NASA CR-
140380

100 AMPERE-HOUR NICKEL CADMIUM BATTERY DEVELOPMENT PROGRAM

FINAL REPORT

VOL. 1 of 2

(NASA-CR-140380) THE 100 AMPERE-HOUR NICKEL CADMIUM BATTERY DEVELOPMENT PROGRAM, VOLUME 1 Final Report (Grumman Aerospace Corp.) 384 p HC $10.25 CSCL 10C G3/44

N75-14266

Unclas
07247

Prepared for
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

GRUMMAN

100 AMPERE-HOUR
NICKEL CADMIUM
BATTERY DEVELOPMENT PROGRAM

VOLUME I

S. Gaston
Grumman Aerospace Corporation
Bethpage, New York 11714

March 1974
Final Report

Prepared For:
National Aeronautics & Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058
Contract NAS 9-11074

PREFACE

This final program report on the development of a 100 Ampere-Hour Battery Module for a large Manned Space Station fulfills a part of the requirements listed in NASA/JSC Contract NAS 9-11074, Exhibit "A", Statement of Work, paragraph 5.0, Table I. Specifically this report covers the Entire Cell Development phase, the Charge Controller and Test Equipment Design phase, the Computerized Data Analysis/Reduction Program phase and the parametric cell characterization test phase. The Design and Test phase of the Battery Module was reported separately and was published in March 1973.

The author gratefully acknowledges the guidance, assistance, patience and understanding of the Technical Monitor, Mr. J. Cioni, of NASA/JSC and Mr. F. E. Ford of NASA/GSFC.

Gratitude is also hereby expressed to Messrs. E. Carr and W. Harsch of Eagle Picher Industries for their cooperation.

NOTICE

This report was prepared as an account of government-sponsored work. Neither the United States, nor the National Aeronautics and Space Administration (NASA), nor any person acting on behalf of NASA:

(a) makes warranty of representation, expressed or implied with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights;

(b) assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method or process disclosed in this report.

As used above, "person acting on behalf of NASA" includes any employees or contractor of NASA, or employee of such contractor to the extent that such contractor prepares, disseminates, or provides access to any information pursuant to his employment with such contractor.

GRUMMAN

TABLE OF CONTENTS

PRECEDING PAGE BLANK NOT FILMED

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

APPENDIX

APPENDIX (CONTINUED)

APPENDIX (CONTINUED)

LIST OF FIGURES AND ILLUSTRATIONS

LIST OF FIGURES AND ILLUSTRATIONS (CONTINUED)

LIST OF FIGURES AND ILLUSTRATIONS (CONTINUED)

LIST OF TABLES

LIST OF TABLES (CONTINUED)

1.0 INTRODUCTION

It was the purpose of this 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 K.W. of electrical power.

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. Long term life testing of these cells could not be performed due to lack of program funds.

2.0 OBJECTIVE

2.1 100 Ampere-Hour Cell

A long life 100 ampere-hour cell was designed and developed. Three design variations have been established and initial performance characteristics under simulated conditions have been obtained. All initial life objectives were met. Long term life performance testing has not been conducted due to lack of funds for this effort. However, long term life performance capabilities were given prime consideration in these designs and high reliability materials and process controls were applied. These factors should result in long life capabilities. Life cells are now being fabricated.

2.2 100 Ampere-Hour Battery Module

The problem of heat transfer from the cells to the station mounting rack was carefully analyzed. An optimum design, using conventional cold rail-cooling loop system was established. A four (4) cell module was developed and an engineering test module using active cells and built-in heaters was fabricated. Its purpose was simulation of heat generation to evaluate and verify computed heat transfer capabilities. It met all design objectives. All module design and test information was reported in an earlier document.

2.3 Charge Control Test Equipment

A reliable efficient and safe charge control technique was developed . Nine (9) charge control test cyclers were designed and constructed for the parametric test program.

Five (5) other units are partially constructed and were scheduled for the life performance test.

The test equipment is partly automated for unattended operation. The charge technique and test cycles were evaluated during the parametric cycling and met all objectives.

2.4 Computer Programs

Cell performance model and data analysis/reduction problems were developed. These were tested and met all of their objectives.

3.0 PROGRAM SUMMARY

Cost effectiveness, without quality compromise, was exercised throughout the program. With this consideration in mind, the manufacturer's established cell design was carefully analyzed with respect to materials, components and processes applied to achieve a long term reliable cell. From this review a baseline cell design was evolved. Subsequently, variations of this design were evaluated and major items are listed below:

- Opposite face terminal location.
- Large terminal design (0.5" diameter) with different ceramic purity and surface finish.
- Polypropylene Separator Material
  - WEX 1242 (washed)
  - T21047 (washed)
  - Hercules MF
  - Combination of FT 2140 (washed) and woven polypropylene (washed)
- Stack compression.
- Electrolyte quantity.
- Sensing type auxiliary electrode
  - Design
  - Wrap
  - Terminal insulated from container
- Thin electrode (.022" thickness).
- Application of semi-automatic plaque laying process on large size electrodes.

- Optimization of plate characteristics through the Manufacturing Process Variable Study (NAS 5-21159).
- Application of a low cost, highly reliable pressure sensitive switch..

These variables were selectively evaluated in three consecutive cell development groups and in a parametric characterization group under anticipated space station conditions. The cell development and characterization phases have been successfully completed. The life test cell groups, consisting of a "preferred design" with nylon separator and thin electrodes and two alternate designs with polypropylene WEX 1242 (washed) separator and thin and standard thickness electrodes respectively, have been constructed. However, no life tests are scheduled under this program since funds are not currently available.

Associated with a long life capability 100 A.H. cell the following major items were developed under this program:

- Flat lug type large size Butt-Seal Terminal.
- Non-destructive terminal braze uniformity examination technique-Radiographic analysis.
- A more sensitive mass spectrometric leak inspection technique.
- Contamination-free electrolyte filling technique.
- An electrolyte quantity filling technique based on the cell's free volume.
- A closely predictable precharge adjustment technique.
- A more uniform large size electrode from the "Dry Powder Process" as applied from the Manufacturing Process Variable Study (NAS 5-21159).

Since the station will require a large number of cells (up to 672 are anticipated) a modularized concept must be applied for maintainability and logistic reasons. Study determined that optimized conditions (maintenance/replacement costs, human factors) will be achieved when each module contains four (4) cells. After a thorough analysis of difference packaging factors and cooling concepts, a four cell battery module was developed and designed to meet the thermal, mechanical, electrical and handling requirements for this application. An engineering model was constructed, tested and evaluated, and met all of its requirements. This information was published last March in a report entitled, (Design & Test of a 100 Ampere-Hour Nickel

Cadmium Battery Module). No final development module as previously scheduled, was constructed for dynamic testing. This was caused by lack of funds and anticipated lower dynamic levels, yet to be established, due to a change to the shuttle vehicle.

The Grumman Segmented Source Power Regulator was used as a baseline charge controller. The main control consists of three temperature compensated voltage control levels, using four consecutive constant current (3 main and one trickle) steps. The current stepping is triggered by the voltage limit achieved (main control mode), or by a preset auxiliary electrode voltage level or pressure level (backup control mode). Since these cells have yielded inconsistent auxiliary electrode signals as a function of cell pressure it appears that a pressure signal will result in a more reliable backup control.

A low cost, reliable, pressure switch was selected for this purpose. Automated test equipment was developed and designed capable of handling the high currents with complete safety. Nine (9) independent charge control-cycles units were constructed for the parametric tests and five (5) additional units are partially completed for life cell testing. An independent over-under voltage detector system was designed. It samples each cell's voltage at one (1) second intervals. As an additional safety feature, the pressure gauge of each cell was modified to terminate cycling in case a cell reaches +85 PSIG. This charge control-test equipment was successfully evaluated during the parametric testing. A Hewlett-Packard Model 2012B Digital Data Acquisition System with magnetic and paper tape readout monitored all test data, except pressure. Computerized performance prediction model and data reduction analysis programs were developed and tested. These programs have performed well.

4.0 REQUIREMENTS, GROUND RULES & ASSUMPTIONS

The basic requirements for this program are those called out in paragraphs 1, 2 and 3 of the Statement of Work, Exhibit A of NASA/JSC Contract NAS 9-11074.

In addition certain ground rules, assumptions and estimates were used. These are fully described in paragraph 4 of the "Design & Test of a 100 Ampere-Hour Nickel Cadmium Battery Module Report", issued in March 1973.

5.0 CELL DEVELOPMENT

5.1 Approach Philosophy

5.1.1 Phase I - Parametric Cell Design Selection Program at Cell Manufacturer

To achieve a cost effective program the following approach was taken. A Baseline 100 ampere-hour cell design was established. Then a parametric selection test program was conducted at the cell manufacturer, whereby a limited number of major design variables were evaluated and established on the first cell group. The established parameters were then kept constant in the following cell group and other parameters evaluated. In this fashion a total of three (3) consecutive cell development groups were constructed and evaluated. With the completion of this phase, the cell designs for performance characterization at Grumman were selected.

5.1.2 Phase II - Parametric Performance Characterization Test Program at Grumman

The chosen cell designs were characterized at Grumman in a partial factorial parametric test program under anticipated Space Station conditions. These early life performance characteristics were then used to establish a computerized performance prediction model.

5.1.3 Phase III - Cycle Life Verification and Memory Investigation Testing

The last Phase of this program was to be conducted to obtain long term performance data to determine life capabilities, performance characteristics changes and "memory effect" and its prevention. This phase was to be conducted in a partial factorial fashion under simulated space station orbital conditions. Cells for this phase were not started due to lack of funds.

5.2 Cell Program Description

5.2.1 Phase I - Development Program at Cell Manufacturer

A few 100 ampere-hour sealed nickel-cadmium cells had been constructed by a number of manufacturers at the start of this program. However, none had received extensive evaluation and characterization testing. The cell dimensions, however, were pretty well established and differed little between manufacturers. One manufacturer (Gulton) had designed his cell with opposed end terminals, based on findings of a NASA funded study under contract NAS 1-4289 and reported in Report No. CR 66300. It was concluded that better voltage characteristics and reduced thermal gradients were achieved in this fashion on large size cells. However, a weight and volume

increase is essential for this design to provide two head spaces for leads and terminals. All existing designs were carefully reviewed to establish the base-line cell design for this program. Included in this design were all material and process controls and experience from OAO and other Grumman programs to assure reliable long life operation. Since the selected cell manufacturer (Eagle-Picher Industries) conducted concurrently a "Cell Manufacturing Process Variable Study" under Contract NAS 5-21159, a strong effort was made to include pertinent findings into this program as they became available.

