a 30% KOH electrolytic bath with the matrix as cathode and Ni electrode as the anode. A charge of 10 amp. for 30 min. sufficed to produce a spongy metallic Cd matrix which was subsequently passed through smooth Ni rollers (500 psi.). The rolled matrix (0.02 in. thick) was discharged to $CJ(OH)_2$ under the same conditions as it was charged, washed with H_2O, and air dried. Electrodes produced by this process take a charge better and are distinctly superior with respect to self-discharge.

B-221

Positive active material for alkaline batteries. Lutz Horn, Fritz Philipp, Siegfried Dickfeldt, and Rolf Dieberg (to Varta Pertrix-Union G.m.b.II.). U. S. 3,214,297 (Cl. 136-29), Oct. 26, 1965; Ger. Appl. Dec. 16, 1960; 2 pp.

> This invention relates to a novel method of manufacturing positive active material which will deliver approximately the theoretically maximum output of electrochem. energy. For example, the active material is prepared by the following method: 1.6 kg. of $Ni(OH)_2$ which has been ground and air clutriated with a grain size of 12-SO and sp. surfaces of 3000 cm^2/g. was thoroughly mixed for 3 min. with 0.4 kg. of graphite of 6 grain size and sp. surface of 50,000 cm^2/g. in a high-speed blender. The resulting mixt. was blended in a pin mill operating at 14,000-18,000 rpm. The blended powder was worked over a tight friction mill with a gap width of 0.5-0.1 mm. The final powder is then sepd. into portions of grain size 60 and the other 60 -1 mm. with a granulator having a strainer. The latter served as the finished active material.

B-222

Sealed miniature storage battery. Lutz Horn and Fritz Philipp (to Varta Pertrix-Union G.m.b.II.). U. S. 3,170,818 (Cl. 136-6), Feb. 23, 1965, Appl. Oct. 14, 1960; 6 pp.

> A gas-and liquid-tight alk. cell provides self-contained means for coping with the gases normally generated on charging over-charging. The electrochem. capacity of the neg. electrode is at least twice that the pos. electrode. Absorption of O at the anode suppresses evolution of H at that electrode during the charging cycle and prevents the generation of harmful internal pressure, thus making the cell safe for use. The cell, which may have a vol. of < 0.2 cc., encloses cylindrical electrodes, sepd. by a layer of fabric (e.g. nylon) of pore diam. < 15 u, with a cylindrical metal (e.g., Ni or steel) case. The separator, which may be 0.1-0.3 mm. thick, absorbs and immobilizes the aq. KOH electrolyte, but is permeable to gas. The electrode supports may be of powd. or flaked Ni (of 3 size) in a spongy skeleton-type structure. $Ni(OH)_2$ alone, or contg. a small amt. of $Cd\text{-}(OH)_2$, may comprise the pos. active material, while $Cd(OH)_2$, packed into the support, acts as the neg. electrode. The cathodic material is in contact with the case, while the anodic material and the electrolyte, as well as the cover, are insulated from the case by a plastic liner. The latter also serves as a gasket between the crimped edge of the Ni cover and the case. The cover has a spiked internal projection which pierces and makes contact elec. with the spongy anode. Because of its small size and method of construction the cell is able to withstand extreme internal gas pressure. The cells may be paired into a single unit of 8-10 mm. length and approx. .4 mm. diam. Primary batteries of this type may be used in hearing aids, in instruments for medical diagnosis, and the life.

B-223

Battery electrode. Grenville B. Ellis, U. S. 3,184,339 (Cl. 136-75), May 18, 1965, Appl. April 10, 1962; 3 pp.

A battery electrode was readily formed into any convenient shape by carrying the active material in a porous plastic cage. Thus, a Ni-Cd positive battery electrode was made by mixing 20% nodules of polystyrene coated with acetylene black (CA 49, 1364a) with 80% of a suitable nickel hydrate and molding into a sheet at 450°F. and 200 psi. The product was interlocked at various points yielding a porous sponge-like structure open to circulation of electrolyte. Neg. plates were made by mixing 5-10% conductive plastic with 90% $Cd(NO_3)_2$ and (or) CdO and then wetting with sufficient McCOEt to just render the plastic tacky. The particles were then subjected to 500 psi. molding pressure and dried.

B-224

Effect of the conditions of preparation of the active part of a positive electrode (for accumulator without a commutator segment) on its initial electrical properties. L. N. Sagoyan (F. A. Dzerzhinskii Chem.-Technol. Inst., Dnepropetroysk). Izv. Akad. Nauk Arm. SSR, Khim. Nauki 17(5), 473-6(1964)(Russ).

The efficiency coeff. of a Ni electrode increases with the increasing temp. of alk. treatment and drying the plate. The best results were obtained by treating the plate with alk. soln. (200-220 g./l) at 120° and drying at the same temp. The coeff. of Ni utilization increases as the amount $Ni(OH)_2$ in the electrode drops. The less is the amount of $Ni(OH)_2$ in plate the more is the amount of Ni formed during charge.

B-225

Primary alkaline cell. Theodore II. Meltzer and Thomas K. Krebs (to Electric Storage Battery Co.). U. S. 3,207,633 (Cl. 136-83), Sept. 21, 1965, Appl. July 18, 1962; 6 pp.

An electrolyte solution (A) for a primary cell was made by dissolving 31 g. KOH, 6.9 g. ZnO, and 0.52 g. of polycarboxylic acid (I) in 69 g. of H_2O. An anode electrolyte (B) was made by combining 4.0 g of powdered Zu (contg. 14% Hg), 2.5 g. of A, and 0.014 g. of I. The cell was constructed of concentric cylinders as follows (starting with outermost): steel container, HgO depolarizer, separator of microporous polyethylene, neg. electrode material, i.e. B, and an inner conductor, which extended from one end of the cylinder through an insulating plug. The other end of the cylinder was plugged with rubber. Such a cell had a discharge time to reach 1.0 v. (through a resistance of 83.3 Ω) of 16.3 hrs., compared to 10.3 hrs. for a com. cell.

B-226

Electret storage battery with roughened electrodes. Varta Pertrix-Union G.m.b.H. (by Joachim Euler and Paul Scholz). Ger. 1,193,121 (Cl. II 01m), May 20, 1965, Appl. June 3, 1961; 5 pp.

To reduce the high resistance between metal electrode and electret (swelled artificial resin coatg. $ZnCl_2$)arising towards the end of the charging and thus limiting the elec. capacity, the sp. surface both of the neg. Zn and the pos. Ag electrode is increased by roughening, dusting or profiling. By application of sintered instead of smooth Ag anodes, the discharging time at 6 ma./sq. cm. could be increased from 7 to 45 min. Instead of using plates, a wire-shaped cathode can be surrounded by electrolyte layer, the surface of which is covered by a star shaped pos. electrode.

B-227

Alkaline dry battery for low temperature operation. Richard R. Clune and Roger M. Goodman (to P. R. Mallory & Co., Inc.). U. S. 3,205,097 (Cl. 136-162), Sept. 7, 1965, Appl. June 22, 1960 and May 12, 1964; 5 pp.

An alk. primary cell having improved low-temp. properties was prepared by using a metal containers, a pressed powder compact in the bottom of the container that includes a cathode depolarizer and cathode, a roll of interleaved zinc foil anode-porous spacer material, an electrolyte absorbed in the spacer composed of 1.0-2.5% ZnO, 32-6% KOH, and 61.5-7% H_2O and a metal top closure that holds the anode in place under pressure. The anode roll was constructed of corrugated Zn foil of 0.004 in. thickness with 40 corrugations/in. with a thickness of 0.014 in. The spacer and the anode foil are so placed that at the bottom of the container the spacer protrudes while the foil extends upward sufficiently at the top to make contact with the closure. The corrugations provide room for deposition of ZnO at the lower temps. When discharged to 0.9 v. on a load of 22 ohms, the cell had the following service life at temp: 79.12 hrs. at 70°F.; 70.53 hrs. at 32°F.; 66.46 hrs. at 20°F.; 30.25 hrs. at 0°F.; and 6.78 hrs. at -20°F.

B-228

Effect of some additives on the electrical capacitance of a silver electrode.
G. V. Mikhailenko and M. F. Skalozuhov (Polytech. Inst. Novocherkasski)
Zh. Prikl. Khim. 38(2), 420-1 (1965)(Russ).

The effect was studied of adding Li, Hg., or S compds. to the electrolyte in a Zn-Ag battery to retard the enlargement of the particles of the active mass. The effect was detd. by measuring the elec. capacitance of an industrial Ag electrode in a KOH soln. Li_2O, which increases the O overvoltage on a Ag electrode increases the elec. capacitance. HgO has no noticeable effect during discharge. The effect of S compds. is similar to that of Li_2O indicating that the S acts as an electron acceptor and affects the semicond. properties of Ag_2O. It facilitates a more complete oxidn. of the metallic Ag thereby retarding the enlargement of its crystals.

B-229

The use of ion exchange membranes as separators in batteries. Lloyd H. Shaffer (Am. Machine & Foundry Co., Springdale, Conn.). J. Electrochem. Soc. 113(1), 1-6(196
(1966)(Eng.)

The factors that affect selective transport are reviewed. In available membranes, selectivity is controlled primarily by concn. effects rather than by mobilities. The fluxes of elec. current and matter through membranes are analyzed in terms of the thermodynamics of irreversible processes. The effects of a selective membrane on the operation of a Ag-Zn battery are discussed. The charge-selective character of the membrane causes sharp changes in electrolyte concn. when current flows through the boundary between membrane and electrolyte. This introduces both a high resistance film and a concn. potential; both of these operate to reduce the power output of the cell.

B-230

Battery assembly. Robert G. Byers, Richard A. Jones, and Glenn W. Schubert (to General Motors Corp.). U. S. 3,235,410 (Cl. 136-163), Feb. 15, 1966, Appl. June 1, 1961; 5 pp.

The steam pressure generated during the extremely rapid discharge of an alk. high rate battery, i.e. a AgO-Zn missile battery, is relieved by passing the steam expelled from the battery cell to a condenser within the housing, where it is condensed by dissolving a substance with neg. heat of solu., such as KSCN, KNO_3, NaOAc, NaCl, and NH_4SCN. The condensed steam is absorbed on cotton. A detailed description is given of a battery assembly of this type. The retention of the steam and the electrolyte carried by it within the housing eliminates the possibility of corrosive attack on adjacent equipment in the missile.

B-231

T. P. Dirkse, Calvin College, "Investigation of the Electrode Migration and Reaction Process Occurring in Alkaline-Zinc Batteries", Quarterly Technical Progress Report No. 2 (March 1, 1966 to June 1, 1966), Wright-Patterson Air Force Base Contract AF 33(615)-3292.

Silver-zinc cells containing additives in the electrolyte have been cycled. The additives used were: poly (methyl vinyl ether) maleic anhydride, cellulose gum, and maleic anhydride. Polyethylene and cellulosic separators were used. Cells with cellulosic separators gave longer cycle life. Additives in the electrolyte did not affect the cycle life significantly.

B-232

T. P. Dirkse, Calvin College, "Investigation of the Electrode Migration and the Reaction Process Occurring in Alkaline-Zinc Batteries", Quarterly Technical Progress Report No. 1 (December 1, 1965 to March 1, 1966), Wright-Patterson Air Force Base Contract AF 33(615)-3292.

The work under this contract will concentrate on the activity of the zinc electrode in alkaline solutions. To get adequate background for this a review of all the literature on this subject is being made and plans are also being made to determine the solubility of various types of zinc oxide in KOH solutions.

Some silver-zinc cells have been assembled and cycled to determine the effect of electrolyte additives on the cycle life, but not enough results have yet been obtained to warrant drawing any conclusions.

B-233

J. J. Lander and J. A. Keralla, General Motors Corporation, Delco-Remy Division, "Development of Sealed Silver Oxide-Zinc Secondary Batteries", Final Report, Technical Documentary Report No. ASD-TDR-62-668 (October 1962), Wright-Patterson Air Force Base 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. Probler 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. Eighty-nine cells were cycled to failure. On basis of cell testing, batteries were designed, constructed and life-cycle-tested. Twelve batteries were cycled to failure; one additional battery was tested environmentally.

B-234

Inland Testing Laboratories, Cook Electric Company, "Alkaline Battery Evaluation. 25 AH Silver-Zinc Cells. Failure Analysis Report on Twelve Groups Evaluated in a Two-Hour Cycle", Report prepared under Wright-Patterson Air Force Base Contract AF 33(616)-7529. No date on report, received during July 1966.

This report covers the performance and analysis of twelve eight-cell groups of 25-ampere-hour, sealed silver-zinc cells, Delco-Remy Part No. X-44869. These cells were subjected to a cycle-life test using a two-hour cycle period, with one group in each combination of test conditions consisting of three discharge depths and four temperatures. The cycle life of these cells ranged from 3 cycles at 50 with deep discharges to 428 at 25 C with shallow discharges. The physical and chemical analysis of the failures showed that the major cause of failure was the zinc negative plate limiting the cell capacity. This report also contains recommendations regarding areas of investigation and research to improve the silver-zinc cell design.

B-235

Inland Testing Laboratories, Cook Electric Company, "Alkaline Battery Evaluation. 25 AH Silver-Zinc Cells. Failure Analysis Report on Twelve Groups Evaluated in a Twenty-Four Hour Cycle", Report prepared under Wright-Patterson Air Force Base Contract AF 33(616)-7529. No date on report, received during July 1966.

This report covers the performance and analysis of twelve eight-cell groups of 25-ampere-hour, sealed silver-zinc cells, Delco-Remy Part No. X-44869. These cells were subjected to a cycle-life test using a twenty-four hour cycle period, with one group in each combination of test conditions consisting of three discharge depths and four temperatures. The cycle life of these cells ranged from 0 cycles at 5 C with deep discharges to 4C2 at 25 C with shallow discharges. The physical and chemical analysis of the failures showed that the major cause of failure was the zinc negative plate limiting the cell capacity. This report also contains recommendations regarding areas of investigation and research to improve the silver-zinc cell design.

B-236

T. P. Dirkse, Calvin College, "Silver Migration and Transport Mechanism Studies in Silver Oxide-Zinc Batteries", Final Report, Technical Documentary Report No. ASD-TDR-63-863 (September 1963), Wright-Patterson Air Force Base Contract AF 33(657)-8689.

A study has been made of the methods by which silver is transported from the silver electrodes in silver-alkaline batteries. This study has been made using radioactive silver tracers as well as by straight analytical techniques. This transport is due primarily to diffusion.

Various kinds of separator materials have been tested with respect to reactivity with dissolved silver oxides as well as with respect to effectiveness in preventing the transport of silver in a working silver-alkaline battery. Generally, effectiveness in preventing transport is due to reaction with the silver oxide dissolved in the potassium hydroxide electrolyte.

Two screening tests have been devised for testing the effectiveness of a given separator material in preventing the transport of silver.

B-237

J. A. Keralla, General Motors Corporation, Delco-Remy Division, "Test Report on Sealed Silver Oxide-Zinc Secondary Cells", Technical Report ASD-TR-61-636 (February 1962), Wright-Patterson Air Force Base Contract AF 33(600)-41600.

Sixty-five cells, constructed with hand-fabricated lucite containers and equipped with pressure gauges, were employed to determine cycle life using various combinations of separators and negative plate additives. Cycle life with one separator combination was also determined at three different depths of discharge in three different temperature ranges. The maximum cycle life obtained from the above group w 1760 cycles at 21% depth of discharge at room temperature.

Three cells with molded nylon containers and covers, with a metal terminal-to-plastic seal successfully passed the required environmental tests. This and five cells with the same construction have completed over 600 cycles to date. Eight additional cells with the same construction except for a negative plate variation have completed over 400 cycles.

Eight cells, employing the best design parameters from the previous eighty-one cells, were activated in lucite jars and placed on cycle life test. A projected battery energy-to-weight ratio utilizing these eight cells is about 8 watt hours/pound for the two hour cycle.

B-238

J. J. Lander, L. M. Cooke, and P. A. Scardaville, General Motors Corporation, Delco-Remy Division, "Applied Research Investigation of Sealed Silver-Zinc Batteries", Technical Documentary Report No. APL-TDR-64-85 (August 1, 1964), Wright-Patterson Air Force Base Contract AF 33(657)-10643. AD 603 023

Cycle life studies were made on groups of cells in which the ratio of ZnO to silver was varied from 0.75:1 to 4:1. Maximum cycle life was obtained at the 2:1 ratio.

Tests designed to show the effects of life of separator overhang at the tops and around the plate perimeter indicate that a ¼" to ½" overhang around the plate perimeter gives the maximum cycle life in this study.

Electrolyte quantity tests indicate that both initial capacity and cycle life are improved if a high electrolyte level is provided, but problems result for sealed cell operation.

Cells containing various combinations of acrylonitrile type separations wrapped around negatives do not show any significant improvement in cycle life as compared to control cells.

Cells containing 35%-45% NaOH show the same or better cycle life as that obtained with 45% KOH. A repeat test with 1% palladium added to the positive plates is in progress.

A detailed theoretical study and an experimental study, concerning the possibility of utilization of a neutral salt electrolyte in silver-zinc cells, is presented. The results indicate that no suitable neutral salt electrolyte is satisfactory for cell performance in this application.

Neither CdO additions to the negative active material nor provision for double grids in the negative plate construction showed advantages in initial capacity or cycle life.

The separator screening tests developed for this program have proved partially effective in determining the ability for a sample membrane to satisfactorily perform in a full scale cell.

B-239

G. R. Argue, H. L. Recht, W. A. McCollum, and D. E. McKenzie, North American Aviation, Inc., Atomics International Division, "The Effects of Radiation on Nickel-Cadmium Battery Electrodes. II", Interim Report AI-64-161 (March 13-June 13, 1964), Jet Propulsion Laboratory Contract No. 950514. AD 604 037.

A study of the effects of gamma radiation on nickel-cadmium cells was continued with emphasis on the loss in capacity of the cadmium electrode and on the radiolysis of the aqueous KOH electrolyte. The previously reported loss of cadmium electrode capacity was confirmed. A total average gamma dose of 9.0 x 10^7 rads (H_2O) caused a cadmium electrode, being cycled near 75 percent of full charge, to lose about 15 percent of its original capacity. The same dose caused essentially no loss in capacity of a fully charged cadmium electrode. A blank cell run at 45°C, the temperature inside the Co-60 source, showed no loss of capacity, indicating that this is not a temperature effect. Several attempts to restore the lost capacity were unsuccessful. It is tentatively concluded that gamma radiation causes an irreversible inactivation of some of the oxidized species, $Cd(OH)_2$, on the cadmium electrode.

Experiments were carried out to study the radiolysis of aqueous KOH solutions at concentrations from 0.5 percent to 40 percent. Hydrogen and oxygen were evolved in a ratio of approximately 2:2 by volume at a concentration of 0.5 percent KOH. At concentrations from 10 percent to 40 percent, the amounts evolved of both gases were considerably reduced, with the oxygen being undetected in most samples. A mechanism is proposed to explain these results.

Radiolysis of 30 percent KOH containing a portion of a nickel electrode produced relatively large amounts of oxygen whereas only hydrogen was evolved during the irradiation of a similar solution containing a portion of a cadmium electrode. The proposed mechanism is used to explain these results also.

B-240

S. B. Brummer, A. C. Makrides, and J. Bradspies, Tyco Laboratories, Inc., "Electrode Passivation Studies", Second Quarterly Report (May 31, 1966), Wright-Patterson Air Force Base Contract AF 33(615)-3433.

Studies of the passivation of Zn and Zn-alloys in KOH at 30°C have been made potentiostatically. Zinc shows the characteristic active-passive current-potential curve although the passive current is too high for use in the passive reserve mode in Zn-AgO batteries. Studies of the corrosion of Co, Cu, Fe, Mg, Mn, and Ti in alkaline solutions show them as possible choices for alloying with Zn to improve its standby characteristics. Cu-Zn alloys are not acceptable, however, since the addition of Cu lowers the Zn critical current but does not lower the passive current sufficiently. Zn-Mg solid solutions show the formation of an inactive surface layer and are therefore not suitable. Cu-plating of Zn may be suitable for its protection on standby.

Studies of the passivation of Mg from pH 2 to 14 were carried out with a view toward using the high energy density characteristics of the Mg-m-dinitrobenzene battery. In neutral and alkaline solutions Mg is passive on open circuit and cannot be used in the passive reserve mode. A secondary passivation may be present in mildly acid fluoride solutions.

B-241

S. B. Brummer, A. C. Makrides, and J. Bradspies, Tyco Laboratories, Inc., "Electrode Passivation Studies", First Quarterly Report (December 1, 1965 to February 28, 1966), Wright-Patterson Air Force Base Contract AF 33(615)-3433.

The possible operation of primary, reserve batteries in a passive mode is discussed. Anodic passivation of reactive metals, such as Zn, Fe, etc., occurs at critical currents which are of the order of 0.1 to 1 amp/cm^2. Passive anodes dissolve at current densities less by orders of magnitude than the critical current. An anode can be put into the passive state and maintained in this condition by an appropriate electrical pulse followed by a suitable connection to the positive battery electrode. Activation of the anode prior to use can be achieved by a cathodic electrical pulse which reduces the passive film. The activation time may be from a few milliseconds to seconds, depending on the magnitude of the cathodic pulse.

The Fe and Fe-Cr systems have been examined as possible anodes in $HClO_4$ solutions. Data on passivation of these systems suggest that a Fe (alloy) / acid electrolyte / PbO_2 reserve battery could be operated in the passive mode.

B-242

John Liska, Gulton Industries, Inc., "Investigation of Sterilization of Secondary Batteries", First Quarterly Report, NASA CR-66105 (October 26, 1965 to January 26, 1966), NASA Langley Research Center Contract NAS 1-5708.

This report covers the first quarter of an eight month study to develop a nickel-cadmium cell which, after being sterilized according to the Test Approval Procedure, will give a power density and cycle life approaching a standard nickel-cadmium cell.

The first phase of this investigation was to evaluate existing separator materials. The procedure was to subject separator test samples to the environment that cells would be required to experience.

The second phase of this study will incorporate the more promising separator materials in cells. After the cell characteristics have been determined, they will be subjected to the Test Approval procedure.

The third phase of this program will go through a more detailed evaluation of the effect of test environment on the individual cell components.

B-243

A. J. Salkind and G. W. Bodamer, The Electric Storage Battery Company, "Changes in Physical Chemical Properties of Secondary Battery Electrodes During Cycling", Batteries 2. Proceedings of the 4th International Symposium held at Brighton, September 1964, Edited by D. H. Collins, Pergamon Press, New York (1965), Chapter 5, pp. 55-62.

It is the author's aim in this paper to show the utility and limitations of such methods as chemical analysis, X-ray examination, surface area determinations, Tafel overvoltage, and porosity measurements in understanding the behavior of battery electrodes. To illustrate the utility of these techniques we will use data from a five-year cycling program on nickel-cadmium cells now underway in our company. This program is part of a project which was initially partially sponsored by Bell Telephone Laboratories.

B-244

N. E. Bagshaw, M. I. Gillibrand, and K. P. Wilson, Chloride Technical Services Limited, "The Microscopic Examination of Active Materials From Nickel-Cadmium Alkaline Cells", Batteries 2. Proceedings of the 4th International Symposium held at Brighton, September 1964, Edited by D. H. Collins, Pergamonon Press, New York (1965), Chapter 7, pp. 81-92.

> The results given in this paper have confirmed that the discharge mechanism of the nickel cadmium cell involves the formation of cadmium hydroxide at the negative plate. An explanation for the reaction occurring in the active positive material has not yet been established but it is considered that the microscopic evidence of the similarity between the charged and discharged state may be significant.

B-245

Batteries 2. Proceedings of the 4th International Symposium held at Brighton, September 1964, Edited by D. H. Collins, Pergamon Press, New York (1965), "Investigations on the Negative Electrode of Nickel-Cadmium Cells with Sintered Plates" (J. P. Harivel, B. Morignat, and J. Migeon, Societe des Accumulateurs Fixes et de Traction), Chapter 9, pp. 107-127.

B-246

H. B. Lunn and J. Parker, Chloride Technical Services Limited, "Reactions in Sealed Nickel-Cadmium Cells", Batteries 2. Proceedings of the 4th International Symposium held at Brighton, September 1964, Edited by D. H. Collins, Pergamon Press, New York (1965), Chapter 10, pp. 129-145.

> The mechanism of oxygen reduction in sealed nickel-cadmium cells has been considered. Experimental evidence showed that the electrolytic reduction on sintered nickel surfaces involved the formation of perhydroxyl. When cadmium was present in the cathode, the chemical reaction between oxygen and cadmium predominated. The effects of the steady state oxygen pressure of variations in the quantity and composition of the electrolyte, the porosity and state of charge of the active materials, the temperature of the cell and certain features of the assembly have been investigated. Of these the quantity of electrolyte appeared to be the most critical, confirming indications by other workers that the reaction is diffusion controlled. The activation energy of the recombination reaction was estimated. The reaction between gaseous hydrogen and the nickel oxide positive active material was also examined. The experiments proved that this reaction took place but at such a low rate that its effect on the gas recombination in sealed cells was insignificant.

B-247

J. M. Hale, Royal Aircraft Establishment, "Kinetics of the Nickel Hydroxide Electrode", Batteries 2. Proceedings of the 4th International Symposium held at Brighton, September 1964, Edited by D. H. Collins, Pergamon Press, New York (1965), Chapter 11, pp. 147-166.

> A diffusion controlled mechanism is proposed for operation of the nickel hydroxide electrode. The corresponding boundary value problem in diffusion theory is analysed, and predictions made about the "top of charge", galvanostatic, and potentiostatic electrochemical behavior of the electrode. The parameters are identified which control the response of the electrode to any perturbation, and means of their experimental determination are described.

B-248

C. Luciani, Army Equipment Engineering Establishment, Ottawa, "Field Maintenance of Nickel-Cadmium Batteries at Low Temperatures", Batteries 2. Proceedings of the 4th International Symposium held at Brighton, September 1964, Edited by D. H. Collins, Pergamon Press, New York (1965), Chapter 30, pp. 419-430.

> This paper describes some effects of low temperature on the maintenance of vented, sintered-plate, nickel-cadmium batteries. Particular attention is given to the methods of charging, battery usefulness and general maintenance. A charging system is described which is compatible with field operation using engine-generator sets. The regulated charging system permits charging of batteries by inexperienced personnel with resulting minimum damage to the batteries. Batteries charged at low temperatures provide an output equal to or slightly more than batteries charged at normal temperatures and discharged at low temperatures. Some field experience with pocket-plate, nickel-cadmiun batteries is also included in the paper.

B-249

R. C. Shair and H. N. Seiger, Gulton Industries, Inc., "Operating Characteristics of Sealed Nickel-Cadmium and Silver-Cadmium Batteries", Batteries 2. Proceedings of the 4th International Symposium held at Brighton, September 1964, Edited by D. H. Collins, Pergamon Press, New York (1965), Chapter 31, pp. 431-443.

> Recent advances in the technology of hermetically sealed nickel-cadmium and silver-cadmium cells have resulted in cells for aerospace use that are capable of a year's operation, about 7000 cycles, in a 100-min cycle of charge-discharge. Reliability assessments in excess of 0.99 have been determined from actual cycle life tests. True hermetic sealing of cell containers has been achieved with welded cases and ceramic-to-metal seals. Complete electrical information has been collected to permit the design of reliable charge control systems. Charge control by voltage has usually been used, but interest is growing in the use of auxiliary electrodes for this function.

B-250

F. Solomon and G. W. Work, Yardney Electric Corporation, "Present-Day Long Life Silver-Zinc Secondary Batteries", Batteries 2. Proceedings of the 4th International Symposium held at Brighton, September 1964, Edited by D.H. Collins, Pergamon Press, New York (1965), Chapter 33, pp. 463-473.

The silver-zinc battery has been studied to gain a better understanding of its characteristics and to improve its capabilities for secondary battery applications. Factors which limit cell life are discussed as are the effects of cycling regime and certain design parameters. Results of a detailed study of hydrogen evolution are reported. The potentialities of the silver-zinc battery for float applications are shown. Experimental cells have given as many as 350 deep discharges and 650 shallow discharge cycles. Cell life of up to 2½ years has been demonstrated in cycle services and up to 3 years in float service. Battery life may be defined in terms of time, cycles or ampere hours discharged until the battery can no longer give a satisfactory output. The silver-zinc battery is not generally considered a long-life battery in time or cycles, but it may equal or exceed other batteries of the same size and weight on the basis of total ampere hours discharged because of its high energy density. The studies reported reflect several years of development of large low-rate, silver-zinc batteries. It is intended to show not only the state of the art as it concerns battery life but also the results of some interesting tests not directly related to battery life. Except for the float application, the discussion will be based on cell results, rather than those of multi-cell batteries.

B-251

J. Goodkin and F. Solomon, Yardney Electric Corporation, "A Zinc-Silver Oxide Cell for Extreme Temperature Application", Batteries 2. Proceedings of the 4th International Symposium held at Brighton, September 1964, Edited by D. H. Collins, Pergamon Press, New York (1965), Chapter 34, pp. 475-487.

This paper describes a zinc-silver oxide battery system for use over the temperature range -65 to 160 F. The limiting current densities of zinc and argentous oxide electrodes are reported from room temperature down to -65 F. The electrode utilization efficiencies for both of these electrodes have been measured as a function of the current density over the temperature range of battery operations. The stability of the electrodes to high temperatures has been established. A general method of preparation of electrodes for optimum operation over the extreme temperature range is described.

B-252

J. L. Blonstein, D. F. C. Poole, and D. E. Mullinger, British Aircraft Corporation, "Some Methods of Spacecraft Battery Control", Batteries 2. Proceedings of the 4th International Symposium held at Brighton, September 1964, Edited by D. H. Collins, Pergamon Press, New York (1965), Chapter 35, pp. 489-502.

> The paper reviews the problems facing the satellite designer in developing solar power supply systems that must be compatible with present-day satellite batteries. After introducing the basic requirements of spacecraft power supply systems, the paper reviews the characteristics of solar cells and batteries, and the particular problems of batteries in the space environment. Several systems of battery control are then described, showing the shortcomings of the simpler systems and the consequent complexities that are often adopted. The system proposed for the UK.3 satellite is then discussed in detail, illustrating the advantages to be gained from a split solar array system.

B-253

P. Ruetschi and J. B. Ockerman, The Electric Storage Battery Company, "Sealed Cells With Auxiliary Electrodes", Electrochemical Technology, 4 (7-8), 383-393 (July-August 1966).

> Conventional secondary and primary batteries may be operated in a hermetically sealed condition, even if containing excess electrolyte forming a free liquid bath , by utilizing auxiliary electrodes which are designed to consume hydrogen or oxygen gas electrochemically and which are held for this purpose at fixed half-cell potentials. Using solid-state diodes as potential-regulating means, unidirectional current flow to the auxiliary electrode is achieved, rendering the latter specifically selective to either electrochemical oxidation or reduction in the desired potential range. This innovation relieves the battery electrodes from the function of gas removal as in ordinary sealed cells and thus permits cell designs with higher electrolyte content and associated higher energy density.

B-254

Frederick P. Kober, General Telephone & Electronics Laboratories, Inc., "An Electrolytic Impregnation Method: Nickel Hydroxide Electrode", Electrochemical Technology, 4 (7-8), 423-426 (July-August 1966).

> A method is described whereby a conducting porous matrix is impregnated electrolytically with nickel hydroxide. Impregnation is achieved by making the porous plaque anodic in an ammine nickel formate solution. Use of a current-interruption technique, as opposed to continuous d-c polarization, makes the degree of impregnation a linear function of time. Also, the method eliminates the need for cathodic polarization in a caustic solution after impregnation. Plaques impregnated in this manner show excellent voltage characteristics and are suitable for use as positive electrodes in high-capacity, nickel-cadmium batteries.

B-255

G. Scott Atkinson, Alkaline Batteries Limited, "A Short History of the Nife Nickel-Cadmium Battery", Electrochemical Technology, 4 (7-8), 431-438. (July-August 1966).

This paper presents discussions on the following topics: The Start of the System; The First Public Company; The First Cadmium Electrode; Early Positive Electrodes; The Discovery of Fundamental Weaknesses; Design Principles; The Significance of Cobalt; Graphite Step and Conductivity; Rediscovery and Cure of Iron Poisoning; Development of High-Performance Batteries; Improvement of the Charge Characteristic; The Levin Strip and The Improvement of Deep-Cycle Life; Development of Center-Conductor or Double-Positive Plates; Laver Developments; and The Future.

B-256

Varta A.G., "Alkaline Storage Battery and Process for Making the Same", U. S. Patent 3,208,880 (September 28, 1965).

B-257

Galvanic Cell. W. Krebs. British Patent 928,469, 26th Jan. 1961. Met. Pat. J., 9th July 1963, 3(27), Gen. Inorg. Abstr., p. 1

The primary and secondary cell described incorporates a negative electrode made of iron or cadmium, a positive electrode consisting of nickel hydroxide and a third electrode made of a metal such as zinc which dissolves in the alkaline electrolyte used. The third electrode is located between the positive and the negative electrodes and forms a primary cell with one of them.

B-258

Electrode Assembly. Yardney Intern. Corp. U. S. Patent 3,207,630, 27th June 1961, Office. Gaz. U. S. Pat. Office, 21st September 1965, 818(3), Abstr., p. 1069

The electrode assembly described is designed for use in alkaline batteries. Two electrode active materials are used; silver/silver oxide and either zinc/zinc oxide or cadmium/cadmium oxide. The assembly comprises at least one electrode made of one active material flanked by two electrodes made of the other active material; the first electrode is wrapped with a separator strip, a second separator strip being wound jointly round and individually enveloping the other two electrodes. The two separators are in contact with each other, each separator including at least one inner layer of a semi-permeable sheet material and an outer layer of an absorbent sheet material.

B-259

Battery. S. Zaromb. U. S. Patent 3,207,631, 26th Jan. 1962. 1 fig., 3 pages

The battery design described is applicable to nickel/cadmium batteries and other high current density batteries including the zinc/silver oxide and cadmium/silver oxide types. The electrodes of the batteries are set up in two series, arranged in bipolar pairs with the exception of the end electrodes. The individual electrodes of each pair are separated by a porous, electrically conducting body impregnated with a gas-pervious water-impermeable material. The porous bodies provide for the flow of oxygen between the electrodes while restricting the electrolyte to predetermined spaces between the electrode pairs. The grids supporting the reacting material of each electrode pair and the separating non-reactive conducting material can all be composed of a single grid or grid structure, simplifying the manufacture of the batteries.

B-260

Recent developments in battery electric vehicles. B. S. Hender. Power Record, Dec. 1965, pp. 2297-2308. 8 illus., 4 figs., 4 tables.

A review is presented of the improvements made since about 1952 in the design and manufacture of battery-powered vehicles and their components. Batteries, including the lead/acid and nickel/cadmium types, controllers, motors, chargers and transmission systems are considered. The design of electric vehicles is dealt with and some recent models are described, including some experimental vehicles powered by a silver/zinc battery. The advantages of battery-powered vehicles, such as reduced noise and atmospheric pollution, are stressed. 43 refs.

B-261

Galvanic primary and secondary element or cell with three electrodes. W. Krebs. U. S. Patent 3,132,053, 24th January 1961. Offic. Gaz. U. S. Pat. Office, 5th May 1964, 862(1), Abstr., p. 222

The cell contains an alkaline electrolyte, a cadmium or iron negative electrode and a positive electrode of nickel hydroxide. Between these electrodes is placed the third electrode which consists of a metal core surrounded by layers of fibre coated with the same metal, which may be either zinc or aluminum. Connection between the third electrode and one of the other two gives a primary cell which is fully discharged when the third electrode is completely dissolved away. The secondary cell may then be obtained by connection of the positive and negative electrodes.

B-262

Hermetically sealed storage battery and method for its manufacture.
W. Krebs. U. S. Patent 3,108,908, 6th January 1959. Offic. Gaz. U. S.
Pat. Office, 29th Oct. 1963, 795(5), Abstr., p. 1280

Claims are made for a battery comprising a casing, positive and negative electrodes and a porous separator between the electrodes for absorbing the electrolyte. The electrodes and the separator occupy substantially the entire space within the casing, at least one electrode being made of a porous fibrous material firmly secured to the casing. A cavity in the fibrous material contains a mixture of a gas absorbing material and an active electrode mass.

B-263

Sealed Cd/Ni accumulator. Soc. des Accumulateurs Fixes ef de Traction.
Belgian Patent 632,887, 28th May 1963. Met. Pat. J., 14th Jan. 1964,
4(2), Gen. Inorg. Abstr., p. 1

Claims are made for a cadmium/nickel battery in which the internal pressure in the absence of current is much lower than the atmospheric pressure. High current densities are obtained. Details of the battery are given.

B-264

Performance characteristics of rechargeable batteries. H. Belofsky.
Design News (U.S.A.), 14th Nov. 1962, 17(23), 108-11. 5 figs, 1 table,
200 words

Essential performance characteristics of lead-acid, Ag/Zn, Ni/Cd, Ag/Cd and Ni/Fg batteries are provided in tabular form for comparison. Graphs are given showing discharge times against voltages, discharge rates against watt-hours per pound, discharge rates against time to reach 1-1V, and temperatures against watt-hours and volts at mid-point.

B-265

Storage battery emergency supply systems. E. R. Sanderson, Power Works Eng.,
Jan. 1964, 59(691), 6-14. 4 illus., 5 figs., 3300 words

The use of lead-acid and nickel-cadmium alkaline batteries as sources of emergency power supply is reviewed. Battery characteristics, arrangement, maintenance, and recharging details are presented and the emergency power requirements of various environments are discussed.

B-266

A method for making positive electrodes for silver-zinc accumulators.
V. V. Romanov, Russian Patent 138,283 (1961)

When the positive electrode of a silver-zinc accumulator is wrapped in cellophane, a thin layer of magnesium hydroxide on both sides of the electrode will reduce attack on the cellophane by silver oxide and by oxygen released during overcharging.

B-267

Storing electrical energy. K. Spring. New Scientist, 31st May 1962, 14(289), 453-6. 1 illus., 4 figs, 2600 words

Reviews and discusses the systems used including lead/acid storage batteries and silver/zinc and silver/cadmium alkaline batteries. The latter two are considered to be the ultimate in storage batteries; they are about 5 times better than the lead-acid or nickel-alkali batteries for a given weight and volume. They are in great demand for various specialized uses in aircraft, missiles and space satellites. They are capable of recharging but are often used as 'single shot' devices.

B-268

Peter R. Stromer, Lockheed Missiles and Space Company, "Electrochemical Batteries: An Annotated Bibliography", Special Bibliography SB-63-14. 2-02-63-1 (February 1963) Air Force Contract AF 33(616)-7957. AD 441 578.

An extensive review of the recent (1961-1962) literature on electrochemical batteries and their components has been made. Emphasis has been placed on power sources for guided missile and spacecraft applications. While much publicity has been given to the more exotic power supplies currently under development, such as fuel cells, nuclear batteries, thermionic converters, magnetohydrodynamics, etc., the vast majority of aerospace satellite and weapons systems continue to use electrochemical batteries as their prime source of power. Latest developments in electrolytes indicate a trend from liquid to solid forms for high temperature use. Wherever weight considerations are paramount, nickel-cadmium, silver-cadmium, silver-zinc, and magnesium components have largely replaced the older lead-acid combinations.

B-269

Newell D. Sanders, James F. Morris, Lester D. Nichols, Andrew H. Potter, Jr., Harvey J. Schwartz, and Warner L. Stewart, Lewis Research Center, "Electric Power Generation", Conference on New Technology held at Lewis Research Center, Cleveland, Ohio, June 4-5, 1964, NASA-SP-5015, Chapter 3, pp. 65-89.

The topics discussed are batteries, solar photovoltaic cells, thermoelectric converters, fuel cells, turbine conversion systems, magnetichydrodynamic converters and thermionic converters. In each case, the fundamental principles are explained briefly, the state of the art with respect to space application is discussed, and some guesses are made concerning applications to everyday living.

B-270

P. Ritterman, S. Lerner, and H. Seiger, Gulton Industries, Inc., "Investigation of Battery Active Nickel Oxides", Fourth Quarterly Report, NASA CR-72018 (June 12, 1966), NASA Lewis Research Center Contract NAS 3-7620.

A study of the oxidation state of the sintered nickel oxide electrode, by iodometric titration, shows some agreement with the X-ray data. A study of the effect of stand, at various temperatures, on structure, was completed. Positive electrodes with cobalt, and positive electrodes with manganese additives were shown to retain 75% of original capacity after a charged stand at 65 C for 7 days.

B-271

Tivadar Z. Palagyi, Central Research Institute for Chemistry, Hungarian Academy of Sciences, "Investigation on the Silver-Zinc Storage Battery With Radioactive Zn^{65} Isotope", Journal of the Electrochemical Society, 108 (3), 201-203 (March 1961).

Zn^{65} isotope was deposited electrolytically on the middle negative electrode of silver-zinc storage batteries assembled in three different ways. The path of the dissolved zinc ions could be followed by measuring the radioactivity of the nonlabelled electrodes. In the deteriorated cells all the negative and nearly all the positive plates became contaminated with the isotope. The cycle life was longest with cells assembled tightly and with little electrolyte.

See also: T. Z. Palagyi, Central Research Institute for Chemistry, Hungarian Academy of Sciences, "Investigations on the Silver-Zinc Alkaline Storage Battery by the Aid of Radioactive Isotopes", Journal of the Electrochemical Society, 106 (9), 846 (September 1959).

B-272

Otto C. Wagner and Robert F. Enters, Yardney Electric Corporation, "Development of Manufacturing Methods and Techniques for the Production of Improved Alkaline Batteries". Final Report, IR-8-253 (IV), (June 1966), Wright-Patterson Air Force Base Contract AF 33(615)-2578. (Rough Draft Report).

A development program directed at the problem of producing improved sealed alkaline batteries with matched cell capacities ± 1% of nominal ampere-hour rating is described. The required properties of cell components are reviewed, and methods of fabrication along with cell designs are presented.

The ± 1% matching in cell capacity was attained with five-cell sealed 14 ampere-hour nickel-cadmium batteries and five-cell sealed 15 ampere-hour silver-cacmium batteries on short orbit cycling regimes. For the silver-cadmium battery the ± 1% capacity was attained through 535 cycles on the short orbit regime up to 75% depth of discharge. This type of cell balance was obtained by employment of the following controls:

1. Weight control of the active materials, including ratio of charged materials.
2. Programmed characterization cycling of the Ni/Cd electrodes.
3. Batch utilization tests of the silver and cadmium-oxide powders used for the Ag/Cd batteries.
4. Selection of separator materials to a uniform weight and thickness.
5. The electrode pack thickness controlled to a uniform thickness.
6. The battery cells to be formed by constant input-output cycling.
7. Leak detection of the metal cell containers and terminal-seals.

Other important factors for the fabrication of closely matched battery cells are:

1. Uniform multi-step impregnations of the Ni/Cd electrodes to a ± 2% active material weight gain.
2. Batch B.E.T. mean surface area measurements of sintered-nickel plaques, silver and cadmium-oxide powders.
3. Control of the proper amount of electrolyte in the alkaline cell prior to and after battery cell formation.

Short orbit cycling data of sealed 15 AH - Ag/Cd battery cells are presented and discussed. The batteries deliver a minimum capacity of 11.5 AH at -10°F, at the rates employed at the 75% depth of discharge, and a maximum of 20.7 AH at 150°F, at the rates employed at 25% depth.

The 14 AH - Ni/Cd battery cells deliver a minimum capacity of 5.7 AH at -30°F, at the rates employed at the 75% depth of discharge, and a maximum of 14.8 AH at 75°F, at the rates employed at 25% depth.

B-273

Guy Rampel, Gulton Industries, Inc., Method of Preparing an Electrode Structure. U. S. Patent 3,248,266, April 26, 1966, Application, January 4, 1962.

A method of preparing an electrode structure comprising dipping a nickel plaque into a solution comprising essentially 60 to 85% of a compound selected from the group consisting of nickel nitrate and cadmium nitrate and 40 to 15% of methyl alcohol, substantially drying the plaque at a temperature of about 50 to 200 C, placing the plaque in a heated 25 to 35% caustic solution and subjecting the plaque while in the caustic solution to cathodic electrolytic process to convert said compound to its potentially electrochemically active hydroxide, removing substantially all caustic solution from the plaque, and repeating the cycle until a weight increase of at least 15% over its original weight is elicited by the plaque.

B-274

S. Charlip and A. Lyall, Gulton Industries, Inc., Development of Pile Type, High Discharge Rate Nickel-Cadmium Squib Batteries. First Quarterly Report, March 4-June 4, 1966, Goddard Space Flight Center Contract NAS 5-10160.

The object of this report is to summarize the work accomplished, during the past quarter, in a program directed toward the design and development of a pile type, nickel-cadmium, squib battery.

A cell consisting of two bipolar plates was developed, manufactured, and tested. The cell consisted of two end plates with an active area of 4 square inches (2¼" diameter) and .030 inch thick sinter. Each plate had an exposed border ¼ inch wide, for sealing. The cell was compressed between two plastic sheets and submerged in an open beaker filled with 34% KOH solution.

The cell delivered 600 mAh capacity at the C rate (four times the minimum specified) and 6 pulses of 1.4 seconds duration each at the 11.5 ampere discharge rate, above 1.0 volt. This is in excess of the specified requirements -- 1 pulse at 10 amperes.

The cell tested was the largest size which would make a 5 cell squib battery within a volume of 3 cubic inches.

In view of the performance characteristics of the largest cell, smaller sizes are being constructed and tested to establish the minimum size of bipolar plate capable of meeting specification requirements.

B-275

Allen Charkey, Yardney Electric Corporation, Research and Development Study of the Silver-Cadmium Couple for Space Application. Final Report, no date, received September 21, 1966, Goddard Space Flight Center Contract NAS 5-9106.

The goal of this contract was to provide an insight into the problems associated with the sealed silver oxide-cadmium system. The work included. determination of the rates of gas evolution and recombination as a function of temperature. A study of the efficiencies of active materials, and investigations of the passivation of electrodes and variation of cell characteristics with cycling on the 100 minute and 24 hour orbital regimes were also carried out.

During the fourth quarter of work, cells which contained lead doped positive electrodes were evaluated on the 100 minute orbit regime. A series of deep discharges at -10, 0 and 20°C after 750 cycles showed that the beneficial properties afforded early in cycle life by the lead had disappeared. The initial improvement in voltage and capacity however, were evident after 500 shallow cycles.

Two 5 cell batteries and four single cells with RAI 2.2XH irradiation grafted polyethylene were fabricated to study performance characteristics during long and short orbital cycling regimes. In addition, gas recombination experiments were also carried out with the single cells. The two batteries failed after 1400 and 110 cycles on the short and long orbit regime, respectively. The control batteries which contain cellulosic separators were still maintaining good capacity after the same period of time. Recombination studies showed that the oxygen consumption rate was about 3 times lower than for cells containing either Yardney silver-treated cellophane C-19, or Visking cellulosic sausage casing.

B-276

The Electric Storage Battery Company, Auxiliary Silver Electrode Eliminates Two-Step Voltage Discharge Characteristic of Silver-Zinc Cells. NASA Tech Brief 64-10114 (June 1964).

The two-step voltage discharge characteristic is eliminated by using the AgO capacity on the surface of the positive electrode to charge an auxiliary silver electrode to the Ag_2O state. The auxiliary silver electrode is assembled in the cell in such a manner that it is electrically isolated from the positive and negative electrodes. It is connected to a third terminal.

In operation, the cell is charged to its nominal cutoff, with the third terminal electrically isolated from the charging circuit. The third terminal is then connected to the positive terminal by a shorting strap of nominal resistance (0-20 ohms). Surface AgO on the charged positive electrode reacts electrochemically with the silver in the auxiliary electrode to reduce the AgO on the charged electrode and correspondingly oxidize some of the silver on the auxiliary electrode to Ag_2O. The higher voltage that would result from the AgO on the electrode is thus eliminated, and a substantially constant voltage is obtained during discharge. Adjustment of the amount and quality of silver in the auxiliary electrode permits the voltage decrease to be tailored to suit the requirements of the cell. No capacity is lost from the cell, and both the auxiliary and positive electrodes are discharged to a common end voltage.

B-277

W. N. Carson, Jr., J. A. Consiglio, and R. R. Nilson, General Electric Company, Characterization of Nickel-Cadmium Electrodes. Final Report (July 1, 1963 - December 31, 1964), Goddard Space Flight Center Contract NAS 5-3477.

The principal characterization data obtained was the complete potential versus time curve for each electrode against a nickel oxide reference electrode for a small number of charge-discharge cycles (6-7) prior to assembling the electrodes into test cells for the cyclic tests. The majority of the characterization tests were made at a constant current of C/10 at room temperature. These curves show the electrode capacity, graphitic and anti-polar capacity, and the effect of impurity levels. In addition a small number of positive electrodes were tested to determine the onset of gassing and gassing rate as a function charging current.

Periodically test cells were removed from the cyclic tests and the individual electrodes were recharacterized and examined for changes in physical properties and comparisons made with the original characterization data.

Some of the electrodes removed from the cyclic tests were examined by x-ray diffraction and photo-micrographs in cross section to determine composition and structural changes. The remainder of the test electrodes, providing they appeared in good mechanical condition by visual inspection, and where time permitted were reassembled into test cells for further cycling.

Test cells fabricated with the characterized electrodes were cycled in three modes of operation, simulating conditions most likely to be encountered in space applications. These modes were as follows:

(1) Shallow Discharge Cycling to a depth of 21% of the cell capacity at constant current.

(2) Random Depth of Discharge Cycling averaging 10, 20, 50, and 75% of the cell capacity over a six-day period using random Beta and rectangular distributions for the individual cycle depth of discharge over the six-day period.

(3) Current Limited Constant Voltage Charging Cycling

The cyclic tests were run concurrently at three temperature levels: 0°, 25° (room temperature), and 40°C.

The plates used in the program were the impregnated sintered plaque type VO made by S.A.F.T. of France and some of the same type made by the General Electric Company at Gainesville, Florida. The latter are designated as KO in this report. The plates had a nominal capacity of 1.2 amp-hrs.

Details of experimental equipment and procedures used as well as relations developed and conclusions for each of the four major program tasks are presented in four separate sections which follow. The breakdown of tasks is:

1. Characterization Tests
2. Shallow Discharge Cycling Tests
3. Random Depth of Discharge Cycling Tests
4. Current Limited Constant Voltage Cycling Tests

B-278

The formation of a porous Ag electrode in an acoustic field. M. F. Skalozubov, F. I. Kukoz, and G. V. Mikhailenko (Polytech. Inst., Novocherkassk). Zashchitn. Metal. i. Oksidnye Pokryliva, Kerroziva, Metal. i Issled. v. Obl. Elektrokhim. Akad. Nauk SSSR, Old. Obschch. i. Tekhn. Khim, Sb. Slatei 1965, 280-4 (Russ).

Improvement of the Ag electrode used in a Ag-Zn battery was studied by the employment of sound waves by using an ultrasonic generator (21 kc.sec., 600 w., 2-3 w./cm^2, at 20° ± 2°) and an electromagnetic vibrator (100 cycles/sec., amplitude 1.2 mm). A Ag electrode was kept in the center compartment of a cell consisting of 3 communicating compartments and contg. 150 ml. KOH soln. (d. 1.4 g./cc). A ni-foil electrode was placed in each of the outside compartments. The Ag electrode was charged at 16 ma./cm^2 up to 0.8 v. (Hg-HgO reference electrode) and discharged at 32 ma./cm^2 to -1.3 v. By subjecting the Ag electrode for the 1st 30 min. during its charge to the ultrasonic waves, its capacity was increased by 8-10%, while a longer exposure up to the start of vigorous gas evolution had the addnl. effect of the disappearance of the 1st discharge voltage level. The discharge of an untreated Ag-electrode takes place at 2 voltages under the given conditions (0-20 min. at 0.4 v., 20-80 min. at 0.2 v.). The discharge of the treated electrode started immediately at 0.2 v. The new discharge-voltage characteristics were preserved on cycling without repetition of the acoustic treatment. Sediment was formed, but the capacity remained 10% higher than for an untreated electrode. Exposure of the Ag electrode to the ultrasound for 30-40 min. at the 1st discharge increased the capacity by 20% and reduced the discharge voltage level at 0.4 v. considerably. Exposure of the Ag electrode to 100 cycles/sec. for 20-30 min. increased the capacity by 20%. The cell retained its higher capacity (compared to a untreated cell) upon cycling without further treatment. The low frequency had little effect on the discharge voltage levels; shedding is much less than for 21 kc./sec. The addn. of LiOH 1-5 g./l. or Na_2S 0.1 g./l. to the electrolyte was found to increase the capacity of an Ag electrode exposed for 30 min. to the ultrasound even further, to 40%. After 50 ordinary charge-discharge cycles, the capacity of the Ag electrode is still 30-35% higher than for an untreated electrode. The voltage of the Cd electrode during charge remained const. at 0.3 v. for 30 min., rose to a peak somewhat > 0.6v., and then dropped to a level slightly < 0.6 v. When the application of the ultrasound was started at the moment of the change in voltage, there was no effect upon the peak, but a redn. in the 2nd voltage level, by 40-50 mv. This procedure resulted in a capacity increase of 15-20% in the following cycles without further treatment. The acoustic waves, apparently, increase the effective surface of the active material. It is assumed that the charge of the Ag electrode proceeds 1st to Ag_2O and then to AgO, and that AgO cone near the terminal lead. The sound waves change the behavior of the Ag_2O (semiconductor) and cause a dispersal of the AgO throughout the vol. of the active material.

B-279

Batteries and electric cells, secondary: introduction. W. W. Jakobi (Gould-Natl. Batteries, Inc., Minneapolis, Minn.). "Kirk-Othmer Encycl. Chem. Technol., 2nd. Ed. 3 ," 161-71(1964) (Eng.).

A review on design features, terminology, and advantages of alk. secondary cells. 3 references.

B-280

Electrochemical reduction of iron oxide in electrodes of alkaline batteries. N. A. Vozhova and L. L. Kuz'min. "Zh. Prikl. Khim" 39(3), 573-6(1966)(Russ.).

The direct formation of pocket-type electrodes prepd. from a hematite without preliminary thermal redn. was studied. The ore contained Fe_2O_3 98.7, Mu 0.013, Si 0.5, Al 0.06, Ca 0.023, insol. residue 0.8%. Briquets were pressed from the ore and then cathodically reduced in alkali. The redn. was more effective at a c.d. of 0.10 amp./cm.^{2} but satisfactory results were obtained at 0.025 amp./cm^2 by extending the redn. time to 15-20 hrs. The optimum NaOH concn. at 70° was 30%.

B-281

A stable high-valency nickel oxide. P. Bro and D. Cogley (P. R. Mallory & Co., Inc. Lab. for Phys. Sci., Burlington Mass.) "J. Electrochem. Soc." 113(6), 521-5(1066)(Eng.)

A high-valency amorphous Ni oxide prepd. by the hypochlorite oxidn. of Ni nitrate exhibited a mixt. of oxidn. states characterized by a mean Ni valency of ~3.5. The high-valency amorphous oxide was stable in strongly alk. solutions, but it decompd. rapidly below pH 9. The oxide discharged efficiently when used as a cathode in an alk. primary cell.

B-282

Overvoltage of oxygen on cadmium in alkali solutions. L. A. L'vova. "Tr. Moledykh Uchenykh, Saratovsk. Univ., Vyp. Khim., Saratov 1965," 12-20 (Russ.)

Anodic generation of O on Cd was studied over wide temp. and alkali concn. ranges by plotting potentiostatic and galvanostatic polarization curves, and by direct measurement of the amt. of generated O. Anodic generation of O on Cd has 2 potential regions which differ sharply from each other with respect to the mechanism of the process. The real activation energy of anodic generation of O on a Cd electrode in concd. KOll solns. was detd. The process is limited by the electrochem. stage. At all temps. the process was accompanied by considerable oxidn. of the Cd electrode surface. From "Ref. Sh., Khim. 1965" Abstr. No. 24L21G.

B-283

Battery casing with unproved seal and vent. Glenn N. Howatt and Bernard B. Herman (to Gulton Industries, Inc.). U.S. 3,256,117 (Cl. 136 178), June 14, 1966, Appl. Sept. 25, 1963; 4 pp.

The invention is best suited to a battery casing consisting of 2 casing parts positioned in confronting relation. One of the casing parts may comprise an open-ended casing body contg. battery plates and a separator for the plates impregnated with an electrolyte for providing a d.c. voltage across the plates, and a cover for the open end of the casing. A sealing ring made of a soft resilient insulating material (a S-free neoprene) is mounted between the cover and the rim of the open end of the casing body to form a seal and to insulate the cover from the casing body.

B-284

Chemical formation of positive nickel electrodes. Gould-National Batteries, Inc. (by Claude J. Menard). Fr. 1,410,464 (Cl. H "01m'), Sept. 10, 1965; U.S. Appl. Oct. 2, 1963; 8 pp.

$Ni(OH)_2$ can be produced in porous Ni plates previously impregnated with Ni^{2+}, e.g., with $Ni\ (NO_3)_2$, by immersion in an aq. soln. of 4-7 wt. % NaOH and 9-10 wt. % NaOCl (09-110g. free Cl/l.) at 20-35° for 30 ± 2.5 min. followed by immersion in an aq. soln. contg. 1 part NeOH to 13 parts NaOH at 1%, at 20-35° for > 5 min. followed by washing. The plates are suitable for use in Ni-Cd batteries.

B-285

Alkaline batteries. Masayoshi Matsui. Fr. 1,418,424 (Cl. H 01m), Nov. 19, 1965. Appl. Nov. 25, 1964; 9 pp.

A battery capable of yielding high currents for short periods of webbing carrying a deposit of $Ni(OH)_2$ of $Cd(OH)_2$ as the active material. These are arranged in a pile, the pos. and neg. plates being sepd. by films of a suitable material soaked in electrolyte. The entire assembly is submitted to a pressure of 10-50 $kg./cm^2$ to compress the active deposits. The active layers are 0.04-0.4 mm. and 0.03-0.4 mm on the pos. and neg. plates, resp. The ratio of the discharge capacity on the neg. plates to that on the pos. plates is 1.0-4.0. The discharge capacity is 0.068-0.092 amp.-hr./cc. or 0.020-0.025 amp.-hr/g. At the current c which discharges the battery in 1 hr., the power yeild is 0.085-0.100 w.-hr./cc. or 0.025-0.028 w.-hr./g. At 100c, these values become 0.0075-0.0096 2.-hr/cc. or 0.0022-0.0026 w.-hr./g. J. R. Boyack

B-283

Battery Casing with Unproved Seal and Vent. Glenn N. Howatt and Bernard B. Herman (to Gulton Industries, Inc.). U.S. 3,256,117 (Cl 136 178) June 14, 1966, Appl. Sept. 25, 1963; 4 pp.

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B-285

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A battery capable of yielding high currents for short periods of time is composed of electrodes consisting of metal sheet or webbing carrying a deposit of $Ni(OH)_2$ or $Cd(OH)_2$ as the active material. These are arranged in a pile, the positive and negative plates being separated by films of a suitable material soaked in electrolyte. The entire assembly is submitted to a pressure of 10-50 $kg./cm.^2$ to compress the active deposits. The active layers are 0.04-0.4 mm. and 0.03-0.4 mm. on the positive and negative plates respectively. The ratio of the discharge capacity on the negative plates to that on the positive plates is 1.0-4.0. The discharge capacity is 0.068-0.092 amp. hr./cc. or 0.020-0.025 amp. hr/g. At a current c which discharges the battery in 1 hour, the power yield is 0.085-0.100 w.-hr./cc. or 0.025-0.028 w.-hr./g. At 100c these values become 0.0075-0.0096 w.-hr./cc. or 0.0022-0.0026 w.-hr./g.

B-286

The formation of nickel oxides during the passivation of nickel in relation to the potential /pH diagram. T. S. DeGromoboy and L. L. Shreier (Sir John Cass Coll., London). "Electrochim. Acta 11 (7)," 895-904(1966)(Eng.)

Potentiostatic studies of the anodic polarization of Ni and Ni in acid solns. have revealed that traces of impurities result in curves that have more than 1 passivation potential. With a galvanostatic technique. it has been shown that the potential arrests, which are linearly related to pH, correspond to the several reversible metal-oxide/metal potentials. The different passivation potentials are therefore thought to be due to direct oxidn. of Ni to one or other of the oxides NiO, Ni_3O_4, Ni_2O_3, and NiO_2, 27 references

B-287

Anodic oxidation of cadmium and reduction of cadmium hydroxide and oxide in alkaline solutions. M. W. Breiter and J. L. Weininger (Gen. Elect. Co., Res. & Devel. Center, Schenectady, N.Y.). "J. Electrochem, Soc." 113(7), 651-5 (1966)(Eng.)

The anodic oxidn. of smooth Cd and the subsequent redn. of Cd hydroxide and oxide were studied by voltammetric methods with and without superimposed a.c. voltage. Under voltammetric conditions, a layer of $Cd(OH)_2$ appears to be formed at potentials below the passivation potential. Passivation results from a continuous thin film which forms at potentials between 0.05 and 0.1 v. The small capacitance and the large resistance of the interface electrode/solu. are due to this film. On redn. the thin film is reduced 1st. A pseudocapacitance which is attributed to the absorption of OH radicals is observed during the anodic sweep in a potential range where formation of $Cd(OH)_2$ or CdO is not yet possible. 16 references.

B-288

Nickel hydroxide electrodes. I. Nickel(II) hydroxide hydrate. II. "Bode K. Dehmelt, and J. Witte" (Hauptabteilung Forschung Varta A.-G., Frankfurt/M., Ger.). "Electrochim. Acta" 11(8), 1079-87(1966)(Ger).

Exptl. results leading to a new understanding of reactions and reaction products on the Ni oxide electrode of the alk. storage battery are reported. The 1st communication deals with a hitherto unknown compd. of bivalent Ni, which is genetically similar to the oxidn. products found on a charged Ni oxide electrode.

B-289

Use of a multichannel analyzer as a data acquisition system in electrochemistry. George Laner and R. A. Osteryoung (N. American Aviation Sci. Center, Thousand Oaks, Calif.). "Anal. Chem. 38 9," 1137-40(1966)(Eng.)

The described multicannel analyzer with digital readout has been used in chronocoulometric studies of electrode adsorption and kinetics ("ibid." 1106-12). Digital readout is obtained with either a voltage-to-frequency converter (V-F-C) or an internal analyzer anlog-to-digital converter (A-D-C). For a fixed voltage input, the no. of counts recorded by the V-F-C decreases as the sampling rate increases, while that recorded by the A-D-C is independent of the sampling rate, up to a limit depending on the conversion time.

B-290

Reducing the self-discharge of an alkaline iron-nickel storage battery. State All-Union Scientific-Research Battery Institute (by T. K. Teplinskaya, Z. V. Scherbakova, S. A. Rosentsveig, V. N. Drobyshevskii, and L. A. Byzina). U.S.S.R 180,223 (Cl. H 01m), March 21, 1966. Appl. Aug. 13, 1964.

The battery, contg.a neg. electrode made of an iron-ore mass, is subjected to a charge-discharge treatment for its prepn. for storage. To increase the residual capacity of the battery after storage in the charged state and to reduce the rate of dissoln. of the Fe electrode during storage, the battery is subjected to one final discharge (to a potential of the Fe electrode of 2 v. maintained for 0.5-1.5 hrs.) and then to one intensified charging cycle, by adding 150-200% of the capacity, removed in the preceding discharge. From "Izobret., Prom. Obrazisy, Tovarnye Znaki 43(7), 22(1966)."

B-291

Anodic behavior of silver single crystals in alkaline solution. Guido Poli, Zolia Siedlecka, and Bruna Rivolta (Politecu., Ist. Chim. Fis. Elettrochime Met., Milan). "Rend. Ist. Lombardo Sci. Lettere," A 97, 631-8(1963)(Ital).

An amperostatic method was used to study the behavior of Ag single crystal surfaces which were oriented at 25^{o} in 0.1N NaOH according to the (100), (110), and (111) planes. Before the test the elecrodes were chem. polished in a solu. of 100 parts 0.2M KCN and 2.5 parts 30% H_2O_2 and afterwards washed with KCN solu. then with H_2O. The c.d. was 0.1 ma./cm^2. The orientation effect of the electrode surfaces on the measurement results could not be established. On the current-voltage curve at 0.4-1.2 ma./$cm.^2$ a linear relation with the overvoltage values was found, which corresponds to the formation of Ag_2O. At c.d. of approx. 0.4 ma./$cm.^2$ a sudden increase appeared at which a max. value of 700 mv. was reached. In time it was stabilized at 620 mv., corresponding to the formation voltage of AgO. A linear voltage increase, which reached 650 mv. at 1 ma./$cm.^2$ was again observed at c.d. 0.4-1.2 ma./$cm.^2$. Another sudden voltage increase occurred at even higher c.ds., whereupon the addnl. increase was again linear, at values which correspond essentially to the development of O. Electron diffraction studies showed that Ag_2O forms at low c.ds., whereas AgO forms at high c.ds. At (111) and (100), Ag_2O appeared generally as a single crystal, sometimes with slight, azimuthal disorientation. The (111) plane of Ag_2O was parallel to the level of the substrate in both cases. At the (110) level Ag_2O was always polycryst. without any preferred orientation. AgO was always polycrystd., often with preferred orientation of (113) at the (110) level of Ag. A preferred orientation of the other 2 Ag levels could not be established. From CZ 136(42), Abstr. No. 297(1965).

B-292

Problems associated with the manufacture of nickel-cadmium batteries. L. Horn (Varta G.m.b.H., Hagen, Ger.) "Chem. Ingr. Tech." 38(6), 660-4(1966)(Ger).

The most important development in these has been the introduction of sintered plates. Problems arise particularly in the introduction of the active mass in the sintered holders. Description are given of the chem. pptn. technique and the electrochem. process. Rational processing is important for acid Pb batteries to maintain neg. plates and for the dry charged batteries. In the production of Pb powders the ultrasonic pulverization process opens up a completely new field.

B-293

Nickel-cadmium batteries in Telstar satellites. D. C. Bomberger, D. Feltman, and L. F. Moose (Bell Telephone Labs. Inc., Whippany, N. Y.). "Chem. Ingr. Tech." 38(6), 665-71 (1966)(Ger.).

These batteries must withstand many charge-discharge cycles and overloads in their life. Most suitable are the Ni-Cd batteries which give reliable service between -10 and 32^{o}, because they are well sealed they do not loose electrolyte, and therefore have a long life. Details are given about the development program, the construction of the cells and the testing program to which they were submitted. They have already proven themselves, and the 2nd Telstar satellite has given 2 years of satisfactory service.

B-294

J. P. Harivel, B. Morignat, J. Migeon, and J. F. Laurent, Societe des Accumulateurs Fixes et de Traction, "Physical Chemical Mechanisms of Oxidation-Reduction of Electrodes Impregnated with Cadmium Hydroxide," Chem. Ingr. Tech., 38 (6), 671-675 (1966).

B-295

Hermitally sealed secondary batteries. Karl Kordesch (to Union Carbide Corp.). U.S. 3,258,360 (Cl. 136-6), June 28, 1966, Appl. June 27, 1962, 4 pp.

A Pb-acid battery is provided with a catalyst chamber to promote the recombination of the H and O gases which are evolved during discharge. This recombination prevents an increase in internal pressure during charge-discharge cycles. The catalyst is Rh(80 wt. %)-Pd(20 wt. %) deposited on activated charcoal (0.5 mg. metal/g. carbon).

B-296

Alois Langer, Earl A. Pantier, and Sidney Barnartt, Westinghouse Electric Corporation, "Electrodes for Secondary Storage Batteries," U. S. Patent 3,262,815 (July 26, 1966), Application, August 11, 1964

This type of electrode exposes a large area of active material which also constitutes a major portion of the weight of the electrode. The supporting and conducting structural member is a grid of compacted, essentially parallel, metal fibers, such as steel wool. This grid may be placed with another metal for improved operation. A larger amount, by weight, of an active electrode material is then disposed upon and within the interstices of the compacted flat grid. Than an electrolyte-permeable sheet wrapping is applied to enclose the grid and its active electrode material. An elec. lead is then affixed to the fiber ends of the grid. A good method of adding the active material to the grid is to apply it as a paste, or to strain it through the grid, with the particles being retained in the fine interstices. Various components of active material are given for this type of electrode for use in an alk. (KOH) storage battery. The principal batteries discussed consist of positive plates containing active electrode material of Ag oxide, Ag oxide with additives, of Ni hydroxide, and a negative electrode containing $Cd(OH)_2$ with additive material. Ag-oxide electrodes containing an additive of Ni hydroxide showed efficiencies as high as 80% which remained 70% for 80 consecutive cycles of charging and discharging. Poorer results were obtained without the Ni additive. A continuous-process flow-sheet is presented, along with curves and sketches of the electrode and battery. 16 references.

B-297

Terminal system for leakproof electrochemical generators. Renato Di Pasquale and Otto C. Wagner (to Yardney International Corp.). U.S. 3,262,818 (Cl. 136-135). July 26, 1966. Appl. Sept. 25, 1963, 4 pp.

A leakproof joint between a metallic terminal and a synthetic-resin cell casing is obtained by using a terminal of porous sintered metal that has been impregnated with an elec. insulating synthetic resin readily bondable to the casing. For example, the shape of the terminal can be that of a flanged cylindrical plug, such that the small-diam. section can be snugly fitted and cemented into a hole in the casing, and the flanged portion firmly cemented to the surface of the casing. Each end of the plug is first abraded to remove the outer layer of plastic to assure that these protruding ends are clean metallic conductors, while the other plastic-coated surfaces can be heat-sealed to the cell casing. Sketches of a button-type cell and various modifications of terminal and cell design are shown.

B-298

Nickel-matrix cathodes. Telefunken A.-G. (by Manfred Tischer and Walter Held). Ger. 1,214,793 (Cl. H 01_j), April 21, 1966, Appl. Feb. 25, 1965; 3 pp.

Cathodes, esp. those of large surface area, were prepd. by mixing alk. earth nitrates with a Ni carbonyl of small mesh; on stirring, alk. earth carbonates were pptd., the resulting powder pressed on a hydraulic press, and sintered in H at 1100-1350° for 20 min. The carbonates were further converted to alk. earth oxides by re-hardening the electrodes in a press at 1100-1250° in H, followed by annealing at 110-1200° in a H flow of 3-400 l./hr.

B-299

Nickel electrodes for alkali cells. Horst Scheibe. Ger. (East) 45,392 (Cl. H 01m), Jan. 20, 1966, Appl. April 8, 1965; 3 pp.

Porous and mech.-stable Ni electrodes for alkali cells are prepd. by a redn. process. Thus, commercial-grade hydrated $NiCl_2$ was dried at 130° for several hours, pulverized, sieved, and pressed into flat rectangular plates. These were heated for 2 hours at 450° in a reducing atm. of 3:1 N:H. The stability was increased by subsequent sintering though with some loss of porosity.

B-300

Activated nickel-foil for use as electrode in alkaline batteries. International Nickel Ltd. Neth. Appl. 6,514,589 (Cl. II 01m), May 17, 1966; Brit. Appl. Nov. 16, 1964; 3 pp.

Ni foil (0.025-0.125 u) for smaller batteries can be activated by anodic treatment in an electrolytic soln. of $NaHCO_3$ when the Ni foil is in contact with an inert, porous, elec. non-conductive membrane during the activation. The Ni foil may be covered with a material made of nylon, polyethylene, poly(vinyl chloride), polystyrene, glass, etc. (porosity 5-200 u). To obtain a uniformly activated layer a texture with uniform porosity should be used. This activated Ni foil may be further subjected to anodic treatment in the absence of the membrane. Thus, Ni foil was immersed as anode in a soln. contg. 90 g./l. $NaHCO_3$. The foil was covered with porous polyethylene, thickness 0.8 mm., size of pores 50 u, max. passage of air of 150,000 l./min./$cm.^2$ at a pressure of 203 mm. water. The soln. was kept at 60°, and the pH was kept const. by passing CO_2. Using a c.d. of 200 uamp./$cm.^2$ for 2 hours the activated foil showed a capacity of 10 uamp. hrs./$cm.^2$. The activated foil was subjected to the same treatment for 4 hours, but without using the membrane, and showed a capacity of 25 uamp. hr./$cm.^2$.

B-301

Erminio J. Settembre, U. S. Army Electronics Laboratories, Standard Line of Secondary Batteries. Proceedings of the 18th Annual Power Sources Converence (May 19-21, 1964), pp 41-43.

This program will yield a standard line or family of alkaline batteries consisting of the following:

A. 144 possible power supplies in,
B. 12 battery case sizes to furnish,
C. 6, 12, and 24 volts in,
D. a range of capacities from 3.5 to 200 AH in,
E. vented and sealed structures.

In conclusion, the standard line of alkaline batteries has left the design phase and is being developed into an available line of secondary batteries which will make possible operation under extremely diverse conditions with greater reliability and simplified logistics and maintenance.

B-302

E. B. Cupp, Eagle-Picher Company, "Sealed Nickel-Cadmium Batteries," Proceedings of the 18th Annual Power Sources Conference (May 19-21, 1964), pp 44-46.

B-303

H. H. Kroger, General Electric Company, Characterization of Sealed Nickel-Cadmium Cells. Proceedings of the 18th Annual Power Sources Conference (May 19-21, 1964), pp 46-50

The objective was to study the influence of the amount of the electrolyte, of the concentration of the electrolyte and of the separator materials respectively, on the pressures, potentials and capacities of sealed nickel-cadmium cells over an extended period of time. At the ranges of variables and the temperature investigated, and the number of cycles achieved, it was found that:

1. The initial capacity increased with increasing amounts of electrolyte and went through a minimum with increasing concentration of electrolyte.
2. At any cycle the maximum absolute pressure and the maximum difference in pressure was increased with increasing amount and concentration of the electrolyte.
3. In cells with the smallest amount and concentration of electrolyte, the maximum absolute pressure and maximum difference in pressure did not follow the general upward trend.
4. No systematic influence of amount and concentration of electrolyte and separator material on end of charge and end of discharge voltage could be detected.
5. The state of the electrodes was generally enhanced by the increasing amount and concentration of the electrolyte.
6. A reconditioning charge temporarily broke the downward trend in the state of negative electrodes.

B-304

R. C. Shair, John Liska, and Guy Rampel, Gulton Industries, Inc., Silver-Cadmium Batteries. Proceedings of the 18th Annual Power Sources Conference (May 19-21, 1964), pp 50-54

The paper presents discussion on the following subjects:

Recent developments in Separator Systems and Electrode Construction
Charge and Discharge at Various Rates and Temperatures

Enhanced Overcharge with Adhydrodes

Cycle Life

B-305

G. A. Dalin, M. Sulkes, and Z. Stachurski, Yardney Electric Corporation, "Sealed Silver-Zinc Batteries," Proceedings of the 18th Annual Power Conference (May 19-21, 1964), pp 54-58.

