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BATTERY LITERATURE SEARCH

BIBLIOGRAPHY AND ABSTRACTS

July 1976

Volume V

Prepared by

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

For

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California 91103

JPL Contract 953984, W.O. 343-20

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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

TBC-3001

G. W. Bengtson, Bendix Corp., Kansas City, Mo., "Ultrasonic Welding of Nylon cell Cases on a Nickel-Cadmium Battery," BDX-613-888-REV. August 1973. (N74-13765)

TBC-3002

R. Barnard, J. A. Lee and A. D. Sperrin, The Ever Ready Co. (G.B.) Ltd., "Behavior of Nitrate Impurity in Nickel-Cadmium Cells," Journal of Applied Electrochemistry 4, 1974, pp. 143-154.

The oxidation-reduction behaviour of NO_3^-, NO_2^-, $N_2O_2^{2-}$, NH_2OH and NH_3 at a platinum electrode in alkaline solution has been investigated using cyclic voltammetry. The results have been compared with the corresponding behaviour of these species at charged, porous cadmium and nickel hydroxide electrodes in order to understand the likely behaviour of NO_3^- impurities in nickel-cadmium cells. The reactions are shown to be irreversible processes and strongly dependent on the nature of the electrode surfaces. The reactions which are likely to be involved in a charged cell can be represented by the overall scheme:

$$NO_3^- \underset{\text{slow}}{\overset{\text{fast}}{\rightleftharpoons}} NO_2^- \underset{\text{fast}}{\overset{\text{slow}}{\rightleftharpoons}} NH_3 \xrightarrow{\text{slow}} N_2$$

It is suggested that the self-discharge of cells containing NO_3^- is limited by slow kinetic effects rather than by diffusions as previously supposed.

TBC-3003

F. Benjamin, Christie Electric Corp., Los Angeles, Calif., "The reFLEX Principle of Charging Nickel-Cadmium and Other Batteries," IEEE Power Processing and Electronics Specialists Conference, Atlantic City, N.J., May 22, 1972, 25th Power Sources Symposium. PPESC 72 Record pp 111-119. (73A13938)

The reFLEX principle is a new battery charging technique. This paper explains how it works, why it is superior to other battery charging methods and what effect various parameters have on its operation. It provides results of Government and commercial tests, evaluations and daily use. It reports on the present status of reFLEX charging with various types of batteries.

TBC-3004

G. Halpert, "Screening and Selection of Nickel and Cadmium Cells Plates to Improve Uniformity," NASA SP-295 Significant Accomplishments in Technology, The Proceedings of a Symposium held at NASA Goddard Space Flight Center, January 13, 1971, pp 56-58.

The nickel-cadmium battery has long been the backbone of the satellite's power supply. The cells which make up the battery, however, have suffered for a long time from operational problems and lack of uniformity. These problems can be tied to the materials within the cell-plates, separator, electrolyte, etc.--which until recently have been neglected. A study of the plate materials was initiated in which the purpose was to determine which factors affect operation--which could be predicted prior to cell assembly, and which could be determined nondestructively.

TBC-3005

W. J. Billerbeck, COMSAT Laboratories, Clarksburg, Maryland, "Electric Power for State-of-the-Art Communications Satellites," National Telecommunications Conference, Atlanta, Ga., Vol. 1, Nov 26-28, 1973, pp 19D1-19D12. (74A18006)

This paper analyzes the effects of new devices and technology on solar-battery primary power systems for communications spacecraft. The effects of the new technologies discussed herein include a new silicon cell which achieves about 25 to 35 percent more power; silver-plated INVAR, which is recommended for solar cell interconnections; a foldout solar array, using a flexible substrate, which will yield three to six times the power to weight ratio of a drum spinner; an early design Ni-H_2 battery which is expected to yield about 20 Whr/lb; and a power conditioning system that uses individual-boost regulators feeding each TWT converter to provide a 30-percent increase in power output for a given weight.

Thin substrate solar arrays are the most important factor in improving power/weight ratio of the entire synchronous spacecraft power system. The next most important factor is the use of an improved design power conditioning system. Within this decade, improved spacecraft power systems can increase the power/weight ratio by a factor of about 4.0 to 5.0

TBC-3006

A. Briglio, Jr., Jet Propulsion Laboratory, "Planetary Batteries," 120-34-10. (71W70837)

This task consists of (1) the development of long-life planetary batteries; (2) the definition and resolution of interfaces related to long-life-battery system integration for future spacecraft such as the advanced mariners and outer-planet spacecraft; and (3) the development of the technology for heat-sterilizable batteries. The elements of this task will be accomplished by: (1) investigations of the effects of particular environmental conditions on batteries; (2) the design of suitable battery

systems; (3) the development of reliable components and of methods for assembling and using batteries; (4) the testing and evaluation of components, batteries, and battery systems. The work will be done by contracts and by in-house efforts. These developments are directed toward providing the technologies for planetary missions requiring long-lived battery systems (7 to 12 years) and for Mars lander missions requiring heat-sterilizable batteries, thus forming a part of the planetary focused technology program.

TBC-3007

A. Briglio, Jr., Jet Propulsion Laboratory, "Electrochemical Energy Storage Research," 502-05-55. (74W70315)

The objectives of this task is to improve battery performance for spacecraft as well as for terrestrial use. This is to be accomplished through a continuing research effort, the major activity of which is the investigation of pulse charging effects on battery performance. Most batteries exhibit performance problems which can be linked to capacity decline, gassing or dendrite formation. Preliminary results of pulse charging experiments and the literature indicate that pulse charging has the potential for improving battery performance in this area. It is anticipated that improved charging and maintenance methods for batteries will directly support long-term space missions as well as terrestrial battery applications. The immediate objectives are (1) to determine the effects of pulse charging on degradative changes in alkaline cells; (2) to develop pulse charging procedures to extend the life of spacecraft batteries; (3) to define the interfaces imposed by integration of pulse charging systems on spacecraft. The elements of this task will be accomplished by (1) the determination of the effects of pulse charging techniques on the gassing behavior of sealed nickel cadmium cells; (2) the determination of the effects of pulse charging on the formation and propagation of dendritic growths on zinc and cadmium electrodes; (3) the development of optimum pulse charging techniques for extending the useful lifes of spacecraft batteries.

TBC-3008

A Briglio, Jr., Jet Propulsion Laboratory, "Electrochemical Energy Conversion and Storage," 506-23-23. (75W70346)

The battery technology to support future planetary missions and terrestrial applications is provided. The objectives, in accord with the NASA program objectives, are to attain longlife (10-year), high-energy-density, and highly reliable electrochemical energy storage devices by advancing the technology of its components, operating and storage techniques, and test and evaluation procedures. Additional requirements, such as high-rate discharge and cost reduction are also addressed. A more thorough understanding of battery failure modes will be obtained, and means for eliminating these failure sources in order to permit highly reliable battery operation will be investigated. This is to be accomplished through a continuing research effort, the major activity of which is the investigation of pulse charging effects on battery performance. The specific targets of the RTOP include

(1) achieving doubling of life of NI-CD batteries by means of non-gassing construction and improved fabrication techniques; (2) determining the effects of zero gravity on high power outputs of NI-CD, AG-ZN, NI-H2 and other candidate systems using test vehicles such as astrobee and the shuttle; and (3) screening and evaluating candidate electrochemical systems for selected probe applications requiring high-rate (up to 15C) performance with a life of up to five years, by the end of FY-1977. The immediate objectives of the research effort are (1) to determine the effects of pulse charging on degradative changes in alkaline cells, and (2) to establish a better theoretical understanding of the relationship between pulsed current parameters and electrode polarization.

TBC-3009

B. Bring and S. Landstedt, Svenska Ackumulátor, "Studies on Current Distribution at Nickel and Cadmium Electrodes by Laser Interferometry," Power Sources 4, D. H. Collins, Ed., Sept. 1972, Oriel Press, Newcastle-upon-Tyne (1973)

An optical method has been used for measuring local current densities in the electrolyte close to the electrodes. The basic components and principles of operation of a laser interferometer are described. The paper discusses variations in the density of hydroxyl ions and explains the origin of the heat observed. On the basis of these discussions it is shown that the local current density can be measured from interferograms. As a result it is shown that the current density distribution is not critical for either sintered or pocket type electrodes at the current densities used.

TBC 3010

E. W. Brooman and J. McCallum, Battelle Memorial Institute, "Thermal Conductivity Measurements of Nickel-Cadmium Aerospace Cells, Part 2. Component Conductivities," Journal Electrochemical Society, 119, 9, September 1972, pp. 1137-1141.

Thermal conductivities have been determined for the positive and negative electrodes from various 20 A-hr sealed, nickel-cadmium cells. The thermal conductivities of the three separator materials studied, nonwoven, calendered, and uncalendered nylon, and nonwoven polypropylene, are a function of porosity, electrolyte absorption, and amount of compression. It is found that as electrolyte is added to the separator materials, the conductivity initially increases relatively little compared with the conductivity of the electrolyte itself. 11 refs.

TBC-3011

E. W. Brooman, J. McCallum, E. A. Roeger, Jr., Battelle Columbus Labs, Columbus, Ohio and G. H. Miller, AFAPL, WPAFB, Ohio, "Temperature and Temperature Gradients for Accelerated Life Tests of Nickel-Cadmium Cells," Technical Report AFAPL-TR-72-66, August 1972. Contract No. F 33615-69-C-1537. (AD-748 252)

Cycling tests were performed on cell groups at ambient temperatures of -20, -5, 10, 25, and 40 C, and both with and without temperature gradients. Internal heaters provided an internal temeprature of 40 C for those cells with temperature gradients.

Acceleration factors indicate a valid accelerated life test using temperature gradients might be developed. However, the data did not support the expected result.that a range of environmental temperatures could be used to structure an accelerated life test.

Failure determination for all failed cells was loss of capacity at the positive electrode. Ampere-hour capacity was lost at both electrodes due to a "nitrate shuttle."

Considerable attention was given to analysis of quality data. Knowledgeable corrections to the data were required. Significant results seem to be obtainable by using only seven data points collected from evenly spaced intervals during the life of the test.

Recommended procedural improvements for future accelerated life tests are presented.

TBC-3012

D. E. Christy and J. D. Harkness, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells," Annual Report on Cycle Life Test, Report No. NASA-CR-133088, NASA Order S-23404-G (May 22, 1973) AD-762 602 QEEL/C-73-4. (N73-26046)

A life cycle test of secondary electric batteries for spacecraft applications was conducted. A sample number of nickel cadmium batteries were subjected to general performance tests to determine the limit of their actual capabilities. Weaknesses discovered in cell design are reported and aid in research and development efforts toward improving the reliability of spacecraft batteries. A statistical analysis of the life cycle prediction and cause of failure versus test conditions is provided.. QEEL/C-73-4. (N73-26046)

TBC-3013

D. E. Christy, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells: Synchronous Orbit Testing of General Electric Company 6.0 Ampere-Hour Sealed Nickel-Cadmium Cells," Report NASA-CR-136317, NASA Order S-23404-G (October 15, 1973). QEEL/C-73-302. (N74-13762)

The performance of sealed nickel cadmium cells operating under a synchronous orbit regime is analyzed. Results show that: (1) A temperature of 40 C is very detrimental to cells as may be noted from the low capacities for the 40 C pack; (2) a temperature of -20 C results in high cell voltages during charge. (3) Coulometers are effective charge control devices when operative. However, they have shorter lives than the cells they control; (4) the voltage balance, during discharge, between the high and low cells of a synchronous pack is best at 25 C and worst at 40 C. Also, age and

greater depths of discharge result in greater degradation of pack voltage balance; and (5) all packs, except 5 and 6 which are coulometer controlled, show a tendency to be reconditioned by the capacity check at the middle of each eclipse.

TBC-3014

D. E. Christy and J. D. Harkness, Naval Aummunition Depot, "Evaluation Program for Secondary Spacecraft Cells: Cycle Life Test," Annual Report, No. NASA-CR-138604, NASA Order S-23404-G (February 15, 1974)

Cycle life tests of secondary spacecraft cells are reported. The purpose of the cycle program is to determine the cycling performance capabilities of packs of cells under different load and temperature conditions. A summary of the results of life cycling programs is given. Weaknesses discovered in cell design are analyzed. Cells are tested on the basis of depth of discharge, temperature effects, and orbit period. The test facilities used in the program are described. QEEL/C-74-34. AD-781 835. N74-26502

TBC-3015

H. Ewe, Braunschweig University, W. Germany, "Surface Diffusion on Oxidized Nickel," Electrochimica Acta, 1973, Vol. 18, pp. 127-132, Pergamon Press, Great Britain.

A porous electrode of sintered nickel powder was used as a separating diaphragm between two electrolyte-solution spaces and its flow resistance for the solution and the electrical diaphragm resistance was measured. By galvanostatic or potentiostatic oxidation the electrode was oxidized on the surface to $Ni(OH)_2$ and NiOOH, causing a decrease of pore volume indicated by an increase of flow resistance. In contrast under certain conditions the electrical diaphragm resistance simultaneously diminishes. Thus the electric current is now carried not only by the ions of the electrolyte in the pores of the electrode; there is now an additional charge transport, which is assumed to be proton diffusion on the oxidized nickel surface. The thickness of the diffusion layer, the diffusion coefficient and the temperature dependence of proton diffusion were measured.

TBC-3016

D. Chua and R. J. Diefendorf, Rensselaer Polytechnic Institute, "Effect of Electrode Structures on Capacity of Sealed Cells During Cycling," Proceedings 25th Power Sources Symposium, pp. 52-55 (1972).

SEM is a powerful tool in analysing electrode morphology. This technique demands the least specimen preparation and preserved the original identity of the specimen without damage, as compared to transmission electron microscopy.

The second active phase, γ-$Cd(OH)_2$, has been found over a wider range of conditions than previously reported but the γ-$Cd(OH)_2$ was always the minor constituent.

It has been shown that the platelet of β-$Cd(OH)_2$ crystals not only increase in size but also a high degree of stacking occurs with the platelets. Both of these processes lead to inefficient utilization of the active materials during charging. It is suggested that the active sites during charging, for the larger hexagonal crystals, were the layer edges of the platelets. Thus, it probably can be expected that both the size and the stacking of the platelets play a major role in the charging efficiency and consequently the capacity of the battery.

It must be stated that emphasis was placed on the correlation between the electrode surface structures and the cell performance. Whether the same correlation holds true or not in the bulk of the electrodes is presently under investigation.

TBC-3017

J. L. Cioni and S. Gaston, Grumman Aerospace Corp., "One Hundred Ampere-Hour Nickel Cadmium Battery Module Development," (Mod-001) NAS9-11074, July, 1970/ July, 1973. (72K11015)

TBC-3018

R. E. Corbett, M. C. Glass, R. G. Matsui, Lockheed Missile & Space Co., Sunnyvale, Calif., "Development of a Power Module using Third Electrode Battery Charge Control," 9th Intersociety Energy Conversion Engineering Conference, August 1974, pp 137-143. (749068)

A spacecraft power system has been developed that is packaged into a single spacecraft structural member, which permits handling and testing of the system as a separate module. The power module, weighing 44 pounds, is designed to provide power in the 150 - 250 watt range. The module incorporates two 6-ampere-hour batteries whose charging is controlled by sintered-nickel-type control (third) electrodes. A third electrode charge control system was necessitated by a $10^{o}F$ to $110^{o}F$ operating temperature range to be incurred without power system operating restrictions.

Both primary and backup charge control circuits are provided for each battery on a single card integral to the battery package. The charge control circuits incorporate multiple level control of both control electrode and battery voltage threshold switching levels.

The module contains the power controls and telemetry instrumentation and commands required for all power system functions. These include under-voltage load switching provisions; battery overtemperature protection circuits; trickle charge circuits; system current, voltage, and temperature instrumentation; and ground equipment interfaces. The unit is designed to work with an unregulated solar array input.

In the final assembly, two battery units attach to the structural member on which are moutned all electronic boards and large components (power controls) not integral to the batteries. This permits equipment-level acceptance testing of the batteries and the power control assembly prior to final assembly. The unit was qualified at the module level under sine, random, shock, and thermal-vacuum cycling environments.

TBC-3019

P. Fono, "Spacecraft Nickel-Cadmium Battery Cycle Life Assessment," 7th Intersociety Energy Conversion Engineering Conference, San Diego, Calif. September 25-29, 1972, Proceedings. (A73-22755)
Also published in American Chemical Society, Washington, D.C., September 3, 1972. pp 98-102.

Spacecraft battery design requires information on battery cycle life. Most of the battery cycle life test data published to date are taken under simulated low altitude earth orbit conditions. Cycle life tests which were conducted by various testing laboratories are compared with tests conducted at the Navy's Quality Evaluation Laboratory, Crane, Ind. (NAD-Crane).

The analysis of the battery life information indicates a relationship between cycle life and cycle duration. Cycle life curves for cycles of different time durations are constructed and presented.

TBC-3020

P. Fono, Hughes Aircraft Co., El Segundo, Calif., "Battery and Cell Redundancy Considerations for Long Duration Space Missions," 9th Intersociety Energy Conversion Engineering Conference, August, 1974, pp 128-136. (749067)

The redundancy requirements in spacecraft nickel-cadmium battery systems are analyzed . Failure modes of both the batteries and control circuits are considered. Designs with multiple batteries are compared with single batteries which incorporate cell failure protection and series redundant cells to meet reliability goals. Battery control and load sharing circuit efficiencies are evaluated for battery sizing. Sample designs are made for both 50 and 100 A-hr batteries. Battery system weights are determined as a function of bus voltage with either boost or buck discharge regulators. Both low earth orbit and synchronous orbit missions are considered. The functional and weight analyses indicate that multiple batteries seem to be an acceptable compromise between the minimum weight and minimum cost systems. For voltages above 100 volts, a single battery should be seriously considered.

TBC-3021

S. Font, Soc. Des Accumulateurs Fixes et de Traction, Romainville, France, "Study of Nickel-Cadmium Batteries for use in Applications Satellites," ESRO CR(P)-323, Phase 1, November 1972. (N74-15773)
Contract No. 1358/71

Article in French.

TBC-3022

S. Font, Soc. Des Accumulateurs Fixes et de Traction, Romainville, France, "Study of Nickel-Cadmium Batteries for use in Applications Satellites, Phase 2. Evaluation of Charge Storage," ESRO CR(P)-324, December 1972. Contract No. 1358/71. (N74-16812)

This report evaluates the charge retention of Ni-Cd batteries type VO 238. It is concluded that the percentage of available capacity when stored in the charged state is better at lower temperatures for limited storage durations.

TBC-3023

S. Font, Soc. Des Accumulateurs Fixes et de Traction, Romainville, France, "Study of Nickel-Cadmium Batteries for use in Applications Satellites, Phase 2. Evaluation of Electrical Impedance," ESRO-CR(P)-326, February 1973. Contract No. 1358/71. (N74-16813)
Article in French.

The object of the test was the determination of impedance vs. frequency at different states of charge and temperature for Ni-Cd batteries VO238. This was conducted in the same time as the evaluation of charge efficiency vs. state of charge, temperature and charge current. To each determination of charge efficiency is associated the impedance measurement according to the values of the following parameters:

I_C (charge cycle) C/10

I_D (discharge cycle) C/2

States of charge: 0, .2, .6, 1.0, 1.2 Capacity

T: -20, 0, 20, 40°C

Frequencies: 1, 10, 10^2, 10^3, 10^4, 10^5 Hz

TBC-3024

F. E. Ford, Goddard Space Flight Center, Greenbelt, Maryland, "Characterization of the 20-Ah Nickel-Cadmium Cell used for Energy Storage on the Orbiting Astronomical Observatory," Power Sources 4, D. H. Collins, Ed., September 1972, Oriel Press, Newcastle-Upon-Tyne.
(Also released as Reports NASA-TM-X-66093 and X-761-72-330, September 1972).

Tests were conducted on 20-Ah sealed nickel-cadmium cells to evaluate initial and long-term performance at various charge rates, temperatures and voltage-control levels. An average ampere-hour recharge of 103 per cent per orbit at 13°C was able to maintain cell capacity; required watt-hour recharge on an orbital basis was 8 to 10 per cent greater than required ampere-hour recharge. Cells exhibited an early life "burn-in" characteristic. A discharge after periods of repetitive cycling yielded two voltage plateaus which were temporarily eliminated by the discharge. There was a degradation in the amount of watt-hours a battery will store with life, but the amount of watt-hours attainable on discharge to 1.0 V/cell at any specific point in the life is essentially constant, the difference being the voltage at which the watt-hours can be attained.

TBC-3025

F. E. Ford, T. J. Hennigan, C. F. Palandati and E. Cohn, NASA Goddard Space Flight Center, "Progress in Electrochemical Storage for Battery Systems," Report No. NASA-TM-X-66129 (X-761-72-448), (September 1972). (N73-13049)

Efforts to improve electrochemical systems for space use related to: (1) improvement of conventional systems; (2) development of fuel cells to practical power systems; and (3) a search for new systems that provide gains in energy density but offer comparable life and performance as conventional systems. Improvements in sealed conventional systems resulted in the areas of materials, charge control methods, cell operations and battery control, and specific process controls required during cell manufacture. Fuel-cell systems have been developed for spacecraft but the use of these power plants is limited. For present and planned flights, nickel-cadmium, silver-zinc, and silver-cadmium systems will be used. Improvements in nickel-cadmium batteries have been applied in medical and commercial areas.

TBC-3026

H. A. Frank, Jet Propulsion Laboratory, "Evaluation of New Plastic Compression (Ziegler) Type of Seals for Long Life Planetary Batteries," Report No. NASA-CR-130867 (JPL-TM-33-588) Contract No. NAS7-100. (February 1, 1973). (N73-12040)

A program was initiated to develop improved types of terminal seals for aerospace Ni-Cd batteries. The approach used has not involved attempts, such as employed elsewhere, to improve the ceramic-to-metal seal that is now extensively employed for this application. Rather the approach has been directed toward the development and evaluation of new types of seals. Of prime interest in this initial investigation has been the Ziegler type of

compression seal and in particular the injection molded version developed by the Bell Telephone Laboratories (BTL). A number of these units were designed, fabricated, and evaluated on an accelerated life test under a simulated battery environment. Results have shown that there are no major problems involved in scaling up the BTL small-size (5-amp) seal to a larger size (up to 50-amp) seal suitable for most JPL flight batteries. Five out of five such seals successfully completed over 10 months of continuous thermal cycling without developing any leaks greater than 1.8 x to 10 to the minus 9th power atm-cc-He/s. (N73-12040)

TBC-3027

S. Gaston, Grumman Aerospace Corp., Bethpage, New York, "The 100 Ampere-Hour Nickel-Cadmium Battery Development Program, Volume I," Final Report NASA-CR-140380, March 1974. (N75-14266)
Volume II, Final Report, NASA-CR-140381, March 1974. (N75-14267)

A program to develop a long-life, reliable and safe 100 ampere-hour sealed nickel-cadmium cell and battery module with ancillary charge control and automated test equipment to fulfill the requirements of a large Manned Orbital Space Station which uses Solar Arrays as its prime source for 25 kW of electrical power was conducted. A sealed 100 ampere-hour cell with long life potential and a replaceable, space maintainable battery module has been developed for Manned Space Station applications. The 100 ampere-hour cell has been characterized for initial (early life) anticipated conditions.

TBC-3028

V. V. Romanov, K. S. Zimina and P. I. Sandler, Army Foreign Science and Technology Center, "Chemical Charging of Nonlamellar Cadmium Electrode of an Alkaline Battery" Report No. FSTC-HT-23-135-74, Translation of USSR Patent No. 336730 (September 20, 1973). (AS-781 983)

The chemical method of charging the nonlamellar cadmium electrode of an alkaline battery can be made more efficient if the electrode is soaked in a solution of nickel chloride before processing in the reducing solution, and if hydrazine is used as the reducing agent. Using this method, the nominal capacity of the electrode can be obtained on the first discharge.

TBC-3029

S. Gaston, M. Wertheim, and J. Orourke, Grumman Aerospace Corpl., OAO Battery Data Analysis," Report No. NASA-CR-131414, Contract NAS5-11465 (February 1973) 471 p. (N73-20045)

Summary, consolidation and analysis of specifications, manufacturing process and test controls, and performance results for OAO-2 and OAO-3 lot 20 Amp-Hr sealed nickel cadmium cells and batteries are reported. Correlation of improvements in control requirements with performance is

a key feature. Updates for a cell/battery computer model to improve performance prediction capability are included. Applicability of regression analysis computer techniques to relate process controls to performance is checked.

TBC-3030

D. J. Gordy, E. Luksha, & C. J. Menard, "Controlled Porosity and Pore Size Substrates for Nickel-Cadmium Cells," Journal of Electrochemical Society, Vol. 120, November, 1973. pp 1447-1451 (A74-19222) (NAS 5-21097)

A novel process for the preparation of improved cadmium electrode plaques with precisely controlled pore size and porosity is described. The requirements for these plaques include far better uniformity, reproducibility, and life than is currently available with conventional materials. The key features of the work were preparation of plaques via a powder metallurgical technique which consisted of isostatically compacting a blend of a nickel powder with a fugitive pore-former and subsequently sintering the "green" compatct. Cadmium electrodes were prepared from these materials and cycle tested in negative-limited cells using an accelerated, torturous test regime. Results were obtained which showed the new structures yielded electrodes that were superior to the conventional structures in mechanical properties and performance. BET surface areas, SEM photomicrographs, and mechanical strengths using a three-point bend test were used to help in the thorough characterization of the electrodes and the components prepared.

TBC-3031

D. J. Gordy, Gould, Inc., Mendota Heights, Minn., "Fabrication and Testing of Negative-Limited Sealed Nickel-Cadmium Cells," REPT-732-015-3 JPL-953680, NASA-CR-139374, May 1974. (N74-29412)

Negative-limited sealed nickel-cadmium cells are a possible means toward increasing the life of nickel-cadmium cells to about a decade or more. The purpose of this program is to design, construct, and test 100, 20 Ah and 100, 30 Ah negative-limited sealed cells. The cell design was completed and hardware was ordered during the first quarter. Electrode fabrication was started in the first quarter and carried on through the second quarter. The fabrication and selection of the necessary electrodes has been completed during the third quarter. Cell construction has been completed and the preparatory cell cycling is underway. The preliminary testing to select the initial delivery cell has been started.

TBC-3032

D. J. Gordy, Gould, Inc., Mendota Heights, Minn., "Fabrication and Testing of Negative-Limited Sealed Nickel-Cadmium Cells," Quarterly Report REPT-732-015-4, July 74, NASA-CR-140662 QR-4, April 1, 1974 to June 30, 1974. (X74-76824)

TBC-3033

H. J. Ratzer-Scheibe and H. G. Feller, Institut fur Metallphysik der Technischen Universitat, Berlin, "Dynamishe Stromdichte-Und Kapazitatsmessungen Bei Der Erfassung Von Elektrochemischen Adsorptionsreaktionen An Nickelelektrode," Electrochimica Acta, 1973, Vol. 18, pp. 175-183, Pergamon Press, Great Britain.

The experimental relations between potentiodynamically measured current-density/and capacitance/potential curves of the Ni electrode are explained by theoretical derivations of a simple charge-transfer reaction.

In the transpassive potential region, the specific influence of SO_4^{2-} and HSO_4^- ions of the sulphuric acid electrolyte has been demonstrated by capacitance measurements. Even small additions of F^- ions to the solution have a great influence on the electrochemical processes at higher potentials.

The fast potential-sweep method has been used to study the current density related to the redox reaction between $Ni(OH)_2$ and NiOOH that take place in alkaline solution.

TBC-3034

S. Gross and John Malcolm, The Boeing Company, "Thermal Considerations of Sealed Nickel-Cadmium Batteries, Power Sources 4, D. H. Collins, Ed., September 1972, Oriel Press, Newcastle-Upon-Tyne.

Nickel cadmium cells were tested and analyzed to predict thermal behavior for battery designs that provide improved thermal performance. Correlations have been developed to predict accurately cell heat generation and thermal joint resistance. A thermal model was derived and experimentally verified, then used to conduct a parametric study of the variables that determine the effectiveness of the packaging design. Cooling arrangement, materials and heat generation uniformity were variables.

TBC-3035

B. Case, Central Electricity Research Laboratories, Leatherhead, England, "The Diffusivity of Oxygen in Dilute Alkaline Solution from 0° to 65°C," Electrochimica Acta, 1973, Vol. 18, pp 293-299, Pergamon Press, Great Britain.

Diffusion coefficients for oxygen in 0·1 M sodium hydroxide solution have been determined from 0° to 65°C using a rotating platinum electrode. The results may be represented with a standard deviation of approximately 1% by the expression:

$$D = D_o \exp\left[-\frac{Q_D}{RT}\right]$$

where $D_o = 8{\cdot}03 \times 10^{-3} cm^2 s^{-1}$ and the apparent activation energy, Q_D, is $3{\cdot}49$ kcal mol^{-1}. Between 25° and 65°C the product of the diffusivity and the solution viscosity is essentially constant:

$$D\eta \approx 1{\cdot}95 \times 10^{-7} g\ cm\ s^{-2}.$$

Values for diffusion coefficients for oxygen in pure water have been derived from these data with an absolute error probably less than 4%. Solubility data also given.

Difficulties in obtaining reproducible results at a rotating platinum electrode are attributed to deactivation of the electrode by reduction of a surface oxygen phase. Results at the higher temperatures indicate that methods of determining diffusivities by diffusion through a stagnant layer of solution involve an increasing indeterminate error as the temperature rises, due to convective mass transport.

TBC-3036

G. Halpert, O. Ogunyankin, and C. Jones, NASA Goddard Space Flight Center, "Procedure for Analysis of Nickel-Cadmium Cell Materials," Report No. NASA-TM-X-70575 (X-761-73-314), Contract NGR-09-050-003 (October 1973). (N74-15744)

Quality control procedures include analyses on electrolyte, active materials, and separators for nickel cadmium cell materials. Tests range from the visual/mechanical inspection of cells to gas sampling, electrolyte extract, electrochemical tests, and physical measurements.

TBC-3037

J. D. Harkness, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells: Initial Evaluation Tests of Gulton Industries, Incorporated, 20.0 Ampere-Hour Nickel-Cadmium Spacecraft Cells with Auxiliary Electrodes," Report NASA-CR-136138, NASA Order S-23404-G (January 4, 1974) AD-771 861. QEEL/C-74-2. (N74-13761)

The results of the test program for selecting aerospace cells are evaluated. The cells were tested for capacity, voltage, leakage, internal resistance, and charge efficiency. Test data are tabulated.

TBC-3038

J. D. Harkness, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells. Initial Evaluation Tests of Eagle-Picher Industries, Incorporated 3.0 Ampere-Hour Nickel-Cadmium Spacecraft Cells," Report NASA-CR-136253, NASA ORDER S-23404-G (OCTOBER 29, 1973) QEEL/C-73-38. (N74-13763)

The capacity of the cells ranged from 3.58 to 3.97 amperehours during the the three capacity tests. Three cells were removed from test, due to high pressure, during the C/10, 24-hour charge at room ambient temperature. The voltage requirement of 1.480 volts was exceeded by the cells during the C/10, 24-hour charge at 20 C, although the end-of-charge voltage was below this value (1.466-1.475 volts). Average capacity out during the 20 C charge efficiency test was 0.84 AH which represents 48% and is below the minimum requirement of 55%. The cells exhibited no pressure decay during the open-circuit stand portion of the pressure versus capacity test, as all cells reached their voltage limit (1.550 volts) before their pressure reached 20 psia with the highest pressure being 8 psia during charge.

TBC-3039

J. D. Harkness, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells. Initial Evaluation Tests of General Electric Company 8.0 Ampere-Hour Nickel-Cadmium Spacecraft Cells with Auxiliary Electrodes for the Small Astronomy Satellite (SAS-C)," Report NASA-CR-138191, NASA Order S-23404-G (April 17, 1974).

Cells were screened for electrolyte leakage, internal shorts, low capacity, or inability of any cell to recover its open-circuit voltage above 1.150 volts during the internal short test. The average weight of the teflon covered negative plate cells was 10.5 grams heavier than that of the standard plate cells. The standard plate cells exhibited higher average end-of-charge (EOC) voltages than the cells with teflon covered negative plates; but were lower than or equal to the capacity out in ampere-hours of the teflon plate cells following these charges.

TBC-3040

J. D. Harkness, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells: Initial Evaluation Tests of General Electric Company 6.0 Ampere Hour Nicekl-Cadmium Spacecraft Cells with Auxiliary Electrodes for the Atmospheric Explorer Satellite C and D," Report NASA-CR-138985, NASA Order S-23404-G (January 2, 1974). AD-771 998
QELL/C-74-1. (N74-19703)

The capacity of the cells ranged from 6.6 to 7.6 ampere hours during the three capacity tests. No voltage requirements or limits were exceeded during any portion of the test. All cells recovered to a voltage in excess of 1.193 volts during the 24-hour open-circuit portion of the internal short test. All the cells reached a pressure of 20 psia before reaching the voltage limit of 1.550 volts during the pressure

versus capacity test. The average ampere/hours in and voltages at this pressure were 9.1 and 1.513, respectively. All cells exhibited pressure decay in the range of 1 to 5 psia during the last 30 minutes of the 1-hour open circuit stand. Average capacity out was 7.2 ampere/hours. QEEL/C-74-1. (N74-19703)

TBC-3041

J. D. Harkness, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells. Initial Evaluation Tests of 20.0 Ampere-Hour Nickel-Cadmium Spacecraft Cells Manufactured by Gulton Industries, Inc.," Report No. QEEL/C 73-459, NASA Order S-23404-G (December 3, 1973) AD-771 843

The report describes testing and performance of 20.0 ampere-hour Ni-Cd spacecraft batteries.

TBC-3042

S. Font, Soc. Des Accumulateurs Fixes et de Traction, Romainville, France, "Study of Nickel-Cadmium Batteries for use in Applications Satellites, Phase 3. Study and Analysis of Utilization Modes," ESRO-CR(P)-330, July, 1973. Contract No. 1358/71. (N74-16814)

Article in French

TBC-3043

T. J. Hennigan, NASA Goddard Space Flight Center, "Accelerated Test Plan for Nickel Cadmium Spacecraft Batteries," Report NASA-TM-X-70524 (X-761-73-183) (October 1973). (N74-12741)

An accelerated test matrix is outlined that includes acceptance, baseline and post-cycling tests, chemical and physical analyses, and the data analysis procedures to be used in determining the feasibility of an accelerated test for sealed, nickel cadmium cells.

TBC-3044

T. J. Hennigan, NASA Goddard Space Flight Center, "Battery Quality Control and Tests," 502025058 (73W70305)

The objectives are to A. advance battery material development, B. increase the usable energy density of nickel cadmium cells, C. improve cell and

cell component characterization methods and cell fabrication process control, D. develop analytical methods for cell component analysis, E. maintain a NASA test facility to perform battery life tests and investigate methods of accelerated testing, F. investigate thermal properties of sealed cells.

TBC-3045

T. J. Hennigan, NASA Goddard Space Flight Center, "Battery Quality Control and Tests," 502-25-58. (74W70320)

This RTOP covers (1) advance battery material development; (2) to increase the usable energy density of nickel-cadmium cells; (3) improve cell and cell component characterization methods and cell fabrication process control; (4) develop analytical methods for cell component analysis; and (5) maintain a NASA test facility to perform battery life tests and investigate methods of accelerated testing.

TBC-3046

T. J. Hennigan, NASA Goddard Space Flight Center, "Battery Quality Control and Tests," 506-23-22. (75W70345)

Objectives are (1) to advance battery material development; (2) to increase the usable energy density of nickel-cadmium cells; (3) to improve cell and cell component characterization methods and cell fabrication process control; (4) to develop analytical methods for cell component analysis; and (5) maintain a NASA test facility to perform battery life tests and investigate methods of accelerated testing.

TBC-3047

John A. Herrmann, Gould, Inc., "Rapid Charger for Maintenance-Free Batteries," Semi-Annual Report ECOM 0209-1-71, May 1, 1971 to December 31, 1971, Contract DAAB07-71-C-0209 (March 1973), 72 p. AD-911 508

The purpose of this program was to evaluate various charging approaches for rapid charging sealed nickel-cadmium, vented nickel-cadmium, and silver zinc-oxide batteries. A programmable charger was to be designed, manufactured and used as a tool during the evaluation of the various charging approaches. To accomplish the objectives, a paper design and breadboard of the circuitry for the programmable charger was initiated at the beginning of the contract. Throughout the first nine months of the program. The charger was designed, breadboard portions were evaluated, and final hardware built. Upon the completion of initial hardware, the system was checked out and problem areas corrected. The charger was designed to have five basic operating modes with each having necessary controls for varying charge current, discharge current, charge frequency, and mode selection. As of the time period covered by this report, no testing of charge approaches has started; therefore, the only results which can be stated are that a working programmable charger was designed, fabricated, and tested.

TBC-3048

John A. Herrmann, Gould, Inc., "Rapid Charger for Maintenance-Free Batteries," Final Report ECOM 0209-F-71, Contract DAAB07-71-C-0209 (October 1973) 116A AD-913 957L

The purpose of this program was to evaluate various charging approaches for rapid charging sealed nickel-cadmium, vented nickel-cadmium, and silver zinc-oxide batteries. A programmable charge was to be designed, manufactured, and used as a tool during the evaluation of the various charging approaches. To accomplish the objectives, a paper design and breadboard of the circuitry for the programmable charger was initiated at the beginning of the contract. Throughout the first nine months of the program, the charge was designed, breadboard portions were evaluated, and final hardware built. Upon the completion of initial hardware, the system was checked out and problem areas corrected. The charger was designed to have five basic operating modes with each having necessary controls for varying charge current, discharge current, charge frequency, and mode selection, after the completion of the programmable charger, a test program was executed to evaluate various rapid charging approaches for sealed nickel-cadmium batteries. In general, it was concluded that pulse charging of sealed nickel-cadmium batteries is a viable approach to rapid charging, assuming an effective cut-off means is used to terminate high-rate charge when approximately 90-(U)

TBC-3049

B. J. R. Hodge, R. Bonnaterre, and F. Putois, SAFT, "Fast Charging of Sealed Nickel-Cadmium Batteries - Theory and Practice," International Power Sources Symposium Committee, 9th International Power Sources Symposium, Brighton, England, September 17-19, 1974, 20p. 75A13063#

TBC-3050

G. Holleck, M. Turchan and J. Hopkins, Tyco Labs., Inc., "NiCd Battery Electrodes," Final Report NASA-CR-127890, Jet Propulsion Laboratory Contract No. 953185 (May 1972), (N72-30032)

The objective of this research program was to develop and evaluate electrodes for a negative limited nickel-cadmium cell and to prove its feasibility. The program consisted of three phases: (1) the development of cadmium electrodes with high hydrogen overvoltage characteristics, (2) the testing of positive and negative plates, and (3) the

fabrication and testing of complete negative limited NiCd cells. The following electrode structures were manufactured and their physical and electrochemical characteristics were evaluated; (1) silver sinter-based Cd electrodes, (2) Teflon-bonded Cd electrodes, (3) electrodeposited Cd sponge, and (4) Cd-sinter structures. All cadmium electrode structures showed a sharp increase in potential at the end of charge, with the advent of hydrogen evolution occurring at approximately -1.3 V Hg/HgO. The hydrogen advent potentials on pure cadmium structures were 50 to 70 mV more cathodic than those of their silver-containing counterparts.

TBC-3051

P. Jonville, J. M. Fresnel, K. D. Beccu, & J. Bezaudin, "A New Technique for Manufacturing Electrodes by Hot Pressing," Power Source 4: Research and Development in Non-Mechanical Electrical Power Sources; Proceedings of the Eighth International Symposium, Brighton, Sussex, England, September 24-26, 1972. (A74-20637)

Oriel Press Ltd., Newcastle-Upon-Tyne, England, 1973. pp 223-240 Research Sponsored by the Centre National D'Etudes Spatiales. (A74-20627)

A new process is presented which describes the fabrication of cadmium and nickel electrodes for secondary alkaline batteries by means of a hot-pressing technique. It consists of submitting, in special dies and for a short time (6 min), a powder mixture of metallic support (nickel) and active mass, or a compound which acts as a precursor of the active mass (cadmium and nickel fluorides), to a high pressure (500 kg/cm^2) at a moderate temperature (550°C) relative to the normal sintering conditions. Better reproducibility of electrode characteristics and a longer cycle life are obtained compared to conventional sintered electrodes owing to a stricter control of all process parameters. Other types of electrodes can also be made by this method. An industrial scale, continuous process can be envisaged.

TBC-3052

G. L. Juvinall, E. Luksha and C. J. Menard, Jet Propulsion Laboratory, "Novel Negative-Limited Sealed Nickel-Cadmium Cell," 9th Intersociety Energy Conversion Engineering Conference, 1973, pp. 881-887 (Paper No. 749 125)

The development of the negative-limited, sealed, nickel-cadmium cells described in this paper stems from a need for a reliable cell which is essentially free of gassing during operation. Elimination of the gassing problem results in a long-lived cell which is immune to catastrophic failure and does not require the complex charge control systems used by conventional cells. The new cell is designed to be negative-limited on charge and utilizes a negative electrode which incorporates a substrate possessing high hydrogen overvoltage characteristics. The negative-limited feature of the cell precludes the formation of appreciable amount of oxygen since the positive electrode is never overcharged. The effect of the high hydrogen

overvoltage substrate is to provide a rapid rise in voltage at the end-of-charge which is used to terminate charge and prevent the formation of hydrogen. Thus, the performance of the cell under controlled conditions is essentially gas-free. 2 refs.

TBC-3053

E. Kantner, Gulton Industries, Inc., "One Hundred Ampere-Hour Nickel-Cadmium Battery Cells of Improved Design," Report No. NASA-CR-112139, Contract NAS1-8151 (1972). (N72-32071)

Nickel cadmium battery cells with 100 ampere hour capacity were developed. The design features, notably extension of the current collector tab to the full width of the battery plate, and the location of the cell terminals on the opposite ends, resulted in a reduction of internal impedance, and improved electrical performance with expected improvement in thermal performance. Tables of data and performance curves are included to support the theoretical considerations.

TBC-3054

P. Kelson, A. D. Sperrin, & F. L. Tye, "The Behaviour of Sintered Plate Nickel Hydroxide Electrodes in Lithiated Electrolyte Solutions," Power Sources 4: Research and Development in Non-Mechanical Electrical Power Sources; Proceedings of the Eighth International Symposium, Brighton, Sussex, England, September 24-26, 1972. (A74-20636)

Oriel Press Ltd., Newcastle-Upon-Tyne, England, 1973. pp 201-220 (A74-20627)

The importance of measuring true charge acceptance when studying the charge-discharge behaviour of nickel hydroxide electrodes is discussed and two techniques developed for this purpose are described. The quantitative effects of lithium hydroxide addition to the electrolyte on charge acceptance at charge rates between 0.05C and 0.65C in the range 10°C to 70°C have been investigated. Lithium is shown to improve charge acceptance significantly only at temperatures above 35°C, except at very low charge rates when some improvement is obtained at lower temperatures. Discharge efficiency is unaffected. The mechanism by which lithium affects electrode behaviour has been examined by considering the charge-discharge potentials observed in pure potassium hydroxide and lithiated electrolyte.

TBC-3055

R. L. Kerr and J. D. Reams, Aero Prupulsion Laboratory, Wright-Patterson AFB, "Advances in Space Power Generation, IAF Paper 74-086, International Astronautical Federation, 25th International Astronautical Congress, Amsterdam, Netherlands, September 30, 1974 to October 5, 1974. 28 p. (75A13718)

TBC-3056

R. L. Kerr, AFAPL, WPAFB, OHIO, and D. N. Stager, TRW Systems Group, Redondo Beach, Calif., "Kilowatt Battery Systems," 7th Intersociety Energy Conversion Engineering Conference, Sept. 1972, pp 103-109. (729023). (73A22756)

High energy density, kilowatt level battery systems are being developed to meet new spacecraft needs. The goals of systems supplying 1 and 2 kW of power, respectively, to a spacecraft in synchronous orbit are 7 and 8 watt hours per pound with 7 years life at 0.95 reliability. The systems are radiation hardened and are compatible with typical spacecraft internal temperatures and bus voltage. A high depth-of-discharge allows maximum utilization of energy. Electronics for both forward and reverse cell current bypass provide maximum cell protection and recharge capability. Added cells in series provide for individual cell degradation or failure. Oxygen sensing electrode signals control charging through reliable electronics. The battery average temperature of 40°F is maintained by variable conductance heat pipes connecting the battery system to an external spacecraft radiator. One complete 1 kW prototype system has been assembled and is on life test.

TBC-3057

E. Levy, Jr., E. C. Duncan, C. E. Maiden, W. E. Michel and G. I. Cardwell, Hughes Aircraft Co., El Segundo, Calif., "Low Earth Orbit Battery Development Project," Rept. No. SCG-10288R, August 1971, AFAPL Contract No. F33615-70-C-1710. (AD-887 970L)

Work described includes parallel efforts on nickel-cadmium cell improvement and development of a 500 watt breadboard battery system. The 500 watt breadboard system consists of two eight-cell packs of 50 amp-hr cells and a battery controller. The battery controller provides the functions of charge and discharge control. Charge and discharge control concepts were investigated and a system selected using a bilateral charge-discharge circuit with common utilization of components and circuits for both charge and discharge. A charge control system using temperature-biased voltage to taper charge and pressure to discontinue charge was selected. Cell reversal, reconditioning, and radiation hardening were also studied. Improvements were studied on separator material, cadmium migration treatment, electrolyte quantity, and thermal design, cells incorporating combinations of these improvements are currently in test. Ceramic-to-metal seal metallurgy and geometry have been studied.

TBC-3058

E. Levy, Jr., E. C. Duncan, C. W. Maiden, W. E. Michel, and G. I. Cardwell, Hughes Aircraft Co., "Low Earth Orbit Battery Development Project," Interim Technical Report AF APL-TR-71-62, July 1, 1970 to June 15, 1971, Contract F33615-70-C-1710 (August 1971) 205 p. (AD 887-910L)

Work on this program includes parallel efforts on nickel-cadmium cell improvement and development of a 500 watt breadboard battery system. A General Electric (GE) 50 amp-hr cell was selected after a 3 month test program on 12 evaluation cells purchased from each of three vendors. The 500 watt breadboard system consists of two eight-cell packs of 50 amp-hr cells and a battery controller. The battery controller provides the functions of charge and discharge control. Charge and discharge control concepts were investigated and a system selected using a bilateral charge-discharge circuit with common utilization of components and circuits for both charge and discharge. A charge control system using temperature-biased voltage to taper charge and pressure to discontinue charge was selected. Cell reversal, reconditioning, and radiation hardening were also studied.