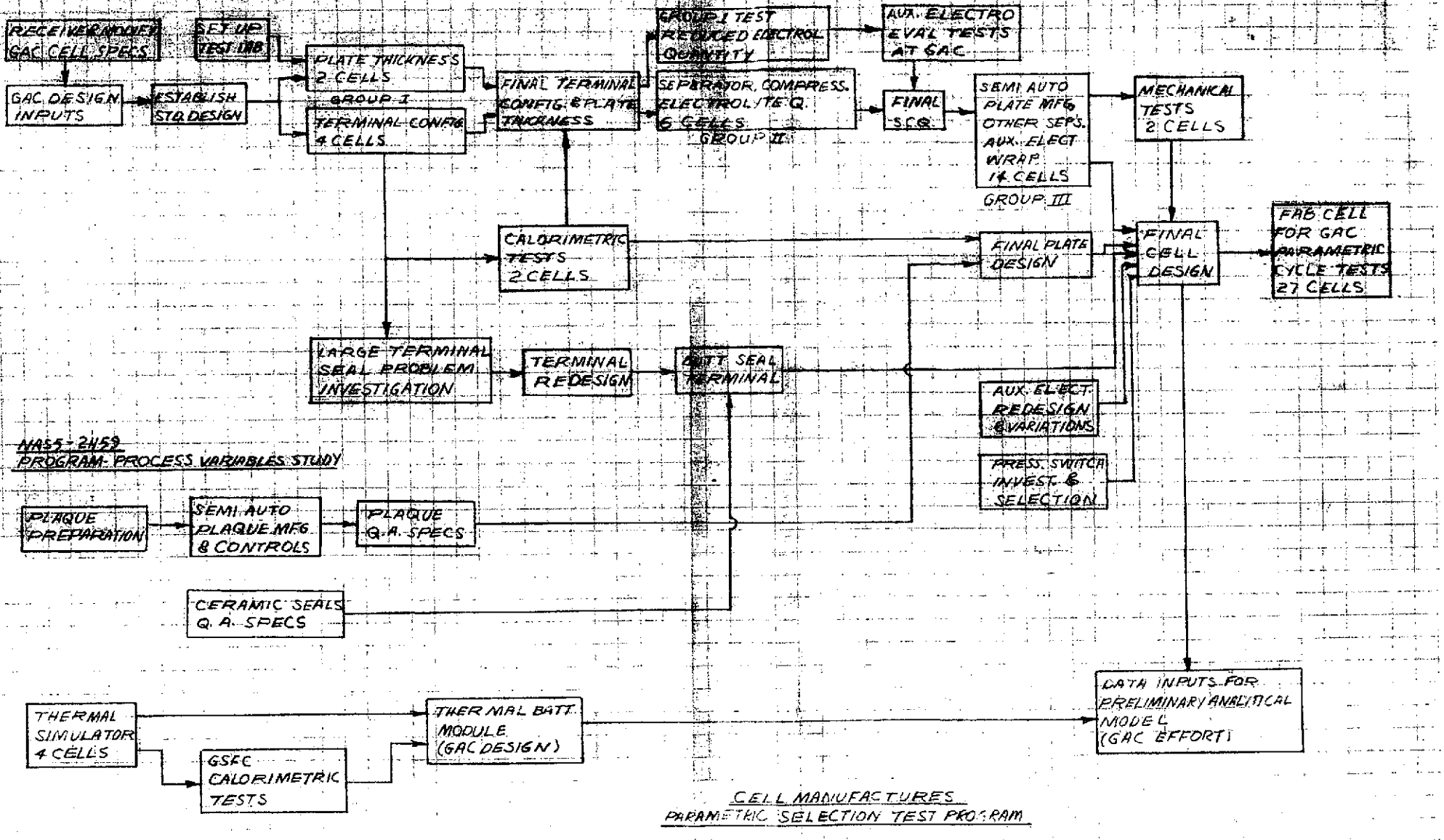
Figure 5.2-1 shows a step-by-step chart of the cell manufacturer's parametric selection test program. The interphase sequences of the various phases leading to the fabrication of the parametric cycle cells are depicted. The cell development portion consisted of construction and evaluation of a total of 26 full size 100 A. H. cells. These cells were constructed in 3 consecutive groups. Its purpose was to evaluate a few variables at a time, select the variables yielding best results, hold it constant for the next group and evaluate other variables.

5.2.1.1 CELL DESIGN DESCRIPTION

5.2.1.1.1 Group I Cells

This group consisted of a total of six (6) cells of three (3) different designs. In addition, two pre-contract cells, constructed under an earlier program, were included in the evaluation testing of these cells.

All cells, except those with opposed end terminals which are described later, had overall dimensions of 7.30" (H) X 7.34" (W) X 1.46" (T) and outline is shown on figure 5.2-2 (E.P. DWG. 005265). All cell cases and covers were constructed using type 304 stainless steel. 0.031" material thickness stock was used for the pre-contract cells, and 0.051" material thickness stock was used for all the other cells. (The material thickness was increased at Grumman's request based on a stress analysis study which had shown that fatigue can occur below the design value of 100 PSIG if the cell is restrained on the broad faces only. Subsequently, Grumman's cell packaging approach was modified to restrain all 6 cell faces. Accordingly, later cells in this program (parametric and life cell groups) returned to the .031" housing material thickness.). All cells had (2) ceramic-to-metal hermetically sealed terminals. The overall terminal assembly is shown in figure 5.2-3 (E.P. DWG. 85-40-138-5). The terminal stud was constructed of #270 cold drawn nickel stock with 0.500" diameter. The terminal was made by Ceramaseal



CELL MANUFACTURES
PARAMETRIC SELECTION TEST PROGRAM

FIGURE 2-1

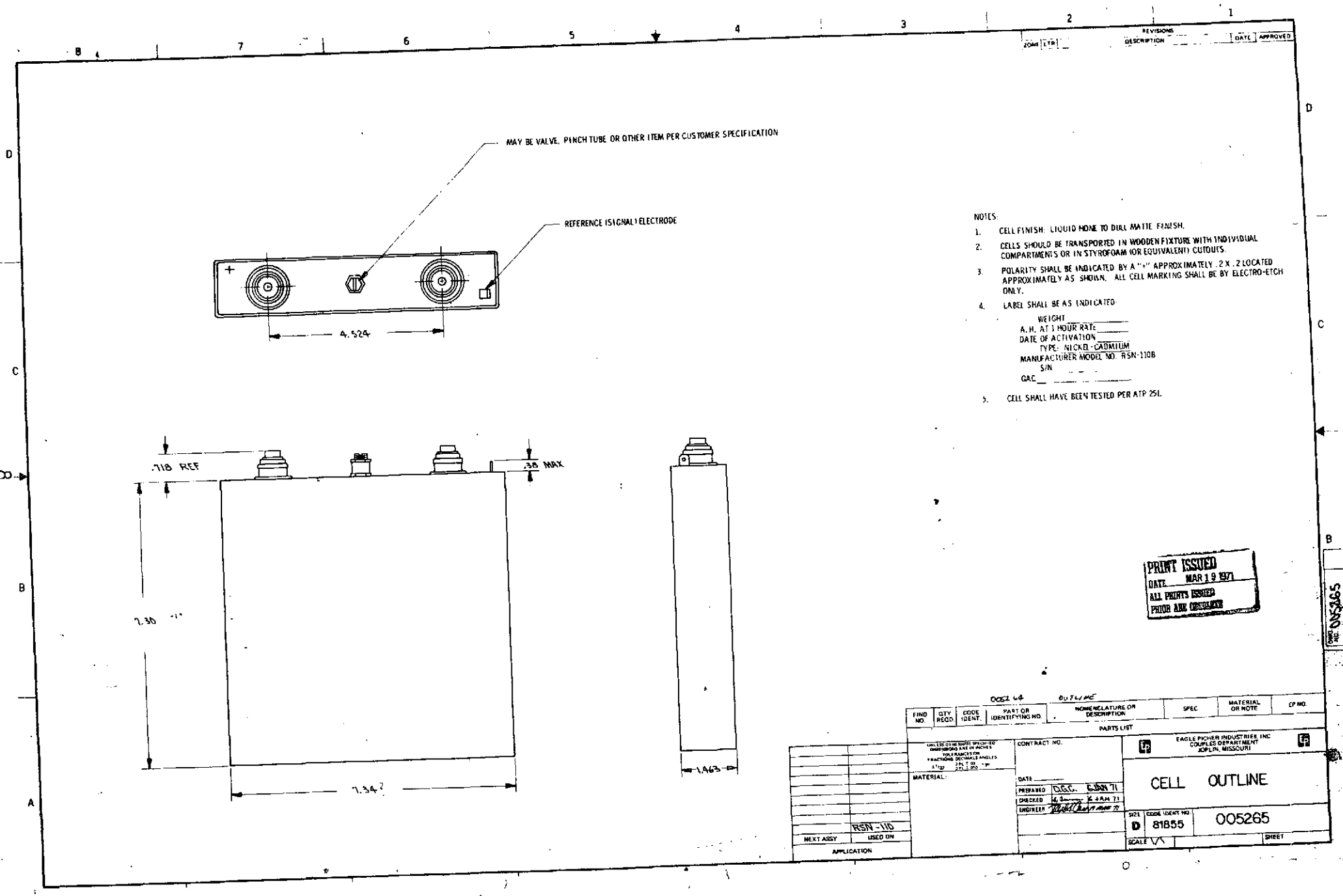
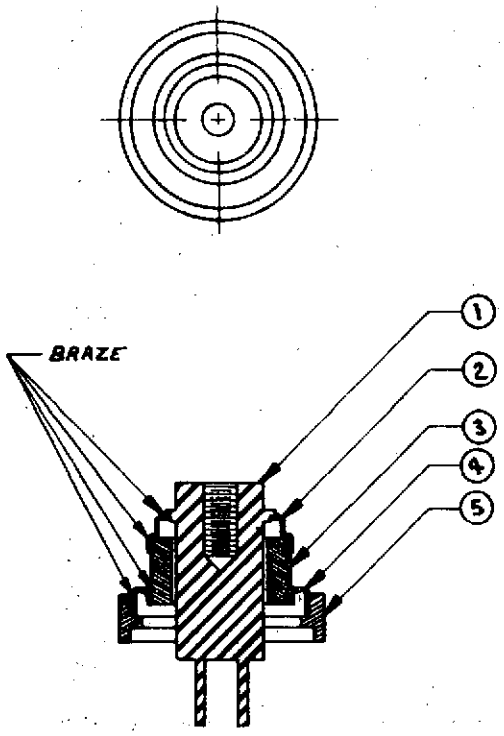

MAY BE VALVE, PINCH TUBE OR OTHER ITEM PER CUSTOMER SPECIFICATION
REFERENCE (SIGNAL) ELECTRODE
4.524
.718 REF
.38 MAX
7.30 "1"
7.342
1.463
NOTES:
1. CELL FINISH: LIQUID HONE TO DULL MATTE FINISH.
2. CELLS SHOULD BE TRANSPORTED IN WOODEN FIXTURE WITH INDIVIDUAL COMPARTMENTS OR IN STYROFOAM (OR EQUIVALENT) CUTOUTS.
3. POLARITY SHALL BE INDICATED BY A "+" APPROXIMATELY .2 X .2 LOCATED APPROXIMATELY AS SHOWN. ALL CELL MARKING SHALL BE BY ELECTRO-ETCH ONLY.
4. LABEL SHALL BE AS INDICATED:
WEIGHT
A.H. AT 1 HOUR RATE
DATE OF ACTIVATION
TYPE: NICKEL-CADMIUM
MANUFACTURER MODEL NO. RSN-110B
S/N
GAC
5. CELL SHALL HAVE BEEN TESTED PER ATP 251.
PRINT ISSUED
DATE: MAR 19 1971
ALL PRINTS ISSUED PRIOR ARE OBSOLETE
REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
0052 64 OUTLINE
PARTS LIST
FIND NO. | QTY REQD. | CODE IDENT. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | SPEC | MATERIAL OR NOTE | EP NO.
CONTRACT NO.
DATE
PREPARED D.G.C. 5 JAN 71
CHECKED 5 JAN 71
ENGINEER
MATERIAL:
RSN-110
NEXT ASSY | USED ON
APPLICATION
EAGLE PICHER INDUSTRIES INC
COUPLES DEPARTMENT
JOPLIN, MISSOURI
CELL OUTLINE
SIZE D | CODE IDENT NO. 81855 | 005265
SCALE | SHEET
DWG NO. 005265

FIGURE 5.2-2

ZONE LTR	REVISIONS DESCRIPTION	DATE	APPROVED



PRINT ISSUED
DATE MAR 19 '71
ALL PRINTS ISSUED
ARE OBSOLETE

FIND NO.	QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	SPEC	MATERIAL OR NOTE	EP NO.
5	1		85-40-138-3	ADAPTER			85-40-138-5
4	1		85-40-138-2	FLANGE			85-40-138-2
3	1		41-85-407-0	INSULATOR			41-85-407-0
2	1		85-40-138-1	CAP			85-40-138-1
1	1		85-40-138-0	STUD			85-40-138-0

PARTS LIST

DWG NO. 85-40-1385

NEXT ASSY	USED ON
	RSN-50
	RSN-116

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES ±1/32 2 PL ± .03 3 PL ± .010 ±2°

MATERIAL

CONTRACT NO.