The principal objective of this program is the development of silver-zinc batteries which can function sealed over a wide range of conditions. As is generally the case with electrochemical systems, gases may be produced in normal operation. Difficulty arises only because the silver-zinc cell requires semi-permeable separator and a substantial amount of free electrolyte which is needed for satisfactory charge and discharge. The free electrolyte and the membranes hinder access of gas to the electrodes and thus decrease the rate at which gas recombination takes place. The problem of the pressure rise which may ensue is only one phase of the program but the information which has been developed appears to us to warrant presentation at this time. In this study we have aimed at determining fundamental mechanisms, because an approach through specific devices can be inconclusive. In summary, gas recombination rates, while relatively low, are nevertheless rapid enough to keep pressures within tolerable limits, especially where cells are designed for this objective. Cells now being cycled are yielding results consistent with this view.

B-306

W. N. Carson, Jr., General Electric Company, "Charge Control for Secondary Batteries. Part 1--Auxiliary Electrode for Charge Control," Proceedings of the 18th Annual Power Source Conference (May 19-21, 1964), pp 59-61.

We use a proprietary fuel-cell oxygen electrode for the auxiliary electrode. In use, this is connected through a control circuit impedance to the cadmium electrode. The electrode gives a large signal upon the onset of oxygen evolution in the cell. Figure 1 shows the typical responses of the auxiliary electrode at the 2C charging rate at room temperature. This test was run on a 2 AH cell with a 3 cm^2 auxiliary electrode area. The pressure rise at 105% charge was less than 10 mm. The circuit is shown schematically at the top of the figure. This general response is shown in cells charged from 0.5C to 10C rates at temperatures from 10 C to 42 C, for all depths of previous discharge. The magnitude of the voltage rise is a function of the ratio of auxiliary electrode area to circuit impedance but is almost independent of oxygen pressure above a few millimeters. The very large signal plus the impedance matching characteristics available in the electrode design make possible the use of simple charge circuits using electromechanical or solid state relays or current controls.

B-307

H. N. Seiger, R. C. Shair, and P. F. Ritterman, Gulton Industires, "Charge Control for Secondary Batteries. Part 2--The Adhydrode in Charge Control," Proceedings of the 18th Annual Power Sources Conference (May 19-21, 1964), pp 61-64.

Three VO-oHS cells with Adhydrodes were used for tests designed to obtain information on charge rate, temperature and state-of-charge. These cells were cycled manually to stabilize capacity, and then were charged at 5 different rates ranging from C/10 to C, and at 4 different temperatures ranging from) C to 55C. Measurements were taken of pressure and Adhydrode currents during charge. Discharges were run at 3A to 1.0 volt cut-off. Six other cells of the kind described above were placed in an automatic cycle routine. The "orbit" was 100 minutes. The cells were discharged at 4.5 amperes for 40 minutes, which corresponds to a 50% depth of discharge. The charge circuit delivered 5.4 amperes. Although this current was available for 60 minutes, the cells could place themselves on open circuit. The Adhydrode was connected to the negative electrode through a meter relay. This relay, when tripped by the Adhydrode current, opened one leg of the charge circuit.

B-308

Frank J. Cocca, P. R. Mallory & Company, Inc., "Charge Control for Secondary Batteries. Part 3--Stabistors--Their Application in Battery Operation," Proceedings of the 18th Annual Power Sources Conference (May 19-21, 1964) pp 65-67.

The work described has demonstrated that nickel-cadmium cells can be protected at high charge rates and large depths of discharge. This method of protection is particularly adapted to applications in which batteries are used in a cyclic charge and discharge manner. The stabistor will slowly discharge a cell on open circuit stand and will completely discharge the cell after several days. If intermittent cycling is required, then the stabistor should be removed from the cell after full charging.

B-309

Eugene R. Stroup and Armin O. Apelt, National Aeronautics and Space Administration, "Secondary Battery Evaluation Program," Proceedings of the 19th Annual Power Sources Conference (May 18-30, 1965), pp 56-58.

The paper presents discussion on the following subjects:

Program Philosophy
Test Cells
Acceptance Tests
Performance Tests
Life-Cycle Testing
The Test Cycles
Charging Controls and Limits
Test Temperatures
Depth of Discharge
Failure Analysis
Test Results
Conclusions and Recommendations

B-310

Charge control of nickel-cadmium batteries. Auxiliary electrodes for overcharge and overdischarge control. A. J. Catotti and M. D. Read. "Proc., Ann. Power Sources Conference" 19, 63-6 (1965).

A large gas electrode connected to a very low resistance to the Cd electrode is used to recombine H evolved from the Ni electrode upon overdischarge (cell reversal). This large gas electrode provides improved charge control when used in conjunction with a smaller gas control electrode connected to the Cd electrode by a low resistance. The larger electrode acts as getter for small amts. of O evolved before the Ni electrode is completely charged. A signal appears on the control electrode only when O is evolved at an appreciable rate.

B-311

Charge control of nickel-cadmium batteries. R. E. Amsterdam. "Proc. Ann. Power Sources Conf." 19 66-9(1965)(Eng.)

The forward voltage-current characteristics of the Amp-Gate diode are used to equalize the voltage across individual cells in a battery during charge. The diode acts as a voltage-sensitive gate which shunts the charging current around the cell when the cell voltage reaches a definite value.

B-312

G. A. Dalin and M. Sulkes, Yardney Electric Corporation, "Sealed Zinc-Silver Oxide Batteries. Part 1," Proceedings of the 19th Annual Power Sources Conference (May 18-20, 1965), pp 69-73.

> Summing up our results on sealed silver-zinc, a number of developments have produced an increase in reliability and usefulness. These are:
>
> 1. Increased positive utilization and reliability through lower density and higher content of electrolyte in the electrode itself and in the adjacent interseparator.
> 2. Decrease negative shape change and decreased sponging as the result of binding with Teflon and removal of free electrolyte from the negative.
> 3. Increased cycle life stemming mostly from the more stable negative and increased oxygen recombination rate stemming from absence of free electrolyte on the negative.
>
> In none of the above developments has the energy density been adversely affected.

B-313

G. M. Wylie, Electric Storage Battery Company, "Sealed Zinc-Silver Oxide Batteries. Part 2," Proceedings of the 19th Annual Power Sources Conference (May 18-20, 1965), pp 73-76.

> The Model 205 Surveyor Battery is the prime energy storage device in the Surveyor power system. It operates in parallel with a solar panel to provide power for transit and lunar operations. The battery is sealed and consists of 14 series-connected, rechargeable, silver oxide-zinc cells. The cells are assembled in a magnesium canister and the total assembly weighs 46.2 pounds. The battery is approximately 8.75 inches high, 10.16 inches long (plus mounting and connectors) and 6.6 inches wide for a volume of 587 in^3.
>
> Mean voltage (volts): 21
> Nominal capacity (AH): 170
> Special energy (WH/): 80
> Energy Density WH/in^3): 6.3

B-314

J. J. Lander and J. A. Keralla, General Motors Corporation, "Sealed Zinc-Silver Oxide Batteries. Part 3," Proceedings of the 19th Annual Power Sources Conference (May 18-20, 1965), pp 77-80

Preliminary testing of acrylic acid-grafted polyethylene and teflon showed that these materials (0.001" thick) could be made with suitable conductivities and, moreover, were extremely resistant to degradation in hot strong alkali and did not "pick up" enough silver to become electronically conducting. Furthermore, it was believed that the pore sizes in these materials were at least comparable to those of the semi-permeable cellulosics. On these accounts, it was considered that they provided a suitable basis for development as exceptionally thin separators suitable for long-lived secondary silver-zinc batteries.

B-315

G. D. Nagy, W. J. Moroz, and E. J. Casey, Canadian Defense Research Board, "Studies on the Stability of Oxides of Silver," Proceedings of the 19th Annual Power Sources Conference (May 18-20, 1965), pp 80-85

The goal of the work was a better understanding of the mechanism of thermal decomposition of silver-oxides themselves, i.e., without stabilizing ligands. A start was made on a method of characterizing chemically-prepared AgO, both from the theoretical and experimental standpoints. Some new information is reported on preparation and properties of anodically formed wet "Ag_2O_3."

B-316

Autoradiographic investigation of current distribution on plates of lead batteries. I. H. Bode and J. Euler (Zentral-Lab., Varta-A.-G., Frankfurt/M (Ger.) "Electrochim, Acta 11(9)", 1211-20 (1966) (Ger).

Pos. grid plates of Pb-acid accummulators are discharged in labelled H_2SO_1. A distribution of the radiation, of the surface of the plate results from this procedure, giving an image of the distribution of current; characteristic patterns can be seen. At the beginning and shortly before the end of the life of the plates small surface singularities, almost points can be recognized, whereas the distribution of the activity is almost uniform for most of the life.

B-317

Autoradiographic investigation of current distribution on plates of lead batteries. H. H. Bode and J. Euler (Zentral-Lab., Varta-A-G., Frankfurt/M, (Ger.). "Electrochim, Acta 11(9)," 1221-9 (1966) (Ger): cf. preceding asbtr.

Particularities that appear during the autoradiographic investigations of the current distribution on grid plates of Pb acid accumulators are reported. The plates were labelled with ^{25}S and ^{75}Sc.

B-318

Effect of inclusion of nickel hydroxide in the active material of the negative plate of a sintered type nickel cadmium battery. R. Vijayavalli, P. A. Vasndeva Rao, and H. V. K. Udupa (Central Electrochem. Res. Inst. Karaikudi). "J. Electrochem Soc. India" 15(2), 40-3 (1966) (Eng).

Ni salts formed by dissoln. of sintered Ni plaques immersed for impregnation accumulated in the Cd salt solution and ultimately are pptd. on the negative plates of Ni Cd batteries as Ni $(OH)_2$. This is an impurity on the negative plates affecting their performance. A study of the effect of addition of various amounts of Ni salts to the Cd salts showed that the capacity of the negative plate was reduced on cycling and self-discharge on standing also increased. Ethylene glycol addition minimizes Ni dissolution in the Cd salt solution used for impregnation. Gas evolution occurs much earlier on plates with $Cd(OH)_2$ + $Ni()H)_2$ than on plates having only $Cd(OH)_2$.

B-319

High-speed measurement of reversible electrode potentials. T. Hagyard and K. M. Chapman (Univ. Canterbury, Christchurch, N.Z.). "J. Electrochem Soc. 113(9)," 961(1966)(Eng.), cf. Cd 57, 5700h.

The potential of a Cd electrode, cut by a ruby in a solution of 0.001M $CdCl_2$ and M KCI, swept with H, was measured oscillographically. The active Cd potential was attained 10-30 usec after the instant of cutting the passivated electrode.

B-320

Theory of potentiostatic on and off-switching processes during electrocrystallization. K. J. Bachmann and K. J. Vetter (Freic Univ., Berlin). "Electrochim, Acta 11(9)," 1279-99 (1966) (Ger.).

A math. treatment of the time-dependence of c.d./overpotential curves for the anodic metal dissolution and the cathodic deposition processes ($M \leftrightarrows M^{z+} + ze^{-}$) under special conditions is given. The assumption has been made that the surface diffusion of adatoms (D, c_r) and the transfer reaction (i_0, a, z) are simultaneously rate-detg. and that parallel "growth step lines" at a distance 2ℓ (spiral growth on screw dislocations) and a dense concentration of kink sites, for which the equil. concn. of adatoms always exists, are present. The potentiostatic step $\eta \rightarrow \eta^*$ which includes the charging curve 0 → n and the discharge curve n* → 0 is treated through solving the partial differential equation for the surface diffusion with the required initial and boundary values. The theory of Fleischmann and Thirsk has thus been improved upon. An expanded and general definition of crystn. overpotential nk is given along with a discussion of the relation between the total overpotential η and the crystn. overpotential nk. The exptl. detn. of crystn. overpotential is further discussed.

B-321

H. Bode, Varta A.G., "Galvanic Sources of Current in the Past and Future," Chem. Ingr. Tech., 38 (6), 607-611 (1966) (In German).

The economic significance of the battery industry, its future tasks, and the more important fields of application for primary and secondary cells, e.g., as transportable source of current, as buffer batteries for voltage regulation, as emergency electricity supplies, and so on, are considered. An outline is given of the fundamental electrode processes taking place in various cell systems, and of the thermodynamically computable values for the voltage on open circuit and energy density.

B-322

E. C. Bruess, Quality Evaluation Laborator, U.S. Naval Ammunition Depot, "Capabilities for Testing Primary and Secondary Batteries," Report No. CE/C-65-538 (August 6, 1965). AD 481 870.

Organization and Personnel
Operations and Facilities
  Primary Batteries Section
  Secondary Batteries Section
Capabilities of Technical Services Division
  Environmental Test Facilities
  Science Branch Facilities
  Mathematical and Statistical Branch Facilities
Calibration

B-323

W. H. Metzger, Jr., and J. M. Sherfey, Metallurgy Division, National Bureau of Standards, "Electrochemical Calorimetry. III. Thermal Effects of Nickel-Cadmium Batteries," Electrochemical Technology, 2 (9-10), 285-289 (September-October 1964).

> Calorimetric measurements were made during various charge-discharge cycles of nickel-cadmium cells proposed as satellite power sources by the National Aeronautics and Space Administration (NASA). Typical curves of heat changes as a function of time during operation are shown and discussed. The heat of reaction of oxygen with the constituents of the cell was measured and agreement was obtained with the literature value for the heat of formation of cadmium oxide.

B-324

Thedford P. Dirkse, Calvin College, "The Measurement of Zincate Diffusion Through a Membrane," Electrochemical Technology, 3 (3-4), 106-180 (March-April 1965).

> The diffusion rate of zincate ions through a membrane has been determined by a method using voltage measurements and another method using a radioactive zinc isotope. The voltage method is faster, but does not give as good reproducibility as the radioactive method. Measurements show that Fick's law of diffusion is applicable to this zincate diffusion.

B-325

Thedford P. Dirkse, Calvin College, "Cycling Characteristics of the Silver Electrode in Alkaline Solutions," Electrochemical Technology, 4 (3-4), 163-165 (March-April 1966).

> A study has been made of the effect of high current densities at room temperature on the cycling behavior of sintered silver electrodes in alkaline solutions. Further work has been carried out at temperatures below freezing. The silver electrode does not charge at 100% efficiency at high current densities at room temperature.

B-326

W. L. Ball, "Wider Uses in Sight for Nickel-Cadmium Batteries," Chemistry in Canada, 18 (5), 31-33 (May 1966)

At a seminar sponsored by the Defence Research Board, held last November at its Ottawa Laboratories, H. Sheffer stated that the DRB's main reason for organizing the seminar was to encourage and assist the Canadian battery industry to exploit the promising nickel-cadmium field. Defence Research Board scientists expect to reduce the cost and weight of sintered nickel plaque cells by using thinner plates having a higher proportion of active material to total weight in their "foil" battery. They prepare the "foil" for the negative plate by electro-depositing sponge cadmium from chloride baths on a cadmium-nickle substrate. A process for continuous production of low capacity positive plates by anodic oxidation of nickel foil was developed under a DRB contract with Johnson, Matthey and Mallory Ltd. The development of the sealed nickel-cadmium cell with its small voltage rise during charge and its inability to accept high overcharge stimulated interest in charge control devices. Several charge control devices already are in existence: (1) the Amp-Gate Diode, (2) the third Electrode System, and (3) the coulometer. The coulometers developed by DRB were made of sintered negative cadmium plates separated by a porous polyethylene film or woven nylon and cellophane. Defence Research Board's Power Source scientists believe that adoption of the coulmeter method of charge control will increase the applications of nickel-cadmium batteries. For instance, a portable charger/controller/battery unit to power a scintillation counter for measuring the effects of radioactive fallout amongst the Eskimo population has been built. The unit weighs 29 lb., operates off 100 volts ac, and contains 14 22-AH Ni-Cd cells plus coulometrically controlled charger. For a defense application the principle has been used to develop a source of pulses of high power, fast recharging being accomplished, under control, between pulses.

B-327

E. J. Casey, A. R. Dubois, P. E. Lake, and W. J. Moroz, Defence Chemical Biological and Radioation Laboratories, Canada, "Effects of Foreign Ions on Nickel Hydroxide and Cadmium Electrodes," Journal of the Electrochemical Society, 112 (4), 371-383 (April 1965)

The behavior of individual positive and negative electrodes of the sintered-plate nickel-cadmium battery system in the presence of foreign ions in KOH solutions has been examined. Carbonate choke: The variations of electrochemical capacity as a function of carbonate contamination of the electrolyte, temperature, and current density was measured for both positive and negative electrodes. The effect of carbonate on the negative cadmium electrode is much greater than on the positive. The general mechanism and the role of intermediate complexes are discussed. Nitrate shuttle: Self-discharge occurs in cells containing nitrate, as a result of reduction of NO_3^- to NO_2^- at the cadmium electrode with subsequent reoxidation of NO_3^- at the nickel hydroxide electrode. Cations on the positive: Addition of Ni^+, Ag^+ Sb^{+3}, and Al^{+3}, and As^{+3} to the electrolyte had effects on capacity and on charge-retention of well-formed nickel hydroxide positive electrodes. Lithium promoted the highest average oxidation, particularly at high temperatures (55C). Arsenic was the best inhibitor of loss of charge. Possible mechanisms are discussed.

B-328

C. M. Shepherd, U. S. Naval Research Laboratory, "Design of Primary and Secondary Cells. II. An Equation Describing Battery Discharge," Journal of the Electrochemical Society, 112 (7), 657-664 (July 1965)

A discussion is given of the derivation and application of an equation which gives an excellent description of a wide variety of cell and battery discharges. This equation gives the cell potential during discharge as a function of discharge time, current density, and certain other factors. It makes possible a complete description of cell discharge characteristics, using a minimum of experimental data and at the same time pinpointing experimental errors. It can also be used to describe cell charges, capacities, power evolution, and to predict capacities. A description is given of a simple numerical method for fitting this equation to a particular set of battery discharge curves. A graphical method is described for comparing characteristics of various types of cells.

B-329

J. C. Duddy and J. T. Arms, Electric Storage Battery Company, "Sealed Zinc-Silver Oxide Secondary Batteries," Proceedings of the 14th Annual Power Sources Conference (May 17-19, 1960), pp 84-87.

This paper covers the present state of development of the sealed silver-zinc secondary battery system which has resulted from rather extensive research efforts at the SBN Company. Figure 1 is a schematic cross-sectional drawing of a segment of a pile type battery. Early efforts in the development of the pile construction were associated with low rate designs, i.e., in the 30-40 hour discharge rate range. In the latter range, 6-cell stacks, having a nominal 5 AH capacity yielded 70 watt-hours per pound and 6.5 watt-hours per cubic inch. Figure 2 shows one such unit presently in use as the power supply for the accompanying radio. The energy stored therein is capable of providing power for a minimum of 500 hours operation prior to recharge. This sealed Ag-Zn battery powered radio has been in nearly constant use during the summer months as a navigational aid for a sport fishing boat and during the remainder of the year as a portable radio. Investigations have been made of the characteristics of scaled-up units with larger plate areas but otherwise similar in design to these batteries.

B-330

J. J. Lander, General Motors Corporation, "Sealed Zinc-Silver Oxide Batteries," Proceedings of the 15th Annual Power Sources Conference (May 9-10, 1961), pp 77-80

If the information obtained from the single cell is projected, it appears that a sealed battery could be made now with a cycle life of more than 500 cycles which would deliver 10 to 13 watts per pound. The mode of operation on which this estimate is based has involved charge-discharge cycles to a fixed number of ampere hours, i.e., about 20% of the rated capacity. At the present state of our knowledge, there is no reason to regard either 500 cycles or 13 watt hours per pound as limiting or near-limiting in either case. The degree of improvement predictable now is double in each case. Hopefully, life and energy yields can be extended beyond these predicted values.

B-331

J. A. Keralla and J. J. Lander, General Motors Corporation, "Sealed Zinc-Silver Oxide Batteries," Proceedings of the 17th Annual Power Sources Conference (May 21-23, 1963), pp 116-120

The data presented show that the zinc-silver oxide battery is capable of sealed operation over hundreds of cycles when internal pressure build up is controlled by limiting the charge voltage. Operation in this fashion is possible because Faradaic efficiencies for plate material utilization approaching 100% can be achieved. These data, although limited in testing scope in terms of cycle depth, temperature range, and time per cycle, provide a baseline for performance of this system and disclose areas for research and development to achieve increased performance. It can be seen when failure causes are examined, that they are all related to mass migration of the active material of the zinc plate. Therefore, increased cycle life performance should be sought by examining every possible approach to keeping the zinc in place. These include design features to control the current density distribution, overdesign in negative active material, expander research and separator research to discourage direct penetration of dendritic zinc.

B-332

R. C. Shair, H. N. Seiger, H. Cohen, A. Lyall, G. Rampel, and E. Kantner, Gulton Industries, Inc., "Design, Development and Manufacture of Storage Batteries for Future Satellites," Final Report (July 1, 1963), Goddard Space Flight Center Contract No. NAS 5-809. N65-17518.

The work originally contemplated under this contract was divided into three phases:

Phase I Fabricate and Test Advanced State of the Art Hermetically Sealed Nickel-Cadmium Cells

Phase II - Establish a Pilot Line for the Exclusive Fabrication of Hermetically Sealed Cells for Space Applications

Phase III Perform Fundamental Studies on Hermetically Sealed Cells

The initial effort was directed at fabricating the VO-6 HS cell so as to yield a mechanically sound and uniformly reproducible product. Initially the cell closure was achieved by heliarc welding but this caused a large percentage of losses of the ceramic-to-metal seal. An attempt was made to reduce thermal stresses by use of a cadmium solder, but the degradation of the solder in the caustic oxidizing environment plus the undesirable high vapor pressure of cadmium caused this technique to be abandoned. Experimentation in heliarc welding techniques coupled with methods to heat sinc the cells during welding led to a final perfected all welded can. For the VO-6 HS cell a drawn can was developed to reduce cell dimensions and to provide a more uniform package.

VO-6 HS cells were fabricated and their electrical performance observed in continuous repetitive 100 minute cycling routines. At 77°F, at a depth of 70%, 1500 cycles were achieved and at a depth of 50%, 4900 cycles have been reached and the tests continue.

Large size hermetically sealed nickel-cadmium cells were fabricated and tested. The VO-50 HS cell is the largest space cell available today. It has a capability of 18.4 watt-hours per pound. Mechanically it has been optimized for heat transfer and it contains a heavy duty ceramic-to-metal terminal closure.

Thin plate cells were fabricated and found to have enhanced properties for those cases where the performance is dependent on current density. The thin plate cells did not, however, offer any advantages in their watt-hour-per-pound performance.

The thermal aspects of hermetically sealed cells were studied. Temperature profiles were determined for several different temperatures and operating rates. A mathematical analysis was made to determine the optimum cell geometry based on thermal considerations. This was applied to the design of the VO-50 HS.

B-332
Continued

Studies were made of electrode impregnation techniques to improve plate loading without decreasing the coefficient of utilization of active materials.

A detailed fundamental study was made of the charge efficiency of sealed cells. Studies were made both of the negative and positive plates at various rates of charge and at various temperatures.

Fundamental research was carried out on the mechanism of oxygen reduction at the cadmium electrode. A new theory was advanced, postulating that the reduction is a chemical reaction between the oxygen and absorbed hydrogen generated on the nickel matrix of the negative plate. Experimental evidence was collected which substantiates the theory.

B-333

P. G. Garrett and S.E.A. Pomroy, Royal Aircraft Establishment (England), "Initial Assessment of Hermetically Sealed Nickel-Cadmium (VO-3-MS) Cells Manufactured by Gulton Industries, Inc.," Technical Report TN-64023 (October 1964). AD 457 271L.

An initial assessment of 3AH hermetically sealed nickel-cadmium cells (VO-3-HS) for use in the U.K.3 satellite battery was made. Twenty five cells were subjected to a test program consisting of leakage checks, measurement of several aspects of electrical performance including capacity, internal resistance, self-discharge rate, behaviour on overcharge, and charge-discharge cycling. Environmental tests were ALST.

B-334

Philip F. Grieger, Thomas A. Edison Industries, "Auxiliary Electrode for Charge Control of Sealed Nickel-Cadmium Batteries," Quarterly Progress Report No. 2 (December 1964), Contract DA-28-048-AMC-00152(E). AD 458 004

H2 evolution potential (N2 atmosphere) for unplatinized carbonized cloths and charging potential of a cadmium plate were determined. Using these and charge acceptance data previously obtained for a sealed cell, volume of H2 evolved before onset of O2 evolution was estimated for various cell charging rates up to 5c and found to be small; but analogous estimates indicate platinized cloths require a diode and/or resistance (possibly supplemental to that already present) in the signaling circuit. Unplatinized cloths when retested for O2 reduction performed more poorly but both tests are suspect. Thirty pieces of VCB grey, VCB or WCB black were plated from a given bath: weight of PT depos

B-335

P. H. Greenler, TRW Space Technology Labs, "Study of Sonotone Corp. Nickel Cadmium Size F Battery Cells," Final Report No. 2302-0003-RU-000 (May 1961), Contract AF 04(647)-302. AD 459 797

This report presents results and conclusions of tests performed on sonotone F cells which were employed in the pioneer V space vehicle.

B-336

E. Kantner, R. V. Tarantino, H. N. Seiger, and R. C. Shair, Gulton-Industries, Inc., "Investigation of Hermetically Sealed Maintenance-Free, High Rate, Nickel Cadmium Batteries for Aircraft Applications," Quarterly Technical Progress Report No. 3 (May 1965), Contract AF 33(615)-2087. AD 463 855

Studies on the effect of plate thickness on sealed cell behavior showed that thin-plate cells performed better at high rates. The improved performance of such cells is the result of reduced polarization, which is the predominant factor in determining cell voltage and capacity at high rates. A heavier plate backing support (and consequently, a more uniform plate current distribution) appears to have a greater effect on thin-plate cells when such cells are discharged at high rates. A CD/CD (OH)2 coulometer, at high rates, behaves similarly to a nickel-cadmium cell, and an average voltage drop of 0.7 volt can be expected from a coulometer constructed with 0.036-in. plates, during the first minute of a 600 ampere discharge. A breadboard model of the charge control circuit functioned properly, at medium currents, showing that the basic design of the circuit is correct.

B-337

F. Cocca and R. Amsterdam, P. R. Mallory and Company, Inc., "Call Equalization Techniques," Technical Report AFAPL-TR-65-21 (February 1965), Contract AF 33(615)-1342. AD 461 856

The utilization of stabistors for the protection of 4 AH, 5 AH, 12 AH and 20 AH Ni-Cd sealed cells has resulted in a definite increase in battery life. These cells were operated at a 90-minute cycle and at a depth of discharge of 75%. The results obtained from cycling 20 AH Ag-Cd and 25 AH Ag-Zn cells at a two-hour cycle revealed that stabistor protection of these cells was less effective than the protection offered Ni-Cd cells. Reversal studies on Ni-Cd cells show that the critical reverse gassing, voltage for most NiCd cells was about -0.2 volts. The anti-reversal diode was partially successful in protecting cell on reversal. The thermal characteristics of the stabistor were improved by the use of molybdenum backing plates. These disks have a coefficient of expansion very close to that of silicon and increase the stabistors resistance to "thermal fatigue" failure. Environmental testing of stabistors resulted in no failures after subjection and shock tests. The "end of contract" cells have been constructed with the stabistor and antireversal diode potted as part of the cell. Two different types of epoxy packages were constructed and the one that was chosen had a significantly lower temperature rise.

B-338

P. Howard, Yardney Electric Corporation, "Zinc-Silver Oxide Batteries," Proceedings of the 10th Annual Battery Research and Development Conference (May 23, 1956), pp 41-44

Figure II compiles a summary of progress made over the past ten years in the way of cycle life, both from the industrial side and from the Signal Corps development program. These values are given based on an actual loss in capacity of 20% during the cycle life. Therefore, it is seen that in both phases of the investigation great strides have been made in improving cycle life with a minimum loss in capacity.

B-339

G. W. Work and C. P. Wales, Naval Research Laboratory, "Instrumentation for Use in Storage Battery Studies," Journal of the Electrochemical Society, 104 (2), 67-70 (February 1957)

Instrumentation for use in a wide range of storage battery studies has been evolved. This storage battery analyzer features simplicity and accuracy of control, a wide scope of variables measured, and a complete continuous record. A null-balance servo system controls the output of the rectified d-c power supply at any desired current or voltabe by continuously regulating the a-c input. Individual plate potentials, temperature, gas concentrations, and gas volumes are continuously measured and recorded. Optional equipment permits additional types of automatic cycling or other use in varied applications. The possibilities of the use of such methods are briefly illustrated and discussed from data on some Ni-Cd cells.

B-340

Phyllis E. Lake and E. J. Casey, Defence Research Chemical Laboratory, "The Anodic Oxidation of Cadmium," Journal of the Electrochemical Society, 105 (1), 52-57 (January 1958)

Cadmium oxidizes anodically in hydroxide solutions to form films of reaction products which control the subsequent anodic processes. The electrometrics of film formation and reduction were determined, and various other definitive experiments were done which permit an interpretation of the general mechanisms of oxidation to be made. The film forms as CdO which is converted into $Co(OH)_2$ at a rate dependent upon various experimental factors.

B-341

T. P. Dirkse and Frank De Haan, Calvin College, "Corrosion of the Zinc Electrode in the Silver-Zinc-Alkali Cell," Journal of the Electrochemical Society, 103 (6), 311-315 (June 1958)

A study has been made of the factors that affect or bring about the corrosion of the zinc electrode in a silver-zinc-alkali cell. Cells containing 30% potassium hydroxide as electrolyte were used and kept at room temperature. Special attention was centered on open circuits or stand conditions. This corrosion is affected primarily by oxygen and by dissolved silver oxides.

B-342

Thedford P. Dirkse, Calvin College, "Composition and Properties of Saturated Solutions of ZnO in KOH," Journal of the Electrochemical Society, 106 (2), 154-155 (February 1959)

In many alkaline batteries a soluble zinc anode is used. This produces, on discharge, a solution of ZnO or zincate in the electrolyte. To deal with such solutions theoretically, it is often necessary to know the values for certain physical properties of such solutions. For that reason, saturated solutions of ZnO in KOH were prepared and studied at different temperatures.

B-343

Thedford P. Dirkse and Brandon Wiers, Calvin College, "The Stability and Solubility of AgO in Alkaline Solutions," Journal of the Electrochemical Society, 106 (4), 284-287 (April 1959)

Silver oxide is stable in boiling water and decomposes but very little at room temperature in strongly alkaline solutions. The presence of Ag_2O does not affect this stability, but the presence of unoxidized silver does increase the rate of decomposition. When AgO dissolves in strongly alkaline solutions the dissolved form is primarily AgO and $Ag(OH)_3^-$. The standard free energy of formation of the latter is -85,380 cal/mole^3.

B-344

T. P. Dirkse, Calvin College, "The Silver Oxide Electrode," Journal of the Electrochemical Society, 106 (5), 453-547 (May 1959).

A review has been prepared of the electrochemistry of the silver oxide electrode. The discussion covers the structure and electrochemistry of the oxides of silver and their behavior in batteries.

B-345

James F. Bonk and Alfred B. Garrett, McPherson Chemical Laboratories, The Ohio State University, "A Study of the Silver(I) Oxide-Silver(II) Oxide-Electrode," Journal of the Electrochemical Society, 106 (7), 612-615 (July 1959)

A reproducible emf of the cell Ag(c), Ag_2C(c)/NaOM, (1M)/AgO(c), Ag_2) (c), Pt is found to be 0.262 v at 25 C. From this value and the known potential of the Ag, Ag_2O electrode, the standard oxidation potential of the Ag_2O, AgO electrode is -0.604 v. The temperature coefficient of the cell is $+2.20 \times 10^{-4}$ v/deg. The free energy, enthalpy, and entropy changes for the cell reaction are -0040 cal, -4537 cal, and 5.07 cal/deg, respectively. From these values and the existing thermodynamic data on Ag and Ag_2O, values of 3463 cal, -2769 cal, and 13.51 cal/deg are calculated, respectively, for the free energy and enthalpy of formation and for the entropy of AgO at 25 C.

B-346

Phyllis E. Lake and E. J. Casey, Defence Research Chemical Laboratory, Defence Research Board (Ottawa), "The Anodic Oxidation of Cadmium. II. Electrical Properties of the Film," Journal of the Electrochemical Society, 106 (11), 918-919 (November 1959)

Cadmium electrodes under anodic oxidation in hydroxide and carbonate electrolytes have been examined by analysis of the decay of overpotential after current interruption. After passivation while oxygen is being evolved, except for a small instantaneous (<1 msec) ohmic drop, the potential decays longarithmically with time in the manner usually found for the decay of activation overpotential of a gas electrode. Before passivation while the metal is actively being oxidized, however, except for the small ohmic drop, the potential decays exponentially with time in two steps. This behavior is not described by activation theory. Determinations were made of the capacitance of both the oxidizing and the passivated cadmium, both from potential decay curves and from superimposed a.c. All the a-c values correspond to those of a normal double layer, as do those obtained from decay measurements after passivation has occurred. However, the values obtained from decay curves before passivation are two orders of magnitude higher early in the oxidation but drop rapidly toward the a-c values as oxidation proceeds. It is proposed that next to the Helmholtz double-layer at the CdO-electrolyte interface, there exists a highly polarized inner double-layer in which the reaction $OH^- \rightarrow O^- \div H^-$ takes place. When the field strength across the inner double layer becomes high enough for the reaction $OH^- \rightarrow OH + e^-$ to take place instead, oxygen is evolved and the electrode passivates. The roles of adsorption of OH^- to form the Helmholtz layer and of interference by $OO_3^{=}$ are discussed in terms of the results.

B-347

Thedford P. Dirkse, Calvin College, "The Oxidation of the Silver Electrode in Alkaline Solutions," Journal of the Electrochemical Society, 106 (11), 920-925 (November 1959)

The formation of Ag_2O and AgO was studied by means of constant current and constant potential processes. The efficiency of these oxide formations was determined by measuring the gain in weight of Ag electrodes under various conditions of charge, and the extent of the polarization of these processes was measured by using an interrupted current technique.

B-348

Thedford P. Dirkse, Calvin College, "The Cathodic Behavior of AgO in Alkaline Solutions," Journal of the Electrochemical Society, 107 (11), 859-864 (November 1960)

A study has been made of the discharge of AgO to determine why only a part of the discharge capacity of AgO is delivered at the potential of the AgO-Ag_2O couple and to determine the role of oxygen in this process. The difference in discharge capacity of electrodes produced by constant-current and by constant-potential anodization also has been studied. A mechanism involving the transport of $O^=$ ions through the electrode material and the reaction of these ions with the electrolyte is presented.

B-349

Charles P. Wales, U. S. Naval Research Laboratory, "The Silver-Silver Oxide Electrode. I. Anodic Oxidation in Alkaline Solutions," Journal of the Electrochemical Society, 108 (5), 395-400 (May 1961)

Silver electrodes were oxidized anodically at 25 C in 35 or 50% KOH at constant charge currents that ranged from the 1/2 to 40 hour rates. The electrodes were given both partial and complete charges. Except at a low charging rate the capacity was higher in 35% KOH than at 50% KOH. Oxidation was highly efficient at the first two potential plateaus. During a charge at the Ag_2O/AgO plateau initially Ag_2O oxidizes to AgO and then the prevailing reaction is Ag oxidizing to AgO. Simultaneously some AgO reacts with Ag to give Ag_2O. Under certain discharge conditions AgO may reduce directly to Ag, with Ag_2O forming as a secondary product.

B-350

R. F. Amlie and P. Ruetschi, the Carl F. Norberg Research Center, The Electric Storage Battery Company, "Solubility and Stability of Silver Oxide in Alkaline Electrolytes," Journal of the Electrochemical Society, 108 (9), 818-819 (September 1961)

The solubility of Ag_2O and AgO in alkaline electrolytes has been studied with a polarographic technique, using a rotating platinum electrode. Only a monovalent (and no divalent) silver species could be detected in solutions which had been in intimate contact with AgO powder over prolonged periods of time. Quantitative measurements of the solubility of Ag_2O in KOH solutions ranging from 1-14 moles per liter, were carried out utilizing a potentiometric titration method. The solubility has a maximum at about 6N KOH where it reaches a value of $4.8-10^{-4}$N. The rate of the decomposition reaction $2AgO - Ag_2O + 1/2\ O_2$ in alkaline electrolytes was investigated with a very sensitive microvolumetric method. The reaction rate increases with increasing hydroxyl ion concentration and is sensitive to daylight. The decomposition appears to proceed at the solid-liquid interface. Any divalent silver dissolving in minute amounts into the electrolyte is decomposed rapidly due to its instability. The decomposition proceeds at a rate of about 16% in 1 year at 30 C and 49% in 1 year at 45 C. This reaction can contribute significantly to the self-discharge of AgO-Zn batteries.

B-351

Tivadar Z. Palagyi, Central Research Institute for Chemistry, Hungarian Academy of Science (Budapest), "Investigation on the Silver-Zinc Storage Battery with Radioactive Ag^{110} Isotope," Journal of the Electrochemical Society, 108 (9), 904-906 (September 1961)

The experiments were carried out with cells of 10 amp-hr. nominal capacity. Each cell contained only one labeled electrode. As in the experiments with the Zn^{65} isotope, the cells were assembled in three ways. The number of normally and loosely assembled cells was six each, while that of the tightly assembled one was eight. In the tightly assembled cells the degree of contamination of the negative electrodes with isotole was larger than in the normally or loosely assembled cells. The tight assembling method is disadvantageous since it results in the disintegration of the separators of the positive electrodes, in consequence of which the electrochemically active material of the positive plates dissolves and reaches the negative electrodes. In some cases the reduced silver ions form a crystal aggregate on the zinc plate, causing direct short-circuit. The breakdown of the loosely assembled cells generally resulted from the crumbling and shedding of the zinc electrodes and formation of acicular zinc crystals. Consequently, it can be stated that both the excessively tight and the loose method of assembling are disadvantageous.

B-352

M. Eisenberg, H. F. Bauman, and D. M. Brettner, Lockheed Missiles and Space Division, Sunnyvale, "Gravity Field Effects on Zinc Anode Discharge in Alkaline Media," Journal of the Electrochemical Society, 108 (10) 909-915 (October 1961)

Under conditions of zero-gravity such as may prevail in satellites and space vehicles the absence of free convection may represent a major problem in the use of some primary or secondary batteries. An experimental study was carried out on smooth zinc anodes in 30% KOH solutions in which constant current discharge at various current densities was carried out to the point of passivation. By use of three different orientations in the gravitational field, different modes of mass transfer were obtained. An extrapolation of the results for low current density and long duration runs (over 20 sec) led to three limiting current densities values for the three positions. These values were also calculated from theoretical equations using measured or estimated physical properties. The importance of free convection vs. diffusion was also demonstrated by means of incremental fixed current-time experiments which determined anode capacity to passivation. Physical properties of the system were measured and anodic dissolution studies were made to obtain the necessary data for calculations. The gravity field effects important in systems involving density gradients would become even more important under the influence of larger accelerations in space vehicles or missiles. These accelerations could produce sizeable differences in the performance of porous zinc anodes.

B-353

Thedford P. Dirkse, Calvin College, "The AgO-Ag_2O Electrode in Alkaline Solution," Journal of the Electrochemical Society, 109 (3), 173-177 (March 1962)

The standard potential of the AgO/Ag_2O/CH^- electrode has been found by direct measurement against a hydrogen electrode to be 0.599 ± 0.001v at 25 C. The value appears to vary slightly with KOH concentration. Furthermore, dE/dT values appear to change with KOH concentration as well as with temperature. Voltages measured with pellets of AgO and Ag_2O show that the voltage is determined by the materials present at the grid.

B-354

Charles P. Wales, U.S. Naval Research Laboratory, "The Silver-Silver Oxides Electrode. II. Anodization at 0° and 25°C in Alkaline Solutions," Journal of the Electrochemical Society, 109 (12), 1119-1124 (December 1962).

Silver electrodes were studied in 20% KOH at 25 C and in 35% or 50% KOH at 0 C. The capacity decreased when the electrode was cycled in 20% KOH at 25° mainly due to loss of active material during current flow. In 35% KOH at 0° the electrode capacity was close to that at 25°, the capacity decreased with increasing charge current similar to results at 25° although polarization had increased, and the charge-discharge efficiency was 100% at low currents but less when using high currents. In 50% KOH at 0° the capacity was much less than at 25°, the charge acceptance was relatively poor, under certain conditions a silver peroxy compound may form, and the electrode discharged even less readily than it charged.

B-355

E. Kantner, R. Tarantino, P. Ritterman, and R. C. Shzir, Gulton Industries, Inc., "Investigation of Hermetically Sealed, High Rate, Maintenance-Free, Nickel-Cadmium Batteries for Aircraft Application," Technical Report AF/AFL-TR-66-77 (September 1966), Wright-Patterson Air Force Base Contract AF 33(615)-2087

An MS24498 battery was subjected to high rate charge and discharge tests to determine its performance characteristics. These tests indicated excessive polarization at both the positive and negative electrodes.

A theoretical analysis was made of ways to reduce concentration, activation and IR polarization. Based on this analysis, the effects of plate thickness, electrolyze additives and plate backing support on high rate performance of sealed nickel-cadmium cell, were investigated. These investigations showed that a thinner battery plate vastly improved high rate performance.

The effect of impurities on self-discharge of sealed nickel-cadmium cells, was studied. These studies indicated that when acetate salts were used to impregnate nickel and cadmium plates, their charge retention was improved.

Battery plates with differing geometries (rectangular and square) were tested to determine which one has better high rate performance. On the basis of these test results, the rectangular cell was chosen which enabled us to maintain the configuration of the MS24498 battery.

High rate discharges (600 amperes) were carried out at temperatures from -30°F to 140°F, on the 35 AH laboratory prototype cell. Cell voltages after one minute of discharge ranged from 0.45 V at -30°F to above 0.8 V at 140°F. Cell behavior during high rate charging (350 amperes) was also investigated throughout the operating temperature range. At temperatures below 20°F, the cell evolved hydrogen when charged at 350 amperes for 5 minutes. This hydrogen evolution occurred only during the initial stages of charging. Oxygen evolution occurred in the latter part of charging at all temperatures.

Data obtained during high rate (10C) charging was used to calculate the parasitic current (that portion of the current which causes gas evolution) at various temperatures from -30°F to 140°F. The parasitic current varied with temperatures.

High rate charge-discharge tests on the 22AH cell indicated that its high rate performance was very good. Cell voltage after one minute of discharge at 600 amperes was 0.89 V following a 220 ampere charge. Also, the cell delivered about 24 AH following a 220 ampere charge.

A theoretical thermal analysis of the battery indicated that the maximum temperature rise which may be expected in the battery during a duty cycle would be about 58°F with no heat sinking. This temperature rise could be reduced and the magnitude of the reduction was a function of the heat sinks. The calculated values were found to be in good agreement with experimental results.

B-355
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Theoretical and experimental studies were carried out on means to control battery charging and to condition the aircraft bus to the optimum requirements of the battery. The Adhydrode, Cd/Cd(OH)$_2$ coulometer and pressure switch were investigated for charge control. The Adhydrode signal was found to be oxygen pressure and temperature dependent. The coulometer was rate sensitive and gave a premature signal at low temperature. The evolution of hydrogen on high rate charging at low temperatures precluded the use of the pressure switch.

Three methods to condition the aircraft bus to the requirements of the battery were studied. These were the inverter phased control, the SCR phase control and parallel chopper. Of the three systems, the parallel chopper appears to be the simplest one for achieving the desired objective.

B-356

S. B. Brummer, A. C. Makrides, and J. Bradspies, Tyco Laboratories, Inc., "Electric Passivation Studies," Third Quarterly Report (June 1 - August 31, 1966), Wright-Patterson Air Force Base Contract AF 33(615)-3433.

Studies of the passivation of Zn-Fe, Zn-Mn, Zn-Co, and Zn-Ni alloys were made potentiostatically. Alloys of 90 Zn - 10 Fe corrode at a high rate even when passive. The 89 Zn - 11 Co alloys have high dissolution currents in the passive state, while the 78 Zn - 22 Co and 80 Zn - 20 Ni alloys appear promising as anodes which may be kept in a passive, reserve state. These two alloys have acceptably high critical currents and low passive currents. Their activation characteristics were studied in detail in 6N KOH; activation to about 75% of the original current density can be achieved in 20 to 90 sec, depending on the alloy and its history.

Studies of Cr, Al, and of amalgams of Mg show them to be unsuitable for use as reserve anodes.

Initial studies of the passivation of Zn-Co and Zn-Ni in electrolytes containing sulfates and chloride ions showed that their dissolution behavior is similar to that in KOH alone.

B-357

T. P. Dirkse, Calvin College, "Investigation of the Electrode Migration and Reaction Process Occurring in Alkaline-Zinc Batteries," Quarterly Technical Progress Report No. 3 (June 1 - September 1, 1966), Wright-Patterson Air Force Base Contract AF 33(615)-3292.

Information on the zinc electrode processes has been obtained by measuring the overvoltage for the zincate reaction and the limiting current density. This was done both anodically and cathodically. The variables studied were: KOH concentration, zincate concentration, and amalgamation of the zinc electrode. Measurements of the differential double layer capacitance have also been made, and the effects of amalgamation and the presence of surfactants have been noted. Solubilities of zinc oxide in KOH solutions are reported for 25° and 15°C.

B-358

P. G. Garratt and S.E.A. Pomroy, Royal Aircraft Establishment, England, "Study of the Uniformity of Gulton Industries, Inc. (VO-3-HS) Hermetically Sealed Nickel Cadmium Cells and the Establishment of Selection Procedure for the U.K. 3 Satellite," Technical Report TR-65140 (July 1965).
AD 470 386L

In order to study the quality and uniformity of the cells chosen for use in the U.K. 3 satellite, 350 (VO3-HS) hermetically sealed nickel-cadmium cells were subjected to a test program consisting of electrolyte leakage checks and several aspects of electrical performance including capacity and internal resistance measurements, detection of heart circuits, self-discharge rate, and behavior on overcharge. These results will contribute to the establishment of the selection procedures to be used for the U.K. 3 satellite battery, and a test schedule for this purpose has been drawn up. An initial exercise on cell selection was carried out for the development (D2) satellite model.

B-359

Philip F. Grieger, Thomas A. Edison Industries, "Auxiliary Electrode for Charge Control of Sealed Nickel-Cadmium Batteries," Quarterly Progress Report No. 4 (June 1965), Contract DA-28-043-AMC-00152(E). AD 469 278

As called for by the main experiment (16 cells and 6 spares) VCB black auxiliary electrodes were installed in 22 cells made from V07 cells, 30% KOH corresponding to the semi-dry level was added, and the auxiliaries were pretested (1 atm. 02, room temp.) by measuring signaling circuit voltage and current for various resistances, while charging the cells at 0.35 amp. Performance was about that expected, and judged to be satisfactory. Replicability was better for top than side position. With supplemental 30% KOH (3.5 and 14 ML for wet and excess levels-respectively) performance was reduced slightly for the top position but drastically for the side position. 16 cells (4 semi-dry, 2 wet, 2 excess, for both positions) were discharged completely, filled with 02^-, and are being conditioned, prior to making the main experiment tests. 22 similar cells are being made from N76 cells.

B-360

E. Kantner, R. V. Tarantino, H. N. Seiger, and R. C. Shair, Gulton Industries, Inc., "Investigation of Hermetically Sealed Maintenance-Free, High Rate, Nickel-Cadmium Batteries for Aircraft Applications," Quarterly Technical Progress Report No. 4 (August 1965), Wright-Patterson Air Force Base Contract AF 33(615)-2087. AD 468 644.

Studies on the effect of high purity nickel and cadmium salts on the charge retention characteristics of sealed nickel-cadmium cells showed that plates prepared from the acetate salts exhibited better charge retention at elevated temperatures. In an extension of these studies, plates are being made from reagent grade acetate salts with a view to reducing the number of impregnation cycles required to achieve the desired plate loading. The effect of rubidium and cesium as electrolyte additives was investigated at high and low temperatures. Both charging and discharging characteristics were improved at the temperature extremes. A Cd/Cd(OH)2 coulometer, using .025'' plates was constructed and tested at high current rates. The operation of two breadboard models of the charge control circuit was tested with a coulometer and a pressure switch as a means of controlling battery charging. The circuits operated properly. Three methods of conditioning the aircraft charging system to the requirements of the battery have been examined. - the D.C. to D.C. invertor appears to be the most promising approach.

B-361

Arthur Fleischer, Nickel Cadmium Battery Corporation, "Laboratory Investigations and Research Toward the Development of Nickel Cadmium Alkaline Storage Batteries," Quarterly Progress Report No. 5 (September 1947), Contract W-36-039-38-32271. AD 471 546

This progress report covers the laboratory work on the preparation of sintered metal powder plates, impregnation with active masses for positive and negative plates, and the testing of plates for electrical capacity. Theoretical considerations have been omitted.

B-362

W. W. Clark, W. G. Ingling, I. F. Luke, and E. A. Roeger, Jr., Inland Testing Labs., "Alkaline Battery Evaluation," Report No. APL-TR-65-62 (May 1965), Wright-Patterson Air Force Base Contract AF 33(657)-8450. AD 465 888. (Supersedes Report No. APL-TDR-64-65, dated May 1964, AD 602 258)

This report covers an alkaline battery applied research and failure analysis program. The purpose of this program was to establish a broadbase of battery test data for use in the design of the electrical systems of future space vehicles, and to determine the actual failure mechanism of new battery systems under varying environmental and cycle-life conditions so that improved space batteries can be developed. Another objective was to determine techniques and/or materials to prevent these failures, while at the same time increasing the usable watt-hours-per-pound capability and cycle life of the battery. This program included the cycle-life performance evaluation and failure analysis of the following types of sealed, secondary, alkaline cells: Two types of 25 ampere-hour silver-zinc cells; one type of 15 and one type of 20 ampere-hour silver-cadmium cells; and one type of 20 ampere-hour-nickel-cadmium cell. The program also included a study of the effects of radiation upon each type of alkaline cell. This study covers (1) the extraterrestrial space radiation environment and (2) the expected results of space radiation on alkaline storage cells and cell components.

B-363

Eagle-Picher Company, "Laboratory Investigation and Engineering Design Leading Towards the Development of a Lightweight Secondary or Primary Cell Type Battery for One Shot Application," Quarterly Report No. 7 (August 1949), Contract W-36-039-SC-35548. AD 471-979

During this quarter, the work on sponge zinc negatives for low temperature performance of the AG202/KOH/ZN system was continued. Further work was carried out on improving the 48 hour activated stand at 160 F. with indications that addition agents in the electrolyte might solve this problem. Positive plates were heat treated in order to decrease the high initial voltage on discharge. The capacities of multiplate cells were determined at 80 F. and a discharge rate of 20 amperes. The CD/H2SO4-HBF4/PBO2 system was investigated by trying various oxides in the positive plates, different treatments of the formed positive plates and a study of electrolytes made of mixtures of H2SO4 and HBF4. Work was continued on the PB/HBF4/)B)2 system. In trying to improve the PBO2 plated positives in order to obtain consistent results on discharge, various plating solutions were tried. Attempts were made to determine at what discharge rate this system will function at -65 F.

B-364

Wade E. Radford, Johns Hopkins University, "A Comparison of Silver-Cadmium and Nickel-Cadmium Batteries for Use on Satellites," Report No. OF-29070A (January 1962), Contract NOW-62-0604-C. AD 631 700

The power system used on many near earth satellites consists of a solar cell charger and a Ni-Cd battery. This combination has been used satisfactorily on satellites. A constant goal of power system designers is to decrease the weight and increase the reliability of such systems. The replacement of Ni-Cd batteries with Ag-Cd batteries is reported to decrease the weight, while maintaining the capacity, of a given power system. This paper is the result of an investigation of this possibility. Areas investigated were: (1) the capability of a solar cell Ag-Cd cell system to limit overcharge current, (2) the compatibility of solar cells and Ag-Cd cells in such a power system, (3) the relationship between temperature of the secondary cells and their end of charge and discharge voltages for Ni-Cd and Ag-Cd cells, (4) the relative weight and volume advantages in the use of Ag-Cd cells over Ni-Cd cells.

B-365

Martin Sulkes, Yardney Electric Corporation, "Development of the Sealed Zinc-Silver Oxide Secondary Battery System," Quarterly Progress Report No. 7 (March 1965), Contract DA-36-039-AMS-02238. AD 621-563

The use of an unfiltered power supply for charging increased capacity in comparison with a straight D.C. charge, particularly at high charge rates. Evaluation cycle data are presented for 32 cells from a factorial experiment which evaluates 7 separators, 2 KOH concentrations, 4 concentrations of teflon binder, 3 Zn/Ag ratios and the effect of a negative interseparator. Poor results were obtained with various PVA and Borden Methyl Cellulose separators, particularly in 26.5% KOH, finally the rate of oxygen recombination was lowered by increasing the teflon content in the negative and by decreasing the Zn/Ag ratio. Evaluation cycles and an overcharge test were run on 16 cells designed to determine the effect of surfactant additions to the negative and the effect of zinc penetration resistant separators on cell performance. Preliminary results indicate no loss of capacity and voltage. Oxygen recombination however, was low due to a lack of free space in the cell.

B-366

Richard E. Amsterdam and James V. Ball, P. R. Mallory and Company, Inc., "Diode Control Research," First Quarterly Technical Progress Report (September 1966), Wright-Patterson Air Force Base Contract AF 33(615)-3702

During this portion of the contract, Phase A, the Determination of Spacecraft Battery Control, was initiated. This phase of the program deals with the development of a charge control network or system that will permit protection of nickel-cadmium, silver-cadmium, and silver-zinc batteries on an individual cell basis. The control network must be capable of permitting the battery to be cycled in a charge-discharge regime permitting depths of discharge of 75 percent of nominal cell capacity with charging rates in the vicinity of 1.5C. In addition, the protected battery must be capable of being charged at this rate for extended periods of time.

During this quarter the design of the charge control network was initiated. The network will depend upon the characteristics of the stabistor diode as the basis for its operation.. The temperature of the stabistor diode studs will be sensed and compared with the ambient temperature. This temperature difference, converted into a voltage signal will be used to reduce the total battery charging current to a level equal to or less than the safe maximum continuous overcharge rate of the battery.

The design of planar stabistor diodes with dice areas equivalent to 120 mil and 180 mil diameter round dice has been started. Materials for the fabrication of such diodes have been ordered.

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In order to meet the cycling and continuous overcharge requirements of the Statement of Work, a set of specifications for each type of battery needed for the program was drawn up. These specifications were sent out for quotations to eight battery manufacturers. In addition, visits to silver cell vendors have been initiated in order to determine if silver-cadmium and silver-zinc cells are available that can meet the basic cycling requirements of the contract. It has been found that silver-cadmium cells can be commercially procured that will meet most of the requirements, and that silver-zinc cells are available that will meet the requirements to a lesser degree. In addition, information as to the end of charge and end of discharge voltages, float potentials, and maximum safe continuous overcharge rates of the silver cells were obtained. This information will be used in the design of the stabistor diode parameters and in the charge network specifications.

B-367

J. J. Lander and J. A. Keralla, General Motors Corporation, Delco-Remy Division, "Applied Research Investigation of Sealed Silver-Zinc Batteries," Technical Report APL-TDR-64-85, Supplement 1 (May 3, 1965), Wright-Patterson Air Force Base Contract AF 33(657)-10643. AD 463 102 (Supplement to B-238)

The use of LIOH either alone or as an additive to regular NAOH and KOH electrolyte systems did not affect cycle life. For the purposes of this program relating to a long cyclic Ag-Zn secondary battery, there appeared to be no benefit from use of LIOH electrolyte. Appreciable gains in cycle life were made by cells using 45% and 50% NAOH electrolyte. Polypor films did not by themselves prove suitable for use in the Ag-Zn secondary cell as cycled in this program. Additional development work on these membranes in the area of pore size reduction might prove beneficial: These separators are inert in the alkali environment, and resist chemical deterioration.

B-368

J. Farrar, R. Keller, C. J. Mazac, and S. R. Webb, North American Aviation, Inc., Rocketdyne Division, "High-Energy Battery System Study," Quarterly Progress Report No. 3 (January 1 - March 31, 1964), U. S. Army Electronics Research and Development Laboratory Contract AD-36-039-AMC-03201(E). AD 452 714

This report period was concerned with systematic half-cell studies. Prospective electrode materials, electrolyte solvents, and salts were screened by testing in various combinations according to a statistical plan. These experimental results were then analyzed mathematically. The limited number of tests makes it difficult for statistical analysis to take into account the interactions and chemical considerations which seem influential in these systems.

B-368
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Therefore, the results of the present statistical analysis can only serve as a guideline, tempered by practical limitations. Theoretical minimum weights for the anode and cathode can be estimated for a battery delivering 200 watt-hours/pound based upon the measured potential. For lithium paired with CUF2 this value is approximately 0.25 pound. The value of lithium paired with less favorable cathodes (e.g., MMO2 and AGO) and for magnesium combined with the best cathodes is 0.5 pound, which makes these combinations just feasible.

B-369

P. G. Garratt and S.E.A. Pomroy, Royal Aircraft Establishment "Characteristics Affecting the Operation of the UK 3 Satellite Battery," Technical Report No. 65172 (August 1965). AD 478 910.

To ensure the compatability of the UK 3 satellite storage battery with the remainder of the power supply system, several aspects of cell and battery performance have been investigated. These include charging characteristics, overcharge behaviour and thermal effects. The power supply parameters affecting battery operation have been fixed using the results obtained from these studies.

B-370

E. Kantner, R. V. Tarantino, H. N. Seiger, and R. C. Shair, Gulton Industries, Inc., "Investigation of Hermetically Sealed Maintenance-Free, High Rate, Nickel-Cadmium Batteries for Aircraft Applications," Quarterly Technical Progress Report No. 5 (November 1965), Wright-Patterson Air Force Base Contract AF 33(615)-2087. AD 473 883.

Charge retention characteristics of sealed, nickel-cadmium cells prepared from reagent grade nickel and cadmium acetates were compared to those prepared from high purity nickel and cadmium acetates. The two groups of cells behaved comparably. Complexation of nickel acetate with ammonia to increase its solubility, and thereby reduce the number of impregnation cycles required to achieve the desired active material weight gain, had no effect on the charge retention characteristics of sealed cells. The effect of rubidium and cesium hydroxides, as electrolyte additives, was investigated at 0 F. Both rubidium and cesium were found to increase the available energy output of cells during high rate discharges.

A welding jig was designed and fabricated to facilitate the construction of laboratory prototype cells. A rectangular, 35 ampere-hour prototype cell was constructed and subjected to electrical testing. The results showed that the high rate discharge requirements were met and exceeded at room temperature. Reorientation of the charge control and charge conditioning program resulted in the formulation of preliminary specifications for an integrated system. Also, a signal flow diagram of this system was established.

B-371

A. Grenall and R. L. Hammel, TRW Space Technology Laboratories, Inc., "Study of Sonotone Corporation Nickel Cadmium Size F Battery Cells - Failure Analysis," (August 1961), Contract AF 04(647)-302, AD 449 249. (Addendum to Report No. 2303-0003-RU-000, dated April 1961, AD 272 497 and AD 459 797 (B-355)).

The results are presented of X-ray diffraction. Microscopic and visual examination of component parts of representative size F nickel-cadmium cells.

B-372

G. M. Wylie, Electric Storage Battery Company, "Investigation of AgO Primary Batteries," Final Report No. E-30-61 (September 8, 1961), Signal Corps Contract DA-36-039-SC-78319. AD 267 953

Fundamental electrochemistry of silver zinc batteries is discussed. A polarographic technique study is presented of AG2O and AGO solubility in alkaline electrolyte. Study was made of the factors affecting shelf life of ZN/KOH/AGO cells. Cells were developed with capacity loss rate of 50% per month at 160 F. Flat plate and buttontype silver-zinc cells were evaluated at various temperatures and discharges rates.

B-373

M. Lurie and H. N. Seiger, Gulton Industries, Inc., "Investigation of Methods Leading to the Determination of the State of Charge of Nickel-Cadmium Batteries," Quarterly Progress Report No. 1 (March 1963), U. S. Army Electronics Command Contract DA-36-039-AMC-00109(E). AD 408 617

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.

B-374

M. M. Nicholson, H. L. Recht, and R. E. Kelchner, Atomics International, North American Aviation, Inc., "Effects of High-Energy Protons on Selected Cells," Final Report AI-66-149 (August 1966), Jet Propulsion Laboratory Contract No. 951648.

> Experimental silver-cadmium and nickel-cadmium cells containing commercial battery electrodes and aqueous potassium hydroxide electrolytes were exposed to 60 and 137 Mev protons in the Harvard Cyclotron. Total integrated proton fluxes were twice the maximum values anticipated from solar flare activity during travel to Venus in 1967-69. Irradiated and control cells were examined for gas evolution, loss of electrode materials, and changes in discharge capacity. With the exception of low-level, rapidly-decaying radioactivity, no proton effects were detectable.

B-375

Phillip F. Grieger, Thomas A. Edison Industries, "Auxiliary Electrode for Charge Control of Sealed Nickel-Cadmium Batteries," Quarterly Progress Report No. 5 (September 1965), Contract DA-28-043-AMC-00152(E). AD 475 526

> Eighteen cells (and one replicate) have been tested in the main experiment which calls for two auxiliary positions and three quantities of electrolyte as levels of construction factors, and three rates (C/10, 1C, 5C) and three temperatures (0 F, room, 120 F) as levels of testing factors. At room temperature and 120 F signaling voltage response to pressure is generally good. At 0 F massive H2 evolution occurs on the cadmium electrode, thereby causing heavy polarization of the O2-reduction electrode; As a result signaling is adversely affected and may fail to respond to O2. Statistical analysis confirms the conclusion that side/semi-dry is the best construction. For this combination auxiliary performance depends upon the state of charge, probably because water is formed during charging; The signaling voltage vs. input curve is thereby improved. Auxiliary behavior is roughly independent of charging rate.

B-376

I. Young and G. Evans, North American Aviation, Inc., Report No. MC-461-0007 (June 1964). AD 457-647

> This specification covers the requirements for the design, performance and test of one type of silver oxide-zinc spacecraft storage battery for use in the Apollo Program.

B-377

M. Lurie and H. N. Seiger, Gulton Industries, Inc., "State of Charge Indicators for Alkaline Batteries," Second Quarterly Technical Progress Report (August 15, 1962), Wright-Patterson Air Force Base 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 technique, 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 parameters being studied were displayed on an oscilloscope and a photographic record made. Results of the transient peak height measurements have been inconsistent. The height shows a somewhat random variation although there is a general decrease in transient peak height with decreasing capacity. The ohmic resistance shows a capacity dependence. The double layer capacitance varied with state of change but the lack of reproducibility of the measurements caused errors in predicting the state of charge that were too large to be acceptable. Two successive refinements in the apparatus failed to reduce this error appreciably. The phase techniques rely on the measurement of the shift in phase between the cell voltage and current. It appears that with the phase method a battery would have to be tested cell by cell. With the resistance method an entire battery could be checked with one measurement by bringing all cell terminals to a common multi-pin connector on the battery.

B-378

Leroy Folks and C. O. Gosch, Eagle-Picher Company, "Investigations Leading to the Design of a Reliable Sealed Nickel-Cadmium Cell," Final Report (May 31, 1964), U.S. Army Electronics Research and Development Laboratory Contract DA-36-039-AMS-00135(E). AD 460-165

The investigative work carried forward in the last quarter as well as that of the entire contract is summarized. The purpose remained that of yielding an improved Ni-Cd cell. Four experiments were completed in this quarter: (A) cycle life performance, (B) self-discharge, (C) chg. accept., and (D) overcharge accept. Experiment A followed the factorial design for main effects (27 cells) as delineated in PR 5. They were analyzed by the analysis of variance and yielded these significant effects: Neg. linear trend with increasing KOH conc.: Type separator: Type Neg.: 80% LIOH as additive. Experiment B followed the factorial design for main effects (16 cell-5) as delineated in PR 7. They were analyzed by the "T" test and by the half-normal ploy. Significant effects were given.

B-379

S. Lerner and H. N. Seiger, Gulton Industries, Inc., "Characterization of Recombination and Control Electrodes for Spacecraft Nickel-Cadmium Cells," First Quarterly Report (June 9 - September 9, 1966), Goddard Space Flight Center Contract NAS 5-10241

A rapid method for determining the oxygen recombination ability of scavenger electrodes (both Anhydrode and fuel cell types) has been devised. Two types of fuel cell electrodes, supplied by American Cyanamid and Leesona Moos, and Adhydrodes in various thicknesses and porosities, have been studied. The best recombination achieved for the Anydrode has been on an electrode 0.055" thick and of 85% porosity. However, since the adhesion of the active material to the substrate is poor, the next best material, 0.020" thick and 70% porous, was chosen as the Adhydrode to be further studied in test cells. The American Cyanamid AB-6X fuel cell electrode is shown to have an oxygen recombination rate about 10 times greater than the best Adhydrode material. An outline for the program work is also presented.

B-380

A. W. Speyers, F. J. Keim, and R. B. Naugle, Vitro Laboratories, "Production of a Series of Nickel-Cadmium Battery Testers," Final Engineering Report (November 1958), Signal Corps Contract DA-36-039-SC-64703. AD 229-195

The performance of the testers built under this Contract was generally satisfactory. Changes performed on Testers No. 1 and No. 3, accomplished during the contract extension period, increased the reading time in accordance with the requirements of USASRDL. Interference between the power circuitry and the sensitive indicating circuitry was experienced with Tester No. 4. Reading time in these testers is dependent on the size of the storage capacitor, and, since the VTVM input impedance is fixed, a compromise must be made between the length of reading time and the size of the storage capacitor. The reading time with a 30-megohm VTVM input impedance is approximately 15 sec theoretically with a 10 u fd capacitor; 46 sec with a 30 u fd capacitor; and 61 sec with a 40 u fd capacitor. If a difference reading is to be made between the voltages stored on two capacitors of equal size, reading time will be half of that listed above. These theoretical values assume perfect insulation; actual reading times will be somewhat less. The values of storage capacitors in each tester have been changed to provide a minimum 15-sec reading time (5% decay). A considerable amount of development work has been completed on Tester No. 4, but more remains to be done to secure satisfactory field performance.

B-381

G. Robinson and E. George, Boeing Company, "Instrumentation Section Acceptance Test - AMR," (November 1960). AD 448 985. (Revision of Report dated March 11, 1960)

Presented are the functional test procedures to be performed to insure functional conformity of airborne instrumentation subsystems to the specified requirements. The procedures contained herein are for testing of airborne telemetry, and closely related equipment.

B-382

H.C. Williams and T. L. King, Jr., Electric Storage Battery Company, "Report of the Development Testing of ESB Model 264 Batteries to North American Aviation, Inc.," ESB Report No. TR-28-64 (October 13, 1964), AD 457 722

The test results described herein indicate that the battery is capable of limited off-limit operation at 30 F, but that performance at 50 F is marginal with respect to the capacity requirement of 36 seconds run time. This data also shows that the battery performance at other temperatures is satisfactory and that the cycle life of 6 cycles can be met. With regard to the acceleration test, the data indicates that the battery discharge time is limited due to acceleration force in the direction from battery base to cover. The data indicates that a voltage suppression can be expected during acceleratin force in the transverse direction, but that acceleration in the axial direction will have little effect on battery performance. It was also indicated that the battery is capable of performing properly immediately following severe acceleration.

B-383

Floyd E. Ford, U. S. Navy Marine Engineering Laboratory, "Nickel-Cadmium Battery Reconditioner," MEL Report 183/66 (August 1966). AD 638 603

A device has been designed for automatically reconditioning a nickel-cadmium battery. Individual cell voltage detectors and/or a battery terminal voltage are utilized to determine when reconditioning is necessary. Reconditioning is accomplished by discharging each cell to nearly 0 volts, then recharging the battery at a small current. Controlled discharge of the battery is accomplished by individual cell shunting transistors and a battery current shunt transistor. Cell reversal is prevented by cutting off the battery dump current when a cell voltage reaches a low limit.

B-384

Eliot A. Butler, Brigham Young University, "Studies of Reaction Geometry in Oxidation and Reduction of the Alkaline Silver Electrode," Final Report J.P.L. 951157 (April 1966), Jet Propulsion Laboratory Contract NAS 7-100. Re-Order No. 66-259.

The report is divided into three major sections which describe the work of the contract period. The sections are: I. Oxidation of Sintered Silver Electrodes at Constant Potential (page 2); II. Charge Characteristics of Silver Electrodes at Constant Current (page 5); and III. Variations of Surface Potential in the Oxidation of Silver Electrodes at Constant Current (page 14).

B-385

E. Kantner, A. E. Lyall, and R. C. Shair, Gulton Industries, Inc., "Nickel-Cadmium Batteries," Technical Documentary Report No. ASD-TDR-62-67 (April 1, 1962), Wright-Patterson Air Force Base Contract AF 33(600)-41670. AD 275 983

Sealed cells of different designs were fabricated, assembled, and tested. Heat from welding the cover to the can frequently damaged the seal, this was overcome by applying heat sinking to conduct the heat away from the seal. In fabricating seals for the squat cells, the cover was redesigned to eliminate shadowing, which prevented proper seal formation. Results indicated that the optimum quantity of electrolyte to improve overcharge was that which completely filled the pores of the separator and plates. Of the various separator materials tested nonwoven nylon and nonwoven polypropylene appear to be the most desirable from the standpoint of overall performance. Efforts to improve the watt-hour efficiency of sealed nickel-cadmium cells resulted in negative plates with improved overcharge capabilities. The complexity of reactions at the negative electrode was demonstrated. Laboratory type sealed cells were assembled so that in case of failure they could be disassembled without damaging any of the components.

B-386

Thedford P. Dirkse, Calvin College, "Constant-Potential and Constant-Current Charging of Silver-Cadmium Cells," Technical Report No. 4 (July 1965), Office of Naval Research Contract Nonr-1682 (02). AD 469-933.

The constant-current and constant-potential charging of a silver-cadmium cell was studied using two reference electrodes, one of each working electrode. The sum of the individual electrode potentials was compared with the measured cell voltage. At charging rate of three hours or less the measured cell voltage is affected by the Oh- ion concentration gradients as well as by the state of charge of the electrodes.

B-387

Power Information Center, University of Pennsylvania, "Transcript of the Conference on Secondary Space Batteries. Volume II. User's Problems, Conclusions, and Recommendations," (June 11-12, 1968), Washington, D.C., Report No. PIC BAT209 6-1, Contract DA-36-039-SC-90831. AD 417 061

> The transcript that follows records a unique series of discussions conducted under the auspices of the National Aeronautics and Space Administration and the Electrochemical Working Group of the Interagency Advanced Power Group in the NASA Auditorium, Federal Office Building, No. 6, Washington, D. C. The announced objectives of this conference were to highlight current problems experienced with NICD, AGCD and AGZN batteries; to obtain suggestions for rational solutions to these problems; and to explore methods for obtaining improved performance, reliability, and availability of these secondary batteries.

B-388

J. B. Oaks and W. J. Billerbeck, Johns Hopkins University, "A New Charge Control System for Satellite Batteries," Report No. CM-1041 (July 1963), Contract NOw 62-0604-c. AD 439 673

> This paper describes a simple, reliable charge limiter for controlling the charging of nickel-cadmium batteries in a solar-cell powered satellite. It discusses several initial approaches, and the theory, detailed design, fabrication, and testing of a current limiter for the NASA S-66 satellite. In brief, the device is a constant-current series limiter which senses battery charge current and utilizes this measurement to control the solar array input current. A thermistor bridge, which measures the difference between battery temperature and satellite structure temperature, switches the limiter between a high-current and a low-current level. Since the battery is insulated from the satellite structure with a known thermal resistance, the long-term average battery overcharge power is controlled to a constant level. This arrangement tends to provide constant battery case temperature.

B-389

Martin Sulkes and George A. Dalin, Yardney Electric Corporation, "Development of the Sealed Zinc-Silver Oxide Secondary Battery System," Quarterly Progress Report No. 1 (September 1963), Contract DA-36-039-AMC-02238(E). AD 432 195

An experimental program was prepared for the first year's work, which consists of Phase 1, the evaluation of standard sealed cells; Phase 2, the study of recombination reactions; and Phase 3, the study of cell components. Sixteen sealed Zn-AgO cells were built for Phase 1 and have completed formation cycles. Tests were run on sealed Zn-AgO cells to determine pressure increase during discharge stand. It was found that an externally shorted cell would develop 40-50 psig after 3 days stand at RT. Capacity maintenance and pressure buildup on charged stand at 160 F were determined and found to be within acceptable limits. Three sample materials were received and subjected to various evaluation tests to determine their suitability as separators.

B-390

D. F. Huebner, General Electric Company, "Communication Satellite Project Advent. Section 5, Electrical Power Subsystem. Volume VIII," Final Technical Report (March 1963), Contract AF 04(647)-476. AD 405 367

Contents: Electrical power subsystem, flight proof vibration tests, solar module vibration tests, plan and reports, battery charge regulator vibration test, report, nickel-cadmium battery module test plan and report, power control unit vibration test report, thermal vacuum tests, electrical power subsystem tests, solar module tests (U)

B-391

Naval Ammunition Depot, "Extended Life Cycle Tests of One Aircraft Battery, Nickel Cadmium, Type MS 25218 (AER) Manufactured by Sonotone Corporation," Report No. QE/C-63-312 (May 1963), AD 405 630L

Life cycle tests and data of aircraft nickel cadmium battery type MS 25218 (AER) of Sonotone Corp.

B-392

E. B. Cupp, Eagle-Picher Company, "Investigations Leading to the Design of a Reliable Sealed Nickel-Cadmium Cell," Quarterly Progress Report No. 3 (February 1963), Contract DA-36-039-SC-89084. AD 408 569

This report presents the results of continued investigations into plate and electrolyte parameters and their influence upon charge discharge efficiencies and self-discharge characteristics of nickel-cadmium cells. Also included are tables and curves illustrating the influence of time and temperature on the rate of self-discharge to be mainly a temperature function. The low temperature charge acceptance (charge efficiency) studies recorded in the report show no improvement in charge efficiencies which could be attributed to ZNO or LIOH additives to the electrolyte. (Author) (U)

B-393

Gerald H. Miller, Air Force Aero Propulsion Laboratory, Wright-Patterson Air Force Base, Ohio, "Sealed Nickel-Cadmium Batteries for Aircraft Electrical Systems," Report AFAPL-COMF-66-6 (July 1966), presented at the IEEE Aerospace Systems Conference July 11-15, 1966 at Seattle, Washington AD 634 845

Adapting sealed batteries to aircraft electrical systems is feasible. The major problem to be solved is the development of a suitable charge conditioner to operate with the battery and the aircraft electrical system. The interchanging of vented-cell, nickel-cadmium aircraft batteries with sealed-cell, nickel-cadmium aircraft batteries is considered possible by mid-1968. The major advantages of sealed-cell aircraft batteries are improved flight safety, maintenance-free operation, and improved performance in terms of life and reliability.