A nickel-cadmium cell improvement study was subcontracted to GE. In addition, a study of improved seals, and experimentation with state of charge indication methods was done at Hughes. The improvements studied at GE are separator material, cadmium migration treatment, electrolyte quantity, and thermal design. Cells incorporating combinations of these improvements are currently in test. Ceramic-to-metal seal metallurgy and geometry have been studied, and three seals of advanced design have been ordered for evaluation. The method selected for initial investigation of state-of-charge indication is the resistance change of the negative electrode with state of charge. Experimentation with a number of samples is in process. Thermal analysis and design of the system and cell improvement were also undertaken.

TBC-3059

E. Levy, Jr., E. C. Duncan, C. E. Maiden, W. E. Michel, and G. I. Cardwell, Hughes Aircraft Co., El Segundo, Calif., "Low Earth Orbit Battery Development Project," Final Report, June 72, Contract No. AF 33615-70-C-1710, July 1, 1970 to June 30, 1972, AFAPL Report No. SCG-20308R (AD-902/570L)

Work on this program included parallel efforts on development of a 500 watt breadboard battery system and improvement in nickel-cadmium cell design. A General Electric (GE) 50 amp-hr cell was selected for the breadboard battery. The 500 watt breadboard system consists of two eight-cell packs of 50 amp-hr cells and a power conditioner which provides the functions of charge and discharge control. Charge and discharge control concepts were investigated and a system selected using a bilateral charge-discharge circuit with common utilization of components and circuits for both charge and discharge.

TBC-3060

C. H. Liebert, NASA Lewis Research Center, Cleveland, Ohio, "Heat-Transfer Experiments on a 34-Ampere-Hour Nickel-Cadmium Cell," NASA Technical Memorandum TMX-2371, September 1971.

Local transient temperature distributions throughout the plate pack of operating nickel-cadmium cells and accompanying jar temperatures are reported herein for a 34-ampere-hour cell. The cell was charged at 7 amperes and was discharged into the exhaustion region at constant currents ranging from 16 to 68 amperes. Temperature distributions were recorded for a variety of heat-transfer conditions which could be encountered in practical battery applications. At given times, average theoretical temperatures calculated by use of transient lumped heat-transfer models predicted local experimental temperatures within ± 4 percent. This suggests that simple lumped theory can be applied with confidence to the thermal design of nickel-cadmium batteries.

TBC-3061

E. Luksha and D. J. Gordy, Gould, Inc., "Nongassing Nickel-Cadmium Battery Electrodes and Cells," Quarterly Report NASA-CR-126623 (REPT-712-122-2) September 15 to December 15, 1971, Jet Propulsion Laboratory Contract 953184 (February 18, 1972). (N72-24046)

The failure of nickel-cadmium storage batteries due to severe gassing during charging is discussed. In order to increase the life of such cells, nongassing positive and negative electrodes are used. The gassing characteristics of nickel electrodes were evaluated as a function of their loading, charge rate, and charge temperature.

TBC-3062

E. Luksha & D. J. Gordy, Gould, Inc., Mendota Heights, Minn., "Non-Gassing Nickel-Cadmium Battery Electrodes and Cells," Quarterly Report, May 72, NASA-CR-127061 QR-3 Rept.-712-122-3. (N72-26035)

Supposedly long-lived nickel-cadmium batteries often fail due to severe gassing on charge. In order to increase the lives of such cells attempts are being made to construct nongassing positive and negative electrodes. The gassing characteristics of both electrodes in negative limited cells were determined as a function of charge rate, charge temperature, and loading. Cycle life tests, up to 70 cycles, of some of the cells show they operate in a nongassing manner with very low degradation rates.

TBC-3063

E. Luksha and D. J. Gordy, Gould, Inc., "Non-Gassing Nickel-Cadmium Battery Electrodes and Cells," Final Report NASA-CR-128355 (Rept-712-122-4) June 15, 1971 to June 15, 1972, Jet Propulsion Laboratory Contract No. 953184 (July 15, 1972). (N72-33056)

The concept of a negative limited nongassing nickel-cadmium battery was demonstrated by constructing and testing practical size experimental cells of approximately 25 Ah capacity. These batteries operated in a gas-free manner and had measured energy densities of 10-11 Wh/lb. Thirty cells were constructed for extensive testing. Some small cells were tested for over 200 cycles at 100% depth. For example, a small cell with an electrodeposited cadmium active mass on a silver screen still had 55% of its theoretical capacity (initial efficiency was 85%). There was no evidence of deterioration of gassing properties with cycling of the nickel electrodes. The charge temperature was observed to be the most critical variable governing nickel electrode gassing. This variable was shown to be age dependent. Four types of cadmium electrodes were tested: an electrodeposited cadmium active mass on a cadmium or silver substrate, a porous sintered silver substrate based electrode, and a Teflon bonded pressed cadmium electrode. The electrodeposited cadmium mass on a silver screen was found to be the best all-around electrode from a performance point of view and from the point of view of manufacturing them in a size required for a 25 Ah size battery.

TBC-3064

E. Luksha and D. J. Gordy, Gould, Inc., "Non-Gassing Nickel-Cadmium Battery Electrodes and Cells Testing of 24 AH Cells," Supplementary Report No. NASA-CR-130932, August 25, 1972 to November 25, 1972, Jet Propulsion Laboratory Contract No. 953184 (February 23, 1973). (N73-19060)

The testing of 30 practical size, experimental 25 ampere hour cells constructed as part of an earlier negative limited cell development program is discussed. The test results showed that the negative limited cell is a possible means of developing a long-lived secondary cell. The cells were tested for 500 cycles using an accelerated regime approximating a 90-minute orbit period. Three groups of ten cells were tested at 0, 25, and 40en 1 C. The cycle data showed that the negative limited cells had higher degradation rates at the higher operating temperatures. At the conclusion of 500 cycles, the three groups had average capacities of 16.83, 12.74, and 5.71 ampere hours for testing at 0, 25, 40en 1 C, respectively. The conditioning capacities of these cells was in the 25 ampere hours range. The internal cell pressures of the three groups was also temperature dependent and was, in general, in the 2 psig range during the course of the test program. No periodic variation of the internal pressure with the state-of-charge was observed except with some cells tested at 40 C.

TBC-3065

E. Luksha and K.C. Kohl, Gould, Inc., "Fabrication and Testing of Negative-Limited Sealed Nickel-Cadmium Cells," Quarterly Report, NASA CR-135981 (REPT-732-015-1), July 1, 1975 to September 30, 1973, Jet Propulsion Laboratory Contract No. 953680 (October 10, 1973). (N74-10078)

The design, construction, and testing of 100, 20Ah and 100, 3 Ah negative-limited sealed cells are reported. The required physical dimensions of the hardware and components necessary to produce 20 and 3 Ah cells were established. The stainless steel cans and covers have been ordered. The covers contain two ceramic seals. The fabrication of electrodes was started. About 55% (879 electrodes) of the required cadmium electrodes has been prepared. About 44% of the porous nickel substrates (plaques) required for the preparation of the nickel oxide electrodes has been completed.

TBC-3066

S. W. Mayer & D. Taylor, Aerospace Corporation, El Segundo, Calif., "Penetration of Cadmium into Nylon Separators of Ni-Cd Batteries," January 1974, Contract No. F04701-73-C-0074, SAMSO-TR-74-17. (N74-20707) (AD-774562)

Because of the preflight occurrence of failure resulting from a short circuit between plates and extensive cadmium migration to the separators of a Ni-Cd cell intended for long-term use in a satellite, a series of photomicrographic investigations has been made of the depth of cadmium penetration into a separator from the cell and related cells. Electron probe and ion probe studies were also conducted. It was found that cadmium penetrations as deep 80% occurred, and, in many instances, a depth of more than 30% of separator penetration was observed. Since cell failure and battery performance losses can be caused by 100% penetration depths of cadmium, the results of the investigation indicate that cadmium migration and penetration into the separators of this set of Ni-Cd cells constitute a serious problem with respect to meeting the power-storage lifetime requirements of the electrical system for the satellite.

TBC-3067

Stanley W. Mayer, Aerospace Corp., "Electrophoretic Mobilities of Cadmium Hydroxide, Nickel Hydroxide, and Silver Oxide in NiCd and Ag-Zn Battery Electrolytes," Interim Report TR-075(5270-10)-1 Contract F04701-74-C-0075 (July 5, 1974). (AD-783-853)

Cadmium migration damage of separators is a major cause of Ni-Cd battery failures or performance degradation. A series of electrophoretic mobility measurements has been made for cadmium hydroxide suspensions in concentrated KOH battery electrolyte at several concentrations of K_2CO_3 to investigate whether electrophoresis of cadmium hydroxide could be the mechanism for migration to separators. It was found that the mobility of the cadmium hydroxide suspension in an applied electrical field is adequate to account for the observed migration of cadmium hydroxide to separators. The view that high carbonate concentrations in Ni-Cd battery electrolyte may increase cadmium migration damage of separators is consistent with these electrophoretic measurements. Zeta

potentials have been calculated from the data. Similar measurements have been made for nickel hydroxide suspensions in Ni-Cd battery electrolyte at several K2C03 concentrations. The results are consistent with ion probe analyses for nickel in nylon separators exhibiting considerable cadmium migration. Silver oxide mobility was also measured.

TBC-3068

J. McCallum, Battelle Memorial Institute, "Corrugated Battery Electrode," GFSC-11368 (March 1974). (73B10515)

Performance of porous electrodes in batteries and other electrochemical cells is greatly improved when supports for active material have pores of uniform size, extending completely through electrodes, from side to side, with no interconnections between pores.

TBC-3069

J. McCallum, E. A. Roeger, Jr., & G. H. Miller, Battelle Memorial Institute, Columbus, Ohio, "Rate of Discharge of Accelerated Life Tests of Nickel-Cadmium Cells," Report No. AFAPL-TR-72-67, August 1972, Contract No. F33615-69-C-1537. (N73-13065) (AD-748253)

Special demountable cells were designed, constructed, and tested with rates of discharge as the primary independent variable. Duplicate experiments were performed with groups of five demountable cells. Separate groups were discharged at C/2, C, 2C, 4C, and 8C rates. One experiment maintained uniform temperatures of about +25C in all cells. The other experiment had an environmental temperature of +25C, but internal heaters were maintained at +40C. Otherwise, all known variables were held constant. Both groups of cells degraded at a higher rate in measured qualities at higher rates of discharge. Results are discussed.

TBC-3070

J. McCallum & G. H. Miller, Battelle Memorial Institute, Columbus, Ohio, "Failure Mechanisms and Accelerated Life Tests of Nickel-Cadmium Batteries," Final Report, August 1972, Report No. AFAPL-TR-70-44-PT-3 Contract No. F33615-69-C-1537, May 1, 1969 to June 30, 1972. (N73-14061) (AD-749129)

Preliminary experiments indicated valid tests were developed with temperature gradients and/or with rates of discharge as the primary variables for accelerated life testing of sealed nickel-cadmium batteries. Depth of discharge was indicated to have only a very small effect on the life of cadmium electrodes. New sealed cells having longer life without, significant loss of performance, were designed and constructed. Verification tests were recommended for them.

TBC-3071

E. J. McHenry, P. Hubbauer, "Hermetic Compression Seals for Alkaline Batteries," Electrochemical Society Journal, Vol. 119 May 1972, pp 564-568. (A72-28434)

Long life leak-proof Hermetic Compression Seals for Alkaline batteries, describing design, fabrication and accelerated thermal cycle test method.

TBC-3072

C. J. Menard, Gould, Inc., Mendota Heights, Minn., "High Energy Density Nickel-Cadmium Batteries," 7th Intersociety Energy Conversion Engineering Conference, Sept. 1972, pp 95-97. (729020) (73A22754)

Data are presented for high energy density sealed cylindrical type cells which yield between 22 to 27 Wh/lb at the 5-hour rate discharge, depending on electrode configurations and cell size. The cathode and anode in these cells consist of porous sintered nickel substrates loaded with their respective active materials. The cell construction is that of the conventional coiled electrode design. The increase in energy density over commercial cells is accomplished through improvements in the internal cell components.

Specific data are given on the 'D' and Sub C size cells. For example, electrode designs have been formulated that yield a 'D' size cell with an energy density of 25 to 27 Wh/lb over the capacity range of about 4.5 to 6.7 Ah. This energy density represents an increase of about 40% over the standard commercial cell. The energy per unit volume of the lower capacity cell equals that of the commercial cell; namely, about 2 Wh/in.^{3}. Under high drain rates a Sub C design yields twice the energy density of the standard commercial cell.

The performance characteristics of these high energy density systems are discussed. Projections are made for future high energy density nickel-cadmium batteries based on the cylindrical cell data and experience on other nickel-cadmium designs.

TBC-3073

R. E. Meredith, Oregon State University, and G. L. Juvinall and A. A. Uchiyama, Jet Propulsion Laboratory, Pasadena, Calif., "Gravitational Effects on Electrochemical Batteries," Technical Report No. 32-1570, November 15, 1972, NASA-CR-129091. (N73-11039)

The existing work on gravitational effects on electrochemical batteries is summarized, certain conclusions are drawn, and recommendations are made for future activities in this field. Theoretical evaluations of the problem have met with only limited success; theories based upon a treatment of natural convection have fallen short of the mark, partly because the mass transfer involved in the power-producing electrochemical reactions in a battery is not completely due to convection and

and partly because a battery is far removed from the idealized models necessarily employed in the development of the theory. The latter point is best illustrated by the fact that although theory generally predicts that the limiting current density will vary with the 1/4 power of the acceleration constant, the experimental data falls in the range of a 1/3 to 1/5 power dependence because of differences in the way the cell is constructed.

The effects of sustained high-G environments on cycled silver-zinc and nickel-cadmium cells have been evaluated over four complete cycles in the region of 10 to 75 G. Although no effects on high current discharge performances or on ampere-hour capacity were noted, severe zinc migration and sloughing of active material from the zinc electrode were observed. This latter effect constitutes real damage, and over a long period of time would result in loss of capacity.

The work of Arcand, based upon smooth zinc electrodes, predicted a limiting current density of 7 mA/cm^2. However, the Mariner 7 battery easily provided a current density of 10.5 mA/cm^2 in deep space. Fundamental battery studies performed at zero G are necessary to resolve the conflict. To this end, experiments have been planned and a breadboard model of an in-flight battery test unit has been designed and fabricated.

It is recommended that a zero-G battery experiment be implemented. Both an orbiting satellite and a sounding rocket approach are being considered.

TBC-3074

L. Miller, D. J. Doan, E. S. Carr, Eagle Picher Company, Joplin, Mo., "Study of Process Variables Associated with Manufacturing Hermetically-Sealed Nickel-Cadmium Cells," Quarterly Report, September 1971, NASA CR-122289 QR-4, November 25, 1970 to February 25, 1971. (N71-37623)

Process variables associated with positive and negative plate impregnation/polarization and linear multiple regression analysis of fractional factorial design experiment data.

TBC-3075

L. Miller, Eagle-Picher Co., Joplin, Mo., "Study of Process Variables Associated with Manufacturing Hermetically-Sealed Nickel-Cadmium Cells," Quarterly Report, May 1972, NASA-CR-122454 QR-5, March-May 1971. (N72-30030)

The effort and results of a program to determine and study the critical process variables associated with the manufacture of aerospace, hermetically-sealed, nickel-cadmium cells are reported. During the period, the impregnation/polarization process variable study was brought to a close with the completion of a series of related experiments. The results of the experiments are summarized. During this period, a general characterization of cell separator materials was initiated. The major conclusions resulting from the characterization of materials are included.

TBC-3076

L. Miller, Eagle-Picher Co., "Study of Process Variables Associated with Manufacturing Hermetically-Sealed Nickel-Cadmium Cells," Final Report, NASA-CR-139025, Contract NAS 5-21159 (April 1974).

A two year study of the major process variables associated with the manufacturing process for sealed, nickel-cadmium, aerospace process variables associated with a manufacturing process, experimentally assessing each variable's effect, and imposing the variables to improve results and uniformity. A critical process variable associated with the sintered nickel plaque manufacturing process was identified as the manual forming operation. Critical process variables identified with the positive electrode impregnation/polarization process were impregnation solution temperature, free acid content, vacuum impregnation, and sintered plaque strength. Positive and negative electrodes were identified as a major source of carbonate contamination in sealed cells.

TBC-3077

D. Dubois, A. Jouanneau, and M. C. Petit, University of Bordeaux, Talence, France, "Dissolution Du Nickel En Transpassivite 2 Eme Partie: Etude Du Degagement D'Oxygene Simultane Et Influence Du pH," Electrochimica Acta, 1973, Vol. 18, pp 583-588, Pergamon Press, Great Britain.

The oxygen discharge was studied in the transpassive range of nickel in 0·5M H_2SO_4. The potential range is separated into two parts, the experimental data indicating that, above 1650 mV/sce the oxygen discharge occurs alone and between 1360 and 1650 mV/sce two reactions namely nickel dissolution and oxygen discharge occur simultaneously. A model is proposed where two OH^- ions are simultaneously absorbed on the first formed layer of Ni(OH), a fraction of the surface is covered by $Ni(OH)_3$. The oxygen discharge is also a multistep reaction. Between 1360 and 1650 mV/sce, the dissolution of metal and the oxygen discharge are in competition at all times, the surface is covered simultaneous by $Ni(OH)_2$ and $Ni(OH)_3$.

The calculated curves are in good accord with the potentiostatic curves, the influence of pH is correlated with the experimental data.

TBC-3078

NAVAL AMMUNITION DEPOT, CRANE, IND., "Evaluation of Nickel-Cadmium Batteries with Non-Cellulosic Separators," QEEL/C-72-189, May 1972. (X73-72999) (AD-901311L)

TBC-3079

L. Nanis, Pennsylvania University, "Electrochemical Engineering of Battery Systems," Final Report N00019-72-C-0166, November 10, 1971 to November 9, 1972. (October 1973), 91 p. AD-914248L. 74X70935#

Changes in diffusely reflected light scattered from a battery electrode (Cd negative) have been shown to be well correlated with the electrochemical behavior. Change in the diffusely reflected light from the current collector side of a cadmium negative anode (for discharge) precedes the onset of rapid passivation type of polarization determined at the front (solution) side of the porous electrode. The chemical change of Cd to Cd(OH) 2 during discharge is considered to cause the variation of optical parameters for light scattering and absorption and thus the change in diffuse reflectance. The monitoring by optical changes corresponding to the material changes of the current collector region of the anode permits determination of the essential features of the profile without disturbing the battery operation. Thus, cycling effects on the current redistribution can be analyzed and effective battery performance evaluated.

TBC-3080

NASA Goddard Space Flight Center, "Transcript of Proceedings National Aeronautics and Space Administration, Goddard Space Flight Center, 1972 GSFC Battery Workshop, First Day," Report No. NASA-MX-X-69240 (1972).(N73-21956)

The proceedings of the 1972 NASA/Goddard Battery Workshop are reported. Topics discussed include: separators, materials and processing, test and storage experience, and improved energy density systems.

TBC-3081

NASA Goddard Space Flight Center, "Transcript of Proceedings National Aeronautics and Space Administration, Goddard Space Flight Center, 1972 GSFC Battery Workshop, Second Day," Report No. NASA-TM-X-69239 (November 15, 1972). (N73-21957)

TBC-3082

Naval Air Test Center, Patuxent River, Md, "Temperature Investigation of OV-10A Battery and Battery Compartment," Final Report No. NATC-WST-143R-72 May, 1971 to December 30, 1971. (November 1972) 16 p. AD-905 610L

Fleet activities have reported numerous nickel-cadmium (Ni-Cad) battery failures in the OV-10 aircraft. These failures are believed to be caused by thermal runaway, an action occurring in Ni-Cad batteries caused by overcharging (high charging voltage) in conjunction with high ambient temperatures. Thermal runaway will cause excessive electrolyte spewage and/or cell explosion or melting of the cell jars. The Naval Air Systems Command (NAVAIRSYSCOM) requested the Naval Air Test Center (NATC) to investigate the ambient temperatures to which batteries in the OV-10A may be exposed and recommend remedial action if required. Recorded data from an instrumented NOV-10A Airplane revealed battery compartment temperatures that exceed the safe temperature for batteries under charge and high, 29 to 29.5, DC bus voltage. A properly adjusted voltage regulator should maintain the DC generator output voltage at 27.5 to 28.5 volts. Incorporation of adequate ventilation for each of the two battery compartments and proper adjustment of DC voltage regulators to maintain generator output voltage at 27.5 to 28.5 volts, are recommended to prevent battery failures in OV-10 aircraft.

TBC-3083

C. H. Nelson, NASA Langley Research Center, "Thermal Analysis and Design of Thermal Control Hardware for 200 AH NiCad Battery," 502-25-59. (73W70306)

The objective of this RTOP is to develop the thermal control technology required to build 20C AH batteries for space use. Experimental 200 AH NiCad cells are being developed on Contract No. NAS1-10982 by Heliotek at the present time. Preliminary thermal studies of these cells have indicated that thermal control of large batteries will be a major factor in their design. Heat pipes, or similar devices will be investigated. Since these batteries will be assembled, repaired and serviced while in orbit, special emphasis will be placed on ease of handling. This will be accomplished by modularization of cell and thermal control device into one basic, easily handled and assembled unit.

TBC-3084

W. Newman, Gulton Industries, Inc., Hawthorne, Calif., "A Comparison of Sealed and Vented NI/CD BATTERY CHARACTERISTICS," NAECON 1972 RECORD, pp 151-153 (621.38106 Sy 68 n

This paper is designed to assist users of nickel-cadmium batteries in finding the best battery and charger for their particular application. All too often the battery and charger that is selected is not suitable for the job.

This paper gives a comparison of the vented and sealed cell batteries and gives the advantages and disadvantages of both types. Special emphasis is placed on the plate run-down, charging techniques, battery maintenance, water consumption, etc. Several curves will be shown to indicate what kind of cycle life to expect from the various types of batteries under various conditions of charging and temperature.

This battery study has developed from a study program with Wright-Patterson Air Force Base.

TBC-3085

S. F. Pensabene, General Electric Co., Gainesville, Fla., "Sealed Nickel-Cadmium Cells for Hybrid Battery Applications," Semi-annual report, May 1973, Contract No. DAAB07-72-C-0316, July 10, 1972 to March 1, 1973, ECOM 0316-S-72 (AD-910/663L)

A factorial designed experiment was conducted in order to determine the most significant design parameters for hybrid battery operation with emphasis on low-temperature operation. The cell size chosen for study was the C sub S. Cells were built with four construction factors at three levels each resulting in a total of 81 design modifications. Design parameters included positive and negative plate capacity, electrolyte concentration, and electrolyte volume. Cell performance was characterized by capacity at 77 F and -40 F, overcharge voltages at 200, 100, 50, 25, and 10 MA at 125 F, 77 F, 25 F, data were processed using a multiple linear regression program. Regression equations were established and used to select favorable designs.

TBC-3086

Y. N. Pervushin & M. F. Skalozubov, "High Temperature Impregnation of Sintered Metal Bases of Alkaline Battery Electrodes," Issladovaniya v Oblasti Prikladnoy Elecktrokhimii, Russian, Editorial & Publishing Department of the Novocherkassk Polytechnic Institute, Vol. 190, 1969, pp 96-100. FTD-HC-23-1813-71, March 23, 1972, Foreign Technology Division. (AD-744 254)

The proposed method of high temperature impregnation of sintered metal bases under excessive steam pressure eliminates the negative factors of impregnation in highly concentrated solutions and allows us to intensify the impregnation process in the two ways mentioned above simultaneously. In this work, we investigate the possibility of using high temperature impregnation of sintered metal bases in high concentrated given solutions for the purpose of intensifying the process of filling the pores with an active mass.

TBC-3087

Y. N. Pervushin, M. F. Skalozubov, "High-Temperature Impregnation of Sintered-Metal Alkaline-Battery Electrodes," Report No. FSTC-HT-23-823-72, June 1972, Army Foreign Science & Technology Center, Charlottesville, Va. (AD-754 257)

Sintered-metal CD-NI electrodes for alkaline batteries are difficult to make because of the low efficiency of the liquid process used on the sintered-metal alloy. Impregnation of the sintered metal may be increased in two ways: by increasing the active-metal concentration in the impregnating solution, which increases the weight of nickel hydroxide due to physical filling of the pores, and by increasing the dissolution rate of the sintered metal, which increases the NI(OH)2 weight due to hydroxide formation in the pres. The proposed method of high-temperature impregnation of sintered metal under excess vapor pressure eliminates the disadvantages of soaking in highly concentrated solution and accelerates the impregnation process simultaneously in the two ways mentioned above.

TBC-3088

D. F. Pickett, V. J. Puglisi, H. N. Seiger, R. L. Oliver, Heliotek, "High Energy Density Sintered Plate Type Nickel-Cadmium Battery Cells. Part II. Electrochemical Impregnation Methods to Produce Nickel Oxide Electrodes." Technical Report AFAPL-TR-74-56-Pt-2, December 1972 to December 1973, Wright-Patterson Air Force Base Contract No. F33615-73-C-2012 (August 1974). AD/A-002 142

A pilot plant operation for producing nickel hydroxide electrodes for use in satellite battery cells is described. Reproducibility, loading level dependence on process time, formation procedure and degree of plate swelling as a function of loading level are discussed. Analytical procedures for both electrode and impregnation solution are given. The process offers considerable savings in time over conventional processes with remarkable electrode reproducibility.

TBC-3089

E. A. Roeger, Jr., J. McCallum, G. H. Miller, Invention Talents, Inc., "Analysis of Accelerated Life Test Data for Aerospace Nickel-Cadmium Cells," Final Report AFAPL-TR-74-75, November 1972 to July 1974, Wright-Patterson Air Force Base Contract No. F33615-73-C-2024 (October 1974). AD/A-002 848

A process was developed for the accelerated life testing of a particular cell or battery which comprises the comparison and extrapolation of the end of discharge voltages plotted versus the logarithm of the cycle number in combination with prior knowledge about the probable cycles to failure for similar cells or batteries under the same end use conditions. When the slope of the voltage-log cycle line in the test can be made to coincide with similar slopes from prior knowledge, the battery under test will have the same cycle life and failure mechanism

as prior cells or batteries. Acceleration of the test results is achieved because a duplication slope for the data obtained during about the first hundred cycles indicates the probable presence of thousands of cycles anticipated by the prior knowledge.

TBC-3090

Earl A. Roeger, Ralph E. Thomas, John McCallum, John H. Waite and H. Gerald, Battelle Memorial Institute, "Simulated Orbital Life Tests for Spacecraft Cells. Part II. Automatically Acquired Data, Review, and Recommendations," F33615-69-C-1537 (August 1972). (AD-748 251)

Content, availability, and recommended procedures for analysis of the data automatically acquired during 4-1/2 years of simulated orbital life testing of nickel cadmium spacecraft cells are described. A sample of the approximately 1,000,000 records that are stored on magnetic tape is included and summary tables list documented conditions that may have yielded discontinuities, irregularities, or biases in the record data. Recommendations for data analysis by empirical, statistical, and physical methods are provided. The empirical method attempts to identify all possible indicators associated with failed cells. The physical methods examine the data, or its form for regular and irregular trends, and explain these trends by cause and effect relationships and underlying physical concepts.

TBC-3091

P. Scardaville, Marathon Battery Co., Waco, Tex., "Design and Development of High Charge Rate Nickel-Cadmium Batteries," Interim Progress Report, March 1973, Contract No. DAAB07-70-C-0150, Oct. 70 to Nov. 72 ECOM 0150-2. (AD-908/765L)

The objective of this work is the design, fabrication, and testing of a sealed nickel-cadmium battery capable of being safely and efficiently charged at very high rate (2C or higher). The specific battery is the BB-478( )/U which is an 'F' size, 1.2V, 7 AH sealed nickel-cadmium cell. In order to achieve a reproducible voltage signal at the end of charge, the battery must have low impedance. Attempts to achieve this by multiple internal tabbing and increased electrode area are described. The inability to obtain sufficient capacity and repeated shorting failures forced a compromise design. This design employs a lesser number of internal tabs to increase reliability and thicker loading of active material and thus more capacity. Initial tests indicate a successful compromise.

TBC-3092

G. R. Schaer, Battelle Memorial Institute, "Honeycomb Battery Plaque," GSFC-11367 (March 1972). 73B10519*

Performance of porous electrodes in batteries and other electrochemical cells is greatly improved when supports for active material have pores of uniform size, extending completely through electrodes, from side to side, with no interconnections between pores.

TBC-3093

H.J. Schwartz, NASA Lewis Research Center, "Electrochemical Power Devices," 113-34-12 (72W70015)

Electrochemical power devices have been used on virtually every launch vehicle and spacecraft flown to date, and will continue to be used for the foreseeable future. The broad spectrum of mission power requirements already known and anticipated dictate development of a variety of electrochemical power sources to meet these needs. Major emphasis will be placed on technology, leading to an advanced H2-02 fuel cell system for space shuttle applications; on improved silver-zinc batteries for 5 year operation in synchronous orbit; new approaches to nickel-cadmium and silver-cadmium battery construction for long-life in low-altitude orbit; and on solid ionic conductors as an approach to a 150 watt-hour per pound secondary battery.

TBC-3094

H.J. Schwartz, NASA Lewis Research Center, "High Energy Cells," (7370302) 502-25-53

The broad spectrum of space mission power requirements already known and anticipated dictate development of a variety of electrochemical power sources to meet these needs. Because of the similarity in energy source requirements, most of this same technology development will be directly applicable to terrestrial electric vehicle applications. Major emphasis will be placed on technology leading to an advanced H2-C2 fuel cell system; on improved silver-zinc batteries for 5 year operation in synchronous orbit; new approaches to nickel-cadmium and silver-cadmium battery construction for long-life in low-altitude orbit; and on the application of solid ionic conductors to a 150 watt-hour per pound secondary battery.

TBC-3095

W.R. Scott, TRW Systems Group, "A Study of Degradation of Plates for Nickel-Cadmium Spacecraft Cells," Interim Report, NASA-CR-136863 (TRW-24118-6001-RU-00), Jet Propulsion Laboratory Contract No. 953649 (November 1973)

The relative merits of coining and not coining of sintered nickel-oxide and cadmium plates was investigated. A survey of the industry including cell manufactures and users was made and results summarized. Sample plate materials from most commercial cell suppliers were obtained and characterized for properties that may correlate with the tendency toward physical disintegration during handling and over long periods of time in the cell. Special test methods were developed to obtain comparative data in a short time. A wide range of physical

properties and coining thicknesses was observed, resulting in a range of responses. The stronger, less brittle materials resisted loss of sinter better than weaker materials whether or not coined. Coining improved handling and resistance to electrochemical cycling in all materials tested. An apparent exception was found to be due to improper coining of a tapered edge.

TBC-3096

H.M. Seiger, V.J. Puglisi, P.F. Ritterman, & D.F. Pickett, "High Energy Density Sintered Plate Type Sealed Nickel-Cadmium Battery Cells. I - The Positive Electrode/Plaque Relationships." 9th Intersociety Energy Conversion Engineering Conference, San Francisco, Calif. August 26-30, 1974 Proceeding, pp. 868-872 (Paper No. 749123) (A75-10569) American Society of Mechanical Engineers, New York, 1974 PP. 868-872, (A75-10476)

This paper deals with the physical and chemical interaction of the sintered plaque material and the behavior of highly loaded positive electrodes. The work has produced experimental evidence that the utilization of active materials depend rather strongly on sinter porosity. It indicates that there appears to be an upper limit to the loading of active material (Ni(OH)//2) into the voids present in the plaque. A hypothesis is presented that reasonably explains blistering often observed in positive electrodes and thickening of positive electrodes that usually occurs even after cell manufacture. These topics are important in designing and processing plaques into positive electrodes for the higher energy densities densities. 7 refs.

TBC-3097

V.J. Puglisi, H.N. Seiger and D.F. Pickett, Textron, Inc., "High Energy Density Sintered Plate Type Nickel-Cadmium Battery Cells Part II. Electrochemical Impregnation Methods to Produce Nickel Oxide Electrodes," 9th Intersociety Energy Conversion Energy Conference, 1974 Proceedings, pp. 873-879 (Paper No. 749124)

This paper reports on the effort to produce high specific capacity nickel oxide electrodes employing electrochemical impregnation techniques as presently being carried out by Heliotek-WPAF Aeropropulsion Laboratories. 13 refs.

TBC-3098

K.L. Senderak, Naval Ammunition Depot, "Evaluation of a Forced-Air-Cooled Battery Manufactured by Marathon Battery Company," Report No. QEEL/C-73-37 (January 1973) 13P. AD-907 585L

Evaluation tests were conducted on one forced-air-cooled battery manufactured by Marathon Battery Company. The objective of the test was to evaluate a forced-air-cooled battery, and compare its performance with that of an ordinary battery.

TBC-3099

David N. Stager, Willard R. Scott, D. W. Zerbel, H. E. Haugen and H. L. Layte, TRW Systems Group, "Two Kilowatt Long Life Battery," Interim Technical Report AFAPL TR-72-99, May 15, 1971 to September 15, 1972, Contract F33615-70-C-1627 (December 1972) 325 p. AD-906-407L

The objective of this program is to design, develop, and test long life, highly reliable, lightweight, low volume, radiation hardened, rechargeable nickel-cadmium battery systems for synchronous orbit satellites. The work comprises systems analysis, design studies, component and subsystem development, prototype battery system design, fabrication, and testing. The approach taken to fulfill all the requirements is the use of high quality, large capacity cells operated at a low average temperature and high depth of discharge. The system contains nickel-cadmium cells with individual charge and discharge current bypass circuits; overall battery charge and discharge control electronics; thermal control and heat rejection equipment; packaging and structural support; and appropriate radiation shielding. The detailed design of two representative battery systems (1 KW and 2 KW) has been completed.

TBC-3100

David N. Stager, Williard R. Scott, D. W. Zerbel, H. E. Haugen and H. L. Layte, TRW Systems Group, "Two Kilowatt Long Life Battery," Interim Technical Report AFAPL TR-71-43, June 15, 1970 to May 15, 1971, Contract F33615-70-C-1627 (June 1971) 326 p. AD-885 799

The objective of the program is to design and develop a long life, highly reliable, lightweight, low volume, radiation hardened, rechargeable nickel-cadmium battery system for synchronous orbit satellites. The work comprises systems analysis, design studies, component and subsystem development, prototype battery system design, fabrication and testing. The approach taken to fulfill all the requirements is the use of high quality, large capacity cells operated at a low average temperature and high depth of discharge. The system contains nickel-cadmium cells with individual charge and discharge current bypass circuits; overall battery charge and discharge control electronics; thermal control and heat rejection equipment; packaging and structural support; and appropriate radiation shielding. The battery detailed design is nearly completed and all requirements are being met.

TBC-3101

D. L. Chua, Rensselaer Polytechnic Institute, "Relationship of Electrode Structures and Cell Performance in Sealed, Sintered-Type Nickel-Cadmium Button Cells During Cycling," Ph.D. Thesis (Univ. Microfilms Order No. 74-12781) 267 p. (74N27520)

The purpose of this investigation is to determine whether a correlation exists between the performance of the nickel-cadmium cell and the morphological structures of the plates during prolonged cycling.

Numerous cells were conditioned and matched before they were subjected to cyclic charge-discharge under deep and shallow discharge regimes.

Operating variables consisted of a specified charge-discharge rate, time of charge and discharge, termination conditions, and depth of discharge (DOD) at specified temperatures. Each mode of operation was quantitatively described by cell voltage, capacity, and impedance measurements. At an arbitrarily selected cycle number, the plates from the disassembled cell were structurally characterized by scanning electron microscopy, optical microscopy, and x-ray diffraction. The limiting electrode of the cycled plates was detected by half-cell measurements using the galvanostatic technique and under the flooded condition.

Sealed nickel-cadmium cells made of sintered plates were found to exhibit capacity degradation during extended charge-discharge cycles. Under slow to moderate discharge rates, drastic changes in negative plate's morphology occurred and this dramatic change was found to be effected by the severe crystal growth of β-$Cd(OH)_2$ active materials.

For the $Cd/Cd(OH)_2$ plates, the derived general plate morphologies were consistent with a dissolution - precipitation mechanism during discharge and one involving dissolution - electrodeposition during charge. Under very fast discharge rate, the observed general electrode morphologies were correlated partially to a solid-state mechanism.

Crystal growth of β-$Cd(OH)_2$ active materials were found not responsible for the so-called "memory effect" in the nickel-cadmium cells. "Memory effect" was conclusively found to be caused by the $Ni(OH)_2$ or positive plates.

TBC-3102

I. Toshio and S. Keiichi, "The Latest Trends in the Battery Manufacturing Field in Japan." Report No. FSTC-HT-23-762-72 Dec 72, Army Foreign Science & Technology Center, Charlottesville, Va. (AD-909/939L)

The recent trends in the Japanese secondary battery industry are surveyed, with emphasis on lead storage batteries, alkali storage batteries, and new models of batteries. Considerable attention is given to the development of batteries for use as power sources for electric automobiles.

TBC-3103

Tyco Labs, Inc., "Development of Uniform and Predictable Battery Materials for Nickel-Cadmium Aerospace Cells," Final Report, Jan 1972, NASA-CR-130094, May 8, 1968 to Jan 31, 1972. (N73-10050)

The objective of this study was to analyze battery materials and manufacturing methods with the aim of developing uniform and predictable battery plates for nickel cadmium aerospace cells. The results are presented of an extensive factorially-designed experiment aimed at

illuminating, in a comparative study, the effect of plaque preparation, plaque thickness, impregnation process, and loading level with active material. The following impregnation processes were investigated: (1) chemical conversion, (2) electrochemical conversion, and (3) high temperature electrochemical impregnation. The test parameter on which the conclusion regarding the manufacturing variables are based was the capacity change during a simulated near-earth orbit cycle regime. As operational variables, the effect of various charge and discharge rates was investigated. During the 100 test cycles, overall capacity changes of positive plates and the differences between the various plates were found to be small. Plates prepared by the high temperature electrochemical impregnation of slurry-coated plaque (at the conditions used) showed surface buildup of active material. They also retained slightly less of their capacity during cycling compared to other plate preparations.

TBC-3104

A. Ushirokawa, K. Takahashi, T. Ishikawa, S. Yamamoto, and K. Fujita, Tokyo University, "The Hermetically Sealed Nickel-Cadmium Batteries for the Satellites, Shinsei and Denpa," 10th International Symposium on Space Technology and Science, Tokyo, Japan, September 3-8, 1973, Proceedings (A74-42352 21-31) Tokyo, Agne Publishing, Inc. 1973 p. 729-736. 74A4230

The first Japanese scientific satellite, SHINSEI which was already launched and put into orbit by the Institute of Space and Aeronautical Science, University of Tokyo, has been transmitting data back to the earth over two years. Now, we are pleased to announce the brief summary of the design features including the triple sealing methods of the hermetically sealed Ni-Cd rechargeable cells used for the first and second satellites, SHINSEI and DENPA.

Since 1965, the developmental work of our homemade battery has been continued. As a result of actual use, the battery has been proved to be high reliable as the power source of satellite. Each of the two satellites has two pairs of 15 cells which consist of 2 Ah and 1.2 Ah capacities, provided with a power control unit. Especially, SHINSEI cells are still working satisfactorily now in the surface temperature range from -11°C to +58°C.

The nominal capacities of these newly developed batteries are 5, 3, 2 and 1.2 Ah respectively.

TBC-3105

W. H. Webster, Jr., Federal City College, Washington, D.C., "Fundamental and Analytical Investigations of the Mechanisms and Phenomena Related to Spacecraft Electrochemical Devices," February 1, 1972 to November 30, 1974, Contract (SUP-005)NGR-09-050-003. 72K10934

TBC-3106

James L. Woods, Naval Ammunition Depot, "Evaluation of Pulse Charger Manufactured by Christie Electric Corporation," Report No. QEEL/C-72-2 (January 1972) 51 p.

The objective of this test was to obtain data by which an evaluation of the Christie pulse charger can be made with respect to recharging nickel-cadmium batteries during bench tests from various depths of discharge, and with respect to the recharges following the discharges during the life cycle test.

TBC-3107

P. Stonehart and P. A. Zucks, Pratt & Whitney Aircraft, Middletown, Connecticut, "Sintering and Recrystallization of Small Metal Particles. Loss of Surface Area by Platinum-Black Fuel-Cell Electrocatalysts." Electrochimica Acta, 1972, Vol. 17, pp. 2333-2351. Pergamon Press, Northern Ireland.

Operation of high-surface-area platinum-black electrodes in hot concentrated phosphoric acid produces a loss of surface area with time, giving consequent loss of performance.

The loss of surface area is the result of sintering produced by surface migration of platinum atoms on the individual crystallites to sites of lower surface energy. As the sintering process is a surface phenomenon, potential changes cause changes in the surface tensions of the metal crystallites giving rise to variations in sintering rate. The rate of sintering is greatest at low potentials and smallest at high.

Carbon monoxide and phosphoric acid impurities adsorbed on the surfaces of the platinum crystallites retard the sintering at low potentials. Similar adsorption-induced changes in physical properties of materials (Rebinder effects) have been observed with ionic solids, but in only a few instances is this effect known to operate on metals. The presence of a strongly adsorbed molecule on the metal surface alters the inter-atomic bonding between the surface metal atoms and illustrates the dependence of the sintering mechanism on the mobility of the surface atoms. Changes in crystallite morphology accompany the sintering process and are considered to be the result of a surface rearrangement of ad-atoms or clumps with elimination of the [100] faces.

The activation energy for the sintering process is 25 ± 2 kcal/mole at 0·5 V and is not significantly changed by adsorbed carbon monoxide on the platinum.

TBC-3108

Defense Documentation Center, "Batteries, Report Bibliography January 1967 - April 1973," Report No. DDC-TAS-73-59. AD-768 500

The bibliography is a selection of unclassified and unlimited citations on Batteries. These references present information on design, cells, test, development, components, and performance characteristics. Discussed are many types of batteries, with most references relating to the nickel cadmium batteries and organic batteries.

TBC-3109

D. E. Christy, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells Acceptance Test of Eagle-Picher 100 Ampere-Hour Nickel-Cadmium Cells with Auxiliary Electrodes," Report No. NASA-CR-126384, NASA Order S-23404-G (March 10, 1972).

Tests were conducted on a group of 29 cells for the purpose of removing from the life cycle program all cells found to have electrolyte leakage, internal shorts, low capacity, or inability to recover open circuit voltage above 1.150 volts after the cell short test. The test findings include the following: (1) All the cells exceeded the rated capacity of 103.5 to 119.0 ampere-hours on all three capacity checks. (2) All cells recovered above the 1.150 volt requirement after the cell short test. (3) The cells cannot be overcharged at the c/10 rate without exceeding 1.500 volts after approximately 12 to 13 hours of charge. (4) The resistance value necessary to provide maximum signal power across the auxiliary electrode was found to be 10 ohms. (5) One cell revealed a definite leak at the negative terminal. QEEL/C-72-126. (N72-23049)

TBC-3110

D. E. Christy, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells Acceptance Tests of Eagle-Picher 20.0 Ampere-Hour Nickel-Cadmium Cells with Auxiliary Electrodes," Report No. NASA-CR-126385, NASA Order S-23404-G (March 21, 1972). QEEL/C-72-127. (N72-23050)

A group of 29 cells with capacities ranging from 21.7 to 28.8 ampere-hours were tested. A summary of the results indicates: (1) All cells exceeded the rated capacity on all three capacity checks. (2) Five cells failed to recover to 1.150 volts. (3) During the overcharge tests, 15 of the 29 cells had to be removed from charge before completion of the respective tests due to high pressure.

TBC-3111

D. E. Christy, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells Acceptance Tests of General Electric 4.5 Ampere-Hour Nickel-Cadmium Cells, Nimbus Type," Report No. NASA-CR-126659, NASA Order S-23404-G (March 29, 1972). QEEL/C-72-128. (N72-24039)

Results are presented of acceptance tests conducted on eleven nickel cadmium batteries of the Nimbus satellite type.

TBC-3112

F. Przybyla and G. R. Ramsay, Mallory Battery Co. of Canada, Mississauga, Ontario, Canada, and T. C. O'Nan, Mallory Battery Co., Tarrytown, N.Y., "Passivation of a Porous Cadmium Electrode in Potassium Hydroxide Solution," Power Sources 4, D. H. Collins, Ed., September 1972, Oriel Press, Newcastle-Upon-Tyne.

Passivation time of a porous cadmium anode in 31 per cent KOH solution was determined as a function of porosity and current density for the temperature range -40°C to +23°C. Curves depicting passivation time versus initial porosity show a maximum near 66 per cent. A relationship between passivation time, apparent current density and temperature is derived.

TBC-3113

G. Holleck, Tyco Labs, "NiCd Battery Electrodes, C-150," Report No. NASA-CR-126143, QR-1," Jet Propulsion Laboratory Contract No. 953185 (November 1971)

A research program to develop and evaluate electrodes for a nongassing negative limited nickel-cadmium cell is described. The concept of the negative limited cell and its implications on electrode structure are discussed. The key element is the development of a cadmium electrode with high hydrogen overvoltage. For this, Teflon-bonded Cd electrodes and silver-sinter based Gc electrodes were manufactured and in preliminary experiments their physical and electrochemical characteristics were evaluated. Hydrogen evolution on cadmium was found to occur approximately 100 mV more cathodic than on silver. Both electrode structures exhibit a fairly sharp potential rise at the end of the charging cycle and the advent of gas evolution occurs at potentials between -1.2 and -1.3 V versus a Hg/HgO reference electrode. These results are compared with conventional Ni-sinter based Cd electrodes.

TBC-3114

G. Holleck, M. Turchan, and J. Hopkins, Tyco Labs, Inc., "NiCd Battery Electrodes, C-150, "Quarterly Report NASA-CR-126624, QR-2, Jet Propulsion Laboratory Contract No. 953185 (January 1972). (N72-24045)

Electrodes for a nongassing negative limited nickel-cadmium cell are discussed. The key element is the development of cadmium electrodes with high hydrogen overvoltage. For this, the following electrode structures were manufactured and their physical and electrochemical characteristics were evaluated: (1) silver-sinter-based Cd electrodes, (2) Teflon-bonded Cd electrodes, (3) electrodeposited Cd sponge, and (4) Cd-sinter structures.

TBC-3115

A. I. Kloss and V. D. Nosovelova, Army Foreign Science and Technology Center, "Carbonate Impurities in the Active Masses of Nickel-Cadmium Batteries," Report No. FSTC-HT-23-1760-72 (November 12, 1973) Translation of Vsesoyuznyi Nauchno-Issledovatelskii Akkumuliatornyi Institut. Sbornik Rabot po Khimicheskim Istochnikam Toka (USSR) n4 p 43-47 1969. AD-770 970

This translation investigates the components of carbonate impurities in the active masses of nickel-cadmium batteries. It is shown here that the positive active mass contains potassium carbonate. Nickel hydroxide adsorbs carbon dioxide in the air, and on contact with the electrolyte, carbonizes it. The negative active mass basically contains carbonates in the form of cadmium carbonate.