DATE

PREPARED	D.G.C.	1-OCT-70
CHECKED	RL	19 MAR 71
ENGINEER	DR	19 MAR 71

EAGLE PICHER INDUSTRIES, INC.
COUPLES DEPARTMENT
JOPLIN, MISSOURI

TERMINAL ASSEMBLY

SIZE	CODE IDENT NO	
C	81855	85-40-138-5

SCALE — SHEET

FIGURE 5.2-3

using their standard manufacturing technique. 94% minimum purity alumina ceramic material was used. The electrodes were separated with the standard maximum loft non-woven nylon (pellon type P2505). The separator was washed twice in methanol, followed by distilled water rinses in order to remove organic impurities prior to use.

All cells, except the two pre-contract cells, contained a signal type auxiliary electrode. This electrode consisted of a teflonated nickel strip of 10 cm^2 area and was located along one edge of the cell pack. It was grounded to the cell container and a small stainless steel bracket was welded to the cover to form the electrode's terminal.

The electrolyte concentration was kept at specific gravity of 1.300. The quantity used per cell was based on an electrolyte to cell core weight ratio and was held at a value of 21% for these cells. The two pre-contract cells had a 23% ratio.

Each cell, except the pre-contract cell S/N 13, was equipped with stainless steel compound pressure gauge with a pressure range (-30 inches of Hg to +100 P.S.I.). The gauge was connected to a stainless steel "T". One end of the "T" held a stainless shut-off valve, and the other end was mounted to the cells' fill tube by means of a stainless "Swage-lok" fitting.

5.2.1.1.1.1 Baseline Design - Two (2) such cells were manufactured and assigned S/N 14 and 15. They contained 17 positive and 18 negative electrodes of standard .028" thickness. After completion of the group I tests, electrolyte quantity in cell S/N 14 was reduced and the cell retested in the group I retest series.

5.2.1.1.1.2 Thin Electrode Design - Two (2) cells (S/N 16 & 17) were built with 20% thinner electrodes. This decrease allowed use of four (4) additional electrodes per cell. There were then 19 positive and 20 negative plates. Again after completion of the group I tests the electrolyte quantity in cell S/N 17 was reduced and the cell retested in the group I Retest series.

5.2.1.1.3 Opposed Terminal Design - The third design tried consisted of two (2) cells (S/N 22 & 23) with the positive and negative terminals on opposite faces of the cell.

To accomplish this, a different plate design was used. The plate tabs used for connection were fusion welded across the width of each plate at one end. These tabs were then shaped together and fusion welded to the appropriate terminal on each end of the cell. The dimensions of the cell are 9.00" (H) X 7.34" (W) X 1.46" (T), with an overall height to the ends of the terminals of 10.24". An X-ray photograph showing front and side views can be seen in attached figure 5.2-4. Cell S/N 23 also had its electrolyte quantity lowered after completion of the group I tests to evaluate its effect during the group I retest series.

5.2.1.1.1.4 Precontract Design - Two (2) cells (S/N 1 and 13) were manufactured prior to this contract. These are identical to the baseline designs with respect to the number and thickness of the electrodes, separator material and overall dimensions. This design differs from the baseline design in the negative to positive active material ratio (lower for these cells), electrolyte quantity (23%) (higher), auxiliary electrode (not present), electrode tab design (narrower), and cell container material thickness (.031"). No quality assurance cell specification provisions were applied.

5.2.1.1.2 Group II Cells

This group consisted of a total of six (6) cells. These were constructed after electrical test and evaluation of the cells of Group I. All Group II cells had the same signal type auxiliary electrode, container, cover, and terminals as described above. The electrolyte quantity for all cells in this group was kept at a 19% ratio (electrolyte weight to core weight).

5.2.1.1.2.1 Polypropylene WEX-1242(W) Design - Two (2) cells were built (S/N 24 & 25) with baseline type electrodes, but with non-woven polypropylene separator, type WEX-1242 (after washing in identical fashion as the previous nylon separators to remove organic impurities). Each cell had 17 positive and 18 negative electrodes.

5.2.1.1.2.2 Baseline and Shim Design - A design to evaluate cell compression was tested. This consisted of two (2) cells (S/N 26 and 27) of the Baseline Design, with increased internal cell pack compression. Two .030" stainless steel shims were placed next to the inside flat faces of each cell to accomplish this.

5.2.1.1.2.3 Combination Polypropylene Design - Two (2) cells, (S/N 28 & 29) using a combination of polypropylene separators were built. One layer of FT-2140 non-woven polypropylene manufactured by Pellon Corporation, Lowell, Massachusetts and one layer of woven polypropylene manufactured by Howard Textile Mills, Roslyn, New York.

RADIOGRAPH OF OPPOSITE
TERMINAL CELL

FIGURE 5.2-4

5.2.1.1.3 Group III Cells

This group consisted of fourteen (14) cells of six (6) different designs. This was the first group which applied the semi-automatic plaque laying technique and the "Quality Assurance Specification for Use During Manufacture of Porous Nickel Plaques". Both the semi-automatic plaque laying technique and the Q.A. Spec. were developed under the "Manufacturing Process Variables Study", contract NAS 5-21159. This factor plus two additional candidate polypropylene separator materials and a tighter design using two additional electrodes were evaluated. As a secondary goal, an auxiliary electrode wrap variation, to obtain a more reliable signal-pressure-full state of charge relationship was evaluated. Also a design with an electrically isolated auxiliary electrode terminal to determine possible signal masking due to commonality to a large housing was evaluated.

All cell hardware was identical to those of groups I and II. The electrolyte quantity for all cell in this group was kept at a 19% electrolyte to core weight ratio.

5.2.1.1.3.1 Thin Electrode, Standard Stack Design - Six cells (S/N 32-37) were constructed with thin electrodes (19/20) and P2505 (washed) separator material. Cells S/N 32 & 33 had a type I auxiliary electrode wrap. This wrap was used on all previous cells and had the auxiliary electrode sandwiched in nylon separator on both large surfaces. Cells S/N 34-37 had the type II wrap, where the nylon separator was removed from the surface facing the gas spacer. Cells S/N 36 & 37 had an electrical isolated auxiliary electrode terminal.

5.2.1.1.3.2 Thin Electrode, Polypropylene Separator Type Hercules Microfiber Design - Two cells (S/N 38 & 39) with thin electrodes and Hercules microfiber (MF) polypropylene separator material were constructed. The Hercules microfiber separator material had shown some successful results on a number of 6 A.H. cells constructed by Eagle-Picher for NASA/GSFC for screening tests. This is the only material evaluated where the washing process to remove organic impurities could not be applied since it disentegrates during this process. It was, therefore, used in the "as received" condition. Material was brittle due to its short fiber length and was difficult to handle during plate wrapping and stack assembly. This handleability problem becomes worse the larger the plate size. For this large plate it was extremely difficult to determine that the material did not tear during assembly. Both of these cells had the type II auxiliary electrode wrap.

5.2.1.1.3.3 Thin Electrode, Tighter Design - Two cells (S/N 40 & 41) with thin electrodes and nylon P2505 (washed) separator and two additional electrodes (one positive and one negative) were constructed. These cells were identical in construction to those in paragraph 5.2.1.3.1 except for the additional two electrodes. Both cells had a type II auxiliary electrode wrap.

5.2.1.1.3.4 Thin Electrode, Polypropylene Type T21047 Design - Two cells (S/N 42 & 43) with polypropylene separator type T21047 (washed) were constructed. This separator is the U. S. made material from the Pellon Corp. and replaces the FT2140 material which was discontinued and had been imported from Germany. These cells were in all other respects identical in design to those in paragraph 5.2.1. except for the type II auxiliary electrode wrap.

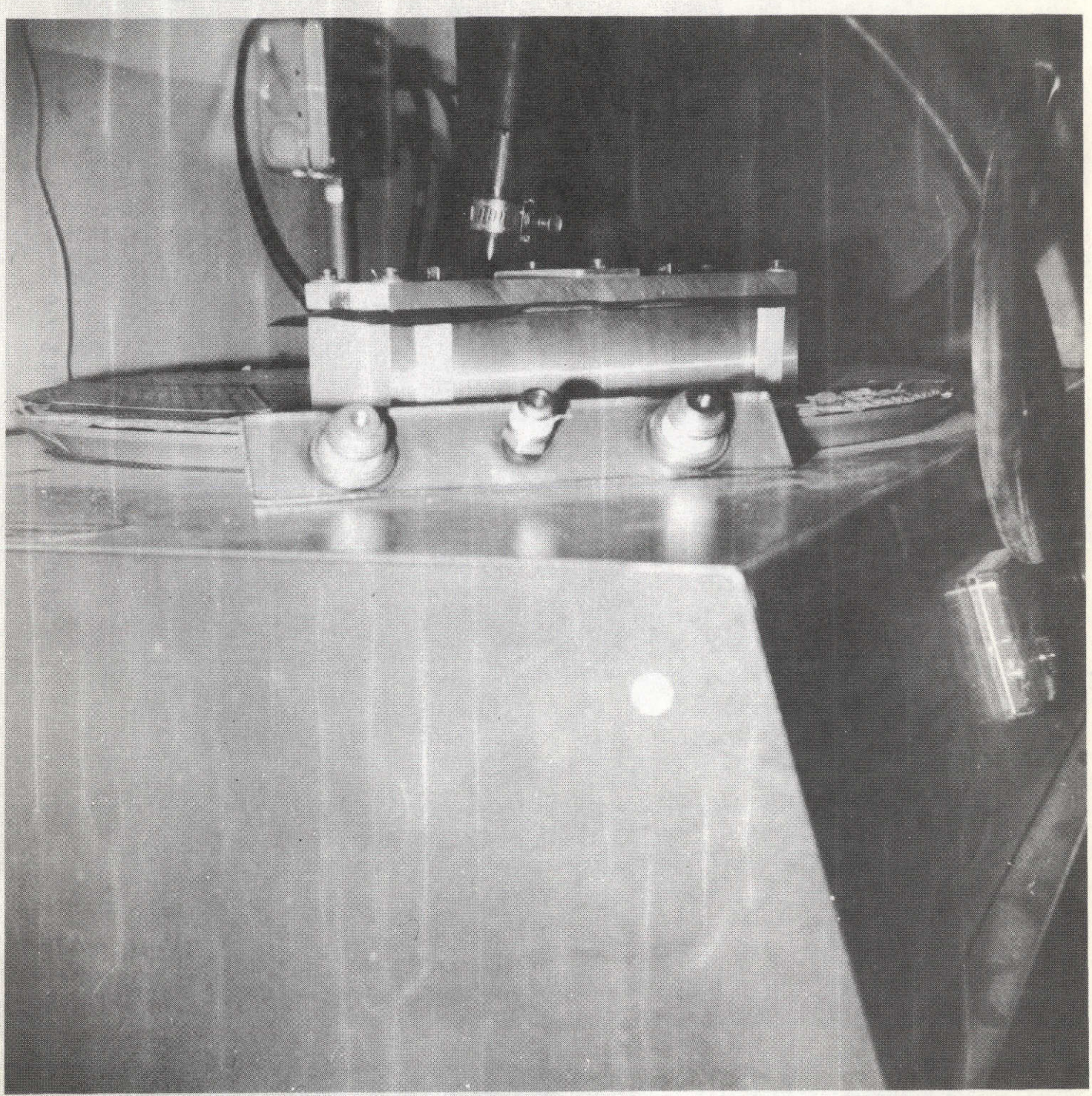
5.2.1.1.3.5 Baseline Electrode, Standard Stack Design - Two cells (S/N 44 & 45) were constructed with baseline electrodes and nylon P2505 (washed) separator material. Again the auxiliary electrode wrap type II was used in these cells.