B-394

J. H. Hettmer, H. M. Schultz, E. C. Bruess, and C. M. Austin, Naval Ammunition Depot, "Evaluation Program for Nickel Cadmium Sealed Cells," Quarterly Report No. 1 (June 1964), Report No. QE/C 64-274, AD 446 494L

This report presents results of the cycle life test, which is the third phase of the evaluation program of sealed nickel cadmium cells. The purpose of the cycle life program was to determine the cycling performance capabilities of packs of the cells under different load and temperature conditions. The load conditions include cycle lengths (orbit periods) of 90 minutes and 3 hours and depths of discharge ranging from 15 to 40%. The cells are cycled under normal atmospheric conditions at temperatures of 0, 25, 40, and 50 C. The packs are cycled until more than half of the cells of each pack have failed.

B-395

G. M. Apgar, Gulton Industries, Inc., "Design, Fabrication and Testing of Sealed Rechargeable Silver-Cadmium Cells," Semi-Annual Progress Report (June 6, 1965), U. S. Army Electronics Command Contract DA-36-039-AMC-03358(E). AD 624 410

The items investigated were positive plate capacity at various silver loading levels, negative plate capacity, and dimensional stability of various separator materials under load and under no-load conditions. Based on the results of these tests, prototype cells were built and tested. These cells met the capacity requirements. A restraining load in excess of the specified limit of 20 psi and in the order of 50 to 60 psi was required to meet dimensional requirements. Tests were also run on prototype cells to determine their cycling characteristics. Charge retention at 77F and 160F, overcharge capability, and low temperature capacity. Further work is required in the area of charge retention. The investigation was also concerned with testing of prototype cells, as well as with fabrication of separators and plates for cell assembly.

B-396

Martin J. Sulkes and Gary Gellman, Yardney Electric Corporation, "Maintenance Free Silver-Cadmium Batteries for Aircraft Emergency Application," Quarterly Technical Progress Report No. 3 (March 1966), Wright-Patterson Air Force Base Contract AF 33(615)-2615. AD 480 501

The rate of recombination on stand of AGCD cells with teflonated negative was C/1000. With PVA binder in the cadmium it was lower. Cells containing 3rd electrodes were capable of recombining oxygen generated on overcharge at temperatures from -30 to 140 F. Placing the 3E along the edges of the CD electrode was more effective than placing against the face of the CD electrode. Of the cells designed to operate on the argentous level, those with a separator consisting of 3T of FSC charged most rapidly and gave the highest discharge voltage, but the separator was severely attacked by the PD additive. Discharge voltage in two-level cells is decreased following float! However, cells with thin plates are less affected than those with thick ones.

B-397

M. Lurie and H. N. Seiger, Gulton Industries, Inc., "State of Charge Indicators for Alkaline Batteries," Quarterly Technical Progress Report No. 1 (May 1962), Wright-Patterson Air Force Base Contract AF 33(657)-8130, AD 289 111.

Efforts to find measureable cell parameters which vary monotonically with state of charge are reported. In particular, measurements of the frequency at which a cell produces no phase shift have provided indications of residual capacity with errors from plus or minus 10% to plus or minus 25%. Measurements of ohmic resistance, impedance at audio frequencies and transient response are also reported.

B-398

M. Lurie and H. N. Seiger, Gulton Industries, Inc., "State of Charge Indicators for Alkaline Batteries," Quarterly Technical Progress Report No. 3 (November 1962), Wright-Patterson Air Force Base 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 19% is reported for manually cycled batteries. Results of the first stages of tests on batteries with various histories are given. Data is presented indicating 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.

B-399

K. W. Much, Department of National Defence, Ottawa (Ontario), "Evaluation Tests of D-Size, Nickel-Cadmium Sealed Cells Type S-103, Manufactured by Sonotone Battery Corporation, Elmsford, New York, USA," Report No. 5381-03 (September 1962). AD 298 416

Descriptors: Electric Power Production, Power Supplies, Storage Batteries, Cadmium Alloys, Electrical Properties, Nickel Alloys

B-400

C. P. Wales, Naval Research Laboratory, "Increasing the Discharge Capacity of a Silver Electrode," Report No. NRL-5912 (April 1963) AD 403 350

Pulses of charging current were added to the normal charging current of a silver electrode in 35% KOH at 25 C. While the electrode was being charged at the AG2O/AGO plateau the potential following a pulse was lower than it was before the pulse. Pulses had little effect after gas evolution had commenced or during the AG/AG2) plateau. Another result of added charge pulses was a changed discharge capacity. When pulses were added to a 20-hr-rate charge, discharge capacity reached a maximum and then decreased with increasing charge pulse current, pulse length, or pulse frequency. The maximum capacity of the test electrode was obtained when current was increased to four times the normal value for 5 seconds every 30 minutes in 35% KOH. The capacity of a commercial silver-zinc secondary cell containing 44% KOH was little changed by this charge method, except for having less capacity following long pulse using a high current. This difference was attributed to the higher KOH concentration, as indicated by results using a silver electrode in 50% KOH, where the capacity after pulses was always below normal.

B-401

H. M. Schultz, E. C. Bruess, and C. G. Lynch, Naval Ammunition Dept, Crane, Indiana, "Evaluation Program for Nickel Cadmium Sealed Cells General Performance Test of Gould-National Batteries, Inc. 3.5 ampere Hour 'D' Cells," Report No. QE/C-64-7 (January 1964) AD 446 624L

The general performance or characterization tests were performed at existing relative humidity and atmospheric pressure and at three specific temperatures. The tests and test temperatures were as follows: vibration test at room ambient temperature; mechanical shock test at room ambient temperature; acceleration test at room ambient temperature; charge and discharge voltage versus time at 0 C ± 25 C., and 50 C; overcharge characteristics at 0 C. ± 25 C., and 50 C; and charging efficiency at 0 C.' 25 C., and 50 C. The five cells used for these tests were picked from the 200 cells in the acceptance test section. The capacity of cells 123 and 160 was above the average of the 200 cells. Cell RRR38 approximated the average capacity, and cells 17 and 76 were below the average capacity. The 3.5 ampere hour "D" cell is cylindrical with an average diameter of 1.279 inches and an average over-all length of 2.221 inches exclusive of the negative terminal seal. The average weight of the 200 cells was 135.2 grams.

B-402

E. A. Roeger, Jr., and P. R. Voyentzie, Inland Testing Laboratories, "Alkaline Cell Evaluation and Analysis," Quarterly Technical Progress Report No. 1 (September 1964), Contract AF 33(615)-1580 AD 447 480

The purpose of this program is to determine the actual failure mechanism of all components of alkaline storage batteries and to determine the techniques and materials to prevent these premature failures, and to devise analytical methods for predicting the life of cells under any environmental condition. The program is also concerned with determining methods for gas suppression and the hermetic sealing of alkaline cells.

B-403

I. F. Luke and R. L. Koesters, Inland Testing Laboratories, "Investigations Leading to the Development of the Optimum Method(s) for Charging Sealed Nickel-Cadmium Batteries," Final Report (October 1, 1962 - September 30, 1963) and Addendum (May 4 - October 4, 1964), Contract DA-36-039-SC-90823, AD 456 387

Experiment designs, test data, analyses and results for investigations of constant current and constant potential charging at 125, 75, -10 and 40 F for cells at different initial states of charge are presented. Results of a preliminary investigation of pulse charging at -40 F are also presented. Experiments include test variables of ambient cell temperature, charging period, charging potential, percent input, initial state of charge, cell size and discharge rate depending upon the type of charging method employed. Cells of type BB 412 ()/U and BB 440()/U were used in these investigations. Analysis of the charging procedures are based upon the percent capacity obtained at the test conditions to that obtained in a normalizing cycle at 75 F. The average of the results obtained at 75 and 125 F following constant potential charges was greater than that following constant current charges over the selected levels of the test variables.

B-404

Samuel Ruben, "Alkaline Dry Cell," U.S. Patent 2,422,045 (June 10, 1947)

The present invention comprises an alkaline dry cell having an amalgamared zinc anode; a cathode of a depolarizer material including an electrolytically reducible oxygen-yielding compound, such as electrolytically reducible metal oxides and permanganates; and an alkaline electrolyte, such as an aqueous solution of an alkali metal hydroxide initially containing a substantial quantity of dissolved zinc; said electrolyte being immobilized against free motion or flow from the anode to the cathode or vice versa, preferably by means which physically space them apart and comprise absorbent, or minutely porous and ionically permeable, inert material or materials whereby migration of impurities and deleterious materials from the cathode to the anode or vice versa is inhibited.

B-405

Samuel Ruben, "Primary Cell with Permanganate Depolarizer," U. S. Patent 2,462,998 (March 1, 1949). Reissue 23,427 October 31, 1951

A primary cell containing a cathode comprising a solid silver permanganate an anode comprising zinc, and an alkaline electrolyte.

B-406

Litigation on Gould-National Batteries, Inc., et al. v. Gulton Industries, Inc., No. 228-61, Decided June 8, 1964, District Court, D. New Jersey, Patent Trademark and Copyright Weekly Reports, 142 (10), 475-493 (September 28, 1964)

This is an action for infringement of United States Letters Patent Numbers 2,571,927 (hereinafter '927) and 2,636,058 (hereinafter '058). Patent '927 entitled "Electrolytic Cell and, in particular, Alkaline Cell," was issued on October 16, 1951 to George Neumann and Uscha Gottesmann on an application filed January 29, 1949. Patent '058, entitled "Gastight Storage Battery and Method of Manufacturing Same," was issued on April 21, 1953 to Georg Neumann on an application filed November 18, 1950. Plaintiff bases this action upon Claims 1, 2, 3 and 4 of '927, and 2, 5, 6, and 9 of '058. The patents in suit pertain to sealed, rechargeable electric cells and batteries. We have discussed only those issues in this lengthy and complicated suit which merit detailed consideration. We find claims 1, 3 and 4, Patent Number 2,571,927, and claims 2, 5, 6 and 9 Patent Number 2,636,058, to be invalid. We find claim 2 of Patent Number 2,571, 927 to be valid and infringed by defendant Culton's cells VO .250, VO .500, VO 1.750, VO D, VO 4D and VO 9.

B-407

E. B. Cupp, Eagle-Picher Company, "Investigations Leading to the Design of a Reliable Sealed Nickel-Cadmium Cell," Final Report (May 1963), U. S. Army electronics Research and Development Laboratory Contract AD-36-039-SC-89084 AD 421 035.

Studies of various cell components were made and evaluated. Charge retention studies are detailed and demonstrate the influence of temperature and time on the degradation of capacity in both positive and negative plates, both types of plates illustrated the ability to retain at least 70% of original capacity after six months storage at +90 F. The effects of addition agents such as lithium and zinc are recorded, and definite influence in shown under fixed conditions of charge and discharge.

B-408

J. J. Lander, J. A. Keralla, R. C. Brown, and R. D. Weaver, General Motors Corporation, Delco-Remy Division, "Applied Research Investigation of Sealed Silver-Zinc Batteries," Quarterly Technical Progress Report No. 2 (November 1963), Wright-Patterson Air Force Base Contract AF 33(657)-10643 AD 423 685

Cycle life studies were made on groups of cells in which the ratio of ZNO to silver was varied from 0.75:1 to 4:1, maximum life was obtained at the 2:1 ratio. Electrolyte quantity tests indicate that both initial capacity and cycle life are improved if a high electrolyte level is provided. This is discussed in terms of sealed-cell operation. Dynel-wrapped negatives have shown decreased cycle life so far, additional testing is under way. Cells containing NAOH electrolytes are still under test. Utilization of the maximum LIOH concentration as the electrolyte sharply reduced both capacity and cycle life. Neither CDO additions to the negative active material nor provision for double grids in the negative plate construction showed advantages in initial capacity or cycle life. A detailed theoretical study concerning the possibility of utilization of neutral salt electrolytes in silver-zinc cells is reported.

B-409

General Motors Corporation, Delco-Remy Division, "Applied Research Investigation of Sealed Silver-Zinc Batteries," Quarterly Technical Progress Report No. 3 (February 1964), Wright-Patterson Air Force Base Contract AF 33(657)-10043. AD 430 588.

Tests designed to show effects of separator overhang continued with both positive and negative plates reduced in area to obtain sufficient separator overhang. Cells containing various combinations of acrylonitrile type separations wrapped around negatives did not show any significant improvement in cycle life as compared to control cells. Cells containing NAOH electrolytes completed over 1500 cycles before failure. Experimental results of tests made on some potential electrolyte materials are reported. Evaluation tests on sample separator materials are nearly completed, and pilot run materials are on order.

B-410

Thedford P. Dirkse, David Vander Hart, and Jack Vriesenga, Calvin College, "The Decomposition of Silver Oxide in Alkaline Solutions," Technical Report No. 2 (July 1964), Office of Naval Research Contract Nonr-1682 (02). AD 603 306.

The decomposition of silver (I) oxide in aqueous potassium hydroxide was studied using titrimetric, radioactive tracer, and gas evolution techniques. The rate of decomposition is dependent on temperature, photo effects, and the presence of foreign materials.

B-411

T. P. Dirkse and L. A. Vander Lugt, Calvin College, "Silver Migration and Transport Mechanism Studies in Silver Oxide-Zinc Batteries," Quarterly Technical Progress Report No. 5 (August 1963), Wright-Patterson Air Force Base Contract AF 33(657)-8689 AD 415 697

> A further study has been made of the mechanism by which silver is transported in a silver alkaline battery. This transport appears to take place primarily by diffusion. Two screening tests have been devised and tested for determining the tendency-of a separator to pick up silver from the electrolyte and also its ability to prevent transport of silver through the material.

B-412

T. P. Dirkse, Calvin College, "Silver Migration and Transport Mechanism Studies in Silver Oxide-Zinc Batteries," Quarterly Technical Progress Report No. 5 (June 1964), Wright-Patterson Air Force Base Contract AF 33(615)-1236 AD 601 471

> The effect of the presence of surfactants in the electrolyte of silver-zinc batteries on the cycle life has been briefly investigated. In some cases there is an improvement in cycle life. To determine the reason for this, the effect of surfactants on the following processes has also been investigated: (1) silver ion diffusion through cellophane: (2) throwing power of a potassium zincate solution: (3) limiting passivation current density for the zinc anode: (4) polarographic reduction potential of zincate ions: and (5) zincate ion diffusion through cellophane membranes.

B-413

T. P. Dirkse, Calvin College, "Silver Migration and Transport Mechanism Studies in Silver Oxide-Zinc Batteries," Final Technical Report AFAIL-TR-64-144 (December 1964), Wright-Patterson Air Force Base Contract AF 33(615)-1236 AD 610 563

> Methods for testing the ability of separator materials to allow the diffusion of dissolved silver oxides, zincate ions, and hydroxide ions, have been checked to determine the reproducibility of the diffusion rates obtained by these methods. The results have also been studied to determine the applicability of Fick's First Law of Diffusion to these processes. The use of surfactants in the electrolyte and in the zinc electrodes has been studied. The effect of these substances on cycle life and on various zinc electrode processes was measured. The greatest effects noted were those associated with the zinc electrode processes. Various aspects of the decomposition of silver oxide in aqueous KOH were studied, particularly the effect of solid materials, some ions, and separator materials. A possible mechanism for these effects is given. This decomposition is very closely related to the deposition of silver on the separators in silver-alkaline batteries.

B-414

F. J. Cocca, P. R. Mallory & Company, Inc., "Cell Equalization Techniques," Quarterly Technical Progress Report No. 3 (October 1964) Wright-Patterson Air Force Base Contract AF 33(615)-1342, AD 609 895 (Supersedes report dated October 15, 1964, AD 607 296).

Hermetically sealed NI-CD cells were cycled with and without stabistor charge control. The capacity range used was 50 to 20 ampere-hours. In the four charge control circuits BCC-9, BCC-10, BCC-11 and BCC-12, the stabistors were effective in clamping cell voltages and minimizing gassing. In BCC-11, 20 AH NI-CD cells were cycled and the stabistors were effective in preventing internal cell shorting and extending battery life. Some antireversal studies were also conducted. Initial results indicate that antireversal diodes are partially successful in preventing gassing during cell reversal. The data suggest the use of a larger antireversal diode for adequate protection.

B-415

C. P. Wales and Jeanne Burbank, U.S. Naval Research Laboratory, "Electrolyte Cell for X-Ray Diffraction Studies of Electrode Phenomena," Interim Report NRL 6050 (March 2, 1964) AD 605 707

An electrolytic cell was designed for use on a horizontal circle X-ray spectrogoniometer to permit simultaneous diffraction and electrochemical study of electrode specimens. This cell has one electrode a partly submerged rotating disk of the sample from which X-ray diffraction patterns are made as a portion of this electrode rotates out of the solution. The cell is designed to study electrochemical processes of widely varied nature including active material transformations in primary and secondary battery electrodes, electrolytic deposition and corrosion phenomena. To illustrate the application of the cell to electrochemical investigations, preliminary work shows that silver oxides can be identified on a working silver electrode in KOH solution.

B-416

N. W. Snyder, Institute for Defense Analyses, "Battery Research," Report No. IDA-TN-61-7 (April 19, 1961) AD 428 659

The potentialities of storing much larger amounts of energy in a battery for a given weight is worth a great deal of attention: To be more specific: (a) the present Ni-Cd battery has a theoretical limit of 95 watt-hr/lb., a practical limit of 25 to 30 watt-hr/lb., and a present status of 1 to 5 watt-hr/lb. in space vehicles; (b) the sealed rechargeable AgO-Zn battery has a practical potential of 35 watt-hr/lb. for space use but has not been realized; (c) the alkali metal Halogen primary battery system has a potential of 250-500 watt-hr/lb. but has never been pursued. Reliability is a major factor that can be improved greatly by research as well as development.

B-417

E. J. Settembre, U.S. Army Electronics Laboratories, "Standard Line Alkaline Batteries," Technical Report ECOM-2527 (July 1964) AD 610 010

The development of a family of secondary batteries based on the design of only 18 sizes of battery boxes will make available for field use 108 units to provide 6-. 12 and 24-volt operation in capacities from 3.5 to 220 ampere hours. These 108 units will be built in three electrochemical systems (the nickle-cadmium, the zinc-silver oxide, and the cadmium-silver oxide) and will be made up of vented or sealed cells which will have been standardized previously. The flexibility and interchangeability to be derived from such a family of batteries will be enhanced further by incorporating in the design capability for operation of one-third of these batteries at 24 or 12 volts and one-third at 12 or 6 volts. The cases will be designed of fiberglas reinforced plastic to withstand severe environmental conditions and to provide operation with or without covers. With the covers removed, coupling directly to using equipment will be possible. Standardization of nickel-cadmium and silver-cadmium cells is being accomplished at present and two of the vented nickel-cadmium batteries are under development.

B-418

E. Kantner, H. N. Seiger, and R. C. Shair, Gulton Industires, Inc. "Investigation of Hermetically Sealed Maintenance-Free, High Rate, Nickel-Cadmium Batteries for Aircraft Applications," Quarterly Technical Progress Report No. 2 (February 1965), Wright-Patterson Air Force Base Contract AF 33(615)-2067 AD 611 404

An MS 24498 battery was subjected to constant potential charging at 26V, 28V, 30V, and 32V to determine the charging current at these voltages. Following charging, the cells were discharged to 1.0V/Cell to determine if the battery can be charged to 70% of its rated capacity in five minutes between these voltage limits. These data were also used to calculate charge efficiencies. A theoretical analysis outlining the factors which contribute to polarization was made. Sealed nickel-cadmium cells containing plates of varying thickness were tested to determine the effect of current density on voltage behavior during high rates of charge and discharge. High purity nickel and cadmium salt solutions (nitrates, chlorides, and acetates) were used to impregnate plates to study the effect of impurities on self-discharge of sealed nickel-cadmium cells. Two different circuit configurations were tested to obtain data for use in the design of the input stage of the charge unclassified 057159HOR)

B-414

F. J. Cocca, P. R. Mallory & Company, Inc., "Cell Equalization Techniques," Quarterly Technical Progress Report No. 3 (October 1964) Wright-Patterson Air Force Base Contract AF 33(615)-1342, AD 609 895 (Supersedes report dated October 15, 1964, AD 607 296).

Hermetically sealed NI-CD cells were cycled with and without stabistor charge control. The capacity range used was 50 to 20 ampere-hours. In the four charge control circuits BCC-9, BCC-10, BCC-11 and BCC-12, the stabistors were effective in clamping cell voltages and minimizing gassing. In BCC-11, 20 AH NI-CD cells were cycled and the stabistors were effective in preventing internal cell shorting and extending battery life. Some antireversal studies were also conducted. Initial results indicate that antireversal diodes are partially successful in preventing gassing during cell reversal. The data suggest the use of a larger antireversal diode for adequate protection.

B-415

C. P. Wales and Jeanne Burbank, U.S. Naval Research Laboratory, "Electrolyte Cell for X-Ray Diffraction Studies of Electrode Phenomena," Interim Report NRL 6050 (March 2, 1964) AD 605 707

An electrolytic cell was designed for use on a horizontal circle X-ray spectrogoniometer to permit simultaneous diffraction and electrochemical study of electrode specimens. This cell has one electrode a partly submerged rotating disk of the sample from which X-ray diffraction patterns are made as a portion of this electrode rotates out of the solution. The cell is designed to study electrochemical processes of widely varied nature including active material transformations in primary and secondary battery electrodes, electrolytic deposition and corrosion phenomena. To illustrate the application of the cell to electrochemical investigations, preliminary work shows that silver oxides can be identified on a working silver electrode in KOH solution.

B-416

N. W. Snyder, Institute for Defense Analyses, "Battery Research," Report No. IDA-TN-61-7 (April 19, 1961) AD 428 659

The potentialities of storing much larger amounts of energy in a battery for a given weight is worth a great deal of attention: To be more specific: (a) the present Ni-Cd battery has a theoretical limit of 95 watt-hr/lb., a practical limit of 25 to 30 watt-hr/lb., and a present status of 1 to 5 watt-hr/lb. in space vehicles; (b) the sealed rechargeable AgO-Zn battery has a practical potential of 35 watt-hr/lb. for space use but has not been realized; (c) the alkali metal Halogen primary battery system has a potential of 250-500 watt-hr/lb. but has never been pursued. Reliability is a major factor that can be improved greatly by research as well as development.

B-417

E. J. Settembre, U.S. Army Electronics Laboratories, "Standard Line Alkaline Batteries," Technical Report ECOM-2527 (July 1964) AD 610 010

The development of a family of secondary batteries based on the design of only 18 sizes of battery boxes will make available for field use 108 units to provide 6-. 12 and 24-volt operation in capacities from 3.5 to 220 ampere hours. These 108 units will be built in three electrochemical systems (the nickle-cadmium, the zinc-silver oxide, and the cadmium-silver oxide) and will be made up of vented or sealed cells which will have been standardized previously. The flexibility and interchangeability to be derived from such a family of batteries will be enhanced further by incorporating in the design capability for operation of one-third of these batteries at 24 or 12 volts and one-third at 12 or 6 volts. The cases will be designed of fiberglas reinforced plastic to withstand severe environmental conditions and to provide operation with or without covers. With the covers removed, coupling directly to using equipment will be possible. Standardization of nickel-cadmium and silver-cadmium cells is being accomplished at present and two of the vented nickel-cadmium batteries are under development.

B-418

E. Kantner, H. N. Seiger, and R. C. Shair, Gulton Industires, Inc. "Investigation of Hermetically Sealed Maintenance-Free, High Rate, Nickel-Cadmium Batteries for Aircraft Applications," Quarterly Technical Progress Report No. 2 (February 1965), Wright-Patterson Air Force Base Contract AF 33(615)-2067 AD 611 404

An MS 24498 battery was subjected to constant potential charging at 26V, 28V, 30V, and 32V to determine the charging current at these voltages. Following charging, the cells were discharged to 1.0V/Cell to determine if the battery can be charged to 70% of its rated capacity in five minutes between these voltage limits. These data were also used to calculate charge efficiencies. A theoretical analysis outlining the factors which contribute to polarization was made. Sealed nickel-cadmium cells containing plates of varying thickness were tested to determine the effect of current density on voltage behavior during high rates of charge and discharge. High purity nickel and cadmium salt solutions (nitrates, chlorides, and acetates) were used to impregnate plates to study the effect of impurities on self-discharge of sealed nickel-cadmium cells. Two different circuit configurations were tested to obtain data for use in the design of the input stage of the charge unclassified 057159HOR)

B-419

Power Information Center, University of Pennsylvania, "Transcript of the Conference on Secondary Space Batteries. Volume I. Manufacturing and Testing Problems." (June 11-12, 1963), Washington, D.C., Report No. PIC-BAT-209/6 (September 1963), Contract DA-36-039-SC-90831. AD 417 060

> The announced objectives of this conference were to highlight current problems experienced with NiCd, AgCd and AgZn batteries: to obtain suggestions for rational solutions to these problems; and to explore methods for obtaining improved performance, reliability, and availability of these secondary batteries.

B-420

National Aeronautics and Space Administration, "Battery Program Review," presented at NASA Headquarters, Washington, D.C., April 7, 1966

> Opening Remarks - Ernst M. Cohn, NASA Headquarters
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> Survey of Batteries Used in Space Flight - T. Hennigan, NASA Goddard Space Flight Center
>
> Status of Nickel-Cadmium Battery - E. Stroup, NASA Goddard Space Flight Center
>
> Charge Control Methods and Devices - K. Sizemore, NASA Goddard Space Flight Center
>
> Special Projects on Nickel-Cadmium Cells - J. Sherfey, NASA Goddard Space Flight Center
>
> Hydrogen Control Devices - J. Unger, NASA Goddard Space Flight Center
>
> Results of NASA Spacecraft Battery Test Program - D. Mains, Naval Ammunition Depot, Crane, Indiana

B-421

Naval Ammunition Depot, "Evaluation of Yardney Electric Corporation Silver-Cadmium Aircraft Batteries Type 18 X YS-35," Report No. CE/C-64-674 (September 1964) AD 449 662L.

> (*Storage Batteries, Performance Tests), Silver, Cadmium, Helicopters, Environmental Tests, Test Methods, Simulation, Acceptability, Electric Insulation, Thermal Stresses, Vibration, Shock (Mechanics), Failure (Mechanics), Temperature.

B-422

R. K. Packer and G. W. Allvey, Admiralty Underwater Weapons Establishment (England) "The Thermal Decomposition of Silver Dioxide: Part 2," Technical Note AUWE-TW-110/63-PT-2 (July 1965) AD 478 639

The thermal decomposition of silver dioxide was studied in the temperature range 50 to 150 C; the curve of oxygen evolved versus time is sigmoid in shape, with a noticeable initial induction period. An assessment was made of the expected electrical capacity loss from plates containing silver dioxide on storage over long periods; for example, over a five year period the estimated loss of total capacity was 1.24% at 30C, 6.5% at 40 C and and 21.6% at 50 C. Chemically prepared samples of silver dioxide were also studied and found to decompose about twenty times as fast as silver dioxide prepared by electrochemical oxidation of sintered silver plates.

B-423

R. F. Chireau, Yardney Electric Corporation, "Silver-Zinc Missile Power Supply," Quarterly Technical Progress Report No. 3 (April 1966), Wright-Patterson Air Force Base Contract AF 33(615)-2663. AD 482 897

The design of a power supply utilizing an "all battery" approach with conventional (individual) cells and with duplex electrodes (pile construction) is presented and analyzed in depth. Alternate primary battery activation systems are reviewed and the system selected for use in the design of the power supply is described. Experimental work performed on cell and battery activation has been outlined. Test data and results are summarized. A weight and volume analysis is presented for a battery system capable of meeting the power requirement (133 watt-hours at a maximum power output of 8.5 kw). The work done on the battery section of the battery-converter design approach to the power supply is discussed. Extensive data on projected battery size and weight versus battery voltage (5.6, 28, 56, 90, 200 volts) have been compiled for batteries utilizing both individual cell as well as duplex electrode constructions. Results of tests on cells that were built to verify experimentally the paper design of a 90 volt 133 watt-hour conventional cell battery are given in detail. The study phase of the DC-DC converter development program is scheduled to start on April 15, 1966.

B-424

Leak-tight Alkaline Ni-Cd Storage Batteries. State All-Union Scientific Research Battery Institute. Fr 1,429,091 (Cl. II 01m) February 18, 1966. Appl. April 5, 1965: 3 pp.

The battery design consists of Ni-ceramic and Cd electrodes with C serving to absorb the O evolved during charging. Vinyl plastic rings are used to isolate the positive electrode from the container and to prevent leakage.

B-425

Electrodes and Methods of Making Same. Aldo S. Berchielli and Renato Di Pasquale (to Yardney International Corp.). U.S. 3,271,195 (Cl. 136-67), September 6, 1966. Appl. July 30, 1962, 2 pp.

> Composition electrodes made from oxides such as CdO, ZnO, or AgO; a resinous binder; and reinforcing fibers are described. Up to 5% of carboxymethyl cellulose or poly(vinyl alc.) binder is mixed with the above materials, and the material is dried and pressed at room temperature into thin plates. A cond. grind with electrode terminals is sandwiched between these plates to form an electrode assembly.

B-426

Sintered-Plate-Type Nickel Cadmium Alkaline Batteries. III. "Effect of Additives on the Thermal Decomposition of Nickel Nitrate in Steam." Tsutomu Iwaki, Teketsugu Hirai, and Masataro Fukuda (Matsushita Elect. Ind. Co., Ltd., Central Research Lab., Osaka, Japan). Denki Kagaku 34 (5), 402 8(1966) (Japan). cf. Cd 64, 9231h.

> The effect of additives on the decomposition of $Ni(NO_3)_2$ with steam was studied to find a way to shorten the time of dipping in alkali solution in the process of producing a sintered Ni electrode. The $Ni(NO_3)_2$ powder, with or without the additives, was treated with steam for 20 minutes at 230^o, and then treated with an alkali solution to be converted to $Ni(OH)_2$. The reaction products were examined by chemical analysis, by X-ray analysis, and by irspectoscopy. Various amines and alcs. were tried as the additive. The role of additives was also studied by the thermogravimetric method. Ethylene glycol and Carbowax were the most effective.

B-427

Manufacture of Nickel Electrodes, Yutaka Okinaka and Dennis R. Turner (to Bell Telephone Laboratories, Inc.) U.S. 3,274,028 (Cl. 136-29) September 20, 1966. Appl. January 7, 1965; 4 pp

> A process is described in which Ni electrodes are prepared by activating the porous electrode anodically in a $Ni(NO_3)_2$ solution (0.1-6m). The electrode is electrolyzed at a c.d. of 0.05-5.0 amp./in.^{2} to anodically pptd. $Ni(OH)_2$ is in the pores of the sinter and then electrolytically cycled in K_2CO_3 colution (1-8N) at approximately 55^o through discharge, charge, and overcharge according to the relation: TC = 2.5 to 7, where T is the time of the cycle and C is the ratio of charge-discharge current to electrode capacity. C varies from 1/2 to 2. An alternate method consists of cathodically treating the electrode in 5 N KOH at 1 amp/in^2. These electrodes are used for increasing the amp-hr. capacity of Ni-Cd batteries.

B-428

Silver/Silver Oxide, Electrodes for Alkaline Batteries. Maurice Latig (in Yardney International Corp.), U.S. 3,272,054 (Cl. 13d, d7), September 13, 1966, Appl. July 17, 1963; 3 pp

A positive electrode for a storage cell is produced by manual pasting and sintering methods. A past of 2:1 $Ag_2O:H_2O$ is doctored into the interstices of an Ag metal grid 0.006 in. thick. This pasting is done on an Al foil 0.003 in. thick; then the Al foil is used to carry the pasted plate into the sintering furnace where it is heated at 900-1200^{0}F for two minutes. The Ag_2O decomposes to metallic Ag, which is sintered into coherent masses of active metal disposed within the interstices of the grid. The plates have a high effective surface area and exceptionally uniform surfaces and cross-sections. Al foils 0.002-0.005 in. thick operate most effectively; plates 0.004-0.009 in. thick can be made efficiently by this method.

B-429

Battery Grid, Robert E. Barnett and James M. Dines (to Eagle-Picher Co.) U.S. 3,275,473 (Cl. 136-64), September 27, 1966. Appl. January 3, 1964; 3 pp

Electrolytic cells such as storage batteries, etc., are desired. One form of electrode is fabricated from a woven or expaneded metal screen. It is subsequently plated with an active metal to produce electrodes for acid Pb, alk. Ni-Fe, Ni-Cd, Ni-Zn, Ag_2O_2-Zn, and Ni-Ni type cells. The principal object of the invention is to provide an improved grid or screen which will not break, even when subjected to severe vibration. By dipping the tab and adjacent edge portion in an elec. conductive molten metal, a grid having improved strength and vibration resistance is produced. A gradual transition is effected between the reinforced tab and the non-reinforced main grid portion. There is no sharp line of demarcation between the two portions which portions which represents a high stress line. The transition results when the grid is dipped. The wetting effect of the molten metal causes a gradual, slightly irregular build-up of solder between the fully open and fully closed pores in the grid. The dipped tab portion not only has increased strength but has greater conductivity.

B-430

E. Kantner, R. V. Tarantino, and R.C. Shair, Gulton Industries, Inc., "Investigation of Hermetically Sealed, Maintenance-Fre, High Rate, Nickel-Cadmium Batteries for Aircraft Applications," Quarterly Technical Progress Report No. 6 (February 1966), Wright-Patterson Air Force Base Contract AF 33(615)-2038. AD 479 652

The effect of various concentrations of rubidium and cesium hydroxide, as electrolyte additives, was investigated at 77 F and -30 F during high rates of charge and discharge. The results obtained in these experiments did not show the improved high rate electrical performance found in earlier experiments. Two battery plates, one with a rectangular configuration and the other with a square one, were tested in laboratory prototype cells to determine their relative high rate electrical performance. The cell with the rectangular plates showed the better performance characteristics at both low and room temperature. Additional testing of the rectangular cell was performed at temperatures of -30 F, 77 F, and 144 F. Three charge control-charge conditioning systems were proposed. Investigations of two of these systems were completed.

B-431

Naval Ammunition Depot, "Extended Life Cycle Test of One Aircraft Battery, Nickel Cadmium, Type MS 25218, Manufactured by Sonotone Corporation," Report (January 1965). AD 454 908L

Extended life cycle test results on Type MS25218 nickel-cadmium aircraft battery.

B-432

Nels B. Palmquist, Aerospace Corporation, "Evolution of the Low Rate Silver Peroxide/Zinc Primary Battery as a Basic Power Source for Space Flight," Report No. TDR469 5102 1 and SSD TDR 64 261 (November 1964), Contract AF 04(095)-469. AD $51 696L

This report presents some of the pertinent historical information on the evolution of the low rate silver peroxide/zinc primary battery as a basic power source for space flight. The status of electrochemical systems in 1956 is given as a reference starting point. The growth in energy to weight performance is shown from 1956 to November of 1964 for the silver peroxide/zinc system, which was chosen to be the work horse power source for numerous USAF and several NASA space flights. This primary battery was first developed for the AGENA space vehicle in 1957-58, and has been subsequently used in other USAF spacecraft, and by NASA in its early Ranger flights. It is scheduled to be used in the USAF in future space flights and also by NASA in some of the early short duration manned Gemini flights.

B-433

J. D. Selby, General Electric Company, "Communication Satellite. Project Advent. Configuration Structure and Subsystem Engineering Analysis Report. Section 7 - Electrical Power and Distribution Subsystem Engineering Analysis," Report No. 62SD4300, V. 12 (October 1962), Contract AF 04(647)-476 AD 298 758

Electrical power and distirbution subsystem engineering analysis for Advent communication satellite.

B-434

Kenneth O. Sizemore, NASA Goddard Space Flight Center, "Use of the Adsorption Hydrogen Electrode and the Oxygen Fuel-Cell Electrode in Nickel-Cadmium Cells," Report X-716-06-83, NASA TMX-55469 (April 1966) N66-24926

> The characteristics of two types of auxiliary electrodes are investigated. The essentially linear response of the adsorption hydrogen's electrode voltage as a function of oxygen pressure and its stability in potassium hydroxide electrolyte make it an ideal electrode for charge control. Although the oxygen fuel-cell electrode is a very good gas recombination electrode and better by a factor of 20 over the adsorption hydrogen electrode, it is difficult to use as a charge-control electrode because of its high sensitivity to oxygen pressure.

B-435

Emery F. Boose, Harold K. McCard, and Joseph Lundholm, Jr., AVCO Corporation, Research and Advanced Development Division, "Preliminary Engineering Analysis of Power Sources for Space Vehicles," Technical Memorandum RAD-TM-61-12 (August 25, 1961), Air Force Systems Command Contract AF 04(647)-305. AD 263 044

> A preliminary investigation has been made of five different power systems capable of continuously furnishing 10 kilowatts of electrical power. The study was done in order to determine the pertinent system characteristics and to see which type of power system appeared most suitable for early use with an electro-thermal propulsion system on a space vehicle. Of the systems considered, the study shows that at the present time, the nuclear turbine-alternator system is the best choice. If there was a question of reliability of the turbine-alternator unit, or if the orbital startup problem is not satisfactorily solved, then the nuclear thermoelectric system would be the next choice with a 400-pound weight penalty over that of the nuclear turbine-alternator system. The development of a high temperature nuclear or solar heat source with thermionic conversion was not considered sufficiently advanced at the time of the study to be included. This work was completed in early 1960. Since that time considerable additional work has been done at Avco RAD in thermionic power systems and high temperature thermoelectric materials. The thermionic power system studies have been reported in RAD-SR-61-83, A Study of Several Nuclear-Thermionic Space Vehicle Powerplant Systems. When the development of thermionic elements and an associated high temperature heat source is completed, this system will probably be the lightest weight system. It will also be similar to the thermoelectric conversion system as to ease of system startup in space.

B-436

John J. O'Connell and Elizabeth A. McElhill, Monsanto Research Corporation, "Separator Development for a Heat Sterilizable Battery," Quarterly Summary Progress Report 1 (May 1 - August 31, 1966), Jet Propulsion Laboratory Contract JPL 959524 under Prime Contract NAS 7-100

Several ligand-containing vinyl polymer systems were selected for evaluation as battery separator materials that would be usable in heat sterilizable Ag-Zn batteries. These ligand polymers are prepared by two general procedures: (1) copolymerization of vinyl ligand monomers to form polymers having bidentate chelate functionality, and (2) direct substitutaion of ligand groups on a pre-existing polymer backbone. Of the 28 polymers tested for stability in 40% KOH at 135°C thus far, several types have shown high resistance to degradation by 40% KOH at 135°C after 60 hours exposure. The most promising materials were copolymers of 2-vinylpyridine with either acrylic or methacrylic acid, and polymers containing ligand groups substituted on a polystyrene backbone through a methylene group. Polymers that show high stability in 40% KOH in our first phase tests are now being made into membranes for comprehensive evaluation as battery separators. Initial tests indicate that membranes prepared by the in situ saponification of 2-vinylpyridine-methyl acrylate copolymers have both acceptable electrical resistances ($\sim$ 100 ohm-cm) and usable mechanical toughness.

B-437

A. Langer, R. G. Charles, and C. R. Ruffing, Westinghouse Electric Corporation, "Separator Development for a Heat Sterilizable Battery," Westinghouse Research Report 66-1B6-BSEPA-R1, First Quarterly Report (June 1 - September 30, 1966), Jet Propulsion Laboratory Contract JPL 951525 under Prime Contract NAS 7-100

Two approaches are being pursued in attempts to produce separators for silver-zinc cells that must be subjected to sterilization heat treatment. The major effort is on preparation and characterization of composite separators, containing inorganic materials within a porous matrix of organic material. Several filler and matrix materials have been identified as promising components by screening tests of many candidate materials for KOH resistance. Experimental composites have been prepared by impregnation. These are being characterized by measurement of electrolytic conductivity, electrolyte diffusion rate, silver and zinc diffusion rates, resistance to dendrite penetration, and mechanical measurements. Instruments are described for carrying out the conductivity and diffusion rate measurements. The results are not yet conclusive; however, it appears that conductivity requirements of battery separators are initially met or exceeded by several of the experimental composites. Additional measurements are required after subjecting the separators to heat cycles.

A secondary effort is aimed at bonding of chelating functional groups to a porous organic structure. The approach has been to incorporate 8-hydroxyquinoline into epoxy resins through the use of Mannich bases as hardeners. Work so far has been devoted to synthesis of the Mannich base intermediates.

B-439

Helmuth L. Pfluger and Howard E.Hoyt, Borden Chemical Company, "Improved Separators for Silver Oxide-Zinc and Silver Oxide-Cadmium Cells for Spacecraft Application," Final Report (November 10, 1964 - November 10, 1965), NASA Goddard Space Flight Center Contract NAS 5-9107

This report summarizes the progress made under Contract NAS-5-9107 during the period November 10, 1964 to November 10, 1965. Sections A through D cover in detail the experiments carried out during the fourth quarter of that period.

The chief aims of the studies herein described were to improve upon the properties of the membranes developed under the previous contract NAS-5-3467. Extensive life-cycle tests (5) of certain of these membranes in secondary silver zinc cells at the Naval Ammunition Depot at Crane, Indiana, have shown that modifications of methyl cellulose, exemplified by types C3 and B3, extended cell-life fivefold and, in particular, prevented catastrophic shorting due to zinc dendritic growth. The continued work covered in this report took three approaches:

1) The types of membranes developed in the proceding Contract were studied in greater detail with particular emphasis on their permeability to and reaction with silver ions.

2) Further modifications of methyl cellulose formulation were aimed at increased conductivity of electrolyte-swollen films - particularly desirable when the swelling electrolyte is potassium hydroxide in concentrations greater than 30%.

3) Synthesis of new polymers was undertaken to explore the possibility of combining within the same molecule the balance of polarity needed for efficient separator performance.

B-440

W. N. Carson, Jr., G. Rampel, and I. B. Weinstock, General Electric Company, "Characterization of Recombination and Control Electrodes for Spacecraft Nickel-Cadmium Cells," First Quarterly Report (October 1966), NASA Goddard Space Flight Center Contract NAS 5-10261

Task I - Oxygen Sensing Electrode. Oxygen sensing electrodes were fabricated with two film thickness (1/2 and 1 mil) of Teflon heat sealed to representative metallic porous and mesh type substrates. Test cells to evaluate these sensing electrodes as a function of oxygen pressure, were designed and fabricated. Test equipment to evaluate the electrodes was designed and fabricated. At the end of the quarter the equipment was assembled and being checked out in preparation for testing of electrodes.

B-440

Task II - Oxygen Recombination Electrode. Test cells for the characterization of electrodes were designed and built. Electrodes of various structures and compositions have been fabricated and evaluated over the operating range. The capability of recombination electrodes to perform over the entire -20 C to +40 C temperature range has been demonstrated.

Task III - Negative Plate Evaluation. During the first quarter, two lots of plate were received from manufacturing and were subjected to standard aerospace formation cycles. Test cells incorporating these plates are being assembled.

B-441

R. M. Richards, TRW Systems, "Nickel-Cadmium Cell Heat Sterilization Test Program, Phase I," Final Report (October 1966), Jet Propulsion Laboratory Contract JPL 931092 under Contract NAS 7-100

Tests were performed on sixty (60) 4.0 ampere-hour "D" size Sonotone nickel-cadmium cells capable of heat sterilization in accordance with the program as outlined in JPL's "Nickel-Cadmium Cell Test Statement of Work," dated February 10, 1965, and TRW Systems Test Procedure 9363.4-343, entitled "Heat Sterilization Testing of Nickel-Cadmium Cells," dated April 28, 1965.

It is clear that nickel-cadmium cells of the type tested cannot withstand the sterilization process as performed while the cells are in a charged condition without a high probability of subsequent failure or erratic or abnormal behavior. Sterilization in the discharged-shorted condition produced a general and immediate loss of about 25 percent of initial capacity, but continued cycling showed little additional loss in capacity and consistent charge-discharge characteristics up to end of the 300-cycle test conducted.

Trickel charging cells or allowing cells to stand on open circuit for varying periods of time prior to start of cycling had only minor and temporary effects on cell performance, both for controls and sterilized cells. Charging after any form of inactive stand was more difficult for the first severalcycles, but this effect disappeared on continued cycling.

Thus, within the 300-cycle test limitations used on this program, sterilization of discharged and shorted cells did not produce serious damage to the cells from an electrical performance standpoint, provided a certain de-rating can be tolerated.

Whether or not internal changes were produced that would begin to show up on longer cycling or on a different type of cycling is not known. Information bearing on this point will be obtained by extending the cycling period on certain cells, using different cycling parameters, and performing dissection of cells and analysis of cell components.

B-442

Melvin H. Gottleib and T. H. Willis, Bell Telephone Laboratories, Inc., "Operating Characteristics of Sealed Nickel-Cadmium Batteries at Low Temperatures," Electrochemical Technology, 4 (11-12), 515-519 (November-December 1966).

The performance of an experimental sealed nickel-cadmium cell made at Bell Telephone Laboratories was studied over the temperature range -40 to +77 F in order to determine the energy storage limitations, discharge capability, and overcharge capability at low temperatures. It was found that evolution of hydrogen gas occurred during the charging periods of the first cycles run at progressively lower temperatures. At -40F, there is a marked lowering in cell discharge midpoint voltage and cell capacity. Nearly half of the lowering of discharge voltage was found to be due to IR drop at the positive electrode. The decrease in capacity and discharge voltage is not serious at temperatures down to -30 F. The evolution of hydrogen gas can lead to the irreversible development of high pressure and to reduction of cell capacity.

B-443

P. Ritterman, S. Lerner, H. N. Seiger, Gulton Industries, Inc., and P. Vaughan, Rutgers-The State University, "The Structure of Battery Active Materials Existing on the Sintered Nickel Oxide Electrode at Various States of Charge," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Philadelphia, Pa. (October 9-14, 1966). Extended Abstracts Publication, Abstract No. 15, pp 37-38.

The changes in structure of the active material were studied by following the changes in intensity of the three major reflections of $Ni(OH)_2$; namely, the 001, 100, and 101-002. During the charging process, the active material is oxidized from Ni^{2+} to Ni^{3+} with the simultaneous loss of a proton to the electrolyte soltuion. It has been determined that, as far as discernible by X-ray techniques, there is little or no structural change between a discharged positive electrode and those up to 90% charged. At 100% charge the intensity of the 100 and 101-002 reflections begins to decrease. At 133% charge the 100 reflection has completely disappeared and the 101-002 reflection is considerably reduced in intensity, while the intensity of the 001 reflection remains essentially constant.

B-444

Michael A. Ala, General Telephone & Electronics Laboratories, Incorporated, "Structure and Stoichiometry of Nickel Hydroxides Found in Sintered Nickel Positive Electrodes," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Philadelphia, Pa. (October 9-14, 1966). Extended Abstracts Publication, Abstract No. 16, pp 39-41.

The formation and state-of-charge of nickel positive electrodes have been studied extensively by chemical analysis, by magnetochemical analysis, by x-ray diffraction, and recently by infrared absorption analysis. To date, no definitive information has been obtained by differential thermal analysis (DTA). The present work shows that valuable insight into structural changes occurring in nickel positive electrodes can be obtained by DTA coupled with chemical and x-ray diffraction analysis. Particular attention is given to the formation and thermal decomposition of the charged state arising from the anodic polarization of $Ni(OH)_2$-impregnated sintered nickel electrodes in concentrated KOH solutions.

B-445

Keith Johnson and Oscar Nietzel, Metals & Controls, Inc., a corporate division of Texas Instruments Incorporated, "The Effect of Plaque Structure and Impregnation Parameters on Corrosion of the Nickel Hydroxide Electrodes," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Philadelphia, Pa. (October 9-14, 1966). Extended Abstracts Publication, Abstract No. 17, pp 42-44.

Corrosion is expected to be directly proportional to internal surface area and should, therefore, decrease for electrodes sintered with increasing temperature and/or time. One would also expect that the pore structure would shift toward larger pores. In fact, however, it was found that pores less than approximately 7 u do not participate in the corrosion process and are, therefore, unaltered during the impregnation conditions of this investigation, even though 35-40% of the total sinter material was corroded. An analysis of various commercial positive electrodes indicated that the plaque volume occupied by pores less than 7 u can be very large (up to 60%). The reason for this behavior of small pores is not understood. For corrosion control, a major advantage is gained by the use of techniques which tend to increase average pore size and minimize the increment of "small pores." Corrosion rates of the total plaque are improved because corrosion is more universal through the structure. This decreases the vulnerability of the plaque to disintegration at any given level of corrosion.

B-446

E. J. McHenry, Bell Telephone Laboratories, Inc., "Impregnation of Porous Nickel Electrodes by Electrochemical Precipitation," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Philadelphia, Pa., (October 9-14, 1966). Extended Abstracts Publication, Abstract No. 18, pp 45-48

Nickel electrodes were prepared by precipitating $Ni(OH)_2$ at three different temperatures (25 C, 50 C, and 70 C), three $Ni(NO_3)_2$ concentrations (0.2 M $Ni(NO_3)_2$) (pH = 2.8), 1.0 M $Ni(NO_3)_2$ (pH - 1.2), and 4.0 M $Ni(NO_3)_2$ (pH $<$ 0), and at three currents (0.2A, 1A, and 5A). A total of 1500 coulombs of charge were passed through each electrode which means that the process time at the three currents were 125, 25, and 5 minutes respectively. Reasonably good electrodes were obtained at each of the three currents, but at different temperatures and $Ni(NO_3)_2$ concentrations. A good electrode is defined as one which has at least 0.2 AH capacity and shows that the active material is distributed uniformly through the electrode. In general, the higher the current the higher the nickel nitrate concentration required for good electrodes. The active material tended to deposit on the outside edge of the electrodes at 1 and 5A precipitation current in 0.2 M $Ni(NO_3)_2$. The highest capacity electrodes were produced at 1A in 1.0 M $Ni(NO_3)_2$. The effect of temperature did not appear to be great except at 0.2 and 1A in 4.0 M $(NO_3)_2$ where 25 C gave higher capacity electrodes than those obtained at higher temperatures.

B-447

J. P. Elder and E. M. Jost, Metals & Controls Inc., a corporate division of Texas Instruments Incorporated, "Statistical Studies of the Nickel-Cadmium Battery System," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Philadelphia, Pa. (October 9-14, 1966). Extended Abstracts Publication, Abstract No. 19, pp 49-50.

Statistically designed experiments were found very valuable in identifying variables and initiating analytical approaches to certain problems. The following experiment which was aimed primarily at investigating the positive electrode in the Ni-Cd system, involved the following four factors: (1) Pore structure of the nickel support matrix of the positive electrode, (2) Ratio of cadmium to cadmium hydroxide at full charge, (3) Potassium hydroxide electrolyte level, and (4) Cobalt addition to the positive electrodes. The cells were charged and discharged in series galvanostatically. The following variables were monitored; end-of-charge voltage, resistance and pressure, open-circuit voltage, terminal voltage at 50% discharge, electrochemical capacity as functions of the above factors as well as charge input level, charge and discharge rates.

B-448

P. Ritterman, E. Kantner, and H. N. Seiger, Gulton Industries, Inc., "High Rate Charge Characteristics of the Sealed Nickel Cadmium System at Low Temperatures," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Philadelphia, Pa. (October 9-14, 1966). Extended Abstracts Publication, Abstract No. 20, pp 51-54.

35 ampere-hour sealed rectangular nickel-cadmium cells, equipped with active Adhydrodes^R and pressure gauges, were charged at 350 amperes. The charge was initiated from the completely discharged state and performed at temperatures ranging from -20 F to 72 F.

B-449

Stanley M. Caulder, Alvin J. Salkind, and P. F. Bruins, Polytechnic Institute of Brooklyn, "Nickel-Cadmium Cells. II. Adiabatic Calorimetry Studies," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Philadelphia, Pa. (October 9-14, 1966). Extended Abstracts Publication, Abstract No. 21, pp 55-56.

An adiabatic calorimeter was designed and constructed, and a calorimetric technique developed to determine thermal characteristics of electrochemical cells. The heat of reaction of Ni-Cd cells containing 6.3 N (12.7%) LiOH was found to be 37.7 K cal/equ. This if 4.5 K cal higher than in the KOH electrolyte cells. The open circuit potentials of the Ni-Cd system in 6.3 N LiOH and 7.9 N KOH were determined at 43 C by the extrapolation technique previously utilized and were found to be 1.293 v and 1.270 v respectively. However, these voltage differences are not sufficient to account alone for the differences in heats of reaction.

B-450

A. Himy, F. C. Arrance, and M. P. Strier, Douglas Aircraft Company, Astropower Laboratory, "Silver-Zinc Electrodes for Operation in the Temperature Range of 50° - 150°C in Secondary High energy Density Batteries," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Philadelphia, Pa. (October 9-14, 1966). Extended Abstracts Publication, Abstract No. 43, pp 118-119.

For the past three years, Astropower Laboratory has been developing silver and zinc electrodes capable of operation for prolonged periods of time at temperatures in the 25oC-150°C range. The cycle life at ambient and high temperatures was enhanced through the use of specially developed inorganic electrode separators (Astroset), and by the incorporation of inorganic, fibrous network support materials including potassium titanate and asbestos-type structures. The network support materials are built into the electrode matrix by special pressing techniques during electrode fabrication. The results obtained in various silver-zinc test cells are described: Cycle life at 25°C and 100°C; Deep Discharge Capability; High Temperature Operation; Environmental Testing of Silver-Zinc Multiplate Cells, and Thermal Sterilization of Silver-Zinc Cells.

B-451

Helmuth L. Pfluger and Howard E. Hoyt, The Borden Chemical Company, "Silver Ion Diffusion Through Membranes Functioning as Separators in Alkaline Silver-Zinc Cells," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Philadelphia, Pa. (October 9-14, 1966). Extended Abstracts Publication, Abstract No. 44, pp 120-122

A study was made of the diffusion of silver ions from saturated solutions of silver oxide in 30% potassium hydroxide through various membranes equilibrated with these solutions. The radioactive tracer procedure employed an apparatus based on Dirkse and Weiss et al, but incorporating improvements which avoid silver losses on the walls of the cell. Three types of behavior are illustrated in Table I: (1) Membranes with cellophane, polyvinyl alcohol or hydroxyethyl cellulose reduce silver oxide to metallic silver. During the course of a diffusion experiment the loss of radioactivity on Side 1 is at first more rapid than the gain on Side 2, indicating that passage through the membrane is initially halted. However, these membranes are also eventually damaged by their reaction with silver and are prone in battery tests to short circuit via zinc. (2) Methyl cellulose coacervates with carboxylic polymers allow minimal passage of silver but resist oxidation by silver oxide. These membranes have been found to resist catastrophic termination in battery tests. (3) The S-type film was intermediate in that it picked up only small amounts of silver but also allowed silver to pass through at only a very small rate. Cell tests of this film have been unsatisfactory due to development of high internal resistance.

B-452

J. McBreen and G. A. Dalin, Yardney Electric Corporation, "The Mechanism of Zinc Shape Change in Secondary Batteries," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Philadelphia, Pa. (October 9-14, 1966) Extended Abstracts Publication, Abstract No. 45, pp 123-124.

As a silver-zinc cell is cycled, zinc migrates from the top and sides of the negative plate to the bottom of the plate and the edge space near the bottom of the cell. This movement of zinc continues as cycle life progresses and results in a reduction in the capacity of the cell. This phenomenon is known as "shape change." Since it results in capacity loss and in a situation favorable for zinc penetration of separators, it counters the advantages of high energy-to-weight-and-volume ratios made feasible by zinc. The present investigation was devoted to identification of the factors which contribute to zinc shape change. Our present knowledge of cell construction and operation suggests a number of possible mechanisms. During cell discharge, the electrolyte level drops in the negative compartment; it rises again during charge. This rise and fall of electrolyte could favor zinc deposition of the bottom during the initial stage of charge. Furthermore, the fall of electrolyte during discharge could serve to carry zinc oxide to the bottom of the cell pack. Hence, the term "washing" used by some workers to describe shape change. The nature of the shape change would also suggest that gravitational effects, such as sedimentation (slumping) of zinc oxide in zincate to the cell pack bottom could cause shape change. If this were the case, one would expect such sedimentation to be facilitated by the usual cell case taper.

B-453

A Langer, Westinghouse Research Laboratories, "A Coulogavimetric Study of the Zinc Electrode in Potassium Hydroxide," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Philadelphia, Pa. (October 9-14, 1966). Extended Abstracts Publication, Abstract No. 46, pp 125-126.

Zinc electrodes in the form of solid sheets were discharged against cellophane wrapped, silver-oxide half cells of high capacity. Identical volumes of potassium hydroxide saturated with zinc oxide at room temperatures were used over the concentration range 0-15 Molar. During the discharge process, either through a constant resistance, or at constant current, the zinc electrode was continuously weighed in the electrolyte by the aid of a modified torsion balance which carried the current from the electrode through the balance to the different recorders for weight potential and current. The cell and the balance were completely enclosed to prevent evaporation and reaction of the electrolyte with atmospheric carbon dioxide. The enclosure could be thermostated.

B-454

P. V. Popat and Edward J. Rubin, Metals & Controls Inc., a corporate division of Texas Instruments Incorporated, "Low Temperature Kinetics of Cadmium Hydroxide Electrode," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Philadelphia, Pa. (October 9-14, 1966), Extended Abstracts Publication, Abstract No. 47, pp 127-128

The object of this investigation was to determine the Faradaic efficiency of the cadmium hydroxide reduction and hydrogen evolution as a function of temperature and current density. The degree of charge acceptance by the cadmium hydroxide electrode before any hydrogen evolution (the so-called hydrogen-free capacity) was determined as a function temperature and current density. Also, the total delivered capacity with 150% of the theoretical charge input and charge voltage under these conditions were measured. At -40 C, for example, the hydrogen-free capacity at C/5 charge rate is approximately 5% whereas at -34.4 C, at the same charge rate, the hydrogen-free capacity is approximately 30% of the room temperature capacity. Total delivered capacity at -40 C at the C/5 charge rate and C/2 discharge rate is 29.3% compared to 55% of room temperature capacity at -34.4 C at the same charge and discharge conditions. A plot of electrode potential versus charge input shows two voltage plateaus at which cadmium hydroxide is reduced, thus indicating two mechanisms of cadmium hydroxide reduction. In some cases, particularly at low temperatures and high charge rates, a voltage overshoot is observed in the voltage-charge input curve. These results will be presented and discussed in terms of modern electrochemical concepts.

B-455

Yutaka Okinaka, Bell Telephone Laboratories, Inc., "Electrochemical Reactions of the Cadmium Electrode in Alkaline Solutions," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Philadelphia, Pa. (October 9-14, 1966). Extended Abstracts Publication, Abstract No. 48, p 129

Oxidation and reduction processes of the cadmium electrode in concentrated alkaline solutions have been investigated by using a rotated cadmium disk-ring electrode. The method has provided a direct, conclusive proof for the dissolution-precipitation mechanism of the anodic process and yeilded information on the dissolved intermediate species involved. An evidence has been obtained, showing that the cathodic reduction of $Cd(OH)_2$ also proceeds through a soluble intermediate. The reduction of an underlying layer (possibly CdO) takes place without going through a soluble intermediate and procedes the reduction of bulk $Cd(OH)_2$.

B-456

Ernest M. Jost, Metals & Controls Inc., a corporate division of Texas Instruments Incorporated, "Solubility of CdO in KOH, K_2CO_3 and Their Mixtures," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Philadelphia, Pa. (October 9-14, 1966). Extended Abstracts Publication, Abstract No. 49, pp 130-131.

The solubility of CdO in aqueous KOH, K_2CO_3 and mixtures was measured as a function of molality of the solution (from 1 to 12 molal) and as a function of temperature (from -40 C to room temperature). A spectrophotometric method was adapted for quantitative analysis of the Cd solutions: Cadmium ion is extracted with a dithizone cholroform solution and the absorbance of the colored complex is monitored at a wavelength of 4180 ^{o}A (Table I).

B-457

Earl M. Otto, National Bureau of Standards, "The Dissociation of Ag_2O_2," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Philadelphia, Pa. (October 9-14, 1966). Extended Abstracts Publication, Abstract No. 49A, pp 132-133.

An investigation of the dissociation of Ag_2O_2 was undertaken because of the formation of this substance in the charge cycle of silver-cadmium cells and because of the dissociation which this oxide may undergo. Investigations were conducted at 30^o, 50^o, 70^o, and 100^oC. The apparatus previously described was used at the three lowest temperatures. The rate of dissociation was found to be highest (1.8m% hr^{-1}) for 13 molar KOH at 100^oC and the lowest (0.00015m hr^{-1}) for water at 50^oC. (No data are yet available for water at 30^oC.) There was usually an incubation period probably due to temperature equilibration and liquid penetration to the Ag_2O_2; then the evolution of O_2 occurred for an unexpectedly long time, suggesting a zero order of reaction, before exhaustion of the sample became evident. At 100°C exhaustion was sometimes reached in two or three days. Only one sample was held at 50°C until exhaustion was essentially achieved; that sample was in 11.6 molar KOH and it required nine months. Figure 1 presents in graphic form the effect of temperatures and KOH concentration on the rate of Ag_2O_2 dissociation. A positive plate (with grid removed) of a fully charged 5AH Ag-Cd cell was heated in 11.6 molar KOH at 100°C until no more O_2 was evolved. The time required was the same as for the 97% Ag_2O_2, but the volume indicated only about 35% Ag_2O_2. This is in fair agreement with the percent of time the discharge of a cell is at the higher of the two voltage levels.

B-458

G. Rampel, J. Liska, and R. C. Shair, Gulton Industries, Inc., "Silver-Cadmium Battery Program," Technical Documentary Report No. WADD-TR-61-131, Pt. II, Final Report (March 1963) Wright-Patterson Air Force Base Contract AF 33(600)-42397. AD 402 981

A research and development program leading to improved, long life, sealed silver-cadmium batteries for aerospace application is discussed. A silver electrode was utilized which yielded up to 50% of its capacity at the AGII oxide voltage plateau and the balance at the AGI 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. Sixty 7 ampere-hour cells, the Ag7HS, were life tested in a 90 minute cycle at several depths of discharge and at several temperatures, utilizing constant current and constant voltage recharge methods. Three thousand cycles were achieved at a 17% depth at 78 F. Charging problems are discussed. It was found that a charge routine consisting of a combination of constant current followed by constant potential was better than constant current charging or constant potential charging alone.

B-459

Martin Sulkes and George A. Dalin, Yardney Electric Corporation, "Development of the Sealed Zinc-Silver Oxide Secondary Battery System," Quarterly Progress Report No. 2 (December 1963), U. S. Army Electronics Research and Development Laboratory Contract DA-36-039-ANC-02238(H). AD 600 395

12AH sealed silver-zinc cells of standard construction when cycled at 120°F had poor capacity maintenance. Due to separator deterioration. Cells cycled at room temperature showed poor charge acceptance at high rates of charge. Studies of the reaction of oxygen with zinc in 12AH cells indicate that the maximum overcharge rate possible with standard construction is 60-90MA 04 1.2-1.8 MA/sq in. The recombination reaction was found to be limited by the diffusion of oxygen through the electrolye. In the range of concentration tested, 26.5-44% KOH, the lower the concentration the greater the rate of recombination. Data are presented on the physical, chemical and electrical properties of separators and inter-separators. The use of one layer of high resistance membrane as a separator is not feasible. Most of the cells built with a single turn of radiation application, inc. irradiated polyethylene shorted during the first charge. Positive-electrode surface areas were studied by double layer capacitance. The result indicated that the area increase takes place during discharge.

B-460

T. P. Krikse and L. A. Vander Lugt, Calvin College, "Silver Migration and Transport Mechanism Studies in Silver Oxide-Zinc Batteries," Quarterly Technical Progress Report No. 3 (February 1963), Wright-Patterson Air Force Base Contract AF 33(657)-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.

B-461

R. M. Vernon, Johns Hopkins University, "Electronic Analog Simulation of Satellite Thermal and Power System Characteristics," Report No. CF-3067 (May 15, 1964), Bureau of Naval Weapons Contract NOw-62-0604-c. AD 622 481

Those parameters are determined in the thermal and power system design that adversely affect the operation of the charge regulator system of an orbiting satellite. Because of the extensive system evaluation which was required to obtain this objective, a major out-growth of this study was the generation of an electronic analog method of satellite performance simulation which may be applied to both satellite systems design and orbital evaluation. Initially simple models of the charge regulator system were chosen for analytical evaluation by hand and digital computer calculations. These methods were found to be inadequate due to both the simplicity of assumed models and the length of time required for calculations. A description is presented of the satellite design characteristics which were simulated. The method of simulation and the results of a parametric study of satellite operation under various conditions.

B-462

R. A. Horne and I. A. Blakc, Arthur D. Little, Inc., "Low Temperature Operation of Batteries," Quarterly Report No. 3 (November 15, 1962 - February 14, 1963), Signal Corps Contract DA-36-039-SC-90706. AD 404 294

Reported values for watt-hr/lb. cu in./lb. and $/lb were assembled for primary and secondary batteries for the temperature range +70 F to -65 F. The specific heat and thermal diffusivity of the BA-270/U battery was measured. The heat leak through electrical leads was analyzed. A computer program was prepared for calculating the time-temperature history of battery-heater insulation systems.

B-463

G. S. Lozier and R. J. Ryan, Radio Corporation of America, "High Capacity Magnesium Batteries," Quarterly Progress Report No. 6 (September 1 - November 30, 1961), Signal Corps Contract DA-36-039-SC-85340. AD 274 750

An analysis of heat evolved during Mg-cell discharge showed the heat is due to the irreversibility of the MG anode and to corrosion. The heat must be controlled for efficient operation. An efficient heat sink must be used at high discharge rates to control voltage tolerance. The use of a water sink permits good operation at rates as low as the 7-min rate. A cathode efficiency of 88% was obtained with a HGO reserve cell at an 8-min discharge rate by using a thin plate construction. Capacity based on element weight and volume was 39 WHR/lb and 4.5 WHR/cu in. delayed-action studies of AZ-21 MG-MG(CL-O4)2 MNO2 cells on a tranceiver-type discharge showed this alloy has characteristics similar to AZ-31 alloy. Impedance of AZ-21 MG-MG(CLO4)2-MNO2 A-size cells was slightly lower than comparable AZ-10 alloy cells. Delayed action and impedance measurements of MG(AZ-10)-MG(CLO4)2-MNO2 and CUO cells stored for one year showed no significant difference from initial fresh-cell results. Cell capacities averaged 90%.

B-464

Joseph J. Holechek, Paul E. Streigle, Robert A. Giovanelli, Thomas R. Trafton and Henry W. Mattheu, Catalyst Research Corporation, "Automatically Activated Zinc-Silver Oxide Battery," First Quarterly Progress Report (July 1-Sept. 30, 1960), U.S. Army Signal Research and Development Laboratory Contract DA-36-039-SC-85361. AD 251-986

A study has been initiated to develop a chemically heated, automatic activation system for zinc-silver oxide batteries which will make them capable of 0.5 second activation and operation throughout the range of -65 to 165 F with close voltage regulation. A literature search was made and studies were performed to obtain heat capacity, thermal conductivity, enthalpy, and other basic data pertinent to battery components. Included is the description of a copper block calorimeter used for the determination of heat capacities of basic battery materials. Calculations were made to determine the safe operating temperature of 31% potassium hydroxide electrolyte. A prototype heat exchanger, based on fundamental design criteria and theoretical requirements was devised. Battery block equilibrium temperatures were calculated on the basis of enthalpy data. The heat absorption rates of several important cell components, based on thermal conductivity values, were analyzed.

B-465

Joseph J. Holechek, Paul E. Streigle, Robert A. Giovanelli, Thomas R. Trafton, and Henry W. Mattheu, Catalyst Research Corporation, "Augomatically Activated Zinc-Silver Oxide Batteries," Second Quarterly Progress Report (October 1 - December 31, 1960), U.S. Army Signal Research and Development Laboratory Contract DA-36-039-SC-85361. AD 255 919

Efforts continued on the basic investigations such as the enthalpy of battery components, electrolyte requirement studies, and studies leading to the formulation of a chemical heat source. Prototype heat exchangers were tested and found to be a feasible means of rapidly heating rapidly flowing electrolyte. Battery block-electrolyte reservoir studies were made to determine the effect of equilibrium temperature and current density on activation. Gas generators or battery initiators were tested to determine whether temperatures in the range of -65 to 165 F would affect gas volume and rate of pressure. A solenoid timer apparatus was designed and constructed for future electrolyte flow rate and temperature studies.

B-466

National Aeronautics and Space Administration, "Battery Workshop," held at NASA Headquarters, Washington, D.C., October 6-7, 1966

Ernst Cohn, NASA Headquarters - Opening Remarks

Dr. Eugene Willihnganz, C&D Battery Corporation - Accelerated Testing, Lead Acid Battery Experience

Dr. Royce Riddick, Gould National Battery Company - Accelerated Testing of Lead Acid and Sealed Nickel Cadmium Cells

Dr. William Scott, TRW Systems - Accelerated Testing of Space Batteries - Nickel Cadmium and Silver Cadmium

Discussion

Frederick M. Bowers, NOL-White Oak - Suggested Techniques for Nondestructive and Sample Testing of Silver Zinc Batteries

Dr. A. M. Chreitzberg, Electric Storage Battery Company - Accelerated Testing Methods for Determination of Wet-Stand Life of Secondary Silver Zinc Batteries

Martin Sulkes, U.S. Army Electronics Command - Accelerated Testing of Silver Zinc Cells

Dr. J. J. Lander, Delco-Remy Division of GM - Failure Analysis of Silver Zinc Cells

Donald Mains, NAD/Crane - Visual Failure Analysis of Nickel-Cadmium Cells

Lee Waltz, NAD/Crane - Physical and Chemical Failure Analysis

Dr. M. P. Strier, Douglas Astropower - Micro Fuel Cell Gas Detection as a Criterion for Battery Failure Analysis

Richard H. Sparks, TRW Systems Lab - Application of Space Hardware Program Failures Data to Battery Design

Peter Fowler, Martin Company - Control of Battery Quality for High Reliability Vehicles - Approach and Case Histories

Gerald Halpert, Goddard Space Flight Center - Computer Program for Analysis of Battery Data

John Waite, Mauchly Systems - Use of the Computer in Monitoring Large Scale Battery Tests

Dr. Ralph Brodd, Union Carbide Consumer Products - Computer Controlled Battery Test Facility

Peter Voyentzie, General Electric Company - Quality Control Techniques to Produce High Reliability Secondary Cells for Space Application

George Dalin, Yardney Electric Company - Preparation of Uniform Plates as a Basis for Increased Battery Reliability

Vincent D'Aftostino, RAI Research Lab - Determination of Properties of Grafted Membranes for Use as Battery Separators

James Oxley, Atomics International - Charging Characteristics of Zinc Electrodes Discussion

Karl Preusse, Gulton Industries - The Evolution of a Standard Line of Space Cells Discussion

B-467

Guy Rampel and R. Dagnall, Gulton Industries, Inc., "Nickel-Cadmium Batteries," Report No. ASD-TR-61-34 (January 1961), Wright-Patterson Air Force Base Contract AF 33(600)-41670. AD 270 870

Research and development leading to improved, long life, reliable, high watt-hour-per pound, sealed nickel-cadmium batteries are reported, fundamental studies on electrode mechanisms were treated theoretically. Improved techniques were developed to impregnate active material into electrodes so as to gain increased output. Studies were made of the parameters involved in assembling sealed cells so as to achieve high overcharge capability without sacrificing capacity. Development progressed on techniques to produce ceramic-to-metal terminal seals; mechanical configurations and designs of prototypes were worked out. Five possible designs of sealed cells to meet the desired performance requirements are discussed.

B-468

Jeff K. Wilson, Eagle-Picher Company, "Advanced Development Models of Sealed Nickel-Cadmium Batteries," Final Report (August 1965), Contract DA-28-043-AMC-00070(E) AD 623 024

Development and production work has been directed toward the production of forty (40) each BB-467/U, BB-468/U, BB-469/U, BB-470/U, BB-471/U, and BB-472/U sealed nickel-cadmium batteries. The work has been directed toward the attainment of a new line of nickel-cadmium batteries in accordance with the signal corps technical requirements SCL-6868B. The batteries have ceramic seals, sintered nickel plaque plates, pellon and polypropylene separation, and contain 1,300 SP. GR. KOH electrolyte. The batteries must meet the specifications as stated in SCL-6868B. These specifications require batteries to discharge at -40F, meet stand test requirements at +80F and +160F, undergo temperature cycling, mechanical shock, acceleration, vibration, constant overcharge, and cycle life tests. Early models of these batteries have passed all these requirements except those for cycle life. Emphasis was placed on cell capacity, high rate discharge, storage at +160F, and constant overcharge using BB-467/U batteries for the development units.

B-469

Alkaline Storage Battery Electrodes, Badische Anum- & Soda-Fabrik A.G. and Societe des Accumulateurs Fixes et de Traction (by Karl Ackermann and Victor Herold). Fr 1,435,566 (Cl. H01m), April 15, 1966; Ger. Appl. June 2, 1964; 3 pp.

The active materials of the positive electrodes of these batteries can be made, in one cycle of operations, directly from the Ni supporting matrix by treatment with a cond. solution of a salt of a weakly basic metal, particularly $Al(NO_3)_3$, followed by an alkali metal hydroxide solution. Electrodes produced by one such operation have similar capacities and have potentials 50 mv. higher than those made by 4 cycles of impregnation by $Ni(NO_3)_2$ followed by alkali. In an example a 0.9 mm thick and 40 $cm.^2$. surface porous plaque, produced by sintering Ni powder, is immersed for 2 minutes in a solution of 1 part H_2O and 3 parts cryst. $Al(NO_3)_3$ at $70-80^0$. The plaque is then placed in atmosphere saturated with H_2O vapor, at $75-80^0$ for 1.5-2 hours. After drying it is immersed for 30 minutes in 25% KOH solution at 80^0 followed by washing and drying. The active material is formed by reaction of 35-40% of the Ni in the plaque and contains about 10% Al. It has a capacity of 1.5 amp. hours.

B-470

H. Cohan and E. A. LaBlanc, Lockheed Missiles & Space Company, "Discoverer Orbital Thermodynamic Design-Predictions and Flight Data Correlation," Report No. P5-76-62-5 (Marck 28, 1962) AD 274 161

Methods used for predicting space vehicle structural and equipment temperatures on orbit are presented. The energy balance between the vehicle, deep space, the sun, and the earth is applied to determine dynamic temperature histories for vehicle equipment. Data received from vehicles on orbit are compared to predictions. Certain anomalies are investigated - and their causes determined. Application of flight results to vehicle design and prediction methods is described.

B-471

TRW Space Technology Laboratories, "Monthly Operational Summary Report. OGO-I," Report No. 2336-6009-RU000, NASA-X-65-91978L (June 1965), NASA Goddard Space Flight Center Contract NAS 5-9100.

The object of this contract is to provide GSFC with technical assistance to conduct the routine in-orbit operations for OGO-1. The contract requires the conduct of the day to day coordination of experiment data requirements to establish orbit operation plans. The analysis of the performance of OGO-1 on a day by day basis at GSFC as it relates to the determination of available duty cycle to support the planned operations is also required by this contract.