TBC-3116

L. Miller, D. J. Doan, and E. S. Carr, Eagle-Picher Co., "Study of Process Variables Associated with Manufacturing Hermetically-Sealed Nickel-Cadmium Cells," Quarterly Report NASA-CR-126147, QR-4 November 1970 to February 1971, Contract NAS5-21159 (September 1970). (N72-22045)

A program to determine and study the critical process variables associated with the manufacture of aerospace, hermetically-sealed, nickel-cadmium cells is described. The determination and study of the process variables associated with the positive and negative plaque impregnation/polarization process are emphasized. The experimental data resulting from the implementation of fractional factorial design experiments are analyzed by means of a linear multiple regression analysis technique. This analysis premits the selection of preferred levels for certain process variables to achieve desirable impregnated plaque characteristics. (N72-22045)

TBC-3117

NASA Goddard Space Flight Center, "The 1971 NASA/Goddard-Aerospace Industry Battery Workshop, Volume 1," Conference Proceedings, Report No. NASA-TM-X-68828 (November 17, 1971). (72-27061)

The proceedings are reported for the first two sessions of the conference on nickel-cadmium batteries. These two sessions were mainly devoted to discussions of: (1) separators and seals, and (2) cell performance and specification experience.

TBC-3118

NASA Goddard Space Flight Center, "The 1971 NASA/Goddard-Aerospace Industry Battery Workshop, Volume 2," Report No. NASA-TM-X-68829 (November 18, 1971). (N72-27062)

The proceedings of the final two sessions the conference on nickel-cadmium batteries are reported. The major subject areas covered in these two sessions include: (1) materials and pre-charge, and (2) thermal problems experienced with nickel-cadmium batteries.

TBC-3119

J. D. Harkness, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells. Initial Evaluation Tests of General Electric Company Standard and Teflonated Negative Electrode 20.0 Ampere-Hour, Nickel-Cadmium Spacecraft Cells with Auxiliary Electrodes," Report No. NASA-CR-139654, NASA Order S-23404-G (July 1, 1974). WQEC/C-74-337

TBC-3120

P. V. Ogrommov and L. P. Savelchikov, Foreign Technology Div., Wright-Patterson AFB, "Possibilities for Increasing the Technical Level and Specific Weight and Volumetric Electrical Rating Characteristics of Chemical Sources of Current," Report No. FTD-MT-24-400-74, Project FTD-T74-03-04. (March 21, 1974)

Edited machine trans. of Vsesoyuznyi Nauchno-Issledovatelskii Akkumuliatornyi Institut. Sbornik Rabot po Khimicheskim Istochnikam Toka (USSR) n^4 p^3-10 1969, by Charles T. Ostertag, Jr.

The authors consider the contemporary state of the production of chemical current sources at battery plants and ways of improving the future design and technology of storage batteries.

TBC-3121

David F. Pickett, Department of the Air Force, "Production of Cadmium Electrodes," U.S. Patent Application 375239, Filed June 29, 1973 AD-164 553

In the patent application a cadmium electrode is prepared by positioning a porous nickel plaque between two cadmium sheets immersed in an aqueous solution of cadmium nitrate having a pH of 3 to 5 and maintained at a temperature of 95 to 110C. After connecting the nickel plaque to the negative pole and the cadmium sheets to the positive pole of a power source, direct current is passed through the solution at 1.2 to 1.6 amperes per square inch of plaque for from 8 to 20 minutes, thereby causing deposition of cadmium metal and cadmium hydroxide inside the pores of the plaque. A cadmium electrode so prepared is especially useful as the negative electrode in nickel-cadmium batteries.

TBC-3122

H. N. Seiger, D. F. Pickett, V. J. Puglisi, P. F. Ritterman and R. L. Oliver, Heliotek, "High Energy Density Sintered Plate Type Nickel-Cadmium Battery Cells. Part I. The Positive Electrode/Plaque Relationship," Interim Report, AFAPL-TR-74-56-Pt-1, December 1972 to December 1973, Wright-Patterson Air Force Base Contract F33615-73-C-2012 (August 1974). AD/A-000 103

This report is the first of a series of papers that describe work done in these laboratories toward development of a 20 watt-hours per pound and 2 watt-hours per cubic inch Nickel-Cadmium battery cell. State-of-the-Art cells have been delivering typically 12 to 16 watt-hours per pound and about 1.5 watt-hours per cubic inch at 100% depth of discharge using the two hour rate. This paper describes the relationship between nickel sinters and nickel hydroxide active material necessary to achieve these goals. A theory on utilization of active material is presented. Data are given showing an optimum porosity exists, but deviations between 77 and 85 percent are not very significant. A hypothesis is given to account for blistering and thickening of nickel hydroxide electrodes.

TBC-3123

W. Stanley and David Taylor, Aerospace Corp., "Penetration of Cadmium into Nylon Separators of Ni-Cd Batteries," Report No. TR-0074(4270-10)-3, Contract F04701-73-C-0074 (January 2, 1974). AD-774 562

Because of the preflight occurrence of failure resulting from a short circuit between plates and extensive cadmium migration to the separators of a Ni-Cd cell intended for long-term use in a satellite, a series of photomicrographic investigations has been made of the depth of cadmium penetration into a separator from the cell and related cells. Electron probe and ion probe studies were also conducted. It was found that cadmium penetrations as deep as 80% occurred, and, in many instances, a depth of more than 30% of separator penetration was observed. Since cell failure and battery performance losses can be caused by 100% penetration depths of cadmium, the results of the investigation indicate that cadmium migration and penetration into the separators of this set of Ni-Cd cells constitute a serious problem with respect to meeting the power-storage lifetime requirements of the electrical system for the satellite.

TBC-3124

R. E. Thomas, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells Evaluation of Storage Methods, Open Circuit Versus Continuous Trickle Charge, Sonotone 3.5 Ampere-Hour Sealed Nickel-Cadmium Secondary Spacecraft Cells," Report No. NASA-CR-126671, Order W-12397 (February 3, 1972). QEE4C-72-31 N72-24048

Twenty-five cells were used in a five-year test to compare, after each successive one-year storage period, the discharge and charge characteristics of charged cells on open circuit versus that of cells on

continuous trickle charge. The test procedure, instrumentation, and results are described. Based on the test results, the following recommendations were made: (1) If the user's purpose will allow a rejuvenation cycle or two after a long storage period, the open circuit regime will likely give slightly greater capacity. (2) If the user's purpose demands immediately available power following a long storage period, the trickle charge method of storage is definitely the regime to use. QEE4C-72-31. (N72-24048)

TBC-3125

Otto C. Wagner and Robert F. Enters, Yardney Electric Corp., "Development of Manufacturing Methods and Techniques for the Production of Improved Alkaline Batteries," Final Technical Report, Report No. 638-66, April 1, 1965 to June 30, 1966, Contract AF 33(615)-2578 (September 1966) AD-802 279

A development program directed at the problem of producing improved sealed alkaline batteries with matched cell capacities plus or minus 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 plus or minus 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-cadmium batteries on short orbit cycling regimes.

TBC-3126

Otto C. Wagner and Martin J. Sulkes, Office of the Secretary of the Army, "Method of Making a Nickel Hydroxide Electrode, U.S. Patent 3,597,829. (August 10, 1971). AD-163 632

The general object of the invention is to provide a simple, direct, and inexpensive method of making a nickel hydroxide electrode suitable for use in alkaline nickel batteries such as nickel-cadmium, nickel-zinc, and nickel-iron. A further object of this invention is to provide such a method wherein the resulting nickel hydroxide electrode will be characterized by excellent electrical conductivity. It has now been found that the aforementioned objects can be attained by pasting a solvent mixture of nickel hydroxide into an expanded conductive nickel foam.

TBC-3127

Curt H. Liebert, Lewis Research Center, "Heat-Transfer Experiments on a 34-Ampere-Hour Nickel-Cadmium Cell," Report No. NASA-TM-X-2371, (September 1971).

Local transient temperature distributions throughout the plate pack of operating nickel-cadmium cells and accompanying jar temperatures are reported herein for a 34-ampere-hour cell. The cell was charged at 7 amperes and was discharged into the exhaustion region at constant

currents ranging from 16 to 68 amperes. Temperature distributions were recorded for a variety of heat-transfer conditions which could be encountered in practical battery applications. At given times, average theoretical temperatures calculated by use of transient lumped heat-transfer models predicted local experimental temperatures within ±4 percent. This suggests that simple lumped theory can be applied with confidence to the thermal design of nickel-cadmium batteries.

TBC-3128

J. D. Harkness, Naval Ammunition Depot, "Evaluation Program for Secondary Spacecraft Cells: Initial Evaluation Tests of General Electric Company 12.0 Ampere-Hour, Nickel-Cadmium Spacecraft Cells for the International Ultraviolet Explorer Satellite," Report No. NASA-CR-140672, NASA Order S-23404-G (October 1, 1974). WQEC/C-74-511 (N75-10583)

Evaluation tests are reported for 20 cells to be put into the life cycle program. Leak, capacity, internal resistance, internal short, and overcharge tests are described.

TBC-3129

E. I. Gamaskin and Yu. M. Pozin, 'Scientific-Research Storage Battery Institute, "Accelerated Impregnation of Negative Sintered Metal Plates for Nickel-Cadmium Storage Cells," Translated from Zhurnal Prikladnoi Khimii, Vol. 43, No. 3, pp 681-683, March 1970. Original article submitted November 10, 1967

Study of impregnation of porous nickel plates (electrodes for alkaline storage batteries) in mixed cadmium chloride and nitrate solutions under cathodic polarization showed that the plates can be polarized by contact with sodium anodes.

By the use of this impregnation method the time needed to make the plates can be shortened by a factor of 3-4 and corrosion of the plates in cadmium solutions is prevented.

TBC-3130

Yu. M. Pozin, E. I. Gamaskin, & M. Sh. Vogman, Scientific-Research Storage Battery Institute, "Introduction of Ni^{2+} into Negative Sintered Metal Plates for Nickel-Cadmium Storage Cells:. Translated from Zhurnal Prikladnoi Khimii, Vol. 43, No. 6, pp 1478-1482, July 1970. Original article submitted May 5, 1968.

During operation of a short-circuited nickel-cadmium couple in cadmium chloride solutions containing nitrate ions the anodic process is concentrated on the cadmium electrode and the nickel plate does not corrode.

It is shown that it is possible to produce, for use in storage cells, sintered nickel electrodes with cadmium active material not containing

nickel oxides, and electrodes with definite contents of nickel oxides. In the latter case the electrodes are impregnated in galvanic couples with cadmium anodes in cadmium solutions containing calculated amounts of nickel.

During cathodic polarization in alkaline solution higher nickel oxides in the cadmium active material of a sintered electrode are discharged in two steps, as in the case of discharge of an ordinary nickel oxide electrode.

TBC-3131

Dale Gordon, Eagle-Picher Co., Joplin, Mo., "Sealed Nickel-Cadmium Battery Assembly BB-655( )/U." Final Report No. ECOM-0406-F, Sept. 1970 Contract No. DAA B07-69-C-0406, June 1969 to September 1970. (AD 714243)

The purpose of this contract was the design, development and testing of the nickel-cadmium battery assembly BB-655( )/U. This battery assembly is a military-ruggedized design consisting of 20 series-connected "F" cells assembled between two (2) fiberglass circuit boards and restrained with a rigid epoxy potting. The battery assembly is rated at 24 volts and 7.0 ampere-hours or 12 volts and 14 ampere-hours. This multiple voltage arrangement is possible as a result of the USAECOM connector arrangement.

The contract was successfully completed. An additional three months extension period was needed to perfect the final battery container. Fifty-nine battery assemblies were constructed and 16 were successfully tested to environmental and electrical testing. The environmental tests included vibration, bounce and four foot drop testing of all corners, faces and edges with cover and simulated equipment.

Forty-three battery assemblies were shipped to USAECOM upon successful completion of this testing. This Final Report outlines the design and development program and fully documents the battery assembly design.

TBC-3132

H. H. Kroger & A. J. Catotti, General Electric Company, "Chemical Analysis of Nickel-Cadmium Electrodes," 24th Power Sources Symposium, May 19-21, 1970, Session on Secondary Batteries, 1970 Proceedings. pp 4-6.

Chemical test methods for the analysis of the composition of nickel and cadmium electrodes have been described. Then methods have been applied to the analysis of sintered negative electrodes and it has been demonstrated that all of the uncharged cadmium hydroxide is available for electrochemical reduction at low charge rates. It has been shown that the described chemical methods for nickel hydroxide electrodes can be used in the study of the charge acceptance of positive plates. Currently, the various methods are applied in our laboratories to cells under a wide range of test conditions.

TBC-3133

E. Kanter and J. Bene, Gulton Industries, Inc., "Large Capacity Nickel-Cadmium Aerospace Cells of Improved Design," IEEE Proceedings National Aerospace Electronics Conference (NAECON '70 Record) May 1970.

This paper describes the mechanical and electrical performance characteristics of a 100 amp-hr sealed nickel-cadmium cell in which novel design features have been incorporated to reduce IR losses. These are notably, the extension of the tab to the full width of the plate and the placement of the terminals at opposite ends of the cells which are intended to minimize voltage and thermal gradients. These features reduce the generation of waste heat,thereby lowering operating temperature.

TBC-3134

J. D. Harkness, Naval Ammunition Depot, Crane, Indiana, "Evaluation Program for Secondary Spacecraft Cells: Initial Evaluation Tests of Eagle-Picher Industries, Inc., 20.0 Ampere-Hour Nickel-Cadmium Spacecraft Cells," Report No. QEEL/C 74-228, March 25, 1974. (AD-778 671)

An evaluation test of the 20.0 ampere-hour cells was conducted to insure that all cells put into the life cycle program are of high quality. This is accomplished by the screening of cells found to have electrolyte leakage, internal shorts, low capacity, or inability of any cell to recover its open circuit voltage above 1.150 volts during the internal short test. The results obtained in the test are given, as well as the recommendations based on these findings.

TBC-3135

R. A. Steinhauer and A. F. Heller, Hughes Aircraft Co., "Measurement of Useful Cadmium in Negative Plates of Space Nickel-Cadmium Cells," Abstract No. 23, Extended Abstracts, Electrochemical Society Fall Meeting, pp. 62-63 (October 1972)

An improved technique for the determination of useful cadmium in hermetically sealed nickel-cadmium cells is described and measurement results are reported. Negative plate cadmium utilization is important because it directly affects cell cycle and calendar life. Specific improvements of the measurement technique include:
1) Use of a positive pressure of nitrogen gas to prevent cumulative carbonate contamination of the electrolyte solution, to permit multiple determination of useful cadmium on the same negative plate, and to exclude atmospheric oxygen.
2) A teflon jig to provide precise plate spacing.
3) Use of a semipermeable membrane to prevent oxygen recombination with the negative plate during charge, thereby reducing recharge fraction.

TBC-3136

Hanns H. Kroger, General Electric Co., "Memory of Nickel-Cadmium Cells," Abstract No. 24, Extended Abstracts, Electrochemical Society Fall Meeting, pp. 65-66 (October 1972)

The cells contained experimental positive electrodes and cadmium electrodes of conventional design. At room temperature, the cells were kept on highly reptitive regimes with depths of discharge of 50% or less. The charge and discharge currents applied were either at the five-hour rate or for a simulated low earth orbiting regime.

The testing regimes lasted between four and twelve months. At pre-selected times, the monotony of cycling was deliberately interrupted by means of deep discharges beyond the normal end points.

Prior to these deep discharges, the cell performances were flawless; however, under the new experimental condition applied, all cells exhibited the symptons of memory, namely:

- Beyond their normal end points of discharge, only insignificant amounts of capacity were delivered.
- In the vicinity of the normal end point of discharge, severe distortions in the cell voltage versus time curves were observed.

Measurements by means of the built-in reference electrodes indicated that, depending on cell size and the repetitive cycle conditions, either or both electrode polarities could be responsible for the termination of useful discharge. However, in all instances, the origin of the cell voltage distortions was traced back to the negative electrodes.

TBC-3137

F. H. Mullersman, General Electric Company, Gainesville, Florida, "Analytical Determination of Secondary Battery Overcharge Performance," Electrochemical Society, Fall Meeting, October 1973. (Abstract No. 37 page 95).

The life and performance of secondary batteries are highly dependent upon imposed overcharge conditions. Large overcharge currents may result in undesirable water loss in vented cells, pressures that may cause venting of sealed cells, and high battery temperatures that may result in general degradation. Improper application of chargers can also result in failure to achieve stable overcharge operation with resultant "thermal runaway". It is therefore desirable to have a technique that would permit an analytical determination of overcharge performance for any proposed battery and charger combination. This paper addresses itself to a technique permitting such analysis.

TBC-3138

E. G. Gagnon, General Motors Corp., "The Triangular Voltage Sweep Method for Determining Double-Layer Capacity of Porous Electrodes. Part 3. Porous Nickel in Potassium Hydroxide," J. Electrochemical Society, Vol. 12, No. 4, April 1974

The effects of faradaic current and distributed capacity on the measurement of double-layer capacity of porous nickel were analyzed as a function of electrode thickness and temperature. Faradaic current observed with electrodes at -46°C was negligible compared to results obtained at 22°C. Distributed capacity effects increased with electrode thickness and with decreasing temperature; the results agreed well with values predicted from a previously developed model. In the potential range of 0 to -0.40V vs. Hg/HgO, the capacity based on the BET area of the electrode was about 30 $\mu F/cm^2$.

TBC-3139

J. F. Jackovitz and D. W. Feldman, Westinghouse Research Laboratories, "A Structural Investigation of Nickel Oxide Electrode Powders Using Infrared and Laser Raman Spectroscopy, Abstract No. 25, Extended Abstracts, Electrochemical Society Fall Meeting, pp. 67-68 (October 1972)

The infrared and laser-excited Raman spectra of charged and discharged nickel electrode powders were recorded from 4000 - 100 cm^{-1}. A spectroscopic study also was made on pure $Ni(OH)_2$ for comparison and to allow unambiguous frequency assignments. Fundamental vibrations of the discharged material are coincident with those of $Ni(OH)_2$ and were assigned according to D_{3d}^3 symmetry with the aid of the deuterated species. Infrared spectra for $Ni(OH)_2$ and $Ni(OD)_2$ were run as KBr or adamantane disks. Raman spectra were obtained from the 5145 Å line of an argon ion laser. Infrared absorptions for $Ni(OH)_2$ were found at 3644, 525, 458, and 340 cm^{-1}; those for $Ni(OD)_2$ occurred at 2676, 2450, 420, and 332 cm^{-1}. Raman frequencies are mutually exclusive with infrared absorptions for $Ni(OH)_2$ or $Ni(OD)_2$ since an inversion center is present. Raman bands were found at 3599, 519, 450, and 319 cm^{-1} for $Ni(OH)_2$ and at 2664, 442, 420, and 314 cm^{-1} for $Ni(OD)_2$. Vibrational analysis for the $Ni(OH)_2$ unit cell containing one molecule yields one internal mode involving hydroxyl stretching and three external modes, one a rotatory type described as hydrogen rocking mode and the other two described as translatory external types associated with motions of the hydroxyl groups as a whole relative to the nickel atoms. Since the centrosymmetric $Ni(OH)_2$ unit cell contains two hydroxyl groups, each of the above vibration types is split into two components, one antisymmetric with respect to the inversion center and infrared active, and the other symmetric to the center and Raman active.

TBC-3140

Gerhard L. Holleck and Michael Turchan, Tyco Laboratories, Inc., "High Hydrogen Overvoltage Negatives for NiCd Batteries," Abstract No. 26, Extended Abstracts, Electrochemical Society Fall Meeting, pp. 69-70 (October 1972)

The generation of hydrogen must be avoided in sealed NiCd batteries since there is no effective mechanism for its removal. Conventional sealed NiCd cells are therefore constructed such that the positive (nickel hydroxide) electrode is limiting (i.e., reaches full state of charge before the negative electrode). The cell characteristically generates oxygen during charge and overcharge which is recombined at the negative (cadmium) electrode. An alternative cell concept wherein the negative electrode is limiting would have several advantages, including safety, cooler operation, and high rate charging capability. Overcharge, however must be avoided in a negative limited cell. If the potential change indicating the end of charge and the onset of hydrogen evolution is sufficiently large, if can be used as the signal to terminate the charging process. Thus, negative electrodes with high hydrogen overvoltage characteristics are the key requirement for sealed negative limited cells. Besides cadmium itself, silver shows a high overvoltage for hydrogen evolution. The following electrode structures were manufactured and their physical and electrochemical characteristics were evaluated: (1) cadmium impregnated silver sinters, (2) Teflon-bonded Cd electrodes on Cd and Ag screens, (3) cadmium sinter structures on Cd and Ag substrates, and (4) electrodeposited Cd sponge on Cd substrate. The first two structures were judged especially attractive for practical plates and investigated in more detail. High porosity silver plaques covering a wide variety of different structures were prepared and impregnated. The electrodes exhibited a sharp potential rise at the end of charge and H_2 evolution began at potentials between -1.2V and -1.3V versus Hg/HgO. Their capacity,however, decreased with increasing cycle number. The rate of this capacity loss was remarkably independent of plaque structure. Scanning electron micrographs of silver sinter and nickel sinter-based electrodes showed significant differences.

TBC-3141

Edward J. Rubin and Elizabeth A. Trickett, Tyco Laboratories, Inc., "Bath Chemistry of the Electrochemical Method for Producing NiCd Plates," Abstract No. 27, Extended Abstracts, Electrochemical Society Fall Meeting, pp. 71-72 (October 1972)

The impregnation of NiCd battery plates using the high temperature electrochemical process is dependent on the electrochemical production of hydroxyl ions at the cathode.

The hydroxyl ions then react with the metal nitrates to form Ni or Cd hydroxide. In the preparation of Ni or Cd battery plates, porous Ni plaques are cathodized, with the majority of the active material being precipitated within the pore structure. The distribution of active material is however dependent on the rates of diffusion of the metal ion, H^+ and OH^-, and is influenced strongly by the concentration of the variou species.

At the nonconsumable anode used in this work, the predominant reaction produces H^+ ions which continually decrease the pH of the bath. The method of treating this effect and the stoichiometry of the reactions are discussed.

TBC-3142

Walter W. Kirsch, Sperry Rand Corp., "Nickel-Cadmium Battery Performance Prediction Models Apollo Telescope Mount Application," Paper No. 739011, 8th Intersociety Energy Conversion Engineering Conference, 1973 Record, pp. 78-85.

Description of the features of two newly developed Ni-Cd deterministic performance prediction models $EM DASH$ i.e., a capacity degradation model, and a cyclic charge/discharge model. The former describes the expected usable battery capacity as a function of time, temperature, and depth-of-discharge. Both transient and steady state parameter variations are considered. The latter describes charge and discharge voltages as a function of state-of-charge over a range of temperatures, charge and discharge rates, and electrical loads. Average cyclic characteristics such as heat, efficiency, and recharge fraction are also included. 3 refs.

TBC-3143

R. V. Boldin, S. N. Sushentsova, and N. M. Milyutin, Army Foreign Science and Technology Center, "Wettability of the Casting and Electrolyte Leakage in Air-tight Nickel-Cadmium Storage Batteries," Report No. FSTC-HT-23-1002-74 (September 30, 1974). Trans. of Vsesoyuznyi Nauchno-Issledovatelskii Akkumuliatornyi Institut. Sbornik Rabot po Khimicheskim Istochnikam Toka (USSR) v7, pp. 161-163, 1972.

The results of studying the wettability of 08KP steel used for manufacture of storage battery casings, with an alkali solution at various potentials of the metal's surface are presented. It is shown that greatest wettability, and consequently, an increased tendency toward electrolyte leakage along the storage battery casing is observed when the casing is connected electrically to the negative block of electrodes; smallest wettability is observed when the casing is insulated from the working electrodes.

TBC-3144

Compagnia Generale di Elettricita S.P.A., "Testing of NiCd Cells Over Geostationary Orbit Type Cycling Period," Report No. ESRO-CR(P)-504, Contract ESTEC-1185/70-HP (January 14, 1974).

The best charge current of Ni/Cd batteries at a given temperature and a given depth of discharge (d.o.d.) was determined. This was achieved by testing a number of cells under continuous cycling of 24 hours (22.8 hours charge and 1.2. hour discharge). A comparison was also made between the cycling routine with variable charge/discharge time for those depths of discharge averaged on the eclipse duration and the similar rate of charge.

The test was performed on 180 sealed cells. The test program demonstrated that temperature is the most important factor affecting cell behavior. Cell operation is good at minus 10 C and + 10 C at any d.o.d. considered, while at + 30 C operation is generally bad. With a few exceptions, cells undergoing the cycling still work after about 440 cycles.

TBC-3145

David A. Aikens and Howard Littman, Rensselaer Polytechnic Institute, "Electrochemical Power Sources," Final Technical Report ECOM-69-0063-F, September 18, 1968 to January 31, 1974, Contract DAAB07-69-C-0063 (September 1974).

The report summarizes research in the areas of electrodes and electrolytes and heat and mass transfer in porous media. Heats of solution were determined for alkali metal salts in nitrile solvents and the structure of electrolytes - nitrile solutions has been studied by Raman spectroscopy and conductance. Data on non-aqueous electrolytes has been compiled. Properties of reference electrodes and liquid junctions in propylene carbonate have been studied potentiometrically and the problem of uncompensated resistance has been studied by electrostatic methods. The effect of cycling on sealed Ni-Cd batteries has been studied. Liquid-gas distribution in porous media has been studied by modeling techniques and by gamma scattering. The coupling of thermal and mass transport with electrochemical processes at the three phase interface has been studied using a microelectrode, and theoretical studies of evaporation from thin films have been performed.

TBC-3146

R. S. Bogner, Jet Propulsion Laboratory, "Mariner Mars 1971 Battery Design, Test, and Flight Performance," Report No. NASA-CR-132986, (JPL-TM-33-591), Contract NAS 7-100 (April 15, 1973) p. 194.

The design, integration, fabrication, test results, and flight performance of the battery system for the Mariner Mars spacecraft launched in May 1971 are presented. The battery consists of 26 20-Ah hermetically sealed nickel-cadmium cells housed in a machined magnesium chassis. The battery package weighs 29.5enl kg and is unique in that the chassis also serves as part of the spacecraft structure. Active thermal control is accomplished by louvers mounted to the battery baseplate. Battery charge is accomplished by C/10 and C/30 constant current chargers. The switch from the high-rate to low-rate charge is automatic, based on terminal voltage. Additional control is possible by ground command or onboard computer. The performance data from the flight battery is compared to the data from various battery tests in the laboratory. Flight battery data was predictable based on ground test data.

TBC-3147

M. A. Hopper and J. L. Ord, Waterloo University (Ontario, Canada), "An Optical Study of the Growth and Oxidation of Nickel Hydroxide Films," Electrochemical Science and Technology, vol. 120, No. 2, pp. 183-187, February 1973. (Revision of report dated May 9, 1972 (September 27, 1972)).

The formation and oxidation of nickel hydroxide films under a variety of experimental conditions are studied using in situ ellipsometric measurements. Two forms of the hydroxide, which we assume to be the alpha and beta forms reported by other workers, are found. The alpha- and beta-hydroxide layers are both transparent with real refractive indices of 1.52 and 1.46, respectively, at 6328A. Upon oxidation the two forms of hydroxide convert to different oxides, both of which absorb light. The process involved in the conversion of the beta-hydroxide appears to be similar to the process postulated for the charging of the nickel battery electrode.

TBC-3148

M. E. Lago and F. P. Plachco, University of Chile, Santiago, Chile, "Rapid Characterization of Porous Solids and Measurement of Molecular Diffusivity: Electrochemical Method," Electrochimica Acta, 1972, Vol. 17, pp. 1707-1716, Pergamon Press, Northern Ireland.

A representative model of the diffusional process in an electrochemical system comprising two successive media has been developed analytically and proved experimentally. From the model a rapid (3-10 min) and simple method was obtained to determine simultaneously the porosity and tortuosity of non-conducting porous media.

Likewise the determination of molecular diffusivities is presented, based on a standard experiment, and a satisfactory agreement between the measured values of molecular diffusivity, D_o, and those given in the literature is obtained.

TBC-3149

V. S. Bagotzky, N. A. Shumilova, G. P. Samoilov and E. I. Khrushcheva, Institute of Electrochemistry of the Academy of Sciences of the USSR, Moscow, USSR, "Electrochemical Oxygen Reduction on Nickel Electrodes in Alkaline Solutions," Electrochimica Acta, 1972, Vol. 17, pp. 1625-1635, Pergamon Press, Northern Ireland.

Electrochemical reduction of oxygen on a nickel electrode in alkaline solutions has been studied using the rotating ring-disk-electrode method. The change in the ratio of two possible reaction courses (viz with or without intermediate formation of hydrogen peroxide) depends on the potential degree of electrode oxidation and the composition. Oxidation of the nickel electrode surface leads to considerable inhibition of oxygen reduction accompanied by increased hydrogen-peroxide yields. In LiOH solution the contribution of the reaction with intermediate hydrogen-peroxide formation is less, as compared with the KOH solution. The constants of individual reaction steps of the oxygen-reduction reaction have been calculated.

A study has been made of the hydrogen-peroxide reduction, oxidation and catalytic decomposition on the nickel electrode. Hydrogen peroxide does not undergo decomposition. Increase in the oxidation state of the electrode surface inhibits hydrogen-peroxide reduction, but scarcely affects its electrochemical oxidation.

TBC-3150

S. Iseki, K. Ohashi and S. Nagaura, Osaka City University, Osaka, Japan, "Impedance of the Oxygen - Evolution Reaction on Noble Metal Electrodes," Electrochimica Acta, 1972, Vol. 17, pp. 2249-2265, Pergamon Press, Northern Ireland.

The impedances of the oxygen-electrode reaction on platinum, palladium, gold and silver electrodes in acidic and alkaline solutions were measured with an ac bridge in the range of frequency from 10 Hz to 20 kHz, under dc polarization. For these electrodes, plots of impedances on the complex plane give semi-circles whose diameter is proportional to the dc being passed through the cell. By analysing these plots and impedance/dc curves, it is shown that the oxygen-evolution reaction on these electrodes is controlled by a charge-transfer process, except for the case of platinum in perchloric acid solution. In the latter system, a chemical reaction on the electrode surface is rate-determining.

TBC-3151

A. C. C. Tseung and B. S. Hobbs, Energy Conversion Ltd., Basingstoke, England, "Influence of Oxygen Partial Pressure on the Electrocatalytic Activity of Nickel-Oxide Oxygen Electrodes," Electrochimica Acta, 1972, Vol. 17, pp. 1557-1562. Pergamon Press, Northern Ireland.

Incubating nickel oxide at different ρ_{o2} changes the $\left[Ni^{3+}\right]$ according to the relationship $\left[Ni^{3+}\right] \propto \rho_{o_2}^{1/6}$. Tests on nickel-oxide oxygen electrodes incubated at various ρ_{o_2} at 220°C, 75% KOH, showed that the electrocatalytic activity is influenced by the $\left[Ni^{3+}\right]$ and that the equilibration process is very slow. The results suggest that pure nickel oxide is unsuitable for use as a high performance and stable oxygen electrocatalyst. On the other hand, no such effect is observed in lithiated nickel oxide electrodes since the $\left[Ni^{3+}\right]$ is controlled by the $\left[Li^{+}\right]$, viz $Ni^{2+}_{(1-2x)}Li_x+Ni_x^{3+}O^{2-}$.

TBC-3152

G. Halpert, W. H. Webster, C. C. Jones and O. Ogunyankin, Goddard Space Flight Center, Greenbelt, Maryland, "Procedure for Analysis of Nickel-Cadmium Cell Materials," NASA Report No. X-711-74-279, October 1974.

This document is intended to provide a comprehensive physical/chemical analysis procedure for nickel-cadmium cells. From the analytical results, characteristics and changes in characteristics of plates, separator and electrolyte can be determined. These results can be used to isolate problems in cell manufacture and/or suggest areas for cell improvement. The analysis is presented in a detailed stepwise manner and includes the principle of each procedure, reagents and materials required, and recommended calculations.

TBC-3153

Dr. R. Knodler, Battelle Frankfort, "The Determination of Phase Boundary Impedances - A Universal Method of Examining Surfaces and Surface Reactions," Report No. 18, 1974.

Inspection methods based on impedance measurements have significant advantages over conventional methods. Measurements of this can be performed fast and in situ, and provide a large number of separate data. Applications include the evaluation of metallic materials to establish susceptibility to corrosion, corrosion rate and the effect of protective coatings, the quality control of batteries, and the characterization of porous materials and surface structures.

TBC-3154

E. S. Carr, Eagle-Picher Industries, Joplin, Missouri, "Lightweight Sponge Negative Plates for Nickel-Cadmium Batteries," 25th Power Sources Symposium, May 23-25, 1972, Proceedings, pp. 57-60.

This paper presents the results of USAECOM Contract Number DAAB07-70-C-0/46, for the development and production of the BB-460 ( )/U battery. The success of this program was a direct result of the application of the Eagle-Picher lightweight sponge cadmium plate in the BB-460( )/U battery. Cycle test results are also presented of sealed spacecraft nickel-cadmium cells incorporating similar sponge cadmium plates. These programs have resulted in nickel-cadmium cells of 19-25 watt-hours per pound, the standard energy density range being about 12-16 watt-hours per pound.

TBC-3155

Hanns H. Kroger, General Electric Co., "Nickel Hydroxide Battery Electrode Development," Annual Interim Report No. 2, AFAPL TR-71-12, January 1, 1970 - December 31, 1970, Contract F33615-69-C-1312 (January 1971) 183 p. (AD883905)

Repetitive cycling regimes failed to induce the 'Memory' effect as commonly defined. Irregularities in the discharge voltage curves could be traced back to the positive electrodes by means of reference electrode measurements. However, chemical analyses could not detect any significant changes in composition. The development of an electro-deposition process on a constant potential basis resulted in positive nickel hydroxide electrodes with specific capacities meeting the 8-10 AH/ CU in contract goal. Comprehensive testing under a variety of experimental conditions was undertaken using C(s) cells. The amount of cobalt additive was optimized for cell performance. Scale-Up attempts to 20 AH-size electrodes were successful and a limited number of nominal 20 AH capacity cells was tested both in the scaled and flooded states. Efforts were also made to fabricate pasted plates and also electrodes on a Raney-nickel basis. Corresponding testing delivered specific capacities below the contract specification.

TBC-3156

M. G. Gandel, Lockheed Missiles & Space Company, Inc., Sunnyvale, California, "Instantaneous Charge Efficiency Determination for Nickel-Cadmium Cells," Electrochemical Society, Fall Meeting, October 1973, Extended Abstract No. 46, pp. 112-113.

A method for calculating the instantaneous Faradaic charge efficiency in sealed Ni-Cd cells is developed based on the thermodynamics of the charge, overcharge and oxygen recombination reactions. Results of tests on two different cells verified the charge efficiency calculation method and the experimental technique.

TBC-3157

D. F. Pickett, U.S. AFAPL, WPABF, Ohio, "Use of Ethanol Solutions for Electrochemical Impregnation of Porous Structures with Nickel Hydroxide," Electrochemical Society, Fall Meeting, October 1973, Extended Abstract No. 49, pp. 119-120.

This paper describes a technique of obtaining highly loaded nickel hydroxide electrodes having high efficiency. In this process ethanol is used, primarily, to reduce the impregnation bath temperature to $80^{o} \pm 4^{o}C$ from 100^{o} - $105^{o}C$ which enables the process be be carried out with plastic tanks, lines and pumps. It also appears to control the solution acidity as no nickel hydroxide solids are present in the impregnating solution at the end of deposition. The deposition is carried out by merely making the porous structure cathodic in a 50 $\pm$ 20% aqueous ethanol solution by volume containing nickel and cobalt nitrates and passing current at 0.039 to 0.078 amperes per square cm for one to two hours. Nickel counter electrodes are usually used.

TBC-3158

D. Yamashita, Ritsumeikan University, Kyoto, Japan, "Studies on Sintered-Type Alkaline Storage Batteries, VII Effect of Cobalt on the Positive Plates of Sintered-Type Alkaline Storage Batteries," Journal of Electrochemical Society of Japan, Vol. 31, No. 47, 1963.

The author studied the effects of cobalt on the positive plates of sintered-type alkaline storage batteries by the experiments as follows.

(1) Charge-discharge curve of the active material of Ni-Co system .

(2) Durability test (capacity change by repeating charge-discharge for long period).

(3) Low rate charge test.

(4) X-ray diffraction diagram and electromicrophotograph of active material.

According to these experimental results, charge-discharge potential dropped with increasing content of cobalt and active material seems to be solid solution (Ni, Co) $(OH)_2$ up to 20% Co, but mixture of (Ni, Co) $(OH)_2$ and $Co(OH)_3$ over 30%. The availability of active material increased by only 5% addition of cobalt.

Capacity drop by charge-discharge for long period and by low rate charge may be fairly prevented by the addition of cobalt.

This behavior of cobalt is probably due to the formation of solid solution (ni, Co) $(OH)_2$ in active material.

TBC-3159

H. N. Seiger, Heliotek/Textron Inc., Sylmar, California, "Effects of Air Entrapped in Sealed Nickel-Cadmium Cells," Electrochemical Society, FAll Meeting, October 1974, Extended Abstract No. 45, pp. 112-113.

A redistribution of electrolyte has been found in sealed nickel cadmium cells that had been extensively cycled. The redistribution is evidenced by a decreased electrolyte content in the separator.

Data from the battery literature are used to exemplify the effects of air entrapment. It has been found that, almost invariably, where polypropylene is used as separators a lesser amount of electrolyte is inserted than when nylon separators are used. Thus, the redistribution problem associated with the air entrapment mechanism is aggravated.

As an alternative to adding electrolyte based on a quantity per ampere hour, it is proposed that a percentage filling of residual void volume be employed. It appears that a satisfactory value is 90% filling of residual voids calculated on the basis of assembling a cell from discharged electrodes.

TBC-3160

C. E. Maiden, A. F. Ahrens, R. R. Eliason, I. L. Kerper, E. Levy, and R. J. McGrath, Hughes Aircraft Company, "Near Earth Orbit Battery for Satellite Secondary Power," Final Technical Report AFAPL-TR-74-21 (SCG 40026R), July 1972 through December 31, 1973, Contract AF33615-73-C-2007 (June 1974) 287 p.

Work was performed over an 18 month period towards development of a 500 watt battery system capable of providing electrical power for near earth orbit satellite applications. This effort continued the work done previously on another Air Force contract. Two years (9000 cycles) of real time testing of a 50 A-hr breadboard system were completed with no cell failures, and 1000 cycles were completed in a test of two 500 watt systems operating in parallel. Battery control electronics development included paralleling circuits, fusing protection, and cell reversal protection. EMI testing of the power conditioner was done. Radiation hardening studies were made and are reported upon in a separate classified supplemental report. A variety of cell design changes were evaluated in a cell improvement program which stressed improvements in seals, separator, and electrolyte optimization. A unique method for measuring the state-of-charge of a nickel-cadmium cell was developed and tested in three sealed 50 A-hr cells. Thermal control studies were made for multiple-battery systems up to 4000 watts total using the basic 500 watt system as a building block. Techniques considered included passive radiators, electrical heaters, thermal louvers, heat pipes, and liquid coolant loops. This report provides sufficient information to facilitate a detailed thermal design upon mission definition. Reliability of the system has been updated to reflect the latest data.

TBC-3161

D. F. Pickett, AFAPL, WPAFB, Ohio and V. J. Puglisi, Heliotek/Textron Inc., Sylmar, California, "Electrochemical Impregnation of Sintered Nickel Structures with Cadmium Using Constant Current Step and Alternating Current Pulse Techniques," Electrochemical Society, Fall Meeting, October 1974, Extended Abstract No. 46, pp. 114-115.

This paper describes techniques which yield highly loaded cadmium electrodes having good utilization of active material. One method uses a constant current step (CCS), while others use alternating symmetric (ACP) or assymmetric with respect to time (ACPT). In the CCS technique a constant current of 1.0 to 2.0 amperes per square inch of plaque is applied in 2.0 molar cadmium nitrate for periods of 3.0 to 20 minutes with an inter-electrode spacing of 0.75 inches. Bath temperature is approximately 100°C and counterelectrode material is cadmium.

TBC-3162

O. C. Wagner and D. D. Williams, ECOM, Fort Monmouth, N. J., "Investigation of Charging Methods for Nickel-Cadmium Batteries," Electrochemical Society, Fall Meeting, October 1974. Extended Abstract No. 49, pp. 120-122.

Results are presented for the second phase of an investigation of charging methods on nickel-cadmium batteries. The results of the first phase conclude: (a) compared with constant current d.c., reflex charging (charge and discharge pulses) will increase the charge acceptance of vented nickel-cadmium batteries by 10 to 15 percent in a temperature range of -40°F to 100°F, (b) the optimum parameters for the reflex mode were an average charge rate of 2C, a frequency range of 30 to 2000 Hz, and a minimum discharge pulse energy of 2.5 milliwatt-seconds, and (c) reflex charging restored the capacity lost by growth of cadmium and/or cadmium hydroxide crystals.

TBC-3163

D. Yamashita and I. Ohata, Ritumeikan University, Kyoto, Japan, "Effect on Lithium Ion on the Formation of Active Material from Nickel Plaque at Various Temperatures," Journal of the Chemical Society of Japan, No. 10, 1974, p. 1882.

The effect of lithium ion on the formation of active material from nickel plaque have been studied at various temperatures by means of the current-potential curves obtained with polarized nickel electrode in alkaline solution and the electromicrophotograph of the surface of nickel electrode.

The results are summarized as follows.

(1) As the temperature increases, the amount of active material formed from nickel plaque increases, but the formation of nickel-lithium compound becomes more rapid. Therefore, the oxidation of nickel plaque is disturbed at higher temperatures.

(2) The increase in activity of OH^- in LiOH with temperature is smaller than that in KOH.

(3) The active material produced by repeated oxidation-reduction cycles reacts with lithium ion, resulting in shedding.

Because of such phenomenon, the over charge-discharge is not desirable when lithium ion is added to electrolyte solution.

TBC-3164

M. Buchner, R. Sh. Mikhail and E. Robens, Ain-Shams University, Abassia-Cairo, Egypt, "Computer Programme for Surface Area and Pore Analysis on the Basis of Sorption Isotherms," Annual Meeting of the German Vacuum Association, together with the Annual Meeting of DECHEMA, Frankfurt (Main), 5th June 1974.

For the machine evaluation of sorption isotherms a programme consisting of the following steps has been elaborated:

- Computation of the coordinates (amount adsorbed and pressure) on the basis of the measured values of the isotherm.
- Determination of the specific surface area after Brunauer, Emmett and Teller, the cumulative specific surface area, and the specific surface area on the basis of the t diagram after de Boer.
- Pore size analysis in the mesopore and micropore range by the model-free and corrected model-free method of Brunauer, Mikhail and Bodor.
- Calculation of the mean values of porosity, pore diameter and density.

TBC-3165

W. Pollack, Westinghouse Electric Corporation, "Diffusion Bonded Plaques," U.S. Patent No. 3,702,019; November 7, 1972.

A process related to an improved method of making flexible, diffusion bonded, fiber metal, electrode plaques for use in battery cells such as nickel-cadmium and nickel-iron systems.

TBC-3166

H. N. Seiger, N. P. Yao, V. J. Puglisi, Heliotek/Textron, Sylmar, California and J. Bene, NASA/Langley Research Center, Hampton Roads, Virginia, "Double Layer Capacitance of Porous Nickel Electrodes by Square Wave Pulse Technique," Electrochemical Society, FAll Meeting, October 1974, Extended Abstract No. 48.

A series of experiments were performed to ascertain the region of the current-voltage curves where faradaic currents are negligibly small. First the open circuit potential of the unpoised plaque electrode was measured to establish a point of reference. This was followed by the determination of the current-potential behavior between -0.9 and 0.0V using cycling voltammetric techniques and the determination of the current-time response illicited by an 8 mV voltage step superimposed upon various bias potentials. Examination of the results revealed that bias potentials of from -0.9 to -0.5V vs. the nickel oxide electrode were regions of minimal faradaic currents. In addition, experiments were carried out in which the relationship between the magnitude of the voltage step and the nonfaradaic current response was investigated. The investigation showed the double layer capacitance to be independent of voltage amplitude for voltage steps varying from 6 to 15 mV.

TBC-3167

J. D. Dunlop and M. Earl, COMSAT Laboratories, "Evaluation of Intelsat IV Nickel-Cadmium Cells," 25th Power Sources Symposium, Proceeding May 23-25, 1972, pp. 40-42.

Starting in December 1969, INTELSAT IV 15 Ah nickel-cadmium cells were tested to simulate the INTELSAT IV synchronous orbit mission in real time. Two different storage methods were used: continuous trickle charge and open circuit charged stand with recharge every 30 days. On each eclipse season one cell was removed from each group for electrochemical and chemical analyses. Data from these analyses were used to evaluate the expected cell performance for the INTELSAT IV mission.

Results to date show that two important parameters are dependent on the storage mode. The first is the rate of increase of the potassium carbonate (K_2CO_3) in the electrolyte. This carbonate, formed by oxidation of the separator hydrolysis products, increases at the rate of approximately 1.0 to 2.0 grams/year for the trickle charge storage mode and 0.5 to 1.0 gram/year for the open circuit storage mode. The result is a shift in the state of charge of the cadmium electrode with respect to the nickel electrode. With time the cell will become negative limited on charge.

TBC-3168

F. E. Ford, Goddard Space Flight Center, Greenbelt, Maryland, "Performance of 3rd Electrode Cells in OAO," 25th Power Sources Symposium, Proceedings, May 23-25, 1972, pp. 43-46.

On December 7, 1968, the Orbiting Astronomical Observatory (OAO) 2 was placed in a near-Earth orbit. This satellite was the first to use nickel-cadmium batteries with auxiliary (signal) electrodes for overcharge control. During the early life of the satellite, these third-electrode signals provided ground control center with an orbit-by-orbit indication of the overcharge the batteries were receiving. By ground command, the battery charger was adjusted on a "need basis" to provide optimum recharge conditions as indicated by the third-electrode signals during all phases of spacecraft

operations and orientations. After more than 2 years (over 10,000 orbits), an unusual degradation in third-electrode signals was observed and provided the first indication of battery degradation. The analysis of the battery system and type of battery degradation observed in the OAO 2 spacecraft is the subject of this paper.

TBC-3169

E. Levy Jr., Hughes Aircraft Company, El Segundo, California and R. L. Kerr, AFAPL, WPAFB, Ohio, "Nickel-Cadmium Cells for Low Earth Orbit Applications," 25th Power Sources Symposium, Proceedings, May 23-25, 1974, pp. 47-52.

A battery system for use in low earth orbiting satellites has been designed, developed, and fabricated, and successfully completed 6 months of cycling in a vacuum chamber. The test demonstrated that a new system can provide power to a 0 to 500 watt load during a 35 minute time period and fully recharge during the succeeding 75 minutes.