5.2.1.2 TEST EQUIPMENT DESCRIPTION

5.2.1.2.1 Leak Test Equipment - Each cell manufactured was tested for leakage prior to cell activation using a C.E.C. Model 24-120A Mass Spectrometer, equipped with a vacuum jar and external probe detector. Figure 5.2-5 shows a photograph of typical leak test setup for a cover prior to assembly to case (extra cover is shown in front). The leak test setup for a completed cell is shown in Appendix A.

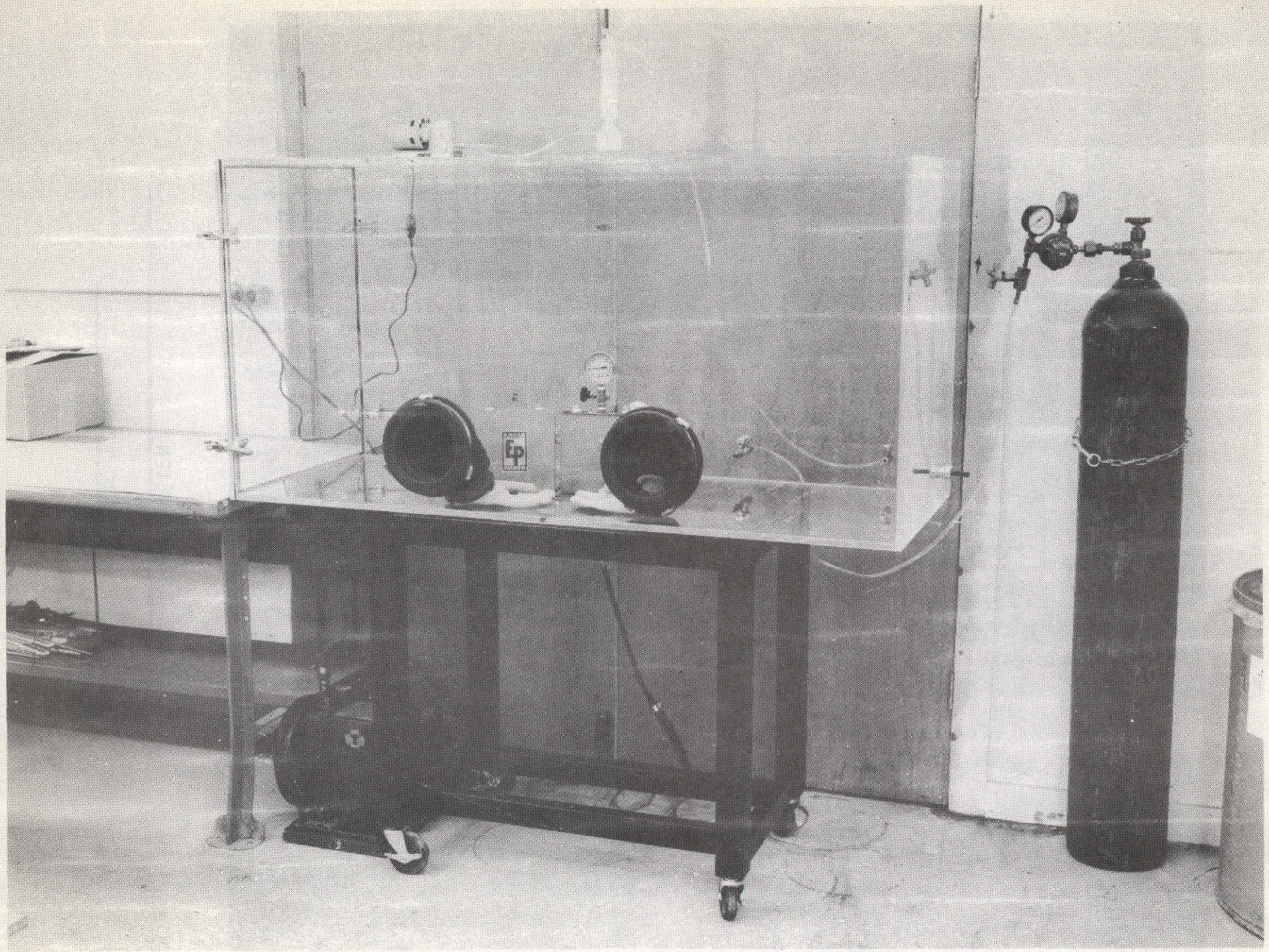
5.2.1.2.2 Glove Box - A glove box, manufactured by Eagle-Picher, was used for activation and cell handling after activation. It is a plexiglass structure with a door at one end. The atmosphere is dry nitrogen. A circulating pump continually cycles the atmosphere through a filter of lithium hydroxide. Figure 5.2-6 is a photograph of this glove box.

5.2.1.2.3 Activation Equipment - For cell activation, a fill tube assembly was constructed. It consists of a flexible, hollow tube with a cell gauge connection on one end and a KOH bottle screw cap on the other. To activate a cell, the cell is first evacuated and the shut-off valve closed. The fill tube assembly is then attached to the shut-off valve by the cell gauge connector. The other end of the assembly is attached to a polyethylene bottle containing a premeasured amount of KOH. The bottle is inverted and the shut-off valve slowly opened. The internal cell vacuum sucks the KOH from the bottle into the cell. Activation is complete when the polyethylene bottle collapses on itself. Figure 5.2-7 shows a typical set-up.

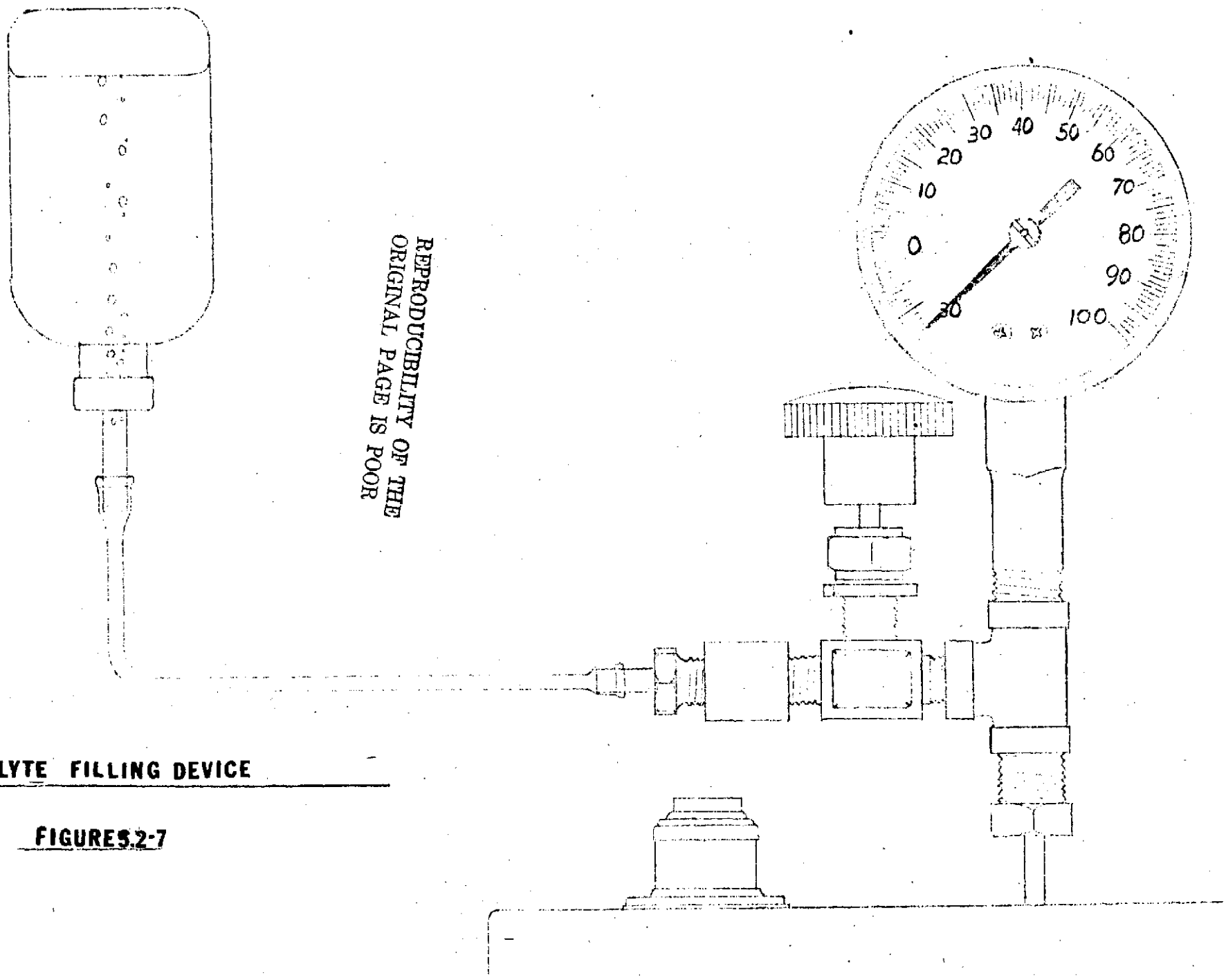


MASS SPECTROMETER

FIGURE 5.2-5



GLOVE BOX FIGURE 5.2-6



ELECTROLYTE FILLING DEVICE

FIGURE 5.2-7

5.2.1.2.4 Cell Restraining Hardware - Each cell was individually restrained on the broad faces during testing. The restraining fixture consisted of two $\frac{1}{2}$" aluminum plates 9.50" x 7.25" mounted to the broad face of the cell. The plates were held together with a total of six (6) bolts along the two short edges. The bolts were torqued to 6-8 inch pounds. The aluminum plates were insulated from the cell by two (2) .060" mylar shims.