Sun Aspect and Spacecraft Orientation
Electrical Power System
Attitude Control-System
Thermal Control System
Command and Data Handling System
Orbit Considerations
Experiment Operations Summary

B-472

TRW Systems, Inc., "Operationa Summary Report. OGO-II," Report No. 2338-6003-R0000, NASA-X-66-36213L (January 1966), NASA Goddard Space Flight Center Contract NAS 5-9277

This report contains a discussion of OGO-II performance characteristics and significant in-orbit events. A brief summary of OGO-I performance is also given.

Performance Summary
Attitude Control System
Electrical Power System
Communications and Data Handling System
Thermal Control System
Experiment Performance

B-473

Irwin M. Schulman, Radio Corporation of America, Astro-Electronics Division, "Correlation of Data from Tests on Nickel-Cadmium Batteries," Final Report (November 1965), NASA Goddard Space Flight Center Contract NASW-1001

This report is divided into five sections. Section I, the Introduction, presents the background of the problem, the philosophy of the technical approach, and a summary of the findings. Section II deals with the problems encountered in data preparation and handling. (These problems ultimately dissolve into the development of a highly effective means of data preparation and handling.) The Theoretical Analysis is presented in Section III. Section IV, an Empirical Analysis, reports the development of an effective means of detecting defective cells and possible early prediction of failure. A possible method of discriminating among failure modes is determined and described. Conclusions and recommendations are presented in Section V.

B-474

Hyman J. Mandel, Electronic Components Laboratory, U.S. Army Electronics Command, "Recent Developments in Secondary Batteries," Design News, 21 (24) 76-82 (November 23, 1966)

Brief review of nickel-cadmium, silver-cadmium, and silver-zinc secondary batteries.

B-475

P. Ritterman, S. Lerner, and H. N. Seiger, Gulton Industries, Inc., "Investigation of Battery Active Nickel Oxides," Final Report, NASA CR-72128 (September 12, 1966), NASA Lewis Research Center Contract NAS 3-7620.

A study of the structures of compounds formed on a nickel oxide electrode with respect to charged stand, charge rate, state of charge and during overcharge has been made. This was done by using X-ray diffraction, chemical analysis and spectroscopy. Most of the work was done by means of X-ray Diffraction.

It was found that the structure of the discharged state corresponds to ordered $Ni(OH)_2$ and that this structure persists until the electrode is close to the fully charged state. At this point, the structure decays into a randomized NiOOH structure which is essentially amorphous to X-ray diffraction techniques. A theory is presented to account for these structural changes.

Continued high rate overcharging recrystallizes the amorphous material into what is called the γ-NiOOH structure.

Experiments for stabilizing the sintered plate nickel oxide electrode by means of formation at various rates and temperatures indicated that formation procedures have no effect on the charge retention properties of the electrode at elevated temperatures. However, electrodes formed at C/30 and 10°C shown an increase in absolute capacity.

The effects of the inclusion of various additives to the active material was also investigated as a method high temperature stabilization. It is shown that the inclusions of cobalt and manganese at the 20 atom percent level significantly increases the charge retention at 65°C as compared to normal positives and positives containing other metal additives.

B-476

7845r Electrochemical Measurements on Thin Layers of Nickel Oxide. M. L. Kronenberg (Res. Lab., Union Carbide Consumer Prods. Co., Parma, Ohio) J. Electroanal. Chem. 13(1-2), 120 3(1967) (England)

Previous studies on thick porous NiO electrode surfaces show that there are significant potential gradients through the bulk of the electrode. Upon charging or discharging, the bulk oxide lags behind the surface in degree of oxidn. or redn. Electrochem. oxidn. of a well-defined surface on a 40-mil Ni wire produced an electrode with approximately 1-2 mol. layers of oxide. The O evolution potential and the Ni^{2+} oxidn. potential increase with decreasing KOH concentration in aq. KOH solution at 23°. The discharge of the higher Ni oxide follows the path $Ni^{(3+1)} \longrightarrow Ni^{2+}$, not $Ni^{(3+1)} \longrightarrow Ni^{2+}$. The reversible potential of the Ni oxide electrode is $\leqq$ 0.447 v. vs. a Hg(HgO,KOH(1N) electrode.

B-477

A. S. Cherdak and H. N. Seiger, Gulton Industries, Inc., "Evaluation of Nickel-Cadmium Battery Testers," Quarterly Progress Report No. 3 (March 1961) Signal Corps Contract DA-36-039-SC-85066 AD 259 472

Several modifications have been made in the tester program which have eliminated high-current pulses due to anticipated damage to the cells under test. Pulsing of the BB412/U cells at -40 F has been eliminated due to the complete freezing of these cells. The accuracy of the tester is presented in the form of a graph. Phase B (storage testing) is in operation, and a partial evaluation has been made. The cycling equipment for Phase C was completed and cycling has been started. Due to questionable operation of cells on cycle, the cycle rates of the BB403/U and the BB418/U cells have been cut in half.

B-478

H. N. Seiger, Gulton Industries, Inc., "Investigations Leading to the Development of Improved Sealed Nickel-Cadmium Batteries. The Testing of Hermetic Seals and Separators, Positive Plate Studies, and Investigations on the Uniformity of Sealed Nickel-Cadmium Cells," Quarterly Progress Report No. 4 (April 1 - June 30, 1961), Signal Corps Contract DA-36-039-SC-85390. AD 265 170

Ceramic-to-metal seals are being made using a batch process using two furnaces. Plate formation in the pilot plant has been made automatic. Additional methods of making the cover to can closure are being investigated. Separator tests on polypropylene from American Felt and Pellon's PVC and polypropylene at 125 and -40 F were completed. The separators which seemed most promising were tested for strength and resistance after storage in electrolyte at 165 F. New cells were fabricated to improve uniformity between cells. Pressure and voltage characteristics were determined. Additional experiments on the oxidation of CD were made.

B-479

H. Bede (Translated by A. S. McKie), Royal Aircraft Establishment, "The Chemical Processes at the Electrodes of Electrochemical Sources of Current," Library Translation No. 991 (Angewandt Chemie, 73 (16), 553-560 (1961), March 1962. AD 275 178

The chemical energy present in the active materials of the electrodes of electrochemical sources of current is converted into current. The chemical reactions thereby initiated can be described formally as redox-reactions, but the individuality of the reacting material is not established by this means. Above all it is necessary to know the crystal structures of the compounds involved. As many of the reactions proceeding in electrodes are to be regarded as topochemical. The structures of those substances present in electrodes that support the electrochemical processes are considered for the most important kinds of battery. The following prototypes are discussed: primary cells of the leclanche system, alkaline nickel cadmium accumulator, leadacid accumulator.

B-480

Nicholas T. Wilburn, Kenneth E. Meade, and Charles J. Bradley, U.S. Army Electronics Command, Electronic Components Laboratory, "Dry Process Divalent Silver Oxide Electrodes," Technical Report ECOM-2628 (September 1965) AD 622 698

Silver oxide positive electrodes for use in zinc-silver oxide batteries have been made traditionally by the electroformed process. A lengthy, cumbersom and relatively expensive method. Attempts in the past to make the electrodes in one step, by applying the divalent silver oxide (AGO) directly to a grid with a suitable binder, have been unsuccessful due to poor mechanical strength. Such electrodes would, however, be highly desirable. In addition to substantial cost savings in production, they would have a greater uniformity, a higher discharge efficiency, and no trace of the objectionable initial high voltage "hump" of the conventional electroformed positive electrode. The development of a successful dry process silver oxide electrode was made possible by a simple but effective technique developed at USAECOM. This report covers this activity with suggestions on the adaptation of the method for use in the high speed, low cost production of silver oxide battery electrodes.

B-481

Benjamin C. Bradshaw, U.S. Army Electronics Command, Electronic Components Laboratory, "A Study of Electrodes and Electrode Reactions: II. The Relation of the Energy Necessary to Remove an Oxygen Molecule from Charged Nickel Oxide Electrodes in Vacua and Soltuions of Potassium Hydroxide," Technical Report ECOM-2646 (December 1965). AD 627 216

The energies that are necessary to remove oxygen from charged nickel oxide electrodes that are in solutions of potassium hydroxide at 25C were calculated. The 21 and 24 Kilo calories that are necessary to release one mole of oxygen into potassium hydroxide solutions agree with the 21 and 24 Kilo carlories that are necessary to release it into vacua. The evolution of oxygen from charged nickel oxide electrodes into vacua obeys the equation describing first-order reactions, and seems to result from the simple decomposition of the higher oxides of nickel. The evolution of oxygen obeys the same equation with the same specific reaction rates when the electrodes are in solutions of potassium hydroxide that are saturated with oxygen. Therefore, it was concluded that the reduction of the higher oxides of nickel results from a simple decomposition in both, that the rate of reoxidation of the lower oxides of nickel is negligible, and that the energy of activation for this reoxidation is large relative to KT. The variation of the electromotive force is calculated as a function of the variation of the ratio of the concentrations of the oxidized and reduced nickel ions that are on the surface of the electrodes.

B-482

Marshall E. Illstrup, General Dynamics/Astronautics, "Search for Critical Weakness Test Report for Centaur Main Missile Battery," Report (April 1962). AD 288 327.

B-486

A. S. Cherdak, Gulton Industries, Inc., "Evaluation of Nickel-Cadmium Battery Testers," Report (July 1961), Signal Corps Contract DA-36-039-SC-85066
AD 271 712

Descriptors: *Alkaline Cells, *Storage Batteries, *Test Sets, *Wet Cells, Cadmium, Instrumentation, Nickel, Power Supplies, Reliability, Temperature, Test Equipment, Test Methods, Tests

B-487

L. W. Kenyon, Aberdeen Proving Ground, Maryland, "Environmental Test of Nickel-Cadmium Storage Batteries," Report No. DPS/OTA-21 (August 1960) AD 240 924

Environmental field evaluation tests of ten 6TN and eleven 2HN type nickel-cadmium batteries were conducted at Yuma, Arizona, and Fort Churchill, Canada. The batteries were installed in test and facility vehicles operating over various types of terrain. The batteries were satisfactory for use under desert summer and arctic winter environmental conditions, however, insufficient data were obtained to determine whether the nickel-cadmium battery is an improvement over the standard lead-acid battery. It is recommended that the environmental tests of the nickel-cadmium batteries at Yuma and Fort Churchill be discontinued and that the batteries be tested under more continuous low ambient temperature field conditions.

B-488

E. C. Bruess, Quality Evaluation Laboratory, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells. Acceptance Test of General Electric Company 12.0 Ampere-Hour Auxiliary Electrode Cells," Report No. OE/C 66-803 (December 1966), NASA Goddard Space Flight Center Contract W11,252B

Presents the results of the acceptance tests of the General Electric Company 12.0 ampere-hour secondary spacecraft cells with auxiliary electrode. The ceramic seals of these cells, manufactured by General Electric Company, are satisfactory as evidenced by no leakers out of the 30 cells tested. The capacities of the cells were in the acceptable range of 15.30 to 16.92 ampere-hours.

B-489

S. Charlip, Gulton Industries, Inc., "Development of Pile Type, High Discharge Rate Nickel-Cadmium Squib Batteries," Second Quarterly Report (June 2 - September 4, 1966), NASA Goddard Space Flight Center Contract NAS 5-10160.

Cells with 2 square inches of active area were constructed and subjected to 10 ampere pulse discharges. The resultant voltage fell below 1.0 volts per cell. Previously cells with 4 square inches of active area gave 1 volt at 20 amperes. Several intermediate sizes of cells with electrode areas of 2.40, 2.76, and 3.14 square inches were constructed and tested. It was found that there is no linear relationship between current density and voltage. The larger plates showed little improvement in voltage. The 2.76 square inch plate appears to be the minimal electrode required, based on cell data only. Cells were pulsed for 20 milliseconds to determine the presence and effects of concentration polarization and activation polarization on positive and negative electrodes respectively. A five cell battery (of 2 square inch electrodes) was assembled and tested. Sealing problems were encountered during the battery assembly.

B-490

Albert Himy, Douglas Aircraft Company, Inc., Astropower Laboratory, "Development of One Ampere-Hour Heat Sterilizable Silver-Zinc Cell," Report SM-49109-Q2 (January 1967), Contract NAS 2-3819

The salient achievement of this period was the demonstration of the capability of a silver-zinc cell using inorganic separators to be sterilized, whether in the unformed state, or in a discharged state after formation, and to run successfully on its duty cycle. To establish the extent of their reliability, the cells were automatically cycled on a simulated low-orbital flight of 60-minute period and yielded up to 274 cycles.

As expected, the cells, which were sterilized in sealed vessels, exhibited different pressures depending on their presterilization state of formation. The preformed cell ran 27 psig higher than the unformed cell and developed a very high hydrogen content. However, higher amalgamation of the zinc in preformed cells will help reduce hydrogen generation and probably the pressure margin.

Different approaches were considered for establishing a seal. The rectilinear case, made of polysulfone, cannot be reliably sealed with solvent or epoxy cements. Ultrasonic welding has been tried, showed encouraging results, and will be pursued as well as hot-gas welding.

As a backup to the rectilinear case, a cylindrical configuration is following a parallel course. Preliminary seal testing showed the feasibility of achieving a hermetic seal capable of withstanding the sterilization procedure of 145°C for 108 hours. A cylindrical separator cup made of inorganic material was developed for the electrochemical cell design intended for this type of configuration.

B-491

Raymond Jasinski, Tyco Laboratories, Inc., "High Energy Batteries," Second Quarterly Report (December 15, 1966), U.S. Navy Air Systems Command Contract NOw 66-0621-c.

> The central area of the present research and development program is to characterize selection high energy density and high discharge rate batteries and to modify appropriate chemical and physical properties of various battery components in order to optimize the performance of the total battery system: (1) "lithium batteries" based on organic aprotic solvents and (2) aqueous AgO/Zn batteries. The studies in these systems include (1) investigation of mechanisms of charge-discharge of positive electrodes, (2) studies of electrolytes as they are directly involved in the electrode processes, and (3) effects of impurities on electrode processes.

B-492

M. Shaw, N. K. Guptz, A. H. Remanick, and R. J. Radkey, Whittaker Corporation, Narmco Research and Development Division, "Electrochemical characterization of Systems for Secondary Battery Application," Second Quarterly Report, NASA CR-72138 (August-October 1966), NASA Lewis Research Center Contract NAS 3-8509

> Multisweep cyclic voltammograms have been obtained from one hundred and fifty-three systems comprising silver, copper, nickel, zinc, cadmium, and molybdenum in acetonitrile, butyrolactone, dimethylformamide, and propylene carbonate solutions of chlorides and fluorides. Voltammograms are presented for fifty-six of these systems. Tabular data includes peak current density, sweep index, charge-discharge efficiency, and discharge capacity.

B-493

Clarence M. Shepherd and Harry C. Langelan, U.S. Naval Research Laboratory, "High Rate Battery Electrodes," Journal of the Electrochemical Society, 114 (1), 8-13 (January 1967).

> It has been shown previously that metal plates of controlled porosities and high surface areas can be produced by the electrolytic reduction of metal compounds subjected to controlled physical pressure during electrolysis. When these plates are discharged as anodes in test batteries their capacities and ampere hour efficiencies are found to increase rapidly as the porosity increases. At porosities of 85-90%, high efficiencies were obtained for extremely high discharge rates over a range of temperatures extending down as low as -60 C. Similar results were obtained with high porosity cathodic active materials. The active materials thus tested included zinc, cadmium lead Ag_2O, and AgO, all of which were highly successful, thus indicating that the technique can be applied to a wide range of batteries and active materials.

B-494

Bruce Jagid, Leesona Corporation, Leesona Moos Laboratories, "Development of a Zinc/Oxygen Battery System for Space Vehicle Application," Quarterly Report No. 1 (November 1966), NASA George C. Marshall Space Flight Center Contract NAS 8-20565

This report covers the work performed on the development of a zinc-oxygen battery system for space application, during the period July 1 through September 30, 1966 for the National Aeronautics and Space Administration. During this report period a detailed theoretical systems analysis has been performed to determine the number of cells and stacking arrangement which would yield the maximum energy density and overall system reliability. A parametric analysis has also been implemented to optimize anode and cell configuration. It was found that energy densities in excess of 120 watt-hours per pound are attainable for the high rate (8-hour) application. A basic and simple heat removal technique, which utilizes the intercell separators as the vehicle for heat removal, was shown to be feasible. Electrode fabrication procedures were defined and are presently being evaluated. A test program designed to characterize activated shelf life problems was initiated this period.

B-495

A. M. Chreitzberg and F. S. Cushing, The Electric Storage Battery Company, "Research and Development on Cells with Bellows Controlled Electrolyte Levels," Fourth and Final Progress Report, ESB Report No. E-13-66 (May 11, 1965 - April 1, 1966), NASA Goddard Space Flight Center Contract NAS 5-3813.

Control of electrolyte level in sealed Ni-Cd and Ag-Cd cells with bellows action has been demonstrated in 8-hour and 24-hour orbit tests over the temperature range $0^{\circ}C-40^{\circ}C$. Bellows installed in the bottom of cell cavities collapse as cell pressures increase near the end of charge allowing electrolyte levels to fall under gravity action, exposing greater negative plate and oxygen electrode area.

Recombination rates were limited by rate and degree of electrolyte drainage from cell packs. In sealed Ni-Cd cells optimum performance was achieved with 20% KOH electrolyte and woven cloth separators. In sealed Ag-Cd cells closed "U" folds of semi-permeable membranes could not be drained. Oxygen recombination rates on exposed negative and oxygen electrodes were enhanced by drainage of electrolyte from bellows action.

A survey of metal bellows was made to locate an efficient design. A stack of rectangular plastic film pillows proved to be more efficient in weight, volume, and volume change per unit volume.

Optimum designs were incorporated in 8-A.H. and 100-A.H. Ag-Cd sealed cells for deliverable hardware. The 100-A.N. cell contains a special metal bellows with an internal normally closed switch actuated by high cell pressure to terminate charge.

B-496

W. N. Carson, JR., and J. A. Consiglio, General Electric Research and Development Center, "Electrodeposited Inorganic Separators," Final Report (August 1966), NASA Goddard Space Flight Center Contract NAS 5-9168

The objective of this program was the evaluation of thin electrodeposited films of calcium and magnesium hydroxides for use as separators in silver-cadmium cells. Potential gains to be achieved with these separators are increased thermal stability at elevated temperatures and a reduction in silver migration with lower overall separator thickness requirements.

The work program was conducted in two phases. The first phase consisted of an investigation to determine the effect of process parameters on the resulting film properties.

The parameters investigated were electrolyte type, concentration, current density and electrode substrate condition with respect to state of charge and liquid content. The principal film characteristics determined as a function of the above parameters were film weight, film thickness and density, and changes in resistance attributed to the film. In addition to these quantative film characteristics, film adherence and uniformity of coverage of the electrode were determined on a qualitative basis.

The second phase of the work was concerned with evaluating the performance of the coated electrodes in terms of capacity developed under short term charge-discharge cycling, polarization increases contributed by electrodes with films of varying thickness, and control of silver transport. In addition, the effect of sterilization at 145°C on the above performance criteria was evaluated.

The process parameters studies showed that the calcium hydroxide films on silver electrodes were more adherent and uniform in electrode coverage than the magnesium hydroxide films. For the calcium hydroxide films, the preferred process parameter ranges for obtaining adherent film thicknesses of one to five mils per side are: electrolyte concentrations of 70 to 280 grams per liter of calcium acetate buffered with one to two grams per liter of calcium hydroxide using current densities of 75 to 150 milliamperes per square centimeter. Film adherence was improved by depositing films on silver electrodes which had previously been cycled once and discharged and which contained no liquid in the pores prior to immersion in the coating bath. Film weight and thickness were found to correlate as a linear function of the ampere-hour product. The coulombic efficiency in the preferred process variable range approached 50 percent. The film densities based on photomicrographic examination and calculations from weight gain and thickness determinations are in the range of 85 to 100 percent of the theoretical calcium hydroxide density. The resistance increases caused by the film as measured by a 1000 cycles per second bridge did not correlate strongly with film thickness, weight increase or ampere-hour product.

The performance evaluation studies showed that the coated electrodes developed their nominal capacity after short term, constant current charge and discharge cyclic tests (six to twelve cycles). Polarization measurements on coated silver electrodes showed no large increases as a function of film thickness or when compared to uncoated electrodes at discharge rates equivalent to a one C rate. At 0.1 ampere ($\sim$0.1 C rate) coated electrode polarization values ranged from 4 to 13 percent lower than the average of uncoated electrodes. At 1.0 ampere ($\sim$1.0 C rate) the polarization values ranged from 10 percent lower to 20 percent greater than the average for the uncoated electrodes.

The films are effective in controlling silver transport based on analysis made after a short number of cycles (six to twelve). The silver transported through the films and collected on a nylon separator ranged from 13 to 55 percent of the amounts collected for uncoated electrodes. The sterilization studies showed that the coated electrodes could be heated to 145°C for a period of 40 hours in either degassed 31 percent by weight potassium-hydroxide solution or in nitrogen without the loss of the coating. The performance of these electrodes in subsequent cell tests with respect to capacity, polarization and silver transport was similar to that obtained with unsterilized coated electrodes.

Ten five-ampere-hour silver-cadmium cells were modified and will be tested by Goddard Space Flight Center personnel for longer term performance evaluation. Five of these cells contain silver electrodes coated with calcium hydroxide of a nominal film thickness of two mils and five cells have a nominal film thickness of five mils.

B-497

E. Kantner, P. Ritterman, R. V. Tarantion, and R. C. Shair, Gulton Industries, Inc., "Investigations of Hermetically Sealed Maintenance-Free, High Rate, Nickel-Cadmium Batteries for Aircraft Applications," Quarterly Technical Progress Report No. 7 (June 1966), Wright-Patterson Air Force Base Contract AF 33(615)-2087.
AD 484 494

The objectives of this program are to design, develop and fabricate hermetically sealed, maintenance-free high rate, nickel-cadmium batteries for aircraft applications. The battery must be capable of delivering the necessary power for engine starting. It must be capable of withstanding the varied environmental conditions that may prevail in an aircraft, and it must be compatible with the constant potential charging system of the aircraft. To achieve these objectives: A basic research program has been undertaken with the ultimate goal of improving the electrochemical operation of sealed nickel-cadmium cells. Improvements sought include longer shelf life, better electrical performance at high rates of charge and discharge, and better electrical performance at high and low temperature extremes. To make the battery compatible with the constant potential charging system of the aircraft, a charge control-charge conditioning system is being studied to allow rapid charging of the battery when it needs to be recharged. When the battery becomes fully charged, the charge control-charge conditioning system must also be capable of terminating the charging current on signal from an end-of-charge signal generating device.

B-498

C. R. Green and A. F. Schaffhauser, Admiral Corporation, "Recorder-Reproducer Set, Signal Data AN/GSH-6 (XE1, 2)," Final Engineering Report (October 1965), U.S. Army Electronics Research and Development Laboratory Contract DA-36-039-AMC-03303(E). AD 477 883

This report covers the design and development of the experimental models of the recorder-reproducer set. Signal data AN/GSH-6. The first portion of the project covered the period from the initial design concepts through the construction and delivery of the four engineering test models AN/GSH-6 (XE-1), while the second portion covered the evaluation of the engineering test models and the construction of the fourteen service test models AN/GSH-6(XE-2). The initial concepts for the equipment were outlined in the design plan and the early quarterly progress reports. These included such overall design parameters as frequency response, tape speed, recording and playback levels, tape bias, total recording time, and signal-to-noise ratios of the recorded messages. The electronic considerations included such items as the design of special circuitry for the IDY (identity) function, stage-to-stage gain, input and output levels, and the characteristics of recording and playback heads as well as of the magnetic recording tape. The mechanical considerations included the functional design and dimensional data of the individual units, including the integrated layout of the electrical and mechanical components such as the operating mechanisms which were furnished by a subcontractor.

B-499

J. T. MacLean and F. S. Kemp, Boeing Company, "Evaluation of Silver-Cadmium Batteries," Final Report (June 1964). AD 469 615

This report describes tests conducted on thirteen-cell batteries of 12 ampere-hour metalcased silver-cadmium cells under simulated orbital conditions. Many thousands of cycles had previously been demonstrated for batteries of three-cell 3 AH epoxy-potted silver-cadmium cells. Four batteries of thirteen sealed, metal-cased, silver-cadmium, 12 AH cells were cyclically charged and discharged under simulated 300-mile orbital conditions. Discharging 35% of nominal ampere-hour capacity per cycle and operating in radiation heat sinks at -10, +20, and +40 C. first cell failures occurred at 313 to 1350 cycles. The early failures appeared to be related to leaking cells and to rapid loss in apparent cell capacity, following the premature failures of the metal-cased cells. Two batteries of 12 AH epoxy-potted cells were placed on test under the same 300-mile orbital cycle conditions and at 35% depth of discharge. It is believed that silver-cadmium batteries will play an increasing role in orbiting space vehicle power systems because of inherent lighter weight than the currently used nickel-cadmium system and demonstrated long cycle life. Thorough evaluation is emphasized of new battery designs before committing to use in space vehicles.

B-500

P.P.M. Liwski, Marine Engineering Laboratory, "Charge-Current Control Circuit for Nickle-Cadmium Cells with Control Electrodes," Final Report, Report No. MEL-25/65 (April 1965). AD 462 426

A circuit to control charge current entering nickel-cadmium cells with control electrodes (three-terminal cells) has been developed by MEL for use in systems requiring minimum space and weight with optimum control. The potential of the third (control) electrode of a cell becomes input to determine time and manner of charge-current change. Presently a laboratory instrument, this circuit is later to be adapted to satellite applications.

B-501

Helen M. Abbott, Lockheed Missiles and Space Company, "Secondary Battery Charge Control: An Annotated Bibliography," Literature Search 1962-64, LMSC-LS-60 (September 1964). AD 479 784L

These 198 references were compiled as the result of a literature search, 1962-64 (August) on methods of controlling the charge of secondary batteries. Special interest was indicated for the NI/CD type batteries. Subject and corporate source index are included. A review of 1961-1962 literature on batteries can be found in LMSC SB-63-14. Electrochemical batteries.

B-502

J. J. Lander and J. A. Keralla, General Motors Corporation, Delco-Remy Division, "Zinc Electrode Investigation," Quarterly Technical Progress Report No. 1 (October 15, 1964), Wright-Patterson Air Force Base Contract AF 33(615)-1583. AD 606 999

Initial experiments with one to five grams of a palladiumon-alumina catalyst for hydrogen-oxygen recombination in sealed cells was successful in maintaining low gas pressures for an 0.5 ampere overcharge condition for up to eight hours. Tin and lead impurities in the negative plate up to 5% were tested for their effects on cycle life. There was no observable effect, either beneficial or deleterious. Effects of silver impurities are uncertain. Cells containing negative plates formulated with broad ranges of composition of both polyethyleneoxide and polyvinyl alcohol were cycle-life tested. The results indicate that 2% polyvinyl alcohol gives best life and voltage performance, other experimental work under way is described.

B-503

T. P. Dirkse, Calvin College, "Silver Migration and Transport Mechanism Studies in Silver Oxide-zinc Batteries," Quarterly Technical Progress Report No. 3 (September 1964), Wright-Patterson Air Force Base Contract AF 33(615)-1236. AD 605 684

The applicability of Fick's Law of Diffusion to the diffusion of hydroxide and zincate ions through a cellophane membrane has been studied and verified. The effect of surfactants on the type of zinc deposit obtained when zinc is electroplated from a zincate solution has been studied over a range of current densities and zincate concentrations. These surfactants have also been incorporated in the zinc electrode. A few of these surfactants appear to improve the cycle life characteristics of the zinc electrode. However, when incorporated in the electrolyte they seem to afford no improvement in cycle life at higher current densities. The decomposition of AG2O in KOH solutions has been followed and the effect of added materials on this process has been noted.

B-504

T. P. Dirkse, Calvin College, "Investigation of the Transport and Reaction Process Occurring Within Silver Oxide-Zinc Batteries," Quarterly Technical Progress Report No. 1 (April 1965), Contract AF 33(615)-2297. AD 461 102

The effect of surfactants on zinc electrode processes and on AG2O decomposition has been studied at room temperature. The four surfactants chosen for this study do have an effect on these processes and this effect differs from one surfactant to another. With AG2O decomposition, two surfactants had but little effect while the other two increased the rate of decomposition considerably. The effects of these surfactants on the zinc electrode processes is not very great.

B-505

T. P. Dirkse, Calvin College, "Investigation of the Transport and Reaction Process Occurring Within Silver-Oxide-Zinc Batteries," Quarterly Technical Progress Report No. 2 (July 1965), Contract AF 33(615)-2297. AD 466 909

The effect of surfactants on the zinc electrode processes in KOH solutions, and on the decomposition of AG2O dissolved in KOH solutions has been studied at 10 C. The surfactants do increase the rate of AG2O decomposition but have little effect on the zinc electrode processes. The effect of silver contamination on amalgamated zinc electrodes has been studied in 40% KOH at room temperature. The silver lowers the hydrogen over voltage at the zinc electrode and it also lowers the current density at which hydrogen begins to be evolved. The amount of surface area of glass has no effect on the rate of decomposition of AG2O dissolved in 30% KOH at room temperature.

B-506

Raymond Jasinski, Tyco Laboratories, Inc., "An Analysis of All Potentially Useful High-Energy Battery Systems," Final Report (July 26, 1965), Bureau of Naval Weapons Contract NOw 64-0653-f. AD 474 950

This document is the final report of contract NOw 64-0653-F undertaken for the Energy Conversion and Propulsion Branch of the Bureau of Naval Weapons, Department of the Navy. The purpose of this effort was to develop an analysis of all potentially useful high energy battery systems for applications in naval aircraft, missiles, torpedoes, and satellites. Within the context of this program, the term "high energy" has been specified as an energy-weight density of at least 50 whr/lb for secondary batteries and 100 whr/lb. for primary batteries. The following three levels of research and development are defined: (1) battery systems which, upon completion of present research, development, and evaluation, can be immediately engineered for specific application in aircraft, missiles, torpedoes, or satellites; (2) those systems having better performance, but requiring extended research, development, and evaluation prior to engineering prototype; (3) those systems having potentially superior performance, but requiring fundamental research prior to any battery development projects. The basic sources of information used were: (1) the open literature, (2) Government reports, principally Department of Defense and NASA, and (3) the patent literature. The information surveyed covered the time period from 1945 to the present.

B-507

E. C. Bruess, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells. Acceptance Test of Gulton Industries, Incorporated 3.5 Ampere-Hour Sealed Nickel Cadmium Cells with the Plitt Seal," Report QE/C 66-709 (November 18, 1966), NASA Goddard Space Flight Center Contract W11,252B.

Evaluation of Gulton Industries, Inc. 3.5 ampere-hour secondary spacecraft cells was begun according to the program outline of reference. These cells utilized a polymerized neoprene compression seal developed by Karl Plitt of Goddard Space Flight Center. From the results of this test, it can be concluded that:

1. The new polymerized neoprene compression seals are satisfactory as evidenced by no leakers out of the 42 cells tested.
2. The capacity of 41 of the 42 cells was in the acceptable range of 3.50 to 4.38 ampere-hours while that of the remaining cell had a capacity of only 2.65 ampere-hours.

B-508

S. Lerner, Gulton Industries, Inc., "Characterization of Recombination and Control Electrodes for Spacecraft Nickel-Cadmium Cells," Second Quarterly Report (September 9 - December 9, 1966), NASA Goddard Space Flight Center Contract NAS 5-10241.

Cells containing various materials as oxygen scavenger electrodes, and cells containing active Adhydrodes in various positions, have been prepared and studied in order to determine the best combination for use in cells that will contain both types of electrodes. It has been determined that the best scavenger electrode material is the AB6X fuel cell electrode and the best position for the Adhydrode is in the center of the pack. Preliminary testing of cells with both types of auxiliary electrodes has been initiated.

B-509

Yu. M. Pozin, A. P. Murachkovskii, and O. I. Bondarenko, Scientific Research Storage Battery Institute (USSR), "Storage Battery Electrodes Made by Rolling Carbonyl Nickel Powder," Soviet Powder Metallurgy and Metal Ceramics No. 10(34) 787-791 (1965)

It is shown that, by rolling a mixture of carbonyl nickel and urea powders, it is possible to produce sintered electrode strip reinforced with gauze or a grid, having a porosity of about 75% after sintering. The rolled strip may have the following constructional features: (a) the powder mass layer may extend 1.0-2.0 mm beyond the edge of the grid strip; (b) the grid strip may protrude from the powder layer along the length of the strip. Sintered strip produced by rolling is superior to pressed strip lengths in respect to thickness and porosity uniformity.

B-510

W. N. Carson, Jr., G. Rampel, and I. B. Weinstock, General Electric Company, Battery Business Section, "Characterization of Recombination and Control Electrodes for Spacecraft Nickel-Cadmium Cells," Second Quarterly Report (January 1967), NASA Goddard Space Flight Center Contract NAS 5-10261.

Task I - Oxygen Sensing Electrode

1. A complete set of polarization studies were made on eleven dual test electrodes at 0, 5, 10, 15, 20, 25, and 30 PSIA oxygen pressure at room temperature.
2. The more promising electrodes were evaluated over the temperature range of -10 C to 35 C.

Task II - Oxygen Recombination Electrode

1. Test cells for the characterization of electrodes were modified to improve heat transfer between the working electrodes and the atmosphere.
2. The ability of our electrode fabrication process to produce electrodes of consistent quality has been demonstrated.

3. The effect of "ageing" on the performance of electrodes has been investigated, and no significant effects have been observed.
4. The performance of a number of fuel cell electrodes have been investigated. Electrodes developed in this program offer the best performance.

Task III - Negative Plate Evaluation

Three lots of negative plate were received from manufacturing and evaluated.

Task IV - Assembly of Plate Racks with Recombination Electrodes

During this quarter the plate was formed, and the packs, recombination electrode and separator were sent to the Research and Development Center to be used in assembly of prototype cells.

B-511

R. L. Hammel, J. M. Robinson, and H. T. Sliff, TRW Systems, "Environmental Research Satellites for Space Propulsion Systems Experiments," Quarterly Progress Report, October 1 to December 31, 1965, Report No. AFRPL-TR-66-64 (March 1966), Edwards Air Force Base Contract AF 04(611)-10747. AD 481 190

The development, fabrication, test, and delivery of environmental research satellites for in-space propulsion systems experiments are reported. Two spacecraft will be built for the friction experiment and two spacecraft for the zero G heat transfer experiment. The first units of each experiment will be designated the prototypes. The flight units will be launched as subsatellites from a primary launch mission. The friction experiment is concerned with the broadening of knowledge with surface friction in the space environment. The experiment can contribute to our understanding of surface friction processes in the combined environment of space vacuum and radiation. The zero G heat transfer experiment is concerned with the influence of change of gravitational acceleration on heat transfer coefficient in the various transfer regimes and heating rates at which transitions between these regimes occur. The low G heat transfer data obtained may be applied in the design of systems involving heat transfer to volumes of fluid as typically occurs in tankage.

B-512

P.P.M. Liwski, Marine Engineering Laboratory, "Solid-State Circuit Development," MEL R&D Phase Report 283/64 (April 1965). AD 462 251

Results are presented of the final design changes to a silver-cadmium battery sensing and switching circuit developed at MEL for satellite electric power systems. This circuit is designed to continuously monitor the terminal voltages of an active and a standby battery and the individual cell voltages in the active battery. When minimum voltage conditions are met, the circuit switches electrical load from the active to the standby battery. This circuit also allows solar cells, when energized, to supply load current and battery charging current. Also described is a circuit designed to control the charge current into recently developed nickel-cadmium cells with control electrodes. The potential on the control electrode of a cell is the input signal to this circuit which, in turn, determines when and how the charge current is to be changed. At present this tube is a laboratory instrument only but will be made suitable for satellite applications in later developments.

B-513

Paul J. Rappaport, U.S. Army Electronics Laboratories, "The Effect of Carbonated Electrolyte on the Performance of Sintered Plate Nickel-Cadmium Cells," Technical Report No. ECOM-2559 (February 1965) AD 614 104.

The effect of the capacities of positive and negative limiting sintered plate Ni-Cd cells of varying the KOH/K2CO3 ratio of an electrolyte which is approximately 7N in total alkalinity is reported. K2CO3 contents of 24, 71 and 238 G/I were investigated. Data are also presented on the specific resistance of various KOH-K2CO3 solutions over the temperature range of 86F to -40F. There was no marked difference in performance of either positive or negative capacity limiting cells with electrolyte containing 24 or 71 G/I of K2CO3. However, there was an appreciable adverse effect on the performance of cells when the carbonate content was 238 G/I K2CO3, particularly for the negative capacity limiting cells. From the results of the capacity and specific resistance measurements. It is recommended that the maximum allowable carbonate content for the electrolyte in sintered plate Ni-Cd cells be set at 100 G/I K2CO3.

B-514

Thedford P. Dirkse, Calvin College, "Low Temperature Cycling Behavior of the Silver Electrode," Technical Report No. 3 (November 1, 1964), Office of Naval Research Contract Nonr 1682(02). AD 609 876

Further work on the cycling characteristics of the silver electrode was carried out. (See AD-404 B41). Emphasis was placed on the performance of the silver electrode at temperatures below freezing and the effect of current density on these characteristics.

B-515

Martin Sulkes and George A. Dalin, Yardney Electric Corporation, "Development of the Sealed Zinc-Silver Oxide Secondary Battery System," Sixth Quarterly Progress Report (December 1964), U.S. Army Electronics Laboratories Contract DA-36-039-AMC-02238(E) AD 464 470.

The rate of reaction of hydrogen with AGO and AG2O-PD was determined in cells with different electrolyte concentrations and silver particle sizes. The combustion AG2O-PD with 26.5% KOH gave the highest reaction rate, 0.14 MA/sq. in. A new test method has been devised for the determination of the rates of reaction and diffusion of silver oxides with and through separators. Surface active agents were investigated with regard to their effect on zinc penetration. The cycle life and failure analysis data are given for 32 cells built for the silver density, interseparator, electrolyte, quantity and concentration experiment. Cells in this group developed pressure after 150 to 260 62 1/2% d.d. cycles due to an accumulation of hydrogen. The cycle life and failure analysis data are given for 14 cells built for the negative binder, amalgamation experiment. Cycle life was unaffected by various types of cadmium grids in the negative. Cells containing B-30 teflon binder were analyzed after failure. The binder appears to be effective in reducing shape change and increasing cycle life. Twelve cells built for operation only on the AG-1 level have completed 10 evaluation cycles. Good charge acceptance on the AG-1 level was obtained in cells containing 1% PD in the positive. These cells yielded up to 70% of theoretical capacity at the C/3 rate of charge.

B-516

L. G. Austin and Harry Lerner, Pennsylvania State University, "Review of Fundamental Investigations of Silver-Oxide Electrodes," Report No. 1 (October 1965), Harry Diamond Laboratories Contract DA-49-186-AMC-197(D). AD 478 632

Brief summaries of 19 recent papers concerned with fundamental aspects of the AGO/AG2O/AG electrode in alkali are included. Instead of reviewing these papers, the most likely physical model of the electrode, based on information in the papers, is discussed.

B-517

Regina D. Wagner, U.S. Naval Ordnance Laboratory, White Oak, "A Method for the Quantitative Analysis of the Silver Oxide Cathode," Final Report NOLTR-64-214 (June 23, 1965). AD 618 479

A method was developed to quantitatively analyze mixtures of the silver oxides and silver metal such as occur in the silver oxide cathode of primary and secondary alkaline silver-zinc batteries. The detailed procedure is given and data verifying its accuracy presented. The occurrence of a reaction between argentic oxide and silver metal is also verified.

B-518

T. P. Dirkse, Calvin College, "Investigation of the Transport and Reaction Processes Occurring Within Silver-Oxide-Zinc Batteries," Final Technical Report AFAPL-TR-66-5 (March 1966), Wright-Patterson Air Force Base Contract AF 33(615) 2297. AD 478 674

The decomposition of silver oxide dissolved in KOH solutions was studied. The effect of temperature, light, KOH concentration, Ag_2O concentration, and the presence of additives on this decomposition was measured. At least two mechanisms are involved in this reaction but the precise paths or routes of these processes is still unknown.

Overvoltages for anodic and cathodic zinc electrode processes were measured by different methods. The presence of additives in the electrolyte had little effect on these overvoltages. These overvoltages are markedly affected by changes in KOH concentration and temperature. Amalgamation improves the performance of the zinc electrode but this effect decreases with decreasing temperature. Silver contamination adversely affects the cathodic zinc electrode processes.

Attempts were made to relate the effects of additives to structural characteristics. It appears that the beneficial effects of additives to the electrolyte are related to the presence of carboxyl groups and that the beneficial effects of additives to the zinc electrode are related to the wetting ability of these additives.

B-519

A. Langer and J. T. Patton, Westinghouse Electric Corporation, Research Laboratories, "A Coulogravimetric Study of the Sintered Silver Electrode in 1 Molar Potassium Hydroxide," Journal of the Electrochemical Society, 114 (2), Part I, 113-117 (February 1967)

Weighing of a sintered silver electrode while immersed in electrolyte during cathodic and anodic reaction reveals breaks in the weight change-coulomb curves. The different slopes can be explained by the volume change during phase transformation, affecting the buoyancy of the electrode. These breaks coincide with the potential changes of the plate, measured against a reference electrode.

B-520

Floyd E. Ford, U.S. Navy Marine Engineering Laboratory, "Automatic Battery Formation Cycler and Controller," MEL R&D Report 50/65 (July 1965), NASA Goddard Space Flight Center Contract S-12730-G. AD 467 988

An automatic cycler and controller was designed to determine charge capacity and perform appropriate charge/discharge operations on electrochemical cells intended for use as satellite power sources. This device is capable of monitoring up to 20 series-connected cells at a time and characterizing each cell according to its terminal voltage and ampere-hour capacity.

B-521

Jeanne Burbank and C. P. Wales, U.S. Naval Research Laboratory, "Oxides on the Silver Electrode. Part 2 - X-Ray Diffraction Studies of the Working Silver Electrode," Final Report NRL-6171 (October 22, 1964). AD 614 058

Silver electrodes were examined in 20-50% KOH using a cell permitting simultaneous X-ray diffraction and electrochemical studies. Highly oriented smooth rolled sheet silver developed randomly oriented Ag on its surface during early cycles. Charge/discharge capacity increased to a maximum as surface area increased. AgO crystal size and amount formed varied inversely with charging current density with high charging rates giving tight coatings of small AgO crystals that limited further oxidation. Reactions took place initially at the outer surface of the electrode with oxidation to Ag_2O and AgO and reduction to Ag_2O and Ag occurring by formation of distinct crystals rather than by expansion or contraction of pre-existing crystal lattices. Discharge capacity at the AgO/Ag_2O potential plateau depended more on surface area than on quantity of AgO. A slow discharge produced smoother Ag surfaces, lowering capacity of the next cycle. There was never evidence of a suboxide, oxidation state higher than AgO, solid solution, or alloy of oxygen and silver.

B-522

A. Langer, R. G. Charles, and C. R. Ruffing, Westinghouse Electroc Corporation, Research Laboratories, "Separator Development for a Heat Sterilizable Battery," Westinghouse Research Report 66-9B6-BSEPA-R2, Second Quarterly Report (December 30, 1966), Jet Propulsion Laboratory Contract No. 951525 under Prime Contract NAS-7-100. Re-Order No. 66-873.

The present report describes progress in the following areas: (1) membrane fabrication by a number of different techniques; (2) properties of membranes, including effects of solvent and filler on resistivity, the effects of sterilization exposure, and the resistance of composite membranes to penetration by zinc dendrites, (3) evaluation of epoxy resins containing 8-hydroxyquinoline groups; (4) and study of the effects of electrode rotation on dendritic growth of zinc. Details of progress are given in the following sections of the report.

B-523

R. A. Powers, Union Carbide Corporation, Consumer Products Division, "Secondary Zinc-Oxygen Cell for Spacecraft Applications," First Quarterly Report (June 23-September 23, 1966), NASA Goddard Space Flight Center Contract NAS 5-10247

Development of a 16 AH unit zinc-oxygen test cell has been completed during the first quarter covered by this report. The ampere hour rating is based upon the 19.2 grams of zinc actually used in the first test cells and represents the calculated theoretical capacity. Optimization of these cells will be carried out in further work. "Lucite" has been used as the material of construction to permit visual observation of the wetproof back side of the "fixed-zone" oxygen electrode as well as the two electrolyte chambers on either side of the charging electrode during the period of cell cycling.

Characterization of cell performance at the twenty-four hour rate is now in progress using a nickel screen charging electrode. Cell performance studies at the two-hour rate have begun. Characterization of cell rechargeability has also been initiated on a two-hour discharge, six-hour charge cycle. This work has now undergone fourteen complete cycles while cell characterization at the twenty-four hour rate has progressed through the sixth complete cycle. The unit zinc-oxygen cell was also operated at discharge currents ranging up to 6.9 amperes. Performance of the first test cells under these conditions clearly indicated its capability of meeting high rate discharge requirements.

B-524

43157m Diminishing-Rate Battery Charger. Walter T. Kuauth, U.S. 3,296,515 (Cl. 320-21) January 3, 1967. Appl. May 5, 1964, 6 pp.

The battery charger can charge a battery at a rate proportional to the amount the battery potential has fallen below its normal full-charge potential. At full charge, the battery charger cuts off regardless of normal power-line voltage fluctuations. In the charger, a transformer has a primary winding connected to an a.c. power source, a center-tapped, step-down, secondary winding, a main circuit, a controlled rectifier, positive and negative battery posts and a return junction. The main circuit has an ammeter and parallel return circuits, each including a return rectifier to return the charge current alternately each cycle from the return junction to a responsible secondary winding. A current limiting resistor, a zener, and a battery current blocking diode are connected in series between the center tap and the return junction to establish a reference voltage. A gate firing circuit connects the series circuit and the current limiting resistor to the gate. The gate firing circuit includes a second battery current blocking diode and a gate firing circuit to dispose the reference voltage for comparison with the actual battery voltage. The difference between the voltages is used to gate fire the controlled rectifier for charge current control. Thus, the charge current is diminished to a minimum as the battery approaches full charge potential.

B-525

43153g. Electrochemical Cell. Frank Solomon (to Yardney International Corp.). U.S. 3,294,590 (Cl. 136-120), December 27, 1966. Appl. November 13, 1957 and November 1, 1962, 3 pp

A method is described to prepare a Ag electrode which will charge fully to the argentous (or oxide) level but which will not accept substantial charge at the argentic (or peroxide) voltage level. For example, 100 g, Ag_2O 2.5 u in diameter was suspended in 240 ml. of 10% KOH. A mixture of 50 ml. 37% HCHO and 50 ml. water was added to the slurry. The reaction mixture was agitated until gas evolution ceased. The material was filtered and the ppt. was washed with water until the effluent was neutral to litmus. The Ag powder was air-dried. The powder was pressed into an electrode and charged against Zn electrodes in a Ag-Zn cell. The cell accepted charge at the argentous voltage, until at 2.05 v., electrolysis of the H_2O in the electrolyte started. The gas evolution precluded further charging.

B-526

43185u. Sealed Battery. John P. Jorgan (to Gulton Industries, Inc.) U.S. 3,294,591 (Cl. 136-133), December 27, 1966. Appl. March 30, 1964, 4 pp.

A cover is provided for batteries utilizing low surface-tension electrolytes, where the insulating and main sealing functions are separated. The cover has an outer member and an inner member secured together by a neoprene rubber insulating layer (0.001-in. thick), which after application is vulcanized at 315°F for 10 minutes.

B-527

43190s. Perfection of Electric Accumulators Containing Electrodes on Cadmium Base. Societe des Accumulateurs Fixes et de Traction. Fr. 1,445,651 (Cl. H 01m), July 15, 1966, Appl. June 1, 1965; 3 pp.

A redn. of capacity losses due to aging on the Cd electrodes in Cd/Ni or Cd/Ag storage batteries is achieved by impregnation of the electrodes with Co. Therefore the skelton of the electrodes consisting of fritted Ni is, soaked with a solution of Cd salts containing 1-2 g. atom % Co related to g.-atom Cd, e.g., as Cd, Co nitrate. The next step is the pptn. of the Cd and Co as hydroxides by treating with alkali. Both steps are repeated until the impregnation of the electrodes with Cd and Co is completed.

B-528

43187w. Electrode for Alkaline Storage Batteries and a Manufacturing Method for the Same. Roland Ackermann and Karl H. Christian. Ger (East) 49,427 (Cl. H 1 m), August 5, 1966. Appl. June 2, 1965. 2 pp

The invention describes an electrode preferably for use in alk. accummulators, and an economical manufacturing method. Conventional manufacturing methods such as inserting the press-formed active electrode mass into suitable supports or covering them with metallic wire mesh have certain disadvantages, e.g., an unfavorable ratio between active electrod mass and total weight. Or, by using another method, the active electrode mass, while soft, is trowelled onto a metallic support and then dried. The disadvantages of this method are poor mechanical stability and leaching of binders leading to the loosening of the mass from its support with resultant short circuits. These disadvantages are minimized by covering the formed electrode mass with a firmly attached porous metallic coating deposited from a solution of metallic salt by galvanic deposition, chemical redn., or by vapor deposition. The metallic coating is porous or can be perforated for free entry of and contact with the electrolyte. In gas-tight Ni-Cd accumulators, this type of coating, if made of Ni improves the O resorption. Electrodes manufactured according to this method have a greater efficient weight, good mechanical stability, and their O resorption is of significance in gas-tight accumulators. The possibility of automating the manufacturing process is also improved. One example is given for the manufacturing of positive electrodes for Ni/Cd or Ni/Fe accumulators. The suitably press-formed electrode mass (disks) is enclosed in a Ni plated sheet steel frame (ring) and the assembly Ni-plated. Operating conditions for the bath are given. Since the components of the mass, essentially Ni hydroxide and graphite, have different conds., a porous coating is deposited.

B-529

T. R. Beck and F. S. Kemp, Boeing Company, "Heat Generation in Lunar Orbiter Battery," Document No. D2-23612-1 (October 1964), Contract NAS 1-3800.

Rate and amount of heat generation in a hermetically sealed 12 ampere-hour nickel-cadmium cell were determined under one set of proposed Lunar Orbiter Spacecraft electrical load and battery charging conditions. Results were correlated with electrochemical theory with the result that reasonably accurate interpolations and extrapolations on heat generation are believed to be possible.

A considerable excess charge capability exists in the condition tested. This excess charge capability is either unused by the battery or it causes unnecessary heat generation and higher temperature and voltage. The increased temperature and voltage are probably damaging to the plates and the separators in the battery.

The testing method developed is a simple but powerful tool and it is recommended that the program be refined and extended to a wider range of conditions as well as to other battery types. A knowledge of the heat generation rate will become increasingly important for design of larger battery systems.

B-530

W. H. Webster and R. T. Foley, The American University, "Research into Fundamental Phenomena Associated with Spacecraft Electrochemical Devices - Calorimetry of Nickel-Cadmium Cells," First Progress Report (January 1, - September 30, 1966), NASA Goddard Space Flight Center Contract NAS 5-10105.

This report summarizes the work accomplished during the first nine months of the project. The program has been directed toward the design and development of an isothermal continuous flow calorimeter capable of measuring the thermal characteristics of batteries undergoing typical orbital cycling.

An isothermal continuous flow calorimeter was developed and calibrated over the range of 0.10 to 1.00 watt which range is characteristic of the thermal output of a six ampere-hour nickel-cadmium cell. The thermal response was found to be linear in this range and the instrument was sensitive to 0.01 watt.

A Gulton six ampere-hour prismatic nickel-cadmium battery complete with an Adhydrode electrode was subjected to the following:

a) 79 cycles undergoing 25% depth of discharge and a 110% recharge.

b) 74 cycles undergoing 15% depth of discharge and a 114% recharge

c) 93 cycles undergoing 25% depth of discharge and a 114% recharge

During the above testing the oxygen pressure in the cell and the rate of heat generation by the cell was recorded. The onthalpy changes (ΔH) corresponding to the reactions occurring during the charge and discharge processes were calculated from the thermal data. These values were in excellent agreement with the literature values for these reactions.

In view of the successful operation of the instrument and the findings to date, additional testing will be performed at various percentages of recharge and depths of discharge.

B-531

51627c Constant-Potential and Constant-Current Charging of Silver-Cadmium Cells. Thedford P. Dirkse (Calvin College, Grand Rapids, Mich.). Electrochem. Technol. 5(1-2), 18-21 (1967) (England)

The constant-current and constant-potential charging of a Ag-Cd cell was studied by using 2 reference electrodes, 1 for each working electrode. The sum of the individual electrode potentials was compared with the measured cell voltage. The measured cell voltage may be affected by OH- ion concentration gradients as well as by the state of charge of the electrodes, depending on the charging rate.

B-532

51684w. Plates for Storage Batteries. Texas Instruments, Inc., Fr. 1,447,724 (Cl. H 01m), July 29, 1966. Appl. September 23, 1965; 5 pp.

A simplified method of manufacturing plates for Ni and Ni/Cd storage batteries with higher capacity per weight is described. Ni flakes with a thickness of 0.016 u and a surface area of 0.026 $cm.^2$ are placed loosely into a mold, and sintered at 1000° for 2 hours without the application of pressure. The thereby obtained plate shows a porosity of 98-99% and a d. of 0.08 g./cc. The plate is immersed into a melt of $Cd(NO_3)_2.4H_2O$ at 70° and removed after soaking. The plate is, after cooling, dehydrated at 50° and 1 mm. Hg for 3-4 hours. Then, $Cd(NO_3)_2$ is transformed to $Cd(OH)_2$ by a cathodic treatment in 30% KOH solution at 100°. The finished plate, having a thickness of 0.4 cm., is then compressed under a pressure of 8.8 $kg./cm.^2$ to a thickness of 0.12 cm. Thereby, the volume effectiveness is increased from 13% to 42%.

B-533

Naval Ammunition Depot, "Extended Life Cycle Tests of One Aircraft Battery, Nickel-Cadmium, Type MS 25217 (AER) Manufactured by Sonotone Corporation," Report QE/C-63-270 (May 1963). AD 405 631L

One of the Sonotone nickel-cadmium aircraft qualification test batteries. Type MS 25217, was placed in storage for 9 months after successful completion of the qualification test requirements. Following completion of the storage period, the battery was subjected to a repeat of the life cycle program. The battery required frequent addition of distilled water. With the exception of water additions, the battery exceeded the specified requirements by the completion of 100 additional successful cycles.

B-534

Naval Ammunition Depot, "The Effect of Storage in a Discharged State on Sonotone MS 25218-2 Nickel-Cadmium Aircraft Batteries," Report QE/C-63-553 (August 1963). AD 415 150L.

Storage of batteries in a wet discharged condition up to 1 year at room temperature had no apparent adverse effect on the batteries as evidenced by a comparison of the maximum capacity tests after the storage period with those made before the storage period.

B-535

W. J. James, G. E. Stoner, and M. E. Straumanis, Missouri School of Mines and Metallurgy, "Anodic Disintegration of Zinc Undergoing Electrolysis in Nitrate Solutions," Report (July 1963), Contract Nonr-229603. AD 430 547

A dark corrosion product forms on zinc during electrolysis in nitrate solution, but does not form when the electrode is amalgamated or when it is dissolved in chloride or sulfate solutions. Optical and X-ray studies revealed that the dark film is composed of many small metallic zinc particles embedded in a matrix of $Zn(OH)_2$. During electrolysis this film spolls off the electrode and reacts with the electrolyte, subsequently turning white. It is concluded that the normal valency of zinc ion does not change during anodic dissolution in nitrate solutions, but rather that the apparent valency of less than two arises as a consequence of partial disintegration of the anode. The small metallic particles may then directly or indirectly reduce the oxidizing electrolyte. The dissolution of zinc outside the electrical circuit thus accounts for the lower coulombic equivalent.

B-536

T. P. Dirkse, Calvin College, "Electrode Migration and Reaction Processes Occurring Within Alkaline-Zinc Batteries," Quarterly Technical Progress Report No. 4 (September 1 - December 1, 1966), Wright-Patterson Air Force Base Contract AF 33(615)-3292.

A review of the literature dealing with zinc electrode processes is given. The processes reviewed are: anodic behavior; cathodic behavior; and corrosion behavior. Suggestions are also made as to areas where experimental information is, as yet, not incorporated in the published literature.

The solubility values of various types of zinc oxide in KOH solution at about 0 C is presented.

B-537

John J. O'Connell and Elizabeth A. McElhill, Monsanto Research Corporation, Boston Laboratory, "Separator Development for a Heat Sterilizable Battery," Quarterly Summary Progress Report 2, MRB623402 (September 1-November 30, 1966), Jet Propulsion Laboratory Contract JPL 951524 under Prime Contract NAS 7-100. Re-Order No. 66-876

Three types of ligand-containing polymers that showed high stability to 40% KOH in our screening tests are now being comprehensively evaluated as battery separator materials. They are: 1) 2-vinylpyridine - methylmethacrylate copolymers, 2) styrene - maleic anhydride copolymers, and 3) polystyrenes containing ligand substrates, are being evaluated before and after a 60-hour exposure to 40% KOH saturated with silver oxides at 135°C. The properties measured in the study include dimensional stability, electrical resistance, electrolyte adsorption, tensile strength, pore size, and resistance to penetration by zinc dendrites. Membranes prepared from both 2-vinylpyridine - methacrylic acide and styrene - maleic anhydride have shown electrical resistances under 20 ohm-in. and survived the above exposure cycle satisfactorily.

B-538

M. A. Vertes, E. G. Katsoulis, J. E. Oxley, and K. Alfredson, Leesona Moos Laboratories, Division of Leesona Corporation, "Zinc/Air High Energy Density Rechargeable Energy Storage System," Interim Report (August 1966), U.S. Army Engineer Research and Development Laboratories Contract DA-44-009-AMC-1469(T). AD 639 609

> Electrically rechargeable Zn/Air Energy storage systems were investigated. Two alternative systems, one with static and one with recirculating electrolyte, were studied. The ability of both systems to sustain charge/discharge cycling was shown experimentally. Parallel analytical studies showed that the static electrolyte system would be less complex and lighter in weight. For example, this latter system would yield, at the 4 hour charge-10 hour discharge cycle, 80 wh/lb energy density and an energy storage efficiency of 52%. Conceptual designs for nominal 10 KWH units are presented.

B-539

H. M. Schultz, E. C. Bruess, C. M. Austin, and V. Yeager, Naval Ammunition Depot, Quality Evaluation Laboratory, "Evaluation Program for Secondary Spacecraft Cells. Acceptance Test of Gulton Industries, Incorporated 12 & 20 Ampere-Hour Adhydrode Cells," Report QE/C-67-1 (January 21, 1967), NASA Goddard Space Flight Center Contract W11,252B.

> The object of this evaluation program is to gather specific information concerning secondary spacecraft cells. Information concerning performance characteristics and limitations, including cycle life under various electrical and environmental conditions, will be of interest to power systems designers and users. Cell weaknesses, including causes of failure of present designs, will be of interest to suppliers as a guide to product improvement.
>
> Twenty-two 12 ampere-hour and twenty 20 ampere-hour cells were purchased from Gulton Industries, Inc., Metuchen, New Jersey, by National Aeronautics and Space Administration (NASA). These cells are rated at 12 and 20 ampere-hours respectively by the manufacturer and include the adhydrode and absorption hydrogen type auxiliary electrode.
>
> The ceramic seals of these cells, manufactured by Gulton Industries, Inc. are satisfactory as evidenced by no leakers out of the 42 cells tested.
>
> The capacities of the cells were in the acceptable range of 14.82 to 16.50 ampere-hours for the 12 ampere-hour cells and 23.30 to 28.70 ampere-hours for the 20 ampere-hour cells respectively.

B-540

General Electric Company, Advanced Technology Laboratories, Characterization of Nickel-Cadmium Electrodes," Fifth Quarterly Report, NASA-CR-60418 (July 1 - October 1, 1964), NASA Goddard Space Flight Center Contract NAS 5-3477. N65-15814

The objective of this contract is to develop a method of analysis and characterization of the electrodes used in nickel-cadmium cells. It is based primarily on a comparison of detailed polarization measurements of single electrodes before and after periodic operation in selected modes of cyclic testing of cells at three temperature levels 0°, 25°, and 40°C. A correlation of this data should provide a basis for specifying improved cells for space applications as well as comparing cells from various manufacturers. During this quarter, Random Discharge tests (RA) and Constant voltage, Current limited Charging Cycling tests (RB) were continued. Shallow Discharge (CC) test electrodes were examined by x-ray diffraction, photo-micrography, electrochemical capacity evaluation and recharacterization tests. Cells will be returned to CC test program next quarter as sealed cells. Examination of these and the other program plates will be completed next quarter.

B-541

G. Halpert, NASA Goddard Space Flight Center, "Some Factors to Consider in Determining the Capacity of a Nickel Cadmium Cell," Report X-735-66-275 (August 1966).

It is widely recognized in the battery industry that the behavior of a sealed nickel cadmium cell is influenced by its past cycling experience. Both the need for "cell-conditioning" and the so called "memory phenomena" could be cited as examples of this effect. The treatment given a cell prior to a capacity test appears to be another example and is the basis for this report. A series of experiments are described in which two types of cells were discharged to 1.0 volt, then discharged further (drained or essentially short circuited) through a 1.0 ohm resistor for varying intervals prior to the capacity test. The experimental results indicate that there was a significant difference in capacity between those cells which were drained for more than 16 hours and those which were drained for short periods of 3 hours or not at all. The information derived from this study should be useful to individuals establishing battery test requirements or those who are users of nickel-cadmium batteries.

B-542

G. M. Apgar and J. W. Callahan, Gulton Industries, Inc., "Prototype Nickel Cadmium Cells for a Future Meteorological Spacecraft," Final Report (May 1, 1966), NASA Goddard Space Flight Center Contract NAS 5-3839

The object of this report is to summarize the work accomplished during a program initiated to design and develop a prototype nickel-cadmium cell for a future meteorological satellite.

A cell, consisting primarily of thin plates to enhance charge characteristics, was developed, manufactured, and tested. A total of 265 cells were fabricated, of which 15 had rubber seals.

It was concluded that the desired characteristics of high rate (C/8) overcharge capability was achieved, but the differential between this cell and the standard 6 AH cell was insufficient in terms of cell voltage. Cell pressure characteristics were significantly different, the new prototype being superior. At higher charge rates, C/3.5 and C/3, the attributes of the thin plate design manifest themselves.

Although the differential existing between electrical characteristics are not great at low level charge rates, the trend exists in the favor of the thin plate cell, and a logical extension of the program is a thinner plate cell.

The rubber seal turned out to be quite unreliable, but a redesign of the seal, and possibly the cell to accommodate the seal design, could lead to a satisfactory solution. Required are a longer leak path, a means of preventing loss of bonding agent during molding, and thermal isolation between rubber and areas to be welded.

B-543

Space Power Systems Engineering, Edited by George C. Szego and J. Edward Taylor, Academic Press, New York (1966), "Thermal Analysis of Hermetically Sealed Nickel-Cadmium Cells for Space Applications," (Karl E. Preusse and Robert C. Shair, Gulton Industries, Inc.), pp 1127-1144

To meet spacecraft requirements, the thermal behavior of nickel-cadmium cells must be known as a function of charge, overcharge, and discharge as well as of the thermal environment. We have determined the variation of the mean thermal conductivity of a nickel-cadmium cell as a function of overcharge current and environmental temperature. We have also determined the effect or cell geometry on heat-transfer rates. The significance of this investigation is that, knowing the overcharge current and the environment temperature, one can determine the thermal conductivity and predict the thermal gradient in the cell and ultimately in a battery.

B-544

Louis Belove and Robert J. McCarthy, Sonotone Corporation, "The Sealed Nickel-Cadmium Battery Cell," Sonotone Corporation Paper BA-112(1/63). Copyright 1963

Construction of Sealed Cell
Electrical Characteristics
Charging
Trickel Charging
State of Charge
Discharging
Temperature Characteristics
Internal Impedance
Charge Retention
Battery Assembly
Battery Performance
Charging
Discharging
Cycle Life
Environmental Conditions
Application of Nickel-Cadmium Cell

B-545

International Nickel Company, Inc., "Characteristics and Uses of Nickel-Cadmium Batteries," Brochure A-422. Copyright 1966

This text has been prepared as a general guide to nickel-cadmium batteries. Its purpose is to acquaint electrical device and system designers with the characteristics available in nickel-cadmium batteries and to assist in selection of optimum batteries for both new and existing installations.

Some Features of Nickel-Cadmium Batteries
Nickel-Cadmium Battery Principles
Charging Practices
Idle Storage
Presentation of Battery Characteristics
Vented Pocket-Plate Batteries
Vented Sintered-Plate Batteries
Sealed-Cell Batteries
Battery Selection

B-546

J. Seremak, Hughes Aircraft Company, "Nickel-Cadmium Batteries: A Bibliography," Report LS-BIB-66-1 (April 1966). AD 484 505

This comprehensive bibliography contains 366 references on nickel-cadmium batteries. A majority of the citations is annotated. The bibliography covers the period from 1940 to December 1965 and includes unclassified reports and articles from periodicals. The following sources were checked: Technical Abstrat Bulletin (TAB) 1952-1965; Scientific and Technical Aerospace Reports (STAR) 1962-1965; Chemical Abstracts 1940 - 1965; Engineering Index 1940 - 1965; Applied Science and Technology Index 1958 - 1965; Industrial Art Index 1940 - 1957; International Aerospace Abstracts 1961 - 1965; and Science Abstracts Sec. B, Electrical Engineering 1940 - 1965.

Entries are arranged alphabetically under personal or corporate author.

B-547

Charles F. McClure, U.S. Naval Ordnance Laboratory, "Battery Separator Mechanisms - Literature Survey Report," Report NOLTR-64-136 (September 26, 1966) AD 642 779

ABSTRACT: In order to improve the characteristics of batteries, it has become necessary to gain a greater understanding of battery separators and how they can inhibit the motion of ions and molecules. This report, based upon a three-month literature survey, reviews some of the theories invented to explain the transport of material through solutions and barriers. Included, for example, are the major fields of diffusion, electrodiffusion, irreversible thermodynamics and reaction rate theory, with specific reference to the work of Fuoss, Laity, Lamm, de Groot, Laidler and Eyring, and others. This report is intended to serve as a guide for future research.

B-548

J. M. Sherfey and Abner Brenner, National Bureau of Standards, "Electrochemical Calorimetry," Journal of the Electrochemical Society, 105 (11), 665-672 (November 1958)

The heat effects of electrochemical processes have been measured calorimetrically to find those areas where such measurements might prove useful. The determination of reaction heat (ΔH) is one such area. The ΔH of the reaction $W + 2H_2O + 2NaOH\ (aq) = Na_2WO_4\ (aq) + 3H_2$ was measured. The results indicate that the heat of formation of Na_2WO_4 (aq) given in the literature is in error by at least 12 kcal. The heat of the reaction $Cu^0 + nCN^- + H_2O = Cu(CN)_n^{(n-1)-} + OH^- + 1/2H_2$ was determined as a function of the cyanide to copper ratio of the electrolyte. These data confirm the existence of the $Cu(CN)_4^{\equiv}$ ion. Another application for such measurements is in studies of electrode polarization. Equations are derived which show the relation between polarization and the other heat-producing phenomena in electrolytic cells. This treatment is extended to include simultaneous reactions, such as alloy deposition, and to compare the calorimetric measurement of polarization with the more conventional methods.
(17 references, 2 tables, 3 figures, 8 pages)

B-549

W. G. Eicke, Jr., National Bureau of Standards, "The 'Vicious Cycle' in Secondary Batteries--A Mathematical Approach," Journal of the Electrochemical Society 109 (5), 364-368 (May 1962)

Equations relating voltage, temperature, heat capacity, time, and current have been derived for a cell on constant-potential charge. The equations have been verified experimentally. The case where cooling occurs is also considered. (5 references, 1 table, 6 figures, 5 pages)

B-550

J. M. Sherfey, National Bureau of Standards, Metallurgy Division, "Calorimetric Determination of Half-Cell Entropy Changes," Journal of the Electrochemical Society, 110 (3), 213-221 (March 1963)

The reversible heat effects ($T\Delta S$) of half-cell processes have been measured in a twin calorimeter. The total heat effect and the heat due to irreversible phenomena are measured separately for each compartment. The difference between these two gives the desired reversible heat. The half-cells studied include copper in acid copper sulfate, silver in acid silver perchlorate, and silver-silver chloride in various chloride solutions. The effect of "transport entropies" on these measurements is outlined. Presently accepted theories of the "irreversible" or "steady-state" thermodynamics of electrolytic cells predict the equivalence of half-cell entropy data obtained by the present calorimetric method and data obtained from thermocell studies. This predicted agreement was not obtained in the case of the half-cell silver-silver perchlorate. (9 references, 3 tables, 3 figures, 9 pages)

B-551

J. E. Clifford, D. E. Semones, J. McCallum, and C. L. Faust, Battelle Memorial Institute, "Improvement of the Zinc-Silver Peroxide Secondary Cell for Storage Batteries," Summary Report to Boeing Airplane Company (March 31, 1955), Prime Contract AF 33(038)-19589

Discussion of Factors Affecting Cell Output; Reactions Relating to the Solubility of Silver (I) Oxide, Reactions Relating to the Instability of Silver (II) Oxide, Reactions Occurring at the Negative Electrode, Chemical Changes in the Electrolyte, Physical Changes in the Separator or Electrodes, Miscellaneous Actions That Decrease Cell Output, and Discussion of Experiments Relating to Improvement of Cell Output; Outline of the Method of Attack on the Problems, Preliminary Tests on Electrolyte Modifications, Modified Procedures for Handling Commércial Cells.
(18 references, 12 tables, 6 figures, 113 pages)

B-552

Frederick P. Kober, General Telephone & Electronics Laboratories, Incorporated, "Infrared Spectroscopic Investigation of Charged Nickel Hydroxide Electrodes," Journal of the Electrochemical Society, 114 (3), 215-218 (March 1967)

Through the use of deuterated samples of $Ni(OH)_2$ electrodes at various stages of charge, it has been possible to make definitive band assignments for the structures of the active material. The relative intensity of the band due to hydrogen bonding in the charged state is shown to be a measure of the electrochemical capacity of the system. The charging reaction gives rise to the formation of active oxygen sites (as defined by Aia) through a site alteration mechanism in addition to the formation of hydrogen bonded sites within the charged phase. The mechanistic and structural implications of these spectral data are discussed in detail.
(9 references, 1 table, 6 figures, 4 pages)

B-553

Sven Olof Aulin, Svenska Ackumulator AB Jungner (Stockholm), "Electrodes for Galvanic Primary and Secondary Cells and Methods of Producing Such Electrodes," U.S. Patent 3,305,401 (February 21, 1967)

Claim 7. The method of producing an electrode for galvanic primary and secondary cells comprising the steps of mixing nickel hydroxide powder and nickel chloride powder with carbonyl nickel powder until a uniform mixture is obtained, heating the powder mixture and mixing it with a warm 5% solution of gelatin in water to obtain a uniform paste, spreading the paste on both sides of wire gauze to provide a plate, cooling the plate, suspending the plate in a cold 15% solution of sodium chloride and electrolyzing the plate as a cathode until the nickel of the nickel chloride has been deposited, and washing the plate in hot water until the gelatin and the chloride ions have been removed. (No Drawing, 7 Claims)

B-554

Thedford P. Dirkse and J. Barry De Roos, Calvin College, "The Formation of Thin Anodic Films of Silver Oxide," Technical Report No. 1 (January 1, 1964), Office of Naval Research Contract Nonr 1682(02). AD 438 188

> The formation of thin anodic films of silver oxide has been studied by means of a constant current technique. The results indicate that this is a diffusion controlled process involving the Hydroxide ion. The study was carried out at room temperature and over a range of potassium hydroxide concentrations. (8 references, 0 tables, 6 figures, 15 pages)

B-555

T. P. Dirkse and L. A. Vander Lugt, Calvin College, "Silver Migration and Transport Mechanism Studies in Silver Oxide-Zinc Batteries," Quarterly Technical Progress Report No. 2 (August 1 - November 1, 1962), Wright-Patterson Air Force Base Contract AF 33(657)-8689. AD 289 062

> Thirteen different materials have been 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 have been 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.
> (4 references, 4 tables, 7 figures, 22 pages)

B-556

H. N. Seiger, Gulton Industries, Inc., "Investigations Leading to the Development of Improved Sealed Nickel-Cadmium Batteries: The Testing of Hermetic Seals and Separators, Positive Plate Studies, and Investigations on the Uniformity of Sealed Nickel-Cadmium Cells," Report No. 8, Final Report (July 1, 1960 - June 30, 1962), Signal Corps Contract DA-36-039-SC-85390. AD 287 816

> Efforts were directed toward: (1) development of a good separator; (2) development of greater uniformity between cells, and test methods for rapidly determining uniformity; (3) a fundamental study of the positive electrode directed at increasing its stability and reducing self-discharge; and (4) fabrication of improved 6 ampere-hour hermetically sealed cells incorporating a ceramic-to-metal seal.
> (19 references, 24 tables, 7 figures, 71 pages)

B-557

Y. Okinaka and D. R. Turner, Bell Telephone Laboratories, Inc., "Anodic Corrosion of Nickel Sinter in Positive Electrodes of Nickel-Cadmium Batteries Containing Carbonate," Electrochemical Technology, 5 (3-4), 67-72 (March-April 1967)

The charge capacity of sealed nickel-cadmium cells using sintered nickel plates was found to increase considerably when the cells were overcharged at a high rate after addition of a sufficient amount of carbon dioxide. A large-capacity increase occurs also under flooded conditions if the nickel hydroxide plate is subjected to repeated charge-discharge cycles or prolonged overcharge in concentrated potassium carbonate, followed by cycling in potassium hydroxide. The capacity increase has been found to be due to anodic corrosion of the nickel sinter to trivalent nickel. The corrosion occurs only with impregnated plates and not with bare, unimpregnated nickel sinters. Mechanism of the corrosion reaction is discussed in this paper. A practical procedure is given for the preparation of high charge capacity plates by utilizing the corrosion reaction.
(6 references, 2 tables, 4 figures, 6 pages)

B-558

W. H. Webster and R. T. Foley, The American University, "Research into Fundamental Phenomena Associated with Spacecraft Electrochemical Devices - Calorimetric of Nickel-Cadmium Cells," Second Progress Report (October 1 - December 31, 1966), NASA Goddard Space Flight Center Contract NAS 5-10105.

The investigation of the six ampere-hour nickel-cadmium cell with "Anhydrode" control electrode were concluded. These investigations involved: (1) Cycling Experiments (40% depth of discharge, 110% recharge); (2) Charge Efficiency Studies; (3) Transducer Study.
(1 reference, 3 tables, 7 figures, 35 pages)

B-559

S. Charlip and T. Staub, Gulton Industries, Inc., "Development of Pile Type, High Discharge Rate Nickel-Cadmium Squib Batteries," Third Quarterly Report (September 5 - December 4, 1966), NASA Goddard Space Flight Center Contract NAS 5-10160.