The key performance data are the amount of ampere-hour overcharge and the cell temperature rise. The data derived through test of a dual voltage/pressure charge control system are considered extremely encouraging. However, additional testing on the current unit and other batteries using this control system will be required for complete performance verification.

TBC-3170

R. Grasser and A. Scharmann, Giessen University (West Germany), "Study on Leak Rate of ESRO 4 Ni/Cd Battery Cells," Summary Report No. ESRO-CR (p. 132) (ESRO-CR (p. 133-ADD-1), Contract ESTEC-1599/72-SL (August 10, 1972), p. 12. 73H13054#

Determination of KOH loss in ESRO 4 Nickel Cadmium batteries by electrical measurements.

TBC-3171

C. Tanis, AFML, WPAFB and J. J. Lander, AFAPL, WPAFB, Ohio, "Long-Life, High Energy Ni-Cd Aerospace Cells," 25th Power Sources Symposium, Proceedings, May 23-25, 1972, pp. 55-57.

This paper presents results of testing an aircraft cell design in which the cellophane layer of the separation is replaced with a single layer of P-2291, and, also, plans for large-scale testing in aircraft batteries.

TBC-3172

Naval Ammunition Depot, "An Improved Method of High-Rate Discharge Testing of Aircraft Storage Batteries," Report No. QEEL/C-72-391, November 1972, p. 4. AD-905118L

This report describes evaluation tests conducted to improve high current step discharge testing of aircraft storage batteries. A nickel-cadmium aircraft battery was used in the evaluation, and was subjected to a discharge routine.

TBC-3173

R. H. Josephs, Cincinnati University, "The Mariner 9 Power Subsystem Design and Flight Performance," Report NASA-CR-132992 (JPL-TM-33-616), Contract NAS 7-100 (May 15, 1973), p. 50.

The design and flight performance of the Mariner Mars 1971 power subsystem are presented. Mariner 9 was the first spacecraft to orbit another planet, and some of the power management techniques employed to support an orbital mission far from earth with marginal sunlight for its photovoltaic-battery power source are described. The performance of its nickel-cadmium battery during repetitive sun occultation phases of the mission, and the results of unique tests in flight to assess the performance capability of its solar array are reported.

TBC-3174

Gerald Halpert, Chairman, NASA Goddard Space Flight Center,"The GSFC Battery Workshop," Report X-711-74-348, November 1974.

A verbatim transcript of the Annual Battery Workshop held at Goddard Space Flight Center, November 19-20, prepared by Ace-Federal Reporters of Washington, D.C. The material covered at the workshop includes a discussion of the low cost/standardization program, test and flight experience, storage experience and manufacturing improvements, materials and cell components, analysis and new developments in the Ni/H_2 system.

TBC-3175

T. B. Selover, Jr. Standard Oil Company of Ohio, "Development of a Seal for Fused Salt Secondary Batteries," Abstract No. 31, Extended Abstracts, Electrochemical Society, Spring Meeting, May 1975.

The need for a stable, leak tight seal for any fused salt battery is obvious. Yet it usually is one of the last major barriers to development of a successful unit cell. The work at Sohio covering several years and four seal designs has resulted in a compact corrosion resistant swaged seal. A joint study with Battelle Columbus Laboratories examined the critical fabrication parameters to find out why the seal works and how to improve it. Thermal expansion of the materials, ceramic formulation, and compaction technique were found to be the important variables. Leak testing at room and operating temperature (500°C) was done. These results as well as postmortem examination of seals from working cells are discussed.

TBC-3176

W. Dennstedt and W. Loser, Varta Forschungs - und Entwicklungszentrum, West Germany, "Nickel Hydroxide Electrode III Thermogravimetric Investigations of Nickel (II) Hydroxide," Electrochimica Acta, 1971, Vol. 16, pp. 429-435. Pergamon Press, Northern Ireland.

Water contained in nickel hydroxide influences its electrochemical reactivity. The water content of α- and β-nickel hydroxides is different in respect of the amount and the bond strength. Thermogravimetric experiments show that the water of the β-nickel hydroxide exceeding the stoichiometric composition is completely removed at 160°C. The water contained in the interlayers of the α-hydroxide, however, is removed only at higher temperatures, together with the water originating from the decomposition of the hydroxide. These differences are attributed to the formation of hydrogen bonds within the interlayers and between interlayers and adjacent main layers.

An attempt is made to explain the relations between water content and the oxidizability of the nickel hydroxides.

TBC-3177

S. LeBihan and M. Figlarz, University of Paris, Paris, "--Nickel Hydroxide Electrode III Thermogravimetric Investigations of Nickel (II) Hydroxide by W. Dennstedt and W. Loser--Comment," Electrochimica Acta, 1973, Vol. 18, pp. 123-124. Pergamon Press, Great Britain. (See TBC-3176 for Dennstedt and Loser Article).

TBC-3178

T. B. Selover, Jr., Standard Oil Company of Ohio, "The Use of Radiography as a Nondestructive Testing Tool in Battery Development," Abstract No. 32, Extended Abstracts, Electrochemical Society Spring Meeting, May 1975.

The Sohio battery pilot production line was capable of producing unit cells as large as 7 in. x 9 in. x 1 in. on a routine basis. These LiAl/(Li, K) Cl/C-$TeCl_x$ cells in steel cans were examined before, during, and after operation by using a desk top x-ray radiography instrument to detect fabrication and operating flaws. Neutron radiography at the Battelle Columbus Laboratories swimming pool reactor was also used to look at components in various stages of fabrication as well as in sealed cells. The elements Li and B present an interesting contrast in the utility of the two radiography techniques and are compared.

TBC-3179

A. J. Salkind, ESB Inc., Technology Center, "The Semiconductor Nature of Battery Active Materials," Abstract No. 1, Extended Abstracts, Electrochemical Society Spring Meeting, May 1975.

The semiconductor nature of battery active materials, especially the positive electrode oxides are discussed. The historical work of Edison and others in obtaining doped semiconductors and modern techniques and interpretations are reviewed. Methods of processing of battery electrodes in order to obtain desired metal oxide structures in situ is compared to techniques used for electronic semiconductors.

TBC-3180

R. F. Chireau and R. Gunther, Yardney Electric Div., Yardney Electric Corp., "Nonsintered Nickel Electrodes Fabricated by Continuous Roll-Compacting of Nickel Hydrate Powder Composites," Abstract No. 49, Extended Abstracts, Electrochemical Society Spring Meeting, May 1975.

Low cost, highly efficient nickel electrodes suitable for use in alkaline cells for vehicular applications, have been fabricated by dry powder roll-compacting techniques. This paper reviews the technology and the problems inherent in the rolling of nickel hydrate powder composites into structures having suitable mechanical integrity. The physical and electrical properties of the rolled, nonsintered nickel electrodes are briefly discussed. The properties of interest are: utilization of active material, specific energy density, electrode dimensional stability and polarization characteristics. Test data showing the cycling behavior of typical electrodes on a 100% depth of discharge regime are presented.

TBC-3181

R. L. Falzone (Editor), General Electric Company, Gainesville, Florida, "Nickel Cadmium Battery - Application Engineering Handbook," General Electric Company, 1971 with supplement 1973. Publication No. GET-3148 (Library of Congress Catalog card no. 71-152881).

Application information is given including charging, storage, electrical characteristics, physical considerations, maintenance, and life.

TBC-3182

L. May, The Catholic University of America, Washington, "The Role of Iron in the Nickel-Cadmium Alkaline Cell," NASA Report No. X-711-74-287, September 1974. Goddard Space Flight Center Greenbelt, Maryland.

Iron is a harmful impurity in the nickel hydroxide electrode. The concentration of both the ferrous and ferric ions are low in the alkaline electrolyte because the respective hydroxides have low solubility products. The ferrate ion, $FeO_4^{=}$, may be formed during anodic oxidation of iron.

This ion spontaneously decomposes to oxygen and ferric ion. The effect of iron is a reduction of the oxidized state of the nickel oxide electrode and a reduction of the oxygen overvoltage.

This results in a decrease in the capacity of the nickel electrode. The extent of the decrease in the capacity depends upon the concentration of the iron. The rates and amounts of contamination of iron increases with temperature.

TBC-3183

P. Faber, Rheinisch-Westfalisches Elektrizitatswerk AG, Germany, "High Purity Divalent Nickel Hydroxide," U.S. Patent No. 3,684,441, August 15, 1972.

This patent describes a method of preparing pur nickelous and ferrous hydroxides. In the manufacture of basic (alkaline) electric storage batteries or accumulators such as those of the nickel/cadmium and nickel/zinc types, the plates associated with the positive electrode can be formed from the divalent hydroxide of nickel ($Ni(OH)_2$) with the possible admixture of some pure nickel. The raw material used in the manufacture of these electrodes must show an extremely high degree of chemical purity since the presence of even small quantities of alien material can poison the electrochemical activity of the finished electrode. Similarly iron hydroxide and iron oxide plates may be employed in electrochemical devices.

TBC-3184

W. Dennstedt, Forschungs-Und Entwicklungszentrum der Varta Batterie AG, Germany, "On Kinetics of the Nickel Hydroxide Electrode-III; Answer to S. LeBihan and M. Figlarz," Electrochimica Acta 1974, Vol. 19, p. 535. Pergamon Press, Great Britain.(See TBC-3176 for article by Dennstedt and Loser).

TBC-3185

T. Katan and H. F. Bauman, Lockheed Palo Alto Research Laboratory, Palo Alto, California, "Relating Structural Variables of Porous Electrodes," Journal of Electrochemical Society, Vol. 122, No. 1, 1975, p. 77.

The purpose of this article is to show how structural variables of battery fuel cell electrodes can be specified and related by adapting a filamentary analog for porous structures. Practical values of these structural variables for typical electrodes are also presented.

TBC-3186

F. G. Will and H. J. Hess, General Electric Company, Schenectady, N. Y., "Morphology and Capacity of a Cadmium Electrode - Studies on a Simulated Pore," Journal of Electrochemical Society, Vol. 120, No. 1, January 1973, p. 1.

Conditions in a single pore of a battery plate were simulated by using a cadmium chip of millimeter dimensions covered with an electrolyte film of micron thickness. In situ microscopy was applied to study changes in the electrode morphology during charge and discharge. Passivation and increases in particle sizes due to precipitation and electrodeposition of dissolved cadmium species were found to cause profound loss in electrode capacity on repeated charge and discharge.

TBC-3187

D. M. Tench and E. Yeager, Case Western Reserve University, Cleveland, Ohio, "Capacitance Measurements on Lithiated Nickel Oxide Electrodes," Journal of Electrochemical Society, Vol. 120, No. 2, February 1973, p. 164.

Differential capacitance measurements have been used to study mosaic lithiated nickel oxide electrodes and to obtain information concerning the potential distribution between the space charge region within the semiconductor and the Helmholtz layer in the electrolyte. Plots of $1/C^2$ vs. E have been found to exhibit linear behavior over substantial ranges of potentials in accord with the Mott-Schottky treatment. The slopes are somewhat higher than expected from the Li content although they approach the Mott-Schottky values for electrodes prepared with shorter Li doping times. At potentials anodic to 1.0V-0.059 (pH)V re SHE the change in electrode potential appears principally across the Helmholtz plane.

TBC-3188

T. R. Jayaraman, V. K. Venkatesan and H. V. K. Uoupa, Central Electrochemical Research Institute, Karaikkudi, India, "Cyclic Voltammetric Studies of Electroless Cobalt in NaOH," Electrochimica Acta, Vol. 20, 1975, pp. 209-213.

The electrochemical behaviour of electroless cobalt in IN NaOH was studied at 35, 60 and 85°C by cyclic voltammetry. Three anodic peaks corresponding to the formation of $Co(OH)_2/CoO$, Co_3O_4, Co OOH were observed. The observed cathodic peaks were due to the reduction of the higher cobalt oxides to $Co(OH)_2$ and also due to the reduction of $Co(OH)_2$ to cobalt. The variation of peak potential with sweep rate was found to be appreciable only in the case of anodic peak (I). The total charge Q_r, for the passivation to occur was obtained by estimating the area under the first anodic peak at each sweep rate. It was found that the Q_r value decreases with increase of sweep rate. The increase of peak current with increase of sweep rate has been explained as due to the insufficient time available for the film growth at the reversible potential, and that the dissolution of the metal continues until a potential at which the rate of film growth exceeds that of active dissolution is reached. It has been suggested that the passivating film is CoO while the prepassive film is $Co(OH)_2$. The shift of the anodic peak (I) potentials to more anodic values compared to that for pure cobalt is probably due to the presence of phosphorus in the cobalt deposit.

TBC-3189

W. J. King and A. C. C. Tseung, The City University, London, "The Reduction of Oxygen on Nickel-Cobalt Oxides -I. The Influence of Composition and Preparation Method on the Activity of Nickel-Cobalt Oxides," Electrochimica Acta, 1974, Vol. 19, pp. 485-491. Pergamon Press, Great Britain.

Nickel cobalt oxides were prepared by coprecipitation, freeze drying and nitrate decomposition. The resistivity, surface area, crystal structure and electrochemical activity of the powders were determined. The highest activity was found in freeze dried samples with the composition Co_2NiO_4 and the spinel structure. TGA and X-ray analysis showed that the spinel phase is metastable and begins to change to a cubic phase at about 450 C significantly reducing the electrochemical performance. Maximum activity in the catalyst is obtained by heat-treating it to this point.

TBC-3190

W. J. King and A. C. C. Tseung, The City University, London, "The Reduction of Oxygen on Nickel-Cobalt Oxides-II. Correlation Between Crystal Structure and Activity of Co_2NiO_4 and Related Oxides," Electrochimica Acta, 1974, Vol. 19, pp. 493-498. Pergamon Press, Great Britain.

The implications of the substitution of nickel for cobalt in Co_3O_4 are discussed. From the effects of substitution of other ions into Co_2NiO_4 its curious properties may partly be understood. The cations present are unable to satisfy the requirements of both crystallographic siting and oxidation state to fit the classical spinel distribution. The result is a weakening of the crystal lattice and hence rather loosely bonded oxygen, eg possibly as O^- instead of O^{2-}. This factor causes the low thermal stability and the exceptional activity towards oxygen reduction, and is maximised by incorporating the highest possible proportion of nickel and then heat-treating the catalyst near its point of breakdown.

The importance of preparing the oxide in complete absence of OH^- or H_2O is deduced. A site and charge distribution for Co_2NiO_4 based on this work and other published data is advanced. The importance of the ferrimagnetic order remains to be clarified. The electrocatalyst is gradually and irreversibly deactivated on exposure to alkaline electrolyte. A mechanism for this unfortunate property is suggested.

TBC-3191

Clarence M. Shipherd, Electrochemistry Branch, Naval Research Laboratory, Washington, D. C., "A Battery Analog," Journal of the Electrochemical Society, Electrochemical Science and Technology, Vol. 120, No. 7, July 1973.

The current density distribution inside a battery can be very well approximated by assuming the current flow is perpendicular to the electrodes. The ratio of electrode spacing to electrode height is found to have a negligible effect on this approximation. A battery analogue was constructed that consisted of resistances alone and eliminated any polarization effects. Measurements made on it were in excellent agreement with those predicted mathematically.

TBC-3192

H. A. Frank and A. A. Uchiyama, Jet Propulsion Laboratory, Pasadena, California, "Leak Rates in Sealed Cells," Journal of the Electrochemical Society, Electrochemical Science and Technology, Vol. 120, No. 3, July 1973.

Water vapor loss rates were determined from simulated and imperfectly sealed alkaline cells in the vacuum environment. The observed rates were found to be in agreement with a semi-empirical equation employed in vacuum technology. Results thereby give support for using this equation for the prediction of loss rates of battery gases and vapors to the aerospace environment. On this basis it was shown how the equation can be applied to the solution of many heretofore unresolved questions regarding leaks in batteries. Among these are the maximum permissible leak size consistent with a given cell life or conversely the maximum life consistent with a given leak size. It was also shown that loss rates of these cells in the terrestrial environment are several orders of magnitude less than the corresponding loss rates in the aerospace environment.

TBC-3193

H. L. Bevan and A. C. C. Tseung, The City University, London, "The Electrochemical Reduction of Oxygen on High Surface Area Lithium Doped Nickel Oxides," Electrochimica Acta, 1974, Vol. 19, pp. 201-206, Pergamon Press, Great Britain.

The electrochemical activity of high surface area lithiated nickel oxides, prepared by freeze-drying or hydroxide precipitation, towards the reduction of oxygen in KOH, was investigated as a function of surface area, temperature

and oxygen partial pressure. For very high surface area oxides (180 m^2/g) electrochemically reversible behaviour was achieved at 150 instead of 230°C for the lower surface area oxides. The evidence suggests that oxygen is being reduced directly to hydroxyl ions without forming the peroxide intermediate. The results concur with the Joint Pseudosplitting/ Dissociative Adsorption mechanism proposed by Evans, and also provide further evidence that the temperature at which oxygen is dissociatively chemisorbed on lithiated nickel oxides may be related to the Neel Temperature.

TBC-3194

B. MacDougall and M. Cohen, Division of Chemistry, National Research Council of Canada, Ottawa, Ontario, Canada, "The Effect of Cathodic Treatment on Nickel Dissolution," Journal of the Electrochemical Society, Vol. 122, No. 3, March 1975, p. 383.

In recent years, numerous workers have reported two (or more) current peaks associated with the anodic dissolution of nickel in aqueous solutions using both polarization and transient techniques (1-7). A variety of possible explanations have been put forward to account for the existence of more than one current peak for the $Ni \rightarrow Ni^{2+} + 2e$ reaction, but have not been fully substantiated. This work indicates that the anodic polarization curve of clean nickel has a single sharp dissolution peak and that the extension of the potential range of active nickel dissolution with possible resolution of multiple peaks is probably due to adsorbed impurities.

TBC-3195

E. Philip Dahlberg, UOP Corporate Research Center, Des Plaines, Illinois, "Instrumentation for Surface Analysis," Research/Development, June 1975, pp. 16-20.

The problem of analyzing surfaces with complex morphologies that are resolvable only at high magnification has been simplified by the commercial availability of the scanning electron microscope (SEM) and the associated energy-dispersive x-ray microprobe. This combination instrument makes possible the routine display of surface structural details with dimensions of less than 10^{-3} metre and the partition within a few micrometres of the chemical elements that make up those surface details.

Of equal importance in revealing the unique characteristics of material surfaces are x-ray diffraction for compound and phase determination and photoelectron spectroscopy for chemical analysis within the first few atom layers of a surface. These techniques have contributed significantly to the understanding and improvement of a wide variety of useful materials.

Many aspects of the scanning electron microscope make it an extremely useful tool for visual analysis of complex surfaces. Within restrictions imposed by the physics of scanning microscopy, such as operation under an electron beam in a moderate vacuum, electrical conductivity and manageable size, the

surface of nearly any material can be analyzed quickly and directly with the SEM. The normal specimen size varies from a few tenths of a millimetre to 20 mm on an edge. Evaporated carbon or gold or sputtered metals provide electrical conductivity and enhanced contrast to nonconductors; other surfaces to be studied can be viewed directly, without any additional preparation.

Another surface analytical technique that compliments SEM is electron spectroscopy for chemical analysis (ESCA). Although not yet as widely used as SEM, ESCA is potentially the most powerful technique available for the study of surface chemistry. Where SEM-microprobe chemical analysis is directed at the first few micrometers on the surface, the ESCA spectrometer sees a much shallower region extending only a few angstroms deep. The chemical information provided by ESCA, though sometimes difficult to obtain, is more simply related to composition.

Auger analysis, available on some SEM units, is a similar technique. In Auger, the specimen is irradiated by an electron beam, and the energy measured by the spectrometer relates to the electronic energy levels of the atom. Microanalysis is possible because an electron beam can be focused. Resolution in the plane of analysis is not possible with ESCA, however.

TBC-3196

M. L. Kronenberg, Union Carbide Corporation, Battery Products Division, Cleveland, Ohio, "The Use of D-C Resistance and A-C Impedance Measurements on Discharged and Undischarged Cathodes as a Measure of the Relative Electronic and Ionic Conductance," journal of the Electrochemical Society, Vol. 121, No. 3, March 1974, p. 375.

Dry cell cathodes are normally compacted mixes containing electronically conducting powders (i.e., acetylene black and graphite plus MnO_2) and ionically conducting solutions (i.e., solutions of NH_4Cl-$ZnCl_2$ or KOH). In attempting to understand the mode of discharge of cathodes, it is helpful to know how the conductivity of this mixture is shared by the electronically and ionically conducting phases in fresh and in discharged cells. In this investigation a method was devised to distinguish between ionic and electronic conductivity. The system was regarded as an electronically conducting matrix (NmO_2 + acetylene black and/or graphite) permeated by an ionically conducting phase (solutions of $AnCl_2$ + NH_1Cl or KOH). The two types of conductivity were considered to be in parallel. A simple, electrical model of a cathode, therefore, could be approximated by a platinum wire immersed in a conducting solution. The d-c resistance of the wire would be independent of whether or not the wire was immersed in electrolyte as long as no Faradaic reaction takes place. Total resistance (ionic + electronic), as measured by an a-c bridge, depends on whether an ionic path is in parallel with the electronic one, i.e., whether the wire is immersed or not. In the work reported here, measurements were made on fresh and discharged cathodes, not on complete cells. These were obtained from commercial "D" size Leclanché, alkaline MnO_2, and mercuric oxide cells.

TBC-3197

M. J. Graham, R. J. Hussey and M. Cohen, Division of Chemistry, National Research Council of Canada, Ottawa, Ontario, Canada, "Influence of Oxide Structure on the Oxidation Rate of Nickel Single Crystals," Journal of the Electrochemical Society, Solid State Science and Technology, November 1973.

The influence of metal orientation and the prior oxide film on the oxidation rate of nickel single crystals has been investigated at 600°C in 5×10^{-3} Torr oxygen using a manometric technique and the specimens examined before and after oxidation by electron diffraction, x-ray emission analysis, and electron microscopy. For nickel electropolished in sulfuric acid, the order of decreasing oxidation rate is found to be (100), (111), and (112). This anisotropy together with changes in oxidation rate with surface pretreatment can be explained by modification in the structure of the prior oxide; when a single orientation prior oxide persists the oxidation rate is low; when the oxide contains twin orientations or becomes polycrystalline, the oxidation rate is increased. The results may be interpreted in terms of a variation in the number of easy diffusion paths in the oxide; the higher the density of these paths the greater is the oxidation rate.

TBC-3198

John P. Elder, ESB Incorporated, C. F. Norberg Technology Center, Yardley, Pennsylvania, "Computer-Controlled Battery Pulse Charging," Journal of the Electrochemical Society, Electrochemical Science and Technology, Vol. 121, No. 2, February 1974.

A Fortran language program system has been developed for computer-controlled, square wave, constant current battery pulse charging. It provides complete experimental control and rapid, accurate data acquisition for a set of test cells with or without in situ reference electrodes. It incorporates automatic charge termination and individual cell cut-out features, which may be brought into play for a variety of reasons. Multicell operational data is readily available for cell to cell comparison and interpretation. Examples of the use of the program for charging secondary alkaline battery systems are presented. Information regarding the charging behavior of the limiting mercury-silver substrate positive electrode in the secondary mercury-cadmium cell, not readily available when using conventional pulse charging techniques, has been obtained.

TBC-3199

Dennis M. Tench and Ernest Yeager, Chemistry Department, Case Western Reserve University, Cleveland, Ohio, "Redox Couple Behavior on Lithiated Nickel Oxide Electrodes," Journal Electrochemical Society; Electrochemical Science and Technology, Vol. 121, No. 3, March 1974.

The rotating electrode technique has been used to study the kinetics of various redox couples {$Fe(CN)_6^{4-}/Fe(CN)_6^{3-}$, Fe^{2+}/Fe^{3+}, Cr^{2+}/Cr^{3+}, and quinone/hydroquinone} on mosaic lithiated nickel oxide electrodes in sulfate solutions. At potentials cathodic to the flatband potential, the redox reactions are very inhibited. At potentials anodic to the flatband potential, the oxidation of the ferrocyanide ion exhibits a transfer coefficient of $\alpha = 1/2$ with an apparent standard rate constant approximately two orders of magnitude smaller than on Pt. The other couples exhibit abnormal transfer coefficients under these conditions, probably because of specific adsorption on the oxide electrode surface.

TBC-3200

Dimitri Gidaspow, Institute of Gas Technology, Chicago Illinois and Bernard S. Baker, Energy Research Corporation, Bethel, Connecticut, "A Model for Discharge of Storage Batteries," Journal of the Electrochemical Society: Electrochemical Science and Technology, Vol. 120, No. 8, August 1973.

The common porous electrode model has been rederived to include the transformation of one solid phase into another, for example, lead into lead sulfate. Differential mass balances for the solid porous reactant and the solid product yielded new dimensionless groups which characterize the structural changes that occur during discharge or charge of storage batteries. Effects of fraction of active material, exchange current and molar density ratios on overpotential at a constant current were investigated numerically. The trends agree well with the empirical correlation of Shepherd.

TBC-3201

W. R. Scott, TRW, Redondo Beach, California, "A Study of Short-Test and Charge Retention Test Methods for Nickel-Cadmium Spacecraft Cells," TRW Final Report No. 24118-6003-RU-00 JPL Contract No. 953649 Supplement, April 1975.

Three different methods for testing nickel-cadmium cells for internal shorts and charge retention were studied. Included were (a) open circuit voltage decay after a brief charge, (b) open circuit voltage recovery after shorting, and (c) open circuit voltage decay and capacity loss after a full charge, with emphasis on the first of these methods. The investigation included consideration of the effects of prior history, of conditioning cells prior to testing, and of various test method variables on the results of the tests. Sensitivity of the tests was calibrated in terms of equivalent external resistance. The results from the different methods were correlated. It was shown that a large number of variables may affect the results of these tests significantly. Recommendations are given for improved procedures to minimize these effects. It is concluded that the voltage decay after a brief charge and the voltage recovery methods are more sensitive than the charged stand method, and can detect an internal short equivalent to a resistance of about $(10^4/C)$ ohms where "C" is the numerical value of the capacity of the cell in ampere hours.

TBC-3202

K. Kanetsuki, M. Yamaga and H. Ogawa, Matsushita Electric Industrial Co., Ltd., Japan, "Method of Making a Nickel Positive Electrode for an Alkaline Battery," U. S. Patent 3,779,810, December 18, 1973

This patent describes a method of making a nickel positive electrode for use in an alkaline battery. The process involves immersing a porous sintered plaque of nickel in an aqueous solution of a nitrate, nitrite nitro compound, amino compound, ammonate or the like of nickel and cathodically polarizing the nickel plaque so as to cause the continuous deposition of an active material forming substance in the pores of the plaque without the accompaniment of the undesirable generation of hydrogen.

Then the cathodically polarized nickel plaque is immersed in water above 65°C, preferably above 95°C, to convert the active material forming substance into nickel hydroxide and also to convert a part of the metallic nickel constituting the plaque into nickel hydroxide thereby filling the pores of the plaque with the active material within a short period of time with high efficiency.

TBC-3203

E. R. Bowerman and I. Sheinhartz, General Telephone and Electronics Laboratories, Inc., "Secondary Battery Electrode and Methods of Making," U.S. Patent 3,306,778, February 28, 1967.

This patent describes a positive electrode which comprises a metallic substrate or core having a layer of electrochemically active hydrated nickel oxide. Preferably, the metallic core is formed of fully dense nickel in order to obtain maximum conductivity and mechanical strength. However, a nickel alloy sheet having additions of chromium, cobalt, lithium, titanium or similar metals may also be used as the electrode core.

The coated electrode is formed by bringing aluminum into contact with the surface of the nickel-containing core at an elevated temperature thereby interdiffusing the aluminum and nickel to form a layer of nickel aluminide (Ni_2Al_3) metallurgically bonded to the substrate. By metallurgically bonded it is meant that in the interface the distance between the atoms of the substrate and the coating is on the order of an atomic diameter. After the nickel aluminide layer has been formed to the desired thickness on the core, the structure is placed in a caustic solution to dissolve out the diffused aluminum. The dissolution step produces a layer of active nickel containing hydrogen and some residual aluminum.

TBC-3204

G. R. Schaer, "Method of Making Porous Conductive Supports for Electrodes, U.S. patent 3,759,747, September 18, 1973. Assigned to NASA.

According to the process described porous conductive supports for electrodes suitable for use in electrochemical cells are made by electroforming thin corrugated nickel foil, stacking pieces of the corrugated foil alternately with pieces of thin flat nickel foil, with the corrugations in successive corrugated pieces oriented at different angles, bonding the adjacent pieces of foil by heating in a hydrogen atmosphere, and cutting the bonded stack in planes substantially perpendicular to the foils.

Typical foils consist essentially of nickel, with the corrugated foil about 0.3 to 1 mil thick, and the flat foil about 0.2 to 1 mil thick. The corrugations typically are substantially triangular in cross-section, with each corrugation about 2 to 6 mils high and 2 to 10 mils wide and the height at least about one-half the width. The density of the support preferably is less than about 25%. Alternate pieces of the corrugated foil typically are oriented with their corrugations in approximately the same direction, and the angle between the corrugations in successive pieces of the corrugated foil typically is about 5° to 40°.

The pieces of foil typically are bonded by heating in a nonoxidizing atmosphere, which may comprise essentially hydrogen, and the adjacent pieces of foil preferably are bonded at substantially all contiguous points. The planes in which the stack is cut typically are substantially parallel, about 25 to 50 mils apart, and approximately perpendicular to the direction bisecting the angle between the corrugations in successive pieces of the corrugated foil. Before the cutting, the bonded structure typically is filled with an epoxy which is removed after the cutting by dissolving in hot chromic acid, typically about 250 to 600 grams per liter of chromic acid at about 140° to 200°F.

The corrugated foil typically is electroformed on a conductive corrugated surface where the corrugations are substantially triangular in cross-section and are polished to a highly smooth surface finish from which the electroformed foil is readily removable. Typically it is electroformed on a cylindrical mandrel comprising a continuous helical threaded portion, the thread being substantially triangular in cross-section and polished to a highly smooth surface finish from which the electroformed foil is readily removable. The forming surface typically is subjected to a fine polishing where a slurry of fine abrasive particles in water is spread over the surface by a brush of fine wires, the ends of which typically are provided with sharp points by chemical etching, and then is plated with bright chromium.

TBC-3205

- J. McCallum, "Porous Electrode Comprising a Bonded Stack of Pieces of Corrugated Metal Foil," U.S. patent 3,759,746, September 18, 1973. Assigned to NASA.

  This patent describes an electrode suitable for use in an electrochemical cell which involves a porous conductive support comprising a bonded stack of pieces of thin corrugated nickel foil where the corrugations are oriented approximately perpendicular to the sides of the electrode and form an array of passages through the electrode, and active material such as cadmium hydroxide or nickel hydroxide substantially uniformly distributed within the passages.

The support may comprise also a piece of thin flat nickel foil between adjacent pieces of the corrugated foil, forming a barrier between the passages formed on each side of it. Typically the corrugations in the odd corrugated layers are oriented at a small angle from the perpendicular in one direction and the corrugations in the even corrugated layers are oriented at a small angle from the perpendicular in the opposite direction.

TBC-3206

J. G. Ruzzo, Jr., "Method for Preparing Pasted Nickel Hydroxide Electrode," U. S. Patent No. 3,725,129, April 3, 1973, Assigned to the U.S. Secretary of the Air Force.

A process is described which relates to a method of preparing pasted nickel hydroxide electrodes that have a high energy density. Nickel hydroxide electrodes in general use consist of a sintered nickel substrate which is chemically or electrochemically impregnated with active material. The procedure followed in preparing such electrodes is time consuming in that a number of operations is involved, thereby resulting in high production costs. Furthermore, because of the complicated procedure involved in fabricating such electrodes, uniformity of product is difficult to attain.

Electrodes having a pasted structure have been prepared in the past, but they have not proven to be entirely satisfactory. While it is known that an electrode prepared by a pasting technique can be made to have a potentially higher capacity, it has not been possible to utilize this capacity. Thus, it has been found that pasted $Ni(OH)_2$ electrodes manufactured by methods described in the prior art can be readily charged

$$Ni(OH)_2 \rightarrow NiOOH + 1e^- + 1H^+$$

but they are not easily discharged

$$NiOOH + 1e^- + 1H^+ \rightarrow Ni(OH)_2$$

It is an object of this process, therefore, to provide a pasted $Ni(OH)_2$ that can be charged and easily discharged.

The process comprises the steps of applying to a foraminous metal substrate a layer of an aqueous paste consisting essentially of nickel hydroxide, nickel powder and a binder; compressing the substrate with its layer of paste to remove excess water; heating the substrate at a temperature and for a period of time sufficient to dry the paste; and compressing the substrate with its dried layer of paste at a pressure sufficient to cause nickel hydroxide-nickel metal interfacial contact.

The electrode has a porosity in the range of about 30 to 50%, preferably from about 30 to 40%. The term porosity as used here refers to the percentage obtained by dividing the void volume of the electrode by the total electrode volume. It has been discovered that the pasted nickel hydroxide electrode of this process having the indicated porosity has a high energy density. Furthermore, the electrode can be readily charged and easily discharged, a distinct advantage over the prior art pasted electrodes.

The porosity of the electrode is an important and critical factor or property in achieving a pasted electrode that may be utilized in place of the conventional sintered electrode. In the fabrication of a particular pasted electrode, there is a direct relationship between porosity and the pressure employed in the final compressing step of the process. Furthermore, at the pressures used to obtain the required porosity, the interfacial contact between the nickel hydroxide and nickel powder is maximized. This results in the enhancement of conductivity within the electrode, a factor that advantageously affects the electrode's performance.

Thus, porosity, pressure used in compressing step, and contact between con-ducting additive (nickel powder) and active material $\{Ni(OH)_2\}$ are interrelated. For example, in preparing a particular pasted electrode, a certain pressure is required to obtain a desired porosity at which there is maximum contact between conducting additive and active material.

TBC-3207

M. Paget and O. Bloch, "Gas Electrodes and Their Fabrication," U.S. Patent 3,311,505, March 28, 1967, Assigned to Institut Francais du Petrole, de Carburants et Lubrifiants, France.

This patent describes an electrode which is usable in an alkaline, neutral or slightly acid medium. It is basically composed of a sintered metal substratum, preferably of nickel, though it could be iron or cobalt or even stainless steel, and of a carbon deposit obtained by heating the substratum in contact with a hydrocarbon at a hydrocarbon cracking temperature.

Not all sintered metal substrata are the same. A substratum which is particularly active and which is preferred for the process is obtained by sintering a nickel, cobalt or iron powder obtained by thermal decomposition of the corresponding metal carbonyl. Such decomposition is usually carried out at a fairly low temperature (e.g., 50° to 250°C) chosen in terms of the decomposition temperature of the carbonyl compound. The powder obtained is then sintered by heating under pressure, preferably in the presence of a gelling agent, for instance, carboxymethylcellulose or methylcellulose.

The metal powder can be mixed with the gelling agent and water. The resultant paste can be shaped, for instance by hot rolling, at about 100° to 150°C. The strip obtained is then heated, screened from air, at a temperature of about 300° to 600°C. Also, a mixture of nickel powder and a binder (e.g., carboxymethylcellulose, methylcellulose or stearic acid) can be tightly compressed. The compressed tablets obtained are then heated, screened from air, at about 300° to 600°C.

TBC-3208

L. Horn and F. Philipp, "Method of Making a Sintered Electrode," March 23, 1965, U.S. Patent No. 3,174,219, Assigned to Varta AG, Germany.

A process for making sinter electrodes which are suitable for use in alkaline storage batteries. According to a preferred example of the process, the method of producing the sinter electrode comprises the steps of (a) forming on a support a layer of predetermined thickness consisting essentially of distinct finely subdivided metal particles adapted to be sintered, (b) sintering the layer so as to form a coherent porous sintered sheet consisting of the metal particles sintered to each other.

Step (c) comprises pressing one face of the sintered sheet and one face of a perforated metallic reinforcing sheet formed with outwardly extending burrs at least partially surrounding the perforations, against each other with the burrs penetrating the sintered sheet so as to compress the sintered sheet, to bend the outermost portions of the burrs and to force portions of the sintered sheet into the perforations of the perforated metal sheet substantially filling the same. The sintered sheet and the reinforcing sheet are united forming a unitary reinforced electrode structure.

Sintering is preferably carried out at a temperature of between 600° and 1000°C, and most preferably at about 900°C when carbonyl nickel powder, i.e., nickel powder formed of nickel carbonyl vapors is to be sintered. Due to the fact that the highly porous sintered nickel layer is gripped by the burrs of the perforated metal support sheet, a firm anchoring of the sintered layer with the performated metal support sheet is achieved and this also results in an improvement of the conductivity of the electrode so that charging and discharging can be carried out with higher current density.

Since sintering of the nickel powder or the like takes place prior to contact between the same and the perforated metal support sheet, the difference in the thermal expansion coefficients of the metal powder, on the one hand, and of the perforated support sheet will be of no significance. Thus, according to the process, the cracks and cavities which are formed in the sintered layer when the same is sintered on a metal support band and which are due to the difference in the thermal expansion coefficients between the sintered metal powder and the metallic support, will not occur.

TBC-3209

A. L. Melin, "Method for Producing an Electrochemically Active Material for Nickel Hydroxide Electrodes," U.S. Patent No. 3,752,706, August 14, 1973, assigned to Svenska Ackumulator Aktiebolaget Jungner, Sweden.

This patent describes a method and apparatus for producing electrochemically active metal hydroxides for nickel hydroxide electrodes for alkaline accumulators. The process involves precipitation of the hydroxides from a solution of metallic salts with the aid of an alkaline metal hydroxide solution, according to which the precipitation, in order to obtain a uniform crystallinity throughout the material, takes place continuously in at least one step by allowing the salt solution and the metal hydroxide solution to run down simultaneously into a reaction vessel, keeping pH value, temperature and concentration in each step constant.

The process thus relates to a method for producing an electrochemically active material of the kind in question in the form of one or more metal hydroxides by precipitation of the hydroxide or hydroxides from a solution of one or more metallic salts with the aid of an alkaline metal hydroxide solution (caustic soda) and is characterized essentially in that in order to obtain a uniform crystal structure of the material (i.e., the same x-ray crystallinity throughout it), the precipitation takes place continuously in at least one step by allowing the metallic salt solution and the caustic soda to run down simultaneously into a reaction vessel, the pH value, temperature and concentration being kept constant during the precipitation in each such step.

It is advisable during the first step of the precipitation to have a constant pH value within the range 7.5 to 10 and during the second step a constant pH value between 9.5 and 13. The temperatures during the precipitation process may be between 10° and 80°C, while the concentration of the solutions may be 5 to 100 g/l Ni, 0.1 to 3 g/l Co and 15 to 300 g/l NaOH.

TBC-3210

E. J. L. Pinard, "Process of Manufacturing Sintered Carrier Type Negative Electrodes for Alkaline Storage Cells," U.S. Patent 3,679,481, July 25, 1972, Assigned to Societe des Accumulateurs Fixes et de Traction SA, France.

This patent describes a method of preparing negative electrodes for alkaline storage cells by incorporating active electrode material into porous metal carriers, for example, of sintered nickel by impregnating the carrier with an acidified cadmium salt solution, then precipitating cadmium hydroxide and incidentally nickel hydroxide in its pores by immersion in an alkali metal solution. Then the precipitate bearing carrier is washed and dried thereafter heating such carrier at temperatures ranging from 200° to 500°C in air or inert atmosphere for a selected period of time to convert the nickel and cadmium hydroxides into respective oxides.

The heated oxide bearing carrier is rehydrated by immersion in an aqueous liquid such as water or an aqueous solution of a nickel salt or an alkali metal hydroxide maintained at a temperature of approximately 80°C for approximately 1 to 2 hours. This converts the cadmium oxide to cadmium hydroxide without substantially affecting the nickel oxide. The so-treated carrier bearing cadmium hydroxide and such nickel oxide is subsequently washed and the electrode finally washed and dried preferably in carbon dioxide-free air. The resultant negative electrode has a materially reduced amount of deleterious or parasitic positive active material and increased porosity and flexibility as compared with like negative electrodes produced by conventional carrier impregnating and precipitating procedure.

TBC-3211

B. B. Herman and V. P. Farley, Jr., "Battery Plate Treatment Process," U.S. Patent 3,671,320, June 20, 1972, Assigned to Gulton Industries.

This patent describes a process and apparatus for treating battery plates formed by impregnating a porous substrate with a metallic nitrate and subjecting the impregnated substrate to an alkaline earth hydroxide for formation of active material in the form of a metallic hydroxide, with formation of soluble nitrates as a by-product. The soluble nitrates are prevented from creating contamination of the plates by cathodizing them into ammonia and carbon dioxide gas in a tank having a pair of electrodes and one or more insulated electrically floating metallic baffle plates between the electrodes.

It is important to eliminate any such contaminants, especially nitrates, since the resulting battery would have a high self-discharge rate, a poor charging efficiency, a marked temperature rise during charging, lower voltage at the end of charging , and increased internal impedance.

According to one aspect of the process, contamination of battery plates by impurities is greatly reduced by treating the sodium hydroxide bath to remove a substantial portion of the impurities between successive impregnation cycles. This prevents the impairment of the rate of conversion of the nickel nitrate into nickel hydroxide, which would otherwise occur if the concentration of nitrates in the sodium hydroxide bath increases after successive impregnation cycles.

TBC-3212

B. B. Herman and V. P. Farley, "Process for Production and Treatment of Battery Plates," U. S. Patent 3,671,321, June 20, 1972, Assigned to Gulton Industries, Inc.

This patent describes a process and apparatus for treatment of battery plates, in which the active material of the plate is electrically formed and decontaminated by electrolyzing without direct connections to a power source, by interposing the active material insulatedly in a bath between two energized electrodes. This is particularly useful in the case of battery plates formed by impregnating a porous substrate with a metallic nitrate and subjecting the impregnated substrate to an alkaline earth hydroxide for formation of active material in the form of a metallic hydroxide.

TBC-3213

T. Nervik, "Method for Removal of Residual Nitrate from Negative Battery Plates," U.S. Patent 3,663,296, May 16, 1972, assigned to ESB Incorporated.

This patent describes a way to reduce the nitrates in sintered nickel plaques which have been impregnated with cadmium nitrate and then treated with an alkaline solution. According to the process, a sintered nickel plaque, fully impregnated with cadmium hydroxide converted from cadmium

nitrate in the normal manner is heated to a temperature between 350° and 900°C until the residual nitrates have decomposed. The plaque is then soaked in a hot alkaline solution until the cadmium oxide formed by thermal decomposition has been converted to cadmium hydroxide. The plaque is then washed and dried.

This treatment differs from other processes in that the nickel plaque is at no time exposed to concentrated cadmium nitrate at high temperatures and the corrosion of the plaque observed with other techniques does not occur. Further, because the corrosive nitrate is not present in any great concentration it is possible to conduct the thermal decomposition step at higher temperatures and thus with more completeness than can be done with processes where nitrates are present in quantity. By this treatment, the nitrate content of the negative plate can be reduced to a range of 0.015 to 0.03% by the treatment described above. This level of nitrate is below the harmful level and plates so treated show exceptionally high charge retention and still maintain maximum plaque strength.

TBC-3214

T. Tsuchida, Y. Hayase and Y. Fujisawa, "Process for Producing Electrodes for Rechargeable Alkaline Cells," U.S. Patent 3,674,561, July 4, 1972, assigned to Fuji Denki Kagaku Kabushiki Kaisha, Japan.

This patent describes electrodes for rechargeable alkaline cells. The electrode comprises a substratum, metallic nickel dendrite electrolytically cohered on the substratum, and nickel oxyhydroxide exposed on the nickel dendrite. The process comprises the steps of preparing an electro-bath containing NO_3 ion in the range of about 0.16 to 3.52%, SO_4 ion in the range of about 1.4 to 18.1%, and Cl ion in the range of about 2.2 to 11.5%, keeping the electro-bath weakly acidic, keeping the temperature of the electro-bath over 40°C, electrolytically cohering nickel dendrite layers to a substratum, and immediately electrolytically oxidizing the layers in an alkaline aqueous solution.

TBC-3215

H. N. Seiger and P. F. Ritterman, "Rechargeable Batteries and Charge Control Circuit Therefore," U.S. Patent 3,769,088, October 30, 1973, assigned to Gulton Industries, Inc.

A process is described which relates to rechargeable sealed secondary dry cell batteries and has its most important application in alkaline nickel-cadmium and silver-cadmium dry cell batteries. The process has its most important application in those rechargeable sealed dry cell batteries where hydrogen and/or oxygen may be generated during the charging or overcharging thereof.

The process, among other things, provides a simple and reliable means for relatively quickly and efficiently absorbing hydrogen gas generated in the battery during a rapid charge at low temperatures or during an overcharge and also for quickly and efficiently absorbing any modest but troublesome

quantity of oxygen which remains or is generated in the battery after termination of a charging operation, so that the current flowing in the oxygen consuming electrode which controls the termination of the battery charging will quickly fall below the trip level after termination.

The process utilizes a metal from the platinum group in the Periodic Table, namely, platinum (which is decidedly preferred), iridium, osmium, palladium, rhodium or ruthenium. Platinum, for example, has been known to be useful as an oxygen gas absorbing electrode when connected to the negative terminal of a battery through a resistor. In accordance with the process, it has been discovered that platinum in a highly porous form has exceedingly good hydrogen gas absorbing characteristics when connected through a very low impedance path to the negative terminal of a battery like a nickel or silver cadmium battery where the negative cadmium plates have a voltage of -0.8 volts.

Thus, it has been discovered that a porous platinum electrode connected directly to the negative terminal of a sealed, rechargeable, dry cell battery permits the battery to be operated under conditions which generate hydrogen gas at a rate as high as 0.3 ml per minute per square inch of scavenger electrode surface area. By its connection to the negative terminal of the battery through a low resistance path, the porous platinum electrode also acts as an efficient oxygen gas absorbing electrode which can absorb the oxygen which remains and is generated in the battery after termination of a charging operation.

TBC-3216

H. T. Francis, "Apparatus for Forming Metal Fibers," June 18, 1963, U.S. Patent No. 3,094,476. Patent assigned to Armour Research Foundation of Illinois Institute of Technology, Chicago, Illinois.

In combination, apparatus for the manufacture of thin metal fibers comprising: container means, a solution containing an electrodepositable material in said container, conductive means suspended within said container but insulated therefrom; a series of discs having conductive and non-conductive sections uniformly spaced from each other about the periphery of said discs; a series of non-conductive discs interspersed alternately between said last mentioned discs whereby all the discs are in axial alignment and substantially completely immersed in said solution; means for rotating said discs in unison; means for applying a voltage across said discs and the conductive means; means for removing the electrodepositable material from said conductive sections; means for regulating the rate of rotation of said rotating means; and means for regulating the magnitude of voltage applied across said discs and the conductive means.