5.2.1.2.5 Thermocouple - Each cell was equipped with a thermocouple located on one flat face of the cell. The thermocouple used was a copper-constantan type and was electrically isolated from the cell by teflon tape.

5.2.1.2.6 Temperature Chamber - Cell testing was done at $0^{o}C$ and $+20^{o}C$. To maintain these ambient temperatures, the cells were tested in a Messimer temperature chamber.

5.2.1.2.7 Electrical Circuitry - The cells tested were connected in series through a series-parallel relay. Each cell could be removed from the circuit without disturbing the rest of the cells in the series string. Each cell had voltage taps that were connected to the cell terminals and fed directly to the recorder. The thermocouples from each cell were connected to a cold junction and then back to the recorder. The thermocouples from each cell were connected to a cold junction and then back to the recorder. Figure 5.2-8 is a schematic of the cell control panel.

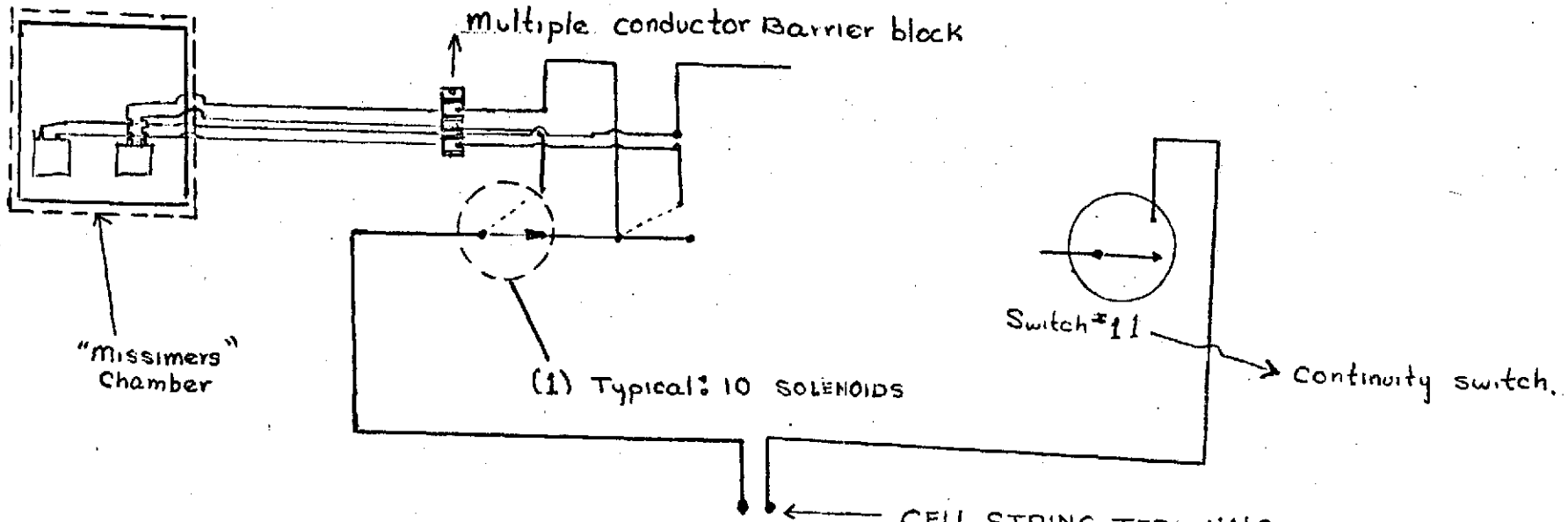
5.2.1.2.8 Data Acquisition System - All test data were recorded using an NLS, Model 24611 Data Acquisition System. This system has a Model 4409 DVM display, a Model 155 printer and a Model 265B paper tape punch. All three (3) readouts were used. Cell voltage readings were taken directly off the data systems cross bar scanner. Cell temperature readings were taken after a 1000 x amplification through the data system Model 144 amplifier. Figure 5.2-9 shows a photograph of the data acquisition system.

5.2.1.3 TEST DESCRIPTION

5.2.1.3.1 Physical Tests

5.2.1.3.1.1 Leak Check - Each cell in Group I received the standard sealed cell mass spectrometer leak test after activation. Group II cells were checked before filling. The latter group, and later cells, used the procedure of EP-MP-152, dated 12 March 1971, a copy of which is attached as Appendix B. This technique, unique for sealed aerospace cells, calls for pressurizing the cell with helium before filling. Past experience in seal integrity testing has demonstrated that presence of moisture (KOH, H_2O, oils, etc) can, and usually does, occlude fine leak

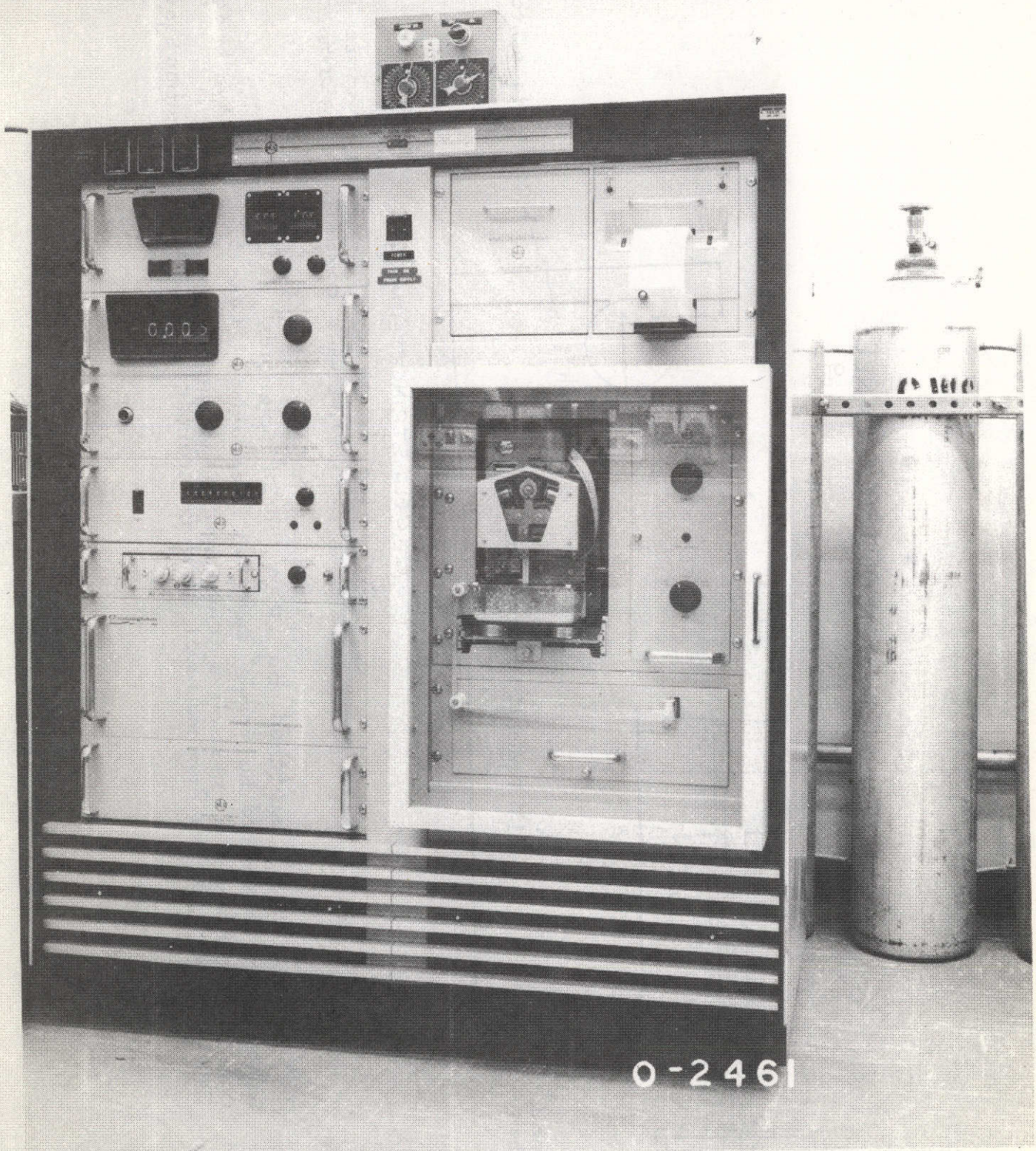
CELL CONTROL PANEL



Notes:

- Cells are individually switched by RBM "70-911" solenoids
- Solenoids are activated by toggle switches regulating 24 vdc from full-wave bridge
- Cells are contained in Missimers circulating air environmental chamber
- Cell voltage leads run from individual cells to scanner of NLS Data Acquisition System.

FIGURE 5.2-8



DATA ACQUSITION SYSTEM

FIGURE 5.2-9

paths (i.e.: openings capable of passing helium at 1.0 atmosphere differential pressure at a rate $< 1.0 \times 10^{-4}$ std cc/sec.). Furthermore, the usual cleaning methods do not prevent this, yielding doubtful random results.

5.2.1.3.1.2 Radiographic Examination - Each cell was subjected to radiographic (X-ray) examination before and after covers were welded in place. This procedure, performed in accordance with EP-ET-QC-8, 2 March 1971 (attached as Appendix C), was used to detect presence of foreign particles, and assess proper location of cell components. The radiographs of Group I cells were poor in quality due to lack of experience with the technique. A typical radiograph picture of a Group III cell is shown on figure 5.2-10.

5.2.1.3.1.3 Separator Analysis - Separator material was inspected and analyzed in accordance with EP-MS-118, attached as Appendix D, to assure compliance with acceptance criteria.