Five-cell, pile type, nickel-cadmium batteries gave satisfactory performance when a sound seal was maintained between cells. Reliable seals were produced using adhesive bonding between the nickel substrate and uncured neoprene. The bond was formed during the vulcanization of the neoprene under heat and pressure. The proper cleaning and conditioning of the electrodes' nickel surfaces is an important factor in achieving reliable bonds. (0 references, 0 tables, 7 figures, 15 pages)

B-560

G. Myron Arcand, Idaho State University, "The Reactions Pertaining to Zinc-Silver and Cadmium-Silver Batteries," Third Quarterly Report (November 11, 1966), Jet Propulsion Laboratory Contract JPL 951458 under Prime Contract NAS 7-100, Re-Order No. 66-941.

This report deals with (a) the investigation of the precipitates of Zn(II) and Cd(II) formed by precipitation with alkaline solutions and (b) thermogravimetric investigations of AgO.
(4 references, 3 tables, 2 figures, 17 pages)

B-561

David Peterson, General Dynamics/Astronautics, "Extended Time Test Report for Battery-Main Power, Missileborne," Report No. 55A 2748 (September 3, 1963). AD 431 381.

The test specimens were Batterys-Main Power, Missileborne, manufactured by the Yardney Electric Corp. Each of the test specimens incurred a transducer failure during testing. In each case, the failure was a large, abrupt drop in resistance of the temperature sensitive resistive element. Testing started on 1 July 1963 and was completed on 19 July 1963. Detailed results are contained in this report.

B-562

Harold F. Leibecki, NASA Lewis Research Center, "Argentic Oxysalt Electrodes," Report No. NASA-TN-D-3208 (1966). N66-14759

Ag ions with plus 3 oxidation states in complex Ag compounds were investigated as cathode electrodes in 45 wt. % KOH electrolytes with Zn as the anodes. The temperature coefficient of open circuit potentials, c.d. as a function of cell voltage, and coulombic efficiencies of the cathode at various discharge rates were obtained for $2Ag(AgO_2)_2.AgNO_3$ and the produce obtained from the stability tests of $2Ag(AgO_2)_2.AgNO_3$ in 45% KOH.

B-563

Thomas J. Wetherell and Paul A. Scardaville, Radiation Applications, Inc., "Fabrication and Test of Battery Separator Materials Resistant to Thermal Sterilization," Report No. NASA-CR-69884 (1965). N66-16190. Abstract only.

Fifty-one materials were fabricated, by using polyethylene as the base polymer, by crosslinking and grafting procedures. Each material was tested for its ability to withstand heat sterilization and to function as a battery separator in the Ag-Zn alkaline system.

B-564

V. V. Romanov, "Methods of Producing Positive Electrodes for a Dry-Charged Ag-Zn Battery," Zhurnal Prikladnoy Khimii, 30 (10), 2261-2266 (1966). Abstract only

Several methods of preparing Ag powder for a positive electrode in a Ag-Zn battery were examined. These include (1) thermal decomposition of Ag_2O, (2) formaldehyde reduction of Ag_2O, (3) thermal decomposition of Ag tartrate, Ag citrate or AgOAc. Electrodes were prepared by pressing the Ag powder at 200 kg/cm^2; negative electrode consisted of pressed Zn sponge. The KOH

s soaked onto

B-565

Tsutomu Iwaki, Taketsugu Hirai, and Masataro Fukuda, Research Center, Matsushita Denki Sangyo Company, Ltd., (Osaka, Japan), "Singered Plate Type Nickel Cadmium Alkaline Batteries. IV. Preparation Procedures of Positive Plates for Sintered Plate Type Alkaline Batteries by Using Thermal Decomposition in Steam with Organic Additives," Denki Kagaku, 34 (9), 765-770 (1966). Abstract only.

The effect of some organic substances such as triethanolamine, ethylene glycol, or Carbowax (100) were added to the $Ni(NO_3)_2$ solution, in which the sintered Ni plate was immersed prior to the activation by the thermal decomposition in steam, was studied. The additives yielded favorable results; the time required for the treatment of the electrode in the KOH solution prior to its practical use as the positive plate of an alkaline battery was shortened.

B-566

Karl Steffens, Varta Pertrix-Union GmbH, "Electric Cell," U.S. Patent 3,287,163 (November 22, 1966). Abstract only

The current delivering surfaces of one plate group are covered with separators or by a separator strip which is folded in a zigzag manner. A plate group of opposite polarity is then assembled by interleafing one group with the other with the separator between the two. This electrode arrangement can be combined into electrode stacks without difficulty.

B-567

Societe des Accumulateurs Fixes et de Traction, "Electrolytic Battery," Netherlands Application 6,601,518 (August 10, 1966). Abstract only

The electrolyte is brought into contact with the electrodes only at the moment of use. A number of elementary cells connected in series are packed into groups, which in turn are connected in parallel and (or) in series. The successive groups of cells can be fed with electrolyte from a reservoir. Conducting carriers which are placed between the groups of cells and connected in series form distribution chambers both for the feeding of the electrolyte and for the venting of gases formed. Each cell consists of an anode of porous Ag_2O_2, a separator, a cathode of porous Zn on a suitable supporting metal, and KOH as the electrolyte. The battery is assembled in a cylindrical form, one end of it being formed by the electrolyte reservoirs coupled with the device for operating the battery, the carriers, the electrodes, etc., while the other end of it is formed by one or more reservoirs for collecting the electrolyte flowing across the electrodes.

B-568

Joseph J. Holechek, Catalyst Research Corporation, "Silver Oxide Electrodes," U.S. Patent 3,276,975 (October 4, 1966). Abstract only

These products are prepared by applying at atmospheric pressure a slurry of Ag_2O uniformly on a permeable support while simultaneously applying vacuum to the support to withdraw moisture from the slurry. A conducting grid is placed on the resulting deposit of Ag_2O and an additional quantity of Ag_2O slurry is deposited on the exposed surface of the grid under the same conditions of application and moisture removal. Thereafter, the structure is compacted to decrease the H_2O content, dried, and heated to convert the Ag_2O to Ag in an unused condition. The resulting electrode is free from surface defects and performs better than conventional, pasted electrodes.

B-569

Thomas J. Hennigan, Paul C. Donnelly, and Charles F. Paladati, Jr., United States National Aeronautics and Space Administration, "Prevention of Pressure Build-Up in Electrochemical Cells," U.S. Patent 3,287,174 (November 22, 1966). Abstract only

A battery cell opening is capped with a plastic container coated with PdO, PdO_2, or a mixture of PdO and PdO_2. The H evolved during cell operation reacts with the PdO or PdO_2 to form Pd and H_2O. The Pd liberated also acts as a catalyst for the combination of H and O to form H_2O. However, the efficiency of this reaction is limited because of Pd poisoning. Thus, pressure build-up due to H and the explosion hazard of H are eliminated with this assembly.

B-570

Charles J. Bradley and Kenneth E. Meade, United States Department of the Army, "Method of Making a Silver Oxide Electrode," U.S. Patent 3,282,732 (November 1, 1966). Abstract only

A plastic binder in a relatively nonvolatile solution is first applied to the Ag grid by any conventional method such as brushing, flush pasting, etc. Ag_2O is then applied immediately to the grid and mechanically levelled. The grid is then pressed at a pressure $\geq$ 1000 psi to form the electrode. For example, a 1% aqueous soltuion of CM-cellulose is flush pasted onto a 40 mesh Ag grid 2 in. x 1-5/8 in. Then 4 g Ag_2O is applied to the grid and smoothed. The grid is pressed at 3000 psi to form the electrode. If a greater conductivity in the electrode is desired, graphite or C black can be mixed with the active material prior to application to the grid.

B-571

Frank C. Arrance, Douglas Aircraft Company, Inc., "Electrode and Battery," U.S. Patent 3,287,164 (November 22, 1966). Abstract only

A method is described for providing improved electrode structures for use in high energy density batteries. A porous conductive metal matrix, such as a Ni matrix, is impregnated with an active electrode material, e.g., a Zn-Zn oxide paste. The conductive metal matrix is formed of an interconnected honeycomb of cells, the electrode material being held securely within the pores of the honeycomb. The porous metal matrix in which the active electrode material is incorporated, usually although not necessarily, constitutes a minor proportion of the total weight of the electrode. To illustrate, Ag and Zn electrodes are prepared in each case employing a porous Ni matrix having a pore diameter of ~0.030 in. and ~25 pores/lineal inch. A Zn paste is prepared by mixing Zn, Zn oxide and ~1% poly(vinyl alcohol) as a slurry with 30% KOH and filling the pores of the Ni matrix with this paste by vibrating the paste into the matrix, and forming a Zn electrode according to the invention. A Ag paste is provided by mixing Ag, Ag oxide powder and aqueous KOH, and filling the pores of the Ni matrix with this paste by vibration of the paste into the matrix, and providing a Ag electrode.

B-572

Frank C. Arrance, Douglas Aircraft Company, Inc., "Battery Electrode and Battery," U.S. Patent 3,287,166 (November 22, 1966). Abstract only

High energy density batteries with improved electrode structures are described. To illustrate, a mixture of 50 wt.% powdered Ag and 50 wt. % Ag oxide is ball-milled in water to form a slip or slurry of ~ 40% solids content. A fine textured polystyrene sponge is saturated with this slurry and is slowly dried to remove water by heating for 24 hrs. at 80-100°. The dried sponge containing the mixture of Ag and Ag oxide is placed in a furnace and heated to 500° gradually over 10 hrs. to burn out the organic sponge material and to sinter the resulting metallic electrode materials which essentially converts the Ag oxide to Ag. A Ag electrode with a pore size of ~ 0.050 in. diameter and ~ 15 pores/lineal in. is formed. Zn oxide is ball-milled in water to form a slip or slurry containing 60% solids content. The fine textured polystyrene sponge is saturated with this slurry and the sponge is then dried and heated at elevated temperatures for ~ 6 hrs. at ~ 300° to burn out the organic sponge material and sinter the resulting Zn structure in a manner similar to that described above. A Zn electrode is formed having a pore size of ~ 0.045 in. diameter and having ~ 16 pores/lineal in.

B-573

Klaus K. Berju and Elmer M. Strohlein, Electric Storage Battery Company, "Electric Storage Battery Electrolyte Circulator Device," U.S. Patent 3,290,176 (December 6, 1966). Abstract Only

A Ag-Zn battery electrolyte circulator which functions as a cooling system and a battery element support, is U-shaped with the bottom resulting on the bottom of the battery container. The cooling coil is mounted on the interior wall of the 2 vertical sides which are hollow and form electrolyte reservoirs. Each side has 2 partitions extending from the top cover plate almost to the bottom leaving space for electrolyte to flow between the 3 compartments.

B-574

General Electric Company, "Secondary Electric Cell," Netherlands Application 6,600,140 (July 8, 1966). Abstract only

A hermetically sealed secondary electric cell with aqueous electrolyte, such as an Pb-acid cell, an alkaline Ni-Cd cell, or a Ag-Zn cell, is protected against excessive pressure by a catalyst for the recombination of H and O. The catalyst, preferably a Pt metal, is in contact with the electrolyte-containing room and is electrically isolated from the anode and cathode. The catalyst is coated with a water-repellent agent. In an example, a mixture of carbonyl Ni 10, Pt black 2, and Pd black 2 g is mixed with 3.5 ml of an emulsion of 10% by wt. poly(tetrafluoroethylene) in H_2O. A paste of this mixture is applied upon a previously etched 40-mesh Ni grid, dried, and sintered 4 hours at 250°. A coating of poly(tetrafluoroethylene) is prepared by applying an aqueous dispersion upon one side of an Al foil and drying. The coating is pressed at 350° upon the Ni grid, the Al is removed by dissolution in aqueous KOH, and the coated catalyst body placed in an alkaline Ni-Cd cell.

B-575

Fritz Philipp, Varta Pertrix-Union GmbH, "Production df Low Stress Fritted Electrodes," Belgian Patent 669,325 (December 31, 1965). Abstract only

Electrodes with good physical properties and good adhesion to their supports can be made by first applying a hard frit of low porosity upon a bed of an oxidized metallic network and then applying a highly porous but less brittle frit. A network of metal ribbon is oxidized in air at 800° for 1 hour. A mixture of Ni carbonyl powder and methylcellulose is applied to the ribbon to a thickness of 50-80 u at a pressure of 2-3 kg/cm^2 and heated at 1050° for 15 minutes. A second coating of high porosity consisting of Ni carbonyl and powdered polystyrene is applied and heated at 850° for 30 minutes.

B-576

Thedford P. Dirkse, Calvin College, "High Rate Cycling Behavior of the Silver Electrode," Technical Report No. 15 (April 1, 1963), Office of Naval Research Contract Nonr 1682(01). AD 404 841

A study has been made of the behavior of the silver electrode when it is cycled at high current rates in alkaline solutions. The ratio of charge to discharge capacity has been measured at room temperature. An explanation is suggested for the inefficiency that is observed.
(9 references, 0 tables, 10 figures, 24 pages)

B-577

Arthur Fleischer, Edward C. Kopper, W. Ralph Miller, and Edward Schweitzer, Electric Storage Battery Company, "High Capacity Vented Nickel-Cadmium Cells," Quarterly Progress Report No. 2 (March 1 - May 31, 1960), Signal Corps Contract DA-36-039-SC-84555. AD 242 920

This project is concerned with the development and manufacture of six sizes of high capacity, vented nickel-cadmium cells. These six sizes of cells have been assigned rated capacities at the 5-hour discharge rate, of 3.5, 5.5, 9.0, 14.0, 22.5, and 36.0 amp-hours. During the second quarter, the principal activity has been in the determination of the capacities at the required rates and temperature over about 50 cycles. The data have been studied in order to reach a decision on the plate thicknesses to use for the cells, 300 of each size to be manufactured under the contract.
(7 references, 38 tables, 3 figures, 79 pages)

B-578

E. B. Cupp, Eagle-Picher Company, "Investigations Leading to the Design of a Reliable Sealed Nickel-Cadmium Cell," Quarterly Progress Report No. 2 (October 1962), U.S. Army Electronics Research and Development Laboratory Contract DA-36-039-SC-89084. AD 298 568

Results of investigations conducted on plate parameters and electrolyte characteristics are presented. Also included is a discussion of nickel-cadmium cells of a three-plate design. Effects of additives upon the ability of plates to accept a charge are presented for several charge rates and at various temperatures.

B-579

R. A. Horne and David L. Richardson, Arthur D. Little, Inc., "Low Temperature Operation of Batteries," Final Report (May 15, 1962 - July 14, 1964), Army Materiel Command Contract DA-36-039-SC-90706. AD 451 940

On the basis of a comparitive evaluation of the low temperature performance of batteries, the properties of available insulating materials, estimates of the weight, cost, and volume of various auxiliary heating devices, and experimental studies of the cool-down rates of insulated battery systems, the following conclusions have been reached: (1) present batteries are serviceable in conditions of extreme cold for very short mission lives or very low current drains; (2) for missions a few hours in length, inexpensively insulated conventional batteries should be serviceable; (3) for somewhat longer missions, auxiliary heat or super-insulation is required; and (4) for long missions (in excess of 8 hours) auxiliary heat, preferably in conjunction with inexpensive insulation, is necessary.

B-580

T. P. Dirkse, Calvin College, "Silver Migration and Transport Mechanism Studies in Silver Oxide-Zinc Batteries," Quarterly Technical Progress Report No. 1 (December 1, 1963 - March 1, 1964), Wright-Patterson Air Force Base Contract AF 33(615)-1236. AD 432 346

A survey has been made of some of the factors that may affect the amount of silver lost by the electrode during the cycling of a silver-alkaline battery. Factors studied were: palladium additions to the silver electrode; presence of zinc oxide and other metallic compounds in the electrolyte. The nature of the silver deposit on a cellophane separator has also been investigated. Finally, the presence of colloidal matter in solutions of silver oxide in potassium hydroxide solutions has been observed.

B-581

Martin Sulkes and George A. Dalin, Yardney Electric Corporation, "Development of the Sealed Zinc-Silver Oxide Secondary Battery System," Quarterly Progress Report No. 4 (June 1964), U.S. Army Electronics Research and Development Laboratory Contract DA-36-039-AMC-02238(E). AD 453 792

The reactivity of AG2O with separator materials was measured with an Ag 110 tracer. The reactivity and permeability of silver oxides with separators was also measured by a cycling test at 120 F. Several separator materials were found which have a lower reactivity than cellophane, but no higher permeability. Cycling data are presented for 16, 12 AH sealed cells. Shape maintenance of the negative electrode and cycle life was increased by the use of 26.5% KOH with a PVA separator. Performance was lowered when C19 (300) was used with 31% KOH.

B-582

Power Information Center, University of Pennsylvania, "Background Material for the Study of the National Space Power Program (1964). Volume I. Electrochemical Papers," Report No. PIC 120/1 (November 1964), Interagency Advanced Power Group Contract NAS4-191. AD 452 617.

Contents: batteries, primary and secondary; fuel cells - status and future of technology and devices for space applications; electrolysis; and system aspects in the design of primary batteries for spacecraft application.

B-583

Martin Sulkes and George A. Dalin, Yardney Electric Corporation, "Development of the Sealed Zinc-Silver Oxide Secondary Battery System" Quarterly Report No. 5 (July 1 - September 30, 1964), U.S. Army Electronics Research and Development Laboratory Contract DA-36-039-AMC-02238(E). AD 457 834

The cycling data for 32 cells from a factorial experiment was evaluated. The construction factors were electrolyte quantity and concentration, silver density and interseparator type. Capacity was improved by the use of low density silver and a thick interseparator. Capacity and teardown analysis data are presented for cells constructed with RAI high resistance irradiated polyethylene and cellophane separators. Performance was lowered by the use of these materials. Data are presented for cells built with Cd grids in the negative electrode and for cells with various negative binders such as PEO, PVA, and CMC.

B-584

M. Lurie and H. N. Seiger, Gulton Industries, Inc., "Investigation of Methods Leading to the Determination of the State of Charge of Nickel-Cadmium Batteries," Quarterly Progress Report No. 2 (April 1 - June 30, 1963), Electronics Command Contract DA-36-039-AMC-00109(E). AD 418 756

A bridge was constructed and tested to measure the equivalent circuit components of a nickel cadmium cell over the frequency range of 4 to 10,000 cps with an uncertainty of approximately = 1%. The values of the equivalent circuit components were investigated for the above range of frequencies and for various states of charge. One component, R sub C. was studied in particular at 20 cps and 40 cps. Measurements were made on one group of vented cells before and after they were exposed to a vacuum to remove gases in the cells. Residual capacity was found to be a double valued function of R sub C for the above conditions.

B-585

Edward F. Schweitzer, Edward C. Kopper, W. Ralph Miller, and Arthur Fleischer, Electric Storage Battery Company, "High Capacity Vented Nickel-Cadmium Cells," Quarterly Progress Report No. 3 (June 1 - August 31, 1960), Signal Corps Contract DA-36-039-SC-84555. AD 247 280

Work is concerned with the development and manufacture of six sizes of high capacity, vented nickel-cadmium cells. The six sizes of cells have rated capacity at the 5-hour rate of 3.5, 5.5, 9.0, 14.0, 22.5, and 36.0 amp-hrs. This report covers principally the progress made in the manufacture of the cells, especially with regard to plate preparation including sintering and impregnation of master plaques. Supplementary experimental studies have been carried out in order to assure the achievement of the goals of the contract.

B-586

D. E. Mullinger, Royal Aircraft Establishment, "Preliminary Design of the Power System for the U.K.3 Satellite," Technical Memorandum No. Space 50 (December 1964). AD 457 284

The power supply system proposed for the U.K. 3 satellite is described and reasons are given for the choice of the particular form of this system.

B-587

Edward C. Kopper, W. Ralph Miller, Edward F. Schweitzer, Michael P. Pochynok, and Arthur Fleischer, Electric Storage Battery Company, "High Capacity Vented Nickel-Cadmium Cells," Report No. 4, Final Report (November 30, 1959 - November 30, 1960) Signal Corps Contract DA-36-039-SC-84555. AD 263 422

The development of 6 sizes of high capacity, vented Ni-Cd cells to meet Signal Corps requirement SCL-7505A and the manufacture of 300 cells of each of the 6 sizes was completed. All cells were given 3 conditioning cycles during which the capacity at the 5-hr. (0.2C sub 5) rate were determined for each cell. Capacity tests were made on 6 representative cells of each type at the 0.2C sub 5 rate at 80 and -40 F and at the 3C sub 5 rate at 80 F. Preliminary tests on 36 type 4 test cells led to the selection of positive plates 0.044-in. thick, negative plates 0.037-in. thick, a nylon taffeta/cellophane/nylon taffeta separator 5-to 6-mil thick. Vacuum impregnation was used for both positive and negative plates and CO (about 5% on total metal basis) was added to the positive impregnation bath, LIOH (CA. 9 G/L) was added to the KOH electrolyte to promote initial capacity and possibly increase cycle life.

B-588

R. E. Barnett, Eagle-Picher Company, "Design, Development, Qualification and Testing of Battery BA-494()/U", Final Report (March 1964 - January 1965) U.S. Army Electronics Research and Development Laboratory Contract DA-28-043-AMC-00054(E). AD 457 141

This report presents chronologically, the development and final qualification of the design of the 2A-494()/U. Also included is the description of special instrumentation and test equipment required to demonstrate the ability of the battery to comply with requirements considerably more stringent and complicated than previously encountered.

B-589

L. A. Kukoz, M. F. Skalozubov, "Effect of Ultrasonics on Some Properties of the Nickel-Cadmium Electrodes in Alkaline Batteries," Novocherkassk. Politekhnicheskiy Institut. Trudy. v. 134. 1962. Raboty Kafedry Tekhnologii Elektrokhimicheskikh Proizvodsty Khimkio-Tekhnologicheskogo Fakul'teta, 19 - 30

This paper reports attempts made to increase the utilization factor of nickel in the $Ni(OH)_2$ electrodes of alkaline batteries by the action of vibration on the precipitation process of $Ni(OH)_2$. Nickel sulfate solution was stirred into alkali solution at 1450 rpm and exposed to ultrasonic vibrations of 27, 80, 340, or 1500 kc/sec for 1-30 minutes, or to mechanical vibrations of 100 cps. The intensities were 1.5 w/cm^2 at 27 and 80 kc/sec, 2-3 w/cm^2 at 340 kc/sec, and 5-6 w/cm^2 at 1500 kc/sec. The $Ni(OH)_2$ precipitated was not pressed out. A mixture of 153 g precipitate, 34 g graphite, 3 ml NaOH, and 10 ml $Ba(OH)_2$ was pressed into briquettes which were then shaped to laminas. The chemical and grain compositions of the nickel hydroxide, its specific volume, and the electrical properties of the laminas were tested and compared with standard specimens made without ultrasonic treatment. Results: The SO_4^{2-} ions washed out of the irradiated specimens more easily. The grain composition of $Ni(OH)_2$ was changed by irradiation; data found for 10 min. precipitation:

Conditions of precipitation	Grain composition, % +48 mesh	+100 mesh	+250 mesh	-250 mesh	cm^3/g
commercial	29	37	22	17	0.64
control	27	53	15	5	0.72
vibrations	35	37	19	9	0.67
27 kc/sec	5	35	34	26	0.63
80 kc/sec	6	38	32	24	0.65
340 kc/sec	23	42	21	15	0.52
1500 kc/sec	30	36	20	14	0.56

The utilization factor of Ni increased on ultrasonic treatment. Its values in % were: 74 for commercial laminas; 56 for controls; 60 for laminas exposed to mechanical vibrations; and, for laminas treated ultrasonically, 78 at 27 kc/sec, 75 at 80 kc/sec, 70 at 340 kc/sec, and 69 at 1500 kc/sec. The value is lower for the controls than for the commercial laminas because the precipitated $Ni(OH)_2$ was not pressed out.

Ultrasonic treatment of nickel hydroxide increases swelling by about 5-10%, most intensely between 20 and 100 kc/sec. Optimum treatment time is 3-5 min. There are 6 figures and 3 tables.

B-590

71868n Activation of Silver Oxide Electrodes. G. Z. Kazakevich, I. E. Yablokova, and V. S. Bagotskii. Elektrokhimiya 3(1), 104-7 (1967) (Russ.)

Curves of applied potential (φ) vs. charge passed had 2 steps in the rangeΔ == 0.25 0.5 v. vs. the HgO electrode, when Ag electrodes were cathodically polarized in 10N KOH immediately after having been anodically oxidized by asym. currents of 10 ma/cm^2. The 1st step disappeared and the 2nd was markedly attenuated after storage of the electrode outside of the KOH for 120 hours; both steps disappeared after 600 hours storage. Passage of current up to the evolution of O caused the formation of AgO. During storage, AgO decomposed to Ag_2O and O_2. Cathodic polarization also causes redn. of AgO to Ag_2O. In the former case, a dense layer of Ag_2O was formed on the surface, so that the electrode assumed a φ corresponding to the redn. of Ag_2O.

B-591

71770z. Reactions of Electrodes in Batteries. Shiro Yoshizawa and Zenichiro Takehara (University, Kyoto, Japan). Denki Kagaku 34(8), 586-96 (1966)(Japan).

Solid state reactions are reviewed. 43 references.

B-592

71911w. Oxidation of Nickelous Hydroxide for Alkaline Batteries. Rheinische Westfaclisches Elektrizitactswerk A.-G. Brit. 1,050,876 (Cl. C 01g), December 14, 1966; Ger. Appl. March 24, 1965; 2 pp.

Uniform-size $Ni(OH)_2$ particles $\leqq$80-u diameter were oxidized by exposing to a mixture of O_3 and inert gas, e.g. N_2, rare gas, or gasified fluorinated paraffin at 20-110°. The mixture was stirred continuously. The product $Ni(OH)_2$ was stable and retained a 100% oxidation potential even with the use of excess O_3.

B-593

Gilbert R. Snyder, Diamond Ordnance Fuze Labs., "Lightweight High-Drain Zinc-Silver Oxide Battery," DOFL Report No. TR-859 (August 22, 1960) AD 243 692 Abstract only

The PS-503 reserve-type power supply has been designed for use in a compact electronic device. The electrically initiated, zinc-silver oxide power supply will function over the temperature range of -40 C to +160 F with a current density of approximately 0.5 amp/in.^{2} of projected electrode area.

B-594

George Economy and Rudolph Speiser, Ohio State University Research Foundation, "Anodic Polarization Behavior of Iron-Nickel Alloys in Sulfuric Acid Solutions," Report No. TR-5 (August 1960), Contract Nonr 49511. AD 241 306. Abstract only

Anodic polarization curves of 12 Ve-Ni alloys were determined by galvanostatic and potentiostatic techniques. Curves for the 95-5, 70-30, 40-60, and 0-100 alloys adequately showed the transition behavior with changing composition; no sharp effect was found with either changing composition or changing structure. The effect of increasing pH was to shift the entire polarization curve to more active potentials. Corrosion or open-circuit potential displayed a dependence on both composition and pH. No special trend in passivation current density (I_p) was noted with changing composition. However, the I_p value of each alloy went through a maximum with changing pH, the maximum occurring in the 0.2 pH range. Flade potentials were determined from high-speed recorder traces of the potential decay of the passive alloys. Flade potentials vs pH value and vs composition were plotted. Steady-state potential-current values for the passive-action transition are shown and discussed with reference to current values, alloy composition, and pH values.

B-595

United Technology Center, "Qualification Testing of United Technology Center Battery UTC P/N 4T4506, Yardney P/N 61403," Report No. 369-63 (April 1964). AD 454 684

The test units were successfully tested to determine conformance with the requirements for the following environments: sine and random vibration, sustained acceleration, shock (operative), terminal stud strength, temperature-altitude (airborne shipment), low temperature (preflight), low temperature-altitude (flight), high temperature (preflight), high temperature-altitude (flight), activation time, operation position, peak current, life, dielectric strength, and temperature transducer operation. The units complied fully with these requirements.
(2 references, 20 tables, 12 figures, 250 pages)

B-596

T. P. Dirkse, Calvin College, "Electrode Migration and Reaction Processes Occurring within Alkaline-Zinc Batteries," Fifth Quarterly Technical Progress Report (December 1, 1966 - March 1, 1967), Wright-Patterson Air Force Base Contract AF 33(615)-3292. AD 809 279

Circulating the KOH electrolyte produced no improved behavior of the zinc electrode under the conditions studied. This is partly due to the fact that in order to circulate the electrolyte the spacing between the electrodes must be greater.
(2 references, 2 tables, 1 figure, 7 pages)

B-597

Albert Himy, Douglas Aircraft Company, Inc., Astropower Laboratory, "Development of One Ampere-Hour Heat Sterilizable Silver-Zinc Cell," Progress Report SM-49109-Q3 (April 1967), NASA Ames Research Center Contract NAS 2-3819

The main effort of this quarter was concentrated on the rectilinear plastic case configuration. The cell pack design was established and proved satisfactory, as demonstrated by repeated cycling. Several cells were built and tested for full characterization after being submitted to a complete sterilization procedure. The work on case-to-cover seal advanced also.
(1 reference, 8 tables, 11 figures, 28 pages)

B-598

Lewis F. Urry, Union Carbide Corporation, "Anode Limited Sealed Secondary Battery Having an Auxiliary Electrode," U.S. Patent 3,278,334 (October 11, 1966). Abstract only

The patent describes an anode limited, rechargeable battery operating at a H cycle. The battery comprises a sealed container having a Zn anode, KOH electrolyte, Ag_2O depolarizer, and a C auxiliary electrode of $\sim$30% porosity on which a finely divided Pt metal has been deposited. A pressure actuated switch inside the container controls the H pressure in the cell, keeping the electrolyte that is in contact with the auxiliary electrode at the proper level to insure the continuous H consuming action of the auxiliary electrode.

B-599

Hans Bierdumpfel, Sonotone Corporation, "Insulating Seals for Metallic Sealed Battery Casings," U.S. Patent 3,279,953 (October 18, 1966), Abstract only.

A seal junction between the open end of a tubular sheet casing and the cover closure, which also constitutes the 2 opposite polarity terminals of the cells, is formed by a novel crimping technique. Previously crimped covers have had only limited effectiveness in suppressing leakage of alkaline flashlight battery cells, such as those of the Ni-Cd type. The method of sealing and structural details are described.

B-600

Louis D. Babusci and David O. Feder, Bell Telephone Laboratories, Inc., "Nickel Cadmium Battery Receptable," U.S. Patent 3,285,784 (November 15, 1966) Abstract only

A battery case for a sealed alkaline storage battery has a bottom and lid which fit into one another. The bottom member has side walls with holes around its periphery and has an inverted U-sectioned, insulating brushing with its U-bend on the rim. These holes act as vents to the atmosphere if the lid blows off the can because of gas pressure. As a result complete separation of the case components does not occur. The lid member has its rim turned down against the bottom member to compress the brushing and to seal the interior of the cell.

B-601

Robert L. Lambert and Russell E. Palmateer, Sylvania Electric Products, Inc., "Thermal Impregnating Process for Negative Electrodes," U.S. Patent 3,284,237 (November 8, 1966). Abstract only

A carbonyl Ni plate with a porosity of 80-85% was dipped in molten $Cd(NO_3)_2$. A plate was then placed in a chamber containing an Ni_3-steam atmosphere at ambient pressure. The chamber was heated to $\approx 250^0$ for 3-5 min. The plate was removed from the atmosphere and the dipping and decomposition cycles repeated 3 times. Then the plate was placed in a KOH solution along with a plate of positive polarity and was activated electrically by a cycle of charging and discharging steps. The resultant negative electrode had about the same electrical capabilities as a similar plate prepared in an electrolytic process.

B-602

L. N. Sagoyan, Dzerzhinskii Chem.-Technol. Inst. (Dnepropetrovsk), "Nickel-Oxide Electrode of Nonlaminated Type Made by Using Plastics as Binder," Zhurnal Prikladnoy Khimii, 39 (9), 213-2133 (1966). Abstract only

Ni oxide electrodes of nonlaminated type for storage batteries were prepared by mixing $Ni(OH)_2$ with graphite, NH_4HCO_3, and polystyrene dissolved in $C_2H_4Cl_2$ as a binder. The mixture was pressed and dried at 100-200^0. The efficiency of Ni in charging-discharging cycles increases with increasing amount of graphite and NH_4HCO_3 (the latter compound affects the porosity of the electrode). During the initial 4-5 cycles, the efficiency increases and reaches a steady value. Best results were obtained and with compositions containing $Ni(OH)_2$ 1.80. graphite 1.20, NH_4HCO_3 1.50, and 12% polystyrene solution 1.60 g in $C_2H_4Cl_2$ giving the volume fraction of pores of 0.516. The changing capacity is 84.2% of the theoretical value at c.d. 0.293 amp/dm^2 and 16% of 10.0 amp/dm^2. The service life of the electrode is $>$700 cycles.

B-603

Joseph A. Mas, Dynamic Instrument Corporation, "Charging Means for Battery," U.S. Patent 3,281,640 (October 25, 1966). Abstract only

Wet or dry batteries such as Pb-acid and Ni-Cd or Zn-C and Hg can be charged to full capacity at any temperature by using a pressure-responsive variable-impedance device, which by varying resistance controls the voltage rate applied to the battery and maintains a predetermined gas pressure within the battery. When the battery had 0 gas pressure, maximum voltage from the generator flowed through a transistor system or a diaphragm arrangement interconnected with an appropriate current control system and charged the battery until a predetermined maximum gas pressure was attained. Thus, a Ag-Cd cell was charged at -20 F and brought to room temperature after attaining full charge. The battery was discharged at initial voltage of 1.4 v at the moment of load application. After 2 hours at constant current of 2 amp, the voltage fell to 1.16 v. The battery then was charged at room temperature. Conventional vehicular 12 v battery used in automobile can be charged using the transducers.

B-604

E. R. Pettebone, U.S. Naval Ammunition Depot, "Cell Test Program," Monthly Progress Report, NASA-CR-62353 (March 31, 1965), NASA Order W11,252B. N65-22173

Topics include: Status of Cycling Program: The cycling program has included cells from the following manufacturers: General Electric Company (G.E.), Gould-National Batteries, Inc. (Gould), Sonotone Corporation (Sonotone), Yardney Electric Corporation (Yardney), Gulton Industries, Inc. (Gulton), and Delco-Remy (Delco). Total Number of Packs Placed in Program: 109. Cell Types: Nickel-Cadmium (10-cell packs); Nickel-Cadmium (5-cell packs); Silver Cadmium (10-cell packs); Silver Zinc (5-cell packs). Test Parameters. Data. Capacity Tests. (0 reference, 0 tables, 0 figures, 115 pages)

B-605

T. E. King and J. L. Lackner, Defence Research Chemical Laboratories, "RCAF Flight Trials of Nickel-Cadmium and Lead-Acid Batteries. Design of Tests and Analysis of Results," DRCL Report No. 344 (March 1961). AD 261 078

This report describes field service trials conducted to assess the serviceability of various battery systems for aircraft applications. Although the trials were conducted on CF-100 aircraft much of the information gained may be applied generally to other aircraft applications. On the basis of results of the trials it is recommended that the RCAF adopt nickel-cadmium batteries for aircraft use and employ the prescribed maintenance procedure. (14 references, 21 tables, 4 figures, 63 pages)

B-606

Irwin M. Schulman and Paul Ritterman, Sonotone Corporation, "Study of Sealed Nickel-Cadmium Batteries. Research Investigations to Develop and Evaluate a Nickel-Cadmium Battery Having a Hermetically Sealed Construction, and to Study Its Reaction Mechanisms," Second Quarterly Report (March 1 - May 31, 1959), U.S. Army Signal Research and Development Laboratory Contract DA-36-039-SC-78249. AD 225 160

> Forty-eight cells with varying concentrations and amounts of electrolyte were started on a life cycling program. Actual and theoretical capacity data are presented for those plaques which were to be used for cells with different negative/positive capacity ratios. A new experiment was designed to test the effects of cobalt addition to the positive plates, lithia addition to the electrolyte, and varying negative/positive capacity ratios. Charge and discharge data are presented for a 3 plate cell (2 negative and 1 positive) in a sealed chamber under atmosphere of varying oxygen partial pressures.
> (8 references, 14 tables, 15 figures, 50 pages)

B-607

H. N. Seiger, Gulton Industries, Inc., "Investigations Leading to the Development of Improved Sealed Nickel-Cadmium Batteries. The Testing of Hermetic Seal and Separators, Positive Plate Studies, and Investigations on the Uniformity of Sealed Nickel-Cadmium Cells," Quarterly Progress Report No. 5 (July 1 - September 30, 1961), Signal Corps Contract DA-36-039-SC-85390. AD 270 456

> Special welding techniques have enabled final cover-to-can seals to be made. Overcharge tests on the HS series cells were continued. Pressure decay experiments are described, in which the complication of oxygen from the nickel-oxide electrode was avoided. Tests on the doped nickel-oxide electrode at 100 F were completed. Discharge of the lithiated electrodes resulted in less total oxygen evolved.
> (11 references, 7 tables, 35 figures, 80 pages)

B-608

E. J. Casey, P. L. Bourgault, and Phyllis E. Lake, Defence Research Chemical Laboratories, "Nickel-Cadmium Batteries. I. Sintered Plates from a New Canadian Nickel Powder," DRCL Report No. 187, Reprinted from Canadian Journal of Technology, 34, 95-103 (1956). AD 117 960

> Sintered plaques of high porosity and good mechanical strength have been made from a new domestic nickel powder. The plaques, when impregnated and given electrolytic oxidations and reductions in a test cell, gave electrical capacities at low rates of discharge equal to those of plates produced commercially from carbonyl nickel powder; and at extremely high rates gave 15-20% less than the commercial plates. Physical and electrical characteristics of the plates are interpreted in terms of the physical properties of the new powder and various factors in the processing. Certain problems which need detailed investigations are pointed out.
> (8 references, 6 tables, 1 figure, 9 pages)

B-609

Ya. I. Tur'yan and Yu. S. Gorodetskii, Translated by J. H. Dixon, Royal Aircraft Establishment, "Oscillographic Research into the Oxides Formed at a Nickel Anote During the Electro-Chemical Evolution of Oxygen," Library Translation No. 770 (September 1958), from Doklady Adademii Nauk SSSR, 117 (4), 655-657 (1957). AD 218 488

A loop oscillator was included in the electrode circuit in order to record discharge curves. "Full" and "incomplete" curves, the first including the reduction of the unstable higher oxide NiO_2 and the second recorded with the vibrator included in the electrode circuit some time after disconnecting the polarizing current, enabled the quantity of NiO_2 to be determined. The electrolyte used was 7.5N KOH. Polarizing current density was varied between 0.1 and 2 A/cm^2. The quantity of the stable oxide Ni_2O_3 is found from the "incomplete" discharge curves and is given in "layers." The coating thicknesses on smooth nickel anodes are shown to be far thicker than was previously thought. It is suggested that the oxygen evolved does not only spring from oxide formation and decomposition.
(11 references, 0 tables, 3 figures, 6 pages)

B-610

G. Grube and E. Doetsch, Translated by A. S. McKie, Royal Aircraft Establishment, "The Behaviour of the Cadmium Electrode in the Alkaline Nickel-Cadmium Accumulator," Library Translation No. 716 (February 1958), from Ztschr. Elektrochemie, 42 (5), 247-258 (1936). AD 159 695

The behaviour of the cadmium/Fe_3O_4 pocket electrode of the Ni-Cd accumulator has been studied by single electrode polarization techniques. It was found that the capacity of a pure cadmium powder electrode decreased rapidly on cycling, and that a form of Fe_3O_4 used commercially to maintain constant electrode capacity took part in the electrode reaction. Water is generated on charging and removed on discharge; the current-efficiency of charging and the capacity of the cadmium electrode are considerably decreased on reduction of the alkali concentration in the electrolyte.
(9 references, 9 tables, 8 figures, 20 pages)

B-611

Arnold Schmeckenbecher, General Aniline and Film Corporation, "Industrial Preparedness Study for Battery Grade Carbonyl Nickel Powder," Third Quarterly Report (December 7, 1957 - March 7, 1958), Signal Corps Contract DA-36-039-SC-72748. AD 157 514

The absorption of nickel tetracarbonyl by activated charcoal and by activated silica was studied in order to obtain data for the design of scrubbing units for the removal of nickel tetracarbonyl vapor from carbon monoxide.
(0 references, 0 tables, 1 figure, 7 pages)

B-612

C. P. Wales, U.S. Naval Research Laboratory, "Silver Oxide-Zinc Alkaline Storage Batteries: Effect of Float and Normal Charges on Capacity and Related Characteristics," NRL Report 5167 (August 11, 1958) AD 201 904

Two 100-amp-hour silver oxide-zinc alkaline storage batteries were studied. After several cycles established their capacity, these 5-cell batteries were charged at the normal rate and then floated at 9.90 volts (1.98 volts per cell) for a 30-day period. A battery was discharged following a float, given one or more cycles, and then floated again. In addition, several other rates of charge and discharge were tried. All of the cells failed from internal short circuits before their capacity reached half of its rated value.
(14 references, 7 tables, 20 figures, 34 pages)

B-613

Irwin M. Schulman and Paul F. Ritterman, Sonotone Corporation, "Investigation Leading to the Development of a Nickel Cadmium Battery Having a Hermetically Sealed Construction," Fourth Quarterly Report (May 11 - August 10, 1957), Signal Corps Contract DA-36-039-SC-73009. AD 143 542.

Additional 3-1x1 (0.45 A.H.) batteries were subjected to automatic cycling (60 minute charge - 40 minute discharge) at discharge rates 0.07 to 0.20 amperes. These batteries have received 656 cycles. The 3-1/4x1 (0.1 A.H.) batteries were normalized with constant current charge-discharge cycles and replaced on cycle service. These batteries have received 414 cycles at discharge rates of 0.05 and 0.06 ampere. The vacuum cycling of the 0.45 A.H. cells was extended from 1149 cycles to 2256 cycles during this quarter at discharge rates from 0.07 to 0.15 ampere. The cadmium oxygen reaction which is supposedly the rate controlling step in the reaction mechanism of the sealed cell was investigated at low pressure of oxygen.
(6 references, 12 tables, 19 figures, 56 pages)

B-614

M. F. Skalozubov, "The Active Mass of a Zinc-Silver Storage Battery," Translation from Novocherkassk. Politekhnicheskiy institut Trudy, 134 (1962). AD 406 029

The following problems needing further investigation are mentioned after a survey has been made of the known properties of a Zn-Ag storage battery and of the methods of producing zinc and silver electrodes: processes on the zinc electrode, and improvement of the electrode; processes on the silver electrode; possibilities of producing a zinc-silver dry cell; replacement of the hydrate-cellulose partition by stabler films, e.g. films made of ion-exchange membrane or other materials; development of a thermal battery without CO_2 absorption, replacement of zinc by cadmium or another metal.

B-615

Naval Ammunition Depot, "Space Cell Test Program," Monthly Progress Report NASA-CR-71448 (1965), NASA Order W11,252B. N66-82693. Abstract only

Aeronautics; Cadmium; Capacity; Cell; Current; Cycle; Discharge; Life; Nickel; Printout; Program; Silver; Space; Temperature; Test; Voltage; Zinc.

B-616

Raymond Nathe, John Herrman, Arthur Fitchman, and Elmer D'Onofrio, Sonotone Corporation, "Standard Line-Battery Assembly BB-610( )/U Nickel Cadmium Vented," Quarterly Progress Report No. 2 (April 1966), ECOM-01508-2, U.S. Army Electronics Command Contract DA-28-043-AMC-01508(E). AD 633-060 N66-30723. Abstract only

This report covers the research and development activities which have been directed towards the design of a 12-volt, vented, nickel-cadmium battery housed in a reinforced fiberglass container, and capable of surviving four-foot, free-fall drops. Based upon our test results, certain modifications on the container were made, subsequently followed by a new series of drop tests. These test results proved out the acceptability of the new modifications, since no significant damage to the container was found at the end of 26 completed drops.

B-617

G. Myron Arcand, Idaho State University, "The Reactions Pertaining to Zinc-Silver and Cadmium-Silver Batteries," Final Report (April 1, 1967), Jet Propulsion Laboratory Contract JPL 951458 under Prime Contract NAS 7-100 Re-Order No. 67-142.

The use of tritium as a tracer permits an estimate of the degree of hydration of zinc and cadmium oxides when they are precipitated from solutions containing ^3H_2O. Chemically prepared AgO is 94% converted to Ag_2O in 4.5 hours at 140 C while electrolytically prepared AgO is 94% converted in 1.1 hours. Different techniques in electrolytic preparation cause differences in the thermal behaviour of the product. Silver dissolved in 10 VH KOH deposits on zinc sheet immersed in the solution with the resultant oxidation of zinc. Preliminary experiments suggest that the rate of reaction in a solution initially saturated with Ag(I) averaged over about 170 hours is about 3 x 10^{-3} milli-equivalents/hours or 0.5 ampere-hour/year. (18 references, 7 tables, 9 figures, 43 pages)

B-618

James M. Rice, Telecomputing Corporation, "Silver-Cadmium Battery Development Program," NASA-CR-85 (September 1964), Contract NAS 5-1431.

All of the original performance objectives of this program have been accomplished. The intended cell capacity of 200 ampere-minutes was the minimum qualification requirement for the cells at formation. Cycled cells and batteries exhibit capacities 50% in excess of the requirement. The temperature range over which the design has been evaluated has been exceeded by a good margin--minus 40 F to 150 F, compared to the original goal of plus 32 F to 122 F. The weight, volume, and permeability values are all less than the original design goals. The negative cadmium plate, made by the pasting procedure, has proved to be reliable.
(1 reference, 38 tables, 55 figures, 211 pages)

B-619

S. Lerner, Gulton Industries, Inc., "Characterization of Recombination and Control Electrodes for Spacecraft Nickel-Cadmium Cells," Third Quarterly Report (December 9, 1966 - March 9, 1967), NASA Goddard Space Flight Center Contract NAS 5-10241

Cells containing active Adhydrodes and fuel cell scavenger electrodes have been investigated as to their cycling and gassing characteristics at various temperatures. It has been shown that cells containing a fuel cell scavenger electrode have superior low temperature cycling, as well as gassing, characteristics when compared to standard VO-12HSAD cells.
(1 reference, 2 tables, 26 figures, 35 pages)

B-620

E. C. Bruess, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells. Acceptance Test of Sonotone Corporation 5.0 Ampere-Hour Nickel Cadmium Cells." Report No. QE/C 65-583, NASA-CR-67713 (September 2, 1965), NASA Goddard Space Flight Center Contract W11,252B. N66-11672

Results of acceptance tests on 40 five amp-hr. Ni-Cd secondary spacecraft cells showed that the ceramic seals were satisfactory, as no leakage occurred, and that the capacity of the cells was in the acceptable range of 5.05 to 6.80 amp-hr to 1.00 v. Test conditions are described, and data on individual cell performance are tabulated.
(0 references, 1 table, 3 figures, 9 pages)

B-621

P. C. Donnelly and C. F. Palandati, NASA Goddard Space Flight Center, "Silver-Zinc Batteries Power Supply for the Atmosphere Explorer-B Spacecraft (AE-B)," Report No. X-716-65-405, NASA-TM-X-55383 (October 1965). N66-17256.

The characteristics and operation of the Ag-Zn batteries which comprise the primary power supply for the Atmosphere Explorer-3 spacecraft (AE-B) are described, as well as the cell characteristics, design, and charging technique. The power supply is composed of 8 batteries of series strings of Yardney modified Ag-Zn cells.
(5 references, 4 tables, 7 figures, 18 pages)

B-622

Terence J. McGurn and Harvey N. Seiger, Gulton Industries, Inc., "Evaluation of Nickel-Cadmium Battery Testers. The Determination of the Accuracy and Reliability of the Vitro Tester and the Optimum Procedure for Its Use," First Quarterly Progress Report (September 1960), Signal Corps Contract DA-36-039-SC-85066. AD 250 491

Vitro Nickel-Cadmium Battery Tester No. 3 and various nickel-cadmium cells and batteries were received for evaluation. The cells (BB 403/U and BB 412/U) and batteries (BB 401/U and BB 412/U) were cycled to obtain their actual capacities. Phase A, the determination of optimum pulse rates for use of the tester presented a major difficulty.
(0 references, 0 tables, 0 figures, 21 pages)

B-623

H. Thomas Staub and Harvey N. Seiger, Gulton Industries, Inc., "Evaluation of Nickel-Cadmium Battery Testers. The Determination of the Accuracy and Reliability of the Vitro Tester and the Optimum Procedure for Its Use," Quarterly Progress Report No. 2 (September 30 - December 30, 1960), Signal Corps Contract DA-36-039-SC-85066. AD 253 390

The Vitro Nickel-Cadmium Battery Tester No. 3 has been modified for use with batteries and cells supplied under the contract by using a microammeter with a series resistor in place of the meter already in the V.T.V.M. With the tester, one can easily distinguish between BB401/U batteries with more than or less than 50% charge. The state of charge of batteries with less than 50% capacity remaining can be estimated with an accuracy of 22% at 80 F. Those with greater than 50% can be estimated with an accuracy of 10%.
(0 references, 11 tables, 9 figures, 54 pages)

B-624

John Rhyne, Jr., General Motors Corporation, Delco-Remy Division, "Silver Oxide-Zinc Battery Program," WADD Technical Report 61-36 (May 1961), Wright-Patterson Air Force Base Contract AF 33(600)-41600. AD 266 351.

A study was made of the Ag 10 migration within the cell during cycling. Distribution of Ag in the various layers of separator was determined as a function of the number of cycles. A comprehensive study of the Zn electrode was partially completed. The effect of current density and certain addition materials was determined in terms of Zn particle size increase during cycling. Methods of controlling Zn penetration of the separator material were established. Other investigations included gas producing reactions at both the negative and positive plates, pressure control, effect of alloying elements on the voltage characteristics of the positive plate, production of a molded terminal seal resistance to KOH leakage. A sealed cell was constructed and cycled over a 20% capacity range for 590 cycles. The pressure change was from a 10 psi vacuum to a 9 psi positive pressure.
(263 references, 12 tables, 62 figures, 152 pages)

B-625

K. P. Nefedov, "An Automatic Charge Cut-Off for Silver-Zinc Storage Batteries," FTD-TT-61-172/1+2 (December 1961), from Byulleten' Izobreteniy, Patent No. 130547, No. 15, 32-34 (1960). AD 268 071

This is a device for the automatic cut-off of silver-zinc storage batteries; it has an electromagnetic relay as the executive unit, a source of control voltage fed to the voltage dividers in the main triode circuits, and indicator lights. Its distinguishing feature is that 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.
(1 drawing, 0 claims)

B-626

H. N. Seiger, Gulton Industries, Inc., "Investigations Leading to the Development of Improved Sealed Nickel-Cadmium Batteries. The Testing of Hermetic Seals and Separators, Positive Plate Studies, and Investigations on the Uniformity of Sealed Nickel-Cadmium Cells," Quarterly Progress Report No. 3 (January 1 - March 31, 1961), Signal Corps Contract DA-36-039-SC-85390. AD 260 629

The successful ceramic-to-metal seal is being placed on a Pilot Plant scale. Pellon 960 and Pellon T materials appear to have the characteristics that should make a good and reliable separator. Three parameters seem to be required to have uniform cells, namely (1) capacity, (2) transfer coefficient, and (3) pressure slope. The self-discharge of pure Ni electrodes, appears to occur by three independent processes. Two of these processes involve 10% of the electrode capacity. The self-discharges of doped electrodes are different. The two more rapid processes proceed consecutively rather than independently. Doping does appear to decrease the self-discharge rate for the second process.
(6 references, 7 tables, 9 figures, 45 pages)

B-627

V. V. Romanov, "Improvement of Certain Operational Characteristics of Silver-Zinc Storage Batteries," FTD-TT-61-272/1+2+4 (June 7, 1962), from Vestnik Elektropromyshlennosti, No. 9, 26-29 (1960). AD 288 701

In this article we give the results of an investigation of the possibility of improving certain operational characteristics of silver-zinc storage batteries by charging them with asymmetric industrial a-c.
(0 references, 1 table, 6 figures, 8 pages)

B-628

Richard E. Amsterdam and James V. Ball, P. R. Mallory & Company, Inc., "Diode Control Research," Third Quarterly Technical Progress Report (March 1967), Wright-Patterson Air Force Base Contract AF 33(615)-3702. AD 810 831

A circuit designed to sense the temperature of the stabistor heat sink was tested with a five-cell battery protected by stabistors and charged at C/1. The circuit successfully detected end-of-charge and reduced the charge current to the safe overcharge rate. Tests on different junction area stabistors indicate that the forward voltage tends to vary inversely with area, so that the proper combination of area and number of junctions may permit stabistor charge control of silver-zinc and silver-cadmium cells. Weight and volume studies of theoretical stabistor charge control systems for aircraft batteries charged at 350 and 220 amperes were conducted. Major problems in designing such systems could be low stabistor voltage and high leakage during open circuit stand, both resulting from the large area junctions required.
(6 references, 3 tables, 15 figures, 31 pages)

B-629

Shiro Yoshizawa, Zenichiro Takehara, Mitsuya Kato, and Kunihiko Kumazaki, Kyoto University, "Charge and Discharge Mechanism of a Nickel Hydroxide Electrode," Denki Kagaku, 34 (8), 661-667 (1966). Abstract only

This charge and discharge reaction mechanism of a Ni hydroxide electrode of an alkaline battery was studied. The Nernst equation was derived for the reaction H_2^+ (proton in the solid phase) + OH^- (soln.) = H_2O + e + H_s^+.v (the proton vacancy in the solid phase), where H_s^+ and H_s^+.v corresponds to $Ni(OH)_2$ and NiOC or NiO_2, respectively. The diffusion of H_s^+.v was rate determining for the equation in charging and discharging, if the electrode concentration was constant and the validity of the equation was quantitatively proved by the experiment. The potential varied with c.d. and the temperature of the electrolyte solution. The activation energy for the diffusion of H_s^+ was as great as 3-5 kcal/equiv. The value of D/ϕ (D is the diffusion coefficient of H_s^+ of H_s^+.v, and ϕ) the quantity of H_s^+ of H_s^+.v formed in unit time on unit effective surface area was useful for the comparison of the electrode activities.

B-630

R. L. Haines, I.H.S. Henderson, F/L.J.R. McKague, and T. E. King, Canadian Defence Research Board, "Charge Control Devices. Coulometric Control of Charging of Ni-Cd Secondary Batteries," Proceedings of the 20th Annual Power Sources Conference (May 24-26, 1966), pp 109-112. Issued as DCBRL Report No. 499

> Batteries should be charged as rapidly as is practical to secure a higher charging efficiency and better utilization of charging currents. A $Cd/Cd(OH)_2$ coulometer coupled with simple circuitry is a reliable charge control. The coulometer and simple circuitry are used to solve high-rate charging problems encountered in the use of Ni-Cd batteries. The system is highly reliable and does not depend on some battery characteristic such as a voltage rise at the end of charging but does depend on a coulometer function, independent of battery behavior, the ability of the coulometer to integrate the number of coulombs removed during discharge and to signal when that number has been returned. (5 references, 0 tables, 5 figures, 4 pages)

B-631

Thomas J. Hennigan and Kenneth O. Sizemore, NASA Goddard Space Flight Center, "Charge Control Devices. Charge Control of Ag-Cd Cells and Ag-An Cells," Proceedings of the 20th Annual Power Sources Conference (May 24-26, 1966), pp 113-116.

> The 2-step voltage limit type charge control, when used with Ag-Cd cells, eliminates unbalance problems, prevents overcharge during pulse charge-discharge cycling and appears to improve the discharge characteristics of the Ag electrode. Use of the charge control method with Ag-Zn cells increased cycle life by a factor of 5.
> (10 references, 0 tables, 6 figures, 4 pages)

B-632

J. E. Oxley, C. W. Fleischmann, and H. G. Oswin, Leesona Moos Laboratories, "Silver Batteries. Improved Zn Electrodes for Secondary Batteries," Proceedings of the 20th Annual Power Sources Conference (May 24-26, 1966), pp 123-126.

> A discussion of variables which cause dendritic (crystalline) deposits on Zn electrodes is given. The propagation rate of these deposits depended on the extent of deposition and tended to increase with overpotential. Specific recommendations are made to minimize these deposits.
> (8 references, 0 tables, 4 figures, 4 pages)

B-633

E. M. Jost and P. V. Popat, Texas Instruments Inc., "Nickel Cadmium Batteries. Improved Sealed Ni-Cd Cells," Proceedings of the 20th Annual Power Sources Conference (May 24-26, 1966), pp 136-139.

Statistically designed factorial experiments were conducted to study the parameters of the sealed Ni-Cd cell. The low temperature behavior depended mainly on 2 factors, the Cd/Cd$(OH)_2$ loading of the negative electrode and the percent pore filling of the electrolyte. The charge efficiency of sintered plate Cd/Cd$(OH)_2$ electrodes at 0-40° is low, and H was evolved before all the Cd$(OH)_2$ was reduced. H evolution was suppressed as soon as the O recomgination rate in the cell was sufficient to satisfy the Faradaic current not used for Cd$(OH)_2$ reduction.
(0 references, 5 tables, 5 figures, 4 pages)

B-634

Kenneth O. Sizemore and Thomas J. Hennigan, NASA Goddard Space Flight Center, "Charge Control Devices. Auxiliary Electrode Instrumentation," Proceedings of the 20th Annual Power Sources Conference (May 24-26, 1966), pp 116-120.
N66-24928

The use of auxiliary electrodes and related charge control instrumentation, or regulating the charge to the Ni-Cd battery is described. The auxiliary electrode discussed is the adsorption H electrode (because of its stability and nearly linear response as a function of O pressure).
(5 references, 0 tables, 7 figures, 4 pages)

B-635

G. A. Dalin and M. Sulkes, Yardney Electric Corporation, "Silver Batteries Design of Sealed Ag-Zn Cells," Proceedings of the 20th Annual Power Sources Conference (May 24-26, 1966), pp 120-123

A discussion of separator materials, the combinations in which they are used and their apparent influence on the rate of pressure decay in sealed Ag-Zn cells is presented. Details are given for construction of the cells.
(5 references, 0 tables, 4 figures, 5 pages)

B-636

J. A. Consiglio, General Electric Company, "Silver Batteries. Electrodeposited Inorganic Separator for Ag-Cd Batteries," Proceedings of the 20th Annual Power Sources Conference (May 24-26, 1966), pp 126-128

The use of inorganic films of Ca$(OH)_2$ or Mg$(OH)_2$ for the separator material applied to secondary cells is discussed. These separators increase chemical stability at elevated temperatures and reduce Ag migration. The films are deposited on the surfaces of the battery plate by making them the cathode in an electrolysis cell using soluble Ca and Mg salts as the electrolyte. Electrolytic Ph and Ca$(OAc)_2$ concentration can be controlled by buffering with excess Ca$(OH)_2$ which neutralizes the AcOH formed. Tests show that coated electrodes can be sterilized in 31 wt. % KOH at 145° for 50 hrs. without loss of coating.
(0 references, 1 table, 3 figures, 3 pages)

B-637

J. H. Waite, Mauchly Systems, Inc., "Nickel-Cadmium Batteries, Performance Prediction for Ni-Cd Batteries," Proceedings of the 20th Annual Power Sources Conference (May 24-26, 1966), pp 130-132

An analysis is presented of the test data from the Crane Life-Cycle Test program. Inherent weaknesses in cells are assumed to be reflected in test data. Thus, improper selection of test parameters and other noise-generating distort essential information. Conclusions are presented. (0 references, 0 tables, 3 figures, 3 pages)

B-638

Hans Vogt, "Sintered-Frame Electrodes for Alkaline Batteries," German Patent 1,233,926 (Addition to German Patent 977,069), February 9, 1967. Abstract only.

Highly porous title electrodes consisting of very thin layers are made by using an apparatus in which the spray powder passes over a vibrator to the suction line of a blower, being carried into a chamber, where the particles settle as a uniform layer on a continuous metal foil. At a constant spray rate, the obtained layer thickness is determined by the velocity of the foil which passes through a sintering furnace onto a roll. Thus, a sintered layer of 5 microns can be obtained.

B-639

H. M. Schultz and E. C. Bruess, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells. Acceptance Tests of Gulton Industries 3.6 and 5.6 Ampere-Hour Nickel-Cadmium Cells with Vulcanized Neoprene Terminal Seals." Report No. QE/C 66-69, NASA-CR-70852 (January 28, 1966), NASA Order W11-252B. N66-19094. Abstract only

Acceptance tests were conducted on a 3.6 and 5.6 ampere-hour sealed Ni-Cd secondary spacecraft cells with vulcanized neoprene terminal seals. The tests were performed at an ambient temperature 23-27^{o} at existing relative humidity and atmospheric pressure, and consisted of the following: phenolphthalein leak test; capacity test; cell short test; overcharge test; internal resistance test; and immersion seal test. The test procedures and results are discussed in detail, and tabulated and graphic data are included. The vulcanized neoprene seals of the cells are satisfactory as evidenced by no leakers out of the 72 cells tested. The weak point in the cell construction may be the cover-to-can weld, as shown by 2 leakers out of all the cells tested.

B-640

R. W. Schult and W. T. Stafford, TRW Space Technology Laboratories, Inc., "The State of Development of Silver Oxide-Zinc and Nickel-Cadmium Batteries," STL-TR-60-0000-09034 (February 1960), Contract AF 04(647)-309. AD 278 140

This report details information about silver oxide-zinc and nickel-cadmium galvanic cells. The data given are often typical rather than specific manufacturers' test results; no bias is intended, since data were selected primarily on the basis of ready availability.
(33 references, 6 tables, 63 figures, 116 pages)

B-641

K. Rasevices, "Thermal Losses in Electric Storage Batteries and Calculation of the Temperature Regime," Energosnabzh. Passazhirskogo Poezda, Akad. Nauk Latv. SSR, Inst. Energ., 135-145 (1965)

Thermal losses during the charging and discharging of storage batteries are given by $P = I_c U_c - I_r E_r - I_p E$ and $P = I_p(E - U_p)$, respectively, where I_c is charging current, U_c is voltage drop between the electrodes, I_r is current used for gas evolution, E_r is decomposition potential of water, I_p is current used in effective electrode process, E is the emf of the battery, and U_p is discharge voltage. The temperature at time t in an assumedly homogeneous storage battery is given by $\theta = P/A + \theta_v - (P/A + \theta_v - \theta_n) \exp (-tA/C)$, where θ_v is ambient temperature, θ_n is initial temperature, and C and A are heat capacity and thermal conductivity, respectively, of the battery. Experimentally determined values for heat loss and temperature agree well with values predicted from the above equations, using empirically determined values for C and A.

B-642

T. R. Beck, Boeing Company, "Thermal Resistance and Temperature Gradients in Cells of Lunar Orbiter Battery," Coordination Sheet No. 2-5466-0-788 C/S to S. G. Browne (February 23, 1965)

The basic problem of the high cell temperature is caused by the high overcharge ratio. A simple way of limiting the ampere-hour overcharge ratio and excess heat generation would be to measure the ampere-hours discharged each cycle and to cut-off charge current when say 120% of this ampere-hour capacity is recharged each cycle. This job could be done by a shunt and integrator and logic circuit.

B-643

R. H. Sparks, TRW Systems, "A Study to Develop a Low Temperature Battery Suitable for Space Probe Applications," Final Report, NASA-CR-54737 (no date given), NASA Lewis Research Center Contract NAS 3-6018.

This study examines in detail the practicability of heating spacecraft batteries to extend their capabilities into the ultra-low temperature space applications. Several acceptable design concepts are established using systematic evalutions of batteries, heat sources, thermal controls and mission interfaces. Potential applications are determined and new technology required for hardware design is defined. A development plan for new technology is presented. Preliminary heated battery designs for two types of thermal requirements are investigated and model analyses are presented detailing technical performance.
(252 references, 28 tables, 93 figures, 294 pages)

B-644

Sidney Gross, Boeing Company, "Development and Fabrication of Advanced Battery Energy Storage System," Mid-Term Report (April 10, 1967), NASA Manned Spacecraft Center Contract NAS 9-6470

Important work has been completed in the areas of cell design, venting system, battery packaging, calorimeter design, and the battery charge-discharge controller.
(0 references, 7 tables, 30 figures, 66 pages)

B-645

J. K. Wilson, Eagle-Picher Company, "Research Investigation Leading to the Development and Evaluation of a Cadmium-Silver Oxide Battery Having a Hermetically Sealed Construction," Quarterly Progress Report No. 6 (October 1 - December 31, 1961), U.S. Army Signal Research and Development Laboratory Contract DA-36-039-SC-85370. AD 275 749

Analyses of cycle life test data on fully assembled elements disclose that multiple layers of membrane type separation sufficiently resist oxidation by, and retard migration of, the silver ion. Capacity measurements of positive and negative active materials were continued. The measurements cover the temperature range of -60 to +120 F. Charge efficiency data disclose that maximum capacity is obtained by subjecting either plate to 30% overcharge, regardless of the temperature at which the plates are charged. It has been disclosed that the amount of electrolyte contained by a cadmium-silver oxide cell has considerable influence on capacity efficiency and rate of recombination. Apparent positive and negative plate density studies have been initiated and are discussed.

B-646

John W. Rhyne, Telecomputing Corporation, "Silver Oxide-Cadmium Battery Program," Final Report No. ASD-TDR-62-450 (August 1962), Wright-Patterson Air Force Base Contract AF 33(600)-42988. AD 287 224

Several specific areas of investigation are included in the program. (1) The investigation of the possible use of chelating or complexing agents for possible use as a means of reduction of the silver ion activity to a minimum. (2) The investigation of ion-selective membrane separators. (3) The investigation of methods of recombination of evolved gases, particularly the possibilities of the use of organic redox additives to the electrolyte.
(35 references, 12 tables, 17 figures, 99 pages)

B-647

E. Lifshin and J. L. Weininger, General Electroc Research and Development Center, "Electron Microbeam Probe Analyses of Nickel-Cadmium Battery Plates," Electrochemical Technology, 5 (1-2), 5-8 (January-Febraury 1967)

The emergence of electron probe microanalyses as a total for metallurgical studies has made it possible to view battery plates with this new experimental technique. This method of analysis is applied to new and used negative electrodes of the nickel-cadmium cell. X-ray and electron distribution images from surfaces and cross-sections of porous electrodes are shown, illustrating the advantages and limitations of the method.
(3 references, 0 tables, 6 figures, 4 pages)

B-648

Melvin H. Gottlieb; Bell Telephone Laboratories, Inc., "Charging Behavior of Cadmium Hydroxide Electrodes at Low Temperatures," Electrochemical Technology, 5 (1-2), 12-17 (January-February 1967)

It is shown in the course of this paper that, under flooded cell conditions, the first charge at low temperature, following room temperature cycling, indeed is anomalously short, the potential changing to that characteristic of hydrogen evolution after only a fraction of the theoretical capacity has been returned. The capacity for subsequent low-temperature charges was not found to be very much smaller than the room-temperature value. It will be seen, however, that the mechanism of this recovery of capacity is such that several low-temperature charge-discharge cycles would be required before a sealed nickel-cadmium cell would stop evolving hydrogen at low temperature. Because of the importance of this effect in the operation of sealed nickel-cadmium cells over a wide range of temperatures, a somewhat detailed study was made of the charging characteristics of the cadmium electrode under flooded conditions in an attempt to understand the anomalously low capacity experienced in the first charge at low temperature.
(7 references, 1 table, 9 figures, 6 pages)

B-649

P. Bauer, TRW Space Technology Laboratories, Inc., "Electrical Charging Characteristics of Nickel-Cadmium Cells," Prepublication draft for publication in the Journal of Electrochemical Technology, October 1963, NASA-CR-74196. N66-82671.

Tests were run on the electrical charging characteristics of 20 and 12 ampere-hour nickel-cadmium cells. Data are reported showing some relationships between terminal voltage, overcharge current, and temperature; between terminal voltage, charge current, and temperature at attainment of the state of full charge; and between efficiency and temperature. An empirical equation expressing these relationships is evolved, and used to control the charge of Ni-Cd cells by controlling applied voltage.
(1 reference, 4 tables, 21 figures, 39 pages)

B-650

Paul F. Bruins, Stanley M. Caulder, and Alvin J. Salkind, Polytechnic Institute of Brooklyn, "Calorimetric Study of the Thermodynamic Properties of the Nickel-Cadmium Cell," Final Report, NASA-CR-71408 (October 1, 1964-December 31, 1965), NASA Goddard Space Flight Center Project SC-MGR-33-006-015. N66-21663

An adiabatic calorimeter was designed and constructed, and a calorimetric technique developed to determine thermal characteristics of electrochemical cells. The heat of reaction for a nickel-cadmium (LiOH) cell was measured and thermodynamic properties ascertained.

B-651

B. R. Hawkins, Eagle-Picher Company, "Investigations Leading to the Development of a Primary Zinc-Silver Oxide Battery of Improved Performance Characteristics," Final Report, NASA-CR-68563 (July 1, 1964 - June 30, 1965), NASA George C. Marshall Space Flight Center Contract NAS 8-5493. N66-13637

Development work has been directed toward the design of an improved silver oxide-zinc battery of limited cycle life. A specific goal has been thirty-day activated stand at +90F, during which time five partial discharges and one full discharge are conducted. Toward this end, phases of study have dealt with improved materials formulation, ratio of materials, electrolyte additives and effects of cell group "compactness" and volume of electrolyte. Whenever practical, the use of full or fractional designed experiments has been emphasized. (8 references, 45 tables, 2 figures, 78 pages)

B-652

Naval Ammunition Depot, "Space Cell Test Program," Monthly Progress Report, NASA-CR-63095 (November 1964), NASA Purchase Order W11,252B. N65-24986

The cycling program has included cells from the following manufacturers: General Electroc Company (G.E.), Gould-National Batteries, Inc. (Gould), Sonotone Corporation (Sonotone), Yardney Electric Corporation (Yardney), Gulton Industries, Inc. (Gulton), and Delco Remy (Delco). Total Number of Packs Placed in Program: 99. Nickel-Cadmium (10-cell packs). Nickel-Cadmium (5-cell packs). Silver-Cadmium (10-cell packs). Silver-Zinc (5-cell packs). (0 references, 0 tables, 0 figures, 108 pages)

B-653

P. Bauer, TRW Space Technology Laboratories, Inc., "Pressure Characteristics of Sealed Nickel-Cadmium Cells," NASA-CR-75669 (1957), Control NAS 5-899. N66-84692

Buildup of excessive pressures in sealed nickel-cadmium cells is investigated by a balanced hydraulic pressure technique and by low rate overcharge methods. The appearance of abnormally high pressures is shown to be related to the appearance of terminal voltages above 1.50 volts, and to the open circuit stand time of the cells. A mechanism for the deterioration of pressure performance with stand time is postulated, and a method of verification suggested. (4 references, 0 tables, 12 figures, 20 pages)

B-654

H. M. Schultz, U.S. Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells. Acceptance Test of Gulton-Industries, Incorporated 6.0 Ampere-Hour Achydrode Cells," QE/C 67-245 (May 5, 1967), NASA Purchase Order W11,252B.

All acceptance tests were performed at an ambient temperature between 23 C and 27 C at existing relative humidity and atmospheric pressure and consisted of the following: (1) Phenolphthalein Leak Test. (2) Capacity Test. (3) Cell Short Test. (4) Immersion Seal Test. (5) Overcharge Test. (6) Internal Resistance Test of the Adhydrode. (7) Internal Resistance of the Cell. (8) Immersion Seal Test. All charging and discharging was done at constant current (±5 percent). Cells were charged in series but discharged individually. (0 references, 3 tables, 3 figures, 11 pages)

B-655

W. N. Carson, Jr., G. Rampel, and I. B. Weinstock, General Electric Company, "Characterization of Recombination and Control Electrodes for Spacecraft Nickel-Cadmium Cells," Third Quarterly Report (May 1967), NASA Goddard Space Flight Center Contract NAS 5-10261

The evaluation of oxygen sensing and recombination electrodes under static conditions has been completed, and the selections for further work have been made. The oxygen sensing electrode selected consists of sintered nickel with a 0.001" Teflon film; the recombination electrode consists of a Pt-catalyzed

sintered nickel structure with a Teflon film on the gas face. Prototype cells, of 6 A-Hr nominal capacity, containing both types of auxiliary electrode have been assembled for cycle testing.
(0 references, 3 tables, 26 figures, 43 pages)

B-656

General Dynamics/Fort Worth, Nuclear Aerospace Research Facility, "Study of Advanced Flight-Vehicle Power-Utilization Systems," Final Report, ASD-TDR-62-591, FZK-148 (June 1962), Wright-Patterson Air Force Base Contract AF 33(615)-8-79. AD 278 204

An unconventional approach toward utilization of vehicle power is presented. Brief mission profiles are given for six manned and unmanned air and space craft to give the schedule of operation of systems which utilize power. Greater detail is presented on the power utilization of two of these, the unmanned reconnaissance satellite and the manned lunar-landing and return vehicle. A general discussion is presented on power sources intrinsic and extrinsic to vehicles, and a forecast is shown for chemical, solar, and nuclear sources. The application of the morphological method to the development of new concepts is discussed and examples given in an appendix of several "morphological boxes." Some of the concepts that developed during the course of the study are also given in appendices. In addition, the appendices contain general reviews of EWASERS, radio space communications, and electrical propulsion. It was concluded that a modified morphological approach offers a better framework for conceiving advanced concepts. Recommendations are made for further study and development of the method and new concepts. (0 references, 10 tables, 26 figures, 98 pages)

B-657

Materials Advisory Board of the Division of Engineering and Industrial Research National Academy of Sciences-National Research Council, Washington, D.C., "Report by the Committee on Materials Aspects of Auxiliary Power Units for Use in Space Vehicles," Report MAB-177-M (October 25, 1961), Contract DA-36-039-SC-76436. AD 269 263

This committee has addressed itself to making a comprehensive survey of the field of energy conversion as applied to generation of power for space vehicles. The effort has been completely oriented toward the delineation of those materials research problems which must be solved in order to provide reliable and efficient systems. Broadly speaking, we have considered chemical, solar, and nuclear energy sources. Coupled with these energy sources we have considered mechanical, thermionic, thermoelectric, photovoltaic, and direct conversion techniques. In addition, we have taken up problems associated with the extremely important ancillary systems of collectors, radiators, and storage devices.
(12 references, 11 tables, 24 figures, 150 pages)

B-658

Robert P. Clark and Efstratios D. Zaffery, Sandia Corporation, "Instrument for Continuous Measurement of Internal Resistance of Voltaic Cells During Discharge," The Review of Scientific Instruments, 38 (4), 492-496 (April 1967)

An instrument for measuring electrolyte conductance or resistance is described. This instrument is unique in that it has the following combination of features: (1) resistance values in the range 1×10^{-1} to 2×10^{5} can be measured with an accuracy of better than 5%; (2) resistance can be continuously recorded as a function of time; (3) the internal resistance of voltaic cells can be measured during cell discharge; and (4) no special conductivity cells are required. The present instrument is a modified ac Wheatstone bridge. The value of the unbalance signal is monitored and mathematically converted to resistance. Uses for the instrument are discussed and typical results are given.
(6 references, 2 tables, 8 figures, 5 pages)

B-659

Bruce Jagid, Leesona Moos Laboratories, Division of Leesona Corporation, "Development of a Zinc/Oxygen Battery System for Space Vehicle Application," Quarterly Report No. 2 (January 1967), NASA George C. Marshall Space Flight Center Contract NAS 8-20565.