TBC-3217

D.V. Louzos, "Nickel Fibers Useful for Galvanic Cell Electrodes," U.S. Patent No. 3,684,480 August 15, 1972. Patent assigned to Union Carbide Corporation, New York, N.Y.

Stable, high surface area nickel fibers composed of a single elongated chain of small, interconnected, nearly perfect spheres. The nickel fibers are prepared by the electrolysis of a soluble nickel salt-containing electrolyte solution under conditions of extremely high cathode current density. Galvanic cell electrodes are fabricated using the nickel fibers by compression molding techniques.

TBC-3218

C.C. Hardman, "Method of Impregnating Flexible Metallic Battery Plaques," U.S. Patent No. 3,600,227 August 17, 1971. Patent assigned to Westinghouse, Pittsburgh, Pa.

A method of loading active battery material into porous, flexible, metallic battery plaques, comprises the following steps: Precipitating nickel hydroxide active material within the plaque by making the plaque cathodic, at a high current density, in an electro-precipitation cell also containing a consumable nickel anode and a solution comprising nickel nitrate; electrochemically oxidizing and reducing the precipitate in caustic formation solution; repeating the electro-precipitation step.

TBC-3219

K. Beccu, "Accumulator Electrode with Capacity for Storing Hydrogen and Method of Manufacturing Said Electrode.

This patent describes an accumulator electrode with capacity for storing hydrogen. The electrode has an active component constituting at least 40% by weight of the electrode and consists of a hydride of a metal belonging to the third, fourth or fifth group of transition elements. The electrode further contains nickel, copper, silver, iron or chrome-nickel steel alloyed with the active component and comprises a metallic supporting structure. A method of manufacturing this electrode, comprises preparing a metal powder containing the active component and the other metal and sintering the powder in hydrogen at 700° to 1000°C.

The accumulator electrode may be advantageously used for storing energy in an electrochemical cell by arranging it, together with a counter-electrode delivering oxygen, in an alkaline, aqueous electrolyte, e.g., in 20% KOH solution. The hydrogen bound in hydride form is thus reversibly exchanged near the potential of the hydrogen electrode, which corresponds to the pH value of the electrolyte used. Thus charging or hydride formation can be carried out by applying a voltage at least equal to the dissociation voltage of water between the hydride electrode and the counter-electrode which has a potential

differing from that of the hydride electrode and may in some cases be an oxide electrode, the hydrogen liberated at the hydride electrode being absorbed by the hydride forming metal.

TBC-3220

R.H. Williams, "Ultrasonic Treatment in Salt Bath," U.S. Patent 3,692,586 September 19, 1972, assigned to Sparton Corporation.

This patent describes a process pertaining to the impregnation of sintered metal electrodes, such as those used in batteries, where an active metal is formed upon the plates by electrolytic action where ultrasonic vibrations are employed to produce and augment penetration of the salt bath liquid in the sintered plate pores.

In the process, the preparation of the sintered metal plate structure is similar to the preparation of the plate when impregnation is to be accomplished by the common vacuum process. The unimpregnated plate is immersed in the molten $Ni(NO_3)_2$ liquid salt bath. The salt bath is located within a tank, and attached to the tank is an ultrasonic transducer or vibrator capable of producing 100 watts output per gallon of bath. In order to obtain maximum efficincy the level of the liquid in the tank is a multiple of the half wave length of the pressure wave produced by the transducer.

Upon energization of the ultrasonic transducer the resultant standing wave produces a cavitation-impolosion cycle which forces the $Ni(NO_3)_2$ into the power of the sintered plate. The cavitation produces a vacuum which displaces the air in the pores and the vacuum produced by this method is considerably stronger than the vacuum that can be produced with conventional vacuum producing apparatus.

Further, it is to be appreciated that the vacuum produced by the ultrasonic vibrations is a local vacuum which occurs at the location desired, i.e., within the void of the sintered metal. After the vacuum occurs due to the cavitation, the next part of the cycle is the implosion resulting from the inward burst of the gas with great pressure, and it is believed that the implosion pressures are as high as 10,000 psi, which forces the salt bath solution into the sintered battery plate pores to displace the air pockets therein. The impregnation time in accordance with the process can be reduced to 30 seconds upon 20,000 cps being imposed upon the formation solution and sintered battery plate for 30 seconds.

The 20,000 cps frequency is the practical lower limit for the ultrasonic vibrations due to the creation of audible sound below this frequency. After the treatment of the salt bath and sintered battery plate with the ultrasonic vibration for the desired length of time, the plaque is removed from the bath solution, allowed to drain, but not significantly cool, and is then immersed in a polarization solution and electric current is applied thereto to polarize the plate as in the vacuum forming process. It is necessary to repeat the process and usually three

cycles are required due to the partial reopening of the pores because the volume of the active material is about 1/3 that of the $Ni(OH)_2$.

The impregnation of the salt bath material into the pores of the sintered metal is augmented by the fact that the vacuum-implosion cycles produced by the ultrasonic vibration causes an increase in temperature at the location of cavitation. The local temperatures during implosion are believed to be as high as 30,000°F, which further accelerates the material flow and displacement of the air within the voids. Thus, the use of ultrasonic vibrations also aids in the flow of the salt bath material into the voids and creates localized heat where it is of most advantage.

TBC-3221

B. Wakefield, "Electro-Chemical Cells," U.S. Patent 3,767,465 October 23, 1973, assigned to The Ever Ready Company (Great Britain) Limited, England.

This patent provides a method of welding a conducting metallic tag to impregnated porous electrode material. The method comprises the steps of forming a layer of sintered metal on the tag, the metal being selected so as not to interfere with the electrochemical operation of the electrode when assembled in a cell, pressing the tag against the electrode material with the sintered metal adjacent the electrode material, and welding the two together by passage of electric current.

The metal on the tag may, for example, be nickel and the electrode material may consist of impregnated sintered nickel on a support member. Normally the porous electrode material is impregnated with nonmetallic material, such as for example, nickel or cadmium oxides or hydroxides. The electrode may be in the form of an elongated strip which has a plurality of conducting metallic tags welded to it at intervals along its length.

TBC-3222

W. Pollack, "Method of Making Diffusion Bonded Battery Plaques," U.S. Patent 3,702,019 November 7, 1972, assigned to Westinghouse Electric Corporation.

A process is described which relates to an improved method of making flexible, diffusion bonded, fiber metal, electrode plaques for use in battery cells such as nickel-cadmium and nickel-iron systems. The method provides these plaques by:

(1) machining foil, bar stock or wire to provide cold worked hardened, metal fibers having a cross-section of between about 0.0005 to 0.005 inches and a length of between 1/8 to 1 1/2 inches

(2) dispersing the fibers in a viscous liquid to provide a slurry of metal fibers

(3) pouring the slurry into a chamber having a porous filter bed bottom plate

(4) applying a vacuum on the slurry to rapidly expel the liquid and leave a uniform density of felted, contacting fibers on the filter bed plate

(5) washing the felt

(6) metallurgically bonding the contact points of the cold worked fibers in each felt together in a nonoxidizing atmosphere such as a vacuum, inert or protective atmosphere at about 800° to 1300°C to provide flexible, bonded, annealed fibrous plaques and bus strips

(7) placing the annealed plaque onto the lower platen of a coining die having a flat surface

(8) placing a center platen having a channel pattern cut therethrough on top of the plaque

(9) placing the annealed, bus felt strips into the channels of the center platen

(10) positioning a top platen, with projections matching the channel pattern of the center platen, so that it projects through the channel pattern of the center platen

(11) compressing the platens at a pressure of between about 9,000 to 20,000 psi, to provide a plaque about 70 to 97% porous, with bus connection areas matching the channel pattern of the center platen which are up to about 70% porous

(12) metallurgically bonding the fiber contact points of the plaques and bus strips together in a nonoxidizing atmosphere such as a vacuum, inert of protective atmosphere at about 800° to 1300°C to insure the formation of the maximum number of fiber contact areas and increase mechanical strength

(13) cutting the battery plaque to size and

(14) attaching a nickel foil tab to the plaque in a coined bus area.

TBC-3223

T.B. Ashcroft, W. Betteridge and V.A. Tracey, "Method for Making a Battery Plate Using Cellulosic Material," U.S. Patent 3,689,320 September 5, 1972, assigned to The International Nickel Company.

A process is described which comprises impregnating a natural cellulosic fibrous material or thread with a solution of one or more thermally decomposable metal salts, drying the impregnated material or thread, decomposing the salt or salts to metal and sintering the resultant metal to a coherent body.

The metal salt must decompose completely and must not form any stable oxide, that is to say, one which is not reduced in the sintering atmosphere used. Suitable salts of nickel, iron, cobalt and copper are halides, for example, nickel chloride. Nitrates or complex salts of these metals may also be used. To produce an alloy product, salts of different metals are mixed together in solution. Generally, aqueous impregnating solutions are employed, so the impregnating salts should have substantial solubility in water.

The fibrous material or thread must have adequate absorptive power for the impregnating salt solution, and it is essential for this reason that it must be a natural cellulosic material. Equivalent results are not obtained with synthetic cellulosic or polymeric fibers. Cotton and paper are particularly suitable, but jute, linen, ramie and sisal may also be used.

The process is particularly applicable to the production of very thin sheets of open-mesh metal, for which purpose the starting material may be any natural cellulosic fibrous material that is in the form of sheet, for example, a fabric, which may be woven, knitted or nonwoven, or blotting paper; or again the natual cellulosic fibrous material may be cotton wool or paper pulp compressed into a sheet.

It is an essential feature of the process that the heating to decompose the salt and sinter the metal is effected in a reducing atmosphere and it is surprising that the cellulosic material is completely removed during this heating. It is important that the carbon be removed, otherwise one does not achieve adequate strength in the porous metal sheet or thread, nor does one obtain the optimum conductivity. Heating may be conducted at a rapid rate, e.g., 800°C per hour, with heating rates of 5°C to about 35°C per minute being satisfactory. The permissible rapid heating rate in a reducing atmosphere makes the process simple and adaptable to high production rates of porous metal in knitted, woven or felted configuration.

Heating in an oxidizing atmosphere to destroy the cellulosic material followed by heating in a reducing atmosphere to reduce the metal oxide formed leads to inferior products in terms of strength, conductivity, etc. Moreover, the overall time is much less when the metal is directly formed by decomposition of the salt in a reducing atmosphere.

In the process, a sintering temperature of at least 900°C is desirable, but the period during which the material is exposed to a temperature of 900°C or more need not, and preferably does not, exceed 60 minutes. The product may, if desired, be resintered in order to increase its strength. During the sintering, sinter bonds are formed at the points where the metal fibers intersect and are in contact.

The impregnation step may also be short, immersion for a few minutes, e.g., 5 or 10 minutes up to 1 or 2 hours, in a solution of the salt being enough, especially when the metal salt employed is soluble to the extent of about 50 grams or more in 100 cc of water. The process leads to products of high porosity, remarkable strength for such porous products and low electrical resistivity. The strengths are reported hereinafter as the force in grams required to break a strand or a strip 1 cm wide when subjected to a straight tensile test. The porosities of the products are reported hereinafter as a percentage derived from a determination of the density of the product in a mercury balance, the balance being sensitive to all pores below 300 microns.

TBC-3224

S. Yamamoto, J. Watanabe, S. Hosoi, and A. Hirano, "Method for Manufacturing A Cadmium Oxide Electrode with a Resin Fiber," U.S. Patent 3,751,300 August 7, 1973; assigned to Matsushita Electric Industries Company Ltd., Japan.

A process is described, in which use is made, as a positive electrode, for example, of a porous substrate which consists of a sintered powder, such as sintered nickel powder, and carries nickel hydroxide thereon; or an alkali-resistant, electrochemically inactive and electrically conductive porous container, e.g., a container of nickel screen, filled with a mixture consisting of nickel hydroxide as being an active material and nickel or carbon as being an electrically conductive material.

The megative electrode is a sheet of paper consisting of an alkali-resistant, electrochemically inert, fibrous material having a powder of active material or a mixture of the powder of active material and a powder of electrically conductive material bonded to the surface. The powder of active material is composed of one or more compounds selected from the group consisting, for example, of cadmium, cadmium oxide and cadmium hydroxide. The powder of electrically conductive material consists, for example, of such a compound as nickel or carbon.

The positive electrode used in the battery is the so-called sintered positive electrode which is prepared by a process comprising impregnating a porous substrate of sintered carbonyl nickel powder with nickel nitrate, decomposing the nickel nitrate in a vapor atmosphere by the method described, e.g., in U.S. Patent 3,041,388 to convert it into nickel hydroxide and then subjecting the substrate to a predetermined formation in an aqueous solution of caustic potash.

TBC-3225

M.H. Gottlieb, "Nickel-Cadmium Battery Electrodes," U.S. Patent 3,398,025 August 20, 1968, assigned to Bell Telephone Laboratories.

A process is described which relates to the manufacture of battery plates for sealed alkaline cells. Excessive internal gas pressures evolved via the electrochemical mechanism particularly during overcharge continues to be a principal problem in the design of long life alkaline batteries, particularly nickel-cadmium cells.

Oxygen produced at the anode will recombine at the cathode by a depolarization mechanism and generally does not create a problem. Hydrogen produced at the cathode will similarly react at the anode but at an extremely slow rate. Consequently if significant hydrogen evolution is permitted the gas will accumulate causing internal pressures within the sealed enclosure. Attempts have been made to effectuate recombination of hydrogen within the confines of the cell which have been largely unsuccessful.

One particularly successful and widely used expedient for avoiding hydrogen evolution is to construct the cell with an excess negative capacity. As long as uncharged material remains on the cathode during charging the cathode electrolysis reaction will not occur and hydrogen will not be evolved. This is described in U.S. Patent 2,571,927. However, even cell designs embodying the excess negative capacity concept are subject to gradual failure due to evolved hydrogen, particularly when exposed to deep cycling and sever temperature conditions.

The observation that the rate of hydrogen evolution, at the potentials experienced during normal charge of the cell, is far greater than would be predicted from literature data on the behavior of solid cadmium, led to the discovery that by precoating the cathode sinter with mercury prior to activation, the hydrogen evolution is significantly reduced. This expedient has been found to reduce the rate of hydrogen evolution by a factor of ten for a given electrode potential. Application of the coating by electroless deposition was found to be effective as illustrated by the following specific embodiment.

The sintered nickel plaque is immersed in a 7% solution of mercuric chloride for approximately 30 minutes. Again degassing of the plaque or ultrasonic agitation may be used to insure complete wetting. The mercury is depositied on all surfaces by chemical displacement. The plaque is then impregnated with cadmium hydroxide by standard procedures. It was found that the hydrogen overvoltages of electrodes prepared in this way are about 0.3 volt higher than for electrodes in which the precoating procedure is not used. Other characteristics of the electrodes such as capacity, charge and discharge voltage and stability, are not affected by the precoating technique. The coating thickness is not critical. Thicknesses in the range 30 mg of mercury per gram of nickel sinter to 300 mg of mercury per gram of nickel sinter are useful.

TBC-3226

Y.J.F. Lecouffe, "Process for the Fixing of the Relative Charging States of the Electrodes of an Alkaline Storage Cell," U.S. Patent 3,713,889 January 30, 1973, assigned to Societe des Accumulateurs Fixes etde Traction SA, France.

A process is described which relates to a method for fixing the relative charging states of the electrodes or an alkaline storage cell. When the amount of excess negative capacity is established by overcharging at ambient temperature, there is such variability due to differing rates of oxygen recombination. By conducting the overcharge at low temperature, preferably -10°C, a precise amount of precharge is attained.

TBC-3227

P. Binder and Y.J.F. Lecouffe, "Electric Cells with Spiral Wound Electrodes," U.S. Patent 3,298,871 January 17, 1967, assigned to Societe des Accumulateurs Fixes et de Traction, France.

This patent describes a protective sheet at one or at both ends of one or several electrodes that are to be wound up to form the spiral cell roll prior to their winding. Such a protective sheet or sheets will serve to suppress sharp or rough end edges of the severed lengths of the electrodes and also avoid the cracking of the sintered layer or layers at the center of the spirally wound roll.

The protective sheet material may be constituted by adhesive tape or similar materials. Commercial products known under the trade names of Scotch or Rubafix tape, etc., give good results. The protective sheets of any of them may be made of regenerated cellulose or other material pervious to ions taking part in the electrochemical reactions, so that the electrochemical exchanges are not hampered in any way.

TBC-3228

J.L. Devitt and D.H. McClelland, "Separators for Secondary Alkaline Batteries Having a Zinc-Containing Electrode, "U.S. Patent 3,669,746 June 13, 1972, assigned to the Gates Rubber Company.

Dendritic growth within zinc electrode-containing alkaline secondary battery cells is greatly retarded if the separator structure and its relative orientation within the battery cell meets the following criteria.

The separator layer immediately adjacent to the zinc electrode must be nonrecticulated, microporous, and microscopically uniform. Furthermore, the separator layer must be highly retentive and absorbent of electrolyte within its pores and interstices to provide a uniformly electrolyte-wetted surface along and surfaces parallel to the interface of the zinc electrode. Previously, separators employed in the prior art utilize

highly porous fibrous materials such as fiber glass, porous papers such as Viskon, membranous materials such as cellophane or relatively nonabsorptive layers such as Pellon.

It is important in preventing or minimizing dendritic growth to maintain an interface between the zinc electrode and the separator which contains substantially no occluded voids or otherwise accommodates a localized excess of electrolyte along this interface. To avoid or minimize such discontinuity along the interface, it is important to apply a certain minimum pressure to the stack of electrodes and included separator layers. Under these conditions, voids will be eliminated or at least minimized if the separator layer intimately follows the contour of the zinc electrode.

The amount of electrolyte within the cell should be in amount only sufficient to permit electrolytic conduction between the plates. Excess accumulation of electrolyte (containing zincate ions) greatly enhances dendritic growth. This required starved electrolyte condition within the cell serves the dual purpose of promoting oxygen recombination at the zinc-containing electrode, which prevents cell pressure buildup, and prolongs the life of the cell, and secondly permits oxidation of the dendrites, which may be branching out from the zinc electrode.

TBC-3229

G. Rampel, "Method of Making an Improved Electrode for Dischargeable Cell," U.S. Patent 3,711,331 January 16, 1973, assigned to General Electric Company.

This patent describes a method of making an improved electrode structure for rechargeable cells. The current collector is positioned on an external surface of the electrochemically active material and that surface is placed adjacent a separator between the positive and negative electrode, thereby inhibiting deterioration of the separator which otherwise results from direct contact with the electrochemically active material of the electrode.

Performance is improved and shelf life lengthened by slightly discharging the cell before storage, thereby placing a layer of the metal reduced from the electrochemically active material on the surface facing the separator adjacent the collector as a barrier between the active material of the electrode and the separator.

TBC-3230

David F. Pickett, Air Force Aero Propulsion Laboratory/Energy Conversion Branch and Vincent Puglisi, Spectrolab, Division of Hughes Aircraft Company, " Electrochemical Impregnation of Sintered Nickel Structures with Cadmium Using Constant Current Step and Alternating-Current Pulse Techniques," Interim Technical Report AFAPL-TR-74-119, January 1971 - June 1974, Contract F33615-75-C-2012 (June 1975) 30 p.

Cadmium electrodes, made by impregnation of sintered nickel plaques with cadmium hydroxide by three electrochemical techniques followed by formation to cadmium, can be used as efficient electrodes in nickel-cadmium secondary cells yielding capacities as high as 9.8 A-hr/in.^{3} In flooded, negative limited cells electrodes made with a constant current step technique retained 80% of the original capacity after 750 cycles at 100% depth of discharge, over a varying temperature range from 21^{o} to 43^{o}C. Alternating current pulse techniques, either symmetric or assymetric with respect to time, can yield electrodes with loadings of 2.1 - 2.3g. of $Cd(OH)_2$ per cubic centimeter of void. These electrodes show promise of being efficient for use in either flooded or starved electrolyte cells.

TBC-3231

J. McCallum, Battelle Memorial Institute, "Failure Analysis Procedures for Sealed Cells," Proceedings Twenty-Third Annual Power Sources Conference May 1969 pp. 131-133.

"Failure" has been interpreted to have a variety of connotations, most of which are bad. The makers of batteries do not want to admit their product has failed when it still can be used or when the failure was caused by circumstances outside the battery. The users of batteries, on the other hand, consider any battery to have failed when it goes outside of tolerances imposed by their application. One doing failure analysis, therefore, must consider both the user and the maker as he tries to deduce the reasons for a battery's "failure".

For the purpose of devising a failure analysis procedure, an analogy was made with medical examinations, including that of autopsy. Analogous to this medical procedure, the examination step is a physical and historical identification of the battery with external inspection. Trained technicians can carry out this part of the diagnosis using prepared forms. The performance step is to characterize the batteries' action, that is to ascertain whether failure is absolute or to ascertain the mode and degree of failure. The final autopsy step is to cut open bad cells for internal examination. This autopsy step requires an experts' training supported by further clinical tests as needed.

During this development of the battery failure analysis procedures for the U. S. Air Force, a definition of terms was found to be necessary. Thus, a review of battery literature had turned up terms like: failure causes, modes, mechanisms, symptoms, characteristics, wear-out, primary and secondary failures, and similar phrases. Different writers have used the same terms with different meanings. Because of this confusion in the literature, the definitions given in Table 1 have been selected for future use.

TBC-3232

Robert H. Kinsey, Lockheed Missiles & Space Co., Inc. Sunnyvale, California and Dale Gordon, Eagle-Picher Industries, Inc. Joplin, Missouri, "Engineering Development and Qualification of Large Sealed Nickel-Cadmium Batteries for Long Duration Space Missions," Tenth Intersociety Energy Conversion Engineering Conference, August, 1975, Paper No. 759190 pp. 1291-1292.

Requirements exist for space power systems capable of supplying electrical energy in the multi-kilowatt range. To meet the needs of such systems, large, highly reliable, sealed nickel-cadmium cells have been developed.

Presented in this paper are details of a program conducted to design, develop and qualify sealed 50 and 65 ampere-hour nickel-cadmium 22-cell batteries for space applications. Data include results of environmental testing, charge/discharge efficiency testing, and life cycle testing.

A summary is also presented of the performance to date of over 70 batteries which have been built and delivered.

TBC-3233

J. Eliason, Sperry Support Services, Huntsville, Alabama, "NiCd Battery Reliability for Shuttle Serviced Spacecraft," Paper No. 759191, Record of the Tenth Intersociety Energy Conversion Engineering Conference, August, 1975, pp. 1297-1306.

Analysis of reported NAD-Crane NiCd life tests has resulted in an empirical model relating cell reliability with number of cycles, temperature and depth of discharge. Extensive charge-discharge life cycling was performed on 5 and 10 cell NiCd batteries by the Quality Evaluation Laboratory (QEL) of the Naval Ammunition Depot at Crane, Indiana (NAD Crane). These tests were conducted from December 1963 through 14 December 1972 on 1688 NiCd cells in the Evaluation Program for Secondary Spacecraft Cells, and described in

the Ninth Annual Report of Cycle Life Test, Report No. QEEL/C 73-4, dated 22 May 1973. Two methods of analysis of this data have been used and compared. The first method consists of straightforward averaging of the battery cycle lives as a function of temperature and depth of discharge. The second method consists of calculating single cell failure and survival probabilities as a function of temperature, depth of discharge, and number of operating cycles. Battery survival probabilities are then calculated from the single cell data.

A dominant wear-out failure mechanism or combination of mechanisms of NiCd cells appears to have been characterized in a mathematical failure model which is a function of the quantity of charge through the battery and the temperature. The probability of single cell failure, P_f, is shown to have the form

$$P_f = \left[\frac{n \cdot DOD}{\alpha - \beta T}\right]^{\gamma}$$

where α, β, γ are empirically determined constants, n is the number of charge-discharge cycles, T the absolute temperature, and DOD the depth of discharge. The identification of such a mathematical model for cell failure implies a predictive capability for performing accelerated tests and for more accurately estimating energy storage subsystem life.

TBC-3234

M. S. Imamura, R. L. Donovan, J. L. Oberg, L. A. Skelly, and D. H. Julseth, Martin Marietta Corp., Denver, Colorado, "Microprocessor-Controlled Battery Protection System," Paper No. 759192, Record of the Tenth Intersociety Energy Conversion Engineering Conference, August, 1975, pp. 1307-1317

This paper describes a charge control and discharge protection system concept for a NiCd battery and preliminary test results of a breadboard model. The system, based on the use of a dedicated 8-bit microprocessor, is primarily designed for spacecraft with long-life and low-cost battery objectives. It is also applicable for laboratory, aircraft, or shipborne use where special monitoring, control and protection are required. Because of inherent flexibility afforded by a computerized approach, the system can easily be adapted for use with other secondary batteries such as nickel-hydrogen, silver-zinc, silver-cadmium, and nickel-zinc, with either cell-level or battery-level charge control.

Long life can be achieved by providing cell-level control and protection and by allowing high flexibility in the charge control technique. Low-cost design is made possible by using microprocessor and memory chips to eliminate analog circuits and devices. Because

microprocessor software can replace circuit hardware, the capability of the microprocessor controlled system will be more limited by the imagination and creativity of the designer than by available hardware.

Included in the paper are discussions of cell-level versus battery-level charge control tradeoff, and advantages and disadvantages of a microcomputer approach. The present microprocessor technology is also briefly summarized.

TBC-3235

Robert D. Walker, Jr. University of Florida, Gainsville, Florida, "Fundamental Studies on Electrolyte Matrix Processing," First Semi-Annual Progress Report, September 1, 1973 - February 28, 1974, NASA Grant No. NGR 10-005-182 (February 15, 1975)

This report discusses briefly the properties and characteristics of the materials presently used in separators for zinc-silver oxide batteries, fiber dispersion, sheet formation, and some physical tests for sheet evaluation. Chrysotile Asbestos is unique among mineral fibers in that the fibril diameter is at least an order of magnitude less than that of other mineral fibers and its physical structure is that of a hollow tube instead of the solid rod which is characteristic of other mineral fibers. Chrysotile asbestos is, therefore, very strong, very flexible, and potentially capable of being formed into sheets which have very small ($\sim$10 nm) interstices between the fibrils. On the other hand, this material may be deficient in chemical stability, and it is somewhat variable in composition and properties.

Potassium Titanate fibers have diameters about two orders of magnitude larger than chrysotile asbestos and the fibers are much shorter. While sheets can be formed of potassium titanate fibers, they are extremely weak and normally require the addition of stronger fibers, such as asbestos, to form sheets which can be handled with undue precautions.

Zirconia is used only as an inorganic powder in the slurry which is coated on asbestos base sheets. The powder is roughly spherical and it contains a substantial number of pores, some of which are large (about 1 μm) while others are much smaller (about 100 nm).

TBC-3236

Robert E. Kesting, "Synthetic Polymeric Membranes," McGraw-Hill Book Company (668.49K489S)

This book includes a treatment of the chemical and physical parameters which relate to membrane structure and function.

Primary structural properties discussed include the membrane chemical nature, the presence of charged species, its microcrystalline structure, and its pore statistics (pore size, pore size distribution and density, and void volume), cell type, and degree of asymmetry. Permeability and permselectivity and their change with time and environmental conditions, resistance to compaction, temperature stability, hydrolysis and microbial decomposition, are also discussed.

TBC-3237

J. McCallum, R. E. Thomas, and J. H. Waite, Battelle Memorial Institute, Columbus, Ohio,"Accelerated Testing of Space Batteries," NASA SP-323, 1973 (N73-21958) 212 p.

The accelerated life test program given in this publication is believed to be the first such program for space batteries that fully satisfies empirical, statistical, and physical criteria for validity. As such, the program is believed to advance significantly the state of the art of such testing by pointing a way toward a single-test program that might ultimately be reduced to a single-sample test.

When this project (NASA Contract NAS5-11594) began, a review of the literature indicated that no generally accepted procedure was available for relating electrical changes in cells to their failure mechanisms. There seemed to be little agreement on how to set up accelerated test programs to predict performance life. However, there did seem to be general agreement about two assumptions: Cells may have a quality that tends to degrade with aging, and the rate of degradation of that quality can be accelerated by increasing stress. Starting with these assumptions, and during the subsequent development of the physical approach to accelerated testing, it was found necessary to generalize the meaning of stress to include thermal and other nonmechanical stresses. This generalization of stress was developed in such a way that the defined qualities can be degraded by the identified stresses. The usual meanings of mechanical stress, strain, and rate of strain were retained as specific illustrations of the more general meaning required for the development of the accelerated test procedures.

TBC-3238

E. J. Casey and C. L. Gardner, Defence Research Establishment Ottawa, Ottawa, Ontario, Canada, "Anodic Passivation by "CdO" studied by ESR," Journal Electrochemical Society: Electrochemical Science and Technology, Vol. 122, No. 7, July 1975, pp. 851 - 854.

The appearance of superoxide O_2^- and ozonide O_3^- ions in strong KOH electrolyte at temperatures 25° to -40°C during the anodic oxidation of cadmium and oxygen evolution has been investigated using the electron spin resonance technique. The fact that O_2^- forms at the higher temperatures and O_3^- predominates at -40°C correlates with the appearance of β-$Cd(OH)_2$ at higher and γ-$Cd(OH)_2$ at lower temperatures, but it is argued that this correlation is coincidental and that it is the character of the surface states of the elusive and dynamic "CdO" underlayer beneath the $Cd(OH)_2$ that determines which paramagnetic species is produced. These new facts and the interpretation are discussed within the framework of the solid state/solution-precipitation mechanism.

TBC-3239

Raymond S. Green, Martin Marietta Corporation, Denver Division, "Skylab Program Payload Integration, Battery Survey," Technical Report ED-2002-1167, Rev. A, December 19, 1970, Contract NAS8-24000

The battery operation and associated electrical power systems discussed in this report present several different control methods designed to obtain the maximum service from the batteries by the careful control of battery temperature, depth of discharge (DOD), end-of-charge (EOC) voltage, and the amount of overcharge. The success of this design philosophy is demonstrated by many programs where the battery life far exceeded the original design requirements.

The improvements in the NiCd cells and battery charge control methods in the past decade have resulted in more efficient battery use by permitting increased DOD without sacrifice in battery life. On some spacecraft, reconditioning of the batteries in orbit is being used to further increase battery life. The accrued battery life since launch for these spacecraft is not sufficient to evaluate the actual benefits of reconditioning; however, analysis of battery discharge characteristics from flight data, strongly indicates that life requirements will be met or exceeded.

The general conclusion that might be made from comparing results of battery actual versus design life presented in this survey is that "it may be anticipated that NiCd battery life will generally exceed design requirements". A review of the designs used in the Skylab Electrical Power System (EPS) shows additional refinements in the control of critical battery parameters. Thus, it could be concluded that the Skylab batteries will exceed their life requirements. However, due to new battery cell designs and charging control methods, differences in battery operating regimes and uncertainties in environmental conditions, such a conclusion must be considered with caution. Also, Skylab battery tests to date have indicated that depending on temperature, the ampere-hour capacity of the battery may be marginal near the end of the mission.

The practice of reconditioning batteries in orbit presents a potential method of improving the ampere-hour capacity during the latter phase of the mission. The ability of the Airlock Module (AM) EPS configuration to provide for reconditioning without design changes appears feasible. The ability of the Apollo Telescope Mount (ATM) EPS to provide for reconditioning is questionable at this time, since there is no capability to recharge at a low rate. ATM battery tests now in progress may establish a method of reconditioning without design modification.

TBC-3240

W. W. Kirsch and A. E. Shikoh, Sperry Rand Space Support Division, Huntsville, Alabama, "Summary Report on Nickel-Cadmium Batteries for Apollo Telescope Mount," June 22, 1970, Contract NAS8-20055.

This report summarizes the operational testing and evaluation program conducted on Ni-Cd batteries for use in the ATM power system. The test program was conducted to determine if Ni-Cd batteries could meet the ATM mission requirements, and to determine battery operating characteristics and efficient methods of operation. The test program was limited to evaluation of the controllable battery characteristics including voltage, charge current, overcharge, depth of discharge, temperature, and cell matching.

The ATM, as an earth orbiting satellite, has power requirements of 0 to 4000 watts. Each orbit of the ATM will be approximately 94 minutes in duration. A solar array will provide ATM system power and charging power for the secondary batteries during the 58-minute daylight portion of the ATM orbit. During the 36-minute night portion of the orbit, the secondary batteries will supply ATM system power. The proposed ATM power system requires eighteen 24-cell, 29-ampere-hour batteries. The power requirements for each battery, as presently specified, will be between 50 and 300 watts with a nominal load of 200 watts.

In addition to the power requirements, the secondary power system has two additional restrictions: all the heat generated must be dissipated by passive cooling, and an 8-month (4000 cycle) operational life is required.

Ni-Cd batteries were selected for the ATM mission because of their reliability, cycling capabilities, and known life capabilities. In addition, standard aerospace 20-ampere-hour Ni-Cd cells were available for immediate testing and evaluation, thus a research and development program was not required. A Ni-Cd cell and battery investigation was started in March 1967 to determine whether these batteries could meet the ATM mission requirements.

An initial literature search was conducted to provide a starting base for the test program and provide a background in existing battery specifications, characteristics, and operating techniques. The primary sources of information were references 1 and 2. Pertinent information derived from the literature research is presented in paragraph 2, which reflects the Ni-Cd battery information and recommended operating parameters at the beginning of the test program.

TBC-3241

Yu. M. Pozin, Yu. S. Golub, USSR, "Formation of Nickel-Cadmium Hermetic Storage Batteries," Chemical Abstracts, Electrochemistry, Vol. 78, 1973, p. 487. Abstract No. 143045q. Translated from Zhurnal Prikladnoi Khimii (Leningrad), Vol. 46, No. 2,1975 pp. 453-455

Long-time cathodic polarization of the Ni oxide electrode of a Ni-Cd hermetic storage battery at the potentials of the evolving of H in the process of the discharge of the battery, activates the surface of the Ni and causes electro redn. of the active mass of the electrode. A part of the electricity at the Ni oxide electrode following charging is consumed for the ionization of H, for dis-soln. of the Ni, and for oxidn. of the active mass. As result of this process, the degree of the elec. charge at the neg. electrode is greater than at the pos. electrode.

TBC-3242

E. A. Tarasov, F. I. Kukoz, V. N. Fateeva, and N. Ya. Avdeev, Novocherk. Politekh. Inst. Novocherkassk, USSR, "Effect of Sintering Conditions on the Porosity of Nickel Substrates for Unlayered Electrodes of Storage Batteries," Chemical Abstracts, Electrochemistry, Vol. 78, 1973, p. 487. Abstract N. 143044p. Translated from Zhurnal Prikladnoi Khimii (Leningrad), Vol. 46, No. 2, 1973, pp. 303-308.

The title conditions were studied with Ni plates prepd. by using a paste made from the mixt. of 1 kg carbonyl Ni of sp. vol. 0.49 cm^3/g and 1 kg 4% carboxymethyl cellulose contg. 44 g of glycerol. This paste was applied in a 2.2-2.3 mm-layer on the 2 sides of a perforated Ni plate, dried at 87° and sintered for 5-240 min at 600-1000°. The method of forcing out one liq. (alc.) by another one (ether) was used for detg. the distribution function of the vol. of the pores with respect to their effective diam. An equation was derived for the calcn. of the dependent of the sp. vol. of the pores on the temp. and the duration of the sintering. The optimum sintering temp. was 1000° at 15 min.

TBC-3243

G. A. Shul'gina, Tr. Novocherkassk, Politekh. Inst., USSR, "Improvement of the Production of Cermet Electrodes for Nickel-Cadmium Storage Batteries," Chemical Abstracts, Vol. 78, 1973 p. 502. Abstract No. 118363y. Translated from Ref. Zh. Khim. No. 266, 1972 pp. 96-99, Abstract No. 18L177.

The cermet electrode matrixes of the Ni-Cd storage batteries were treated with an alk. soln. (after satn. in a salt soln. contg. active metals), and the effect was detd. of the chem. treatment on the NO_3^- and Cl^- content of the electrode. The chem. treatment should start in solns. at $\leq 40^\circ$ to maintain a low content of the above ions, and then the temp. should be increased to obtain a higher degree of conversion of the active metal salts into hydroxides. To obtain the max. removal of Cl^- from the neg. electrodes, the process should be limited to 1 charge-discharge cycle.

TBC-3244

V. N. Kosholkin and O. S. Ksenzhek, Dnepropetr. Khim. - Tekhnol. Inst.-im. Dzerzhinskogo, Dnepropetrovsk, USSR, "Operating Characteristics of Storage Battery Electrodes in Relation to Their Thickness," Chemical Abstracts, vol. 78, 1973, p. 502. Abstract No. 118355h. Translated from Elektrokhimiya, Vol. 8 No. 12 1972, pp 1877-1880.

Discharge curves for Ni oxide electrodes indicate that with increasing thickness the electrode potential is shifted to the neg. region. The exptl. data verify theor. equations for such curves.

TBC-3245

Kloss, A. I. and V. D. Novoselova, USSR, "Selection of an Electrolyte for Nickel - Cadmium Storage Batteries Operating at Temperatures Below $0.^\circ$ Chemical Abstracts, Vol. 78, 1973, p. 502. Abstract N. 36999g. Translated from Sb. Rab. Khim. Istochinikam Toka. No. 5, 1970 pp. 87-96.

The selection was studied of an electrolyte for Ni-Cd storage batteries, intended for operation at below-zero temps. e.g. -40°. The electrolytes used, with various ds. and based on KOH, contained K_2CO_3, and LiOH addns. in amts. of 10 g/l. Characteristics of the batteries were detd. by using electrolytes with various ds. (1.29, 1.37, and 1.45 g/cm^3), and various compns. (243-418 g KOH/l. + 82-177 g K_2CO_3/l.). Electrolytes for storage batteries operating at low temps. should not be selected according to the soly. polytherm in the $KOH-H_2O$ system, but according to soly. isotherms in the system $KOH-K_2CO_3-H_2O$. The compn. of the electrolyte of the charged battery should correspond to the region of nonsatd. solns. of the soly. isotherm in the given system. This principle should be considered when selecting electrolytes for all batteries using alk. electrolytes.

TBC-3246

E. A. Khomskaya and A. S. Kolosov, Sarat. Gos. Univ. im. Chernyshevskogo, Saratov, USSR, "Distribution of Oxygen Reduction Current on the Surface of a Cadmium Electrode During the Charging of a Cadmium-Nickel Battery," Chemical Abstracts, Vol. 77, 1972, p. 528. Abstract No. 69219k. Translated from Elektrokhimiya, Vol. 8, No. 6, 1972, pp. 918-920.

The distribution of the O redn. current may be calcd. from the equation: $I = (nFDc_o/\delta(g))S_{(g)} + (nFDc_o'/\delta(s))S_{(s)}$, where D = diffusion coeff., c_o = concn. of dissolved O, δ = the thickness of the diffusion layer, S = surface area, the subscripts (g) and (s) referring to the gas and the soln. regions on the electrode, resp. At low rates of O evolution, the surface area of the gas regions is negligible. As the rate of O evolution increases, the surface area of the gas regions must also increase so that high process rates can be achieved.

TBC-3247

D. W. Wabner, L. Kandler, and W. Krienke, Inst. Phys. Chem. Elektrochem. Tech. Univ. Muenchen, Munich, Germany, "Positive Electrodes of Nickel-Cadmium Batteries," Chemical Abstracts, Electrochemistry, Vol. 77, 1972, p. 627. Abstract No. 28068s. Translated from Metalloberflaeche, Vol. 26, No. 2, 1972, pp. 68-74.

Ni hydroxide sintered electrodes which are filled electrochem. are superior to chem. treated electrodes. In the electrochem. process, the hydroxide grows on the Ni grains and possesses a well-defined porous structure. Diffusion and conducting mechanisms are therefore facilitated.

TBC-3248

Daijiro Yamashita and Yoshihumi Hamamotor, Fac. Sci. Eng. Ritsumeikan Unit., Kyoto, Japan, "Pressed-Type Alkaline Storage Battery. V. Addition of Antimony to the Negative Active Material of the Pressed-Type Nickel Cadmium Storage Battery," Chemical Abstracts, Vol, 76, 1972, p. 562. Abstract No. 107177j. Translated from Nippon Kagaku Kaishi, No. 2 1972, pp. 309-313.

The effect of Sb on the neg. plate ($Cd(OH)_2$-polyethylene) of a pressed-type alk. storage battery was studied by using capacity decrease of the neg. plate, x-ray diffraction of the active material, and the potential sweep method. The capacity decrease of the neg. plate on standing for a long period in a charged condition is prevented by adding Sb. The x-ray diffraction pattern of the active material shows the discharge reaction forming $Cd(OH)_2$ on standing for a long period in a charged condition is promoted a little, but grain growth of metallic Cd is remarkably reduced by the presence of Sb. The potential sweep method shows the greater part of Sb dissolves in the electrolytic soln. on discharge and does not deposit on charge, but a small part of Sb deposits as a metal with Cd on charge. Therefore, the grain growth of the Cd crystal is prevented. A reversible charge-discharge reaction is promoted by the addn. of Sb.

TBC-3249

Yu. M. Pozin and A. M. Krischevskaya, Nauchno-Issled. Akkumulyatornyi Inst., Leningrad, USSR, "Behavior of Nickel Metal-Ceramic Plates, Containing Cadmium Metal in the Pores, in Cadmium Salt Solutions," Chemical Abstracts, Electrochemistry, Vol. 79, 1973, p. 455. Abstract No. 72838h. Translated from Zhurnal Prikladnoi Khimii, Vol. 46, No. 6, 1973, pp. 1358-1359.

To increase the content of Cd^{2+} in the pores of Ni plates, used in alk. secondary batteries a repeated impregnation was carried out of the Ni plates with Cd^{2+} subsequently electroreduced in KOH soln. The efficiency of the above process can vary with the exptl. conditions. The expts. were made at a const. concn. of 4.5M ($CdCl_2$ + $Cd(NO_3)_2$) in the impregnating soln. An increase of 50-100% of Cd^{2+} in the plates was reached by using 0.03M $Cd(NO_3)_2$ impregnating soln. The concn. of Cd^{2+} in the plates decreased at higher concns. of $Cd(NO_3)_2$ in the impregnating soln. (1.2M) owing to the limited formation of basic CdOHCl salts in the pores. In this case the concn. of Cd^{2+} in the soln. increased.

TBC-3250

M. V. Petrova, V. V. Ten'kovtsev, and M. A. Dasoyan, USSR, "Heat Evolution in the Charge - Discharge Process of Nickel-Cadmium Storage Batteries," Chemical Abstracts, Energy Technology, Vol. 81, 1974, p. 189. Abstract No. 155628g. Sb. Rab. Khim. Istochnikam Toka Vses. Nauchno-Issled. Akkumulyator Inst., No. 8, 1973, pp. 96-101. Title only translated. From Ref. Zh. Khim. 1973, Abstr. No. 21LZ11.

TBC-3251

A. M. Novakovskii, S. A. Grushkina, and R. L. Kozlova, Nauchno-Issled. Akkymulyator. Inst., Lenningrad, USSR, "Effect of Conductivity and Porosity on the Behavior of the Iron Electrode of an Alkaline Storage Battery," Chemical Abstracts, Electrochemistry, Vol. 80, 1974. Abstract No. 43358s. Translated from Zhurnal Prikladnoi Khimii, Vol. 46, No. 10, 1973.

A study was made on the effects of sulfidic S (0.07 and 0.026%), other additives (Ni, Cd, Hg, Sn, Sb, and As), and porosity on the storage capacity of nonsintered Fe powder electrodes. Lower S^{2-} concns. increased the capacity owing to the depassivation effects of S^{2-}, while higher concns. suppressed the cond. of the electrode. The metal additives were effective at higher S^{2-} concn. by increasing the Fe cond., but their passivation behavior (except Hg) prevailed at lower S^{2-} concn. and caused a lower capacity. The marked porosity of the Fe electrode is important for high storage capacity as the vol. of the solid phase is expanded ~4 fold during the conversion of Fe into $Fe(OH)_2$.

TBC-3252

E. A. Kaminskaya, N.Yu. Uflyand, and S. A. Rozentsveig, USSR, "Effect of Elevated Temperature on the Behavior on Nickel Oxide Electrodes," Chemical Abstracts, Electrochemistry, Vol. 80, 1974, p. 509. Abstract No. 21958k. Sb. Rab. Khim. Istochnikam Toka, Vses, Nauch.-Issled. Akkumulyator. Inst. No. 7, 1972, pp. 107-112. From Ref. Zh. Khim. 1973, Abstr. No. 8L234.

The effect of temp. from 20 to 80° on the processes occurring in sintered Ni oxide electrodes contg. β- and γ-NiOOH was studied. With temp. increase from 20 to 50-80°, the charging current utilization factor decreased, the electrode discharge was accelerated and correspondingly, its capacity increased. After storage at increased temp., the electrode discharge capacity increased. The presence of excess metallic Cd in an airtight Ni-Cd battery, which provides more accelerated discharge of the Ni oxide electrode, made it possible to improve the characteristics of batteries intended for operation at increased temps.

TBC-3253

V.Z. Barsukov and L.N. Sagoyan, Dnepropetr. Khim-Tekhnol. Inst. im. Dzerzhinskogo, Dnepropetrovsk, USSR, "Calculation of the Capacity of Sintered Electrodes for Batteries," Chemical Abstracts, Electrochemistry, Vol. 80, 1974, p. 509, Abstract No. 21955g. Translated from Elektrokhimiya, Vol. 9, No. 9, 1973, pp. 1253-1257.

A scheme, based on a math. model which takes into account the factors detg. the discharge process, is presented for evaluating the capacity of a sintered electrode, the current distribution within the pores of which is practically const. with time. The possibility of quant. evaluation of the effect of c.d., terminal discharge voltage, cond. of the phases, temp., and electrode thickness is shown for the Ni oxide electrode. The limiting thickness for optimum capacity is calcd.

TBC-3254

V.Z. Barsukov and L.N. Sagoyan, Dnepropetr. Khim.-Tekhnol. Inst. im. Dzerzhinskogo, Dnepropetrovsk, USSR, "Calculation of the Capacity of Sintered Electrodes for Batteries. II.Calculation of Steady-State Potential," Chemical Abstracts, Electrochemistry Vo. 80, 1974, p.510 Abstract No. 21964j. Translated from Elektrokhimiya, Vol. 9, No. 10, 1973, pp. 1480-1483.

A scheme is proposed for calcg. the steady-state potential of sintered electrodes, particularly sintered Ni oxide electrodes such as are used in alk. storage batteries. Exptl. tested methods are proposed for calcg. the capacity of thin sintered (Ni oxide) electrodes with various parameters and under different conditions of use.