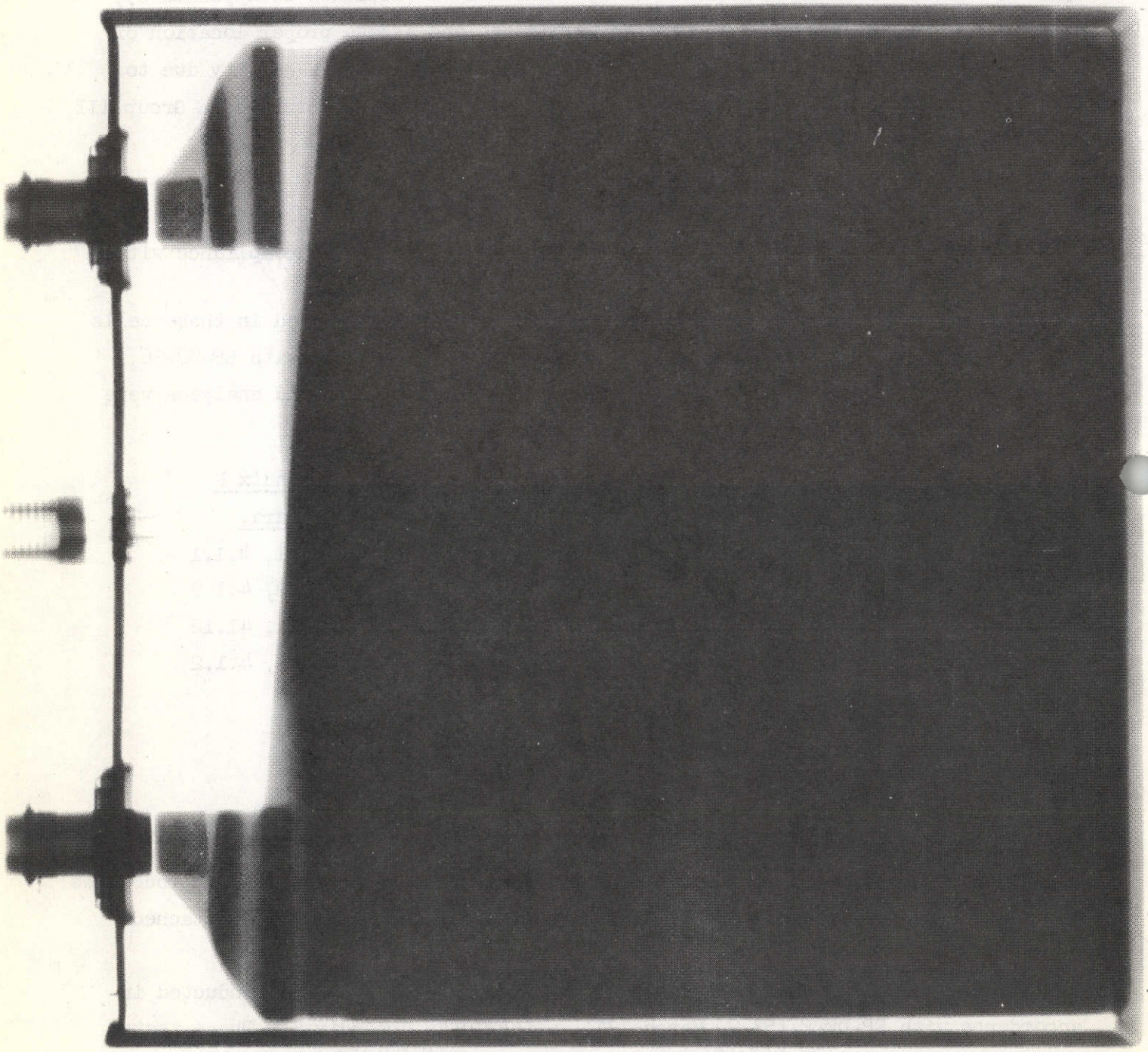
5.2.1.3.1.4 Electrolyte Testing and Analysis - Electrolyte used in these cells was subjected to chemical analysis for acceptance in accordance with EP-MS-36, 6 February 1964 (Appendix E). Thereafter, the following tests and analyses were performed before the electrolyte was used in the cells:

Test	Document	Appendix F Para.
Nitrate	EP-MP-151(3/15/71)	3.1.1, 4.1.1
Silica (Dist. H_2O)	"	3.1.2, 4.1.2
Solids "	"	" , 41.12
Conductivity	"	" , 4.1.2
Alkalinity, Carbonate	"	4.2
Bottled Tests	"	4.3
Spectral Analysis	"	4.4

5.2.1.3.2 Electrical Tests

5.2.1.3.2.1 Activation and Conditioning - Activation and conditioning procedures and tests used for Groups I and II are shown in EP-MP-146, Appendix G attached.

5.2.1.3.2.2 Cell Development Tests - The development tests were conducted in accordance with EP-DVTP-153-2, March 1971, attached as Appendix H. These tests were run after successful completion of the activation and conditioning procedures.



TYPICAL CELL RADIOGRAPHIC PICTURE

FIGURE 5.2 -10

5.2.1.3.2.3 Group I Retest - Four (4) cells from Group I were selected for retest during the tests of Group II. It was decided to remove electrolyte from three (3) cells and add electrolyte to one cell before the retest.
To remove electrolyte from the three (3) cells (S/N 1, 14, 17), the cells were fully charged and allowed to stand on open circuit. After internal pressure decayed, a hole was punched in the cover next to the cover weld. A syringe needle was fitted into this hole and potted in place. The cell was then accelerated at 10 g's with the cover facing out. The electrolyte removed was collected for analysis. After this procedure was completed, the needle was removed and the hole rewelded.

5.2.1.3.2.4 Electrode Capacity Test (Ratio Tests) - Four cells were selected from Group I and II cells to conduct the destructive cell ratio tests. These tests were conducted in accordance with EP-QC-686, dated May 1971 as modified per GAC AVO D559-1-23 shown as attached Appendix I.

5.2.1.4 TEST DATA SUMMARY

5.2.1.4.1 Physical Data

5.2.1.4.1.1 Separator Analysis - The organic and inorganic separator analysis data for most separators used in cell development groups I - III is shown in attached Table 5.2-1. Each separator material was analyzed twice. The first analysis was conducted on the material in the "as received" condition. The second was made after the "methanol-distilled water" wash. The organic residue content shows a substantial decrease for the pellon type 2505 material due to the washing process (from 0.418% to 0.026%). A slight decrease was observed for the FT2140 material (from 0.012 to trace) when the same washing procedure was applied. No significant changes were observed for the other polypropylene materials since the original analysis indicated trace quantities in the "as received" condition. In most instances, a reduction of inorganic content was observed after washing.

5.2.1.4.1.2 Electrode Weight and Thickness Distribution Data

5.2.1.4.1.2.1 Positive Electrode Weight Distribution - Positive electrode weight distribution for group II is shown in Figure 5.2.11. The total plate weight ranged from 58 to 66 grams. A weight tolerance spread of $\pm 6.3\%$ from the average of 64 grams can be observed.

TABLE NO. 5.2-1

SEPARATOR ANALYSIS DATA

Item No.	Separator Material Description	EP Lot Number	Seller's Lot No.	Condition	Organic Content % Residue	Inorganic Content — Spectrographic Analysis (PPM)										Atomic Absorp. (PPM)		Remarks
						Cd	B	Mg	Si	Fe	Cu	Ag	Ca	Ti	Zn	Zn	Ni	
1	Pellon 2505	4		As received	0.418	-	10	3	50	3	1	2	30	500	1000	40.0	0.06	Cl-trace
2	Pellon 2505	4		Washed in methanol	0.026	-	-	3	20	3	3	5	10	200	-	2.10	0.05	Cl-trace
3	Polypro. FT-2140	1		As received	0.012	-	-	1	50	-	-	1	10	-	-	0.16	0.05	
4	Polypro. FT-2140	1		Washed in methanol	trace	-	-	3	100	3	1	2	50	100	-	0.10	0.05	
5	Polypro. WEX 1242	1		As received	trace	-	-	.5	20	-	.5	1	2	1	-	0.18	0.11	
6	Polypro. WEX 1242	1		Washed in methanol	trace	-	-	5	-	-	-	.5	-	-	-	0.13	0.07	
7	Polypro. woven	1		As received	trace	-	-	1	20	-	.5	2	30	500	-	0.10	0.20	

NOTES:

1. Except where noted above no chlorine could be detected
2. NO_3 ion not detected in any of the extracts
3. SiO_2 not detected in any of the extracts
4. CO_3 ion not detected in any of the extracts.

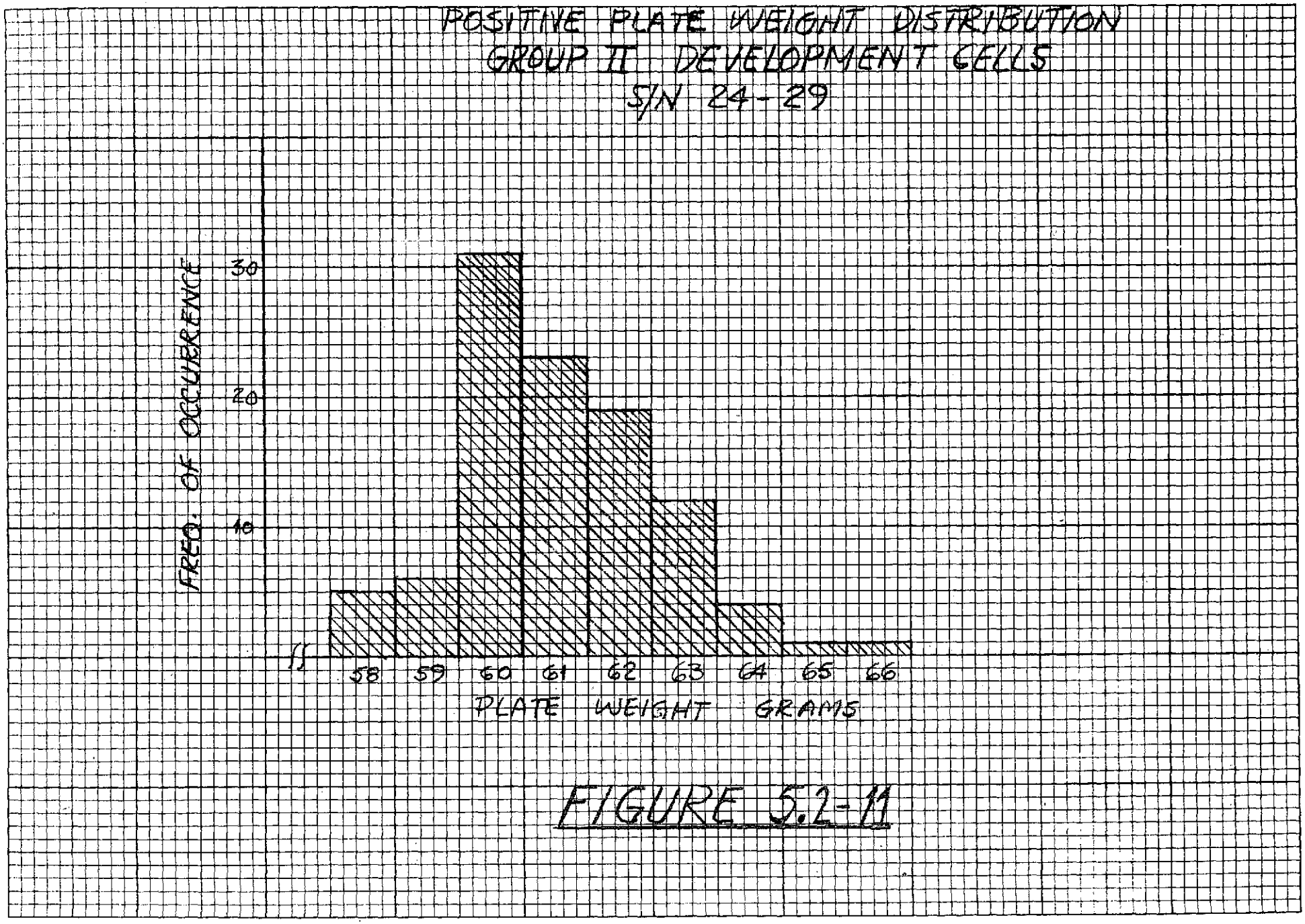


FIGURE 5.2-11

Positive electrode weight distribution for Group III is shown below:

TABLE 5.2 - 2

Electrode Type	No. of Samples	Weight in Grams Average	Range
Thin	195	57.0	55-60
Baseline	41	68.8	65-72

A weight tolerance spread of +5.3%, -3.5% from the average weight for the thin electrodes and +4.7%, -5.5% for the baseline electrodes can be noted. Thus, a 19% spread tolerance reduction was achieved when the baseline electrodes from Group III are compared with those of Group II.

5.2.1.4.1.2.2 Negative Electrode Weight Distribution

Negative electrode weight distribution for Group II is shown in Figure 5.2-12. A total plate weight range of 65 to 77 grams can be noted. This results in ±8.4% weight tolerance from an average of 71 grams.