The primary goal of this program as shown is the development of a reliable zinc-oxygen battery as an auxiliary power source for space vehicle applications. The complete battery system will be capable of yielding 120 watt-hours per pound when operating at 28 volts and 50 amperes for 8 hours. This program was divided into three phases. This report covers in detail the completion of Phase II - Single Cell Design and Evaluation.
(1 reference, 1 table, 16 figures, 29 pages)

B-660

Helmuth L. Pfluger and Howard E. Hoyt, Borden Chemical Company, Central Research Laboratory, "Improved Separators for Silver Oxide-Zinc and Silver Oxide-Cadmium Cells for Spacecraft Application," First Quarterly Report (no date given), NASA Goddard Space Flight Center Contract NAS 5-9107, Modification 6.

Progress in modification of methyl cellulose is described in the present report. Also reported herein are further investigations of the properties of previously developed membranes. These include the effects of radiation, of dry heat and of standing in a charged cell. The problem of frothing encountered with methyl cellulose/FVMMA combinations is discussed briefly. Work has continued on diffusion of silver through experimental membranes, using a radiotracer technique. Among new polymers of non-cellulosic structures, a co-acervate of vinyl pyridine and polyacrylic acid was prepared and is being tested. The possibility of physically modifying polyethylene films is being examined.
(0 references, 8 tables, 5 figures, 28 pages)

B-661

John J. O'Connell, Elizabeth A. McElhill, Michael Lehman, and Ralph C. Steeves, Monsanto Research Corporation; Boston Laboratory, "Separator Development for a Heat Sterilizable Battery," Final Summary Progress Report, MBR6234F (May 1, 1966 - March 15, 1967), Jet Propulsion Laboratory Contract JLP 951524 under Prime Contract NAS 7-100. Re-Order No. 67-221.

Two types of ligand-containing polymers were developed that are very promising as separator materials for the sterilizable silver-zinc battery. A film of one, a 0145:0.55 2-vinylpyridine-methyl methacrylate polymer, had 22 ohm-in. resistivity in 40% KOH and about 1000 psi wet tensile strength after in situ saponification during a 120 hr sterilization in 40% KOH at 135 C. Styrene-maleic anhydride-methyl methacrylate terpolymers also look promising. They require shorter saponification times, have good resistance to zinc dendrites, and give resistivities of about 50 ohm-in.
(28 references, 9 tables, 0 figures, 55 pages)

B-662

G. W. Bodamer, Editor, The Electric Storage Battery Company, The Carl F. Norberg Research Center, "Heat Sterilizable, Impact Resistant Cell Development," First Annual Report (April 21, 1967), Jet Propulsion Laboratory Contract JPL 951296 under Prime Contract NAS 7-100.

During the first 15 months' work reported here, the following points were revealed. Heat sterilization of assembled, uncharged cells causes a loss of capacity of the silver electrode as a result of mercury arising from the mercury oxide added to the zinc oxide electrode. This effect has been overcome by the addition of compounds other than mercury oxide which, nevertheless, have the ability to suppress gassing on stand or on overcharge. Four layers of separators RAI-110 or RAI-116 when wet with 25-45% KOH survive heat sterilization and give satisfactory performance through at least four cycles. A polypropylene absorber, Kendall Mills' EM 476, performs satisfactorily following heat sterilization. General Electric polyphenylene oxide grades PPO 531-801 and PPO 541-801 show satisfactory physical and chemical resistance to concentrated KOH under the heat sterilization conditions. Sealing by means of epoxy adhesives or by hot gas welding show promise. Specially reinforced cell structures have given greater physical stability to impact than achieved by previous designs. However, the maximum impact shock resistance required has not yet been reached.
(0 references, 56 tables, 31 figures, 137 pages)

B-663

G. W. Bodamer, Editor, The Electric Storage Battery Company, The Carl F. Norberg Research Center, "Heat Sterilizable, Impact Resistant Cell Development," Report for First Quarter (May 9, 1967), Jet Propulsion Laboratory Contract JPL 951296 under Prime Contract NAS 7-100.

Vented silver oxide-zinc cells containing Compound 323-43 in the unformed, zinc oxide negative and either RAI-110 or RAI-116 separators have been sterilized, put through 60 deep-discharge cycles, and have retained more than 50% of their initial capacity. Sterilized cells performed as well as unsterilized controls. Cells which had had their cell packs sterilized and cases subsequently sealed showed good capacity retention through 30 cycles when RAI-110 was used as separator. Similar cells using RAI-116 showed failure in 20 cycles or less. Pressure build-up in sealed cells during formation has become a problem in some instances. It is not at present clear whether this is related to certain combinations of components or to some unrecognized variations in method of assembly. Reproducibility of leak-proof case-to-cover seals using heat cured epoxy systems has been increased. However, leaks tend to develop around terminals of the design used until the present. A new design of terminal will be examined. In the meantime, a simple and apparently reliable connection can be made by inserting a silver wire through a small-diameter hole in the cover and sealing it in place with epoxy resin. Activity in hot gas welding has not been great, and results show need of more intensive study if this technique is to be used.
(0 references, 28 tables, 5 figures, 57 pages)

B-664

Kenneth O. Sizemore and Eugene R. Stroup, NASA Goddard Space Flight Center, "Nickel-Cadmium Spacecraft Battery Charge Control with Auxiliary Electrodes," NASA-TM-X-56519 (1965). N66-27741. Abstract only

Ni-Cd spacecraft batteries are being fitted with auxiliary or control electrodes that indicate the fully charged state of the battery. The studies include performance characteristics, methods of instrumentation and utilization, life expectancy, and relation of performance to temperature, depth of discharge, and internal cell pressure. Additional research and development is necessary before the full potential of this device will be realized.

B-665

Robert E. Stark, Union Carbide Corporation, "Method of Producing a Charged Negative Cadmium Electrode by Spraying with a Molten Mixture of Cadmium and a Metal Displaced by Treatment with a Cadmium Salt and Hydrofluoric Acid Bath," U.S. Patent 3,305,397 (February 21, 1967). Abstract only

A method of producing charged negative electrodes for use in Ni-Cd batteries involves spraying a mixture of molten Cd and a molten Cd-replacing metal (which is a metal above Cd in the electromotove series) onto a suitable carrier substrate. The substrate is later immersed in a 0.01M Cd salt solution in 1-5% HF acid to deposit spongy Cd metal by displacing the Cd-replacing metal. The Cd-replacing metal (Al, Zn, Mg, and Fe) is in the ratio 1 to 2 to about 1 to 20 with molten Cd. Cd and Al were flame-sprayed onto a substrate in a ratio of 3.44 g Cd/g Al_2 to form a coating 0.0185-in. thick and containing 0.55 g sprayed metal/in.^{2}. The coated substrate was passed through a bath containing Cd sulfate 20 g, 48% HF 100 cc, and H_2O 900 cc. Immersion was for 12 minutes at ~80 F. After washing in running water at 60 F for 16 hours, the electrode was immersed in 12N KOH at 80 F for 24 minutes. After washing and then drying in N_2 the electrode had a service life of 67 minutes at 110 ma/in^2 and a passivity c.d. 425 ma/in.^{2}

B-666

Tsutomu Iwaki and Masataro Fukuda, Matsushita Elec. Inc. Co. Ltd., Japan, "Sintered Plate Type Nickel-Cadmium Alkaline Batteries. V. Preparation Procedures of Negative Plates for Sintered Plate Type Alkaline Batteries Using Thermal Decomposition in Air," Denki Kagaku, 34 (12), 948-953 (1966). Abstract only

The following procedures were used: (1) Heated at 220° or 300°, $Cd(NO_3)_2$ impregnated in the plaques was kept in a nearly anhydrous form without conversion to CdO_2. Discharge capacities of the plates thus prepared were low and did not increase even when impregnation-heating was applied to the plates repeatedly. (2) Heated at 380°, the $Cd(NO_3)_2$ was almost completely converted into CdO_2, although a small amount of residual nitrate ion was still detected in the decomposition material. The plates thus prepared gave better discharge behavior than those described in (1). However, the residual ion attacks the positive plates while gradually dissolving in the electrolyte solution in the cells. (3) Heated at 420-430°, the $Cd(NO_3)_2$ was almost completely converted to CdO_2 with a faint detection of the residual nitrate ion. When heated at 430°, however, the Ni plaque was slightly oxidized. (4) The plates described in (3) gave almost the same voltage and capacity performances as those of plates prepared by the usual method. Moreover, the slight oxidation of the plaques when heated at 430° had no effects on charge-discharge cyclic performance. The thermal decomposition method presented is suitable for the preparation of negative plates, effectively eliminating laborious procedures.

B-667

Charles V. Herold and Karl Ackermann, Societe des Accumulateurs Fixes et de Traction, "Method for Making Nickel Electrodes for Electrolytic Cells," U.S. Patent 3,305,398 (February 21, 1967). Abstract only

Hydrated Ni aluminate is deposited on the walls of porous Ni electrodes by immersing the electrodes for 2 minutes in aqueous $Al(NO_3)_3$ heated to 70-80°. After draining off the excess solution, the $Al(NO_3)_3$ is allowed to react in the electrode for 1-1/2 to 2 hours in a 75-80° atmosphere of saturated steam. A further treatment with KOH solution followed by washing and drying is also possible. The electrodes produced find application in electrolytic cells, electric storage batteries, and similar applications.

B-668

S. A. Aleshkevich and L. N. Sagoyan, Khim.-Tekhnol. Inst., Dnepropetrovsk, "Mechanism of Operation of a Nickel Hydroxide Electrode," Ukr. Khim. Zh., 33 (2), 143-147 (1967). Abstract only

A model is proposed for the $Ni(OH)_2$-Ni electrode in which H-atoms shift from O-atom to O-atom to and from the Ni oxide-solution interface where the electrode gains or loses electrons as the protons leave or return to the oxide-hydroxide layer. The movement of H atoms is principally parallel to the Ni metal surface and, more slowly, perpendicular to it. This is because of the layer structure of $Ni(OH)_2$.

B-669

Richard G. Black, Melpar, Inc., "Development and Prototype Production of Flexible Thin Film Batteries," (1965). PB 169312. Abstract only

The development of plastic-encased thin film batteries for use as power sources in meteorological balloons which could be safely struck or ingested by aircraft (Project GHOST) is reported. A process for producing such batteries and the efforts to refine and modify the basic process are reported. The major effort was directed toward the production of Ni oxide positive electrodes. It is possible to produce flexible thin film batteries with electrical properties suitable for use in this program. The batteries would maintain performance at low temperatures if low discharge rates are used. Recommendations for future work are included.

B-670

Charles W. Brooke, Jr., California Institute of Technology, Jet Propulsion Laboratory, "Development of an Electrochemical Energy Source for the Mariner II Spacecraft," NASA-CR-71772, JPL-TR-32-854 (March 15, 1966), Contract NAS 7-100. N66-22207. Abstract only

The development of an electrochemical energy source for the Mariner II spacecraft is described. The data presented trace the development of this battery, beginning with the definition of the electrical and mechanical requirements for the battery and concluding with the telemetered data obtained from the battery during 109 days of spaceflight to Venus. The design changes resulting from the type approval test program on the development model battery and the additional changes dictated by the Mariner II spacecraft system requirements were combined in the final Ag-Zn battery design.

B-671

R. Lutwack and G. M. Arcand, California Institute of Technology, Jet Propulsion Laboratory, "Energy Storage," NASA-CR-64605, Space Programs Sum. No. 37-33, Vol. IV, pp 47-48 (June 30, 1965). N65-32420. Abstract only

Progress is reported on the development of a separator for the Ag-Zn battery that will be capable of withstanding heat sterilization. Analysis of test results showed that the material prepared from the low-density polyethylene by precross-linking with electron beam irradiation to the 70-megarad level followed by grafting with acrylic acid should be considered for more extensive testing. Also, experimental results are given for the measurement of the effects of γ -radiation on the behavior of nickel and cadmium electrodes in alkali media. Irradiated Cd electrodes lose more capacity than comparison electrodes. Also, there seems little doubt that maximum loss occurs when the electrodes are cycled about the 75%-of-charge point. Further, the data show that more material is lost from the Cd than from the Ni.

B-672

Martin Sulkes, Yardney Electric Corporation, "Development of the Sealed Zinc-Silver Oxide Secondary Battery System," Report (1966). AD 635 776. Abstract only

The reaction between Zn and O was investigated during overcharge and on stand. The electrolyte level and the type of separator used in cells were the most important factors in the reaction rate. Investigation of the $AgO-Ag_2O$ hydrogen reaction showed that the rate increased with temperature potential, the addition of Pd to the Ag, and the mobility of the electrolyte Sealed Ag-Zn cells may be overdischarged at the C/4 rate without developing excessive pressure. Electrochemically inactive or nondischargeable Zn reacts with the O generated during reversal. Physical, chemical, and electrical properties are presented for many separator and interseparator materials. Several inorganic separator materials were evaluated. Evaluation cycling and cycle life data were obtained for 244 sealed Ag-Zn cells.

B-673

R. S. Bogner, General Motors Corporation, "Heat Sterilizable Silver-Zinc Battery Investigation," Final Report, NASA-CR-63597 (March 15, 1965), Jet Propulsion Laboratory Contract JPL 950364 under Prime Contract NAS 7-100. N65-27367. Abstract only.

Secondary Ag oxide-Zn cells and cell components are under study to determine their ability to survive heat sterilization at 145° for 36 hours. The effect of component degradation products was determined by filling cells of standard construction with the electrolyte obtained from the sterilized cell component and noting cell electrical characteristics. Positive and negative plates were sterilized independently and assembled into cells with unsterilized materials. The prime cause of failure was due to degradation products from the separator materials. The sterilized materials were built into the cells, and the polyethylene base material produced the best results; however, when sterilized in situ, cell capacity was decreased by 50%. The positive plates were attacked by the separator degradation products. The cells were redesigned to minimize the effect of these attacks. The PVA binder can be removed without adversely affecting the negative plates. The sterilization liquors from nylon, Celcon, and Penton case materials did not have adverse effects on cell performance.

B-674

W. N. Carson, Jr., J. A. Consiglio; and J. W. Marr, General Electric Company, "Use of Auxiliary Electrodes in Silver Cells," NASA-CR-405 (March 1966), Contract NAS 5-3669. N66-18430. Abstract only

The work done on the use of auxiliary electrodes in Ag-Zn cells, the design and development of a H combination cell, and the resting of Ag-Cd cells with auxiliary electrodes is reported. A Co aluminate-spinel catalyzed auxiliary electrode can be used to recombine O when connected to the Zn electrode through a suitable diode. Auxiliary electrodes with Pt catalysts can be used to recombine H when connected to the Ag electrode through a 2-10 ohm resistance. The Pt-catalyzed electrode can be used alone in the cell to control pressure as long as an excess of H over O is generated. A design for a H combination cell suitable for use in a satellite was developed and tested. This cell can be used to remove H from the interior gas space of satellites powered by primary Zn cells; the H is evolved from the cells during operation. The results of the testing of Ag-Cd cells with auxiliary electrodes confirm the work done in a previous contract. The auxiliary electrode reduces the cell operating pressures and aids in maintaining uniform cell voltage.

B-675

Michael A. Aia and Frederick P. Kober, General Telephone & Electronics Laboratories, Inc., "Methods for Determining the Structural and Stoichiometric Changes of $Ni(OH)_2$ Electrodes During Polarization in Alkaline Electrolyte," American Chemical Society, Div. Fuels Chem., Preprints 11 (1), 224-229 (1967). Abstract only

Several techniques of structural and chemical analysis were used to study the nature and origin of electrochemical activity in metal-oxide electrode materials. Interest was focused on the development of the charged state of the $Ni(OH)_2$ electrode, the positive electrode in commercial Ni-Cd and Ni-Fe batteries. Electrochemical measurements in 7N KOH are correlated with results of analysis by x-ray diffraction, ir absorption, and thermal decomposition techniques. Anodic oxidation of $Ni(OH)_2$ is characterized by a gradual expansion of the crystal lattice and the continuous formation of H bonds; the composition becomes nonstoichiometric and contains increasing amounts of active O sites, insoluble K ions, and loosely bound water. The increases in active O sites and water of hydration occur largely at the expense of water bound initially as hydroxyl groups in the Ni-OH layer lattice of the solid phase. Removal of bound water by heating of the solid phase, either before or after charging, causes loss of electrochemical activity only when the temperature is sufficiently high to destroy the hydroxyl sites in the layer lattice. Loss of hydroxyl water causes the structure to collapse to a defect rock-salt lattice. The crystal structure of the charged site is still unknown, but from crystal field considerations the site symmetry of the Ni ions must be lower than the D_{3d} site symmetry in the discharged state.

B-676

Manufacturers Information from NUMEC Instruments and Controls Corporation (Numinco)

B-677

Manufacturers Information from Gulton Industries, Inc.

B-678

E. Moses, NASA Goddard Space Flight Center, "The Atmosphere Explorer-B Solar Array (AE-B)," NASA-TM-X-55380, X-716-65-401 (October 1965). N66-17253. Reference only.

Array. Atmosphere. Battery. Cell. Charge. Explorer Satellite. Illumination. Mission. Satellite. Silver. Silver-Zinc Battery. Solar. Solar Cell. Spacecraft. Substrate. Zinc

B-679

C. W. Fleischmann and J. E. Oxley, Leesona Corporation, Leesona Moos Laboratories, "The Improvement of Zinc Electrodes for Electrochemical Cells," Quarterly Report No. 2, NASA-CR-70724 (December 1965), Contract NAS 5-9591 N66-19656. Reference only

Battery. Cell. Charge. Crystal. Crystal Structure. Dendrite. Electrochemical. Electrochemical Cell. Growth. Handling. Manufacture. Parameter. Silver. Silver-Zinc Battery. Structure. Zinc.

B-680

Yardney Electric Corporation, "Design of Sealed Secondary Silver Zinc Battery," Addendum to Final Report, Report 637-66, NASA-CR-70936 (January 1966), Jet Propulsion Laboratory Contract JPL 950959 under Prime Contract NAS 7-100, N66-20079. Reference only

Battery. Charge. Cycle. Design. Electricity. Function. Function Test. Performance. Result. Seal. Secondary. Silver. Silver-Zinc Battery. Structural Design. Structure. Test. Zinc

B-681

E. R. Pettebone, U.S. Naval Ammunition Depot, "Space Cell Test Program," Monthly Progress Report, NASA-CR-71289 (January 31, 1966), NASA Purchase Order W11,252B. N66-82434.

Cycling data is presented on silver-zinc, silver-cadmium, and nickel-cadmium sealed cells. Failure analysis of nickel-cadmium cells is also given.
(0 references, 0 tables, 0 figures, 169 pages)

B-682

R. A. Marsh, Air Force Aero Propulsion Laboratory, Wright-Patterson Air Force Base, "Sealed Aircraft Batteries," AFAPL-CONF-66-3 (May 1966), Technical paper presented at the 20th Annual Power Sources Conference, May 24-26, 1966, Atlantic City, N.J., pp 148-151. AD 636 153

It is now considered feasible to apply sealed spacecraft battery technology to aircraft batteries. Major problems to be solved are the development of suitable charge conditions; integrating conditioners into battery systems; and the development of reliable, long-life components such as seals, separators, etc. Major advantages of sealed cell aircraft batteries are improved flight safety, maintenance-free operation, fewer back-up batteries required, and improved performance (life to reliability). Interchanging the vented cell aircraft batteries with sealed nickel-cadmium batteries is considered possible by late 1968.
(2 references, 1 table, 7 figures, 17 pages)

B-683

Eugene R. Stroup and Armin O. Apelt, NASA, "NASA's Spacecraft Battery Evaluation Program," Report No. NASA-TM-X-56176 (1965). N66-18341.

Newly developed spacecraft batteries are procured, evaluated, and reported on. Significant elements of the program include acceptance testing, determination of performance characteristics, life-cycling and analysis of failed cells. Results are reported monthly and annually. Data and conclusions from failure analysis are reported to the manufacturer for his information and guidance in his improvement program. Approximately one thousand secondary spacecraft cells are currently in this program.
(0 references, 2 tables, 4 figures, 12 pages)

B-684

T. P. Dirkse, Calvin College, "Electrode Migration and Reaction Processes Occurring Within Alkaline-Zinc Batteries," Sixth Quarterly Technical Progress Report (June 15, 1967), Wright-Patterson Air Force Base Contract AF 33(615)-3292.

The solubility of various forms of ZnO in KOH solution has been measured over a KOH concentration range of 20 to 45% and a temperature range of 0 to 50 C. There is very little difference in solubility of the various forms of ZnO, nor is there any significant temperature dependence. A review of reported solubility values of ZnO and $Zn(OH)_2$ is also given. (26 references, 1 table, 4 figures, 11 pages)

B-685

Leonard W. Niedrach and Max Tochner, General Electric Research & Development Center, "Some Observations Concerning the Use of Low-Frequency Interrupter Techniques in Studies of Fuel Cells and Batteries," Electrochemical Technology, 5 (5-6), 270-274 (May-June 1967)

While low-frequency (60-cps) interrupter bridges can serve admirably for the study of fuel cells and batteries, they are not universally applicable. Anomalous results can be obtained when polarizations having short time constants relative to the bridge frequency are encountered. Several effects symptomatic of a malfunctioning system are discussed, and methods of monitoring to obtain the most reliable information are presented.

B-686

E. J. McHenry, Bell Telephone Laboratories Incorporated, "Electrochemical Precipitation of $Ni(OH)_2$ into Porous Electrodes," Electrochemical Technology, 5 (5-6), 275-279 (May-June 1967)

Conventional methods for the impregnation of porous electrodes for use in Ni-Cd batteries are complex, time consuming, and expensive. In addition, these methods are not suited to continuous automatic processing. A simple. rapid, one-step process has been developed which is capable of producing reproducible electrodes. Active material is deposited directly into the pores of the sintered Ni plaque by cathodic precipitation from acid $Ni(NO_3)_2$ solution. Electrodes have been impregnated by this process in as little as 5 minutes with amp-hr. capacity reproducibility of ±2%. These electrodes have performed well in sealed cells under stressed cycling conditions. (14 references, 1 table, 8 figures, 5 pages)

B-687

Thedford P. Dirkse, Calvin College, "Silver Deposition on Battery Separators," Electrochemical Technology, 5 (5-6), 301-302 (May-June 1967)

The silver that deposits on the separators in silver-alkaline batteries comes, to a large extent, from the decomposition of Ag_2O dissolved in the electrolyte. The separator material itself also plays a role in the rate and extent of this decomposition. Because dissolved silver oxide undergoes a decomposition, it is difficult to get a quantitative value for the rate of silver diffusion in alkaline solutions.
(5 references, 0 tables, 1 figure, 2 pages)

B-688

W. H. Webster and R. T. Foley, The American University, "Research into Fundamental Phenomena Associated with Spacecraft Electrochemical Devices--Calorimetry of Nickel-Cadmium Cells," Third progress Report (January 1 - March 31, 1967), NASA Goddard Space Flight Center Contract NAS 5-10105.

A larger calorimeter and air jacket were designed and constructed during this reporting period. This was dictated by inadequate space in the present calorimeter for the twelve ampere-hour cell and the intention to measure the thermal properties of a twenty ampere-hour cell. Dimensional changes in the calorimeter also required the fabrication of a longer copper-constantan thermopile and a different Lucite fixture for positioning the cell and calibration heater. A series of calibration experiments were conducted on the new system. The results indicated that a flow rate of 1500 cc/min produced excellent agreement with the calibration data obtained for the smaller calorimeter, i.e., one hundred microvolt signal for a one-watt input.
(1 reference, 1 table, 9 figures, 14 pages)

B-689

Martin Marietta Corporation, "Nickel-Cadmium Battery Test Project. Relationship Between Operation, Life and Failure Mechanism. Volume I-Experimental Procedure," Final Report, NASA-CR-84028, ER 14543 (February 1, 1963 - July 31, 1966), NASA Goddard Space Flight Center Contract NAS 5-3027. N67-26339

Chapter I presents the background of the problem, the philosophy of the technical approach and a description of the monitoring, data acquisition and data reduction systems. Chapter II, which provides a detail discussion of the technical approach, consists of three major sections. Section II.A deals with the cell characterization tests, which were used to eliminate from study those cells with markedly variant electrical properties (capacity, end charging voltage, internal shorts). Section II.B discusses the cell life tests which form the basis for relating cell life to the various cell operating parameters imposed upon the cells. Finally, Section II.C, Cell Analysis, provides information relating the changes in electrochemical, chemical, and physical characteristics of the cell components to the mode in which the cells were operated. These results should prove useful for correlations and analyses to detect defective cells, predict premature cell failures, and predict cell life.
(5 references, 3 tables, 23 figures, 53 pages)

B-690

A. Langer, R. G. Charles, and C. R. Ruffing, Westinghouse Electric Corporation Research Laboratories, "Separator Development for a Heat Sterilizable Battery," Westinghouse Research Report 67-9B6-BSEPA-R1, Third Quarterly Report (March 31, 1967), Jet Propulsion Laboratory Contract JPL 951525 under Prime Contract NAS 7-100. Re-Order No. 67-325

The work on inorganic-filled composite separators so far shows considerable promise for the development of satisfactory heat-sterilizable separators for silver-zinc batteries. The most satisfactory separator of this type appears to be a polypropylene-reinforced, water-extracted, compressed film of polysulfone with hydrated zirconium oxide or titanium oxide filler material at a loading of about 30 g filler per 15 g polysulfone. This structure and composition of membrane appears at this time to be suitable not only as to required properties but also for development of fabrication procedures of large areas of uniform material. Further work is needed to confirm this expectation. Especially needed is preparation of larger quantities for complete evaluation of product properties resulting from larger scale production and the process variables affecting them.
(1 reference, 6 tables, 40 figures, 79 pages)

B-691

F. E. Betz, Gulton Industries, Inc., "Design and Fabrication of 100 Ampere-Hour Nickel Cadmium Battery Cells," Final Report, NASA-CR-66300 (March 13, 1967), NASA Langley Research Center Contract NAS 1-4289.

The 100 ampere-hour Adhydrode cell has demonstrated its ability to consistently deliver capacities, in excess of its nominal rating. The cell has shown the ability to be charged at the C rate. The effectiveness of the Adhydrode to signal end of charge has been demonstrated. Characteristics have been generated at room temperatures, 90 F and 32 F for the cell and the Adhydrode. Thermal profiles of the cell, while in operation at room temperatures, show results typical of the nickel-cadmium cell.
(0 references, 4 tables, 48 figures, 73 pages)

B-692

Eliot A. Butler and Angus U. Blackham, Brigham Young University, "Studies of Reaction Geometry in Oxidation and Reduction of the Alkaline Silver Electrode," Final Report (April 10, 1967), Jet Propulsion Laboratory Contract JPL 951554 under Prime Contract NAS 7-100. Re-Order No. 67-322.

A double-Luggin capillary method has been used to measure potential variations in the vicinity of a working silver electrode. Current and potential distributions around several simple electrode configurations have been determined. These results can be extended to predict current density and potential variations around other electrode configurations. Equipotential maps are presented for several working electrodes. A comparison of experimental results from this study with a theoretical study on current distribution is made. A method for estimation of effective electrolytic surface

area has been developed. The method is based upon the assumption of constant depth of the Ag Ag_2O oxidation of a silver electrode at fixed current density. A method for preparing a standard electrode surface which has area reproducible to ±3% is reported. Data are presented to show a reproducibility of ±10% in surface area estimations of sintered silver electrodes. Our observations indicate the presence of an organic residue on commercial sintered silver electrodes part of which is hydrocarbon in character and part of which is carbonaceous. This appears to explain the earlier observation that microscopic portions of some sintered silver electrodes are unreactive.
(15 references, 4 tables, 18 figures, 40 pages)

B-693

Leonard Lustbader and Daniel Levy, Leesona Corporation, Leesona Moos Laboratories, "Development of a Zinc/Oxygen Battery System for Space Vehicle Application," Quarterly Report No. 3 (May 1967), NASA George C. Marshall Space Flight Center Contract NAS 8-20565.

During this report period the work effort has been concerned with the fabrication, component integration, and system evaluation of one complete 6 volt battery system which utilizes the same cell configuration (operating at the same current density) as that projected for use with the larger 28 volt system. The 6 volt battery system has demonstrated the voltage regulation requirements at the 8.16 and 24 hour rates with satisfactory capacity and reproducibility. The heat rejection mode and system packaging (to withstand vibration and acceleration environments) have both proven satisfactory. On this basis, the component design of the 6 volt battery will be applied toward the larger 28 volt system.
(0 references, 4 tables, 14 figures, 38 pages)

B-694

R. A. Powers, Union Carbide Corporation, Consumer Products Division, "Secondary Zinc-Oxygen Cell for Spacecraft Applications," Second Quarterly Report (September 23 - December 23, 1966), NASA Goddard Space Flight Center Contract NAS 5-10247.

Work conducted during the present quarter has shown that the development of a rechargeable zinc-oxygen system operating with good voltage regulation for at least 50 cycles is possible. The best results were obtained with a film type separator (C-3) made by the Borden Chemical Company under contract for NASA. This cycle life was obtained on a 2 hour discharge/2 hour charge regime at 25°C in a cell containing only a single layer of C-3 separator and which was operated at a 50 percent abusive overcharge. Cell discharge conducted during the present quarter was taken to the 14 percent zinc depth based on the theoretical equivalent of the actual weight of zinc used in the case of the 2 hour discharge/2 hour charge regime, and to the 28 percent zinc depth in the case of the 24 hour discharge/24 hour charge regime.
(5 references, 0 tables, 33 figures, 33 pages)

B-695

A. A. Kozhakova and V. N. Flerov, A. A. Zhdanov Gor'kovsk. Politekh. Inst., Gorki, "Effect of Discharge Conditioning on Changes, During Cycling, of Characteristics of Powdered Zinc Electrodes in Alkaline Batteries," Izv. Vyssh. Ucheb. Zaved., Khim. Khim. Tekhnol., 10 (1), 73-76 (1967). Abstract only

In the use of powdered Zn electrodes in Ni-Zn storage batteries with 7N KOH electrolyte, the coefficient of utilization of the Zn is markedly reduced (from 66-80% to 30-40%) by limiting the discharge to a low rate (0.38 ma/cm^2). Holding the battery in a charged condition for a month at +40° also reduces the Zn utilization (to 27-41%). At low temperatures (-30°), the battery capacity depends primarily on the amount of true electrode surface.

B-696

Robert L. Lambert and William R. McKeirnan, Sylvania Electric Products Inc., "Storage Battery Electrode of Sintered Metal Particles," U.S. Patent 3,314,821 (April 18, 1967). Abstract only

The manufacture of the electrode is described. A suspension containing 25-75 wt. % sinterable metal particles, the plasticizer, and particle solvents is flowed continuously onto aligned conductors on a support to provide a film casting which is dried and fired to provide a self-supporting metal strip. The metal strip is cut to the desired configuration, and to include a tab for connecting it to an external conductor, and the electrode pores are loaded with active electrode material, i.e., a suspension containing 400 ml toluene, 175 ml Synasol, 25 ml diethylene glycol mono-Bu ether, 25 ml BuOH, 675 g grade B carbonyl Ni powder, and 50 g Et cellulose (ethoxyl content 47.5-49.0% and 200 cp viscosity in a 5% solution of 80:20 toluene: EtOH).

B-697

Philip F. Grieger, McGraw-Edison Company, "Charge Control Devices. Third Electrode Charge Control," Proceedings of the 20th Annual Power Sources Conference (May 24-26, 1966), pp 99-102

At temperature above +24 F, the automatically controlled high rate charging of hermetically sealed cells, resulting in adequate but not excessive inputs, can be achieved by using a VCB Black auxiliary electrode externally connected to the cadmium electrode through a 6 ohm resistor--providing the original characteristics of the pack are such that O_2 is the predominant gas evolved during charging, and that the separator is immune to oxidative attack. Control is possible at temperatures at least down to 0 F, although at lesser rates, if the signaling resistance is temperature compensated (thermistor). By conserving heat generated during charging and including in the cell a high rate O_2 plus H_2 catalyst, the low temperature situation can be improved, but with the cadmium electrodes tested in the present work, H_2 evolution precludes working below -15 F, except at low rates. In brief there appears to be no serious shortcomings to the VCB Black O_2-reduction control system that improved nickel/cadmium cells could not cure.
(7 references, 0 tables, 7 figures, 4 pages)

B-698

W. N. Carson, General Electric Company, "Charge Control Devices. Charge Control Methods for Ni-Cd Batteries," Proceedings of the 20th Annual Power Sources Conference (May 24-26, 1966), pp 103-105.

The use of the new charge control techniques is particularly important for large power systems, in which savings on battery size, battery restraints, and heat evolution are critical. The use of passive auxiliary electrode cells in batteries charged from voltage controlled coulometer circuits appears to be an optimum solution for what is a vexing problem for spacecraft designers. In this type of charge control, the minimum weight for the battery, solar array, and accessory equipment is obtained in a highly reliable manner. A variant of this type of control was conceived and is being worked out at Goddard Space Flight Center for use in a satellite to be launched soon.
(0 references, 2 tables, 4 figures, 3 pages)

B-699

R. E. Amsterdam, P. R. Mallory & Company, Inc., "Charge Control Devices. The Amp-Gate Diode for Charge Control of Sealed Rechargeable Cells," Proceedings of the 20th Annual Power Sources Conference (May 24-26, 1966), pp 105-109.

During the past year of work, it was established that the Amp-Gate diode was able to protect sealed nickel-cadmium cells under cyclical conditions in a simulated space environment and under conditions of extended periods of high current charge rates. This work demonstrates the feasibility of utilizing these diodes in space applications at high rates of charge and discharge and with a maximum protection afforded to the battery in that each cell is individually protected.
(4 references, 1 table, 6 figures, 4 pages)

B-700

Raymond Jasinski, Tyco Laboratories, Inc., High-Energy Batteries, Plenum Press, a division of Plenum Publishing Corporation, New York (1967)

The book discusses the basic electrochemistry of the discharge, general polarization, parasitic effects, and weight factors as they affect performance. Capabilities, advantages, and limitations of specific plate materials, solutes, and solvents are covered. Specific reaction-inhibiting parasitic processes, structural features, and battery charging are dealt with and the state-of-the-art for high-energy systems is summarized.
(804 references, 67 tables, 51 figures, 278 pages)

B-701

H. M. Schultz, U.S. Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells. Acceptance Test of Gulton Industries, Incorporated 4.0 Ampere-Hour Flooded, Sealed Nickel-Cadmium Secondary Spacecraft Cells with Coulometer Charge Control," QE/C 67-307 (May 26, 1967), NASA Goddard Space Flight Center Contract W11,252B.

From the results of this test, it can be concluded that sealed flooded cells are not reliable for spacecraft use as evidenced by 3 of the 10 batteries fracturing the epoxy seal from excessive internal pressure during the acceptance test sequence.
(0 references, 1 table, 3 figures, 4 pages)

B-702

Jerome Goodkin, Yardney Electric Corporation, Inc., "Long Life Stable Zinc Electrodes for Alkaline Secondary Battery," Interim Report No. 1, Technical Report ECOM-0185-1 (June 1967), U.S. Army Electronics Command Contract DAAB07-67-C-0185

This program will be divided into several phases. They are: cell parameters affecting zinc electrode performance, the effect of charging techniques on zinc electrode performance, the relationship between sealing cells and zinc electrode performance, and characteristics of the zinc electrode that may be related to performance or that may indicate reasons for good and bad performance. A cell parameter study was initiated to investigate the relationship between binder concentration (Teflon), zinc-to-silver ratio, negative-to-positive electrode area ratio, and electrode height-to-width ratio on the cycle life performance of the zinc electrode. A statistical design, using surface response as a technique, was developed, and a series of 34 cells was constructed, based on this design, and formed. Techniques of preparing wet-proof zinc (Teflon containing) have been studied. Studies on methods of using the zinc electrode in a sealed cell system have been initiated. (11 references, 14 tables, 5 figures, 30 pages)

B-703

Arthur Fleischer, Nickel Cadmium Battery Corporation, "Laboratory Investigations and Research toward the Development of Nickel Cadmium Alkaline Storage Batteries," Final Report (August 1, 1948), Signal Corps Contract W-36-039-SC-32271

This report relates to the studies on the alkaline nickel-cadmium battery with sintered porous plates produced from carbonyl nickel powder. The continuation of the work on making porous plaques by the sintering of nickel powder under various conditions and with admixtures of other compounds, and on the impregnation of the porous plaques with the active masses to make positive and negative plates is discussed. The testing program is also discussed and results reported in detail.
(32 references, 77 tables, 10 figures, 148 pages)

B-704

William W. Smith, Electric Storage Battery Company, "Preparation of a Compact Nickel-Cadmium Element for Electric Storage Battery Cells," U.S. Patent 3,314,820 (April 18, 1967). Abstract only

Negative and positive electrodes and a separator, prepared from compositions containing a thermoplastic resin and a soluble pore former, are compressed by heated rollers, and the soluble pore former is leached out, giving a compact element which may be rolled into a spiral coil cell or cut into flat battery electrodes. Thus, 1 part by weight of polyethylene pellets (Alathon 14) (I) and 3 parts powdered polyethylene oxide (Polyox WSR-35) (II) were plasticized on a roller mill at 104-121° for 3 minutes, 28 parts of powdered CdO was added and mixed 7 minutes, and the mixture was calendered at $\sim$110° to produce a 10-mil sheet of electrode material. Ni electrode sheets were prepared similarly from I 1, II 1.7, green Ni hydrate 12.2, and powdered graphite 2.8 parts. The graphite and Ni hydrate were premixed for 10 hours before addition to the resin. A 5-mil separator sheet was prepared, similarly from I and II in equal parts. Two sheets of Ni electrode material, with an expanded Ni sheet inserted between as a grid, were placed on one side of the separator sheet, and 2 sheets of Cd electrode material, with an expanded Ni sheet inserted between as a grid, were placed on the other side of the separator sheet. The sheet was passed between rollers at 150° and 140 kg/cm^2, passed through warm water for 10 minutes to leach out the II and dried to give the battery element.

B-705

Harvey J. Schwartz, et al., NASA, "Batteries and Fuel Cells," Space Power Systems Advanced Technology Conference held at NASA Lewis Research Center, Cleveland, Ohio (August 23-24, 1966), NASA-SP-131, pp 9-51. N67-10263

Efforts to improve electrochemical systems in areas of energy density, life, temperature capability, and reliability are related. Improved performance and efficiency in the Ni-Cd and Ag-Zn cells are discussed. In the Ni-Cd battery the persistent problem considered is loss of charge on the Ni-oxide electrode on standing at open circuit. Shortcomings of the Ag-Zn couple are soluble electrode separators not inert to their environment, and Zn electrode susceptible to dendritic growth. High- and low-temperature batteries and methods of coping with extreme thermal environments are the main problems in the exploration of the surfaces of Mercury, Venus, and Mars. Nonaqueous batteries that offer promise of major increases in energy density are considered on the criteria of good stability and conductivity and low viscosity. Practical test results involving anodes, cathodes, and electrolytes are given. Development of electrode materials capable of high power output and long life is termed the critical area with respect to cells. (11 references, 5 tables, 44 figures, 43 pages)

B-706

A. J. Catotti and M. D. Read, General Electric Company, Battery Business Section, "Development of a Nickel Cadmium Storage Cell Immune to Damage from Overdischarge and Overcharge," NASA-CR-62019 (June 21, 1965), Contract NAS 5-3707. N65-34228

The development of Ni-Cd cells which are immune to damage from overcharge and over discharge is given. This was accomplished by the selection of suitable gas electrodes so that the onset of overcharge can be detected, and the cell cannot be damaged by repeated overdischarges. All technical and experimental aspects of the development are given. Tabulated data includes polarization of O electrodes at various pressures and current densities, H polarization, results of overdischarge cycle, formation and acceptance tests, and overcharge tests at various temperatures.
(1 reference, 9 tables, 12 figures, 64 pages)

B-707

G. Myron Arcand, Idaho State University, "The Reactions Pertaining to Zinc-Silver and Cadmium-Silver Batteries," First Quarterly Report (June 15, 1967), JPL Revision June 21, 1967, Jet Propulsion Laboratory Contract JPL 951887 under Prime Contract NAS 7-100, Re-Order No. 67-364.

Preliminary results show that the insoluble product formed on the electro-oxidation of Zn in neutral KNO_3 is about 50% $Zn(OH)_2$. Heavily amalgamated Zn produces an anode which discharges at a reasonable rate. The Zn(Hg) electrode shows promise as a high-rate anode. High quality AgO has been produced electrochemically and approximate activation energies for thermal decomposition of AgO and Ag_2O have been determined.
(3 references, 0 tables, 0 figures, 6 pages)

B-708

John McCallum and Charles L. Faust, Battelle Memorial Institute, Columbus Laboratories, "Failure Mechanisms in Sealed Batteries," First Semiannual Technical Summary Report, AFAPL-TR-67-48, BATT-7770 (May 1967), Wright-Patterson Air Force Base Contract AF 33(615)-3701

This report outlines a new program toward acquiring an understanding of battery failure mechanisms for alkaline spacecraft batteries. Apparatus for simulating charge-discharge conditions for orbiting batteries is described. Experimental programs are suggested for finding new ways (a) to store, retrieve, and use battery literature, (b) to measure quantities that change as batteries age or are used, (c) to improve monitoring of batteries, (d) to make electrodes, cells, or cell components, (e) to provide failure-analysis procedures, and (f) to explain failure mechanisms. Additional objectives are (g) to measure silver solubilities, (h) to recommend accelerated life tests, (i) to describe thermal and heat-transfer properties, and (j) to provide a capability for conducting failure analysis on batteries.
(32 references, 0 tables, 18 figures, 63 pages)

B-709

L. C. Scala, Westinghouse Electric Corporation, Research Laboratories, "Separator Development for a Heat Sterilizable Battery," Fourth Quarterly Report, 67-9B5-STSEP-R1 (June 31, 1967), Jet Propulsion Laboratory Contract JPL 951525 under Prime Contract NAS 7-100.

The coating and testing apparatus used during the work for the original contract is being readied and relocated. Ingredients and chemicals have been ordered and are being collected.
(0 references, 0 tables, 0 figures, 2 pages)

B-710

H. M. Schultz, U.S. Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells. Acceptance Test of General Electric Company 6.0 Ampere-Hour Sealed Nickel-Cadmium Cells," QE/C 67-387 (June 28, 1967), NASA Goddard Space Flight Center Contract W11,252B.

The ceramic seals used by the General Electric Company are satisfactory as evidenced by no leakers out of the 38 cells tested. The capacity of the 38 cells was in the acceptable range of 6.96 to 9.03 ampere-hours.
(0 references, 1 table, 3 figures, 3 pages)

B-711

Helmuth L. Pfluger and Howard E. Hoyt, The Borden Chemical Company, Central Research Laboratory, "Improved Separators for Silver Oxide-Zinc and Silver Oxide-Cadmium Cells for Spacecraft Application," Second Quarterly Report (July 1967), NASA Goddard Space Flight Center Contract NAS 5-9107, Modification 6.

In the development of membranes suitable for exploitation as separators in silver-zinc and related types of battery cells, it is important to know how the membranes behave in contact with silver oxide dissolved in concentrated alkali. The present report describes the silver-barrier properties of a selection of membranes representing the chemical types which appear most promising for consideration as improved separators. The radioactive tracer technique was essentially the same as described in the previous contract. The work herewith reported includes further tests with 30% potassium hydroxide saturated with silver oxide, tests with 45% potassium hydroxide saturated with silver oxide and tests with 30% potassium hydroxide saturated with both silver oxide and zinc oxide.
(3 references, 10 tables, 23 figures, 37 pages)

B-712

Helmuth L. Pfluger and HOward E. Hoyt, The Borden Chemical Company, Central Research Laboratory, "Improved Separators for Silver Oxide-Zinc and Silver Oxide-Cadmium Cells for Spacecraft Application," Third Quarterly Report (July 1967), NASA Goddard Space Flight Center Contract NAS 5-9107, Modification 6.

Among the subjects discussed herein are experiments improving the conductivity of methyl cellulose membranes by precooling in aqueous alkali, or by pre-soaking in alkali solutions less concentrated than those to be used in the battery cell, as well as by formulating with various polar additives including tetramethylammonium hydroxide. Certain acrylic copolymer systems have been prepared as candidates for improved battery separators. Other work in progress includes multiple wraps with alternating layers of different types of membrane.
(0 references, 17 tables, 1 figure, 28 pages)

B-713

Sidney B. Tuwiner, Ernest J. Henley, and H. Kenneth Staffin, Procedyne, Inc., "Commercial Potentials of Semipermeable Membranes," Report NASA SP-5061 (1967), prepared under contract for NASA.

One of a series of publications sponsored by the National Aeronautics and Space Administration to make findings resulting from NASA programs available to potential users, this survey deals with advances in membrane technology. It is based on more than 200 reports on NASA-sponsored research, with particular attention given to power sources and life-support systems.
(25 references + bibliography, 3 tables, 19 figures, 43 pages)

B-714

N. Potter and R. Morrison, NASA Goddard Space Flight Center, "Two Level Voltage Limiter," NASA-TM-X-55446, X-716-66-7 (January 1966). N66-24641

Although sealed silver cadmium cells have attributes such as low self-discharge and nonmagnetic properties that make them a good source of power for spacecraft, in the past, difficulties have been experienced because of excessive pressure rise within the cells. The pressure rise occurs after a 100 percent state of charge has been reached and the cells are on overcharge. If the battery is charged at a constant current with a voltage limit, there will be a sharp reduction of charge current as the fully charged state is approached. A current still flows after the fully charged state has been attained. It is the current flowing after the attainment of full charge that is responsible for the pressure problem. If the charge current were to be interrupted at the 100 percent state of charge, the pressure problem would be alleviated. This report describes the circuitry used to accomplish this.
(0 references, 0 tables, 10 figures, 15 pages)

B-715

Eliot A. Butler, Brigham Young University, "Studies of Reaction Geometry in Oxidation and Reduction of the Alkaline Silver Electrode," NASA-CR-57644 (February 1965), Jet Propulsion Laboratory Contract JPL-AE4-310901 under Prime Contract NAS 7-100. N65-20419.

In reduction of the alkaline AgO electrode the reaction occurs preferentially in regions where the oxide layer is thinnest. Surface roughness and shallow pitting do not cause perceptible effect on the reaction. A depth discontinuity in the AgO, however, results in preferential reactions beneath the thin region. The reaction on discharge of AgO plates started at the grid in our experiments (current density 0.23-6.4 ma/cm^2). In oxidation of sintered silver plates at 3 ma/cm^2 the reaction started always at the solution sintered interface and proceeded toward the grid. In constant potential oxidation of sintered silver plates a current minimum is consistently observed soon after the start of oxidation. Investigation of this is being continued.
(2 references, 0 tables, 7 figures, 16 pages)

B-716

A. M. Chreitzberg and F. S. Cushing, Electric Storage Battery Company, "Research and Development on Cells with Bellows Controlled Electrolyte Levels," Second Quarterly Report, NASA-CR-60932, ESB-E-3-65 (September 10 - December 10, 1964), NASA Goddard Space Flight Center Contract NAS 5-3813. N65-17885.

Cycle tests on 4 AH sealed, nickel cadmium cells containing heat sealed plastic pillows as the operating electrolyte level controlling bellows device have been performed successfully on 24-hour and 2-hour orbits at a 70% depth of discharge. Rectangular, partially inflated plastic pillows have demonstrated on an accelerated test basis 25,000 cycles of expansion and contraction under cell conditions at room temperature and with an expansion efficiency $\Delta V/V$ of 0.58.
(6 references, 8 tables, 9 figures, 46 pages)

B-717

Martin Marietta Corporation, Martin Company, "Acceptance Testing: Phase One of NASA Nickel-Cadmium Battery Test Project," Supplement No. 1 to Final Report, Engineering Report No. ER-13219, NASA-CR-59664 (November 1963), NASA Goddard Space Flight Center Contract NAS 5-3027. N65-13561

This report presents acceptance test data on 13 pressure transducer equipped cells. Also included in this report is a battery breakdown list, by cell, of the 12 batteries to be used in performance of the phase two, cycling test, portion of the battery test project.
(0 references, 7 tables, 0 figures, 7 pages)

B-718

Western Electric Company, Inc., "Nickel-Cadmium Battery Electrode. Netherlands Patent Application 6,609,760 (January 13, 1967). Abstract only.

The porous Cd electrode for alkali cells is made by heating a sintered Ni plate having ≧ 70% porosity for ≧ 10 minutes at ≧ 700°, cooling to 321°, applying Cd foil to its surface and reheating so that the Cd melts on the porous Ni, then cooling. The entire process is performed in a reducing atmosphere.

B-719

Societe des Accumulateurs Fixes et de Traction, "Alkaline Battery," Netherlands Patent Application 6,607,227 (November 28, 1966). Abstract only

Totally or partially enclosed battery with an alkaline electrolyte, e.g., of the Cd-Ni or Cd-Ag type, is described in which the electrodes are separated by an insulating porous body. To the surface of at least one of the negative electrodes a porous layer is attached, containing in finely divided form at least one metal that is more strongly electro-positive than the metal in the active mass of the negative electrode. Suitable metals are Ag, Cu, Ni, Co, Pd and Pt, and the preferred one is Ag. The interior surfaces of the pores of the porous layer were provided with a water repellant or impervious material and (or) C. In this way, the electropositive metal and (or) C in the porous layer is in direct contact with the active mass of the negative electrodes, and the formation of many local Ag-Cd elements accelerates the reduction of O. Large currents can be sustained and large amounts of O can be consumed, enabling high charging currents without the danger of excessive O pressures. The water repellent material prevents the complete filling of the pores of the porous layer by the electrolyte, allowing the coexistence of the gas and liquid phases. Suitable water repellant materials are polystyrene and polytetrafluoroethylene. A further special feature is that the porous layer, which in itself can be the electropositive metal(fibrous) or C, protrudes into the gas atmosphere inside the battery case. The presence of 3 phases furthers the ionization of O and accelerates its consumption.

B-720

Sonotone Corporation, "Battery," Netherlands Patent Application 6,609,599 (January 9, 1967). Abstract only

A sealed chargeable battery cell is described, such as a Ni-Cd cell in a metal casing, which is provided with a safety device against excess gas or liquid pressure in the cell. The safety device consists of an air vent which is covered with an elastomeric cover pressed against the opening by a metal cover. The compressed elastomer will allow gas to escape only at a specific excess pressure.

B-721

Paul Reutschi, Electric Storage Battery Company, "Silver-Cadmium Secondary Battery," U.S. Patent 3,311,501 (March 28, 1967). Abstract only.

Adding 0.1-5% of Sn or Ge to the alkaline electrolyte of a Ag-Cd Secondary battery increases the charge acceptance and decreases the high cell impedance which limits the application of cells utilizing Ag positive electrodes. Thus, when electrodes were charged at a 20 hour formation rate, the electrode which was charged in the conventional 20% KOH solution electrolyte started to gas O after 16 hours charge, indicating an 80% charge acceptance. The electrode charged in the electrolyte containing the Na_2SnO_3 (0.2 g/100 cc) did not start to gas O until after 17.25 hours, which represents 86% charge acceptance. The conductivity of Ag_2O, a material which is formed during the charging cycle, decreases from 60 ohm-cm to 10.7 and 38.2 ohm-cm by adding Sn and Ge in the amount sufficient to provide 0.1% by weight to the amount of Ag present.

B-722

Demetrios V. Louzos, Union Carbide Corporation, "Process for Making a High Surface Area Electrode," U.S. Patent 3,316,159 (April 25, 1967). Abstract only.

Electrodes consisting of a body of compressed elec. conducting particles with an electrolytically deposited coating are described. For example, acetylene black 6.7%, 200-mesh graphite 22.4%, and 20-200 mesh CdI_2 44.4%, were tumble-blended with water 15.3%, and an organic binder (poly(vinyl formal) resin) 15.3% by weight and compression molded on an expanded Ni substrate. The resulting body measured 2 x 3 x 0.02 inches. It was immersed in N KI solution and cathodically energized. After 2 hours at 60 ma/in^2, the CdI_2 was reduced to Cd electrodeposited on the acetylene black and graphite. The electrode was tested vs. a Zn electrode in 12N KOH. The limiting current density was 180-190 ma/in^2.

B-723

Earl M. Otto, National Bureau of Standards, "Electrochemical Processes in Silver-Cadmium Secondary Cells," NASA-CR-62027 (1965). N66-27233. Abstract only.

The discharge characteristics of the Ag-Cd secondary cells were studied. An experiment was performed to conduct the normal 300 ma charge and 1.00 amp discharge at room temperature. This was followed by observations of the effect on charge and discharge resulting from changes in rates of charge and discharge, in temperature, in electrolyte level, in electrolyte concentration, and in partial charge and discharge in both the $AgO-Ag_2O$ and Ag_2O-Ag ranges. All cell tests were conducted in duplicate.

B-724

V. N. Flerov, A. A. Zhdanov Polytechnical Institute, Gorki, "Effect of Superimposition of an Alternative Current on the Electrical Characteristics of a Cermet Silver Electrode in Alkali Solutions," Zhurnal Prikladncy Khimii, 37 (3), 580-586 (1964). In Russian with English abstract.

The effect of a sinusoidal a.c. superimposed on a d.c. in the discharge of an Ag electrode in Sts (Ag-Zn) and StsS-3 (ag-Cd) batteries was studied. The upper potential stage in the discharge of a Ag-Zn battery was eliminated in the 4th cycle when charged with $D_{a c}/D_{d c}$ = 17.5/2.5. This was ascribed to the penetration of the alkali metal cation into the active mass, retarding the solid phase diffusion in the subsequent discharge. Prolonged application of the a.c. to a discharged Ag electrode decomposed a part of the active component and shifted the potential to the negative side.
(13 references, 0 tables, 9 figures, 7 pages)

B-725

V. N. Flerov, A. A. Zhdanov Polytechnical Institute, Gorki, "Influence of the Charging Conditions on the Electrochemical Characteristics of the Silver Electrode in Silver-Zinc Batteries," Izv. Vysshikh Uchebn. Zavedenii, Khim. i Khim. Teckhnol., 6 (2), 280-285 (1963). In Russian with English Abstract

All factors which favor an increase in the solubility of Ag_2O or prevent the variation of the concentration of the electrolyte in the electrode layers (increase in temperature, decrease in anode c.d.), lead to an improvement of the efficiency of the powdered Ag electrode in its first anode step. Such similar dependences confirm indirectly the existence of an intermediate step at this stage of the process. The opposite influence of these factors on the electrochemical characteristics of the electrode in the second anode "platform" shows the existence of another mechanism of the electrode process. At the end of the first anode step, a layer of Ag_2O forms at the surface of the individual Ag particles; this layer prevents mechanically the access of the electrolyte to the remaining unused metal, without, however, stopping the electrode process. An increase and decrease in the anode C.D. and temperature from their optimum values result in a decrease in the capacity assumed during the charging of Ag electrodes of the metal ceramic type. At low anode c.ds. and increased temperatures, the decrease in the total capacity is caused by a sharp decrease in the capacity assumed by the electrode in the top charging step. The conditions of the anode process increase or decrease the length of the top charging "platform."
(11 references, 1 table, 4 figures, 6 pages)

B-726

NIFE Incorporated, Manufacturers Information

B-727

D. R. Turner and T. H. Willis, Bell Telephone Laboratories, Nickel-Cadmium Batteries. 2. High-Temperature Effects on Sealed Ni-Cd Batteries, Proceedings of the 20th Annual Power Sources Conference (May 24-26, 1966), pp 133-136

Sealed Ni-Cd batteries operated at high ambient temperatures self discharge rapidly and have low charging efficiencies at low charge rates. The charging efficiency is improved considerably if the battery is charged at a high rate and/or lithium is added to the electrolyte. When the cell charging efficiency is low, the useful discharge capacity is low even though the cell is given an extended overcharge. Cells cycled at high temperatures for long periods of time show changes, one of which is that the cells have a tendency to generate hydrogen on charge much more easily. Some of the changes which occur are reversible if the cells are carefully cycled at 25^{0} C.
(9 references, 0 tables, 6 figures, 4 pages)

B-728

J. H. Waite and S. D. Epstein, Mauchly Systems, Inc., NiCd Space Battery Test Data Analysis Project. Phase 2., First Quarterly Report (January 1, 1967 to April 30, 1967), NASA Goddard Space Flight Center Contract NAS 5-10203.

NiCd cell-failure-characteristic data, for cells made by four battery-cell manufacturers, was computer examined by a technique of cryptology or cryptanalysis. This is a new use of cryptanalytic technique which was previously only used by security agencies to 'break' ciphers and codes. The Crane failure characteristic reports were assumed to contain hidden information or information not readily extractable by manual analysis. This assumption proved correct when the data was treated like a code or cipher. Application of cryptanalytic technique extrapolated information which identified specific cell failure mechanisms accountable to individual battery-cell manufacturers. This procedure, referred to in this report as "TRI-GRAM Failure Characteristic Technique," is applicable to any coded data.
(0 references, 10 tables, 0 figures, 44 pages)

B-729

S. Charlip and A. Lyall, Gulton Industries, Inc., "Development of Pile, Type, High Discharge Rate Nickel-Cadmium Squib Batteries," Final Report (March 4, 1966 - August 4, 1967), NASA Goddard Space Flight Center Contract NAS 5-10160

The report emphasizes the work of developing thick bipolar electrodes, .030 inch sinter, in circular shapes, capable of being impregnated to a caoacpty of 150 mAh/in^2 of sinter area. The development of ten 5-cell modules, fully encapsulated, which yielded several pulses with current densities of 3.6 A/in^2 above 5 volts, for electrode sizes of 2.76 in^2. Single bipolar cells and five-cell batteries were tested, vented, and sealed. Based on laboratory cell test data, concentration and activation polarization are the limiting parameters of current density outputs in a bipolar nickel-cadmium battery.
(6 references, 0 tables, 32 figures, 53 pages)

B-730

W. N. Carson, Jr., J. A. Consiglio, and J. F. Wilbore, General Electric Company, Schenectady, New York, "Study of Nickel-Cadmium Cells," Final Report S-67-1116 (July 1967), NASA Goddard Space Flight Center Contract NAS 5-9586.

The objective of this program was to assess the importance of variations in the positive nickel-hydroxide electrode behavior and the effect of selected impurities on the performance of sealed nickel-cadmium cells. The principal performance characteristics investigated were the capacity and gassing rate of the positive electrodes and sealed test cells in selected cycling modes. The capacity distribution for the positive electrodes was determined by cycling three-hundred electrodes under constant current charge-discharge for six consecutive cycles. The rate of oxygen evolution from the positive electrodes was determined as a function of the state of charge of the electrode over the course of six to twelve cycles. The effect of some of the impurities on the performance of sealed nickel-cadmium cells was investigated by cycling the cells in a ten percent depth of discharge mode for a total of 402 cycles at room temperature and 0°C.
(0 references, 24 tables, 29 figures, 121 pages)

B-731

J. J. Lander and J. A. Keralla, General Motors Corporation, Delco-Remy Division, "Silver-Zinc Electrodes and Separator Research," Technical Report AFAPL-67-107 (August 31, 1967), Wright-Patterson Air Force Base Contract AF 33(615)-3487

Additions of 1.2% to 2% lignosulfonic acid in the negative mix is helpful to negative plate cycle life. The use of cotton fibers helps to maintain the negative plate active material in place during cycle life. The surfactant BC-610 is the best choice for use in the zinc negative material found to date. However, at cold temperatures, surfactants appear to inhibit cycle life. The use of .1% Ethanol in the negative material helps cell cycle life as well as surfactant FC-95. Small percentages of acicular ZnO mixed with Kadox-15 appear to help negative plate cycle life. The use of 2% to 5% $ZnSO_4$ aids the negative plate cycle life at room temperature but is detrimental to cold ($30-40^{\circ}$F) operation. The best electrolyte to date at 60% depth-of-discharge is 50% KOH yielding 220 cycles.
(37 references, 12 tables, 42 figures, 100 pages)

B-731A

D. O. Carpenter and G. E. Snow, The New Jersey Zinc Company, "Preparation and Characterization of Special Zinc Oxides for Evaluation in Silver Oxide-Zinc Secondary Batteries," Second Quarterly Technical Progress Report (April 19, 1967), prepared under a General Motors Corporation Purchase Order for Wright-Patterson Air Force Base Contract AF 33(615)-3487.

The properties of the initial zinc oxide used to fabricate the zinc electrode may substantially affect the performance of silver oxide-zinc secondary batteries. The special zinc oxides prepared will allow investigation of the effect of surface area (fine particle size) of wet process zinc oside, particle morphology of precipitation process zinc oxides, high electrical conductivity of doped French Process zinc oxides and the effect of a variety of intentionally added metallic cation impurities.
(0 references, 3 tables, 6 figures, 13 pages)

B-731B

Dewitt A Payne, Keith B. Prater, and Allen J. Bard, Universith of Texas, "Adsorption of Organic Materials on Zinc Electrodes," Second Quarterly Technical Progress Report (April 15, 1967), prepared under a General Motors Corporation Purchase Order for Wright-Patterson Air Force Base Contract AF 33(615)-3487.

The chronocoulometric and the differential capacity apparatus were further tested by studying the adsorption of nbutyl alcohol on a mercury electrode from 0.1 N KCl. Work was then started on the Zn, $ZnO_2^=$ system in NaOH and KOH, with both mercury electrodes and zinc electrodes. The zinc electrodes used were both the stationary type and rotating disk type. The kinetics of the Zn, $ZnO_2^=$ system was studied to some extent.
(5 references, 1 table, 10 figures, 16 pages)

B-731C

A. H. Remanick, Wm. I. Nelson, and M. Shaw, Whittaker Corporation, Narmco R&D Division, "Influence of Transport Characteristics of Separators on Cell Electrolyte Distribution," Third Quarterly Report (June 16, 1967), prepared under a General Motors Corporation Purchase Order for Wright-Patterson Air Force Base Contract AF 33(615)-3487.

Equations are presented permitting calculation of electrolyte distribution as a result of membrane absorption, from known weights of membrane and solution. KOH and water transference data, as a function of concentration, are presented for two typical battery membrane separators.
(3 references, 8 tables, 1 figure, 21 pages)

B-731D

Vincent F. D'Agostino, RAI Research Corporation, "Development of Improved Separator Materials for the Alkaline Silver Oxide-Zinc Battery," First Quarterly Report, RAI-381 (July 14, 1967), prepared under a General Motors Corporation Purchase Order for Wright-Patterson Air Force Base Contract AF 33(615)-3487.

During the first quarter, emphasis has been placed on the development of methods to insure the uniformity of the dose received by samples irradiated in our source, and to determine the effect of a non-aromatic solvent and a chain transfer agent on grafting. The proposed program requires a detailed study of grafting procedures during Phase III of this contract. This initial study was undertaken only to determine if gross effects on cycle life could be attributed to the use of chlorinated solvents. These solvents afford certain advantages in grafting over using benzene and a small percentage of carbontetrachloride in the grafting solution. A detailed study was also undertaken on the crosslinking of three basic films to accurately determine the dose received by the samples irradiated with 1 MeV electrons.
(0 references, 3 tables, 2 figures, 13 pages)

B-732

R. F. Chireau, Yardney Electric Corporation, "Silver-Zinc Missile Power Supply," Eighth Quarterly Technical Progress Report (August 1967), Wright-Patterson Air Force Base Contract AF 33(615)-2663.

The Missile Power Supply program, which involves the design, development, fabrication, and test of an 8500 watt battery-converter breadboard power supply. The results of evaluation of partial battery sections (modules), of the final breadboard configuration, are presented. Details of the hardware and mechanical design of the primary battery are discussed and the layout for the 95 volt, 10.5 KW battery is presented. A full size, 95 volt 195 watt-hour duplex electrode battery was fabricated and bench tested. Performance data are reported and analyzed. The progress of the work on the Missile Power Supply DC to DC converter breadboard is reported.
(0 references, 8 tables, 9 figures, 26 pages)

B-732A

R. L. Carlson, Honeywell, Inc., "Silver-Zinc Missile Power Supply. DC to DC Converter," Quarterly Progress Report No. 2 (July 1, 1967), prepared under a Purchase Order from Yardney Electric Corporation for Wright-Patterson Air Force Base Contract AF 33(615)-2662.

The work during this quarter has resulted in the following conclusions: The low-power converter, 30-second timer, and constant-current regulator tested during this period are suitable for integration into the final system configuration. The synchronization circuit used to connect the low-power converter and the 1KW breadboard also operated satisfactorily.
(0 references, 8 tables, 9 figures, 26 pages)

B-733

R. F. Fogle, TRW Systems, "Heat Sterilized Nickel-Cadmium Cell. Failure Analysis Program," Final Report, Phase II (No date, received during August 1967), Jet Propulsion Laboratory Contract No. 951092 under NASA Contract NAS 7-100.

The heat sterilized nickel-cadmium cell failure analysis program definitely showed a degradation of the cell separator resulting from heat-sterilization. This degradation was evidenced primarily by a lower tensile strength of the separators in those cells which had been sterilized. For cells sterilized in the charged or partially charged condition, the degree of separator degradation increased as the state of charge prior to heat-sterilization increased. Evidence of nickel electrode degradation resulting from sterilization was also established. The plate capacities of those cells which had been sterilized were slightly lower than those of non-sterilized cells. Individual electrode potential measurements on nickel and cadmium plates showed that the nickel electrode contributed to the limit on charge and was the major limiting electrode on discharge, indicating a slight degradation of the nickel electrode resulting from sterilization. (0 references, 5 tables, 29 figures, 57 pages)

B-734

R. F. Fogle and R. N. Richards, TRW Systems, "Heat Sterilized Nickel-Cadmium Cell. Electrical Performance Investigation," Final Report, Phase III (June 1967), Jet Propulsion Laboratory Contract No. 951092 under NASA Contract NAS 7-100.

The results of the "Heat Sterilizable Nickel-Cadmium Cell Electrical Performance Investigation" (Phase III) showed that initially a greater percentage (73 percent) of the sterilized cells had a higher capacity than comparable nonsterilized cells. At the termination of the test, only 45 percent of the sterilized cells showed a higher capacity than comparable nonsterilized cells. A comparison of the Phase II capacity data with that of Phase I testing showed that the final capacities of Phase I were comparable with the initial capacities of Phase III, that is, a greater percentage (73%) of the sterilized cells showed higher capacities than comparable nonsterilized cells. There were some cells which exhibited irregularities of input and output capacities, that is, they showed high input capacities coupled with low output capacities or low input capacities coupled with almost equal output capacities. A higher percentage of the cells showing these irregularigies had not been subjected to sterilization. In Phase I testing, a high input capacity reflected itself in a high output capacity and a low input capacity reflected itself in a low output capacity. The effect of increasing the discharge rate at a specific temperature resulted in decreasing the output capacity. In general, the input capacities increased as the temperature increased. The output capacities for a given discharge rate were low at 32°F (2.23 ampere hours), were a maximum at 75°F (3.51 ampere hours) and then fell off at 110°F (2.07 ampere hours). One cell (nonsterilized failed during the Phase III testing but it is doubtful the failure resulted from the cycle regime.
(0 reference, 8 tables, 64 figures, 95 pages)

B-735

A. Himy, Douglas Aircraft Company, Astropower Laboratory, "Development of One Ampere-Hour Heat Sterilizable Silver-Zinc Cell," Final Technical Evaluation Report, SM-49109-F, NASA CR-73110 (July 1967), NASA Ames Research Center Contract NAS 1-3819.

The outcome of this 12-month program was to demonstrate the feasibility of using an inorganic separator for the design of a heat-sterilizable silver-zinc cell. The following important facts have been obtained: 1. An inorganic separator has been found to be capable of heat sterilization, continuous cycling and long wet stand. 2. A design concept making use of a sandwiched negative electrode (wafer design) has been satisfactory. 3. A separator edge sealant has been found capable of keeping its bonding characteristics during and after heat sterilization for very long periods of time. 4. Different types of cover-to-case seals have been established as the most likely candidates to pursue: metal welding or soldering for metal case, ultrasonic and hot-gas welding for plastic cases. Combinations can be made for more reliability, but after complete development and statistical testing, it may be necessary.
(1 reference, 19 tables, 54 figures, 121 pages)

B-736

E. C. Bruess, United States Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells. Acceptance Test of Sonotone Corporation 3.5 Ampere-Hour Nickel-Cadmium Cells," Report QE/C67-471 (August 4, 1967), NASA Goddard Space Flight Center Contract W11,252B.

Twenty of the 25 cells reported on NAD Crane report QE/C 66-340 of 18 July 1966 were subjected to an additional year of testing. Ten of the cells were placed on continuous overcharge at the c/100 rate and 10 cells were placed on 1 year open circuit stand in the charged state. Both tests were conducted at 25 ± 2° C. The ceramic seals of these cells, manufactured by Sonotone Corporation, are satisfactory as evidenced by no leakers out of the 20 cells tested. As the result of both test modes, the cells experienced a loss of capacity that they were unable to regain. Discounting the capacity loss, the cells were still operational after the 1 year of testing. (0 references, 1 table, 3 figures, 9 pages)

B-737

G. W. Bodamer, The Electric Storage Battery Company, The Carl F. Norberg Research Center, "Heat Sterilizable, Impact Resistant Cell Development," Second Quarterly Report (June 30, 1967), Jet Propulsion Laboratory contract JPL 951296 under prime NASA Contract NAS 7-100.

Six of the original twenty sealed silver-zinc cells made with sterilized components still remain on test after 62 deep discharge cycles, and a similar cell constructed to study gassing with constant current charging has failed after 77 deep cycles. The pressure was 15.5 psig at failure. So far, 18 cells have been constructed in PPO cases, sealed, sterilized, and cycled through the required four cycles and placed on stand or float. One cell on stand and one on float have been discharged after the first month. There was no loss of capacity in the one on float, whereas there was a considerable loss on stand. Additional work was done with other cells on high temperature stand. Cells standing one month at 160°F, which might be equivalent to a room temperature stand of 16 to 20 months, showed a capacity loss of about 40%. Capacities on recharge were good. Gas generation is being studied in sealed cells. So far pack tightness, separator type, position of separator, type of additive and the couple effect between zinc and its silver grid have been investigated. Gas generation in some measure continues to be unpredictable. The study of sealed, sterilized silver-cadmium cells on stand, cycle, or float was in part set back by a leaking sterilization bomb which affected one entire group of test cells. The work is again underway. Emphasis is at present on the performance of SWRI-GX separator in this series of tests rather than on RAI-116 separator. Highly reliable case-to-cover seals have been obtained with PPO 531-801 using an epoxy adhesive. However, a crack-free cover of this material, with silver terminals molded in, has not been achieved. On the other hand, covers of PPO 541-801, containing molded-in silver terminals, have been free of cracks, but satisfactory case-to-cover seals with epoxy adhesive have not been achieved with this plastic. Hot gas welded seals on PPO 541-801 have not been attainable. Shock testing of silver-zinc cells in which the electrodes were reinforced with plastic struts produced severe mechanical failures at the 10,000 g impact. The ensuing design is with sheet metal reinforcement of the electrodes, and these cells are currently being fabricated for shock testing.
(0 references, 31 tables, 4 figures, 58 pages)

B-738

J. E. Cooper, Wright-Patterson Air Force Base, and Arthur Fleischer, Consultant, Editors, "Characteristics of Separators for Alkaline Silver Oxide Zinc Secondary Batteries. Screening Methods." Handbook (September 1965).

Dimensional Stability, A. J. Salkind and J. J. Kelley. Tensil Strength, J. J. Kelley and A. J. Salkind. Electrolyte Retention, R. C. Shair and H. N. Seiger. Pore Size Determination, a. Water Permeability method, L. M. Cooke and J. J. Lander; b. Electrolyte Permeability Method, A. J. Salkind and J. J. Kelley. Electrical Resistance, a. Direct Current Method, J. J. Lander and R. D. Weaver; b. Alternating Current Method, A. J. Salkind and J. J. Kelley. Degradation by Soluble Silver, J. J. Lander. Degradation by Oxidants and Alkaline Solutions, A. J. Salkind and J. J. Kelley. Electrolyte Diffusion, E. L. Harris. Silver Diffusion, T. P. Dirkse. Zinc Diffusion, J. J. Lander. Zinc Penetration, G. A. Dalin and F. Solomon.

B-466

Card 2/3

Lee Waltz, NAD/Crane--Physical and Chemical Failure Analysis
Dr. M.P. Strier, Douglas Astropower--Micro Fuel Cell Gas Detection as a Criterion for Battery Failure Analysis
Richard H. Sparks, TRW Systems Lab--Application of Space Hardware Program Failures Data to Battery Design
Peter Fowler, Martin Company--Control of Battery Quality for High Reliability Vehicles - Approach and Case Histories
Gerald Halpert, Goddard Space Flight Center--Computer Program for Analysis of Battery Data
John Waite, Mauchly Systems--Use of the Computer in Monitoring Large Scale Battery Tests
Dr. Ralph Brodd, Union Carbide Consumer Products--Computer Controlled Battery Test Facility
Peter Voyentzie, General Electric Company--Quality Control Techniques to Produce High Reliability Secondary Cells for Space Application
George Dalin, Yardney Electric Company--Preparation of Uniform Plates as a Basis for Increased Battery Reliability
Vincent D'Aftostino, RAI Research Lab--Determination of Properties of Grafted Membranes for Use as Battery Separators

B-466

Card 3/3

James Oxley, Atomics International--Charging Characteristics of Zinc Electrodes Discussion
Karl Preusse, Gulton Industries--The Evolution of a Standard Line of Space Cells Discussion

B-741

Frederick P. Kober and Hiry West, General Telephone & Electronics Laboratories Inc., "The Anodic Oxidation of Zinc in Alkaline Solutions." Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illionis, (October 15-20, 1967). Extended Abstracts Publication, Abstract No. 28, pp 66-70.

> Evaluation of the exchange reactions by Farr and Hampson using the so-called double-impulse method has led to the following suggested mechanism for the anodic oxidation of zinc in alkaline solutions:
>
> $$\mathrm{Zn} + \mathrm{OH}^- \xrightarrow{\text{very slow}} \mathrm{Zn\ OH}_{ad} \qquad (3a)$$
>
> $$\mathrm{ZnOH}_{ad} \xrightarrow{\text{slow}} \mathrm{Zn(OH)}_{ad} + e \qquad (3b)$$
>
> $$\mathrm{ZnOH}_{ad} + \mathrm{OH}^- \xrightarrow{\text{fast}} \mathrm{Zn(OH)}_2 + e^- \qquad (3c)$$
>
> $$\mathrm{Zn(OH)}_2 + 2\ \mathrm{OH}^= \xrightarrow{\text{fast}} \mathrm{Zn(OH)}_4^=$$
>
> This mechanism appears to be compatible with the experimental data discussed. The effect of hydroxyl ion activity on the reaction products is to be anticipated particularly in going from Eq. 3c to Eq. 3d. It is not difficult to envision that in electrolyte solutions of relatively low OH^- ion activity (activity coefficient less than approximately 0.8) the reaction will stop at the formation of the orthorhombic hydroxide as represented by Eq. 3c.