TBC-3255

Jack R. Kettler, Aerospace Corp. El Segundo, Calif., "Batteries for the Hybrid Heat Engine/Electric Vehicle," Chemical Abstracts, Electrochemistry, Vol. 78, 1973, p. 477. From Proc. Symp. Batteries Traction Propul., 1972 pp. 213-241 (Eng). Edited by Robert L. Kerr, Columbus Sect. Electrochem. Soc. Battelle Mem. Inst., Columbus, Ohio.

The requirements of hybrid heat engine/elec. vehicle batteries are discussed. The battery must have high cycle life, power, and energy d. and must be economical to purchase and operate. Ni-Cd, Pb-acid, and Ni-Zn systems could potentially be satisfactory. The Ni-Cd battery has the best characteristics but was not given detailed consideration because of cost and availability. The Pb-acid battery has near term potential if internal resistance can be reduced to increase power and energy d. and optimize cycle life at shallow depths of discharge. The Ni-Zn system may best be suited for this application.

TBC-3256

A.P. Chikisheva, USSR, "Preparation of a Nickel (II) Hydroxide Activating Additive," Chemical Abstracts, Electrochemistry, Vol. 78, 1973, P. 477. Abstract No. 131216h. Issled. Obl. Khim. Istochnikov Toka, No. 28, 1971, pp. 135-137. From Ref. Zh. Khim., 1972, Abstract No. 19L200.

The effect of the gram size on $Ni(OH)_2$,prepd. by vibrogrinding and used as an additive in Cd alk. batteries, was studied on the Cd current efficiency. The max. Cd current efficiency (55-65%) was obsd. at 150 cycles during cycling of the segment prepd. with the addn. of 3 and 5% $Ni(OH)_2$, vibrogrinded for 10-15 min to obtain 85-90% of the particles with <63μdiam.

TBC-3257

V.N. Kosholkin and O.S. Ksenzhek, USSR, "Current Distribution in Storage Batteries. II. Experimental Verification of Current Distribution Along the Electrode Height, "Chemical Abstracts, Electrochemistry, Vol. 78, 1973, p. 478. Abstract No. 131218k. Issled. Obl. Khim Istochnikov Toka, No. 2, 1971, pp. 51-57. From Ref. Zh; Khim. 1972, Abstract No. 19L197.

The polarog. and sp. elec. cond.κ, were studied of NiO cermet and Cd-coated electrodes of a Ni-Cd battery. The κof the Cd electrode is almost linearly dependent on its charge. The κ of the NiO electrode is independent of its charge. The exptl. validation of the equation for calcg. the current distribution along the electrode height revealed good agreement between theor. and exptl. values of the voltage drop on the electrodes.

TBC-3258

V. N. Kosholkin and O.S. Ksenzhek, USSR, "Current Distribution in Storage Batteries. I. Effect of Nonuniformity of the Current Distribution on some Characteristics of Storage Batteries," Chemical Abstracts, Electrochemistry, Vol. 78, 1973. Abstract No. 13122f. Issled. Obl. Khim. Istochnikov Toka, No. 2, 1971, pp. 43-50. From Ref. Zh, Khim. 1972, Abstr. No. 19L196.

Current distribution along the electrode height in batteries with current outlets on 1 or both sides was analyzed and an equation was derived for the battery discharge duration, taking into account the nonuniform current distribution. Conditions are considered under which a uniform current distribution is possible, e.g., in nonlaminated Ni-Cd batteries.

TBC-3259

L.N. Fesenko, Yu. D. Kudryavtsev, and Yu.O.Makogon, USSR, "Behavior of Porous Nickel Substrates in Alkaline Solutions During Polarization with Assymmetrical Alternating Current," Chemical Abstracts, Electrochemistry, Vol. 78, 1973, p. 478 Abstract No. 131219m. Tr. Novocherkassk, Politekh. Inst. No. 266, 1972, pp. 67-72. From Ref. Zh., Khim. 1972, Abstr. No. 19L198.

Polarization with asym. a.c. with cathodic c.d., i_c, exceeding the anodic c.d., i_a, e.g., i_c = 1 A/cm^2 and i_a = 0.56 A/cm^2, is suggested in prepg. an active material for alk. batteries from Ni cermet base NiO electrodes.

TBC-3260

P.A. Antonenko, V.Z. Barsukov, N.G. Krapivnyi, and L.N. Sagoyan, USSR, "Cermet Nickel Oxide Electrode. II. Modeling the Electrode Steady State," Chemical Abstracts, Electrochemistry, Vol. 78, 1973, p. 478. Abstract No. 131220e. Vop. Khim. Khim. Tekhnol. Respub. Mezhvedom. Temat. Nauch.-Tekh. Sb. No. 25, 1972, pp. 18-25. From Ref. Zho, Khim. 1972, Abstr. No. 19L194.

Elec., math, and phys. models of the current NiO electrode in the steady state were studied. Steady-state current radial distribution curves under various performance conditions were calcd. The results may be used to study the dynamics of the charge-discharge processes of the electrode.

TBC-3261

P.A. Antonenko, V.Z. Barsukov, N.G. Krapivnyi, and L. N. Sagoyan, USSR, "Cermet Nickel Oxide Electrode III. Modeling of the Discharge Process," Chemical Abstracts, Electrochemistry, Vol. 78, 1973. p. 478. Abstract No. 131222 g. Vop. Khim. Khim. Tekhnol. Respub. Mezhvedom. Temat. Nauch. - Tekh. sb. No. 25, 1972, pp. 135-141. From Ref. Zh., Khim. 1972, Abstr. No. 19L195.

Dependences of the sp. elec. cond. of the active material of the cermet NiO electrode on the specific degree of discharge at various temps. were obtained and used to study the electrode discharge dynamics. An algorithm was developed which permits modeling of the discharge process of a cermet electrode by an electronic computer.

TBC-3262

O.R. Pryakhin, V.P. Galushko, and E.F. Zavgorodnyaya, Dnepropetr. Bos. Univ., Dnepropetrovsk, USSR."Cathodic Reductions of the Anodic Oxidation Products of Cadmium in Alkaline Solutions," chemical Abstracts, Electrochemistry, Vol. 78, 1973, p. 478. Abstract No. 131224j. Translated from Elektrokhimiya, Vol. 9, No. 1, 1973, pp 60-61.

The curves of the cathodic redn. of a Cd electrode, preliminary oxidized by anodic polarization, using various potential values were studies according to the potentiostatic method. Tests were conducted in 4.5 and 10N KOH solns. The Cd electrodes were oxidized by polarization with following potentials: -0.800, -0.400, +0.500, +1.00, +1.350, and +1.500 V vs a Hg-Hg O electrode. The curves of cathodic redn. were characterized by the presence of several regions of max. currents which indicated the course of the redn. process. Apart from a range of max. currents corresponding to CdO, and $Cd(OH)_2$ redn., an addnl. range of max. currents was noted on the curves of cathodic redn., indicating that during oxidn. of the Cd electrode, the formation of another Cd oxide compd., probably a peroxide, took place.

TB-3263

Daijiro Yamashita and Yoshifumi Yamamoto, Fac. Sci. Eng. Ritumeikan Univ., Kyoto, Japan, "Pressed-Type Alkaline Storage Battery. VI. Characteristics of Pressed-Type Nickel Positive Electrodes Containing Silver or Silver Oxide, "Chemical Abstracts, Energy Technology, Vol. 81, 1974, p. 166. Translated from Nippon Kagaku Kaishi, No. 3, 1974, pp. 459-463.

The effects of addn. of Ag and Ag_2O(5 or 10%) on the characteristics of the pos. plate ($Ni(OH)_2$ 50, graphite 35, polyethylene 15%) of a pressed-type Ni-Cd storage battery were studied by measuring overpotential, capacity changes with charge-discharge cycle, and the potential-current curves obtained by the potential sweep method. The availability of the active material at the initial cycle increased with the addn. of Ag and Ag_2O. The increase exceeded 80% when the Ag_2O content was 10%. The addn. of Ag and Ag_2O decreased the overpotential in charge and discharge processes. The effect of Ag_2O was greater than that of Ag. The capacity of the plates contg. 10% Ag_2O increased gradually with charge-discharge cycles, whereas that of the plates contg. Ag decreased suddenly and shedding was obsd.

TBC-3264

R. Prema, P.V. Vasudeva Rao, and H.V.K. Udupa, Cent. Electrochem. Res. Inst. Karaikudi, India, "Composite Nickel Powder for Preparing Plagues for Nickel Cadmium Batteries," Chemical Abstracts, Energy Technology, Vol. 81, 1974, p. 166. Abstract No. 66166 n. From J. Electrochem. Soc. India, Vol. 22, No. 4, pp. 303-306.

For producing sintered matrixes for Ni-Cd battery plates and for fuel-cell electrodes, a process for prodn. of composite Ni powder with inert core materials like TiO_2 was developed. The core materials are coated at a high temp. to prep. the oxide-coated core. This is reduced in a H or cracked NH_3 atm. to obtain the composite powder. Samples prepd. from such powder alone have a high elec. resistance, and hence pure Ni powder must be added to improve the elec. cond. so the sintered plague could be used as a battery plate. The chem. attack resistance and the polarization characteristics of the composite powder with 50% Ni powder are as good as those of one prepd. from pure Ni powder.

TBC-3265

Jiri Marek, H.P. Bateria, Slany, Czech., "Nickel-Cadmium Storage Batteries with Sintered Electrodes, "Chemical Abstracts, Energy Technology, Vol. 81, 1974, p. 167, Abstract No. 66168q. Translated from Khiznice Odbornych Ved. Spisu Vys. Uceni Tech. Brne B 1972, Vol. 32, Pt. 2, pp. 271-278.

Ni powder prepd. from Ni carbonyl is most suitable for prepg. sintered electrodes for Ni-Cd batteries. This powder exhibits a low thermal contraction, bulk d. 0.5-0.6 g/cm^3, and sp. surface 0.5 m^2/g. The diam. of pores is $\sim$ 15μm. The impregnation of the negative plate is best done by decompn. of Cd formate at 320-350°.

TBC-3266

V.V. Romanov and P.I. Sandler, USSR, "Manufacture of a Dry-Charged Nickel Oxide Electrode by Chemical Oxidation," Chemical Abstracts, Energy Technology, Vol. 82, 1975, p. 138. Abstract No. 88436y. Translated from Zhurnal Prikladnoi Khimii, Vol. 47, No. 9, 1974, pp. 2031-2035.

Replacement was studied of electrochem. oxidn. of powder metallurgical $Ni(OH)_2$plates by oxidn. with hot 3% KOH - $K_2S_2O_8$ soln. for manuf. of NiO(OH) [12026-04-0] cathodes. About 10 g $K_2S_2O_8$ was required to oxidize a plate with a 1 A-hr discharge capacity. The oxidn. efficiency depended on the cathode thickness; cathode plates >1 mm thick were not completed in 4 hr. Cathodes obtained by chem. oxidn. had comparable properties as and a higher discharge capacity than the electrochem. oxidized plates.

TBC-3267

F.I. Kukoz, V.I. Bogdanov, and A. A. Golubtsov, USSR, "Nondestructive Method of Monitoring the Quality of Powder-Metallurgical Nickel Electrodes of Nickel-Cadmium Batteries," Chemical Abstracts, Energy Technology, Vol. 82, 1975, p. 138. Abstract No. 88437z. Translated from Zhurnal Prikladnoi Khimii, Vol. 47, No. 9, 1974 p. 2144.

Addnl. data considered in abstracting and indexing are available from a source cited in the original document. The use of an electromagnetic method (measurement of the 1st harmonic signal of an eddy-current transducer) is recommended for controlling porosity and prodn. of powder-metallurgical Ni[7440-02-0]electrodes of Ni-Cd batteries.

TBC-3268

Daijiro Yamashita and Yoshifumi Yamamoto, Fac. Sci. Eng., Ritumeikan Univ. Kyoto, Japan, "Pressed-Type Alkaline Storage Battery. VII. Behavior of Silver Oxide Added to Pressed-Type Nickel Positive Electrodes," Chemical Abstracts, Energy Technology, Vol. 82, 1975, p. 139, Abstract No. 884466, Translated from Nippon Kagaku Kaishi, No. 11, 1975, pp 2070-2074.

The addn. of Ag_2O (20667-12-3) increases the availability of active material in $Ni(OH)_2$ [12054-48-7] 50, graphite 35, polyethylene 15% cathode of pressed-type Ni-Cd battery. The function of Ag 0 on charge-discharge was studied by current-potential curves obtained with Ag in aq. KOH and at. absorption spectrophotometry. The discharge capacity of Ag_2O is not contained in that of Ni electrode. Ag_2O added to the cathode changes into Ag on discharging, and Ag changes into active Ag 0 on charging. A part of this active Ag_2O dissolves in the electrolyte and dissocs. according to the equation: $Ag_2O \leftrightarrow Ag^+ + Ag_2O$. Ag^+ affects the anode and AgO remains in soln. But, the amt. of Ag dissolved from the cathode contg. 10% Ag_2O is small even after 300 cycles.

TBC-3269

R.U. Panich and A.G. Sukharev, USSR, "Determination of Exchange Current for Alkaline Storage Batteries," Chemical Abstracts, Electrochemistry, Vol. 79, 1973, p. 360. Abstract No. 142212a. Translated from Tr. Mosk, Energ. Inst. No. 112, 1972, pp. 98-101.

A formula was developed to calc. the exchange current for a series of electrodes (Ni, Cd, and Ag oxide) in alk. storage batteries. The accuracy of the method is limited to a great extent by the accuracy of the measurement of the internal surface of the porous electrodes.

TBC-3270

R. K. Kvaratskheliya, Inst. Neorg. Khim. Elektro-Tbilisi, USSR, "Mechanism of Nitrate Ion Reduction at a Cadmium Cathode." Chemical Abstracts, Electrochemistry. Vol. 79, 1973, p. 361, Abstract No. 142213b. Translated from Soobshch. Akaa. Nauk Gruz SSR, Vol. 71, No. 1, 1973, pp. 125-128.

NO_3^- was reduced at -0.89 to -0.97V (SCE) on a Cd (micro- or macro-) electrode to NO_2^-(pH >3) or HNO_2 (pH <3). The probable redn. mechanism is: $NO_3^- + 2H^+ + e^- \rightarrow NO_2 + H_2O$ (1); $NO_2 + e^- \rightarrow NO_2^-$ (2). The half-wave potential $\phi 1/2$ and $d\phi/d\log[i/(i_1 - i)]$ were dependent of pH. Hence 2 is the rate-detg. step. In weakly acidic (pH >1) and neutral solns. there was a decrease in i on the polarogram due, probably, to 1 becoming the rate-detg. step as a result of increase of pH of the catholyte. Besides being reduced to NO_2^-, NO_2 may dimerize, $2NO_2 \rightarrow N_2O_4$, and disproportionate in neutral and alk. solns.: $N_2O_4 + OH^- \rightarrow NO_3^- + NO_2^- + H^+$ (3). In weakly acid solns. HNO_2 may disproportionate: $3HNO_2 \rightarrow H^+ + NO_3^- + 2NO + H_2O$ (4). In strongly acid solns. both 3 and 4 may be neglected. NO_2^- is not further reduced at <-1.6V.

TBC-3271

F. K. Andryushchenko, B. I. Bairachnyi, A. P. Nekrasov, and M. G. Popova, Khar'k. Politekh. Inst. im. Lenina, Kharkov, USSR, "Use of Pulsed Systems During the Formation of Cadmium-Nickel Storage Cells," Chemical Abstracts, Energy Technology, Vol. 81, 1974, p. 165. Abstract No. 52191e. Translated from Izu. Vyssh. Ucheb. Zaved., Khim. Khim. Tekhnol., Vol. 17, No. 3, 1974, pp. 409-411.

A hermetically sealed Cd-Ni storage cell of 0.9 A-hr capacity was charged in 14 min by a pulsed charging current compared to 3 hr required for charging to 1.6V by a const. current of 0.3A. The pulsed current was supplied in 20-30μ sec pulses at a frequency of 71-100 GHz. Discharge characteristics at -30 to 20° of the storage cells charged by pulsed and steady currents were indistinguishable.

TBC-3272

R.V. Boldin, F.F. Karpova, and N.N. Milyutin, USSR, "Corrosion of Steel Parts in Hermetic Nickel-Cadmium Storage Batteries," Chemical Abstracts, Energy Technology, Vol. 81, 1974, p. 164. Abstract No. 52182C. Translated from Sb. Rab. Khim. Istochnikam Toka, Vol. 8, 1973, pp. 117-120.

The corrosion of the steel container of hermetically sealed Ni - Cd storage batteries and the subsequent accumulation of corrosion products in the pos. or neg. electrodes and separators was investigated in long term (up to 11 years) tests. In the case of elec. contact of the container withany of the electrodes, corrosion is due to reasons other than those in the case of elec. insulated containers. Welded sites near the pos. Ni electrode are the most frequent areas of corrosion attack, because of the effect of HCl evolved when the vinyl separators decomp. during welding. Wetting with electrolyte is best when the container is in elec. contact with the neg. electrode and worst when insulated. Poor wetting, esp. in the presence of Cl^-, enhances corrosion. At >40° during active life or storage corrosion is accelerated due to the transition of Fe from a passive to an active corrosion state. In all cases corrosion is negligible and during both active use and storage the corrosion products do not affect performance.

TBC-3273

Per Selanger, University of Lund, Lund, Swedan, "Simulation of Electrochemical Reactors, "Kem-Tek 2 Congress, Section: Progress in Chemical Engineering, Copenhagen, November 2-4, 1971.

A macro model of an electrochemical reactor is constructed using time-depending kinetics, which are divided into two parts. One part is a resistance model model, which is consumption geometrically designed. The other part is a mass transport model. (6 references, 0 tables, 4 figures, 14 pages).

TBC-3274

P.K. Saha, Electron. Radar Div. Establ., Bangalore, India, "Performance Characteristics of 100 percent Indigenous Pocket Plate Sealed Nickel-Cadmium Battery, "Chemical Abstracts, Vol. 80, 1974, p. 496. Abstract No. 115317c. From Prepr. Semin. Electrochem., 13th 1972, pp. 1-7. Cent. Electrochem. Res. Inst., Karaikudi, India.

The development of rectangular sealed-type Ni-Cd batteries of pocket plate construction using 100 percent indigenous plate was described and its advantages over the conventional dry and Pb-acid battery are discussed. The charge and discharge characteristics, the capabilities obtained and the usefulness of the battery for defense communications equipment are discussed.

TBC-3275

R. Ramasubbalaksmi and P.V.V. Rao, Central Electrochemical Research Institute, Karaikudi-3 India, "Present Methods for Determining the State of Charge of Nickel Cadmium Batteries - A review," Society for Advancement of Electrochemical Science and Technology. Transactions, Vol. 7, No. 4,October-December, 1972, pp. 178-180 (QD 551562, Chem.)

A brief review of methods of determining the state of charge of nickel cadmium batteries based the measurements of the following properties: 1) voltage, 2) ohmic resistance, 3) drop due to polarization, 4) double layer capacitance, 5) Farad capacitance, 6) phase shift, and 7) magnitude of impedance. In the authors' opinions, only the method based on the principle of measurement of faradic capacitance seemed to give results which were reliable, at least for a particular type of cell. (7 references, 0 tables, 2 figures, 3 pages).

TBC-3276

G. Sivaramaiah, P.V. Vasudeva Rao and H.V.K. Udupa, Central Electrochemical Research Institute, Karaikudi-623006, India, "Direct Electrochemical Reduction of Cadmium Oxide in Alkaline Electrolyte," Transactions of Society for Advancement of Electrochemical Science and Technology, Vol 9, No. 4, 1974, pp. 167-169.

The conditions under which the direct reduction of certain metal oxides-hydroxides occurred, were applied to the reduction of cadmium oxide in contact with a nickel substrate in alkali electrolyte. This more or less represented the situation under which a negative plate of a sintered plate nickel-cadmium battery is placed during the charging process. It has been found that the reduction of cadmium oxide proceeds predominately in the solid phase and the particle size of the reduced metal is not affected by c.d at low concentrations of alkali up to 5N (i.e.20%). At higher alkali concentrations the reduction occurs both in the solid phase and by dissolution and deposition mechanism due to increased solubility of the cadmium oxide. (10 references, 0 tables, 3 figures, 3 pages).

TBC-3277

P.A. Antonenko, V. Z. Barsukov, N.G. Krapivnyi, and L.N. Sagoyan Dnepropetr. Khim-Tekhnol. Inst., Dnepropetrovsk, USSR, "Sintered Nickel Oxide Electrode. IV. Effect of Temperature on the Dynamic Characteristics of the Electrode," Chemical Abstracts, Electrochemistry, Vol. 78, 1973, p. 501. Abstract No. 118346f. Translated from Vop. Khim. Khim. Tekhnol., No. 26, 1972, pp 110-115.

Using exptl. data on the sp. resistivity of the active mass of porous sintered NiO electrodes as a function of the depth of discharge and the algorithm of the dynamic characteristics, the discharge characteristics of the electrode are estimated by means of an electronic computer. The electrodes (80 X 40 X 1.2 mm) are divided into 3 sections along their thickness and discharged unilaterally at 10 mA/cm^2. The current distribution as a function of discharge time is plotted for -50, +20, and +50°. The consistency of the model is checked exptl. at +20°. The anal. of the c.d. distribution curves shows that more and more back sections of the electrode are included in the discharge process as it proceeds. The c.d. distribution in a nearly discharged electrode is uniform and linear. The effect of temp. on the max. sp. discharge capacity and the degree of nonuniformity of discharge is considered and methods for its calcn. and exptl. evaluation are given. The internal electrode resistance R is studied as a function of the depth of discharge. During discharge, R is increased 2.5-3.5 times at >0° and 4-8 times at >0°.

TBC-3278

P. A. Antonenko, V. Z. Barsukov, N. G. Krapivnyi, and L. N. Sagoyan, Dnepropetr. Khim-Teknol. Inst., Dnepropetrovsk, USSR, "Sintered Nickel Oxide Electrode. V. Discharge Efficiency in Depth," Chemical Abstracts, Electrochemistry, Vol. 78, 1973, p. 501. Abstract No. 118347g. Translated from Vop. Khim. Khim. Tekhnol., No. 26, 1972, pp. 115-119.

On the basis of the dynamic characteristics of sintered NiO electrodes with geometrical area 32 cm^2 and 0.12 cm thick, discharged at 10 mA/cm^2, an estimation is made of the progress of the discharge process along the electrode thickness. The criterion of the most efficient thickness is the efficiency η of the NiO-Cd cell defined as the ratio of the useful to the total energy of the system. As a 1st approxn., the energy losses are assumed to be the heat evolved during discharge. The most efficient electrode thickness is detd. by the max. depth along which the discharge process can proceed. In the case $d > d_1$ (d is the electrode thickness and d_1 is the limiting electrode thickness), the complete discharge at the expense of the energy of the system is impossible. The calcd. values of d_1 at const. $\eta \approx 85$ and 95% are presented as functions of c.d. and temp.

TBC-3279

Y. M. Pozin and N.I. Shtertser, Nauchno-Issled. Akkumulyator-Inst., Leningrad, USSR, "Saturation of Nickel Plates in Cadmium and Nickel Salt Solutions Suitable for the Manufacture of Alkaline Storage Cells. VII. Anodic Behavior of Nickel Metal in a Nickel Nitrate Solution Containing Chloride Ion Impurities," Chemical Abstracts, Vol. 78, 1973, p. 568. Abstract No. 51581h. Translated from Zh. Prikl. Khim (Leningrad), Vol. 45, No. 8, 1972, pp. 1724-1928.

The anodic behavior of smooth Ni metal in $Ni(NO_3)_2$ solns, contg. Cl^- impurities was studied by using a potential scan technique in solns. contg. 5.4M $Ni(NO_3)_2$, and 0, 0.5, 10, and 40 g/l. of Cl^-, at 50° and various pH. The Ni anodic polarization curve depended virtually on pH and the presence of Cl^-. In a pure $Ni(NO_3)_2$ soln., Ni had 2 areas of active dissoln. and passivity. In the presence of Cl^-, the initial passive area disappeared. Acidifying of the soln. facilitated the anodic process and enhanced Ni corrosion. The presence of Cl^- slowed Ni dissoln. at the start of investigations, but the decrease in the corrosion rate with time was slower, resulting from a change in the alk. Ni salt deposits covering the metal surface. In neutral $Ni(NO_3)_2$ soln. Ni passivity in the potential range 0.9-1.3V was obsd. only with Cl^- content $\leq$0.5g/l.

TBC-3280

Yu. M. Vol'fkovich, I. A. Kikushkina, G. V. Shteinberg, and V. S. Bagotskii, Inst. Elektrokliim, Moscow, USSR, "Effect of Transfer Processes on Concentration and Potential Gradients in a Porous Electrolyte-Containing Membrane. IV. Calculation of the Effect of Gas Porosity," Chemical Abstracts , Vol. 78, 1973, p. 568. Abstract No. 51582j. Translated from Elektrokhimiya, Vol. 8, No. 11, pp. 1592-1596 (Russ.)

To explain the effect of some probable factors whose action could lead to a real acceleration of transfer processes in a porous electrolyte-contg. membrane and to a corresponding redn. of the concn. gradient, the effect of gas porosity in the membrane is discussed. The mechanism of the action of gas bubbles during liq. transfer was analyzed using the examples of KOH-satd. asbestos membranes. A math. anal. of the process proved that the effect of gas porosity led to an increase of the total effective coeff. of diffusion by bringing into the process of mass transfer by liq., a parallel process of mass transfer by gas. The effect of gas porosity on mass transfer in the membrane increased with lye concn. An approx. method was given for calcg. the diffusion coeff. at various porosity values of the membrane, taking into account the effect of this porosity. The calcd. and measured values for various KOH concns. in the membrane were compared.

TBC-3281

E. A. Khomskaya and A. S. Kolosov, Sarat. Gos. Univ. im. Cherny Shevskogo, Saratov, USSR, "Distribution of Oxygen Reduction Current on the Surface of a Cadmium Electrode During the Charging of a Cadmium Nickel Battery," Chemical Abstracts, Vol. 77, 1972, p. 528. Abstract No. 69219k. Translated from Elektrokhimiya, Vol. 8, No. 6. 1972. pp. 918-920 (Russ).

The distribution of the O redn. current may be calcd. from the equation $I = (nFDc_o/\delta(g)) + (nFDc_o'/\delta(s))S_{(s)}$, where D = diffusion coeff., c_o = concn. of dissolved O, δ = thickness of the diffusion layer, S = surface area, the subscripts (g) and (s) referring to the gas and the soln. regions on the electrode, resp. At low rates of O evolution, the surface area of the gas regions is negligible. As the rate of O evolution increases, the surface area of the gas regions must also increase so that high process rates can be achieved.

TBC-3282

V. V. Romanov and L.P. Viktorova, USSR, "Acceleration of the Filling of Pores of a Sintered Cadmium Electrode by an Active Mass," Chemical Abstracts, Electrochemistry, Vol. 82, 1975, p. 329. Abstract No. 9250g. Translated from Zh. Prikl. Khim. (Leningrad), Vol. 47, No. 4, 1974, pp. 1562-1566 (Russ.)

At present the porous Ni [7440-02-0] base of a sintered Cd [7440-43-9] electrode is filled with the active mass by treating the base with Cd salt and alkali metal hydroxide solns. in several cycles consisting of impregnating, washing, and drying steps, with each cycle taking 10-15 hr (m. A. Dasoyan, 1969). An attempt was made to reduce duration of the filling procedure by application of the thermal decompn. of org. salts of Cd. The bases were impregnated with solns. of various org. salts of Cd, which was followed by thermal decompn. of the salts in elec. furnaces. The time savings consisted in eliminating the treatment with alkali metal hydroxide and the appropriate washing and in reduced duration of the treatment with the soln. of org. salt of Cd. The treatment was done in a boiling (105°) soln. of $Cd(OAc)_2$ [543-90-8] having a sp. wt. of 1.66-1.70 g/cm^3. The pores were filled with the soln. in 10-20 min. The thermal decompn. of $Cd(OAc)_2$ in pores of the base at 380-400° was complete in 3-5 min. A cycle consisting of impregnating and decompg. steps took 20-30 min. Introduction of the usual amt. of CdO [1306-19-01] into the base pores (1.5-1.7g/cm^3) required 4-5 cycles. The sintered Cd electrodes thus produced did not differ, in their operation characteristics, substantially from the electrodes obtained by the usual process.

TBC-3283

Yu. M. Pozin and N.K. Terent'ev, USSR, "Electrochemical Behavior of Electrodes Prepared by Sintering Powdered Nickel and Cadmium," Chemical Abstracts, Electrochemistry, Vol. 82, 1975, p. 323. Abstract No. 9173j. Sb. Rab. Khim. Istochnikom Toka, vses, Nauchno-Issled. Akkumulyator Inst., No. 8, 1973, pp. 60-65 (Russ.). From Ref. Zh., Khim. 1973, Abstr. No. 23L240. Title only translated.

TBC-3284

F. I. Kukoz and G. A. Shul'gina, USSR, "Improvement of Forming of the Active Mass of a Powder-Metallurgy Cadmium Electrode," Chemical Abstracts, Electrochemistry, Vol. 82, 1975, p. 323. Abstract No. 9172h. Tr. Novocherkassk. Politekh. Inst., No. 285, 1973, pp 3-8 (Russ). From. Zh, Khim. 1974, Abst. No. 8L196. Title only translated.

TBC-3285

Y.M. Pozin, A.S. Miroshnichenko, O.M. Ul'yanova, and V. A. Nikol'skii, USSR, "Structure and Properties of Nickel Oxides in Pores of Sintered Electrodes," Chemical Abstracts, Electrochemistry, Vol. 82, 1975, p. 323. Abstract No. 9174k. Sb. Rab. Khim. Istochnikam Toka, Vses. Nauchno-Issled. Akkumulyator. Inst., No. 8, 1973, pp. 66-71 (Russ.). Abstr. No. 23L241 Title only translated.

TBC-3286

Kurandou Sugita and Shiro Ohkuma, Railw. Tech. Res. Inst., Tokyo, Japan, "Effects of Cobalt, Iron, and Lithium on the Performance of Nickel Oxide Electrodes," Chemical Abstracts, Electrochemistry Vol. 82, 1975, p. 323. Abstract No. 9175m. Translated from Denki Kagaku Oyobi Kogyo Butsuri Kagaku, Vol. 41, No. 3, 1973, pp. 440-446 (Japan).

The influence of Li^+ [7439-93-2] on the durability of Ni oxide electrodes is complicated as the electrodes are usually contaminated with Fe [7439-89-6]. The effect of Co [7440-48-4]or Fe on the performance of the electrode was studied. The durability of the electrode was diminished by Fe migrated from active materials of the neg. electrode, but this was prevented to some extent by the addn. of Li+. The durability of the pos. electrode with Ni-plated Fe screen used as the plague was not very much affected by Fe migration from the screen. Electrodes with a pure Ni screen deteriorated rapidly with addn. of Li^+. DTA and measurements of active 0 revealed that the deterioration was due to deactivation of the active materials of the pos. electrode with Li+. This deterioration could be prevented by Co or a very small amt. of Fe.

TBC-3287

B. P. Ivanov. Omsk. Plitckh. Inst., Omsk, USSR, "Determination of the Temperature of Airtight Cadmium-Nickel Storage Batteries, Chemical Abstracts, Vo. 82, No.26, p.154, 1975. Abstract No. 173474d. Translated from Iav. Vyssh. Uchbn. Zaved, Energ. Vol. 17, No. 11, 1974, pp. 130-133 (Russ).

A method is presented for calcg. the overheating of the title batteries during discharging. Equations are given for the heat effect of the process, the overheating temp., and the overheating of the battery as a function of the discharge time.

TBC-3288

L. I. Soboleva, N. T. Kudrgavtsev, T. E. Tsupak and L. S. Lukashova, Mosk. Khim.-Tekhnol. Inst. im. Mendeleeva, Moscow, USSR, "Electrodeposition of a Cadmium-Nickel Alloy from Polyethylene Polyamine Electrolytes," Chemical Abstracts, Vo. 82 1975, p. 588. Abstract No. 65983k. Translated from Zashch. Met. Vol. 10, No. 6, 1974,

The advantages and differences in using baths based on polyethylenepolyamine, 90% of which is triethylenetetramine (teta) [112-24-3] as compared to other electrolytes, for the electrodeposition of Cd-Ni alloys was studied. Good quality electrodeposits were obtained over a broad range of c.ds. For obtaining alloys contg. 8-12% Ni an electrolyte contg. Cd(teta) SO_4 0.3 and $Ni(teta)_2SO_4$ 0.5N is recommended, at pH 10.5-11.5 and temp. 25°. The c.d. is 3-20 A/dm^2 and the current efficiency is 40-70%.

TBC-3289

Ya. E. Gindelis, USSR, "Prediction of Electrical Characteristic of Nickel-Cadmium Storage Batteries and Design Calculation for them," Chemical Abstracts, Energy, Vol. 82 1975, p. 143. Abstract No. 114060t. Translated from Elektroteknika, No. 8, 1974, pp. 46-47 (Russ).

Equations are presented for calcg. the energy and max. power, P, of a Cd-Ni battery at any discharge current. $P = U_o^2/4r$, Where U_o is extrapolated open circuit voltage at 0 current and r is internal battery resistance.

•TBC-3290

H. Yoneyama, T. Fujimoto, and H. Tamura, Fac. Eng., Osaku Univ., Suita, Japan, "Effect of Crystal Plane on Reduction Rate of Oxygen on Nickel Oxide Electrode," Chemical Abstracts, Electrochemistry, Vol. 82, No. 20, 1975, p. 396. Abstract No. 130920d. From J, Electroanal. Chem. Interfacial Electrochem., Vol. 58, No. 2, 1975, pp. 422-427 (Eng).

Lithiated single-crystal NiO (1313-99-1) electrodes were prepd. by a known method, polished, dipped in concd. HCl and wahed in de-ionized H_2O. Polarization curves of the O (7782-44-7) redn. were made potentiostatically in 3.4M KOH using the (100) and (110) planes of NiO. The exchange c.d. is shown as a function of the carrier concn. of the above electrodes.

TBC-3291

Harvey N. Seiger, Heliotek Division of Textron, Sylmar, California, "Sinter of Uniform, Predictable, Blemish-Free Nickel Plaque for Large Aerospace Nickel Cadmium Cells," Report No. NASA CR-132481, Contract NASI-10694 (February, 1975).

An emperical program was carried out to fabricate sintered nickel plaque that is uniform, reproducible and blemish-free. A series of nickel slurry compositions were tested. Important slurry parameters were found to be the nature of the binder, a pore former and the method of mixing. A slow roll mixing which is non-turbulent successfully eliminated entrapped air so that bubbles and pockets were avoided in the sinter. A slurry applicator was developed which enabled an equal quantity of slurry to be applied to both sides of the grid. The volume of slurry applied is dependent upon the spacing of the doctor blades, the inclination angle, viscosity and composition of the slurry and the pulling rate. Slow drying of the slurry eliminates mud cracking. Cleaning of the grid eliminated air entrapment at the perforations and improved sinter adhesion. Sintering in a furnace having a fraded atmoshpere characteristic, ranging from oxidizing to strongly reduction, improved adhesion of porous sinter to grid and resulted in a uniform welding of nickel particles to each other throughout the plaque. Sintering was carried out in a horizontal furnace having three heating zones and 16 heating control circuits. The temperature profile in the first zone is ramp-shaped while in the other two zones the temperature profile is essentially flat. Eight tests were used for plaque evaluation. These included (1) appearance, (2) grid location and adhesion, (3) mechanical strength, (4) thickness, (5) weight per unit area, (6) void volume per unit area, (7) surface area and (8) electrical resistance. The processes developed were used to manufacture plaques, samples of which were delivered to NASA Langley Research Center. Plaque material was impregnated using Heliotek proprietary processes and 100 AH cells were fabricated. Plates and sealed cells were delivered to NASA Langley Research Center.

TBC-3292

Allen J. Bard, Editor, Department of Chemistry, University of Texas, Austin, Texas, Encyclopedia of Electrochemistry of the Elements, Marcel Dekker, New York (1973).

Volume I contains a chapter on cadmium, with information primarily on standard and formal potentials, and voltammetric characteristics, data and information is provided on aqueous solutions, nonaqueous solutions, molten salts, and equilibrium data.

TBC-3293

S. Uno Falk, Svenska Ackumulator A. B. Jungner Stockholm, Sweden and Alvin J. Salkind, ESB Incorporated, Alkaline Storage Batteries, John Wiley, New York (1969).

This book contains data relating to the design, manufacture, performance characteristics, charging, and maintenance of all types of rechargeable alkaline batteries, Discussing the subject in complete detail, it is the only text currently available which concentrates solely on the subject of alkaline storage batteries. The book closely examines the electrochemical and thermodynamical background of various alkaline systems as well as electrode kinetics and reaction mechanisms and their relationship to engineering principles. Pertinent information concerning the historical background and development of alkaline battery systems is also included.

TBC-3294

Vincent D'Agostino and Joseph Lee, RAI Research Corporation, Hauppauge, L. I., New York, "Manufacturing Methods for High Performance Grafted-Polyethylene Battery Separators," Final Report FR-396-0, (RAI 429), AFLM-TR-72-13, September 1, 1970 to March 30, 1972, Contract No. F-33615-70-c-1193, Project No. 396-0.

This work on the development of new and improved manufacturing methods, controls, equipment and processes was directed toward the generation of methacrylic acid-grafted-polyethylene film for use as a superior alkaline battery separator material. This material is of interest to the Air Force as a means of significantly increasing the life and performance of secondary Ni/Cd and Ag/Zn batteries and thus accomplishing meaningful cost savings.

Technology was developed to permit design of equipment for large scale production of the separator material. Pilot equipment for each phase was constracted and operated to establish optimum operating conditions and to determine process controls. Limitations on processing steps such as, fil extrudion, crosslinking, grafting, washing, converting, packaging and preliminary and final specifications for raw materials, in-testing processing and the end product were established. A preliminary plant layout for a manufacturing capability of 1,000,000 ft^2/year and product costs are predicted.

All objectives of the program were successfully accomplished. The process and product reliability and consistancy was demonstrated by producing 20,000 feat of product.

TBC-3295

A. Cimine and M. Marezio, Instituto Chimica Gen. e Inorg., e Centro di Chim. Gen. del C. N. R., Universita di Roma, Rome, Italy, "Lattice Parameter and Defect Structure of Cadmium Oxide Containing Foreign Atoms," Phys. Chem. Solids, Vol. 17, Nos. 1/2, 1960, pp. 57-64.

The incorporation of additives (In^{3+}, Ag^{1+} or Na^{1+}) into cadmium oxide has been studied by means of precision measurements of the lattice parameter a. It is that a varies linearly with $N^{1/3}$, where N is the concentration (atoms per cent) of additive. When In is added, a increases. The straight line obtained in the plot of a vs. $N^{1/3}$, however, does not extrapolate to the value of a of the pure oxide, but to a lower value. Initially, therefore, addition of In must decrease the lattice parameter. The result is interpreted as pointing to two distinct mechanisms of incorporation. The first mechanism (i) holds for the first fraction (0.02 per cent) of addition, and corresponds to the climination of interstitial cadmium excess, with consequent decrease of a. The second mechanism (ii) is a controlled valency process, which corresponds to a decrease of valency of cadmium ions, with consequent increase of a. Addition of Ag leads to a contraction of a. The result is explained by a mechanism as in (ii), except that the addition will cause an increase of valency, with consequent decrease of a. The possibility of alternate mechanism is dicussed. An excess of cadmium of the order of 0.01 per cent is inferred from the results. A thermal expansion coefficient of 1.35×10^{-5}°C is determined from lattice parameter measurements at different temperatures.

TBC-3296

R. Haul and D. Just, Institute of Physical Chemistry, University of Bonn Germany, "Disorder and Oxygen Transport in Cadmium Oxide," Journal of Applied Physics, Supplement to Vol. 33, No. 1, January, 1962, p.487.

Oxygen-18 exchange between gaseous oxygen and cadmium oxide crystals has been studied in the temperature range 630° to 855°C. Since isotope equilibrium is not instantaneously established at the crystal surface an appropriate solution for this particular diffusion problem has been given. In this way it is possible to evaluate rate constants (K) of the phase boundary reaction as well as lattice diffusion constants (D):

$D=3.8.10^{6}\ \exp(-92\pm4/RT)$; $K=1.3.10^{2}\ \exp(-49\pm11/RT)$.

The influence of the ambient oxygen pressure ($D\sim po_2^{-1/5}$) indicates that a vacancy mechanism is operative in the diffusion of oxygen. This is substantiated by the finding that diffusion is enhanced by incorporation of Li_2O. From experiments with doped crystals the fraction of vacancies can be estimated, e.g., $4.4\cdot10^{-4}$ in "pure" CdO at 790° and O_2. On the basis of thermodynamic considerations the energy of formation of defects can be estimated at 29 leaving 63 kcal/mole for the activation energy of the diffusion process proper.

The rate constant of the phase boundary reaction increases with decreasing oxygen pressure ($K\sim p_{O2}^{-1/3}$) as well as with increasing Li_2O addition. These findings offer a possibility for the suggestion of a mechanism of the surface exchange process.

TBC-3297

R. D. Armstrong, A. D. Sperrin, F. L. Tye, and G. D. West, Dep. Phys. Chem., Univ. Newcastle-upon-Tyne, England, "Mechanism of Discharge of Sintered Plate Cadmium Electrodes," Chemical Abstracts, Electrochemistry, Vol. 78, 1973, p. 568. Abstract No. 51583K. J. Appl. Electrochem., Vol. 2, No. 4, 1972, pp. 265-273 (Eng).

Sintered plate Cd electrodes were studied in alk. solns. using potentiostatic and galvanostatic techniques. The behavior is, in many ways, similar to that of a flat Cd electrode. A pseudo steady-state current is found due to the dissoln. of Cd as $Cd(OH)_4^{2-}$. At more anodic potentials passivation occurs owing to the solid state formation of $Cd(OH)_2$. This model can account for the results obtained on galvanostatic discharge.

TBC 3298

E. Bruder, Forsch. Entwicklungszent., Varta A.-G., Kelkheim, Germany, "Oxygen Evolution During Recharging of Positive Nickel Oxide Sinter Electrodes," Chemical Abstracts, Electrochemistry, Vol. 78, 1973, p. 569. Abstract No. 51584 Mo J. Appl. Electrochem, Vol. 2, No. 4, 1972, pp. 301-308 (Eng).

O evolution during anodic oxidn. of pos. Ni oxide electrodes is of theoretical and practical interest both for open and sealed storage batteries. The gas vol. produced on pos. sinter electrodes during the charging operation was plotted as a function of time. The influence of the anodic current and/or of the electrolyte temp. on the charging efficiency is discussed. The results permit the deduction of the optimum combination of charging parameters which are characterized by min. parasitic O formation. A small but continuous gas formation can be obsd. after the electrode is charged to ~50% capacity by using charging currents of the order of the 1 hr rate at ambient temp. At higher temps. the beginning of gassing is shifted toward lower charge levels, e.g. at 40° it already begins at a charge of ~17%. Furthermore, the gas vol, which is evolved during charging to identical levels, increases with increasing temps. and decreasing c. d. The described phenomenon can, at least in part, be explained by the decompn. of higher Ni oxides. The decompn. rate depends on charging time, charging current, and temp.

TBC 3299

R. Haul, D. Just and G. Dümbgen, Institut für Physikalische Chemie der Universitat, Bonn, Germany, "Sauerstoffdiffusion in Oxyden," Reactivity of Solids, 4th International Symposium on the Reactivity of Solids, Elsevier, Amsterdam, 1961, pp. 65-82.

Self-diffusion of oxygen has been studied by means of isotope exchange between gaseous oxygen and oxide crystals. The progress of this diffusion in the solid was followed by measuring the decrease in oxygen-18 concentration in the well-stirred gas of constant volume. Surface areas of the crystals as determined by low temperature krypton adsorption were used for the calculation of diffusion coefficients. Exchange was followed up to at least 30% of completion in order to ascertain that bulk diffusion is dealt with.

Measurements were carried out in the temperature range of 600 to 850°C using cadmium oxide crystals grown from the gas phase as well as sintered pellets. An activation energy of 93 $\pm$ 5 kcal/mole resulted for both samples. The D_o-value for the crystals is 8×10^6 cm^2/sec corresponding to an estimated activation entropy of 42 e.u. while the smaller D_o for the sintered material requires further discussion. The dependence of the diffusion coefficient on oxygen pressure has been studied at 766°C in the range from 75 to 690 mm Hg. The observed decrease of diffusion coefficients with increasing oxygen pressure,

$D \simeq p^{-1/6}$, is strong evidence for a vacancy mechanism. This is in agreement with the electrical conductivity measurements of Wagner. Obviously significant differences exist between cadmium oxide and zinc oxide, for which Moore has found an extremely large activation energy and an increase of diffusion coefficients with oxygen pressure. In addition experiments were carried out with cadmium oxide doped with mono- and trivalent oxides.

Furthermore, the dependence of the oxygen diffusion on temperature as well as pressure has been studied in titanium dioxide crystals obtained from synthetic single crystal boules. Preliminary experiments have been carried out with silicium dioxide in the form of quartz glass fibres and quartz crystals.

The influence of the surface isotope exchange reaction on the diffusion process is discussed in detail.

TBC 3300

Yoshifumi Yamamoto, Fac. Sci. Eng., Ritsumeikan Univ., Kyoto, Japan, "Characteristics in Charged or Discharged Condition of Pressed-Type Nickel Positive Electrodes Made by Using Polystyrene as a Binder," Chemical Abstracts, Electrochemistry, Vol. 82, No. 20, 1975, p. 395. Abstract No. 130915f. Translated from Denki Kagaku Oyobi Kogyo Butsuri Kagaku, Vol. 42, No 11, 1974, pp. 557-561.

The pressed type Ni [7440-02-0] pos. electrodes in which polystyrene [9003-53-6] was used as a binder were prepd., and compared with the polyethylene electrodes. The practical electrodes were made from $Ni(OH)_2$ 20, graphite 30, NH_4HCO_3 20, and 12% polystyrene soln. 30 wt.%. The potential and the overpotential at charged condition were lower than the polyethylene electrodes, and the potential at dicharged condition was a little higher. The self-discharge rates of these electrodes were ~10% higher than the polyethylene electrodes. In the case of polystyrene the mech. strength was greater than that of the polyethylene electrodes.

TBC 3301

Daijiro Yamashita and Isao Ohata, Fac. Sci. Eng., Ritumeikan Univ., Kyoto, Japan, "Sintered Type Alkaline Storage Battery. XV. Effect of Lithium Ion on the Formation of Active Material from Nickel Plaque at Various Temperatures," Chemical Abstracts, Vol. 82, No. 22, 1975, p. 162. Abstract No. 142630X. Translated from Nippon Kagaku Kaishi, No. 10, 1974, pp. 1876-1882 (Japan).