Negative electrode weight distribution for Group III is shown below.

TABLE 5.2 - 3

Electrode Type	No. of Samples	Weight in Grams Average	Range
Thin	203	64.4	59-69
Baseline	40	78.8	75-81

A weight tolerance spread of +7.1%, -8.4% from the average weight for the thin electrodes and +2.8, -4.8% for the baseline electrodes are observed. A 55% spread tolerance decrease on the baseline electrodes between Groups III and II is shown.

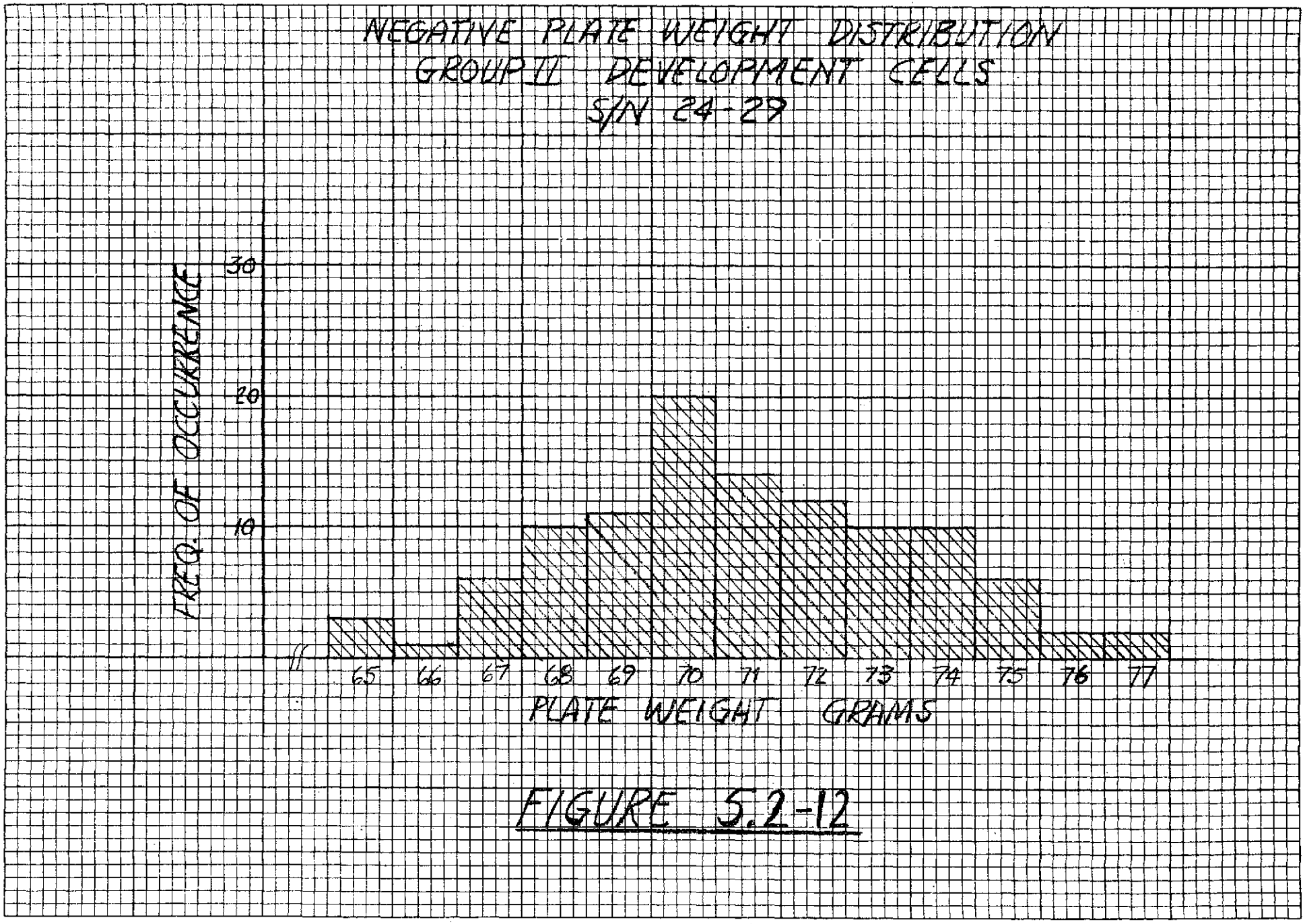


FIGURE 5.2-12

5.2.1.4.2.3 Weight Distribution Comments

A comparison between positive and negative electrode weight tolerances shows that consistently closer weight control was achieved on the positive electrodes.

Lower observed weight tolerances for the Group III electrodes were achieved by application of the semi-automated plague laying process.

5.2.1.4.1.3 Electrode Thickness Distribution

Electrode thickness distribution for development Group II cells are shown in Figure 5.2-13. It was obtained by measuring the thickness of each electrode at each of the four corners, computing an average value therefrom. Positive electrodes range from 0.024" to 0.028", resulting in an average value of 0.26" $\pm$.002". Negative electrode thickness ranged from 0.024 to 0.029", resulting in an average value 0.0265" $\pm$ .0025".

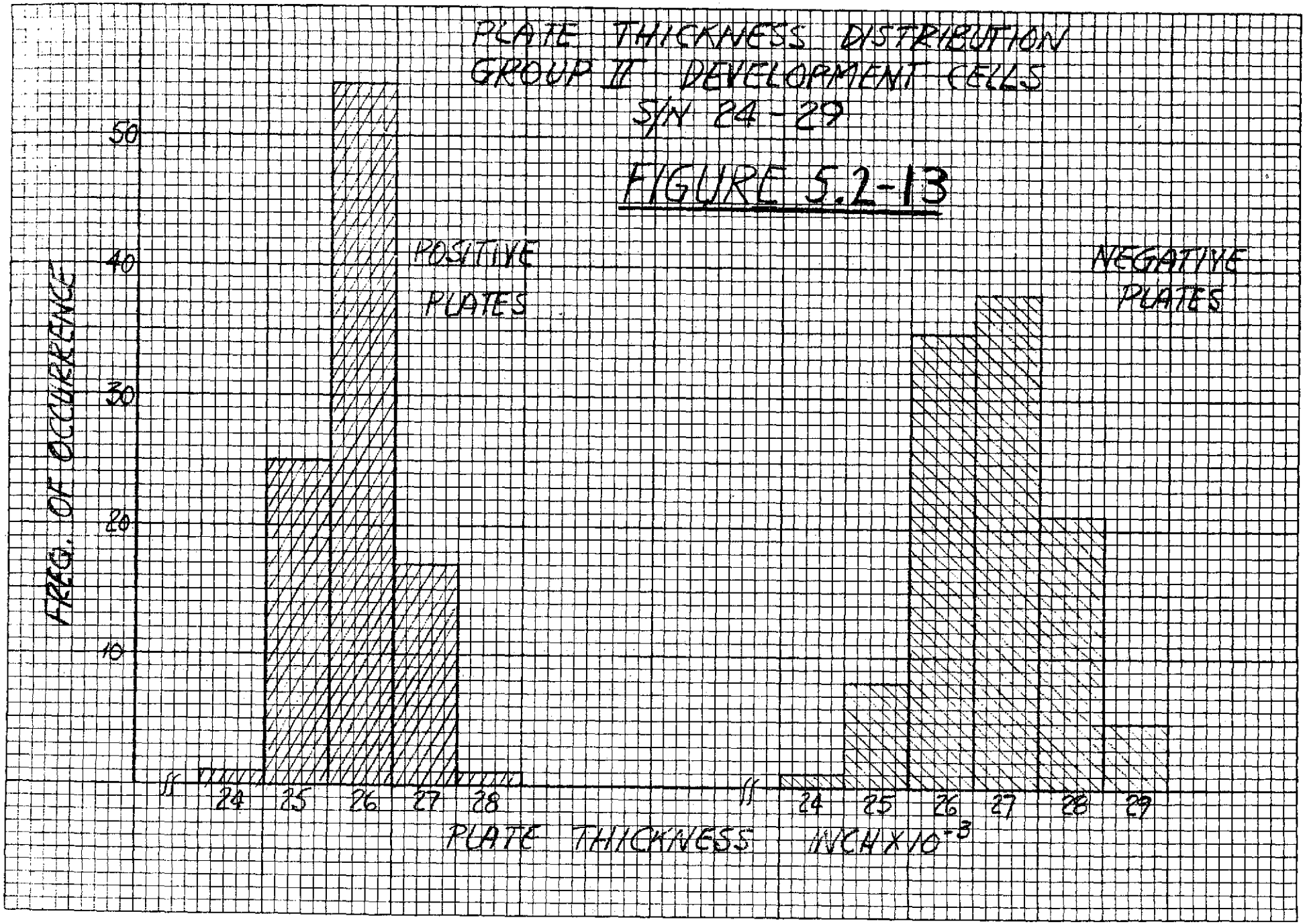
The Group III cell electrode thickness distribution is shown below:

TABLE 5.2 - 4

	No. of	Thickness in inches x10^{-3}	
Electrode Type	Samples	Average	Range
Thin Positive	199	21.2	20.3-22.2
Baseline Positive	36	26.5	25.9-27.5
Thin Negative	204	23.5	21.8-25.0
Baseline Negative	38	31.0	29.0-32.5

5.2.1.4.1.3.1 Thickness Distribution Comments

Again a comparison between positive and negative electrodes shows that closer thickness control was achieved on the positive electrodes. Also the Group III cell electrodes showed closer thickness tolerances than the Group II cell electrodes.



5.2.1.4.1.4 Electrolyte Analysis Data

The electrolyte used for each cell had successfully passed the analysis requirements specified in EP document no. EP-MS-36 (Appendix E).

A sample of electrolyte from pre-contract cell, S/N 1, removed during electrolyte adjustment, was analyzed for potassium hydroxide and potassium carbonate content using the double titration method. (The electrolyte was removed with the cell fully charged). The following results were obtained:

Description	% Total Alkalinity	% KOH	% K_2CO_3	K_2CO_3 (g/lt.)	K_2CO_3 (g/cell)(*)
Electrolyte Prior to filling	30.33	30.29	0.04	0.4	0.2
Electrolyte Removed from cell	28.08	18.61	9.47	102.8	42.2
Electrolyte change	-2.25	-11.68	+9.43	+102.4	+42.0

NOTES: (*) dissolved in the electrolyte solution only

5.2.1.4.2 Electrical Data

5.2.1.4.2.1 Development Group I

5.2.1.4.2.1.1 Capacity

Capacity data for Group I tests, conducted at both +20°C and 0°C, are shown in attached Tables 5.2-5 and 5.2-6.

5.2.1.4.2.1.2 Pressure

Pressure Maximum cell pressures during charge, and at end of discharge, are shown in attached Tables 5.2-7 through 5.2-10.

5.2.1.4.2.1.3 Cell Discharge Voltage

The cell's voltages after 75 AH discharge at 20°C are shown in Table 5.2-11. Voltages after 50 AH and 75 AH discharge at 0°C are shown in Tables 5.2-12 and 5.2-13.