B-742

John P. Elder, Texas Instruments, Inc. "Electrochemical Behavior of Zinc in Alkaline Media," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967). Extended Abstracts Publication, Abstract No. 29, pp 71-73.

> The electrochemical behavior of polished, planar, horizontally disposed zinc in 30% aqueous potassium hydroxide at 25°C has been investigated by slow linear potentiostatic sweep and differential galvanostatic charging curve techniques. A modular, solid-state control instrument was constructed for programmed galvanostatic studies. It incorporates time, voltage level and charge level switches, and differentiating and integrating circuitry. In conjunction with a potentiostat (Wenking, model #61 TRS) and two independent constant current units, adapted from a circuit employed by Bockris et al, a variety of operational sequences may be applied to the working electrode system. A motor potentiometer (Wenkling, model #MP-64) coupled to the potentiostat was employed for the potential sweep experiments.

B-743

J. H. Bartlett, University of Alabam, "Electrical Behavior of Passive Zinc," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967). Extended Abstracts Publication, Abstract No. 30, p. 74.

We have inaugurated an extensive program of investigation, aimed at understanding the kinetics of transport in zinc oxide films. This involves an analysis of open-circuit breaks from the passive state, with the corresponding conclusions concerning the thickness of the oxide layer and its variation with potential.

B-744

M. E. Straumanis, J. L. Reed and W. J. James, University of Missouri, "Anodic Dissolution of Zinc in Potassium Nitrate," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illionis (October 15-20, 1967). Extended Abstracts Publication, Abstract No. 31, pp 75-77.

On the basis of observations the process of anodic dissolution is as follows. In the presence of NO_3^-, similarly as it was proposed for BrO_3^-, surface oxide layer formation occurs:

$$Zn + NO_3^- \quad ZnO + NO_2^- \quad \text{or} \qquad (1)$$

$$ZnO \text{ (on the Zn surface)} + H_2O \quad Zn(OH)_2 \qquad (2)$$

Quantitative determinations of NO_2^- were made. Upon application of an anodic current Zn^{++} is forced through the weakest spots of the layer into the solution:

$$Zn \quad Zn^{++} + 2e \text{ (no } Zn^{+} \text{ is formed)} \qquad (3)$$

Since the reaction (3) occurs as a result of the very high Nernst solution pressure, the moving ions hit the oxide layer on the electrode surface with such a force that the layer breaks away from the surface carrying small particles of the metal electrodes with it. The particles cause the dark discoloration of the oxide. Depending on the adherability of the oxide layers, produced by different oxidizers, various degrees of anodic surface disintegration will be observed.

B-745

W. H. Dyson, L. A. Schreier, W. P. Sholette, and A. J. Salkind, The Electric Storage Battery Company, The Carl F. Norberg Research Center, "Physical-Chemical Studies of KOH-ZnO Electrolytes," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967). Extended Abstracts Publication, Abstract No. 32, pp 78-81.

Studies of the KOH-ZnO electrolyte system were made to obtain fundamental physical-chemical data applicable to the development of a heat-sterilizable silver-zinc cell. Measurements of vapor pressure, electrical conductivity, and solubility were included. Vapor pressures of aqueous KOH above 100°C or by comparison with a reference liquid. In the present work direct measurements of the vapor pressure of 30-46% KOH were taken over the range 100-145°C. Electrical conductivities had been reported for KOH solutions at several temperatures by Klochko and Godneva, and for ZnO-saturated KOH at 25°C by Dirkse. The present studies include conductivities at 10°C, 25°C, and 55°C of 35-46 KOH, both pure and containing varying levels of dissolved ZnO up to saturation. Solubility of ZnO in KOH had been reported by Dirkse for the range -30°C to 44°C. The present work gives data on ZnO solubility in 35-46% KOH for several temperatures in the range 10°C to 145°C.

B-746

R. W. Powers, General Electric Research and Development Center, "The Early Stages of Zinc Dendrite Formation," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967). Extended Abstracts Publication, Abstract No. 33, pp 82-84.

The important role of surface activity in the initiation of protrusions is indicated by microscopic observations of deposition on both polycrystalline and single crystal specimens. When zinc is electro-deposited from a clean 30 percent KOH solution, 0.25 M with respect to zincate ion, onto a smooth polycrystalline zinc specimen at 100 mv of cathodic polarization, a potential corresponding to a limiting current condition, about an hour is required before a substantial number of protrusions appear. Prior to this, the most notable features of the deposition are traces of the basal or growth plane on the specimen surface and the coarsening with time of planes which form ledges on the growth planes. Deposition takes place by addition of material at edges of the basal planes and this deposit is in atomic registry with the base. The importance of the lateral growth of basal planes as the predominant mode of deposition in the initial phase is also shown by a post plating examination of the deposit with an optical goniometer. For grains in which the basal plane lies at 20-50 degrees to the specimen surface, long straight edges with shorter edge segments meeting these at 120° are the outstanding features seen on the growth planes. On the other hand, with grains in which the basal plane is aligned facets are observed. For a given plating time, a higher density of protrusions is found on grains with basal planes lying in the specimen surface than on those grains in which the basal plane is greatly inclined to this surface. The epitaxial layer type of deposit is also seen initially with zinc electrodeposits formed on the basal plane of zinc single crystals specimens under conditions otherwise similar to those used with polycrystalline specimens. In this case, a hexagonally-shaped pattern of growth steps flow out from growth centers which cover the specimen within a few seconds after the onset of plating. The growth steps form a pattern of closed loops rather than one of spirals. Growth from adjacent centers meet in irregular boundaries. With time, the number of growth centers decline as growth from very active centers covers that of less active ones. In general, protrusions are seen at much earlier times for deposition on the basal planes of single crystals than on polycrystalline specimens.

B-747

S. Arouste, K. F. Blurton, and H. G. Oswin, Leesona Moos Laboratories, "Controlled Current Deposition of Zinc from Alkaline Solution," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967). Extended Abstracts Publication, Abstract No. 34, pp 85-87.

The object of the present study was to investigate the deposit produced by charging with other forms of interrupted current sources, i.e., pulsed d.c. charging and periodic reversal of current. We propose that the main benefit of pulsed d.c. charging derives from degeneration of the concentration gradient while the current is off, thus maintaining the surface concentration close to that of the bulk. Dendrites grow under diffusion controlled conditions for then the surface concentration of zincate ions is very small and the asperities protrude into zincate rich regions, resulting in deposition occurring preferentially on these protrusions. When the current is OFF, ions diffuse to the cathode surface. When the current is ON, the ions are now available at all points on the surface and deposition occurs more uniformly. The explanation of the effect of periodic reversal of the current is similar and has been proposed previously by Hickling and Rothbaum. This view is reinforced by the observation that most of the current during dissolution goes toward reducing the thickness of the individual dendrites, rather than reducing their length.

B-748

Peter Radvila and P. V. Popat, Texas Instruments Incorporated, "Investigation of the Zinc Electrode in Ni-Zn Alkaline Rechargeable Cells," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967). Extended Abstracts Publication, Abstract No. 35, pp 88-90.

In our investigation, emphasis was stressed on the nature of the capacity loss of the negative electrode during cycling. The average capacities of eight cells as a function of cycle numbers follow a characteristic pattern as shown in Fig. 2. As the electrolyte is saturated or enriched with zincate at the electrode/electrolyte (in separator material) interface at the first discharge and not all the zincate is deposited on charging, earlier passivation and a smaller capacity is seen on the second discharge. On continued cycling this effect is superimposed by the increase in surface area of the zinc electrode and the capacity increases. This type of behavior is also observed when 38% KOH is used, however, the effect is less pronounced. On further cycling the capacity decreases as the zincate concentration increases and the surface area of the electrode is not further increased. After approximately 50 cycles the diffusion processes and the geometry changes of the electrode surface reach a steady state and the capacity stabilizes (Fig. 3).

B-749

James McBreen and George A. Dalin, Yardney Electric Corporation, "Zinc Penetration of Separators," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967), Extended Abstracts Publication, Abstract No. 36, pp 91-93.

The growth of zinc dendrites during charge of a silver-zinc cell is a particularly undesirable feature of the zinc electrode as it eventually leads to shorting of the cell through growth of metallic trails of zinc through the separator. The present study was devoted to an investigation of the parameters pertinent to zinc growth in the electrode vicinity and in the separator.

B-750

J. A. Keralla and J. J. Lander, General Motors Corporation, Delco-Remy Division, "Effect of Surfactant Additions to the Zinc Plage on Cycle Life Performance of Secondary Silver Oxide-Zinc Cells." Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967), Extended Abstracts Publication, Abstract No. 37, pp 94-95.

As part of a general program having the objective of increasing the cycle life of the zinc plate in the silver oxide-zinc cell, a variety of surface active agents were incorporated in the zinc plate formulations and cycle life tested in 25 a.h. cells. One surfactant, a tridecy-loxypoly (ethyleneoxy) ethanol (Emulphogene BC-610), yielded cycle life increases of 50-80% when used in concentrations of 0.15 - 1.0% by weight when tested in a room temperature ambient.

B-751

W. J. van der Grinten, General Electric Research and Development Center, "Secondary Zinc-Electrodes With Zincate Trapping," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967). Extended Abstracts Publication, Abstract No. 38, pp 96-97.

The incorporation of calcium hydroxide $Ca(OH)_2$ outside the active cell area of conventional low current density primary zinc-air systems has been practical for many years in order to regenerate externally the KOH trapped in the soluble zincate $K_2Zn(OH)_4$ during discharge. Using commercially available chemicals at room temperature and KOH-concentrations in the 10-20% range we have found that: a) The synthesis of calcium zincate is indeed accelerated by several orders of magnitude if it is made to occur in the immediate vicinity of a discharging zinc-electrode. b) In fact zincate trapping appears to be greatly accelerated by the presence of any ionic current flow in KOH regardless of direction. This was verified by studying the rate of trapping between two nickel-electrodes as a function of time under different conditions of ionic current flow. c) The addition of a sufficient amount of $Ca(OH)_2$ to a secondary zinc-electrode reduces the zincate concentration in the electrolyte markedly during cycling. d) Cycle-lives of laboratory type nickel-zinc cells with adequate provision for zincate trapping in excess of 1,000 cycles can be achieved without the use of cellophane type separators at a KOH-concentration of 20%.

B-752

Jeanne Burbank and C. P. Wales, U.S. Naval Research Laboratory, "Further Characterization of the Silver Electrode by X-Ray Diffraction." Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967). Extended Abstract Publication, Abstract No. 41, pp 102-103.

A cell designed for simultaneous electrochemical and x-ray diffraction studies has been used to analyze the anodic coatings forming on smooth sheet silver. Two oxides, Ag20 and AgO were identified by x-ray diffraction while the potentials associated with their appearance on charge and discharge were determined. During the greater part of a discharge at moderate currents, both oxides discharged, however, the AgO discharged through an outer layer of Ag20 of constant thickness. The upper potential plateau of the discharge was associated with the growth of this layer of Ag20. When the potential fell to the second, lower plateau, the Ag20 had reached its maximum thickness, and covered the underlying AgO. For the next 50% of the discharge, the layer of Ag20 remained approximately the same thickness. The final 20-25% of the discharge resulted in a progressive thinning of the Ag20 coating.

B-753

Charles P. Wales, U.S. Naval Research Laboratory, "Charging the Silver Oxide Electrode With Periodically Varying Current. 3. Current Reversals During Charge," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967), Extended Abstracts Publication, Abstract No. 42, pp 104-105.

Sintered silver plaques 41.5 x 38.0 x 0.8 mm were wrapped in cellulosic separator material and used for both cathode and anode of test cells. The test cells contained a Ag/Ag_2O reference electrode and an excess of either 35% or 50% KOH at 25°C. Some charges with current reversals were also tried with commercial Ag-Zn cells rated at 5 amp-hours and containing 35% or 45% KOH. The constant current which required 20 hours for a complete charge or complete discharge was the standard or normal current. Complete normal charges alternated with charges which had periodic reversals. Reversal conditions included asymmetric 60-cycle a.c. and constant current charges having constant current reversals repeated every 1 to 240 minutes. There was comparatively little change from normal capacity when constant charge current at the 20-hour rate was reversed every 1, 10 or 30 minutes. A charge current at the 20-hour rate reversed for 15 minutes out of every 60 minutes gave an average 143% of normal capacity for test cells containing 35% KOH, and 114% for the Ag-Zn cells containing 35% KOH. A disadvantage was the very long total charge time. More widely separated 15-minute reversals gave less or no improvement in 35% KOH. Cells containing 45% or 50% KOH gave normal or less than normal capacity when charged with 15-minute reversals.

B-754

N. Marincic, P. R. Mallory & Company, Inc., "A New Technique for Studying the Rate of Gas Evolution Reactions," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967), Extended Abstracts Publication, Abstract No. 44, pp 110-111.

> A new method is proposed for the determination of small amounts of gas produced in corrosion reactions in solutions. It is based on the measurement of the change in buoyancy due to the gas collected under the glass bell immersed in the solution. The method can be applied in any reaction rate studies whenever gas is involved either as the reaction product or the one of its participants. The stoichiometry must be known of such reaction. The amount of gas is determined indirectly in this method. An analytical balance is used for the buoyancy measurement. 1 ml of gas evolved in water under STP results in 1 g buoyancy change and makes possible the measurement of the gas evolved with the accuracy of $\pm 10^{-4}$ ml.

B-755

Paul A. Hersch, Gould-National Batteries, Inc., "Galvanic Monitoring of Battery Gases," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967). Extended Abstracts Publication, Abstract No. 45, pp 112-115.

> This investigation aimed at replacing the primitive gasometric means of following gas evolution by more precise and convenient electrochemical means. The battery head space is continually swept by pure nitrogen and any oxygen evolved from the positive is carried to a hybrid aklskine cell with an oxygen-absorbing, fuel cell type, cathode and a conventional non-polarizable base metal anode. Its galvanic current is proportional to the feed rate of oxygen. Thus, the rate of evolution of oxygen from the batteries is measureable at any instant of time - not merely as an average - and is expressed directly in electric terms. It should be possible to apply the same principle to evolved hydrogen, using a hybrid cell with a fuel cell type, hydrogen-absorbing, anode and a conventional non-polarizable cathode consuming a solid oxidant. A stable and care-free sensor cell of this type still remains to be developed. By splitting the carrier gas stream and routing one partial stream to the former and the other partial stream to the latter type sensor cell, both oxygen and hydrogen evolution rates could then be measured simultaneously in terms of electrical currents.

B-756

J. Goodkin and G. A. Dalin, Yardney Electric Corporation, "Silver-Cadmium Battery for High Rate Charging," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967). Extended Abstracts Publication, Abstract No. 46, pp 116-119.

The use of good gas recombination electrodes as pressure-sensing devices and proper control of the battery potential, make high-rate charging of silver-cadmium batteries possible. The use of a pulsing-type charge regime, in addition, has been found to eliminate the problem of cell imbalance that has plagued this sytem previously.

B-757

John J. Rowlette, Hughes Aircraft Company, "Heat Generation in the Surveyor Main Battery," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967). Extended Abstracts Publication, Abstract No. 47, pp 120-123.

The curves in Figure 1 and the calculated curves in Figures 2 and 3 are based on equation 1 ($q = I(E_H - E_T)$, and the assumption that the discharge of a silver-zinc cell proceeds in two stages represented by the following equations:

I $2\,AgO + Zn \quad Ag_2O + ZnO$
II $Ag_2O + Zn \quad 2Ag + ZnO$

The assumption was made that the electrolyte was at all times saturated with respect to zincate ion. An alternative model has been proposed in which at least part of the charging current goes into charging silver directly to AgO. But this model is inconsistent with the thermal data obtained in these experiments. Figure 2 shows the comparison between the calculated heat generation rate and the measured heat dissipation rate for battery #70 while undergoing a constant, 3 ampere charge. The area within the calculated curve is 204 watt-hours, whereas the area under the measured curve is about 235 watt-hours. Figure 3 shows the calculated and measured curves, also for battery #70, while undergoing a constant current, 7 ampere-discharge. The average measured heat generation rate was 20.5 watts, which compares well with the calculated average value of 19.5 watts.

B-758

M. G. Gandel and J. T. Sachs, Sr., Lockheed Missiles and Space Company, "Capacity and Load Sharing Predictions for Spacecraft Power Systems," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967), Extended Abstracts Publication, Abstract No. 48, pp 124-126.

The principles upon which this load sharing and performance calculation technique is based are given as follows: 1. Batteries connected in parallel see the same bus voltage or, if isolated by diodes, they are a known voltage (diode drop) above it. 2. The discharge characteristics of a single battery also apply in multiple battery - parallel operation. 3. Based upon spacecraft flight data, the bus voltage is in a constantly decaying mode under a constant (average) system load. 4. For a discrete element of bus voltage decay, individual battery current and temperature are assumed constant. This element can be made as small as desired. 5. A detailed set of discharge characteristics (voltage vs capacity as a function of load and temperature) are available for the particular batteries being considered. 6. Individual battery temperatures are available based on thermodynamic predictions or constantly updated computer inputs derived from a program combining the spacecraft thermodynamic model, individual battery heat dissipation as a function of current and temperature, and feedback from the load sharing program.

B-759

D. M. MacArthur, Bell Telephone Laboratories, "Potential Scan Studies of the $Ni(OH)_2$ Electrode," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967), Extended Abstracts Publication, Abstract No. 49, pp 127-130.

Potential scans of $Ni(OH)_2$ electrodes of various thickness and in various KOH concentrations were taken at several scan rates. Some of the results are shown in Figure 3. The peak height on oxidation (i_p) was plotted as a function of the sweep rate). Some of the data are shown in Figure 4. A straight line resulted which indicated that the reaction was diffusion controlled. Following Lukovtsev it was assumed that protons were the diffusing species in the solid electrode. Since the peak height was a function of the thickness of the film electrode, it was apparent that the diffusion layer depth was greater than the film thickness. These values, called i_{poo}, were then plotted versus (sweep rate)$^{1/2}$ and the slope of the resulting straight line was determined. Using the known equatinn for a reversible electrode the diffusion constant for the protons was found to be about $10^{-8} cm^2 sec^{-1}$.

B-760

Y. Okinaka and Claudia Whitehurts, Bell Telephone Laboratories, "Charge Acceptance of Cadmium Hydroxide Electrodes at Low Temperatures." Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967). J. Electrochemical Society, Vol. 117, 1970, pp 583-587.

The purpose of this paper is to present experimental evidence showing that there is a close correlation between the low temperature charge acceptance and the size of cadmium hydroxide crystals. It was found that both the charge acceptance and the crystal size are greatly affected not only by the temperature during discharge but also by the rate of discharge.

B-761

E. J. Rubin, Texas Instruments Incorporated, "The Electrochemical Behavior of the Cadmium Hydroxide Electrode," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967). Extended Abstracts Publication, Abstract No. 51, pp 134-135.

The electrochemical reduction of cadmium hydroxide in alkaline media at low temperatures (i.e. below 0°C) is known to be inefficient. The associated parasitic reaction, namely, hydrogen evolution precludes the use of conventional, hermetically sealed nickel-cadmium cells and batteries in the aforementioned temperature range. The object of this continued investigation was to determine the mechanism responsible for the inefficient electrochemical reduction of cadmium hydroxide. Electrochemical data establishing the existance of the two forms of cadmium hydroxide are presented. Galvanostatic reduction waves indicating three potential arrests are shown. The first plateau is associated with "active" cadmium hydroxide reduction. The second plateau is the potential at which the "inactive" cadmium hydroxide is reduced while the third plateau is associated with hydrogen evolution. It is shown that the two norphological forms of cadmium hydroxide require separate and distinct reduction potentials as predicted by thermodynamics. The equilibrium between these forms is discussed in terms of defect structures and solid state diffusion versus recrystallization processes.

B-762

H. N. Seiger and S. Lerner, Gulton Industries, Inc., "Auxiliary Electrodes for Sealed Nickel-Cadmium Cells," Paper presented at the Electrochemical Society Fall Meeting, Battery Division, Chicago, Illinois (October 15-20, 1967). Extended Abstracts Publication, Abstract No. 52, pp 136-137.

The work herein described was divided into three phases. The first phase concerned itself with the investigation of auxiliary electrodes to be used to signal the end of charge. The second phase of the project was a study of various electrode materials to be used as a recombination, or scavenger electrode; the materials investigated included both Adhydrode and fuel cell types. The final-phase of the project was the mating of the best parameters from phases one and two into a final working cell design which was then placed in a test program. All cells were fabricated in nylon cases and equipped with pressure gages. The results of these tests indicated that when both a fuel cell scavenger and an Adhydrode for charge control are included in a nickel-cadmium cell designs, long term cycling at 60% depth of discharge is a feasible mode of operation, and at low temperatures, improved cycling and Adhydrode characteristics are achieved. In addition, it appears that the inclusion of a fuel cell scavenger delays the onset of vigorous generation of oxygen so that more stringent charging conditions may be used without fear of excessive pressure buildup and the subsequent catastrophic failure of cells which have been subjected to high rate overcharge.

B-763

J. W. Vogt, TRW Inc., "Materials for Electrochemical Cell Separators," Second Summary Report, NASA CR-72267 (July 3, 1967), NASA Lewis Research Center Contract NAS 3-8522.

This contract is concerned with developing improved materials for use as electrochemical cell separators. Task 1 of the program dealt with determining the properties of "Fuel Cell Grade Asbestos," separator mats. Task 2 of the program has been the study of other types of asbestoses and alternate inorganic fibrous materials. The scope of the original contract has now been extended to include a second year's work. This follow-on work will consist of studying composite mats incorporating fibrous forms of organic materials to add structural integrity to the most compatible inorganic materials uncovered in this program.
(0 references, 8 tables, 14 figures, 39 pages)

B-764

L. M. Adams, W. W. Harlow, Jr., and G. C. Lawrason, Southwest Research Institute. "Development of Battery Separator Material Process," Interim Report No. 67-482 (August 25, 1967), Jet Propulsion Laboratory Contract No. 951718 under NASA Contract NAS 7-100.

The preferred procedure for preparing sterilizable battery separator material involves grafting of low-density polyethylene film with acrylic acid, washing of the product with five percent potassium hydroxide, rinsing in water, drying, and crosslinking the dried material with divinylbenzene. The grafting and crosslinking procedures are initiated by irradiation from a cobalt-60 source. Separator material produced by the above procedure and with the grafting carried out in a nitrogen atmosphere at 86^{0}F has an electrical resistance in the range of 6 to 15 milliohm-inch^2 with an average resistance of 10 milliohm-inch^2. Substantial amounts of material prepared by this procedure were shipped to the sponsor. Separator material with a resistance value range of 2 to 6 milliohm-inch^2 and an average value of 4 milliohm-inch^2 has also been prepared using process modifications. Effect of sterilization irradiation techniques (0 references, 43 tables, 0 figures, 57 pages).

B-765

Z. O. Stachurski, Yardney Electric Corporation, "Study to Investigate and Improve the Zinc Electrode for Spacecraft Electrochemical Cells." First Quarterly Report (June 1967), NASA Goddard Space Flight Center Contract NAS 5-10231.

Electrodeposition of zinc on slowly rotating disc electrodes was conducted. The half wave potential ($E_{1/2}$) on the current-potential curve was confirmed to be the critical value for change from mossy deposition to dendritic. The radius of the dendrites was measured as a function of overpotential and found to change radically around $E_{1/2}$. Absorption isotherms of zincate in five separators were measured. The distribution coefficient of zincate between electrolyte and separator was measured and found to be less than one. Its value varied over a factor of five for different separators.
(3 references, 8 tables, 14 figures, 35 pages).

B-766

James McBreen, Yardney Electric Corporation, "Study to Investigate and Improve the Zinc Electrode for Spacecraft Electrochemical Cells." Second Quarterly Report (June 1967), NASA Goddard Space Flight Center Contract NAS 5-10231.

The diffusivity of zincate has been investigated as a function of KOH concentration and temperature. A qualitative explanation is given for deviations from the Einstein-Stokes equation. Absorption isotherms of zincate in eight separators were measured. The distribution coefficient of zincate was measured and found to be less than one in all cases. Cellulosic separators and unplasticized polyvinylalcohol membranes show no variation in zincate absorption with stand temperature. The absorption of zincate ions in Borden Co. C-3 and 9107-5 increases with stand temperature. Additions of Emulphogene BC-610 do not affect the absorption of zincate in cellulose separators. (1 reference, 6 tables, 17 figures, 29 pages)

B-767

James McBreen, Yardney Electric Corporation, "Study to Investigate and Improve the Zinc Electrode for Spacecraft Electrochemical Cells." Third Quarterly Report (August 1967), NASA Goddard Space Flight Center Contract NAS 5-10231.

This program involves an investigation of the absorption and transport of zincate in separator membranes. The growth of dendritic zinc through separators is correlated with the deposition of zinc in free electrolyte and the absorption and transport of zincate through the membranes. Radiation Applications, Inc. (2.2 XH) gives a similar absorption effects for zincate as do the other membranes tested during this program. The addition of the surfactant, Emulphogene BC-610, does not affect the absorption of zincate in cellophane. The diffusivity of zincate through six membranes was measured. The diffusion coefficient for zincate in the separators tested was approximately directly proportional to the conductivities of the membranes. Zinc penetration tests on various separators indicate that the overvoltage at which zinc penetration of the membrane occurs has an inverse relationship to the diffusivity of zincate in the membrane. The cycling of cells on a scanner, using -150 mV (w.r.t. to a zinc reference) as a cut-off on the zinc electrode resulted in penetration of cell membranes after 14 cycles. (3 references, 1 table, 10 figures, 23 pages)

B-768

S. Arouete and K. F. Blurton, Leesona Moos Laboratories, "The Improvement of Zinc Electrodes for Electrochemical Cells." Final Report (October 31, 1966), NASA Goddard Space Flight Center Contract NAS 5-9591.

Two forms of dendritic growth have been observed and are referred to in this report as dendrites and moss. The former is grown under diffusion control conditions while the latter is gorwn under activation control conditions. It was found that the transition from one type of growth to the other occurs at a critical current density which is a function of temperature. An investigation has been made of the parameters which govern the adherency, propagation, and type of growth. The adherency of the deposit has been increased by pulse charging conditions, by soaking the electrode in potassium hydroxide solution for 18 hours, by decreasing the height of the electrolyte, and by adding a lead salt to the electrolyte. Correlation has been obtained between the adherency of the deposit and the variation of the electrode over-potential with time. An explanation has been proposed for the mechanism of the growth of the two forms of dendrites and for the beneficial effect of pulse charging conditions. (28 references, 1 table, 22 figures, 46 pages)

B-769

Helmuth L. Pfluger and Howard E. Hoyt, The Borden Chemical Company, "Improved Separators for Silver Oxide-Zinc and Silver Oxide-Cadmium Cells for Spacecraft Applications." Fourth Quarterly and Final Report (July 1967), NASA Goddard Space Flight Center Contract NAS 5-9107.

Earlier work resulted in materials whose use extended cell-life five-fold and prevented catastrophic shorting due to zinc dendrite growth. Since the best performance was exhibited by membranes comprising methyl cellulose as the chief component, much of the new work has been focused on means of improving further the properties of methyl cellulose compositions. Synthetic approaches have also been undertaken. New membranes which passed certain preliminary screening tests at the Borden Laboratories were tested under sub-contract by Electric Storage Battery Company using simplified three-plate silver zinc oxide cells in a standard cycling test. The entire E.S.B. final report is included as Appendix to the present report. Based on the findings of the cycle tests, separator materials were chosen for the silver-zinc cells required under contract.
(3 references, 8 tables, 6 figures, 37 pages)

B-769A

J. J. Kelley, The Electric Storage Battery Company, "Battery Test Phase," Final Report (April 1967), Borden Chemical Company, Contract Purchase Order 115362.

A number of separator compositions were tested as components of three plate silver-zinc oxide cells in a standard cycling test. The compositions were in the form of either thin films or envelopes into which the electrodes could be fitted. The electrical cycling was designed to serve as a screening test enabling superior materials to be chosen for more intensive examination. Six materials meet the imposed requirements giving cycling performance superior to cellophane.
(0 references, 5 tables, 2 figures, 14 pages)

B-770

L. Reid, D. Cole, and I. Trachtenberg, Texas Instruments, Incorporated, "A Dynaimc Method of Determining the Internal Resistance of Fuel Cells and Batteries," Journal of the Electrochemical Society, 113 (9), 954-955 (September 1966).

> The method described here employs an electronic switch to interrupt a constant current which is imposed on the cell in its steady-state condition (open circuit or a steady d-c drain).
> (2 references, 1 table, 3 figures, 2 pages)

B-771

Harvey N. Seiger, Arthur E. Lyall, and Steven Charlip, Gulton Industries, Inc., "Bipolar Nickel-Cadmium Cells for High-Energy Pulses." Journal of Spacecraft and Rockets, 4 (8), 974-977 (August 1967)

> The term "bipolar" is applied to an electrode configuration that contains the positive material of another cell on opposite sides of a conducting substrate which acts as an intercell connector. A series of bipolar electrodes are oriented with the positive material on the next conducting substrate, prevented from short-circuiting by a separator. The bipolar electrode configuration permits a series connection which is 7 orders of magnitude lower in resistance than ordinary battery intercell connectors, resulting in unusually high rates of discharge with the current density at maximum power ten times greater than for ordinary high-rate cells. Design problems that were solved include fabrication of 4-mil sintered matrices, impregnation with active materials on one side of the bipolar electrode at a time, and electrolyte leakage. Another problem was testing of cells at high currents and low voltages. Methods for adding electrolyte to cells by prewetting 3-mil-thick separators were investigated. Maximum power delivered into a load occurs at 0.65 v/cell. Cells designed for millisecond discharge yielded 450 and 800 w/lb for 4 and 100 in.^{2} electrodes, respectively, at 10% depth of discharge. Short-circuit current density was 20 amp/in.^{2}. A thicker matrix cell (30 mil) of the same area, designed for discharge of 1 sec., delivered 33 w/in.^{3}, which corresponds to 180 w/lb.
> (6 references, 1 table, 11 figures, 4 pages)

B-772

Paul C. Milner and Upton B. Thomas, Bell Telephone Laboratories, Incorporated. "The Nickel-Cadmium Cell," Advances in Electrochemistry and Electrochemical Engineering Volume 5. Electrochemical Engineering, Edited by Charles W. Tobias, Interscience Publishers, New York (1967), pp 1-86

Historical Development, the Electrolyte, Electrode Preparation and Physical Characteristics, The Nickel Oxide Electrode. 1. The Charge-Discharge Reaction--Chemistry and X-Ray Studies of Nickel Oxide, 2. The Charge-Discharge Reaction - Electrochemical Studies, States of Oxidation, Effects of Previous History, Potential Measurements During Charge and Discharge, Open-Circuit Measurements, Solution Composition Changes, The Charge-Discharge Reaction-Discussion, Oxygen Evolution and Behavior in the Overcharge Region, Measurements of Oxygen Evolution Rates, Open-Circuit Decays of Oxygen Overvoltage, Overcharge Behavior-Discussion, the Cadmium-Cadmium Hydroxide Electrode, The Charge-Discharge Reaction, Hydrogen Evolution, Oxygen Reduction at Sealed-Cell Negatives, the Separator, Cells, Construction and Assembly Cell Behavior. (157 references, 0 tables, 5 figures, 86 pages)

B-773

Delmar R. Riffe, Westinghouse Electroc Corporation, "Composite Electrode," U.S. Patent 3,328,202, June 27, 1967, Application, October 30, 1963.

A novel storage battery with Zn anode, Br cathode, and aq Zn $(Br)_2$ electrolyte made use of a composite electrode of adsorptive activated carbon. The central adsorptive activated carbon body was coated on one side with a mixture of powdered carbon and polymd. CF_2:CHCl (i.e., Kel-F) which was carbonized to a conductive impervious (to the electrolyte) glaze. The other side of the C body was covered with separators of a glass mesh screen surmounted with a sheet of poly(vinyl chloride). These separators were elec. nonconducting, but sufficiently porous to permit passage of ions and mol. Br. A suitable casing and mech. structure were required to hold the cell together. Electrolyte was placed in the zone between the separator and the charging plate. A charging current was applied to leads connected to the carbon plate and the conductive coating causing Zn to be electroplated on the carbon terminating plate as Br was produced and diffused through the separator del. and into the active carbon body where it was adsorbed. Either as a single unit or, better, in batteries of 3 or more cells, the unit was ready for use as a storage battery. From strictly theoretical considerations, a Br-Zn cell could deliver 196 w. hrs./lb. (of Zn and Br) with an open circuit potential of 1.8 v at 25^0.

B-774

Robert J. McCarthy and Ilyitch J. Sobel, Sonotone Corporation, "Rechargeable Battery Assembly with Reverse Polarity Charge Protection," U.S. Patent 3,321,690 May 23, 1967, Application, October 19, 1964.

A sealed rechargeable battery of cells is arranged for preventing discharge of the cells into a reverse polarity condition when connected in series. In the Ni-Cd cell, over-discharge through the lowest capacity cells causes evolution of H. Previous attempts to overcome the difficulty used an auxiliary 3rd cell electrode of Pt or Pt sponge protected against exposure to electrolyte with a gas-previous anti-wetting agent or compound, such as poly(tetrafluoroethylene) or perfluorodecanoic acid. However, this 3rd electrode does not develop voltage sufficient to suppress overdischarging and H evolution. This invention consists of an appropriate monitoring system to sense the approach of the reversed polarity condition. A cell is selected which has a more rapid rate of discharge than the normal cells, and which will approach its reverse charging conditions before the other cells. A transistor is so connected across this cell that it serves as a switch to cut off the current from all cells when the potential of the reference cell approaches a reverse polarity condition. The charging circuit is arranged to by-pass the reverse polarity sensing means.

B-775

Societe des Accumulateurs Fixes et de Traction (SAFT), France, "Nickel-Cadmium Battery Electrodes," French Patent 1,465,642, January 13, 1967, Application, December 1, 1965

Porous graphite fiber felt or clost contg. fibers $\leqq 25\mu$ diamater coated $\leqq 10\mu$ thick with electroactive materials was used for battery electrodes. Electrodes were made by impregnating 2 graphite felts in nitrate solutions, 1 contg. Ni and the other Cd. The felts were dried, treated 1/2 hour at 80° in a solution of 250 g. soda and 1 l. H_2O to ppt. the hydroxides, washed, and dried. The coated electrodes had a porosity $\geqq 50\%$. If desired, they can be compressed by 33 to 66%.

B-776

Lutz Horn and Fritz Philipp, Varta, A. G., Germany, "Method of Producing High-Porous Sinter Plates, Preferably for Alkaline Storage Batteries." U.S. Patent 3,325,280, June 13, 1967, Applied Germany, January 12, 1965.

A method is described for the production of sintered plates from 0.5 to ≈ 4 mm. thickness. The basic material comprises a mixture of ≈ 75-85 wt.% carbonyl Ni powder and ≈ 25-15 wt.% polystyrene powder (in the form of dust). The proportion of polystyrene dust corresponds to the porosity desired. The av. diameter of the Ni powder is 3-5μ and the polystyrene should be 8-20μ. A charge of the powder mixture is fed into a funnel-like feed device which is designed to spread the powder evenly on a continuously moving steel conveyor. The powder is then spread on the conveyor by a rake or doctor blade and the layer is compressed to the desired thickness by applying an adjustable pressure roller to the layer. This roller is applied after the layer has been distributed by the rake end and has a peripheral speed which is lower than the lineal speed of the conveyor. The layer of softly pressed mixture of powders is then passed through a muffle furnace of common type and the polystyrene powder is sintered at $\approx 200°$. By this relatively low temperature treatment, the polystyrene powder is stabilized so that the pores defined are not deformed by the further work process. The carrier material is then applied and the product is subjected to the sintering temperature of the carbonyl Ni, $\approx 1000°$ for 10 minutes. The micro-distributed polystyrene powder which had been stabilized by pre-sintering, now volatilizes, forming addul. micropores. Displacement and shifting of the Ni powder is prevented by the gas pressure of the volatilizing gases as a result of the stabilization of the polystyrene powder in the presintering heat treatment. Unlike the previous production methods, macropores are not formed and the finished sinter-body remains micro-pored. The continuously moving finished sinter-band may be fitted with an edge-fastening by means of a roller arrangement adapted to attach plate lugs by roll-welding. Single plate pieces are separated by flying shears and stapled and finally the plate pieces are impregnated with active material in the usual manner.

B-777

John McCallum and Charles L. Faust, Battelle Memorial Institute, Columbus Laboratories, "Failure Mechanisms in Sealed Batteries: Part II," Second Semi-annual Technical Progress Report No. AFAPL-TR-67-48, Part II, BATT-7770-2, (October 1967), Wright-Patterson Air Force Base Contract AF 33(615)-3701.

Work with battery literature has shown the necessity for dividing information problems into two categories: (1) using published information to answer questions and (2) using published information as a basis for asking questions. Research into both categories was started during this report period. Decisions were made for arranging a new electrode-making facility, and needed equipment was selected and ordered. Final modifications to measurement equipment were completed for life tests on sealed batteries under simulated orbiting conditions. Work was commenced on failure analysis procedures with a discussion and definition of the terms, failures, failure mode, failure determinant, failure mechanism, and failure-analysis procedure. Silver-solubility data are described. Accelerated tests are discussed from three technical viewpoints: the empirical, the statistical, and the physical. A theoretical approach to thermal analsis is outlined. (31 references, 17 tables, 18 figures, 70 pages)

B-778

P. J. Antikainen, Sirkka Hietanen and Lars Gunnar Sillen, Royal Institute of Technology, Sweden. "Studies on the Hydrolysis of Metal Ions. 27. Potentiometric Study of the Argentate (I) Complex in Alkaline Solution." Acta Chemica Scandinavica, 14 (1), 95-101 (1960)

The composition of the argentate (K) complex formed in alkaline solutions of silver oxide has been studied by emf titrations with constant ionic medium (0.95 and 12.6 M NaOH, 1.15 and 11.5 M KOH) using Ag-AgI electrodes. The data indicate that only mononuclear complexes are formed; from this result, together with the solubility data of other workers, it is concluded that the formula of the complex is $Ag(OH)_2^-$. No evidence has been found for the presence of the polynuclear argentate complexes proposed by some previous workers. The solubility product of $Ag_2O(s)$ in 3 M $Na(ClO_4)$ at 25°C was determined as $\log K = \log (AG^+)(OH^-)^2 = -7.42 \pm 0.02$.
(9 references, 1 table, 1 figure, 7 pages)

B-779

George Biedermann and Lars Gunnar Sillen, Royal Institute of Technology, Sweden. "Studies on the Hydrolysis of Metal Ions. Part 30. A Critical Survey of the Solubility Equilibria of Ag_2O". Acta Chemica Scandinavica, 14 (3), 717-725 (1960)

On the basis of recalculation of the data available in the literature the most probable values of the constants of the following equilibria have been estimated at 25°C:

$1/2\ Ag_2O(s) + 1/2\ H_2O \quad Ag^+ + OH^- \qquad \log K_{s0} = -7.71 \pm 0.03$

$1/2\ Ag_2O(s) + 1/2\ H_2O \quad AgOH \qquad \log K_{s1} = -5.75 \pm 0.25$

$1/2\ Ag_2O(s) + 1/2\ H_2O + OH^- \quad Ag(OH)_2^- \qquad \log K_{s2} = -3.72 \pm 0.03$

For the complex formation OH^- -Ag^+ these data give

$\log K_1 = \log (AgOH)\ (Ag^+)^{-1}(OH^-)^{-1} = 2.0 \pm 0.3$

$\log \beta_2 = \log (Ag(OH)^-)(Ag^+)^{-1}(OH^-)^{-2} = 3.99 \pm 0.05$

The different experimental methods which were employed to study these equilibria have been discussed in some detail.
(25 references, 1 table, 1 figure, 8 pages)

B-780

E. A. Butler and A. U. Blackham, Brigham Young University, "Studies of Reaction Geometry in Oxidation and Reduction of the Alkaline Silver Electrode." First Quarterly Report (August 14, 1967); Jet Propulsion Laboratory Contract JPL 951911 under Prime Contract NAS 7-100. Re-Order No. 67-568.

A method for obtaining data for a polarization curve of the silver anode in an ammoniacal electrolyte has been tested. The principal advantage of the method is that it eliminates ohmic overpotential from the measurement and does not introduce the problem of capillary shielding. Further testing of the method for determination of the effective electrolytic surface area of sintered electrodes is being carried out through the development of control sintered electrodes and through application of other methods of surface area determination. Apparatus is being set up to investigate the effects of ultrasonic vibrations on charging capacity, electrolyte depletion, and surface smoothing. (14 references, 1 table, 4 figures, 15 pages)

B-781

I. O. Salyer, E. V. Kirkland, G. L. Ball, III, P. N. Wilken and L. E. Erbaugh, Monsanto Research Corporation. "Silver-Zinc Battery Separator Material Development." First Quarterly Progress Report (October 10, 1967), Jet Propulsion Laboratory Contract JPL 951966 under NASA Headquarters Prime Contract NAS 7-100.

With a limited quantity of ethylene/acrylic acid copolymer (cross-linked), some electrical measurements of resistance of the wet sheet indicate the potential value of these copolymers as separators for silver-zinc batteries. When received the JPL cell will be used for future measurements of resistivities. A few small samples of ethylene/methyl acrylate copolymers have been made in a small rocker bomb. A one liter high pressure stirred reaction has been set up and will be used to synthesize larger quantities of copolymer. As larger quantities of copolymer become available, variables will be evaluated such as copolymer composition, reinforcing methods, extent of cross-linking agent required. Properties will be measured including oxidative, reagent and thermal stability; and electrical resistance.
(No references, 7 tables, 0 figures, 19 pages)

B-782

B. S. Baker, D. Gidaspow, B. Jee, D.Y.C. Ng, S.Sareen, C. W. Solbrig, and W. Toczycki, Institute of Gas Technology. "Electrochemical System Heat and Mass Transfer." First Quarterly Progress Report (September 1967), NASA George C. Marshall Space Flight Center Contract NAS 8-21159.

This report is divided into four main technical tasks in accordance with the program plan. These Are--I. Heat Transfer in Fuel Cell and Storage Batteries, II. Simultaneous Heat and Mass Transfer in Free Convection, III. Heat and Mass Transfer in Immobilized-Electrolyte Cell Systems, IV. Analysis of Transient Pulse Flow. The progress and achievements under each of these four tasks are discussed.
(38 references, 2 tables, 25 figures, 83 pages)

B-782A

Dimitri Gidaspow and Bernard S. Baker, Institute of Gas Technology, "Heat Transfer in a Fuel Cell Battery," Reprint enclosed in Appendix B of "Electrochemical Systems Heat and Mass Transfer," (b-782), 30 pages

Analytical solutions were obtained for temperature distributions in a single adiabatic fuel cell element with heat generation by T S, I^2R, and polarization. Equations were also developed for a battery of cells that consider conduction of heat in three dimensions, and with convection in the fuel and air streams. For equal inlet air and fuel temperatures, the electrolyte temperature can monotonically increase with length of cell, go through a minimum, or decrease, depending upon a ratio of heights of heat to mass transfer units. Although the temperature can be kept within safe limits in low power density batteries, the paper shows that critical dimensions exist beyond which failure by thermal buckling will occur.
(19 references, 0 tables, 7 figures, 30 pages)

-783

H. Frank and M. P. Strier, McDonnell Douglas Corporation, Astropower Laboratory. "Sealing of Silver Oxide-Zinc Storage Cells." First Quarterly Report, DAC-59860-Q1 (September 23, 1967), NASA Goddard Space Flight Center Contract NAS 5-10409.

> Major accomplishments during this first report period were in Task 2 above, design and test of micro fuel cells. Silver oxide cells with 1.0 cm^2 electrodes were found to be capable of consuming hydrogen at rates over 80 cc H_2/hour for short periods (less than one hour) and at rates up to 20 cc H_2/hour for longer periods (hundreds of hours). The range of efficiencies was from 60 to 90% based on the weight of silver oxide. The highest capacity cell tested to date was operated for 460 hours at 5 MA (5 mZ/cm^2) and consumed 966 cc H_2. Dimensions of the cylindrical silver oxide electrode were 0.445 inch diameter by 0.500 inch thick, and the weight was 7.0 grams. The capacity of these cells was increased with thicker silver oxide electrodes. Electrode efficiency has been found to decline only slightly with increased thickness. Efficiency was found to decrease slightly with increased hydrogen consumption rate. Cadmium micro fuel cells were found to be capable of consuming oxygen at rates of over 40 cc O_2/hour for short periods (less than one hour) and at rates up to 10 cc O_2/hour for longer periods (hundreds of hours). Electrode efficiency of the cadmium cells has been found to be independent of current density or oxygen consumption rate and thickness of the cadmium electrode. Efficiency was in the range of 35 to 40% based on weight of cadmium. The highest capacity cadmium cell tested to date was operated for 110 hours at 5 mA; it consumed 115 cc O_2. Dimensions of the cylindrical cadmium electrode in this case were 0.445 inch diameter by 0.210 inch thick, and the weight was 3.0 grams. Gassing studies by volumetric analysis on the commercial silver oxide-zinc cells were initiated during the latter part of this report period. (5 references, 8 tables, 8 figures, 27 pages)

784

E. C. Bruess, United States Naval Ammunition Depot. "Evaluation Program for Secondary Spacecraft Cells. Acceptance Test of Sonotone Corporation 20 Ampere-Hour Sealed Nickel-Cadmium Cells." Report QE/C 67-562 (August 28, 1967), NASA Goddard Space Flight Center Contract W11, 252B.

> The goal of this contract was to study the effect of mechanical pressure on cell plates of nickel-cadmium cells. From the results of this test, it can be concluded that: 1. The sealing technique used to secure the pressure relief valves to the covers may be a problem area as evidenced by one leaker out of the 50 cells tested. 2. The mechanical pressure on the cell stacks makes no appreciable difference on initial capacities as the control cells had a capacity range of 23.8 to 29.2 ampere-hours as compared with the range of 24.8 to 30.0 ampere-hours for the cells with the springs.
> (0 references, 1 table, 5 figures, 13 pages)

B-785

G. Myron Arcand, Idaho State University, "The Reactions Pertaining to Zinc-Silver and Cadmium-Silver Batteries," Second Quarterly Report (September 15, 1967) Jet Propulsion Laboratory Contract JPL 951887 under NASA Prime Contract NAS 7-100. Re-Order No. 67-513.

A cell for the electrochemical preparation of tagged precipitates of Zn(II) and Cd(II) has been fabricated. Electrochemically-prepared AgO is 50% converted to Ag_2O in 24 hours when heated at a constant 130°. Conversion is 84% and 90% complete at 140° and 150°, respectively, in the same time. The maximum solubility concentration of Ag(I) is 4-5 x 10^{-4} VH in 10 VH KOH for both AgO and Ag_2O. The concentration in the AgO system decreases slowly with time. The solubility of Ag_2O depends on the KOH concentration and shows a maximum at about 5 VF KOH.
(8 references, 3 tables, 4 figures, 16 pages)

B-786

R. D. Naybour, The Electricity Council Research Centre. "Morphologies of Zinc Electrodeposited From Zinc Saturated Aqueous Alkaline Solution," Report No. ECRC/R26 (August 1967).

Dendrite formation has been observed on all the major faces of zinc at current densities above 50 $mAcm^{-2}$. This is in agreement with diffusion theory. Differences in nucleation density between different crystallographic faces do not lead to differences in the threshold current density for dendrite formation. Limitation of dendrite formation must rely on breaking down the diffusion controlled region by electrolyte agitation or by reducing the active sites by addition of inhibitors or by accepting current densities below 50 $mAcm^{-2}$.
(18 references, 1 table, 17 figures, 16 pages)

B-787

R. F. Fogle and W. R. Scott, TRW Systems Inc. "Study of the State-of-the-Art of Hermetic Seals for Secondary Alkaline Spacecraft Cells." First Quarterly Report (September 20, 1967), NASA Goddard Space Flight Center Contract NAS 5-10432.

Phase I of the program, consisting essentially of a conceptual analysis of seal types and manufacturing methods, is 80% complete. This phase included a literature survey of manufacturing methods for various types of hermetic seals with emphasis on the integrity of seals, applications, and limitations. As this study phase continues, the life expectancy of the various type seals in regard to use in secondary spacecraft cells will be determined. Phase II, "Secondary spacecraft cell user and test organization contracts," has been initiated. A questionnaire (Attachment A) designed primarily to assist in the collection of information from the users and test organizations for TRW's program, and to provide TRW with results of experience in testing and failure modes relating to hermetic seals has been sent to twelve (12) user and test organizations. Phase III, contacts with secondary spacecraft cell manufacturers, has been initiated.
(0 references, 3 tables, 0 figures, 11 pages)

-789

John J. Kelley, The Electric Storage Battery Company, "Alkaline Battery Separator Characterization Studies." First Quarterly Report (August 23, 1967), NASA Goddard Space Flight Center Contract NAS 5-10418.

This is the first quarterly report on characterization studies designed to evaluate in a comprehensive manner separator materials for alkaline silver batteries. The primary sources of these materials are government funded projects relating to space and defense but it is planned to include all available and practical materials. The characterization tests include measures of the physical and chemical stability of the test specimens, measures of selected transport properties, an assessment of battery performance in a simplified cell design, and the production of 240 cells for evaluation at NAD/Crane. Six materials have been obtained and partially characterized during the first quarter.
(1 reference, 6 tables, 3 figures, 23 pages)

-790

R. F. Chireau, Yardney Electric Corporation. "Silver-Zinc Missile Power Supply." Ninth Quarterly Technical Progress Report (October 1967), Wright-Patterson Air Force Base Contract AF 33(615)-2663.

Phase IIb, Task I of the Missile Power Supply which consists of development, fabrication and test of an 8500 watt battery-converter breadboard power supply, was continued during the quarter ending September 30, 1967. The basic parameters used in the design of the 95 volt battery breadboard are discussed and details of the mechanical design are presented. Performance data on the test discharge of the 95 V duplex electrode battery breadboard S/N 001 are reported and analyzed. The progress of the work on the Missile Power Supply DC to DC converter breadboard is reported. The subcontractor's Third Progress Report on the Phase IIb, Task I effort is appended to the present document.
(0 references, 3 Tables, 15 figures, 29 pages)

-790A

S. D. Heaner, Honeywell, Inc., "Silver-Zinc Missile Power Supply. DC to DC Converter." Quarterly Progress Report Number 3 to Yardney Electric Corporation (September 15, 1967), Purchase Order 57636D.

Because of successful operation of the 3000-watt converter and the similarity of the other high-power converter, and because the other elements of the system have been operated successfully as individual items, Honeywell feels it can now progress rapidly on this program to demonstrate system feasibility by operation of a complete breadboard system. After this has been accomplished we will be prepared to commence Task II, fabrication and test of the pre-prototype missile power supply.
(0 references, 22 tables, 0 figures, 17 pages)

B-791

L. C. Scala, Westinghouse Electric Corporation, "Separator Development for a Heat Sterilizable Battery," Fifth Quarterly Report (September 30, 1967), Jet Propulsion Laboratory Contract JPL 951525 under NASA Prime Contract NAS 7-100.

A continuous coating apparatus to prepare sterilizable battery separators has been built, tested and put into the production of several feet of separator material which exhibited satisfactory properties. The effect of time of immersion in extractant solutioning upon separator composites has been investigated using formulations in which the filler was either Zeolon H or coarse Zirconia. The best extracting solutions contained dioxane. Generally no correlation was found between some separator properties and time of immersion.
(0 references, 3 tables, 31 figures, 54 pages)

B-792

John J. O'Connell, Elizabeth A. McElhill, and Carl A. Olson, Monsanto Research Corporation. "Separator Development for a Heat Sterilizable Battery." Quarterly Summary Progress Report No. 3, MRB6234Q3, Re-Order No. 67-599 (September 30, 1967), Jet Propulsion Laboratory Contract JPL 951524 under NASA Prime Contract NAS 7-100

The following three types of ligand containing polymers are being developed for use as separator materials in sterilizable silver-zinc batteries: (1) Styrene-maleic anhydride copolymers; (2) Styrene-maleic anydride-methyl methacrylate terpolymers; and (3) 40:60 2-vinyl-pyridine-methyl methacrylate copolymer. The mechanical strength and flexibility of our styrene-maleic anhydride copolymer films has been significantly improved by using uniformly high molecular weight materials. The terpolymers have excellent film properties and are being modified to lower electrical resistivity in 40% KOH. Polymers with higher contents of hydrolyzable acrylate and anydride groups, were prepared. Insoluble polymers of this type had resistivities from 35 to 70 ohm-in. after sterilization. Polymers with very high hydrolyzable contents had some solubility in electrolyte and are being modified by cross-linking to make them insoluble. Reaction conditions for preparation of the 40:60 2-vinylpyridine-methyl methacrylate polymer were studied to increase their molecular weight. Polymerization to high conversions gave significant increases in molecular weight.
(5 references, 6 tables, 0 figures, 17 pages)

B-793

J. Hermann, S. Thornell, and M. Ruberto, Sonotone Corporation. "Optimum Structures for Miniature Ni-Cd Sealed Cells and Batteries." Quarterly Report No. 2, Technical Report ECOM 02361-2 (May 1967), U.S. Army Electronics Command Contract DA 28-043-AMC-02361(E). AD 652 700.

Electrochemical investigations have been directed toward evaluation of 1.0 A.H. cylindrical Ni-Cd sealed cells containing pasted negative plates. The investigation also includes an evaluation of the data gathered on 1.0 and 4.0 A.H. cells that have been life-cycled at the 5-hour charge rate for 200 cycles. In addition, investigations are included that evaluate charging efficiencies of the sintered positive, sintered negative, and pasted negative plates at the five-hour charge rate. Disassembly and analysis of the cells, previously tested at various temperatures, during the first quarter are also presented. Mechanical investigations have been directed towards pressure tests and stress analysis of 0.016 in. thick cylindrical cell cases, geometric progression of cylindrical cells down to 0.5 A.H., geometric proportions of 4.0 A.H. rectangular cells, and battery packaging of a 6 volt, 4.0 A.H. rectangular battery with rectangular cells. Stress analysis data are not conclusive enough to determine a numerical value of unit stress. (0 references, 19 tables, 13 figures, 65 pages)

-794

Thedford P. Dirkse, Calvin College, "Silver Oxide Electrode Processes." Technical Report No. 6 (March 1, 1967), Office of Naval Research Contract Nonr 1682 (02). AD 650 152

The cathodic and anodic overvoltages at a silver electrode were measured in a range of KOH concentrations of 20 to 45%. The values of these overvoltages undergo a change in 30 to 35% KOH. Similar changes or maxima or minima have been observed for other phenomena in KOH solutions, e.g., double layer capacitance. An attempt to account for these changes is made in terms of ion-pair association in concentrations greater than 35% KOH. This association is due to insufficient solvent for the normal hydration of the ions. (13 references, 0 tables, 11 figures, 20 pages)

-795

M. M. Nicholson, H. L. Recht, and R. E. Kelchner, Atomics International, Division of North American Aviation, Inc., "Radiation Effects on Silver and Zinc Battery Electrodes. V." Interim Report, AI-66-186 (October 14, 1966), Jet Propulsion Laboratory Contract No. 951109 under NASA Prime Contract NAS 7-100, N67-11722.

The investigation of gamma radiation effects on silver electrodes at 60% and 30% states of charge was continued during this report period. Net capacity increases averaging 5% have been observed during recent irradiations at the 60% level with a total dose of 6 x 10^7 rads (H_2O). At 30%, net losses of 4% and 15% were found in the two runs, respectively. When these results are considered with those of earlier runs, it appears that the losses at 30% may be significant, while the changes at 60% are essentially within the uncertainty of the measurements. Hydrogen was again evolved during the irradiation of silver-cadmium cells. In one run two silver electrodes were cycled

one against the other in the absence of cadmium. Hydrogen and oxygen were then produced in a mole ratio of 1.7:1. Work with zinc electrodes was concentrated on the development of a reproducible procedure for determination of discharge capacity. This was partially accomplished by the use of cellophane-wrapped zinc electrodes in starved-electrolyte cells. With that construction, the capacity will offer at least a semiquantitative criterion for the evaluation of radiation effects.
(4 references, 8 tables, 2 figures, 22 pages)

B-796

G. C. Szego, Institute of Defense Analyses, Research and Engineering Support Division. "A DOD Research Program for Electrochemical Science with Applications to Energy Storage and Conversion." Study S-208, IDA/HQ66-4749 (December 1965). AD 635 503 (FC-3968)

The state of the art of batteries and fuel cells is reviewed in some detail. The problem areas in which difficulties are being experienced, and which are limiting the fruitful use of electrochemical devices, are given in detail. The contributing or limiting factors, promising approaches to these problems, and related fundamental research areas are identified. A series of recommendations is made for systematically improving greatly the position of the United States in electrochemical technology and science. The cost of this program is outlined. Details are given in depth of the precise areas and character of the programs suggested in the recommendations. Comparisons are made with the existing program, which is felt to be greatly in need of modification. (37 references, 6 tables, 0 figures, 130 pages)

B-797

The Electric Storage Battery Company, RAY-O-VAC Division. "Manufacturers Information"

The LeClanche (Zinc-Carbon) Battery System. The Mercury Primary System. The Zinc Silver Oxide Battery System. The Cadmium Mercuric Oxide Battery System. The Magnesium Cuprous Chloride Battery, The Magnesium Silver Chloride Battery.

B-798

B. V. Belyaev, "Inspection of the State of Power Supplies as Self-Contained Devices." Automation and Remote Control, 27, 1771-1773 (April 1967).

It is shown that the concepts of interdependence of the parameters of chemical power sources can serve as a basis for determining the source capacity by measuring its emf, voltage (under load), and short-circuit current without resorting to discharge. A comparison between theory and experiments confirms the validity of the proposed method.
(4 references, 0 tables, 3 figures, 3 pages)

799

B. V. Belyaev, "Reliability of Chemical Sources in Automatic Control Circuits." Automation and Remote Control, 26 (1), 169-172 (January 1965)

Consideration is given to a determination of operating characteristics for the chemical current sources used in autonomous electron relay devices so as to permit a sound choice of a power supply's parameters and an evaluation of its reliability in operation. It is shown that there is a general relationship for the discharge characteristics of the most widely used class of chemical current sources, and that the internal impedance determines the capacity value to a considerable extent while it defines the dependence of capacity and voltage on temperature almost entirely.
(0 references, 0 tables, 4 figures, 4 pages)

800

P. G. Garratt and S. E. A. Pomroy, Royal Aircraft Establishment. "Continuous Charge-Discharge Cycling Studies on Hermetically Sealed Nickel-Cadmium Cells Operating at a 10 Percent Depth of Discharge." Technical Report No. 66045 (February 1966). AD 802 841.

Hermetically sealed nickel-cadmium cells are being subjected to continuous charge-discharge cycling studies in order to investigate their performance at various temperatures and depths of discharge. This report covers one year of cycling, which simulates the maximum dark period conditions (10% depth of discharge) predicted for the U.X.3 satellite. No cell failures have been observed over the temperature range -10°C to 50°C during the first 6000 cycles. Cell performance studies showed some deterioration in cells cycled at 40°C and 50°C, although their performance under charge-discharge cycling was not noticeably affected.
(4 references, 2 tables, 4 figures 48 pages)

801

J. W. Mauchly, J. H. Waite and S. D. Epstein, Mauchly Systems, Inc., "NICD Space Battery Test Data. Analysis Project. Phase 2." Second Quarterly Report (May 1, 1967-July 31, 1967), NASA Goddard Space Flight Center Contract NAS 5-10203.

The data acquisition system in NASA's space battery evaluation program requires updating for reasons of economy and to provide information in a form suitable for analysis and computer reporting. The optimum in performance can be obtained at minimum cost with reasonably priced on-line computer systems replacing the manually operated punch-tape system and adding automatic recording functions directly on magnetic tape. Seven solutions to the problem are studied. The cost of continuing the present outdated system was considered. A functional flow chart was constructed illustrating the features of each approach. Differences are indicated in terms of performance. Hardware required for any and all systems is available and has been proven in service. Cost estimates are based on actual prices obtained from vendors. An automated computer system costing $335K is recommended as the best solution. It will enable data collection and handling at a rate 1000 times greater than present. It will free the human to do more challenging tasks not within the scope of being programmed for the computer. It will eliminate expenditures in excess of $30K per year now used simply to transfer data from punch tape to magnetic tape. It will bring the day of accelerated testing of space batteries closer. The possibilities with this new recommended system are obviously extensive and beyond the imagination. (0 references, 1 table, 0 figures, 8 flowcharts, 30 pages)

3-802

H. N. Seiger, S. Charlip, and A. E. Lyall, Gulton Industries, Inc., and C. Cason, U.S. Army Missile Command. "A Study of High Current Densities in Nickel-Cadmium Bipolar Batteries." Final Report (October 1966), U.S. Army Missile Command Contract DA-01-021-AMC-12509(Z). AD 647 468

Foil type electrodes with 3 mil substrates and 4 mil sinters were developed and assembled into bipolar cells and batteries. Tests were conducted to determine the effects on current and voltage for substrate thickness, sinter thickness, position of end terminals, separator thickness, and plate loading. None of these physical design parameters show significant effects on the change in current densities. Concentration and activation polarization are the limiting parameters of current density outputs in a bipolar nickel-cadmium battery. Calculated internal impedances were in the range of 1.5 to 3.5 milliohms·inch^2. However, experimentally determined internal impedances are 20 times higher. Reference electrode determinations indicate that activation polarization of the negative (cadmium) electrode is the most significant. Activation and concentration polarization of the positive electrode are approximately equal and account for about half of the polarization of the negative. Current densities of 12.5 amperes/in^2 have been achieved at the maximum power point of 0.6 volt per cell. This is a sixfold increase over the state-of-the-art prior to this program.
(7 references, 4 tables, 17 figures, 33 pages)

-803

J. W. Mauchly and J. H. Waite, Mauchly Systems, Inc., "Computer Methods for the Reduction, Correlation and Analysis of Space Battery Test Data." Final Report (May 1, 1966 - December 31, 1966), NASA Goddard Space Flight Center Contract NAS 5-10203.

This report describes the computer techniques developed by Mauchly Systems, Inc., on NASA Contract NAS-10203, to extract information from large volumes of spacecraft battery test data. Novel statistical methods (application of cryptanalytic-like processes) have been used to identify failure mechanisms from descriptions of failed cells, and to predict cell life from data patterns hidden in the test data. Computer programs have been written to reduce the cell test data for a desired interval of time or for any selected measurement parameters, and to produce output documentation easy to understand by the spacecraft design engineer. The results of these programs include specific predictions of failure, many thousands of cycles before actual failure from less than 1000 cycles of data. (0 references, 3 tables, 0 figures, 43 pages)

3-804

James McBreen, Yardney Electric Corporation, "Study to Investigate and Improve the Zinc Electrode for Spacecraft Electrochemical Cells." Final Report (October 1967), NASA Goddard Space Flight Center Contract NAS 5-10231.

The diffusivity of zincate in free alkaline electrolyte has been investigated as a function of KOH concentration and temperature. A qualitative explanation is given for deviations from the Einstein-Stokes equations. Mossy Zinc whiskers are deposited under activation controlled conditions and acicular dendrites are deposited under diffusion controlled conditions. No intermediate form of deposit has been found. Plastic separator membranes in equilibrium with zincate electrolyte is less than one and varies by a factor of seven for the membranes tested. The zincate diffusivity in plastic membranes is directly proportional to the conductivity of the membranes in the alkaline electrolyte. Both parameters are related to the pore sizes of the membranes. When a membrane is in close abuttal to a zinc electrode in alkaline electrolyte, the overvoltage required to initiate zinc growth in the membrane has to be greater than that required to produce dendrites on the electrode. Once the overvoltage is sufficient to produce dendrites zinc growth occurs in cellulosic membranes. Membranes such as C-3 (Borden Chemical Co.) can tolerate overvoltages up to 100 mV in excess of that required to produce dendrites without any zinc growth occurring in the membranes. Silver zinc cells have been cycled using a zinc overvoltage cutoff (75 mV). No penetration of the membranes occurred under these conditions. High resistivity membranes accelerate shape changes. The best shape retention was found with low resistivity cellulose membranes. (2 references, 5 tables, 23 figures, 43 pages)

3-805

J. R. Kent, U. S. Naval Ammunition Depot, Crane, Indiana. "Analysis and Evaluation of Spacecraft Battery. Life Test Data." Summary Report QE/C 67-592 (November 1967)

This report presents the findings from the statistical and reliability analysis of large volumes of data on NASA spacecraft batteries. This data was generated from a life cycling test of 660 nickel-cadmium battery cells which was conducted by NAD Crane beginning in December 1963. A major objective of this work is to develop a life prediction method to reliably estimate the life of any cell after a limited number of test cycles and, hence, allow the screening of inferior battery cells. A promising method is proposed where, after 1000 test cycles, the ultimate cycle lives of cells are predicted and the probability that an inferior cell would be rejected was estimated to be 90.5%. The probability that a good cell would be accepted was estimated to be 84.5%. The test results indicate that the number of test cycles necessary for reliable prediction may be further reduced to a few hundred cycles. No previous method existed to serve this function. Improved design of future experiments and analysis of existing data not analyzed to date are recommended for future work to establish the minimum number of test cycles required and the extent of applicability of this method to any future spacecraft battery operation. For further refinement of this and similar methods, more frequent cycle monitoring is recommended for future testing. Additional analysis of failure mode data is needed to correlate failure characteristics with environmental conditions. (0 references, 20 tables, 8 figures, 52 pages)

B-806

E. C. Bruess, U.S. Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells. Third Annual Report of Cycle Life Test." Report QE/C 67-685 (November 3, 1967), NASA Goddard Space Flight Center Contract W11, 252B.

A total of 58 of the original 84 packs have failed. The remaining 26 packs have completed from 978 to 1123 days (a maximum of 17,962 1.5-hour cycles) of continuous cycling as of 31 December 1966. The status of each pack is given in Table III and Figures 3(a) through 3(g). It was found that 50°C was in general, an unsatisfactory ambient temperature, for the specified currents and orbit periods, due to inefficient charge acceptance and accelerated separator deterioration. There have been 304 cell failures as of 31 December 1966. The table below shows the distribution according to test parameters and cell types. (0 references, 24 tables, 184 figures, 431 pages)

B-807

Raymond Jasinski, Brian Burrows, and Paul Malachesky, Tyco Laboratories, Inc., "High Energy Batteries," Final Report (October 1967) U.S. Naval Air Systems Command Contract NOw 66-0621-c.

The research effort was concerned with two general systems: (1) Lithium batteries based on organic aprotic solvents and (2) aqueous AgO/Zn batteries. Techniques were established for reducing the impurity content of propylene carbonate to < 10 ppm. A Li/Li^+ reference electrode was developed for use with $LiClO_4$/PC solutions. Thin film Cu/CuF_2 electrodes were formed by electroplating in anhydrous HF-KF. The discharge behavior of silver oxide was studied in aqueous KOH. Charge acceptance was a pronounced function of current density for silver and its alloys with Pb, Pd, and Au. The lead and palladium alloys increased in roughness with cycling due to leaching of the metal. Most of the improved charge acceptance was because of this factor. However, the decomposition of AgO was more pronounced. Amalgamated silver and gold are satisfactory O_2-removal electrodes for AgO/Zn batteries. Hydrogen evolution is of the same order as on zinc. Pre-electrolysis of aqueous KOH will introduce trace impurities into solution if the electrode is allowed to reach O_2 evolution. Holding the electrode at 0 mv vs. a $H2/H^+$ electrode will purify the solution and not dissolve the electrode metal.
(67 references, 36 tables, 58 figures 177 pages)

B-808

Z. P. Arkhangel'skaya, N. V. Berezina, and I. N. Shuvalova, "Ways to Increase the Electrical Characteristics of Positive Electrodes in Silver-Zinc Batteries," Issled. Obl. Khim. Istochnikov Toka, 105-113 (1966)

The most complete oxidation of the active material of Ag oxide electrodes was achieved by using finely dispersed materials (e.g., Ag_2O with a particle size of $\sim 2\mu$). For the complete charging of electrodes prepared from Ag_2O, 150-200% of the theoretical capacity was sufficient. The utilization factor of the active material of the Ag_2O electrodes can be raised to 98% by charging them with an asym. current; at the same time the initial discharge potential is decreased. To achieve a maximum increase in the utilization factor of the active material of an Ag oxide electrode or a maximum decrease in the initial discharge potential, different charging conditions with an asym. current are required. An increased stability of the active-material phase component and of the capacity of the electrodes during long storage is achieved by obtaining a practically single-phase component of the active material, containing small amounts of Ag_2O ($\leqq$ 2%), during formation.

B-809

Texas Instruments, Inc., "Nickel and Nickel-Cadmium Containing Storage Battery Plates." Netherlands Patent Application 6,513,605, March 30, 1967, Applied September 29, 1965.

A plate with a porosity $>$ 98-99% is formed by sintering a thick layer of particle-sized materials, containing mainly Ni flakes. The pores are filled by saturating the plate with a solution of $Ni(NO_3)_2$ and (or) $Cd(NO_3)_2$. The solution in the plate is then dehydrated under vacuum at a temperature below the nitrate m.p., and the plate is treated with KOH to convert the nitrates into hydroxides. The plate is then compressed to a porosity of $\leqq$ 95%. This process gives relatively thin plates with a high content of active material. The thus-constructed batteries show a high elec. capacity with regard to their weight and volume.

B-810

A. K. Covington and T. H. Lilley, University of Newcastle-upon-Tyne, England. "The Silver Ion Response of Some Sodium-Aluminum Silicate Glass Electrodes," Phys. Chem. Glasses, 8 (3), 88-91 (1967)

The Ag^+ response of 4 Na-Al silicate glasses was studied by direct comparison with the Ag metal electrode in AgNO3 solutions (1.0-0.0001 m) at constant pH. There was little or no response shown to the Ag^+ by glasses which show Na^+ response. The error in Ag^+ response was large and linear in pAg at constant pH. A Na-response com. electrode gave almost theoretical response to the Ag^+.

B-811

R. C. Shair, S. R. Lerner, P. A. Joyner, and G. E. Evans, Gulton Industries, Inc., "A Review of Batteries and Fuel Cells for Space Power Systems." Journal of Spacecraft and Rockets, 4 (7), 833-838 (1967)

These applications of various electrochemical devices are reviewed.

B-812

Lloyd I. Shure and Harvey J. Schwartz, NASA. "Survey of Electric Power Plants for Space Application." Chem. Engr. Progr., Symp. Ser. 63 (75) 95-105 (1967)

B-813

C. A. Angell, Purdue University. "Fundamental Limitations on the Low-Temperature Operation of Electrolytic Devices." Journal of the Electrochemical Society, 114 (10), 1033-1035 (1067)

A new approach to the understanding of transport behavior in concd. electrolyte solutions requires the recognition at low temperatures of a liquid state limiting temperature which is a thermodynamic const. of any solvent-electrolyte solution. The value of this const., which det. service limits, is a function of electrolyte concentration except at low concentrations where solvent structure may dominate. The results of investigating electrolyte solutions for low-temperature battery applications are used to emphasize the usefulness of the concepts underlying this approach to low-temperature electrolyte problems.

B-814

David Tehiely, Sonotone Corporation, "Rechargeable Cell for Alkaline Battery," French Patent 1,463,836, December 30, 1966, Applied U.S., June 8, 1964

A rechargeable cell, for use as a unit of an alkaline battery contains a principal anode and an additional anode having porous Ni layer and a sensitive means of increasing the voltage between these 2 anodes. This provides for controlling the rate of current discharge across the other cells, and for inversion of the charge near the discharge stage.

B-815

Ian H. S. Henderson Stephan G. Ladan, Minister of National Defence, Canada. "Nickel Cadmium Batteries." U.S. Patent 3,326,721, June 20, 1967. Applied June 10, 1964.

In the manufacture of alkaline storage batteries employing Cd as the active material of the negative plate, an improvement is described so that the Cd can be produced by electrodeposition. This Cd plate is an adherent and coherent electrochemically active Cd sponge deposit. The Cd sponge is deposited from a bath of aq. $CdCl_2$ (175-400 g./l.) and KCl (9-20 g./l.)

solution. The KCl concentration is equal to 0.089 (400-2), where w is the concentration of $CdCl_2$ in g./l. The cathodic c.d. is between 1-20 ma./cm.^{2} The temperature is 20-25^0 and the Ph 5.0-6.00. The sponge can be plated on Ni foil.

B-816

Societe des Accumulateurs Fixes et de Traction, "Cobalt-Impregnated Electrodes," French Patent 1,467,270, July 27, 1967, Applied December 17, 1965.

An improved treatment for activating Co-contg. electrodes for alkaline batteries is described. The heated (90^0) Ni electrode is immersed in a hot (95^0) Ni-$(NO_3)_2$ solution, washed, dried, exposed to steam for 4 hours, immersed in a solution containing 250 g. NaOH/l., and again washed and dried. The Co in the $Ni(NO_3)_2$-$Co(NO_3)_2$ solution is preferably 40% of the total amount of the 2 metals.

B-817

Shiro Yoshizawa, Zenichiro Takehara, and Mitsuya Kato, Kyoto University, Kyoto, Japan. "Effects of Various Additives on the Charge and Discharge Reactions of a Nickel Hydroxide Electrode." Denki Kagaku, 34 (8), 559-563 (1967)

The effects of Li and (or) rare earth metal ions added to an electrolyte on the charge or discharge reaction of Ni $(OH)_2$ electrode were examined. By the addition of Li^+ to an electrolyte, the diffusion velocity of protons within an electrode was promoted during charging, but was delayed during discharge. The potentials of O generation on an electrode being charged were higher, and the amount of chargeable $Ni(OH)_2$ increased. The addition of Li^+ to an electrolyte effectively improved the use of $Ni(OH)_2$. The addition of rare-earth compounds increased the discharging capacities.

3-818

Kuranobu Sugita, "Hermetically Sealed Nickel-Cadmium Storage Batteries. Test Results of Small Cells and Experiments on Oxygen Consumption by Cadmium." Denki Kagaku, 35 (1), 37-42 (1967).

The quality of the 5 common storage batteries was examined by indoor tests. Two kinds of cylindrical Ni-Cd batteries were satisfactory for practical use. The relation between charging current and internal pressure was observed under various conditions on a trial cell which was composed of a hermetically sealed vessel and 2 or 3 electrodes set within the vessel. The internal pressure of the cell was affected by temperature and did not reach an equil. at 5^0 due to the generation of H when the cell was overcharged at 30 ma. The internal pressure was affected by the surface area of the cathode also, and the increase of the pressure was nearly proportional to the surface area of the cathode. The increase of the pressure was reduced by the restriction of the amount of electrolyte contained in separators.

B-819

Joseph J. Holechek and Henry W. Matteu, Catalyst Research Corporation. "Silver Oxide Electrodes for Batteries," U.S. Patent 3,332,801, July 25, 1967, Applied November 12, 1963.

Battery electrodes are prepared by embedding a metal grid in a mass of finely divided AgO and (or) Ag_2O or a mixture of the oxides with Ag, then compressing the powder to form a porous compact plate which is adherent to the metal grid. Thus, 5 g. of a 3/1 AgO/Ag mixture (325 mesh) is evenly distributed over the bottom of a 2 x 2.5 inch rectangular die cavity. A grid of #4/0 mesh expanded Ag metal is placed on the powder, then an additional .5 g. of the AgO/Ag mixture is added. The electrode is then formed with an applied pressure of 20 $tons/in.^2$.