The effect of Li+ on the formation of active material from Ni [7440-02-0] plaque was studied at various temps. by the current-potential curves obtained with polarized Ni electrode in alk. soln. and the electromicrophotog. of the electrode surface. With increasing temps,

the amt. of active material formed from Ni plaque increases and the formation of Ni-Li compd. becomes more rapid. Thus, the oxidn. of Ni plaque is disturbed at higher temps. The increase in activity of OH in LiOH with increasing temp. is smaller than that in KOH. The active material produced by repeated oxidn. redn. cycles reacts with Li^+, resulting in shedding. Therefore, the over charge-discharge is not desirable when Li^+ is added to the electrolyte.

TBC 3302

Tsutomu Takamura, Tamotsu Shirogami and Toshiaki Nakamura, Toshiba Res. Dev. Cent., Tokyo Shibaura Electr. Co. Ltd., Kawasaki, Japan, "Electrochemical Impregnation of Nickel Hydroxide into a Porous Nickel Plate," Chemical Abstracts, Electrochemistry, Vol. 82, No. 22, 1975, p. 471. Abstract No. 146958h. Translated from Denki Kagaku Oyobi Kogyo Butsuri Kagaku, Vol. 42, No. 11, 1974, pp. 582-588 (Japan).

The optimum conditions to impregnate a porous Ni [7440-02-0] electrode of thickness 0.7 mm and porosity 75% with Ni $(OH)_2$ [12054-48-7] were detd. The max. capacity of the Ni-Cd cell, 34 mA/cm^2 was obtained with a Ni electrode impregnated at 10 mA/cm^2 to 150 mA/cm^2 in 0.5M $Ni(NO_3)_2$ [13138-45-9] soln. at 20°. The chem. anal. of NH_4OH in the soln. after impregnation indicated that the pH increase was due to the reaction: $NO_3^- + 9H^+ + 8e^-$ $NH_4OH + 2H_2O$. The capacity and rechargeability of this electrochem. impregnated electrode were satisfactory for practical use.

TBC 3303

I. A. Cherepkova, L. Henni, N. M. Kozhevnikova, and V. V. Sysoeva, Leningr. Tekhnol. Insts., Leningrad, USSR, "Electrophoretic Method of Preparation of Electrodes from Nickel (II) Hydroxide," Chemical Abstracts, Energy Technology, Vol. 82, No. 24, 1975, p. 147. Abstract No. 158591w. Translated from Kolloidn. Zh., Vol. 37, No. 1, 1975, pp. 105-109 (Russ).

Properties of $Ni(OH)_2$ [12054-48-7] suspensions in iso PrOH with poly(vinyl butyral) addn. were evaluated together with effects of the suspension compn. and the electrophoretic conditions on the electrochem. properties and thickness of deposited $Ni(OH)_2$. The resp. optimum suspension compn. and deposition potential for prepg. the title electrodes are: $Ni(OH)_2$ 20, poly(vinyl butyral) 8, iso-PrOH 72% and 20 V.

TBC 3304

Yoshimi Kanada, Ray-O-Van Co. (Japan) Ltd., "Nickel Electrodes for Alkaline Batteries," Chemical Abstracts, Energy Technology, Vol. 82, No. 24, 1975, p. 149. Abstract No. 158616h. Japan Kokai 74,114,748 (Cl. 57 C22, 57 B0), Nov. 1, 1974.

A Ni-salt, a neutralizer, and an oxidn.-agent solns. are sep. heated to 50-110° and mixed to ppt. Ni oxide [11099-02-8] which is useful as the active material in Ni cathodes of alk. batteries. The prepd. oxide is free of hydroxides, has a good elec. cond., and the alk. batteries prepd. from the oxide have improved discharge capacity. Thus, 2M $NiSO_4$ 1, 10% NaClO 2, and 50% KOH 4 1. were heated to 90° and mixed. After standing for 4 hr, the ppt. was washed with 1% KOH, dried, crushed to -80 mesh, mixed with graphite [7782-42-5] flakes and polystyrene [9003-53-6] and compacted.

TBC 3305

V. Ya. Omel'chenko and L. L. Kul'min, USSR, "Self-Discharge of Nickel Oxide Electrodes," Chemical Abstracts, Electrochemistry, Vol. 83, 1975, p. 486. Abstract No. 17545t. Tr. ivanov. Khim-tekhnol. in-ta 1973 (Vyp. 16), pp. 103-108 (Russ). From Ref. Zh. Khim. 1974, Abstr. No. 13L284, Title only translated.

TBC 3306

Kuniaki Inada, Shigeyuki Yamaguchi, Nolouo Shiojima, Naoshi Saiki, and Osamu Ishido, Ray-O-Vac Co., (Japan) Ltd., "Electrode Plate for Alkaline Batteries," Chemical Abstracts, Energy Technology, Vol. 82, No. 26, 1975, p. 157. Abstract No. 173515t. Japan Kokai 75 15,042 (Cl.57 C22), Feb. 17, 1975. 2 pp.

During electrode fabrication for alk. batteries a process involving repetitions of 4 steps, impregnation of a sintered substrate with active materials such as Ni and Cd salts, electrolysis, washing with water, and drying, the washing is done with water contg. a surfactant. The process serves to shorten the time required for impregnating the substrate with desirable amts. of the active material. Thus, a porous substrate obtained by coating a 10-20 mesh Ni screen (wire diam. 0.1-0.2 mm) with a 1:1 mixt. of carbonyl Ni [7440-02-0] and 2-5% aq. CM-cellulose [9004-32-4] soln., drying and heating at 700-900° in a N-H atm. for 5-10 min. was dipped into a $Ni(NO_3)_2$ soln., dried for 30-100 min at 40-60°, placed in an alkali soln. to cause deposition of $Ni(OH)_2$ [12054-48-7] within the substrate, washed with water con-g. a Pluronic-type nonionic surfactant, and dried. After 5 cycles, 9.2 g of the active material was deposited on the substrate as compared to 8.3 g deposited by the conventional method not using the surfactant.

TBC 3307

N. Yu. Uflyand, A. M. Novakovskii, M. P. Yashkov, N. V. Zubova, and Yu. A. Kuz'min, Nauchno-Issled. Akkumulyatornyl Inst., Leningrad, USSR, "Effect of Silicon on the Behavior of a Nickel Oxide Electrode," Chemical Abstracts, Vol. 82, No. 26, 1975, p. 418. Abstract No. 177102d. Translated from Elektrokhimiya, Vol. 11, No. 1, 1975, pp. 116-118 (Russ).

The dependence of the effect of Si [7440-21-3] on the compn. of the active mass of Ni oxide [11099-02-8] electrode in electrolytes of 4.9N NaOH + 5g LiOH/l., and 4.9N KOH + 10 g LiOH/l. soln., was studied by adding Na_2SiO_3 corresponding to 0.2 and 10 g Si/l. to these electrolytes. Cyclization of the Ni oxide electrodes, showed that, in presence of Si, the oxidn. degree of $Ni(OH)_2$ increased both in the charge and discharge conditions. Difficulty in electrode discharge occurred and the utilization coeff. diminished. By further cyclization, the cathodic redn. of the oxides increased and the utilization coeff. of the active elements of the electrodes working in electrolytes contg. Si reached that of electrodes in pure alk. soln. The addn. of Co [7440-48-4] to the electrode mass. facilitated the electrolytic redn. of the $Ni(OH)_2$ and repressed the neg. effect of Si in the 1st cycles.

TBC 3308

B. N. Afanas'ev, V. I. Bukarinov, and N. N. Milyutin, Leningr. Tekhnol. Inst. im. Lensoveta, Leningrad, USSR, "Determination of the Rate of Reduction of Oxygen at a Cadmium Electrode," Chemical Abstracts, Vol. 82, No. 26, 1975, p. 418. Abstract No. 177107j. Translated from Elektrokhimiya, Vol. 11, No. 2, 1975, pp. 270-272 (Russ).

The rate of O [7782-44-7] electroredn. on a rotating disk electrode of oxidized Cd was studied by plotting potentiostatic curves of the dependence of c.d. on time. Testing was carried out in a wide range of potentials from -1.100 to +0.300 V (vs. a std. H electrode) in 1 and 10N KOH [1310-58-3] (0-satd.) solns. at 25°. The dependence of c.ds. in O redn. on the potential was detd. as well as the Cd [7440-43-9] electrode rotation rate. In the passive range of potentials, the rate of O redn. was proportional to its concn. in soln. At more neg. potentials, the rate of O redn. depended on the rotation rate of the electrode and was limited by diffusion. The numerical value of the diffusion coeff. was calcd. and discussed, esp. with respect to divergence from values obtained by other authors.

TBC 3309

I. A. Cherepkova, V. A. Kas'yan, V. V. Sysoeva, N. N. Milyutin, and A. L. Rotinyan, Leningr. Tekhnol. Inst. im. Lensoveta, Leningrad, USSR, "Mechanism of Reduction at a Nickel Oxide Electrode," Chemical Abstracts, Vol. 83, No. 4, 1975, p. 434. Abstract No. 34749e. Translated from Elektrokhimiya, Vol. 11, No. 3, 1975, pp. 443-447 (Russ).

Expts. were carried out to det. the max. possible elimination of the effects of both (1) parallel occurrence of reactions at the solid phase/electrolyte interface and in the mass of the solid phase, and (2) the operation of the electrodes in depth (such as porous electrodes). Thin-layer electrodes were prepd. by electrophoretic deposition on a Ni substrate of a $Ni(OH)_2$ layer 20 μm thick. Also tested were electrodes of foil-type of thickness 0.6-0.7 mm. The chronopotentiometric measurements were carried out at c.ds. 3-170 mA/g in concd. KOH [1310-58-3] solns. (1.0-10.0N) in Pyrex cells contg. 3 compartments: for the NiO_2 [12035-36-8] electrode, for a Hg oxide comparison electrode, and a Pt auxiliary electrode. At high pos. potentials, the redn. of NiO_2 occurs with the formation on the surface of a hypothetical ion $Ni_2O_3^+$, according to the reaction: $2NiO_2 + H_2O + e^- \rightarrow Ni_2O_3^+ + 2OH^-$; $Ni_2O_3^+ + H_2O + e^- \rightarrow 2NiOOH$ (slow). Then the potential is somewhat shifted in the more neg. direction and the redn. of NiOOH begins: $NiOOH \rightleftarrows NiO^+ + OH^-$; $NiO^+ + H_2O + e^- \rightarrow Ni(OH)_2$ (slow); $Ni(OH)_2 + 2NiOOH \rightarrow Ni_3O_2(OH)_4$ [$Ni_3O_4 \cdot 2H_2O$].

TBC 3310

G. S. Zenin, V. V. Korzhavina, and V. V. Sysoeva, Leningr. Tekhnol. Inst. im. Lensoveta, Leningrad, USSR, "Electrochemical Behavior of a Nickel Electrode Studied by Impedance," Chemical Abstracts, Vol. 83, No. 4, 1975, p. 434. Abstract No. 34750y. Translated from Elektrokhimiya, Vol. 11, No. 3, pp. 448-451 (Russ).

The impedance method was used to clarify the peculiarities of the electrochem. behavior of a NiO_2 [12035-36-8] electrode, prepd. 1st by the electrochem. deposition of Ni [7440-02-0] on a Pt wire sealed in glass and then by preliminary oxidn. of the Ni electrode at 0.9 V (vs. std. H electrode) for 1 hr. The reactive and active components of the impedance were measured during galvanostatic redn. of the NiO_2 layer in KOH [1310-58-3] soln. (1.0-10.0N). The reaction $Ni_2O_3 \rightleftarrows Ni_3O_4$ occurs at an equil. potential by at least 2 parallel processes: (1) redn. of Ni oxide and (2) liberation of O, accompanied by the adsorption of the O-contg. particles. The exchange current for the redn. of Ni_2O_3 depends on the KOH concn., which indicates participation of the electrolyte in the electrode processes.

TBC 3311

Junji Mukunoki, Yoshio Shinoda, and Kenzo Kawashima, Matsushita Electric Industrial Co., Ltd., "Nickel-Base Electrodes for Alkaline Batteries," Chemical Abstracts, Energy Technology, Vol. 83, No. 10, 1975, p. 223. Abstract No. 82595y. Japan Kokai 75 02,137 (C1.57 C22) Jan. 10, 1975. 3 pp.

The electrodes are prepd. by cathodically treating porous, sintered Ni [7440-02-0] substrates in an aq. soln. contg. salts of electrode-active substances to impregnate the substrate with the salts, and subsequently treating the dried impregnated substrate in an alk. soln. to convert the salts to active substances. The cathodic treatment improves the impregnation efficiency. Thus, sintered Ni substrate having 70-80% porosity was cathodically treated at 5 A/dm^2 in aq. $Ni(NO_3)_2$ soln. (d. = 1.60 g/cm^3) for 10 min at 40° to give Ni substrate impregnated with $Ni(NO_3)_2$ - $Ni(OH)_2$ mixt., the substrate was dried at 80° for 30 min, and immersed in aq. NaOH (d. = 1.24 g/cm^3) to convert $NI(NO_3)_2$ to $Ni(OH)_2$. The impregnation and alk.-soln. treatment were repeated 2 more times to give a cathode plate for alk. batteries.

TBC 3312

Kuniaki Inada, Shigeyuki Yamaguchi, Nobuo Shiojima, Naoshi Saiki, and Osamu Ishido, Ray-O-Vac Co., (Japan) Ltd., "Electrode Supports for Alkaline Batteries," Chemical Abstracts, Energy Technology, Vol. 83, No. 10, 1975, p. 223. Abstract No. 82599c. Japan. Kokai 75 07,045 (C1,57 C22) Jan. 24, 1975, 3 pp.

Metal screens or perforated metal plates are coated with mixts. contg. metal powders and foamed binders, and they are sintered to give supports for alk. battery electrodes. These supports have high porosity and improved battery discharge duration. Thus, carbonyl Ni [7440-02-0] powder was mixed (1:1) with a foamed 2% Me-cellulose [9004-67-5] aq. soln., the mixt. was coated on a metal screen, and sintered 20 min at 900° in N to give an electrode substrate having 75-85% porosity. The substrate was impregnated with Ni active mass to give Ni cathode which was used together with similarly prepd. Cd anode in a Ni-Cd alkali battery of 1200-mA-hr capacity whose discharge duration was ~20% larger than that of a conventional battery.

TBC 3313

V. P. Tysyachnyi and O. S. Ksenzhek, USSR, "Self-Discharge of Nickel Oxide Film Electrodes with Various Degrees of Change," Chemical Abstracts, Electrochemistry, Vol. 83, No. 10, 1975, p. 545. Abstract No. 87185z. Translated from Vopr. Khim. Khim Tekhnol. 33, 1974, pp. 38-41 (Russ).

A study was made of the self-discharge of a partially charged Ni oxide [11099-02-8] electrode, with films of various thickness after interruption of the cathodic and anodic currents. The increase of potential, obsd. after interruption of the cathodic polarization, did not depend on the stirring rate of the electrolyte (12 N KOH); hence the concn. polarization in the liq. phase, did not appear to be the cause of this phenomenon. In the potential (mV) vs. logt (sec) discharge curves, obtained after cathodic current interruption, the potential increased at first, then it diminished, but the rate of potential increase did not depend on the thickness of the oxide film. The self-discharge curves, obtained after interruption of the anodic polarization, resulted in 2 linear portions of different slope, the 1st of which depended neither on the charge degree, at the moment of the cited interruption, nor on the film thickness. These results showed that the obsd. effects were due to phenomena which occurred on the surface layer of the oxide films.

TBC 3314

P. A. Antonenko, Dnepropetr. Khim-Tekhnol. Inst., Dnepropetrovsk, USSR, "Cermet Nickel Oxide Electrode. VI. Harmonic Analysis of Dynamic Characteristics of an Electrode," Chemical Abstracts, Electrochemistry, Vol. 83, No. 10, 1975, p. 545. Abstract No. 87187b. Translated from Vopr. Khim. Tekhnol., 34, 1974, pp. 82-86 (Russ).

By harmonic anal. of the dynamic characteristics of a trisectional cermet Ni oxide electrode in a given alkali (KOH, NaOH, LiOH) at a given temp. (-30 to +30°), the fraction of the polarizing current Yi(t) in the ith section of the model electrode is expressed as a trigonometric polynomial. Role of temp., nature of cation, etc. are analyzed.

TBC 3315

F. I. Kukoz and G. A. Shul'gina, USSR, "Improvement of the Technology of Sintered Cadmium (Battery) Electrodes," Chemical Abstracts, Electrochemistry, Vol. 83, 1975, p. 601. Abstr. No. 67615 m. Tr. Novocherkas. politekhn. in-ta 1974, No. 289, pp. 68-71 (Russ). From. Ref. Zh., Khim., 1974, Abstr. No. 20L223. Title only translated.

TBC 3316

R. D. Armstrong, E. H. Boult, D. F. Porter, and Hr. R. Thirsk, Department of Physical Chemistry, University of Newcastle upon Tyne, Newcastle upon Tyne 1, England," The Structure of Anodic Films Formed on Cadmium Single Crystals in Alkaline Solutions," Electrochimica Acta, Vol. 12, 1967, pp. 1245-1248.

Anodic films have been formed potentiostatically on electropolished cadmium polycrystalline and (0001) and (10$\bar{1}$0) single-crystal surfaces in 1 M NaOH solution. The films have been examined by glancing incidence electron diffraction and by electron microscopy. The anodic phase is identified as $Cd(OH)_2$, in parallel orientation with the single-crystal substrates at overpotentials >20 mV. For an overpotential of 20 mV these films are one-degree oriented.

TBC 3317

R. D. Armstrong, Electrochemistry Research Laboratories, Department of Physical Chemistry, University of Newcastle upon Tyne, Newcastle upon Tyne, NE1 7RU, England, "Diagnostic Criteria for Distinguishing Between the Dissolution-Precipitation and the Solid State Mechanisms of Passivation," Corrosion Science, Vol. 11, 1971, pp. 693-697.

Two mechanisms for the passivation of metals are considered: (A) dissolution-precipitation; (B) solid-state reaction in parallel with metal dissolution. It is shown that galvanostatic and ring-disc experiments are difficult to use to distinguish these mechanisms. Rotating disc methods are more rewarding in this sense.

TBC 3318

Manfred A. Gutjahr, Rudolf Schmid, and Klaus D. Beccu, Battelle Memorial Institute - International Division, "Nickel-Hydroxide Cathodes for Storage Batteries," Chemical Abstracts, Energy Technology, Vol. 83, No. 8, 1975, p. 311. Abstract No. 63391n. Ger. Offen. 2,427,421 (Cl. H01M). Jan 9, 1975, Swiss Appl. 8240/73, June 7, 1973, 15 pp.

The cathodes are obtained by successive spraying of molten Zn [7440-66-6] and Ni [7440-02-0] on a porous org. substrate (cellulose [9004-34-6] fiber, polyether foam plate), heating to ~700 in air and ~950° in reducing atm. to decomp. thermally the org. substrate and evap. An, resp. and chem. or electrochem. Deposition of $Ni(OH)_2$ [12054-48-7] in the porous sintered Ni mat.

TBC 3319

Peter Ness, Guenter Kraemer and Elvira Tisch, Varta Batterie A.-G., "Nickel Hydroxide Electrode," Chemical Abstracts, Energy Technology, Vol. 83, No. 6, 1975, p. 145. Abstract No. 45780j. Ger. Offen. 2,340,869 (Cl. H01M), March 13, 1975, 9 pp.

Alk.-battery cathodes cont. $Ni(OH)_2$ [12054-48-7] 90, $Co(OH)_2$ [21041-93-0] 37, and $Cd(OH)_2$ [21041-95-2] 3-7 mole% are obtained by copptn. of hydroxides from resp. salt solns. in an electrode frame.

TBC 3320

David F. Pickett, United States Dept. of the Air Force, "Cadmium Electrodes," Chemical Abstracts, Energy Technology, Vol. 83, No. 6, 1975, p. 145. Abstract No. 45782 m. U.S. patent 3,873,368 (Cl. 136-76; C22d, H01m), March 25, 1975, 7 pp.

The electrodes are prepd. by positioning a porous Ni [7440-02-0] plaque between 2 Cd [7440-43-9] sheets immersed in aq. $Cd(NO_3)_2$ (pH is 3-5) at 95-110°. After connecting the Ni plaque to the neg. pole and the Cd sheets to the pos. pole of a power source, d.c. is passed through the soln. at 1.2-1.6 $A/in.^2$ of plaque for 8-20 min causing deposition of Cd and $Cd(OH)_2$ [21041-95-2] inside the pores of the plaque. Electrodes so prepd. are esp. useful as anodes in Ni-Cd batteries.

TBC 3321

V. Z. Barsukov, N. N. Milyutin, P. A. Antonenko, and L. N. Sagoyan, USSR, "Relations of the Structural Characteristics of the Powder Metallurgical Nickel Oxide Electrode," Chemical Abstracts, Energy Technology, Vol. 83, No. 6, 1975, p. 144. Abstract No. 45778h. Translated from Sb. Rab. Khim. Istochnikam Toka, Vol. 9, 1974, pp. 86-90 (Russ).

The exptl. and theor. dependences were studied of the true residual porosity of the electrode on the filling degree of its porous space by the active mass. A satisfactory agreement between the exptl. and theor. values is reported. The homogeneous character of the electrode pores was verified photomicrog.

TBC 3322

David F. Pickett, United States Dept. of the Air Force, "Nickel Electrodes," Chemical Abstracts, Energy Technology, Vol. 83, No. 8, 1975, p. 310. Abstract No. 63371f. U.S. patent No. 3,827,911 (Cl. 136-24; H01m), August 6, 1974, 3 pp.

An electrode esp. useful as the pos. electrode in Ni-Cd batteries is prepd. A d.c. from a power source is passed through an alc. soln. of nickel nitrate or a mixt. of nickel nitrate and cobalt nitrate. The soln. contains a Ni plaque positioned between a pair of Ni sheets with the plaque being connected to the neg. pole and the sheets connected to the pos. pole of the power source. A d.c. is passed through the soln. for a time sufficient to convert metal nitrate which has impregnated pores of the plaque to the corresponding metal hydroxide. The Ni electrode is then washed and dried, ready for use in Ni-Cd batteries. Batteries made by using a Ni electrode prepd. by this method had a greater capacity per $in.^3$ and per lb than did one prepd. by using conventionally prepd. Ni electrodes.

TBC 3323

A. I. Kloss, V. A. Nikol'skii, V. D. Novoselova, and A. I. Baranov, USSR, "Removal of Calcium from the Electrolyte of an Alkaline Storage Battery with a Cadmium Anode," Chemical Abstracts, Energy Technology, Vol. 83, No. 6, 1975, p. 145. Abstract No. 45787s. U.S.S.R. patent 455,404 (Cl. H01m), December 30, 1974. Translated from Otkrytiya, Izobret., Prom. Obraztsy, Tovarnye Znaki, Vol. 51, No. 48, 1974, p. 105.

For increasing the degree of Ca [7440-70-2] impurity removal from e.g. Ni-Cd battery electrolyte, title process is carried out by using Ni hydroxide [11113-74-9] or $Cd(OH)_2$ [21041-95-2].

TBC 3324

P. A. Antonenko, Dnepropetr. Khim.-Tekhnol. Inst. Dnepropetrovsk, USSR, "Use of Experimental Planning Method in the Manufacture of Powder Metallurgy Nickel Oxide Electrodes for Alkaline Storage Batteries," Chemical Abstracts, Energy Technology, Vol. 83, No. 8, 1975, p. 309. Abstract No. 63350y. Translated from Vopr. Khim. Khim. Tekhnol., Vol. 34, 1974, pp. 79-82 (Russ).

Temps. and times were optimized for a 2-cycle impregnation treatment of Ni oxide [11099-02-8] electrode in a $Ni(NO_3)_2$ [13138-45-9] melt. A relation is given for the increase of the active substance in the electrode pores as a function of treatment parameters.

TBC 3325

George T. Croft and Donald Tuomi, Thomas A. Edison Research Laboratory Division, McGraw-Edison Co., West Orange, New Jersey, "A Model for Electrochemical Reaction Kinetics of Solid State Phase Transformations in Reversible Electrodes," J. Electrochemical Society, Vol. 108, No. 10, 1961, p. 915.

An atomistic model is presented for the reversible oxidation-reduction of a compound, MX, which separates a metal, M, from an electrolyte containing anions X. The electrochemical film growth is assumed to depend on the presence of lattice imperfections. The detailed mass and charge transport mechanism is controlled by the particular set of exchange reactions at the M-MX and MX-electrolyte interfaces. If cation vacancies and holes are the relevant lattice and electronic imperfection, there are four possible sets of exchange reactions. Each set and the distribution of the overpotential across each interface determines a particular electrochemical mechanism.

TBC-3326

K. H. Gayer and Leo Woontner, Department of Chemistry, Wayne State University, Detroit, Michigan, "The Equilibria of Cadmium Hydroxide in Acidic and Basic Media at 25°," J. Phys. Chem., Vol. 61, 1975, pp. 364-365.

The solubility of cadmium hydroxide has been studied in perchloric acid and in sodium hydroxide solution at 25°. Cadmium hydroxide was found to have fairly strong basic properties but it was also found to exhibit some acidic properties.

TBC-3327

George T. Croft, Edison Laboratory, Thomas A. Edison Laboratories, Mc Graw - Edison Co., West Orange, New Jersey, "Controlled Potential Reactions of Cadmium and Silver in Alkaline Solution," Journal of the Electrochemical Society, April 1959, p. 278.

Data are reported on the electrochemical oxidation and reduction of both cadmium and silver in potassium hydroxide electrolyte obtained using techniques in which the overpotential was the independent and the current the dependent variable. The rate of oxidation of cadmium is maximum at overpotentials of 18.0 and approximately 40.0 mv. The rate of reduction of cadmium and the of oxidation of silver are both monotonically increasing functions of the overpotential.

TBC-3328

A. J. Bosman and H. J. vanDaal, Philips Research Laboratories, N. V. Philips' Gloeilampenfabrieker, Eindhoven, The Netherlands, "Small-Polaron versus Band Conduction in some Transition-Metal Oxides," Advances in Physics, Vol. 19, No. 77, 1970, pp. 1-117.

In this paper an attempt is made to establish the nature of free charge carriers and of charge carriers bound to centers in p-type NiO, CoO and MnO and in n-type MnO and a-Fe_2O_3.

For free charge carriers, d.c. conductivity, Seebeck coefficient and Hall effect are considered. Effects arising from inhomogeneous conduction and impurity conduction are discussed. Impurity conduction appears to have a strong influence on transport properties in the case of a-Fe_2O_3, less so in NiO, whereas no influence of this effect has been found in CoO and MnO. It is shown that NiO and CoO do not exhibit the features characteristic of small-polaron conductors but rather can be consistently conceived of as large-polaron band semiconductors. It is suggested that magnetic resistance due to exchange coupling, between charge-carrier spin and cation spins plays an important role. The anomalous behaviour of the Hall effect in NiO, and a-Fe_2O_3 is extensively discussed. In contradistinction to NiO, CoO and n-type MnO, free charge carriers in p-type MnO seem to have small-polaron character.

For charge carriers bound to centres, dielectric loss, high-frequency conduction and optical absorption are considered. The dielectric loss data relate to Li or Na centres in NiO, CoO and MnO and to Ti, Zr, Sn, Ta, Nb and presumably oxygen vacancy centres in a-Fe_2O_3. It is concluded from the dependence of dielectric loss on frequency and temperature that bound charge carriers are small polarons. It is shown for the cases of NiO and a-Fe_2O_3 that apart from small-polaron effects, disorder due to locally varying electric fields determines the nature of dielectric loss. The small-polaron character of bound charge carriers in NiO is corroborated by the behaviour of high-frequency conduction and optical absorption due to centres and also by the magnitude of impurity conduction.

TBC-3329

I. G. Austin, Department of Physics, University of Sheffield and N. F. Mott, Cavendish Laboratory, Cambridge, "Polarons in Crystalline and Non-Crystalline Materials," Advances in Physics, Vol. 18, 1969, pp. 41-102.

The current state of polaron theory as applicable to transiton metal oxides is reviewed, including problems such as impurity conduction where disorder plays a role. An estimate is given of the conditions under which polaron formation leads to an enhancement of the mass but no hopping energy of a polaron to a donor or acceptor in narrow-band semiconductors is discussed. The experimental evidence about the conductivity of TiO_2 and NiO is reviewed. Impurity conduction in NiO and conduction in glasses containing transition metal ions is discussed and it is emphasized that the activation energy for hopping nearly all vanishes at low temperatures. Pollak's theory of a.c. impurity conductivity is reviewed and applied to the problem of dielectric loss in these materials.

TBC-3330

H. H. Bauer, "Electrochemical Behavior of Cadmium," J. Electroanal. Chem., Vol. 12, 1966, pp. 64-67.

Studies of the electrochemistry of the Cd(II)/Cd(Hg) system by polarography have been characterized by two features:

(I) Frequently, "anomalous" behaviour has been reported, i.e., behaviour indicating that the electrode process has a mechanism more complex than an electron-transfer step combined with solely diffusive mass transport.

(2) Results obtained in different investigations have not generally been in accordance. In ostensibly similar systems, anomalies have sometimes been reported; even in the absence of anomalies, reported values for the kinetic parameters (rate constant k, transfer coefficient) have generally differed.

It is shown that all reported observations are explicable by taking into account that mass transport is influenced by electrical migration of cadmium ions within the diffuse double layer.

TBC-3331

D. E. Ryans, J. R. Dean, and R. M. Cassidy, Department of Physics, Dalhousie University, Halifax, Nova Scotia, "Cadmium Species in basic Solutions," Canadian Journal of Chemistry, Vol. 13, 1965, p. 999.

The principal cadmium-containing species in basic solutions varies with the concentration of the hydroxide ion such that the solubility of cadmium hydroxide can be satisfactorily expressed, in solutions of high ionic strength, in terms of $[Cd(OH)^+] = 3.0 \times 10^{-9}[OH^-]^{-1}$, $[Cd(OH)_2]_{soln} = 1.0 \times 10^{-6}$, $[Cd(OH)_3^-] = 1.2 \times 10^{-6}[OH^-]$, and $[Cd(OH)_4^{2-}] = 3.1 \times 10^{-6}[OH^-]^2$. Since the solubility varies from 10^{-4} to 10^{-6} M, the predominant species at high concentrations of hydroxide ion is $Cd(OH)^{2-}$; at low concentrations of hydroxide ion $Cd(OH)^+$ is the pricipal cadmium-containgion in solution. There is little free cadmium ion in solutions whose hydroxide ion concentration is greater than 10^{-4}M.

TBC-3332

E. F. Lamb and F. C. Tomkins, Dept. of Chemistry, Imperial College, London, S.W.7, "Semi-conductivity and Thermoelectric Power of Cadmium Oxide," Faraday Society Transactions, Vol. 58, 1962, p. 1424

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

TBC-3333

R. D. Armstrong, K. Edmondson, and G. D. West, "The Electrochemical Behavior of Cadmium in Alkaline Solution," Electrochemistry, Vol. 4, 1974, pp. 18-32, published by the Chemical Society, London.

The anodic behavior of cadmium in alkaline solution is discussed. Planer cadmium electrodes and porous cadmium electrodes are both considered

TBC-3334

M. Fleischmann, K. S. Rajagopalan, and H. R. Thirsk, Chemistry Dept., King's College, Newcastle-upon-Type, 1, "Kinetics of Electrocrystallization of Thin Films of Cadmium Hydroxide," Faraday Society Transactions, Vol. 59, 1963, p. 741.

The formation of cadmium hydroxide on cadmium amalgam has been examined in alkaline solutions at constant potential. Approximately three monomolecular layers are deposited before passivation with the basal plane of the hexagonal crystals parallel to the amalgam. The kinetics of formation of the first two layers are amalyzed. It is shown that the slow stage of crystal growth is the formation of the lattice at the periphery of two-dimensional growth centres of monomolecular height, randomly nucleated on the surface. The variation of the crystal growth constant with potential and concentration implies that the rate-determining step is a rearrangement of two adsorbed hydroxide ions into the lattice planes containing these ions.

TBC-3335

M. W. Breiter and W. Vedder, General Electric Research and Development Center, Schenectady, New York, "Nature of Anodic Film on Cadmium in Alkaline Electrolytes," Faraday Society Transactions, Vol. 63, 1967, P. 1042.

Smooth cadmium electrodes with a surface essentially free of cadmium oxide and hydroxide were oxidized at constant potential between 0.05 and 1.0 V in various alkaline electrolytes. Layer formation was followed by recording the current as a function of time. Anodic films formed after different oxidation times at various potentials were investigated by electron microscopy, infra-red spectroscopy, and X-ray diffraction. The films grow non-uniformly on the surface. The number of nuclei increases with oxidation potential. Infra-red spectra demonstrate the presence of β-$Cd(OH)_2$ or γ-$Cd(OH)_2$, or a mixture of both types of hydroxide in agreement with X-ray diffraction results. The total amount of hydroxide decreases with potential and is, in general, smaller than the amount corresponding to 100 % efficiency of hydroxide formation. This deficit is attributed to the simultaneous formation of amorphous CdO. During the reduction at constant cathodic potential cadmium oxide and γ-$Cd(OH)_2$ disappear first, and then β-$Cd(OH)_2$. The conversion of anodically formed CdO into β-$Cd(OH)_2$ is a slow process.

TBC-3336

P. M. de Wolf, Laboratorium voor Technische Natuurkunde, Technische Hoge school, Delft, The Netherlands, "The Crystal Structure of γ-$Cd(OH)_2$," Acta Cryst. Vol. 21, 1966, p. 432 and correction Vol. 22, 1967, pp. 441

A new $Cd(OH)_2$ phase entirely different from the C6 type was discovered by Glemser, Hauschild & Richert (1957), who termed it γ-$Cd(OH)_2$. It shows a very close similarity to the hydroxyfluoride II' $Cd(OH)_{2-x}F_x$, χ=0.3 to 0.4 (Feirknecht & Bucher, 1943), the powder pattern of which can be indexed (Oswald, 1959) on the basis of an I-centered unit cell:

a=5.63, b-10.18, c=3.40Å; $\alpha=\beta=\gamma=90$

as compared with

a=5.67, b=10.25, c=3.41 Å; $\alpha=\gamma=90$; $\beta=91°.4$

for the pure γ-hydroxide. Moreover, the intensities of corresponding lines agree very closely.

Powder samples of both compounds were kindly submitted to us by Dr H. R. Oswald (Bern). The hydroxyfluoride was chosen for structure analysis because it produced sharper diffraction lines. Its structure can be regarded as essentially identical with that of γ-$Cd(OH)_2$, apart from partial (and in this work unobservable) replacement of OH by F, which will be disregarded in what follows.

The integrated diffraction intensities were obtained from microphotometer records of patterns taken with a Guinier-type camera using the χ_1 component of the Cu K doublet.

In view of the above data, the crystal was considered to be monoclinic, with b unique. A Patterson synthesis at once showed the metal positions, which were in accordance with the number Z=4 derived from Glemser's measured density value. Subsequently, a three-dimensional difference Fourier synthesis with coefficients $F_{obs}-F_{cd}$ (both F's taken as real) was prepared and investigated for each of the space groups 12, 12/m and Im allowed by the absence of special systematic extinctions. Due attention was given to the possible occurence of false or distorted maxima through the use of real coefficients. The first two space groups soon led to contradictions with the formula and with possible distance ranges. In Im, however, a direct and unambiguous interpretation of the three main peaks in the difference synthesis (all at z=0 and 1/2) was possible. The resulting positions were refined by changing the parameters (including the scale factor and an isotropic temperature factor) successively and in steps (Bhuiya & Stanley, 1963) until a minimum of $\Sigma\ (I_{obs} - I_{calc})^2$ was reached, leaving out the strongest two lines. This program was written by Drs J. W. Visser (Delft), who adapted the method to the case of powder intensities with overlapping lines. The atomic scattering factors were desired from analytic expressions given ty Moore (1963) for Cd and O^-. The final value of the temperature factor was 1.8 . The combined effects of absorption in the specimen, oblique incidence on the film and the correction for the Guinier camera geometry were accounted for

by a factor 1 +[0.8 sec (20-30) -1]. The polarization factor was 1 + 0.45 $\cos^2 20$. Tables 1 and 2.

TBC-3337

A. K. N. Reddy, Department of Inorganic and Physical Chemistry, Indian Institute of Science, Bangalore - 12 (India), "On the Dissolution - Precipitation Model of Anodic Film Formation," J. Electroanal. Chem. Vol. 28, 1970, pp. 217-220.

Comments are offered on interpretation of galvanostatic and potentiostatic experiments relative to the dissolution-precipitation model for anodic film formation. It is concluded that low current density results in non-passivating films, whereas high current density results in passivating films.

TBC-3338

R. D. Armstrong, J. D. Milewski, W. P. Race and H. R. Thirsk, Electrochemistry Research Laboratory, Department of Physical Chemistry, University of Newcastle, Newcastle upon Tyne, NE1 7RU, England, "The Effect of Anodic Film Formation on the Dissolution of Cadmium Amalgam in Alkaline Solution," J. Electronal. Chem., Vol. 21, 1969, pp. 517-524.

An earlier investigation of anodic film formation on cadmium amalgam in alkaline solutions showed that the film was one degree oriented β-$Cd(OH)_2$ with the basal plane parallel to the electrode surface. Examination of potentiostatic i-t transients led to the conclusion that the $Cd(OH)_2$ was formed by the successive deposition of monomolecular layers. The concentrations of cadmium species in equilibrium with $Cd(OH)_2$ indicate that it should be possible to measure the kinetics of dissolution of Cd(Hg) at potentials which include the potentials of stability of the anodic film. Such a study which is central to the problem of passivity of metals has certain advantages when carried out on a liquid metal surface. The most important of these is the simplification which arises from the absence of dislocations.

TBC-3339

R. D. Armstrong, Electrochemistry Research Laboratories, Departement of Physical Chemistry, University of Newcastle upon Tyne, Newcastle upon Tyne, NE1 7RU, England, "Diagnostic Criteria for Distinguishing Between the Dissolution-Precipitation and the Solid State Mechanisms of Passivation," Corrosion Science, Vol. 11, 1971, pp. 693-697

Two mechanisms for the passivation of metals are considered: (A) dissolution-precipitation; (B) solid-state reaction in parallel with metal dissolution. It is shown that galvanostatic and ring-disc experiments are difficult to use to distinguish these mechanisms. Rotating disc methods are more rewarding in this sense.

TBC-3340

F. P. Koffyberg, Department of Physics, Brock University, St. Catherines, Ontario, Canada, "Electronic Conduction and Defect Equilibria in CdO Single Crystals," Journal of Solid State Chemistry, Vol. 2, 1970, pp. 176-181.

Measurements of the equilibrium carrier concentration in pure, degenerate CdO single crystals grown by an iodine vapor transport process and quenched after equilibriation with oxygen in the pressure range from 2×10^{-4} to 1.00 atm at temperatures from 605 to 828°C shown that the donor defect is doubly ionized. The dependence of carrier concentration on oxygen pressure and temperature can be explained satisfactorily on the basis of a mode in which the conduction band deviates from the simple parabolic shape by the addition of donor energy levels. The free energy of formation of the donors is 1.95 eV, which differs from the vacancy formation energy as deduced from previous oxygen diffusion measurements. However, the measured donor concentrations are in good agreement with the defect concentrations determined from previous chemical, electrical, and diffusion measurements. The carrier mobility at room temperature is determined only in part by ionized donor scattering.

TBC-3341

Von Oskar Glemser, Ulrich Hauschild, and Hans Richert, "About a New Polymorphic Modification of Cadmium Hydroxide," Translated from Z. Anorg. Chem., Vol. 290, 1957, pp. 58-67 (Ger.).

The following describes the hydrolysis of cadmium alkaly, for example:

$Cd(CH_3)_2+2HOH = Cd(OH)_2+2CH_4$

hydrolized cadmium methyl in 96% percent ethanol at -10° to 0°c to γ-$Cd(OH)_2$ of a new crystalline modification of the cadmium hydroxyl ion. Density = d_4^{25}= 4.819/cm^3, viscostly 1.2x10^{-3} Mol/ℓ. When heated with water in a steel container to 150°, this γ-$Cd(OH)_2$ changes in 4 days to large crystals of β-$Cd(OH)_2$[C6-Typ]. In vacuum, under conditions of torr at 115°, the new hydroxide changes to CdO and H_2O. Ultraviolet pictures suggests hydrogen linkages from the observed ovsorption bands; a minimum O-O band distance of 2.74Å is observed, as well as two different Cd-O bands: 1. Cd-O=2.37Å; 2. Cd-O=2.40Å. For γ-$Cd(OH)_2$ peaked oscillations (δ) of the hydrogens of the OH group are shown.

TBC-3342

D. J. Gordy, Gould Inc., Gould Laboratories, Energy Research, Mendota Heights, Minnesota, "Fabrication & Testing of Negative-Limited Sealed Nickel-Cadmium cells," Final Report No. 752-015, 1 July 1974 to 28 February 1975. Jet Propulsion Laboratory Contract No. 953680 (March 31, 1975)

Based on technology developed on a preceding program 100 each 20 Ah and 3 AH negative limited nickel-cadmium cells were fabricated and assembled in hermetically sealed stainless steel containers. A portion of these were delivered directly to Jet Propulsion Laboratory and the remainder were subjected to special tests and then delivered to the Laboratory.

The cells were purposely designed and shown to exhibit a desired large voltage rise signal, in excess of 250 mA, at the end of each charge period. This built-in voltage characteristic is quite attractive for charge control purposes in that conventional sealed nickel-cadmium cells exhibit little or no such detectable signal at the end of charge. Other attractive features were that the negative limited cells exhibit lower self discharge rates than conventional sealed nickel-cadmium cells and do not require overcharge as do these cells. It was shown that the negative limited cells are capable of operating at charge and discharge rates up to 5C and can deliver at least 1000 cycles on a 30-minute regime at 25% DOD.

The cells were found to be not entirely gas free as was intended at the start of the program. Extent of the gassing was not deemed critical or detrimental however in view of the observed operating pressures which were in the range of 7 to 20 psig for most test conditions as well as the fact that the cells were operated in the flooded conditions and therefore contained very little internal void volume. A yet to be explained result was that the cells were found to exhibit somewhat higher capacity loss rates during cycling than conventional sealed nickel-cadmium cells. When this latter problem is resolved the negative limited cells should constitute a significant advance in the state of the art of sealed nickel-cadmium cell technology.

TBC-3343

E. Rabinowicz, R. H. McEntire, and B. Shiralkar, Massachusetts Institute of Technology, Cambridge, Massachusetts, "A Technique for Accelerated Life Testing," Preprint No. 1068, February 1970.

If it is assumed that test specimens fail as soon as the damage accumulated in them reaches some definite amount, then a simple accelerated testing technique can be devised. Some specimens are failed under uniform accelerated conditions, while others are failed partly under normal conditions and partly under accelerated conditions, and a graphical procedure then gives the life under normal conditions. Experimental tests with light bulbs, electric hand drills, electric motors, and bearing balls gave results which were consistant with the cumulative damage criterion, even though the modes of failure of the test specimens varied widely. (This report does not discuss applications to batteries, but the method is of interest for battery testing.)

TBC-3344

P. Hersch, Development and Research Dept., The Mond Nickel Companl Limited, Birmingham, "Mechanisms of Self-Discharge of the Negative of Alkaline Accumulators," Trans. Faraday Society, Vol. 51, 1955, p. 1442.

The self-discharge of the negative in nickel-iron batteries is caused mainly by the anaerobic attack of the active material by water. As in other instances of corrosion, this process can be retarded by cathodic protection. A cadmium negative is practically immune against water, but in an incompletely sealed battery local action occurs due to reduction of oxygen at the three-phase boundary, supporting rods - electrolyte - atmosphere.

TBC-3345

Clifford A. Hampel (Editor), "Rare Metals Handbook," Second Edition, Reinhold Publishing Corporation, 1961, pp. 82-92.

A summary is given of the occurence, purification, physical properties, chemical properties, toxicity, alloys, fabrication techniques, and applications of cadmium.

TBC-3346

Guy Rampel, "Process of Forming Rechargeable Electrodes Utilizing Unsintered Fluorocarbon Binder," U.S. patent 3,630,781, December 28, 1971, assigned to General Electric Company. (9 claims, no drawings)

Polytetrafluoroethylene in aqueous dispersion is mixed with a finely divided electrochemically active rechargeable electrode material, such as zinc, zinc oxide, cadmium, cadmium oxide, nickel oxide, copper, copper oxide, silver, silver oxide, mercuric oxide, etc. The dispersion is broken by drying, freezing, solvent extraction, etc. Where zinc particles form the active material it may be desirable to amalgamate the zinc with mercury.

TBC-3347

Guy G. Rampel, "Cell Having Anode Containing Silver Additive for Enhanced Oxygen Recombination," U.S. Patent 3,877,985, April 15, 1975, assigned to General Electric Company, Owensboro, Ky. (4 claims, 3 drawing figures)

A nickel-cadmium, secondary cell having the cadmium electrode impregnated with metallic silver to catalyze the oxygen recombination reaction and thereby helping to avoid excessive gas pressure due to oxygen generated during cell overcharge.

TBC-3348

Edward A. Grens II and Charles W. Tobias, Department of Chemical Engineering, University of California, Berkley, California, "Analysis of the Dynamic Behavior of Flooded Porous Electrodes," Berichte der Bunsengellschaff, Vol. 68, No. 3, 1964, pp. 236-249.

A one dimensional model is developed to represent flooded porous electrodes in which there is no bulk flow of electrolyte in the pores. The model includes consideration of changes in composition and conductivity of the electrolyte with depth in the pores. Electrode

TBC-3348

reactions characterized by overpotential expressions of quite arbitrary form can be treated. Analysis is conducted by numerical techniques to furnish descriptions of electrode behavior for both steady state and transient operation. Electrode overpotential, and current and concentration distributions, are predicted as functions of operating conditions. The calculation procedure is implemented with digital computing machinery. Examples based on a cadmium anode in basic solution and on a redox electrode in excess inert electrolyte are investigated. General characteristics of porous electrode performance are discussed. For the cadmium anode, it is concluded that short pores are best.

TBC 3349

N. F. Budgen, "Cadmium, Its Metallurgy, Properties and Uses", C. Griffin & Co., London (1924).

Although this is an older book, it is one of the few devoted to cadmium and is a good source of information on the metal. It gives thorough treatment of this subject up to 1924, and contains good summaries of results from the older literature, plus important old literature references.

TBC 3350

Per Kofstad, "Nonstoichiometry, Diffusion and Electrical Conductivity in Binary Metal Oxides", Wiley & Sons, New York (1972).

Contains useful chemical and solid state information on nickel oxide and cadmium oxide.

TBC 3351

J. W. Mellor, "A Comprehensive Treatise on Inorganic and Theoretical Chemistry,"Vol. 4, pp. 454-473, Longmans, Green & Co., London (1952 printing).