B-820

R. A. Powers, Union Carbide Corporation, Consumer Products Division. "Development of Secondary Cadmium-Oxygen Cells for Spacecraft Applications." First Quarterly Report (April 1, 1967-June 30, 1967), NASA Goddard Space Flight Center Contract NAS 5-10384.

Two modifications of a cadmium-oxygen unit cell with a theoretical capacity of 10 ampere-hours have been developed. Actual capacity obtained is 5 ampere-hours. In one modification, a Union Carbide "fix-zone" cathode is combined with a cadmium negative and a third electrode for charging the cadmium. Over 300 cycles at 100% depth of discharge have been obtained on a 2 hour charge/2 hour discharge regime. The average output is 8.76 watt-hours per pound based on the weights of electrodes and electrolyte. The second modification uses an American Cyanamid Co. "Lab-40" cathode and a cadmium negative with no separate charging electrode. Charging is accomplished directly between the cadmium electrode and the Cyanamid electrode. Reduced cell spacing with resulting decreased electrolyte requirement and increased operating potential is realized in this construction. As a result, a capacity of 10.6 watt-hours per pound is obtained. The cell construction is also simplified. Over 250 cycles at 100% depth of discharge have been attained on a 2 hour charge/2 hour discharge regime. The cadmium negative used in these cells is an electrodeposited electrode previously developed by Union Carbide for nickel-cadmium batteries. The stock of material on hand at the start of this contract had a nominal capacity of 0.031 ampere-hours per square cm. Increased capacity has been demonstrated by using multiple layers of this stock. (5 references, 5 tables, 5 figures, 13 pages)

B-821

J. McCallum, G. R. Schaer, D. G. Trevethan, and C. L. Faust, Battelle Memorial Institute. "Development of Large-Internal-Surface-Area Nickel-Metal Plaques." Final Report, NASA-CR-54831 (September 30, 1965), NASA Contract NAS 3-6003. N66-14376

Porous nickel electrodes having preselected pore sizes and pore shapes were made. They were impregnated with cadmium in various forms and evaluated as rechargeable cadmium electrodes. The results showed a need to understand the changes that occur with cycling of cadmium electrodes. Impregnation of active cadmium into the porous nickel plaque was found to be a critical variable. The use of fused cadmium nitrate hydrate followed by a hot soak in potassium hydroxide solution was found to be preferred. Additional ways to decrease the weight of cadmium electrodes were implied by the results obtained: (1) The weights of active positive and negative materials should be more closely balanced stoichiometrically. (2) Pore volumes should be filled more than the present commercial practice of about 40 percent. (3) Electrode plaques should have straight-through pores with electrode thickness equal to about twice the pore diameters.

B-822

R. F. Fogle and W. R. Scott, TRW Systems Inc. "Study of the State-of-the-Art of Hermetic Seals for Secondary Alakline Spacecraft Cells." Second Quarterly Report (September 20, 1967 - December 20, 1967), NASA Goddard Space Flight Center Contract NAS 5-10432.

It is apparent from both the questionnaire responses and direct discussions with users, test organizations and manufacturers that there is no uniformity of the methods and procedures used for testing the integrity of hermetic seals (leak test especially). In addition, no universally accepted test methods appear to be available.

The conceptual analysis of commercially used hermetic seals showed that these seals are not capable of meeting all the requirements for long life space cells. Some attempts to adapt commercially manufactured hermetic seals to meet the rigid requirements for space cells have been unsuccessful and others are in the evaluation stage, but at present, no hermetic seal has the capability required for space cell application.

Some of the hermetic seals not presently manufactured on a commercial scale (seals in research and development stage) show promise for space cell application. Those seals, such as the Zigler seal and the devitrified glass seal, that show promise for space cell application, do so because they eliminate or greatly reduce the problems (chemical attack, silver migration) associated with the type of seals presently used.
(0 references, 3 tables, 0 figures, 15 pages)

-823

H. Frank and M. P. Strier, McDonnell Douglas Corporation, Astropower Laboratory, "Sealing of Silver Oxide-Zinc Storage Cells." Second Quarterly Report, DAC-59860-Q2 (December 23, 1967), NASA Goddard Space Flight Center Contract NAS 5-10409.

The objective of this program is to evaluate the use of rechargeable micro fuel cells in controlling internal pressure of secondary silver oxide-zinc cells. This will permit operating these cells in the hermetically sealed condition under a wide range of operating conditions.

The miniature fuel cells perform this pressure control function by electrochemically consuming evolved gases (H_2 and O_2) from the silver-zinc cell. In practice, this is carried out by incorporating the miniature fuel cells directly into the gas head space of the silver-zinc cell or a small chamber which communicates with this head space. In this manner the miniature fuel cells are exposed to and consume the evolved gases.
(1 reference, 8 tables, 5 figures, 26 pages)

B-824

E. A. Butler and A. U. Blackham, Brigham Young University, "Studies of Reaction Geometry in Oxidation and Reduction of the Alkaline Silver Electrode." Second Quarterly Report (November 15, 1967), Jet Propulsion Laboratory Contract JPL 951911 under Prime Contract NAS 7-100. Re-Order No. 67-666.

A polarization curve of the silver anode in ammoniacal electrolyte suitable for use in comparing our current density distribution data with a theoretical analysis of current density distribution has been obtained. Attempts to use this system in a determination of surface area of a sintered silver electrode have failed.

Sintered silver electrodes consisting of spherical silver particles of known diameters were prepared. These were oxidized and their effective electrolytic surface area was determined. These experimental surface areas agreed well with calculated areas when particles in the 24-48 micron size range were used. Agreement was not as good with smaller particles.

Silver foil electrodes were oxidized with and without ultrasonic vibrations to determine the effect these vibrations would have on the charging capacity. Increases of 8% and 25% were observed for two different current densities. These increases are attributed to increased surface area caused by fracturing of the oxide layer by the vibrations.
(5 references, 4 tables, 3 figures, 19 pages)

B-825

J. Goodkin, Yardney Electric Corporation, Inc. "Long Life Stable Zinc Electrode for Alkaline Secondary Battery." Second Quarterly Report, Technical Report ECOM-0185-2 (December 1967), U.S. Army Electronics Command Contract DAAB07-67-C-0185

The curing temperature studies of Teflonated zinc oxide as a parameter of the performance of zinc electrodes has been continued. Data have been obtained for 30% D.C., 60% D.D. and charge rates of both .3 and .6C. The overall results show that the curing temperature should be no higher than 300°C, and probably closer to 275°C. Electrodes prepared from such material have cycle lives from two to three times that of the control electrodes.

Teflon concentration studies and the effect of this parameter on the performance of zinc negative electrodes have been initiated. Measurements have been made in the range of between 5% and 7% Teflon. The first study was conducted as a two dimensional surface response. with temperature as the second dimension. An equation has been obtained for the effect of temperature and concentration on cycle life performance. The data indicate a probable increase in cycle life with increasing Teflon content.

Negative electrode-to-positive electrode area ratio and zinc-to-silver weight ratio effects on cell performance are being evaluated. This study also included an effect of Teflon concentration. The study consisted of an 8-cell box surface response design, using the three variables mentioned above. At the time of this report, 125 cycles have been taken from the cell, with no indication of the effect of variables. Cycling of these cells is being continued.

Calcium hydroxide in stoichoimetric concentrations, to prevent shape change, has been investigated. Its use in silver-zinc cells, where high concentrations of KOH are required, is counter-indicated by the substantial loss in capacity during initial cycles. Its usefulness for this purpose is also limited by the fact that the weight and volume of the cell is materially increased by the addition of large quantities of calcium hydroxide.

Carbon-activated third electrodes as signalling devices for cells containing zinc electrodes has been investigated. Initial evaluations show that a good differential current is obtained at the end of charge. This work will be pursued further during the course of this program.
(0 references, 15 tables, 14 figures, 42 pages)

-826

Gerald Halpert, NASA Goddard Space Flight Center. "A Fortran IV Program for Calculating and Plotting Surface Area and Pore Size Distribution Data Obtained by the BET-Gas Adsorption Method." Report X-735-67-505 (October 1967)

Surface area and pore size distribution of materials can be determined using the gas adsorption method of Brunauer, Emmett and Teller (BET), and Pierce. Both techniques involve lengthy, tedious calculations. A Fortran IV program was developed to facilitate the calculating process. The above-mentioned techniques and the computer program are the subject of this paper.
(4 references, 0 tables, 5 figures, 19 pages)

-827

Paul F. Bruins, Polytechnic Institute of Brooklyn, "Calorimetric Study of the Thermodynamic Properties of the Nickel-Cadmium Cell." Six-Month Report, NASA CR-63338 (October 1, 1964 - April 1, 1965), NASA Project SC-NGR-33-006-015. N65-85671.

The progress to date includes the fabrication of an adiabatic calorimeter and the design and fabrication of an electrical system to maintain adiabatic conditions within the calorimeter. The electrical system consists of a sensing unit (a matched pair of thermistors incorporated in a bridge network), power supply for the bridge network, amplifier power supply and amplifier, and a silicon controlled rectifier-firing circuit.

Currently, we are engaged in preparing the Nickel-Cadmium cells for various phase of experimentation to be performed on them. We are also engaged in designing a suitable seal which will allow for the ready removal of the thermistor placed within the cell and which will prevent leakage of oxygen during overcharge. (0 references, 0 tables, 8 figures, 9 pages)

B-828

E. C. Bruess, U.S. Naval Ammunition Depot. "Evaluation Program for Secondary Spacecraft Cells. Acceptance Test of Svenska Ackumulator Aktiebolaget Junger of Sweden 3.9 Ampere-Hour Nickel-Cadmium Cells." Report QE/C 67-681 (November 21, 1967), NASA Goddard Space Flight Center Contract W11,252B.

From the results of this test, it can be concluded that:

1. The compression seals are satisfactory as evidenced by no leakers out of the 16 cells tested.
2. The capacity of the 16 cells was in the acceptable range of 3.90 to 4.26 ampere-hours.

(0 references, 1 table, 3 figures, 8 pages).

B-829

S. Lerner, Gulton Industries, Inc., "Characterization of Recombination and Control Electrodes for Spacecraft Nickel-Cadmium Cells." Final Report (June 9, 1966 - June 9, 1967), NASA Goddard Space Flight Center Contract NAS 5-10241.

The objective of this program was to develop a sealed nickel-cadmium cell having a signal electrode, whose signal can be used for spacecraft charge control in near earth orbits. In such orbits, signal-electrode charge control is made difficult by the residual oxygen pressure present in the cell at the end of discharge. One way of overcoming this problem is by incorporating an oxygen-scavenging electrode in the cell.

In the first phase of this work, the Gulton Adhydrode and fuel cell materials from Leesona Moos and American Cyanamid were critically evaluated for use as scavenger electrodes. The material developed by American Cyanamid (AB6X) was found best for recombination purposes.

The second phase dealt with the signal electrode. The work in this phase was limited to improving the effectiveness of the Adhydrode as a signal electrode by determining the optimum location for it in the cell. Cells constructed with the Adhydrode in the end of the pack, center of the pack, and U-shaped (around the pack edge) were tested. The best signal-to-pressure response was exhibited by the Adhydrode in the center of the pack.

The third phase involved design, construction and testing of cells making use of the results of phases one and two. These tests showed: 1) the recombination rate of oxygen in cells with scavenger electrodes is greater than that in cells without scavenger electrodes; 2) consequently, the cell pressure (and the Adhydrode signal) decays sufficiently during a short discharge to allow for immediate recharge, and the apparent point of vigorous oxygen generation is delayed when charging; 3) cells containing the AB6X fuel cell material have a hydrogen scavenging ability; and 4) cycling at 60% depth of discharge in a near-earth orbit is a feasible mode of operation with signal-electrode charge control. However, degradation in cycle life is experienced at this depth of discharge.
(0 references, 8 tables, 34 figures, 53 pages)

B-830

G. Baumstark, S. Thornell, and A. Fitchman, Sonotone Corporation. "Cell-Core Compression Studies on Nickel Cadmium Cells." Final Report, NASA CR-72317 (November 1967), NASA Lewis Research Center Contract NAS 3-6001.

This final report covers the research performed on Sonotone sealed nickel-cadmium cells in which the cell-core assemblies were maintained at a known compression. The compression of these rectangular cell-cores was accomplished by the incorporation of two leaf-type springs within the cell assembly.

Static and dynamic tests were performed at various, discrete compression forces, ranging from 0 psi to over 100 psi. Data compiled indicate that little, if any, change in the charge-discharge characteristic was achieved by variations in the force applied to compress the cell cores; but there were definite indications that a cell under optimum compression may be immune to damage caused by prolonged over-discharge.
(0 references, 17 tables, 32 figures, 108 pages)

B-831

I. O. Salyer, E. V. Kirkland, P. H. Wilken, and R. J. Taylor, Monsanto Research Corporation. "Silver-Zinc Battery Separator Material Development." Second Quarterly Progress Report (January 10, 1968), Jet Propulsion Laboratory Contract JPL 951966 under NASA Headquarters Prime Contract NAS 7-100

Several ethylene/methyl acrylate copolymers have been synthesized in a small batch-operated autoclave at high pressures. By controlling the degree of conversion and incremental monomer addition, the product composition may now be predetermined, despite unfavorable monomer activity ratios. The molecular weight of the polymer product can also be controlled now by incorporating a chain transfer agent so that product with a desirable melt viscosity may be predetermined. The third purpose of the synthesis work - namely, preparing adequate samples of different compositions for subsequent test work - will be accomplished as soon as possible. The copolymer composition currently is calculated from elemental analysis of carbon and hydrogen content; this appears to be the most precise method at the moment. A thin film of polymer (about 1 mil) has not been successfully prepared by hot pressing, but it has been successfully prepared by casting from a warm dope. In the latter process, the film is vulcanized in a separate step. Samples of film for more than test work may be prepared by blow extrusion. The resistance (Ra) of a recently prepared membrane (5.3 mil thick, dry) of ethylene/acrylic acid copolymer was measured as 0.55 ohm-in^2. The bridge employed has been shown to be satisfactory for resistance measurements by means of a reference membrane sample supplied by JPL. (0 references, 4 tables, 1 figure, 16 pages)

B-832

P. V. Popat and E. J. Rubin, Texas Instruments Incorporated, "Heat Sterilizable Ni-Cd Battery Development." First Quarterly Report (July 1, 1967 - September 30, 1967), Jet Propulsion Laboratory Contract JPL 951972 under NASA Headquarters Prime Contract NAS 7-100.

Contractual work conducted during the first quarterly reporting period was concerned with construction of testing stations, preliminary separator and seal evaluation and definition of the basic problems associated with the effects of heat sterilization on the electrochemistry of the Ni-Cd systems. Early in the program a panel consisting of 60 test stations which monitor current, voltage and resistance of the cells was constructed. This panel was subsequently integrated into our existing data acquisition system which automatically records the pertinent electrochemical parameters.

Several polypropylene separators were selected for further evaluation on the basis of their thermal and chemical stability of 7N KOH. Approximately forty cylindrical cells were constructed using these separators. Pellon 14019 separator is the most promising in terms of lower voltage, lower resistance, higher capacity and lower uniformity both before and after sterilization. All cells evaluated exhibit an increase in end-of-charge voltage after sterilization. This effect cannot be explained by resistance increases and is believed associated with morphological changes at the cadmium electrode.

At present glass-to-metal seals which are protected by a KOH resistance coating have been the most successful in undergoing heat sterilization. A decision on the final design as well as materials of construction will be made during the second quarter.
(4 references, 12 tables, 3 figures, 34 pages)

B-833

E. A. Butler and A. U. Blackham, Brigham Young University. "Studies of Reaction Geometry in Oxidation and Reduction of the Alkaline Silver Electrode." Third Quarterly Report (January 10, 1967), Jet Propulsion Laboratory Contract JPL 951554 under NASA Headquarters Prime Contract NAS 7-100. Re-Order No. 67-36.

1. Equipotential maps for several electrode configurations have been drawn and related to current distribution and electrode geometry. Potential differences and solution resistivities have been plotted as functions of temperature. From these plots there appears to be an approximately linear relationship between potential difference and resistivity.
2. An extension of surface area determinations which includes sintered silver electrodes has been made. Data are presented which show the dependence of depth of penetration upon temperature.
3. Determinations of products of pyrolysis of sintered silver electrodes in high purity helium have altered slightly the conclusions of the previous report. The absence of low molecular weight hydrocarbons in these pyrolyses indicates that the residue is essentially carbonaceous in nature.

(5 references, 4 tables, 11 figures, 22 pages)

B-834

A. A. Pospelov and V. G. Chukhlantsev, S. M. Korov Ural'sk. Politekh. Inst., Sverdlovsk. "Use of Freezing in the Production of the Active Material for Alkaline Batteries." Izv. Akad. Nauk SSS$, Neorg. Mater., 3 (4), 747-749 (1967)

The effect of freezing on the sedimentation vol., moisture content, and filtration properties of gel or amorphous ppt. of Ni $(OH)_2$, used in the production of positive alkaline battery plates was investigated. $Ni(OH)_2$ was prepared by the addition of a 350 g NaOH/l. solution to a 189 g $NiSO_4\cdot{}^2/H_2O$/l. solution at $40-50^{\circ}$ with constant stirring. The final mixture had the following composition: 62.7 g. $Ni(OH)_2$, 86.2 g Na_2SO_4, and 9.5 g. NaOH, total volume 1050 cc, H_2O 87%. It was frozen at -6°, -10°, and -20°. Complete freezing was attained after 4, 2, and 1 hours, respectively. Freezing coagulates the $Ni(OH)_2$ suspension. The sedimentation volume decreases by only 40-50%, but the time necessary for the filtration of the suspension was reduced by a factor of 50-120. The sedimentation volume of the $Ni(OH)_2$ ppt. was 32-37 cc. at -6° with a filtration time of 50-65 seconds. The respective figures at -20° were 53-58 cc and 3.5-4 minutes. The freezing effect at lower temperatures is less pronounced due to the increased freezing rate. During the freezing of the investigated system, $Na_2SO_4\cdot 10H_2O$ crystals are formed initially, after attaining the eutectic concentration a mixture of ice and $Na_2SO_4\cdot 10H_2O$ crystals appears, and even after reaching -20°, liquid inclusions are still present in the system. The method offers excellent possibilities for improving of the filtration characteristics of gel suspensions in a high salt content system. The activity of $Ni(OH)_2$ can be increased by pptn. at lower temperatures and from solutions of 10 times more dil. Detailed properties of $Ni(OH)_2$ prepared from different initial solutions are tabulated and compared with the improvement caused by freezing. Several hints are given for the applicability of the proposed process to the production of active Fe material for the negative plates of Ni-Fe alkaline batteries. The method is strongly recommended for the production of finely divided powders used in porous electrodes, catalysts, etc. (Abstract only)

B-835

Frederick P. Kober, General Telephone and Electronics Laboratories, Inc., "Nickel Electrodes for Alkaline Batteries." U.S. Patent 3,335,033. August 8, 1967, Applied August 27, 1964.

Porous plaques of sintered Ni are impregnated with $Ni(OH)_3$ by continuous anodic polarization in an ammine Ni bath preferable at Ph 10-11 and a temperature of 45°. The c.d. is adjusted to 0.4-1.0 amp./in.^{2}. The current is applied for periods of 25 minutes separated by a 5-minute interval of zero current for a total of 20 hours. The resulting impregnated plaque is removed from the bath and charged in KOH or NaOH solution following which it is washed with deionized H_2O at ~70° and dried at 80°. Any excess NH_3 which may be trapped in the pores of the plaque is removed during the charging process. It is claimed that this method is less time consuming and the electrodes are less contaminated and have longer shelf life. (Abstract only)

B-836

Robert Carmichael and William V. Vulpio, Union Carbide Corporation. "Galvanic Cell Pressure Vents." German Patent 1,247,430, August 17, 1967, U.S. Application, February 25, 1960

Galvanic cell is provided with a U-shaped cover consisting of a gasket and a gas-permeable, alkaline electrolyte-impermeable diaphragm, the bursting strength of which depends on its thickness and type of material. As tests with 50 storage cells indicate, the use of the diaphragm prevents bursting of the cells. Bursting pressures and permeability consts. are given for various polymers. (Abstract only)

B-837

Societe des Accumulateurs Fixes et de Traction. "Electrodes for Electric Batteries." French Patent 1,469,157, February 10, 1967, Applied December 28, 1965

A porous material, preferably electric conducting (sponge metal), and serving as a support for the active material of the electrode, was used for separating the 2 phases, (1) gas or liquid passing through it and (2) the electrochemical active solid trapped in its pores. The liquid or gas serving as the vehicle was inert to the porous material and to the active solid. An electrochemical inactive but electric conducting material was mixed with the active solid. The adhesion of the active solid to the porous material was improved by adding a binder (CM-cellulose). The chemical state of the active solid immediately produced a current when the electrode was mounted in a battery, as e.g. in a Ag-Zn battery. (Abstract only)

B-838

F. I. Kukoz, "Experimental Study of the Swelling of a Lamellar Nickel-Oxide Electrode in a Battery." Issled. Obl. Khim.-Istochnikov Toka, 1966, 3-12.

The swelling kinetics of mass-produced electrodes during impregnation and cycling was studied in a thermostat with continuous measurement of the thickness of the plates. The thickness reached a limit 1 hour after immersion in the impregnating solutions; this limit increased in the solution order KOH, NaOH, LiOH (4N). For the 1st 3-4 cycles, the thickness increased during both charging and discharging, and as a result electrochemical swelling was 3 times greater than impregnation swelling for an LiOH solution, 6.5 times greater for an NaOH solution, and 22.4 times greater for KOH. With further charge-discharge cycling, the thickness continued to increase since its increase during discharge was greater than its decrease during charging, although the thickness increment with charge-discharge cycling decreased (especially rapidly for 10-15 cycles) and stabilized after 20-5 cycles. The stabilized relative thickness increment for 1 cycle at the 30th cycle in the order LiOH, NaOh, and KOH was ~35, 40, and 50% (~3 x 10^{-2} -- 6 x 10^{-2} mm.). Swelling was independent of the time of immersion of the electrode in a solution without a current, but was proportional to the amount of electricity passing through and increased with polarization c.d. The capacity varied proportionally to the swelling. Combinations of solutions, the addition of SiO_2, the effect of electrode resting, etc., were also studied. (Abstract only)

B-839

Joseph M. Sherfey, NASA. "Bonded Elastomeric Seal for Electrochemical Cells." U.S. Patent 3,340,099, September 5, 1967, Applied January 15, 1965.

After degreasing and coating with a primer such as chlorinated rubber, phenolic-based, or isocyanate primers, a T-shaped electric terminal (1/10 in. diameter) is situated in aperture of the cell, over, which is 1/5 in. diameter and is provided with a downward extending lip, and an uncured neoprene sealant (1/20 in. thick) is positioned between the 2 metallic surfaces. The device is pressure-cured at 300-70°F. and cooled. The seal is lightweight, alkaline resistant, shock- and thermal resilient and can be used in manufacture of storage and aerospace batteries. (Abstract only)

B-840

Varta A.G. "Sintered Plaques for Storage Batteries." French Patent 1,474,841, March 31, 1967, German Application, January 12, 1965.

Sintered plaques of increased porosity, especially for alkaline storage batteries, are made by first heating a mixture of powdered metal and powdered plastic until fusion of the latter, whereupon the mixture is again heated until sintering of the powdered metal so as to obtain a product of homogeneous pore size. During the sintering process, the powdered mixture is distributed on an endless steel strip by means of a doctor blade. The starting material consists of a mixture of 75-85% powdered carbonyl Ni, and 25-15 weight % powdered polystyrene. This mixture is first heated to $\sim 200^{0}$ and then for $\sim$10 minutes to 1000^{0}. (Abstract only)

B-841

Paul Scardaville, Thomas Wetherell, and Lawrence Sears, Radiation Application, Inc. "Separators for Alkaline Batteries." French Patent 1,470,131, February 17, 1967, U.S. Application, February 26, 1965

The separator consists of a thin foil of acrylic copolymer grafted to polyethylene (I). Pellets of I of 24.5μ thickness and 0.914 g./cc. d. were irradiated by an electron accelerator with a dose of 10 megarads. The pellets were than wrapped in gauze and plunged into a solution of glacial HOAc 25, CCl_4 7.5, and C_6H_6 67.5%. Irradiation was done to a total dose of 1012 megarads at the rate of 50,600 rads/hour, using ^{60}CO. The pellets were washed with a solvent of homopolymer. The ratio of graft was 5.0 mole % of the total grafted polymer. The thickness of separator was 6.35-22.86μ. (Abstract only)

B-842

August M. Chreitzberg, George S. Hartman, and Gayle M. Wylie, Electric Storage Battery Company. "Battery Utilizing Bibulous Material Wick Means to Feed Electrolyte by Capillary Action." U.S. Patent 3,333,986, August 1, 1967, Applied June 26, 1964.

Alkaline batteries, having Ag-Zn or Ag-Cd electrodes separated by semipermeable membranes, are given increased electrolyte flow between electrodes by the use of bibulous wicking. Sheets (0.003-0.006 in.) of the wicking are placed between the electrodes and the folded cellophane membrane, and give greater electrolyte distribution during high discharge or recharge. Felted, nonwoven, fibrous sheets of nylon, polyurethane, polypropylene, and Dynel are suggested bibulous materials. (Abstract only)

B-843

G. Myron Arcant, Idaho State University. "The Reactions Pertaining to Zinc-Silver and Cadmium-Silver Batteries." Third Quarterly Report (December 15, 1967), Jet Propulsion Laboratory Contract JPL 951887 under NASA Headquarters Prime Contract NAS 7-100. Re-Order No. 67-730.

Preliminary experiments indicate that electrochemical oxidation of zinc in 10 VF KOH produces less than 10% $Zn(OH)_2$ and more than 90% ZnO. The product is blue-gray while in the KOH but changes to white upon being washed with water.

The rate of conversion of AgO to Ag_2O rapidly increases with increasing temperature. Fifty percent conversion occurs in 24 hours at 121^o, 11 hours at 131^o, 4 hours at 141^o, 2 hours at 151^o, and 1 hour at 160^o. The rate of conversion depends on the method of preparation of the original material.

The solubility concentration of Ag(1) in 10 VF KOH saturated with ZnO is about 4×10^{-4} VF. This concentration is reached in less than a half-hour in a stirred system containing solid AgO and somewhere between 25 and 100 hours in an unstirred system containing a AgO electrode. The concentration of Ag(1) drops to less than 1×10^{-4} VF in 24 hours when a zinc plate is placed in the solution, provided no solid AgO is present.
(6 references, 1 table, 3 figures, 11 pages)

B-844

W. N. Carson, Jr., C. Rampel, and I. B. Weinstock, General Electric Company. "Characterization of Recombination and Control Electrodes for Spacecraft Nickel Cadmium Cells." Final Report (January 1968), NASA Goddard Space Flight Center Contract NAS 5-10261.

Oxygen signal and recombination electrodes were developed to provide reliable charge control for spacecraft nickel-cadmium cells operable over a -20^oC to $+40^oC$ temperature range in near-earth orbits to cycle depths of 75%.

The signal electrode voltage output was essentially proportional to oxygen pressure in the range of 5 to 30 PSIA. Performance was constant during the test program.

The rate of oxygen recombination provided by the recombination electrode was greater than required to reduce pressure between charge cycles. The electrode is also active in recombining any hydrogen formed in the cell. Utilizing these features it was possible to operate cells with the negative electrode nearly fully charged. The cycle capability of these cells was greater by a factor of more than 10 at 40^oC to 50% DOD and more than 8 at 25^oC to 75% DOD. The cells were still cycling at the conclusion of the contract so that the full capability was not obtained. It was also possible to alter the cycle regime of cells without a reconditioning procedure, indicating that the "memory effect" has been greatly reduced.
(0 references, 8 tables, 38 figures, 94 pages)

B-845

Ernest M. Jost, Texas Instruments Inc. "Storage Battery Plaques." U. S. Patent 3,314,822, April 18, 1967, Applied May 18, 1964.

Sintered porous plaques for Ni and Ni-Cd batteries are prepared by sintering a layer of Ni flakes to form a porous plaque, saturating the plaque to infill its pores with a $Cd(NO_3)_2$ or $Ni(NO_3)_2$ melt, cooling the plaque to solidify the nitrate, heating the plaque under vacuum at $<$ m.p. of the nitrate to remove its crystal water, converting the dehydrated nitrate to a hydroxide by cathodically treating the plaque in an alkali metal hydroxide, and compressing and reinforcing the cathodically treated plaque. (Abstract only)

B-846

Hans E. Vogt. "Forming Process for Alkaline Nickel-Cadmium Storage Batteries of the Thick Layer Sintered Frame-Foil Electrode-Separator Type." German Patent 1,238,524, April 13, 1967, Applied December 21, 1962

Prevention of self-discharge, decrease of internal resistance, and improvement of short-time discharge capacity and average discharge voltage at higher loads are obtained for alkaline Ni-Cd storage batteries of the thick-layer, sintered frame-foil electrode-separator type by filling with 23% KOH solution, 30-60% KOH may be used, and subjecting to a forming current of 1/5-1/10 the value corresponding to the ampere-hour capacity (i.e., 30 ampere-hour for a rated 250 ampere-hour battery) for 24 hours at a temperature of $\sim$50-65^0 charging not less than 15 hours. The cell shows a capacity loss of $<$ 30-50%/year. (Abstract only)

B-847

Joseph J. Coleman, Milton E. Wilke, and Clifford J. Vander Yacht, Servel, Inc. "Nickel Electrode." U.S. Patent 3,317,347, May 2, 1967, Applied July 2, 1962

A porous Ni electrode for Ni-Cd cell was prepared. A mixture of $Ni(OH)_2$, a H_2O insoluble resin such as polystyrene, and CCl_4 was coated on a conductive metal screen. The solvent was evaporated and a grid of Ni was deposited on the screen electrolytically by using $NiCl_2$ or $NiSO_4$ in an electroplating bath. Addition of finely divided C of Ni to the coating on the screen and the application of a nonwoven cellulosic fiber sheet proved advantageous. The process avoided the plurability of cycles in preparing electrode. (Abstract only)

B-848

Anthony Sabatino and Daniel Orland, Globe-Union Inc. "Storage Battery Construction." U.S. Patent 3,313,658, April 11, 1967, Applied August 1, 1962, and September 16, 1965.

An open top storage battery case has a partition which divides the case into at least 2 separate compartments. Each partition has an aperture. Battery elements are positioned in the compartments which include a strap with connector lug precast to the elements. Each lug has a sealing face with an area adapted for interconnection so that the area on 1 connector lug is in contact directly or indirectly with the area on the connector lug in the adjacent compartment. These areas are joined by a pressurized resistance weld. The aperture is completely filled with lug material to prevent leakage of electrolyte between the cells. An annular ring on the face of each strap will seat into the cell partition to form a positive seal. This design is characterized by low elec. resistance and high mechanical strength. (Abstract only)

B-849

Jiro Konishi. "Storage Battery with Magnesium or Beryllium as Active Materials on the Negative Electrode." German Patent 1,239,376, April 27, 1967, Applied August 17, 1962.

A storage battery with Mg or Be as the active materials on the negative electrode is described. The electrolyte is a solution of an alkaline hydroxide containing very small amounts of the alkali metal salts of a S, P, or halogen acid, and the positive electrode is made of an alkali-resisting metal or alloy. For example, the base consists of a steel plate or a steel wire mesh. On the surface of this is an alloy layer consisting of Fe-Zn, Ni-Mg, or an alloy composed of Mg or Be. (Abstract only)

B-850

Carl O. Schilling, Eagle-Picher Company. "Battery Dry-Charging Method and Apparatus." U.S. Patent 3,328,893, July 4, 1967, Applied December 14, 1964.

An improved method of drying wet, formed plates for dry-charged Pb-acid batteries is described. The wet plates are subjected to a recirculating atmosphere of Ch_4, LPG (liquefied petrolum gas), or natural gas heated to 180-275°F. for drying positive and negative plates simultaneously or 180-400°F. for drying negative plates only. (Abstract only)

B-851

Thomas A. Edison, Edison Storage Battery Company. "Means and Method for Preventing Depletion of Electrolyte," U.S. Patent 1,016,874, February 6, 1912, Applied June 21, 1911.

The method of preventing depletion of electrolyte in a secondary cell which consists in preventing the escape from the cell of the gases evolved during the charging of the same, and causing the oxygen and hydrogen evolved to recombine within the cell to form water, by application of sufficient heat to cause such recombination within the space occupied by said gases during the formation thereof. (1 drawing, 5 claims)

B-852

Jean Salauze, Societe des Accumulateurs Fixes & de Traction. "Negative Electric Plates for Alkaline Accumulators and Methods for Making Same," U.S. Patent 2,683,181, Serial No. 351,479, July 6, 1954, Applied April 27, 1953

In a method of manufacturing negative electric plates for alkaline accumulators comprising the step of mixing together a basic material composed of finely divided copper having the shape of microscopic acidular, arborescent or dendritical crystals with an active material which consists of a finely divided iron or iron providing substance, the step of compressing the said mixture under a high pressure on suitable supporting frames, and the step consisting of subjecting the plates after they have been compressed to a thermal or sintering treatment resulting in the sintering of copper particles and establishing among the copper particles, by superficial coalescence, a system of local welded bonds. (1 drawing, 7 claims)

B-853

Hans Vogt, Stockholm-Malarhojden. "Electrode for Electric Batteries and a Process for Producing the Same." U.S. Patent 2,681,375, June 15, 1954, Applied April 25, 1949, Serial No. 89,416

An electrode arrangement including in combination at least one pair of strip-shaped electrodes each comprised of a thin carrier sheet having a thickness of between .02 and .05 mm., sintered metal powder particles adhering to said carrier sheet in the form of at least one thin porous layer, and an electrochemically active substance embodied in the pores of said layer, the total thickness of each of said strip-shaped electrodes being less than 1 mm., and permeable insulating strip of a lye-resistant material interposed between the adjacent electrodes, said electrodes being wound up spirally in the form of rolls. (9 drawings, 3 claims)

B-854

Robert A. A. Jeannin, Societe des Accumulateurs Fixes and de Traction, "Electrolytic Cell and Battery," U.S. Patent 2,646,455, July 21, 1953, Applied October 23, 1951, Serial No. 252,646.

An electrolytic cell in which in normal operation the voltage at the terminals never exceeds 1.48 volts and which is, consequently, without substantial gas evolution, comprising an electrolyte, at least one positive electrode and one negative electrode located opposite one another, each electrode comprising consolidated finely-divided particles of a metal substantially unaffected by the electrolyte, a thin, distortable diaphragm of nonconducting matter unaffected by the electrolyte and having a surface at least equal to that of the adjacent faces of the opposite electrodes, said diaphragm being closely engaged between the adjacent faces of the electrodes at least by previously exerted strong pressure against the assembly of electrodes and diaphragm, whereby each face of the diaphrgam is substantially in the configuration of a compression-matrix of the face of the adjacent electrode, and said electrodes and said diaphragm being saturated with said electrolyte. (3 drawings, 16 claims)

B-855

Hans Vogt, Malarhojden. "Porous Electrode." U.S. Patent 2,627,531, Serial No. 64,197, February 3, 1953, Applied December 8, 1948

An electrode for accumulators containing an electrochemically active substance and having a body comprised of two intertwined yet distinct porous masses of a distinctly different order of pore size, said larger-pored mass being irregular conformation and said smaller-pored mass being a sinter mass of substantially uniform porosity, with said electrochemically active substance contained within the pores of said smaller-pored mass. (2 drawings, 8 claims)

B-856

Michel C. J. Jacquier, Societe des Accumulateurs Fixes & de Traction. "Series Connected Cells with Individual Rectifier Shunts," U.S. Patent 2,624,033, December 30, 1952, Applied September 10, 1951, Serial No. 245,781.

A battery comprising a plurality of cells connected in series with a rectifier shunting each cell, each rectifier being so connected that its direction of current passage is from the negative to the positive terminal of the corresponding cell. (5 drawings, 4 claims)

B-857

Jean Salauze, Societe des Accumulateurs Fixes & de Traction. "Negative Electrode for Alkaline Storage Batteries and Method of Manufacturing the Same," U.S. Patent 2,683,182, July 6, 1954, Applied April 27, 1953, Serial No. 351,480

A method of producing a negative plate for an alkaline electric accumulator, comprising the steps of preparing a mixture by intimately mixing a fine 16-divided copper composed of minute crystals having an acicular, arborescent, dendritical or needlelike shape, with an active negative material consisting of finely-divided iron providing substance, said active negative material in said mixture being in the proportions of between 20% and 80% and preferably in the proportion of 50% of said mixture, coating the mixture over and into the interstices of a mesh-like support and compressing the coated assembly at substantially ordinary room temperature and at a pressure of at least 1 metric ton per square centimeter, said iron providing substance being of very low apparent density and very high porosity and being produced by appropriate thermal reduction of an appropriate form of ferric oxide that is of low apparent density and high porosity. (1 drawing, 16 claims)

B-858

Pierre A. C. Jacquier, "Sealable Storage Battery Construction," U.S. Patent 2,614,138, October 14, 1952, Applied August 9, 1950, Serial No. 178,429.

A storage battery comprising a casing sealable to prevent escape of gas therefrom and adapted to be filled to a predetermined level with a liquid electrolyte, a first electrode structure within said casing positioned to be immersed at least partially in said electrolyte when said battery is in the normal operating position, said structure defining therewithin at least one cavity having an opening facing toward said electrolyte when said battery is in said position, and an anode structure having a portion projecting into said cavity, whereby gas evolved between said electrodes during operation of said battery may be trapped in said cavity, said first electrode being constituted of a material capable of absorbing said gas, an expansion chamber for said electrolyte and a duct means connecting said expansion chamber with said cavity whereby said electrolyte may be forced into said expansion chamber by gas pressure in said cavity, and a chamber above said first electrode in which said gas may collect and contact the upper surface of said first electrode. (6 drawings, 15 claims)

B-859

Robert L. Tichenor, Thomas A. Edison, Incorporated, "Storage Battery Charging System and Method," U.S. Patent 2,578,027, December 11, 1951, Applied March 15, 1948, Serial No. 14,953.

In combination: an hermetically-sealed battery comprising an aqueous electrolyte solution and main electrodes of opposite polarity contacting said solution, said battery having initially a gas phase predominantly of one of the gases oxygen and hydrogen; an auxiliary electrode in said solution adapted to evolve hydrogen when the potential thereof is more negative than the negative electrodes of the battery and to evolve oxygen when the potential thereof is positive by the prescribed amount with respect to the positive electrode of the battery; means connected to the battery for charging the same; a voltage source; means responsive to the pressure in said container when the pressure is below a first threshold for connecting said source between said auxiliary electrode and one of said main electrodes as a reference to cause evolution of said one gas and to cause simultaneously said one electrode to be charged at a lesser rate than that of the other; means responsive to the pressure in said container when that pressure is above a second threshold higher than said first threshold for connecting said source between said auxiliary electrode and the other of said main electrodes as a reference to cause evolution of the other of the said gases and simultaneously cause said other electrode to be charged at a lesser rate; means for combusting said gases; and means controlled by the pressure in the battery to limit the charge of the nonreference one of the battery electrodes while said auxiliary electrode is connected to said voltage source to evolve gas. (0 drawings, 33 claims)

B-860

Jean Salauze, Societe des Accumulateurs Fixes et de Traction, "Negative Plate for Alkaline Accumulator and Method of Making Same," U.S. Patent 2,554,125, May 22, 1951, Applied March 19, 1947, Serial No. 735,803.

A process for the preparation of negative plates adapted for use in electric storage batteries employing alkaline electrolyte and comprising a mixture of substratum and active material, comprising the steps of mixing in a desired proportion metal adapted to form the substratum, and being finely divided crystals of interlacing form, with material adapted to form the active material and being in finely divided form, thereafter placing this mixture in a dry state upon suitable supports forming a part of the plate, and finally compressing the mixture without increase of temperature to the fusion point of any constituent thereof and forming a compact porous plate. A process according to claim 1 in which the material adapted to form the active material comprises cadmium hydrate and iron and constitutes approximately 50% to 25% of said mixture, and the metal adapted to form the substratum is copper. A process according to claim 1 in which the particles of the finely divided material adapted to form the active material comprise crystals of interlacing form and said material comprises iron and cadmium and constitutes approximately 75% to 50% of said mixture, and the metal adapted to form the substratum is copper.
(0 drawings, 7 claims)

B-861

John Ferreol Monnet, "Improvements in or Relating to Electric Storage Batteries," England Patent 214,799, May 1, 1924, Applied March 17, 1923, No. 7762/23.

A storage battery electrode prepared by coating a very thin perforated metal ribbon, preferably of nickel, with a thin layer of active material in the form of paste, the coated ribbon being then wound upon a small tube until a substantial diameter is reached, whereupon the coiled disc or ring is subjected to heavy pressure so as to form a solid plate or disc.
(11 drawings, 12 claims)

B-862

Allan Levin and William Sidney Thomson, Nife Batteries Limited. "Improvements Relating to Electric Storage Batteries," British Patent 561,820, June 6, 1944, Applied January 30, 1943, No. 1610/43.

An electric storage battery comprising the combination of a pair of cupped or dished sheet metal body parts, a layer of active material in each of said parts, a sealing and insulating ring of soft rubber or like flexible material arranged between the said parts, and a sheet metal or other securing piece surrounding at least one of the said parts and having one or each of its ends turned over to unite the said parts and compress the said ring, the said securing piece being integral with one of the said parts or consisting of a separate shell surrounding the said parts. An electric storage battery as claimed in any of the preceding claims, in which one of the body parts has a hole formed in its outer side, and has in association with the hole a cover piece of soft rubber or like material through which a hollow syringe needle can be inserted for replenishing the electrolyte in the battery, the performation formed by the needle subsequently serving as a vent.
(4 drawings, 7 claims)

B-863

Victor Herold, "Improvement in and Connected with Secondary Electric Batteries," British Patent 317,130, August 12, 1929, Applied May 12, 1928, No. 14,055/28.

A secondary electric battery comprising in combination a positive of numerous layers of nickel oxide powder regularly alternated with flakes of metallic nickel, a negative of cadmium or cadmium hydrate in a finely crushed or divided condition, and an alkaline electrolyte, the positive and negative materials being in appropriately adjusted relative quantities substantially as described. (5 drawings, 5 claims)

B-864

B. Brady, D. Gidaspow. R. W. Lyczkowski, C. Y. C. Ng, S. Randhava, S. Sareen, C. W. Solbrig, W. Toczycki, D. Wasan. "Electrochemical Systems Head and Mass Transfer." Second Quarterly Progress Report, January 1968, National Aeronautics & Space Administration, George C. Marshall Space Flight Center, Contract No. NAS8-21159.

This report is divided into four main technical tasks in accordance with the program plan. These are: I. Heat Transfer in Fuel Cell and Storage Batteries. II. Simultaneous Heat and Mass Transfer in Free Convection. III. Heat and Mass Transfer in Immobilized-Electrolyte Cell Systems. IV. Analysis of Transient Pulse Flow. (15 references, 5 tables, 18 figures, 53 pages)

B-865

Jerome Goodkin, Yardney Electric Corporation. "Long Life Stable Zinc Electrode for Alkaline Secondary Battery." Third Quarterly Report, January 1968, Technical Report Ecom-0185-3, United States Army Electronics Command, Contract DAAB07-C-0185.

Edge overlap-zinc oxide addition combinations have resulted in up to 25% capacity improvement. A 1:1 relationship between capacity and zinc per ampere-hour was observed. The overlap increased interaction with the zinc to yield an additional unit increase per percent zinc addition.

Teflon content increases from 7% to 9% improved performance 10%. Lowering the cure temperature also improved performance, but the change was small. Better electrode performance is obtained at high c.d. when a Teflon binder is used.

Carbon-activated recombination electrodes were found to give good end-of-charge signals. A cut-off device has been designed to by-pass sealed cells on signal.

Cycling on the 6-hour regime has shown that 300 cycles are easily obtainable. Cycle life can be increased substantially by increasing the end-of-charge cut-off.

Reference electrode control of charge cut-off is under investigation. A 4-cell unit is now being cycled on a 0.07 v reference to anode cut-off regime.

Charge current wave form studies, to date, show that best condition for pulse to relaxation measurements will require sophisticated electronics.

Geometry considerations have resulted in the development of an electrode with more zinc at the edges and a center pocket. Cells with this type of electrode have vastly improved performance over the first 114 cycles. (0 references, 11 tables, 13 figures, 34 pages)

B-866

G. W. Bodamer, Electric Storage Battery Company, The Carl F. Norberg Research Center and Exide Missile and Electronics Division, "Heat Sterilizable, Impact Resistant Cell Development," Interim Summary Report (September 30, 1967), Jet Propulsion Laboratory Contract JPL 951296 under Prime Contract NAS 7-100.

The present report reviews and summarizes all of the work during the first two years of this contract. Since additional tasks have been added during the course of the investigation, this is not truly a final report, and some studies are expected to continue for a considerable time to come. (0 references, 78 tables, 38 figures, 181 pages)

B-867

G. D. Mitchell and R. T. Foley, The American University. "Research into Fundamental Phenomena Associated with Spacecraft Electrochemical Devices - Calorimetry of Nickel-Cadmium Cells." Fourth Progress Report, June 30, 1967, NASA Goddard Space Flight Center, NAS 5-10105.

The present work on this project consists of calorimetric measurements on nickel-cadmium cells of various capacities undergoing discharge at depths of 15, 25, and 50%, and recharge at 110%.

During this reporting period changes were made in the system to accommodate the larger 20 ampere-hour cell and to increase the reproducibility and sensitivity of the heat measurement. These changes included rebuilding the external heat exchanger, altering the flow pattern of the oil through the calorimeter, and fabricating an improved thermopile.

Calibration experiments on the heater and the pressure transducer were performed.

The data from the charge efficiency study on the six ampere-hour cell reported in the Second Progress Report were replotted to better represent the heat dissipation problem. (0 references, 3 tables, 6 figures, 15 pages)

B-868

John J. O'Connell, Elizabeth A. McElhill, Carol A. Olson, Monsanto Research Corporation. "Separator Development for a Heat Sterilizable Battery." Quarterly Summary Progress Report 4, MRB623404, Re-Order No. 67-764 (December 31, 1967), Jet Propulsion Laboratory, Contract JPL 951524

Two ligand-containing polymers were developed and prepared as 1.5 mil flexible films that have satisfactory electrical and mechanical properties as separators for sterilizable silver-zinc cells. One type is a modified styrene-maleic anhydride-methyl methacrylate-methyl acrylate tetrapolymer with high content of hydrolyzable anhydride and acrylate groups. Methods were developed to cross link these polymers with bis (4-anilino)methane during film formation to make them usable separator materials by insolubilizing them in 40% KOH. Tests on duplicate samples from different batches of this type polymer showed good reproducibility.

The second type polymer, 31:69 2-vinylpyridine-methyl methacrylate copolymer, had shown promising electrical properties in our initial program. The mechanical properties of films of this polymer, both before and after sterilization, were improved by increasing its molecular weight.
(3 references, 6 tables, 1 figure, 19 pages)

B-869

L. C. Scala and G. D. Dixon, Westinghouse Electric Corporation. "Separator Development for a Heat Sterilizable Battery," Sixth Quarterly Report (December 31, 1967), Jet Propulsion Laboratory Contract JPL 951525 under NASA Prime Contract NAS 7-100.

The investigation of the effect of varied zirconium oxide loadings in the coating of Webril tape for battery separators showed that: a) higher oxide loading result in faster electrolytic diffusion; b) lower restivities are also a result of high oxide loadings; c) the coating, however, tend to be more prone to cracking. Best results seem to be obtained at a 3:1 oxide: polysulfone ration, at a speed of 3-4 ft/min.

Ball milling the coating mixtures for several days results in smoother coatings and better filling of the Webril tape voids.

Long term exposure to concentrated KOH of battery separator material containing polysulfone 361 instead of polysulfone 1700 as binder indicated that PS 361 dissolves almost completely in the caustic. Separator material containing PS 1700, however, withstands the sterilization cycle satisfactorily.

The continuous coating apparatus is being modified to allow dip coating of the basic tape instead of doctor knife coating.

The polarograph has been calibrated to test for silver ion diffusion.
(0 references, 10 tables, 0 figures, 19 pages)

B-870

Joseph M. Sherfey, Gerald Halpert, and Smith E. B. Tiller, NASA Goddard Space Flight Center and Melpar, Inc. "A New Technique for Measuring the Internal Pressure of Sealed Electrochemical Cells," Electrochemical Technology, 6 (1-2), pp 25-28, (June 2, 1967)

> A technique is described for measuring the internal gas pressure of sealed secondary electrochemical cells. In use, such cells are ordinarily restrainted by a clamp or restraining device. The internal gas pressure can be determined by using a load cell to measure the force exerted by the secondary cell on this clamp. (2 references, 0 tables, 5 figures, 4 pages)

B-871

Raymond Jasinski, Tyco Laboratories, Incorporated. "Electrochemical Power Sources in Nonaqueous Solvents," Electrochemical Technology, 6 (1-2), pp 83-85, (August 1967)

> Batteries employing the alkali or alkaline earth metals as negative plates are, in principle, capable of energy densities in excess of 100 whr/lb. The realization of this performance, of course, also requires an active positive plate material of low equivalent weight and high positive potential, as well as an ionically conducting electrolyte which is compatible with the electrodes. This paper reviews progress made with ambient temperature batteries of this type, employing electrolytes based on organic solvents. (56 references, 15 titles, 10 figures, 8 pages)

B-872

R. P. Hamlen, J. M. McQuade, E. G. Siwak, General Electric Company. "Silver-Zinc Cells with Electrolytically Deposited Calcium Hydroxide Separators." Electrochemical Technology, 6 (1-2), pp 83-85, (August 1967)

> Silver oxide electrodes were coated with electrolytically deposited calcium hydroxide by making this electrode the cathode in a calcium-acetate solution. The pH change occurring at this electrode caused calcium hydroxide deposition on the electrode. The deposit was used as one layer in the separator system of a silver-zinc cell, and was found materially to decrease silver migration. (3 references, 2 titles, 1 figure, 3 pages)

B-873

P. E. Piehn, Technical Industrial Intelligence Division, U.S. Department of Commerce. "Nickel Cadmium Storage Batteries in Germany." Fiat Final Report No. 800, February 28, 1947, Office of Military Government for Germany (US) S. O. Code No. 51-8264

> Alkaline storage batteries of the nickel-cadmium type are widely used in Europe, but have only recently been introduced into the United States. This report gives details for the manufacture of three types of these cells: those with tubular pocket positive and flat pocket negative plates, those with flat pockets only and those with porous, sintered plates impregnated

with active materials. Methods of manufacture of the various types of plates, the active material and formation of the active material by electrolysis are given. Special treatment is given to the manufacture of the sintered porous plates, as this type of cell was in the developmental stage. The latter was to have been used as starting batteries for jet planes and in rockets.
(0 references, 0 titles, 0 figures, 23 pages)

B-874

E. A. Butler, A. U. Blackham, Brigham Young University. "Studies of Reaction Geometry in Oxidation and Reduction of the Alkaline Silver Electrode." Third Quarterly Report, February 15, 1968, JPL 951911 Jet Propulsion Laboratory, California Institute of Technology under NASA Contract NAS 7-100, Re-Order No. 68-8

A reproducible roughness factor of 1.74 has been found for silver foil which has been oxidized in the ammonical electrolyte. This roughness factor will be used as a correction for all current density and overpotential data.

Preliminary investigation of alternative methods for the determination of the effective electrolytic surface area of sintered and foil silver electrodes have been performed. The basis for these determinations of the surface area is an oxidation of the silver electrode at a constant potential. The development of the necessary instrumentation for further study is now under way.

Silver foil was oxidized with and without ultrasonic vibrations at various current densities with the temperature controlled to ± 0.1°C. The increase in charging capacity was larger at high and low current densities than at moderate current densities. Vibration prior to oxidation failed to increase charging capacity, indicating that no persisting strains in the silver occur and that surface cleaning by the ultrasonic vibrator plays no significant role. (6 references, 3 tables, 0 figures, 13 pages)

B-875

A. Himy, Douglas Missile & Space Systems Division, Douglas Aircraft Company, "Batteries for Undersea Applications," Douglas Paper 4417, August 13-17, 1967

It is a certainty that within an immediate future silver-zinc and silver-cadmium batteries will be as widely used in submersible applications as in space applications. They offer to the boat designer a new dimension, and the flexibility of choice between the different types of batteries will now make it possible to tailor the battery to the mission and not the mission to the battery. (0 references, 3 tables, 2 figures, 11 pages)

B-876

A. Himy, F. C. Arrance, M. P. Strier, Douglas Aircraft Company. "Silver-Zinc Electrodes for Operation in the Temperature Range of 100°-145°C." Douglas Paper 4172, December 1966, presented at the fall meeting of the Electrochemical Society, October 9-14, 1966, Philadelphia, Pennsylvania

> The development of silver and zinc electrodes capable of operation in the temperature range of 100°-145°C is described. The use of inorganic network support material (NSM) in these electrodes has resulted in silver and zinc electrode configurations which are capable of more than 3000 discharge-char cycles at 100°C and operation at 125°, 135° and 145°C.
>
> Test results are reported comparing the performance of experimental electrodes at elevated temperatures with performance at normal ambient temperature in silver-zinc test cells fabricated using Astroset inorganic battery separators. (6 references, 0 tables, 13 figures, 24 pages)

B-877

Harvey N. Seiger and Stephen Lerner, Gulton Industries, Inc. "Sealed Cells and Auxiliary Electrodes," Journal Spacecraft, 5 (1), pp 110-112 (January 1968)

> This note assesses the state-of-the-art of auxiliary electrode development, and considers what may be coming next. The battery systems discussed are the Leclanche, the silver-cadmium, and the nickel-cadmium. Two kinds of auxiliary electrodes are of interest: the "Fuel-cell" electrodes developed for H_2-O_2 fuel cells, and the Adhydrode, standing for the adsorbed hydrogen electrode. An auxiliary electrode may be used in two ways within a galvani cell. 1) In the active or signalling mode, it is brought to the outside of the cell through a third terminal; a resistor is placed between the thir terminal and the negative electrode terminal, and as O_2 is developed within the cell, a signal is generated across the resistor. 2) In the passive or scavenger mode, it is connected to one of the two electrodes within the cell; H_2 or O_2 is consumed when it is connected to the anode or cathode, respectively. (14 references, 0 tables, 4 figures, 3 pages)

B-878

T. P. Dirkse, Calvin College, Grand Rapids, Michigan. "Electrode Migration and Reaction Processes Occurring Within Alkaline-Zinc Batteries." Ninth Quarterly Technical Progress Report, March 1968, AF Aero Propulsion Laboratory, Wright Patterson Air Force Base, Contract No. AF 33(615)-3292

> The zinc electrode was studied by means of cyclic voltammetry. Variable studies were: presence of carbonate ion; presence of zincate ion; the effect of stirring; the effect of amalgamating the zinc electrode. The results obtained confirm mechanisms suggested earlier.

Additional nickel-zinc cells have been assembled and cycled. Additional layers of separator were used to extend cycle life. The cycle life of the cells was then limited by the loss in capacity of the nickel oxide electrode. (1 reference, 1 table, 6 figures, 14 pages)

B-879

H. H. Hirsch, W. J. van der Grinten, W. N. Carson, and P. H. Morgan, General Electric Company. "Rechargeable Metal-Air Cell," Second Quarterly Report, January 1968, U.S. Army Electronics Command, Fort Monmouth, N. J., Contract No. DDAB 07-67-C0257, DA Project No. 1T6-22001-A-053-02-57, Technical Report ECOM-0257-2

Experimental work was carried out to evaluate the lead-air, the cadmium-air, and the zinc-air secondary battery systems. In the lead-air battery, platinum could not be used at the cathode since its migration to the lead electrode causes severe gassing results from this. Redox cathodes have been investigated and Ferroin materials appear best.

Zinc electrode utilizations of greater than 70% have resulted; however, relatively high self-discharge rates are encountered. The two-phase zinc electrodes that have been used in this work appear to be capable of sustaining higher rates than the cathodes that have been tested to date. Cycle lives of 65 cycles represent the best to date.

Cadmium-air cells have shown good cycle life (greater than 100 cycles in the best case). The electrode technology for cadmium electrodes is in place. Preliminary cell design studies are underway, as it appears that cadmium-air cell systems are those most likely to be developed into hardware earliest.

A number of cathodes were screened and several types, all of which contain platinum, are preferred. Additional cathode studies are proceeding. (6 references, 8 tables, 28 figures, 70 pages)

B-880

S. Senderoff, M. L. Kronenberg, T. Z. Kurtzweil, and E. M. Klopp, Union Carbide Corporation. "Feasibility Study on High Performance, Short Duration Power Batteries." Sixteenth Quarterly Technical Progress Report (March 15, 1962 - June 15 1962), Naval Ordnance Contract NOrd-18240. AD 284 392

Attempts to determine the diffusion coefficient of the phosphate ion failed, the metaphosphate ion is converted to the much less soluble orthocompound by traces of moisture. The diffusion coefficient as well as the activation energy for the diffusion process were determined for the sulfate ion. D at 500°C was found to be $1.95 \times 10^{-5} cm^2/sec$ while ΔH was 5765 cal. Cell tests have shown improved power outputs from both Li_2SO_4-K_2SO_4 and $CuPO_3$-$LiPO_3$ combinations when they are used as depolarizers. Attempts to design a satisfactory package for the phosphate depolarized cell have disclosed a number of problems which are being worked out. (0 references, 0 tables, 1 figure, 13 pages)

B-881

S. Senderoff, E. M. Klopp and M. L. Kronenberg, Union Carbide Corporation. "Depolarizers for High Energy Density Thermal Batteries. Part II. Oxides and Oxgenated Anions of the Elements of Groups III A to VI A." Final Report (September 15, 1962), Naval Ordnance Contract NOrd-18240. AD 287 518

> Various sulfates, phosphates and other oxygenated anions and oxides of Groups III A to VI A elements have been shown to be effective depolarizers for thermal batteries at temperatures above 500°C. Polarization curves, chronopotentiometric studies and diffusion reactions indicate that in the case of sulfates, the pyrosulfate ion is the active species at the cathode and that sulfur is a probable end-product of reduction. In the case of phosphates a complex mixture exists at the cathode which is reduced by one or more steps to phosphorous. Large numbers of cell discharge tests were run which confirmed the large energy density potentially available in cells depolarized by these materials.
> (13 references, 5 tables, 14 figures, 41 pages)

B-882

Frederick P. Kober, General Telephone and Electronics Laboratories, Inc. "Method of Making Electric Battery Electrodes." U.S. Patent 3,335,033, August 8, 1967, Serial Number 392,615

> Positive electrodes (for alkaline batteries) are prepared by the anodic polarization at a c.d. of 0.4 - 1 ASI with intermittent interruption of current or of a brief current reversal, of porous nickel plaques, usually carbonyl nickel plaques, in an ammine nickel bath, such as made by dissolving nickel fermate in an ammonium hydroxide solution with the addition of potassium or lithium hydroxide to control pH_3 and maintained between 40° and 60°C. After anodic polarization, the impregnated plaque is charged in the usual manner in NiOH or KOH solution, then washed with deionized water at 70°C, and finally dried at 80°C.
> (17 claims, 0 drawings)

B-883

Sidney Gross, The Boeing Company, "Development and Fabrication of Advanced Battery Energy Storage System." Final Report (November 27, 1967), NASA Manned Spacecraft Center Contract NAS 9-6470.

> Batteries, charge-discharge controllers, calorimeters, and required accessories were designed, built, calibrated and delivered in accordance with contract requirements. All critical components were tested to verify that they met performance requirements. It is appropriate to note development concepts which have been suggested during this program, but which were outside the scope of the contracted work. The most practical of these concepts are: (1) Ampere-hour and watt-hour meters; (2) Coulometer charge control; (3) Calorimetry; and (4) Load programming.

B-884

Floyd D. Trischler, Whittaker Corporation, Narmco Research and Development Division. "Separator Development Phase of Heat-Sterilizable Battery Development Program. Battery Case Development." Final Report (February 15, 1968), Jet Propulsion Laboratory Contract No. 951091 under Prime Contract NAS 7-100. Supplement No. 2.

The objective of this program was the development of an injection-moldable polymer suitable for use as the case in heat sterilizable batteries. The polybenzimidazole studied, which was based on diaminobenzidine and sebacic acid (PBI-8), met all of the preliminary requirements for the battery case. Some bonds were made with the aid of epoxy adhesives. Solvent welding was found to be the best method to join the PBI-8 polymer. A capped PBI-8 was extruded and injection molded. A number of injection-molded tensile specimens were prepared and tested.
(0 references, 7 tables, 1 figure, 10 pages)

B-885

Norman Peach. "Batteries" Power, 112 (2), 177-184 (February 1968)

As service continuity is increasingly demanded by energy systems, more than ever batteries are looked to as a source of emergency power for switchgear and controls, and for loads through inverters.
(0 references, 8 pages)

B-886

R. F. Chireau, Yardney Electric Corporation. "Silver-Zinc Missile Power Supply.' Tenth Quarterly Technical Progress Report (January 1968), Wright-Patterson Air Force Base Contract AF 33(615)-2663

Task I of Phase IIb of the Silver-Zinc Missile Power Supply program was completed during the preceding quarter and work on the Task II effort (preprototype design and fabrication) initiated. Details of the battery cell block (monoblock) design for the 95 volt, 200 watt-hour preprototype battery are presented and the results of verification tests on 1.7 ampere-hour duplex electrode cells are discussed. A full size 95 volt, 200 watt-hour preprototype duplex electrode monoblock (S/N 001) was fabricated durin the past quarter. An analysis of the weight and volume of the assembly is reported. The progress of the work on the Missile Power Supply DC to DC converter Phase IIb Task I effort is presented in the Converter subcontractor's Fourth Quarterly Progress Report. The latter document has been appended to this report. (0 references, 3 tables, 14 figures, 25 pages).

B-886A

S. D. Heaner, Honeywell Inc., "Silver-Zinc Missile Power Supply. DC to DC Converter." Quarterly Progress Report No. 4 to Yardney Electric Corporation (January 18, 1968)

The objective of this program is to design and construct the breadboard and a preprototype model of a high-power density converter for a missile application. The major effort expended during this quarter consisted of selection of circuit components, modifying the technical approach somewhat to accommodate these components, and solution of the problem of high initial current due to charging of the filter capacitor. (0 references, 0 tables, 6 figures, 17 pages)

B-887

C. E. Kent and E. G. Siwek, General Electric Company. "Rechargeable Metal-Air Cell." Technical Report ECOM-0257-1, First Quarterly Report (December 1967) U.S. Army Electronics Command Contract DAAB 07-67-C0257

Preliminary design calculations indicate potential energy densities of the following ranges for operating cells: Lead-Air - 30 - 33 watt-hours/pound; Cadmium-Air - 35 - 45 watt-hours/pound, and Zinc-Air - 30 - 60 watt-hours/pound. Principal technical problems associated with the battery systems under study are: (1) Obtaining maximum anode utilization in terms of ampere-hours per square foot of electrode geometric surface area during successive charge-discharge cycling. (2) Control of corrosion of the cathode (air electrode), particularly during the charge portion of the charge-discharge cycle. (3) Control of gases generated during the charge and discharge portions of the charge-discharge cycle. (4) Use of the air electrode (cathode), in alkaline electrolyte systems as a bifunctional electrode, i.e., as an electrode operable during both the charge and the discharge modes of the charge-discharge cycle. In addition: (5) The Lead-Air system requires a low cost, non-platinum catalyst air electrode. (6) The Zinc-Air system requires the control of electrolyte migration during charge-discharge cycling. (20 references, 11 tables, 11 figures, 48 pages)

B-888

G. W. Bodamer, ESB Incorporated, "Heat Sterilizable, Impact Resistant Cell Development." Report for Fourth Quarter (March 14, 1968), Jet Propulsion Laboratory Contract No. 951296 under Prime Contract NAS 7-100.

The requirements of this contract were detailed in the Interim Summary Report which reviewed all the work from September 24, 1965 to September 30, 1967. The present report covers work during the period October through December 1967. Impact specifications have been changed to require survival of shock at 2800 ± 200 "g" from a velocity of 115 ± 3 ft./sec. In addition, new heat sterilizable battery capabilities have been required and can be summarized as follows: (1) a. 5 AH, 120 WH, 2800 ± 200 "g" from 115 ± 2 ft./sec., 4 cycles thereafter. b. 25 AH, 600 WH, 2800 ± 200 "g" from 115 ± 2 ft./sec., 4 cycles thereafter. (2) 1200 SH non-impact, 400 cycles

of 50% depth. (3) 2000 WH, 200 "g" impact, 4 cycles thereafter. Studies during the last quarter of 1967 have revealed the following facts. A prolonged low current preformation charge virtually eliminates the pressure build-up previously encountered during formation. A partial discharge followed by recharge at the end of normal charge increases capacity 15%. This technique, however, is not sufficient to overcome capacity losses which follow sterilization of sealed cells and which run between 20 and 60%. Five ampere-hour sealed cells with silver sheet electrode reinforcement have survived 2000 to 2400 "g" shocks but show a 30% loss in capacity thereafter; however, the loss is recovered upon recharging. Future work will be concentrated on determining the cause of capacity loss following heat sterilization and on making more strongly reinforced plates.
(0 references, 26 tables, 6 figures, 59 pages)

B-889

H. Frank and M. P. Strier, McDonnel Douglas Corporation, Astropower Laboratory. "Sealing of Silver Oxide-Zinc Storage Cells." Third Quarterly Report, DAC-59860-Q3 (March 23, 1968), NASA Goddard Space Flight Center Contract NAS 5-10409.

The objective of this program is to evaluate the use of miniature hybrid fuel cells in controlling pressure and thereby permitting operation of sealed silver oxide-zinc cells. The fuel cells perform this function by electrochemically consuming evolved hydrogen and oxygen. Two types of fuel cells are being used for this purpose. The first consists of a silver oxide cathode in conjunction with a hydrogen-consuming anode. The second consists of a cadmium anode in conjunction with an oxygen-consuming cathode. These fuel cells and their use in controlling pressure and in sealing batteries, including silver-zinc batteries, are proprietary with McDonnell Douglas Corporation, and are covered in one or more pending patent application of McDonnell Douglas Corporation. The silver oxide-zinc cells under investigation are commercial 16-Ah high rate units. The scope of this work consists of the following tasks: Task 1 - Determine the gassing characteristics of the silver-zinc cells under four different operating regimes; Task 2 - Design and test micro fuel cells to accommodate the gassing rates in these cells; Task 3 - Evaluate composite micro fuel cell/silver-zinc cells in the sealed condition under the same regimes as indicated above; Task 4 - Assemble and deliver 15 sealed silver-oxide-zinc cell/micro fuel cell composites to NASA/Goddard for evaluation. All of the experimental effort during the past report period was devoted to sealed cell tests under Task 3 above. Twenty-four sealed assemblies were used. Each of these consisted of a composite silver oxide-zinc cell and dual micro fuel cell assembly. Successful operation in the sealed condition was demonstrated for all cells operated on two different conditions of stand and for a continuous 24-hour cycle regime. Some difficulty was experienced in operating all cells in the sealed condition on a continuous 90-minute cycle regime. However, the situation was eventually improved. The most significant results and conclusions of these tests are tabulated below.
(2 references, 6 tables, 12 figures, 34 pages)

B-890

E. C. Bruess, U.S. Naval Ammunition Depot. "Evaluation Program for Secondary Spacecraft Cells. Acceptance Test of Gulton 20.0 Ampere-Hour Standard and Adhydrode Nickel-Cadmium Secondary Spacecraft Cells." Report QE/C 68-14 (February 2, 1968), NASA Goddard Space Flight Center Contract W11,252B.

From the results of this test, it can be concluded that: (1) The ceramic seals used by Gulton Industries, Inc., are satisfactory as evidenced by no leakers out of the 54 cells tested. (2) The capacity of the 54 cells was in the acceptable range of 24.7 to 27.3 ampere-hours.
(0 references, 5 tables, 6 figures, 18 pages)

B-891

G. Myron Arcand, Idaho State University, "The Reactions Pertaining to Zinc-Silver and Cadmium-Silver Batteries." Fourth Quarterly Report (March 15, 1968) Jet Propulsion Laboratory Contract JPL 951887 under NASA Headquarters Prime Contract NAS 7-100. Re-Order No. 68-105.

Tracer studies have demonstrated that electrochemical oxidation of zinc and cadmium in 10 VF KOH solutions produces a zinc product which is less than 5% $Zn(OH)_2$ and a cadmium product which is 50-80% $Cd(OH)_2$. Oxidation of cadmium in a Cd-AgO cell containing a tritiated electrolyte solution results in a decrease in solution activity which cannot be accounted for simply by the formation of $Cd(OH)_2$. The rates of decomposition of AgO and Ag_2O apparently depend on how the original materials are prepared. These rate differences are very pronounced for Ag_2O at temperatures between 320° and 420° and are real, though smaller, for AgO at 160°. A procedure has been established for determining silver in KOH solutions by liquid scintillation counting using ^{110m}Ag as a tracer.
(9 references, 2 tables, 3 figures, 15 pages)

B-892

K. B. Green and R. L. McLaughlin, RCA Service Company, Division of Radio Corporation of America. "Accelerated Test Techniques." Final Engineering Report, RADC-TR-60-113 (May 31, 1960), Rome Air Development Center Contract AF 30(602)-1989. AD 245 502

This report describes a method of accelerated life testing by increasing the ambient air temperature to 70 degrees Centigrade for equipments that use vacuum tubes, and 60 degrees Centigrade for transistorized equipments. The average accelerated factor for all equipments was 2.3. This was proven by actual tests, both normal and accelerated on five single channel communications equipments, AN/GRR-7/GRT-3, three multi-channel communications equi ments AN/GRC-27, and ten transistorized AVR-200 marker beacon receiver equipments. (12 references, 24 tables, 30 figures, 229 pages)

B-893

T. Yusahara, Honda Electric Company, "Alkaline Storage Battery." Japanese Patent 21236 (1967), October 20, 1967. Applied December 18, 1964.

The cycle life of tubular or pocket-plate type alkaline batteries was greatly extended by placing an alkali-resistant, semi-permeable membrane having pore diameters of less than 100 Å on the inner surface of the perforated steel case of the negative cadmium electrode. This membrane (cellophane or nylon) prevents diffusion of oxygen to the negative plate during charge and minimizes the growth of cadmium crystals.

B-894

Y. Tomita, Yuasa Battery Company. "Sealed Alkaline Battery." Japanese Patent 21114 (1967), October 19, 1968, Applied September 4, 1964.

As a means of increasing the rate of oxygen recombination in sealed nickel-cadmium batteries, it is proposed to use a cadmium electrode with an especially large porosity (45 to 60%) for the outermost electrode of the electrode stack. The inner cadmium electrode has an ordinary porosity (25 to 45%). The oxygen recombination takes place mainly on the outermost, high porosity cadmium electrode.

B-895

Union Carbide Corporation, "Rechargeable Alkaline Battery." Japanese Patent 23079 (1967), November 9, 1967, Applied February 11, 1964.

A separator of special design is described which extends the cycle life of alkaline batteries using zinc anode. The separator permits effective contact of oxygen formed during charge of the tree-like deposit of zinc metal, and thus the latter is easily oxidized by the oxygen. The separator consists of a gas-and electrolyte-permeable mat or sheet with a number of small pieces of a suitable material attached to one side of the sheet. The separator material can be vinyl chloride-vinyl acetate copolymer (80-96 wt. % vinyl chloride), nylon, or acrylonitrile-vinyl chloride copolymer.

B-896

M. Fukuda, H. Ogawa, and K. Kanezuki, Matsushita Electric Industrial. "Manufactur of Electrodes for Sealed Alkaline Batteries." Japanese 23080 (1967) November 9, 1967, Applied March 13, 1964

The oxygen recombination rate at the cadmium electrode in sealed nickel-cadmium batteries decreases with increasing amount of carbonate in the electrode. Most of this carbonate was found to come from the air during the drying stage after the cadmium plates are formed and washed. This patent describes a process in which the drying is carried out under reduced pressure at 40 - 60°C and the cell is assembled in an inert atmosphere to avoid contamination by carbonate.

B-897

Power Sources 1966, Edited by D. H. Collins, Pergamon Press Symposium. Publications Division, New York (1967), "Absorption and Diffusion of Zincate Ions in Cellulose Membranes" (George A. Dalin and Z. O. Stachurski, Yardney Electric Corporation), pp 21-37.

Evidence is presented to show that zinc penetration through separators proceeds by growth and not by mechanical puncture. A principal factor in the effectiveness of separators for preventing zinc penetration is therefore the rate of diffusion through the separator. Measurements of the concentration of zincate ion in separators as a function of the concentration in the external solution show a plateau at low zincate concentrations which resembles a Langmuir adsorption isotherm. In this range the internal concentration is substantially greater than the external concentration. On the assumptions that the membrane zincate is partially adsorbed and partially free and that the log of the zincate activity coefficient at constant ionic strength is a linear function of zincate concentration, an absorption isotherm is derived which gives the adsorbed and internal free zincate as a function of the external zincate concentration. The equation, which involves no arbitrary constants is shown to fit experimental data for regenerated cellulose film. From this equation is calculated the distribution of zincate concentration through the membrane as a function of external concentration on one face, the other fact being at zero concentration. The distribution is linear with respect to either face. However, the gradient of the free zincate activity is lower than would correspond to the external zincate concentrations. Zincate growth must occur by deposition of zinc within the membrane, and therefore must be dependent on the permeation rate. Evidence is presented to show that adsorption-takes place only at selected positions on the cellulose chain. Competition between zincate and surfactants for adsorption sites is demonstrated. (9 references, 3 tables, 11 figures, 17 pages)

B-898

Power Sources 1966, Edited by D. H. Collins, Pergamon Press, Symposium Publications Division, New York (1967), "The Fabrication of Battery Plates Direct From Metal Powders" (D. H. Morrell and D. W. Smith, Joseph Lucas Ltd. Group Research Centre), pp 207-225.

Chemically prepared silver oxide (AgO) is used as the depolarizer in electrodes designed for a high-rate primary application. The AgO, blended with a few percent of carbon, is compressed into a plaque on a silver grid, usin methyl cellulose as binder. Coulombic efficiencies in the range 75 - 80 pe cent of theoretical are attained on discharge at about 1.1 amp/in^2. Variations in preparation designed to increase efficiency are described, as are some characteristics of the resulting plates. The added carbon is thought to act by maintaining electrical contact within the plate during discharge. (7 references, 5 tables, 7 figures, 13 pages)

B-899

Power Sources 1966, Edited by D. H. Collins, Pergamon Press, Symposium Publications Division, New York (1967), "The Fabrication of Battery Plates Direct from Metal Powders" (D. H. Morrell and D. W. Smith, Joseph Lucas Ltd. Group Research Centre), pp 207-225