An older classic chemistry reference, with an old but useful treatment on cadmium and its compounds.

TBC 3352

R. W. Ohse, "An Oscillographic Investigation of the Electrode Reaction in the System Cd-Aqueous Solution by the Intermittent Galvanostatic Method", Z. Elecktrochem., 64, p 1171 (1960).

Interrupter experiments were conducted on the cadmium electrode. It is concluded that $Cd(OH)_2$ is formed first, then later partially dehydrated to form a CdO layer between the cadmium metal and the hydroxide.

TBC 3353

S.Yoshizawa and Z. Takehara, Department of Industrial Chemistry, Faculty of Engineering, Kyoto University,"On Electrode Phenomena of Cadmium in the Alkaline Battery: The Discharge Mechanism", Electrochimica Acta, Vol. 5, pp 240 to 257 (1961).

The discharge mechanism of the cadmium electrode in the alkaline battery was examined by means of electron microscopy, X-ray and electron diffraction, observation of decay and growth of overpotential and current/potential relations. Cadmium seems to be transformed to cadmium hydroxide through an intermediate product, probably (from electron microdiffraction

after discharge at low temperature in dilute potassium hydroxide solution) cadmium oxide. This dissolves as the complex ion ($[HCdO_2]^-$) and then deposition of cadmium hydroxide on the electrode surface takes place. The overpotential is largely caused by ionic migration in the intermediate layer, which may be explained the current/potential relation and the decay and growth of overpotential.

TBC 3354

K. Huber, J. Electrochem. Soc., "Anodic Formation of Coatings on Magnesium, Zinc and Cadmium," 1953, 100, p. 376.

A report is given of recent investigations of anodically formed coatings on magnesium, zinc and cadmium in NaOH and Na_2CO_3 solutions. The growth of the coatings was followed by means of X-ray and electron diffraction and electron microscopy. It was found that the metal oxide was favored as initial product. Depending upon the relative magnitude of the solubility products, the coatings remained in the form of oxides or were converted into the respective hydroxides or carbonates. The semiconductance of the initial coatings was significant in determining the electrochemical behavior of the electrodes.

TBC 3355

Y. Okinaka, Bell Telephone Laboratories, Incorporated, Murray Hill, New Jersey, "On the Oxidation-Reduction Mechanism of the Cadmium Metal -- Cadmium Hydroxide Electrode," J. Electrochem, Soc. 117, pp 289-295, (1970).

Electrochemical oxidation-reduction processes of the $Cd/Cd(OH)_2$ electrode in concentrated alkaline solutions were investigated by using a rotating ring-disk electrode as well as a stationary electrode. Results support the mechanism that the anodic oxidation of Cd to $Cd(OH)_2$ in the active potential range proceeds entirely through the dissolution-precipitation sequence, while the cathodic reduction of $Cd(OH)_2$ takes place both through the solution phase and by a direct solid-state mechanism.

TBC 3356

P. E. Lake and J. M. Goodings, University of Toronto, "The Nature of the Cadmium Ions in Hydroxide and Carbonate Solutions," Canadian Journal of Chemistry, Vol. 36 (1958) pp 1089-1096.

The nature and concentration of the cadmium-containing ions in potassium hydroxide and potassium carbonate solutions have been studied polarographically. Cadmium can exist in finite concentrations in concentrated hydroxide and carbonate solutions in the form of complex ions $Cd(OH)_4^{-2}$ and $Cd(CO_3)_3^{-4}$ respectively. The hydroxide-cadmium complex is the more stable of the two. The coordination number for the hydroxide-cadmium complex is 4 and its dissociation constant 2×10^{-10}. The coordination number for the carbonate-cadmium complex is 3 and its dissociation constant 6×10^{-7}.

TBC 3357

J. Harivel, B. Morignat, J. Migeon and J. Laurent, "Investigation on Physicochemical Oxidation-Reduction Mechanisms of Porous Electrodes Impregnated with Cadmium Hydroxides", Dec. 1965 Advances in Battery Technology Symposium, Southern California-Nevada Section, Electrochem. Soc., pp. 219-240.

Studies are reported in the cadmium electrode, including solubility in KOH.

TBC 3358

S. Gilman and L. Sangermano, "Adsorption of Cadmium Ions from KOH Solution at a Platinum Electrode", J. Electrochem. Soc., 118, pp 1953-1957 (1971).

The adsorption of cadmium ions on a platinum electrode was verified. Evaluation is made of the nature and extent of the adsorption process, which degrades the electrode.

TBC 3359

R. Visco and R. Sonner, "The Soluble Cadmium Species in Strong Base", Extended Abstract No. 7, Electrochem. Soc., Fall Meeting, Oct. 1969, pp 18-21.

Solubility studies of cadmium species were studied using a polargraphic technique. Solubility results agreed with those of Jost (Ref. 456). It was concluded that the principle soluble species was $Cd(OH)_3$.

TBC 3360

A. R. Hutson, in "Semiconductors", N. B. Hannon, Ed., Reinhold Publishing Co., New York, N. Y. (1959).

Information is reported on the electrical conductivity of CdO.

TBC 3361

G. Halpert, "Electrolyte Concentration Changes During Operation of the Nickel Cadmium Cell", Goddard Space Flight Center Report X-711-75-135, May (1975).

This paper discusses concentration and distribution of aqueous potassium hydroxide (KOH) electrolyte in a sealed nickel cadmium cell. Reactions at both electrodes during charge and discharge involve the production or utilization of hydroxyl ion (OH^-) or water (H_2O) which

directly affects concentration. Changes in electrolyte concentration relative to the individual electrode reactions is discussed. In addition to the changes at each electrode, there is a net change in concentration in the cell as a whole. During charge there is an increase in water and during discharge, a decrease in water. There is also a decrease in OH^- on charge and increase during discharge. The net effect is a significant decrease in concentration from beginning to end of charge and increase during discharge. The extent of precharge must also be considered in that during this process OH^- is converted to water which also dilutes the electrolyte.

Quantitative values are provided for the changes in concentration for 6, 12 and 20 ah cells with accepted quantities of precharge and accepted initial quantity of 31% aqueous KOH. Consideration is given to a more correct equation which includes net changes in hydroxyl concentration in addition to water. Also, expected concentrations of electrolyte in cells in the fully charged, 75% charged, 50% charged, 25% charged and discharged condition are calculated. The expected concentration changes for cells in the accelerated tests at NAD Crane are also tabulated and compared with measured values. All calculations are made on the assumption that there are no side reactions to the ones described.

TBC 3362

J. P. G. Farr and N. A. Hampson, "The Anodic Behavior of Cadmium and Lead in Alkali", Electrochemical Technology, 6 Feb. 1968, pp 10-15.

The anodic behavior of cadmium and lead in alkaline solution has been investigated. The metals develop surface films well before the potential rises to that for oxygen evolution at cadmium anodes and for the transition from the Pb (II) to the Pb (IV) oxidation state at lead anodes. No simple law was found relating passivation time and current density. For cadmium, the grain size of the passive layer was influenced by the current density and electrolyte concentration. Comparison of the metals is made with zinc. Among the three metals, formations of surface films during the "active" regions of polarization corresponded to the solubilities of the anodic products in the electrolyte.

TBC 3363

L. May, "The Effect of the Electrolyte on the Open Circuit Potentials in the Nickel-Cadmium Cells", Goddard Space Flight Center Report X-711-75-271, Oct. 1975.

Properties of the electrolyte and its contribution to the open-circuit (equilibrium) potentials in the cell were examined. Potentials for the cell and each half-cell were calculated at various concentrations of the hydroxide and at various temperatures. As the cell

is discharged or charged, the concentration of the hydroxide in the electrolyte changes. The potentials at various depths of discharge can be evaluated from the calculations. The effect of carbonate on cell potentials was calculated using the data available in the literature. The presence of carbonate in the system suggests that other electrochemical couples are present: i.e., a) nickel hydroxide; cadmium carbonate; b) nickel carbonate: cadmium hydroxide; and c) nickel carbonate: cadmium carbonate. The fundamental data for calculating the mixed potentials involving the carbonate are not available.

TBC 3364

G. Sivaramaiah, P. V. Vasudeva Rao and H. V. K. Udupa, "Direct Electrochemical Reduction of Cadmium Oxide in Alkaline Electrolyte", (Central Electrochemical Research Institute, Karaikudi-623006). Transactions of SAEST, Vol. 9, October-December 1974.

The conditions under which the direct reduction of certain metal oxides-hydroxides occurred, were applied to the reduction of cadmium oxide in contact with a nickel substrate in alkali electrolyte. This more or less represented the situation under which a negative plate of a sintered plate nickel-cadmium battery is placed during the charging process. It has been found that the reduction of cadmium oxide proceeds predominately in the solid phase and the particle size of the reduced metal is not affected by c.d. at low concentrations of alkali up to 5N (i.e., 20%). At higher alkali concentrations the reduction occurs both in the solid phase and by dissolution and deposition mechanism due to increased solubility of the cadmium oxide.

TBC 3365

Y. Okinaka and C. M. Whitehurst, Bell Telephone Laboratories, "Charge Acceptance of the Cadmium-Cadmium Hydroxide Electrode at Low Temperature", J. Electrochem. Soc., 117, pp 583-587, (1970).

Premature hydrogen evolution occurs when a discharged cadmium hydroxide electrode is brought to a low temperature and charged at a moderate rate. It was found that, in addition to various other known factors, the discharge rate and the temperature during discharge just prior to the temperature lowering greatly affect the charge acceptance in the first low temperature charge. Light and electron microscopic examination and BET surface area measurement showed that the cadmium hydroxide crystals formed at lower discharge rates and at higher temperatures are larger in size and more difficult to reduce. The results are interpreted on the basis of the mechanism involving a soluble intermediate species in both the charging and the discharging reactions. X-ray and electron diffraction analyses of the cadmium hydroxide crystals formed on discharge in 6.9N KOH at temperatures below -18°C showed the presence of γ -$Cd(OH)_2$

in addition to the ordinary B -$Cd(OH)_2$. Electrodes containing γ -$Cd(OH)_2$ have a greater low-temperature charge acceptability than those containing B -$Cd(OH)_2$ alone.

TBC 3366

D. M. MacArthur, Bell Labs., "The Anodic Dissolution of Cadmium, Zinc and Silver", Extended Abstract 240, 1968 Spring Meeting of the Electrochemical Soc.

The mechanism of dissolution of cadmium, zinc and silver was studied by the chronopotentiometric method. In this type of experiment a constant current is applied to the electrode and the time to the occurrence of the rapid potential change on passivation is measured. In the derivation of the potential-time relationships, it is generally assumed that mass transfer is solely controlled by linear diffusion. In this work the experimental procedure satisfactorily met this condition. It was also found that reproducible results could only be obtained by using a fresh surface for each experiment.

From these results several conclusions may be drawn: (1) The Ag - Ag (I) reaction at the test current densities is by film growth with no dissolution; (2) The Cadmium reaction is by dissolution followed by a homogenious reaction in competition with precipitation; (3) The Zinc reaction does not fit into any of the models.

TBC 3367

S. Yoshizawa and Z. Takehara, Kyoto University, "Studies on the Cadmium Electrode. III. An Intermediate Product at the Discharge of the Cadmium Electrode," Denki-Kagaku 32, 203 (1964). (See J. Electrochem. Soc., Japan, 1964, 32, 59+) (1964).

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.

TBC 3368

S. Yoshizawa and Z. Takehara, Kyoto University, "Studies on the Cadmium Electrode. IV. Overpotential During the Discharge of the Cadmium Electrode", Denki-Kagaku 32, 266, 1964. (See J. Electrochem. Soc., Japan, 1964, 32, 107).

With a view to studying the mechanism of the discharge from a cadmium electrode in alkaline solution, the decay and build-up characteristics of overpotential, and the relationship between current and potential during discharge were measured with the oscilloscope and recording potentiometer.

The cadmium electrodes used were prepared by electroplating. The electroplated cadmium platinum electrode was oxidized anodically in a KOH solution containing KNO_3, after this it was reduced cathodically in a KOH solution saturated with CdO.

In the discharge process from the cadmium electrode, cadmium dissolves into the solution electrochemically as $(HCdO_2)^-$ through an intermediate substance, probably cadmium oxide. However, cadmium oxide accumulates on the electrode after once the solution becomes saturated with $(HCdO_2)^-$. Then the oxide layer deposited onto the electrode surface dissolves chemically and is transformed into the hydroxide. All the results obtained can be explained on the basis that the overpotential consists of a shift in the equilibrium potential due to the above mentioned mechanism and in the diffusion resistance of Cd^{2+} in the cadmium oxide layer. Therefore, the major part of the overpotential depends upon the migration of the cadmium ion in the oxide layer in the $(HCdO_2)^-$ saturated solution.

TBC 3369

A. A. Abdul Azim and K. M. El-Sobki, Laboratory of Electrochemistry, National Research Centre, Dokki, Cairo, U.A.R., "On the Mechanism of the Cadmium Electrode in Alkaline Solutions", Electrochemica Acta, 17, pp 601-608 (1972).

The electrochemical behaviour of the Cd electrode in 0.1-6N NaOH has been investigated. Both the potentiostatic and galvanostatic techniques were employed. It has been shown that the electrode surface is primarily covered with a porous layer of $Cd(OH)_2$ which is precipitated from the solution. Above the Flade potential, CdO starts to form at the exposed metal parts. The results are discussed in the light of the dissolution - precipitation and the solid-phase transport mechanisms.

Crystal growth of B-$Cd(OH)_2$ active materials were found not responsible for the so-called "memory effect" in the nickel-cadmium cells. "Memory effect" was conclusively found to be caused by the $Ni(OH)_2$ or positive plates.

TBC 3372

G. Halpert, W. W. Webster, C. C. Jones, O. Ogunyankin, "Procedure For Analysis of Nickel-Cadmium Cell Materials," Goddard Space Flight Center Report X-711-74-279, Oct. 1974.

This document is intended to provide a comprehensive physical/chemical analysis procedure for nickel-cadmium cells. From the analytical results, characteristics and changes in characteristics of plates, separator and electrolyte can be determined. These results can be used to isolate problems in cell manufacture and/or suggest areas for cell improvement. The analysis is presented in a detailed stepwise manner and includes the principle of each procedure, reagents and materials required, and recommended calculations. The detailed data are recorded on data sheets in Appendix A. The data sheets are coordinated with the analytical procedures by number. Appendix B summarizes the analytical data and provides a suitable form for management review.

TBC 3373

B. Bring and S. Landstedt, Svenska Ackumulator Aktiebolaget Jungner, "Studies on Current Distribution at Nickel and Cadmium Electrodes by Laser Interferometry," in Power Sources 4, D. H. Collins, Ed., Oriel Press (1973).

An optical method has been used for measuring local current densities in the electrolyte close to the electrodes. The basic components and principles of operation of a laser interferometer are described. The paper discusses variations in the density of hydroxyl ions and explains the origin of the heat observed. On the basis of these discussions, it is shown that the local current density can be measured from interferograms. As a result it is shown that the current density distribution is not critical for either sintered or pocket type electrodes at the current densities used.

TBC 3374

G. Milazzo, Istituto Superiore di Sanita, Rome, "Electrochemistry," Elsevier Publishing Co., (1963).

This textbook discusses primarily the fundamental concepts of electrochemistry. Familiarity with basic chemical and physico-chemical concepts is assumed, but the book is designed primarily for the non-specialist.

TBC 3370

S. Yoshizawa, Z. Takehara and M. Matsui, Electron Microscopic Studies on Surface Structure of Cadmium Hydroxide Electrode, J. Electrochem. Soc. Japan (Denki Kagaku, Overseas Suppl. Ed.) 28, No. 1-3, E9-E14 (1960).

Electron microscopic studies were conducted on smooth cadmium electrodes. It was observed that cadmium hydroxide crystals gradually enlarge during discharge, and that cracks are seen on the surface of some crystals. Reactive and unreactive parts exist simultaneously on the electrode surface.

TBC 3371

Chua, David., Rensselaer Polytechnic Institute, "Relationship of Electrode Structures and Cell Performance in Sealed, Sintered-Type Nickel-Cadmium Button Cells During Cycling", Ph. D. Thesis, 1974.

The purpose of this investigation is to determine whether a correlation exists between the performance of the nickel-cadmium cell and the morphological structures of the plates during prolonged cycling. Numerous cells were conditioned and matched then subjected to cyclic charge-discharge under deep and shallow discharge regimes.

Operating variables consisted of a specified charge-discharge rate, time of charge and discharge, termination conditions, and depth of discharge (DOD) at specified temperatures. Each mode of operation was quantitatively described by cell voltage, capacity, and impedance measurements. At an arbitrarily selected cycle number, the plates from the disassembled cell were structurally characterized by scanning electron microscopy, optical microscopy, and x-ray diffraction. The limiting electrode of the cycled plates was detected by half-cell measurements using the galvanostatic technique and under the flooded condition.

Sealed nickel-cadmium cells made of sintered plates were found to exhibit capacity degradation during extended charge-discharge cycles. Under slow to moderate discharge rates, drastic changes in negative plate's morphology occurred and this dramatic change was found to be effected by the severe crystal growth of B-$Cd(OH)_2$ active materials.

For the $Cd/Cd(OH)_2$ plates, the derived general plate morphologies were consistent with a dissolution-precipitation mechanism during discharge and one involving dissolution-electrodeposition during charge. Under very fast discharge rate, the observed general electrode morphologies were correlated partially to a solid-state mechanism.

TBC 3375

O. C. Wagner and D. D. Williams, U. S. Army Electronics Command, "Investigation of Charging Methods for Nickel-Cadmium Batteries," 26th Power Sources Symposium, April - May, 1974, pp. 96-99

This paper presents data on the effects of pulse and direct current charging on the electrical performance of nickel-cadmium batteries. Reflex charging and positive pulse charging provide an excellent means for restoring the capacity lost by vented and sealed nickel-cadmium batteries.

Reflex charging with an average charge rate of 2C, a frequency range of 30 to 2000 Hz, and a minimum negative pulse energy of 2.5 milliwatt-seconds increased the charge acceptance of vented and sealed nickel-cadmium batteries by 10 to 15 percent in the temperature range of -40°F to about 100°F. Life cycling of a vented nickel-cadmium battery using the reflex mode of charge showed that the battery maintained its capacity at about 100% of theoretical up to the 500 cycles tested.

TBC 3376

G. Kortum, Tubingen University, "Treatise on Electrochemistry," Second Ed., Elsevier Pub. Co., Amsterdam (1965).

This book presents the theoretical fundamentals of electrochemistry. The thirteen chapters cover definitions and fundamental laws; thermodynamics; solvation of ions; electrolytes ionic interaction; association and dissociation of strong electrolytes; conductance measurements; electromotive forces; poteniometric measurements; acids and bases potential differences at phase boundaries; electrical polarization and kinetics of electrode processes; and applications of electrochemical processes.

TBC 3377

B. J. R. Hodge, R. Bonnaterre and F. Putois, SAFT England and France, "Fast Charging of Sealed Nickel Cadmium Batteries; Theory and Practice." Power Sources 5, D. H. Collins, Ed., Academic Press, London (1975).

The paper examines the electrical, electrochemical and physical behaviour of sealed nickel-cadmium cells during fast charge. Various existing charge control systems are re-examined, and two new systems are described, one a simple system for use at normal temperatures, the other suitable for a wide temperature range (-20°C to - 50°C). Life, reliability, fading and charging efficiency at high temperature are all improved by fast charging, and the results of a study in depth over a wide temperature range are presented. Pulse charging is also studied, and reasons given to support our finding that the longer the pulse the more efficient the charge.

TBC 3378

R. Barnard, J. A. Lee, A. H. Rafinski, and F. L. Tye, Ever Ready Co., London, "Investigation Into the Mechanism of Capacity Loss by Porous Cadmium Electrodes During Cycling."

Loss of capacity of porous cadmium electrodes during cycling is confirmed. Chemical analysis establishes that the substantial losses experienced in early cycling are due both to the presence of residual cadmium after discharge and residual $Cd(OH)_2$ after charge, with the former being the major effect. The rate of loss decreases with charge rate but, revealingly, is independent of discharge rate.

The techniques of linear sweep voltammetry and microscopy show that on cycling cadmium migrates toward the outer surfaces of the electrode and increases considerably in crystallite size.

The failure mode proposed is coverage of cadmium surface by precipitated $Cd(OH)_2$ which induces passivation by a solid state mechanism. The increase of residual cadmium on cycling is due to the increased cadmium crystallite size yielding less area to be blocked and to the confinement of cadmium to a smaller volume making blocking of the surface more probable.

TBC 3379

C. Pierce, Pomona College,"Computation of Pore Sizes from Physical Adsorption Data," J. Physical Chemistry, 57, (1953) pp. 149-152.

A new and simplified method, based on Kelvin equation radii, is described for computation of pore size distributions from nitrogen desorption isotherms. Applications are shown for a variety of samples and a critical discussion is given of the limitations. Analyses for pores above 20-25 Å. in radius are self consistent and in agreement with other methods of analysis. For pores less than 25Å. the computed radii are not believed to be reliable, the error becoming greater as the radius decreases.

TBC 3380

Puglis , V. J. and Ralph, E. L., SPECTROLAB, "Development of Nickel Alkaline Batteries for Aerospace Lightweight Secondary Power" AFAPL-TR-75-64, Final Report, June 1975.

This was a very ambitious program that successfully incorporated new improved electrode fabrication procedures into a small scale pilot production facility and produced advanced lightweight aerospace nickel-cadmium cells. The objectives of achieving a minimum energy density of 20 WHR/lb with the 50 AH sealed nickel-cadmium cells was accomplished

and two pilot production runs demonstrated that this objective was reached with reproducible results and good yields.

Sinter porosities of 82 to 84% for the positives and 89-90% for the negatives were achieved with good characteristics. Loading levels of 2.3 to 2.5 g/cc of void volume was obtained. A computer design of several cells that met the program objectives was developed. A scaled-up pilot plant facility was then built for use in demonstrating that these advanced cell designs could be achieved on a production basis.

A Phase I production run was then made using the newly built production facility. Twenty cells of three different designs were fabricated. All these designs produced greater than 50 AH cells and exhibited a capacity of 20 WHr/lb.

Sixteen cells were produced in the pilot production facility for the Phase II run. They were built using the same production processes as used in the Phase I build, with only slight modifications being made in the cell design. The cells produced demonstrated that reproducible performance characteristics could be achieved and the performance objectives were met with high yields. Ten of the cells yielded 20 WHr/lb five cells yielded 21 WHr/lb capacity.

TBC 3381

Parry, J. M. "Development of Uniform and Predictable Battery Materials for Nickel-Cadmium Aerospace Cells" First Quarterly Report, Contract No. NAS5-11561, Tyco Laboratories, Covering the period May 8 through August 7, 1968.

The development of more reliable nickel cadmium batteries for aerospace application is dependent on improvements in the uniformity and reproducibility of the battery plates. It is the purpose of this program to study the sintering and plaque filling processes associated with plate manufacture in order to improve these factors.

The first report presents a survey of the literature pertaining to the manufacture of nickel cadmium battery plates and examines present industrial practices in this field, particularly quality control. The general conclusions are that the industry, though manufacturing a successful commercial product, is not geared to the production of high quality plates for aerospace application.

The experimental program to define the critical variables in the manufacturing process is outlined briefly.

A preliminary analysis of the uniformity of physical characteristics of several samples of the commercial nickel powder, exclusively used in battery plate manufacture, indicates variations in bulk density, surface area and particle size distribution. The grain size and Fisher number, however, show much less variation.

TBC 3382

Bidler, J. L. and Fisher, J. I. "Preparation and Evaluation of Fiber Metal Nickel Battery Plaques" Final Report, NASA-CR-54777, July 1965, Huyck Metals.

Flexible fiber metal plaques can be produced with internal surface areas greater than 500 cm^2/gm, tensile strengths greater than 300 psi,

porosities of 90% or greater and electrical resistivities of 400 microhm-cm or less. Although not all of the values indicated above can be achieved in the same plaque, sufficient data are presented to permit an evaluation of the effect of processing parameters upon the plaque characteristics and to indicate which fiber characteristics should be varied to optimize specific plaque properties. A new fiber type has been developed to maximize the internal surface area and porosity. It is anticipated that this material can be processed into plaques with greater than 90% porosity and with an internal surface area in excess of 800 cm^2/gm.

TBC 3383

Tyco Labs, Inc., "Development of Uniform and Predictable Battery Materials for Nickel-Cadmium Aerospace Cells" Seventh Quarterly Report for the period 8 March 1970 to 7 June 1970, Contract No. NAS 5-11561.

This report describes studies of the impregnation of nickel plaque to form nickel cadmium battery plates. Two basic processes were examined: (1) chemical conversion of the nitrates to the hydroxides, and (2) the method first described by Fleischer. The aim was to define the procedures and preparative conditions that would give rise to the most uniform components in a reproducible manner.

The variables considered were solution concentration for chemical conversion, current density for the Fleischer method, and the loading for both methods. These variables were chosen for more detailed study from a previous preliminary examination of impregnation methods. The plates were examined in terms of uniformity and reproducibility of weight gain, capacity and utilization. The determination of utilization demanded chemical analysis of the active materials.

It was concluded from the experimental data collected that more uniform and reproducible plates were prepared by the chemical conversion process. For the positive plates, the less concentrated impregnation solution are to be preferred. No distinction could be drawn for the negatives. It should be stressed that this is an interim assessment based on capacities measured after up to ten cycles and has not included factors such as cycle life or behavior under sealed cell conditions.

It is also apparent from the data that uniformity and reproducibility of weight gain and capacity improve with loading, suggesting that there is a leveling effect (as might be expected). More surprisingly, utilization was found to be independent of loading up to quite high levels. From a limited amount of data, plaque thickness was found to have no influence on uniformity. Plaque corrosion during impregnation was more extensive for the chemical conversion process.

Future work will include an assessment of electrochemical methods of

impregnation and a study of plaque and plate preparative conditions on cycle life and sealed cell behavior.

TBC 3384

O. C. Wagner, U. S. Army Electronics Command, "Investigation of New Cell Components for Vented Nickel-Cadmium Batteries," ECOM-4364, Nov. 1975.

An investigation of new cell components for vented nickel-cadmium batteries shows that it is possible to prevent capacity loss due to crystal growth of cadmium and cadmium hydroxide by the addition of 1% indium hydroxide to the active cadmium powder. Cadmium anodes with 5% nickel hydroxide were found to be partially effective in resisting crystal growth. The investigation also shows that the low temperature performance of vented nickel-cadmium cells (-20°F) with methacrylic acid-grafted polyethylene membranes, E-2291 (40/20), is equal to that of cells with standard cellophane membranes if the former are initially formed by means of an optimized pulse mode of charging (based on USAF data, the room temperature life of vented nickel-cadmium batteries with E-2291 separator is about five times greater than standard batteries with cellophane membranes).

TBC 3385

V. S. Bagotzku, N. A. Shumilova, G. P.Samoilov, and E. I. Khrushcheva, Institute of Electrochemistry of the Academy of Sciences of the USSR, Moscow,"Electrochemical Oxygen Reduction on Nickel Electrodes in Alkaline Solutions--II."

Electrochemical reduction of oxygen on a nickel electrode in alkaline solutions has been studied using the rotating ring-disk-electrode method. The change in the ratio of two possible reaction courses (viz with or without intermediate formation of hydrogen peroxide) depends on the potential degree of electrode oxidation and the composition. Oxidation of the nickel electrode surface leads to considerable inhibition of oxygen reduction accompanied by increased hydrogen-peroxide yields. In LiOH solution the contribution of the reaction with intermediate hydrogen-peroxide formation is less, as compared with the KOH solution. The constants of individual reaction steps of the oxygen-reduction reaction have been calculated.

A study has been made of the hydrogen-peroxide reduction, oxidation and catalytic decomposition on the nickel electrode. Hydrogen peroxide does not undergo decomposition. Increase in the oxidation state of the electrode surface inhibits hydrogen-peroxide reduction, but scarcely affects its electrochemical oxidation.

TBC 3386

E. A. Khomskaya and A. S. Kolosov, N. G. Chernyshevskii,Saratov State University, Russia,"Distribution of the Oxygen Reduction Current at the Surface

of a Cadmium Electrode in the Discharge of a Cadmium-Nickel Accumulator," Elektrokyimiya, Vol. 8, No. 6, pp. 918-920, June, 1972.

Calculations based on prior experimental work are reported of oxygen recombination rates on cadmium electrodes with a porous nylon separator. Account is taken of oxygen transported in the gaseous phase and oxygen transported through the liquid phase only. The gaseous region comprises only 10% of the electrode surface, yet accounts for more than half of the current. Current density on the gaseous region is on the order of 10 mA/cm^2, and the gaseous diffusion layer is approximately 0.4 micron. Potassium hydroxide next to the nickel electrode is found to be supersaturated by a factor of 10 to 50 times the oxygen equilibrium concentration. The separator material is found to have no significant influence on the degree of supersaturation.

It is concluded that only when gaseous regions are present on the surface of the cadmium electrode can high oxygen reaction rates be attained.

TBC 3387

L. G. Austin, North Caroline U., "Fuel Cells, a Review of Government-Sponsored Research, 1950-1964." NASA SP-120 (1967).

The primary objective of this monograph is to review fuel-cell investigations funded by Government agencies of the United States of America. The magnitude of the U. S. effort to develop fuel cells can be judged by the contracts and reports within the scope of this book. Up to December 1963, nearly 200 contracts had been awarded to 90 contractors, and nearly 800 reports have been issued describing the work performed under the contracts. The reports contain much detailed information. So this work should be treated as a sourcebook for information existing in contract reports. The state of fuel-cell technology is still changing rapidly and it is not easy to decide which results are important enough to be reported in detail, but the author has given due weight to all aspects of the field. Development of practical fuel cells is a prime example of an interdisciplinary field of work requiring contributions from specialized chemical and engineering disciplines. A comprehensive listing of the contractor reports used as the basis for the book is presented in Appendix F.

TBC 3388

R. D. Walker, Jr., U. of Florida, a Study of Gas Solubilities and Transport Properties in Fuel Cell Electrolytes, Tenth Semi-Annual Report, Oct. 30, 1970, Research Grant NGL 10-005-022.

Theoretical studies of the solubility of gases in electrolytes, based on the Percus-Yevick theory, have been made, following the extensive experimental studies of the solubilities of these systems. The theory

predicts accurately the solubility and activity coefficients for both the salting-in and the salting-out systems. Several problems were solved in the measurement of partial molal volume of gases in electrolytes, and results for a few measurements are reported. Improvements on the theory for partial-molal volume were made, and comparison with experimental data shows favorable results. Diffusion coefficients of oxygen in lithium hydroxide were measured using the dropping mercury electrode method for temperatures up to 60°C. Measurement at higher temperatures presented severe problems. In the case of the theoretical studies, a hard sphere kinetic theory has been developed; this theory gives fair prediction on the diffusion coefficients of gases in electrolytes. An extensive literature survey was made on the physical properties of the ternary system K_2CO_3 - KOH - H_2O. Even though the volume of work on such properties as solid-liquid equilibrium, electrical conductivity, solubility and absorption of CO_2 in this system is significantly large, relatively little work has been done on the liquid-vapor equilibrium. Experimental measurements of the vapor pressure using the isopiestic method were performed, and feasibility of using an empirical mixing rule was investigated.

TBC 3389

H. Bode, K. Dehmelt, H. Dohren, Accumulatoren-Fabrik A. G., Working Mechanism of Gas Removal in Permanently Sealed Alkaline Accumulators, International Symposium on Batteries, Oct. 1958, Signals R & D Establishment of the Ministry of Supply, Christchurch, New Zealand.

The principles of oxygen recombination in a sealed nickel cadmium cell are discussed, based on experiments on an instrumented button cell. It was determined that oxygen recombination rates on cadmium and nickel elextrodes are comparable if they are at the same potential. Factors considered important in design of the negative are adequate charge reserve and discharge reserve. For overdischarge protection, antipolar mass in the positive is necessary. An interesting finding was that if the potential of the negative is raised so hydrogen evolves, then lowered so that it stops, the current density at a given potential is three times greater afterwards than before.

BAC 3390

NASA GSFC 1973 Battery Workshop, NASA Goddard Space Flight Center, Nov. 1973.

Informal discussions are presented on battery problems and technology. Categories include seals, separators, storage experience, manufacturing, testing and metal-hydrogen technology.

BAC 3391

J. T. Crennel and F. M. Lea, Alkaline Accumulators, Longmans, Green and Co.

London, 1928, p. 94.

This old book on batteries is primarily of historical interest. Information is included on early nickel iron cells and the cadmium-iron electrode.

BAC 3392

O. C. Wagner, U. S. Army Electronic Command,"Secondary Cadmium-Air Cells," 22nd Power Sources Conference, May 1968, pp. 72-76.

Experimental work on the cadmium electrode is reported for use with cadmium-air cells. Cadmium migration with sintered plates is less than for sponge plates. Migration can be reduced by use of porous felt material between the cadmium electrode and separator, by minimizing overcharge, and by minimizing carbonate contamination. Capacity fading can be minimized by use of ferric oxide extended, by minimizing carbonate contamination, by use of cellulosic expanders, by charging at high rates (over 150 ma/in^2), and by an occasional low rate overcharge.

TBC 3393

D. Stanimirovitch and J. Piechon, SAFT,"Studies of the Reversal in Gastight Storage Cells,"Extended Abstract No. 7, ECS Fall Meeting, 1963.

The reversal phenomenon of nickel cadmium cells was investigated with sealed cells. The amount of precharge was a variable. At the C/5 reversal rate, three negative voltage steps were observed, one at about -0.3 V, a second at about -0.7 V, and a third at about -1.5 V. The unique second voltage level occurs at the nickel positive electrode, and the oxygen evolution rate at this condition is less than at the third voltage step. This is attributed to the reduction of oxygen at the nickel positive electrode.

TBC 3394

H. Seiger, Gulton Industries,"On Overdischargeable Sealed Cells,"Extended Abstract No. 35, ECS Fall Meeting, 1965.

Results are reported on experiments in which cells are reversed. Tests were conducted with and without oxygen consumption electrodes. The tests demonstrated that when the cells are negative limited, oxygen evolved from the negative will recombine on the nickel positive. However, repeatability and long-term operation were not investigated.

TBC 3395

A. J. Hartner, M. A. Vertes, V. E. Medina and H. G. Oswin, Leesona Moos Labs,"Effects of Oxygen Partial Pressure on Fuel Cell Cathodes"; in Fuel Cell Systems, by G. Young and H. Linden, American Chemical Society, Washington, D. C. 1965.

The effect of the partial pressure of oxygen on the electrode/electrolyte/gas interface has been studied using hydrophilic electrodes. The meniscus was established by partly immersing a flat plate into the electrolyte. Polarization at 200°C decreases with increasing partial pressure of oxygen in the range of 0.1 to 2.0 atmospheres, but higher pressures do not give much additional improvement. The results suggest that the decomposition of peroxide species or surface oxide formation may be the rate-controlling step, accounting for the nonlinear relationship between current and partial pressure of oxygen.

TBC 3396

D. R. Turner, Bell Telephone Labs., "The Effect of State of Charge of the Cadmium Electrode on Oxygen Recombination in Sealed Nickel-Cadmium Cells." Electrochemical Technology, 2 (1964) pp. 313-319.

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.

TBC 3397

A. T. Kuhn, Ed., U. of Salford, Industrial Electrochemical Processes, Elsevier, London, 1971.

A wide variety of industrial electrochemical processes is reviewed, each by a specialist in the particular field. Broad technology areas include electrochemical fluorination and production, the chlor-alkali industry, industrial water electrolysis, heavy water manufacture, electrowinning of metals, electrorefining in acquesous electrolytes and molten salts, electrochemical machining and finishing of metals, electroforming, electrodeposition of paint, electrodialysis, electrodes, diaphragms, electrolytes, and cell design.

TBC 3398

J. P. Elder and E. M. Jost, Texas Instruments, Statistical Studies of Re-Chargeable Battery Systems , J. Electrochem. Soc, Vol. 116, 1969, pp. 687 to 693.

The application of the 2^n factorial experiment to the study of the factors influencing the behavior of hermetically sealed, rechargeable Ni-Cd cells is discussed. The characteristic cell parameters may be expressed as logarithmic functions of the pertinent charge-discharge conditions. Data fitting is accomplished by means of a linear regression analysis. Both primary and factor interaction effects contribute to the behavior of the cells. The magnitudes of the effects are dependent on the cell operating conditions. The effects resulting from a cobalt addition to the positive electrode are primarily related

to the kinetics of the charge and discharge reactions.

TBC 3399

P. Selanger, Lund Institute,"Analysis of Porous Alkaline Cd-electrodes. I. Anodic High Rate Transients." J. Applied Electrochem, 4 (1974) 249-257.

Galvanostatic anodic high-rate transients in porous Cd-electrodes are analysed. A one-dimensional electrode model is developed. The model includes effects of variation in electrolyte composition and reaction surface activity. Overpotential transients are computed and compared with experimental transients. Failure in low porosity electrodes with great surface activity is in general caused by the blockage of pores at low rates. At high rates the discharge depth is limited by pure mass-transfer limitations. The reaction activity group $i_o S$ is estimated from the experimental electrodes in conjunction with the model. Transition from pore blockage to pure mass-transfer limitations occurs between 100 and 200 mA cm^{-2} for a medium porosity of 0·60.

TBC 3400

P. Selanger, Lund Institute,"Analysis of Porous Alkaline Cd-electrodes. II. Potential Recovery Transients After a Period of Discharge." J. Applied Electrochem., 4 (1974) 259-262.

The recovery of the diffusion potential after a period of discharge is analysed for porous Cd-electrodes. A composite process with discharge-idle time and discharge is simulated and compared with an experimental process. The general influence of porosity on charge capacity is examined in a charge porosity diagram.

TBC 3401

P. Selanger, Lund Institute,"Analysis of Porous Alkaline Cd-electrodes. III The Application of Charge Porosity Diagrams in Electrode Design." J. Applied Electrochemistry, 4 (1974) 263-266.

A simple charge-porosity diagram is presented for the rapid estimation of charge capacity in battery electrodes. Porosity changes reflect differences in mole volumes of the reactants and reaction products. Each system has a specific sensitivity to porosity changes. This diagram can be a useful tool for the assessment of mass and current transport performance of electrodes that give insoluble reaction products. Alkaline Cd, Zn and Fe electrolytes are compared.

TBC 3402

P. Selanger, Lund Institute,"Analysis of Porous Alkaline Cd-electrodes. IV. Optimization of Current Density," J. Applied Electrochem., 5 (1975) 255-262.

Optimization of the electrode-thickness, porosity and the amount of active material necessary for a defined electrode polarization is carried out with a mathematical model on porous Cd-electrodes. Three different problems were formulated for a constant current-load, and a specified final total polarization in order to maximize the utilization of active materials. The results obtained show that the best high rate electrodes ($100mAcm^{-2}$) are high porosity electrodes with the half-width thickness in the interval of 0·10 0·18 cm depending on the formulated optimization problems.

TBC 3403

G. van Ommering, COMSAT, Battery Evaluation Program Final Report for TELESAT CANADA, Feb. 1974, P. O. 3811.

This report covers electrochemical and chemical analyses of two nickel cadmium cells. One had been on 18 months simulated earth synchronous orbit battery operation (3 occultation seasons), and the other had undergone little more than acceptance testing. Inbetween occultation means the cells were open circuited. The major problems observed were cadmium migration, loss of usable capacity, increase in total precharge, negative electrode limiting on discharge, and non-uniform expansion of both electrodes.

TBC 3404

S. W. Mayer, Aerospace Corp.,"Electrophoretic Mobilities of Cadmium Hydroxide, Nickel Hydroxide, and Silver Oxide in Ni-Cd and Ag-Zn Battery Electrolytes," J. Electrochem, Soc., 118, (1971) pp. 159-162.

Since cadmium migration damage of separators is a major cause of Ni-Cd battery failures or performance degradation, a series of electrophoretic mobility measurements has been made for cadmium hydroxide suspensions in concentrated KOH battery electrolyte at several concentrations of K_2CO_3 to investigate whether electrophoresis of cadmium hydroxide could be the mechanism for migration to separators. It was found that the mobility of the cadmium hydroxide suspension in an applied electrical field is adequate to account for the observed migration of cadmium hydroxide to separators. The view that high carbonate concentrations in Ni-Cd battery electrolyte may increase cadmium migration damage of separators is consistent with these electrophoretic measurements since it was demonstrated that increasing K_2CO_3 concentration from 0.8 to 6.2% increased cadmium hydroxide migration by a factor of 3. Zeta potentials have been calculated from the data. Similar measurements have been made for nickel hydroxide suspensions in Ni-Cd battery electrolyte at several K_2CO_3 concentrations. The results are consistent with ion probe analyses for nickel in nylon separators exhibiting considerable cadmium migration. Silver oxide mobility reached a maxmum at 5.1% K_2CO_3 and declined at 15.8% K_2CO_3.

TBC 3405

K. Appelt, Centralne Laboratorium Akumulatorow, Poland, "The Effect of Crystal Habit and Surface Properties on the Electrochemical Properties of Porous Electrodes Made of Cadmium Hydroxide," Batteries 2, D. H. Collins, Ed., Pergamon Press, London (1965).

Cadmium hydroxide precipitated in the presence of a large excess of potassium hydroxide from CdI2 solution was characterized by a distinct sheet structure. This structure, however, was not stable and by cathodic and anodic polarization, it steadily passed into cadmium hydroxide deprived of its texture. The formation of the sheet structure was observed both with concentrated solutions of CdI_2 and $Cd(NO_3)_2$ (cold solution). Changing the conditions of precipitation of $Cd(OH)_2$ from CdI_2, by changing the concentration of KOH, involved a change in secondary structure.

TBC 3406

K. Appelt, Laboratorium fur Electrochemische Generatoren, Poland," Surface Conductivity of Lead Dioxide Powder, Cadmium Hydroxide and Nickel Hydroxide in Relation to Their Structure and Electrochemical Properties."

Collected results of measurements of surface conductivity of lead oxides, cadmium hydroxides and nickel hydroxides are presented. The advantages of using the method of surface conductivity measurements are discussed. Dependence of surface conductivity on lattice structure is reported. Measurements of surface conductivity along with other methods (X-ray, ir adsorption) may be helpful in investigation of mechanisms of electrocatalytical reactions in porous electrodes. Thus, for example, an attempt is made to elucidate the electrochemical reduction of $Cd(OH)_2$.

TBC 3407

T. S. Lee, Union Carbide Corp.," Hydrogen Overpotential on Pure Metals in Alkaline Solution," J. Electrochem Soc., B (1971) pp. 1278-1282.

Hydrogen overpotentials on pure Zn, Cd, Fe, and Pb were measured in 6N potassium hydroxide solution at 2°, 25°, and 50°C. Measurements were also made in 9N potassium hydroxide solution at room temperature. Exchange current densities, transfer coefficients, and heats of activation for the hydrogen solution process were obtained, and the mechanism for process in the solution is discussed. The transfer coefficients in the alkaline solutions are compared with these in acid solutions.

TBC 3408

F. Ford, G. Halpert and W. Webster, NASA Goddard Space Flight Center, "The 1975 GSFC Battery Workshop," Report X-711-76-21, November, 1975.

A verbatim transcript of the Annual Battery Workshop held at Goddard Space Flight Center. The material covered at the workshop includes a discussion of separators, chemical analysis, cell manufacturing, test and flight experience, storage experience and manufacturing improvements, materials and cell components, analysis and new developments in the Ni/H_2 system.

BAC 3409

H. T. Francis, Armour Research Foundation, U. S. Patent 3,094,476," Apparatus for Forming Metal Fibers," June 1963.

An apparatus has been invented to manufacture thin metal ribbons. The metal ribbons are electrolytically deposited on a rotating, segmented drum, then removed continuously. Such ribbons have a possible application for making high area, low cost battery plaques.

TBC 3410

Ford, Floyd E., NASA GSFC, "Summary of Test Results on Spare Nickel-Cadmium Cells from OAO-A-2 Flight Batteries", NASA/GSFC Report X-761-71-228, April 1971.

Five cells from the production lot for OAO flight batteries for the A-2 spacecraft were subjected to 6091 orbital cycles simulating some of the various electrical conditions the spacecraft battery experiences in flight. It was shown that the undervoltage cut-off of 1.18 volts per cell would yield over 85% of the battery's ampere-hour capacity to 1.00 volts average when new, but provided less than 65% after extended periods of orbital cycling. The loss of discharge voltage with cycling is attributed to the onset of a "double plateau" effect observed after extended periods of repetitive cycling. Partial improvement in the discharge voltage was obtained by allowing the battery to "run down" in ampere-hour capacity; however, the voltage was enhanced only to the depth-of-discharge the battery experienced during the "run down." A like "new" discharge voltage profile can be obtained only if the deep discharge is conducted to 1.0 volts per cell average, or below the voltage exhibited on the lower plateau.

Low temperature ($0^{o}C$) tests conducted at various cycle intervals revealed an increase in each cell voltage of approximately 0.020 volts. One cell exhibited an abnormal voltage increase (above 1.55 volts) and was shown to be generating hydrogen gas during the overcharge test. After reverse charging the cell to remove 3.0 ampere-hours of precharge, the overcharge voltage decreased to the values exhibited by the other four cells. All cells operated satisfactorily after 450 days of test and delivered 23.0 ampere-hours after completing 6091 cycles.

The test results have demonstrated that cells with apparently "normal" characteristics when new may exhibit "abnormal" changes in overcharge characteristics with cycling. Change in overcharge voltage for one cell is attributed to excessive precharge combined with the effects of "negative capacity fading" with cycling. The importance of rigid controls during the manufacturing of nickel-cadmium aerospace cells is shown through correlation of cell test results to the manufacturing process.

TBC 3411

J. D. Dunlop, Battery Evaluation Program Final Report for TELESAT CANADA, Sept. 1974, P. O. 1538.

This report covers electrochemical and chemical analyses of two nickel cadmium cells after 28 months of simulated earth synchronous orbit spacecraft battery operation, during which the cells were open circuited between occultation seasons. Data are compared with four cells previously analyzed. Results showed ten percent of the cadmium had migrated into the separator and the positive electrode, and that the total precharge is increasing with time. Some cells were negative limited. Also, the negatives are becoming thicker with time, especially in the lower regions.

TBC 3412

J. D. Dunlop, Battery Evaluation Program Final Report for TELESAT CANADA, Oct. 1975, P. O. 1991.

This report covers electrochemical and chemical analyses of six nickel cadmium cells after 37 months of simulated earth synchronous orbit spacecraft battery operation (seven eclipse seasons), during which the cells were open circuited between occultation seasons. The amount of cadmium migration and the increase in precharge are both nearly the same as that determined after five seasons. Both positive and negative electrodes continue to expand with time, especially in the lower regions. A large increase in microporosity has been observed, which has caused electrolyte redistribution.