TABLE 5.2-5

+20°C TEST - DEVELOPMENT GROUP I
CAPACITY TO 1.0 VOLT

Test Condition No. (*)		1	2	2	2	3	4	5	6	7
Design Description	CELL S/N	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CHARGE	15 AMP CHARGE	AFTER OVERCHARGE	AFTER 3 ORB. CYCLES
	1	116.7	115.9	112.5	109.6	105.1	106.3	106.6	122.5	113.3
Precontract Cells	13	116.7	117.5	112.5	107.8	103.3	104.9	103.3	117.5	105.7
	AV	116.7	116.7	112.5	108.7	104.2	105.6	103.5	120.0	109.5
Baseline Design	14	101.2	97.4	97.6	95.0	93.4	93.5	98.4	99.1	92.5
	15	101.6	97.4	97.6	95.0	93.4	93.5	99.1	99.3	92.9
	AV	101.4	97.4	97.6	95.0	93.4	93.5	98.8	99.2	92.7
Thin Plate	16	115.9	116.3	113.8	112.9	108.3	110.1	115.0	115.4	110.0
	17	114.1	113.2	112.1	112.1	105.0	107.1	113.0	112.9	107.8
	AV	115.0	114.8	113.0	112.5	106.7	108.6	114.0	114.2	108.9
Opposed Terminals	22	106.7	104.1	97.5	94.1	85.9	92.8	97.5	97.4	95.4
	23	106.7	104.1	98.0	94.1	85.9	91.1	95.9	97.4	94.0
	AV	106.7	104.1	97.8	94.1	85.9	92.0	96.7	97.4	94.7
Discharge Current Amp.		50.0	50.0	50.0	50.0	100.0	50.0	50.0	50.0	50.0
Charge Current Amp.		10.0	30.0	30.0	30.0	30.0	60.0 +30.0	15.0	30.0 +10.0	37.4

NOTES: * As defined in the DVTP-153-1 test plan, Table I.

TABLE 5.2-6

0°C TEST - DEVELOPMENT GROUP I
CAPACITY TO 1.0 VOLT

Test Condition No. (*)		8	9	9	9	10	11	12	13	14
Design Description	CELL S/N	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CHARGE	15 AMP CHARGE	AFTER OVERCHARGE	AFTER 3 ORB. CYCLES
Precontract Cell	13				93.4	87.4	87.5	83.4	88.3	81
Baseline Design	14	90.8	90.8	88.7	91.7	91.7	89.7	90.0	97.9	91
	15	90.8	90.8	88.7	91.7	91.7	90.0	90.5	97.3	92
	AV	90.8	90.8	88.7	91.7	91.7	89.9	90.3	97.6	91.5
Thin Plate Cells	16	101.6	100.0	100.8	101.3	97.1	101.2	102.5	113.3	105
	17	____	96.4	96.6	100.4	96.4	99.1	101.3	110.0	103.3
	AV	101.6	98.2	98.7	100.9	96.8	100.2	101.9	111.7	104.2
Opposed Terminals	22	88.0	87.1	82.6	90.0	70.8	84.2	79.6	77.5	75
	23	90.8	89.3	88.7	90.9	90.9	90.9	83.4	90.8	87.5
	AV	89.4	88.7	85.7	90.5	80.9	87.6	81.5	84.2	81.3
Discharge Current Amp.		50.0	50.0	50.0	50.0	100.0	50.0	50.0	50.0	50.0
Charge Current Amp.		10.0	30.0	30.0	30.0	30.0	60.0 +30.0	15.0	30.0 +5.0	37.4

NOTES: * As defined in the DVTP 153-1 test plan, Table 1.

TABLE 5.2-7

MAXIMUM PRESSURE ON CHARGE (PSIG) 20°C TEST

DEVELOPMENT GROUP I

CELL NO.	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CHARGE	15 AMP CHARGE	OVERCHARGE	3 ORBITAL CYCLES
1	52	16	12	13	12	11	27	86	--
14	-2	12	28	33	22	14	85	78	45
15	-4	10	26	33	22	14	77	70	39
16	-11	6	15	16	7	9	47	43	14
17	-6	4	25	30	18	12	79	75	36
22	-1	0	12	18	18	14	38	30	15
23	-4	1	13	20	18	10	43	35	22

TABLE 5.2-8

PRESSURE AT END OF DISCHARGE (PSIG) 20°C TEST

DEVELOPMENT GROUP I

CELL NO.	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	60 AMP CHARGE	15 AMP CHARGE	OVERCHARGE	3 ORBITAL CYCLES
1	26	6	5	5	5	7	41	
14	-2	-5	0	3	0	25	23	20
15	-4	-5	0	4	0	21	20	19
16	-11	-10	-7	-6	-6	0	0	2
17	-6	-6	-1	2	-4	15	15	0
22	-1	-3	-2	8	7	16	11	0
23	-4	-4	-4	9	5	20	15	4

TABLE 5.2-9

0°C TEST MAXIMUM PRESSURE ON CHARGE (PSIG)

DEVELOPMENT GROUP I

CELL NO.	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CHARGE	15 AMP CHARGE	OVERCHARGE	3 ORBITAL CYCLES
14	4	-6	-7	-6	-6	-6	2	50	27
15	0	-9	-9	-8	-9	-9	-2	43	20
16	-2	-10	-10	-10	-10	-10	-7	24	6
17	-15	-12	-12	-10	-10	-10	-5	38	9
22	-6	-3	2	0	0	2	4	56	14
23	-10	-9	-7	-7	-7	-8	-4	23	9

TABLE 5.2-10

PRESSURE AT END OF DISCHARGE (PSIG) 0°C TEST

DEVELOPMENT GROUP I

CELL NO.	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CHARGE	15 AMP CHARGE	OVERCHARGE	3 ORBITAL CYCLES
14	-2	-7	-7	-7	-9	-7	-2	20	-5
15	-2	-10	-9	-10	-10	-10	-5	12	-10
16	-7	-11	-10	-11	-11	-11	-9	-1	-10
17	-15	-13	-11	-11	-10	-10	-6	9	-10
22	-1	-3	2	-1	0	0	2	46	+8
23	-2	-9	-7	-8	-7	-8	-4	16	0

TABLE 5.2-11

20°C TEST VOLTAGE AFTER REMOVAL OF 75 A-H

DEVELOPMENT GROUP I

CELL NO.	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CHARGE	15 AMP CHARGE	OVERCHARGE	CYCLE
1	1.215	1.217	1.216	1.216	1.179	1.221	1.211	1.219	1.202*
13	1.214	1.218	1.217	1.217	1.172	1.221	1.207	1.207	1.179
14	1.191	1.198	1.192	1.192	1.161	1.207	1.193	1.190	1.170
15	1.188	1.198	1.192	1.192	1.153	1.200	1.188	1.185	1.163
16	1.213	1.217	1.212	1.214	1.185	1.226	1.215	1.212	1.196
17	1.211	1.216	1.216	1.219	1.182	1.225	1.216	1.212	1.195
22	1.192	1.208	1.195	1.191	1.115	1.199	1.190	1.188	1.167
23	1.199	1.208	1.197	1.190	1.119	1.197	1.186	1.187	1.164

* After 79.2 A-H removed.

Table 5.2-12

0°C TEST VOLTAGE AFTER REMOVAL OF 50 A-H

DEVELOPMENT GROUP I

CELL NO.	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CHARGE	15 AMP CHARGE	OVERCHARGE	3 ORBITAL CYCLES
13	-	-	-	1.224	1.179	1.126	1.222	1.224	1.217
14	1.222	1.227	1.227	1.227	1.189	1.229	1.222	1.219	1.213
15	1.218	1.223	1.224	1.223	1.185	1.225	1.221	1.212	1.211
16	1.241	1.239	1.239	1.239	1.208	1.240	1.239	1.230	1.226
17	-	1.237	1.238	1.239	1.210	1.240	1.238	1.230	1.225
22	1.229	1.227	1.223	1.221	1.175	1.217	1.211	1.168	1.190
23	1.235	1.232	1.231	1.231	1.201	1.231	1.230	1.223	1.215

TABLE 5.2-13

0°C TEST VOLTAGE AFTER REMOVAL OF 75 A-H

DEVELOPMENT GROUP I

CELL NO.	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2*	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CHARGE	15 AMP CHARGE	OVERCHARGE	3 ORBITAL CYCLES
13	-	-	-	1.186	1.063	1.176	1.141	1.169	1.143
14	1.171	1.191	1.151	1.189	1.148	1.193	1.181	1.188	1.177
15	1.161	1.184	1.141	1.182	1.139	1.186	1.177	1.176	1.172
16	1.212	1.217	1.201	1.214	1.184	1.215	1.213	1.212	1.204
17	-	1.211	1.196	1.213	1.186	1.215	1.212	1.210	1.203
22	1.155	1.179	0.944	1.155	-	1.151	1.101	1.023	0.967
23	1.183	1.191	1.128	1.188	1.153	1.191	1.185	1.182	1.168

NOTES: #[redacted]lts after 83.3 A-H removed.

5.2.1.4.2.1.4 Ampere Hour Input

The inputs for all charges are shown in Table 5.2-14 and 5.2-15.

5.2.1.4.2.1.5 Cell Performance Curves

The following cell performance curves are included in this report:

Figure 5.2-14 - Test Cond. #1 - Cell and aux. signal discharge voltage profiles

Figure 5.2-15 - Test Cond. #2, Cycle 2 - Cell. and aux. signal charge and discharge voltage profiles

Figure 5.2-16 - Test Cond. #2, Cycle 3 - Cell. and aux. signal charge and discharge voltage profiles

Figure 5.2-17 - Test Cond. #3 - Cell. and aux. signal charge and discharge voltage profiles

Figure 5.2-18 - Test Cond. #6 - Charge and overcharge cell and aux. signal voltage profiles

Figure 5.2-19 - Test Cond. #6 - Cell charge and overcharge pressure and temp. profiles

Figure 5.2-20 - Test Cond. #7 - Cell and aux. signal voltage profiles for 30% D.O.D.

Figure 5.2-21 - Test Cond. #9, - Cycle 3 - Cell and aux. signal voltage profiles

Figure 5.2-22 - Test Cond. #10 - Cycle 3 - Cell and aux. signal voltage profiles

Figure 5.2-23 - Test Cond. #13 - Charge and overcharge cell and aux. signal voltage profiles

Figure 5.2-24 - Test Cond. #13 - Overcharge cell pressure profiles

Figure 5.2-25 - Test Cond. #14 - Cell and aux. signal voltage profiles for 30% D.O.D.

For test condition details, see appendix H Table 1.

- Test conditions 1-8 were conducted at +20°C ambient and test conditions 9-16 were conducted at 0°C ambient temperatures.

TABLE 5.2-14

20°C TEST CHARGE INPUT, AMPERE HOURS

DEVELOPMENT GROUP I

CELL NO.	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	HIGH RATE CAPACITY	HIGH RATE* CHARGE	LOW RATE CHARGE	OVERCHARGE	FINAL DISCHARGE
1	150	126.5	123.5	113.5	115	105	108.8	190	155
13	150	126.5	123.5	113.5	115	105	108.8	190	155
14	160	121	115	105	105	98	150	190	160
15	160	121	115	105	105	98	150	190	160
16	160	138	127.5	120	120	112.5	150	200	160
17	160	138	127.5	120	120	112.5	150	200	160
22	160	133	118.5	107.75	105	93	150	190	160
23	160	133	118.5	107.75	105	93	150	190	160

*NOTE: Charger malfunction at beginning of charge caused charge rate in excess of 100 amps for approximately 45 seconds; this input was not included in calculations.

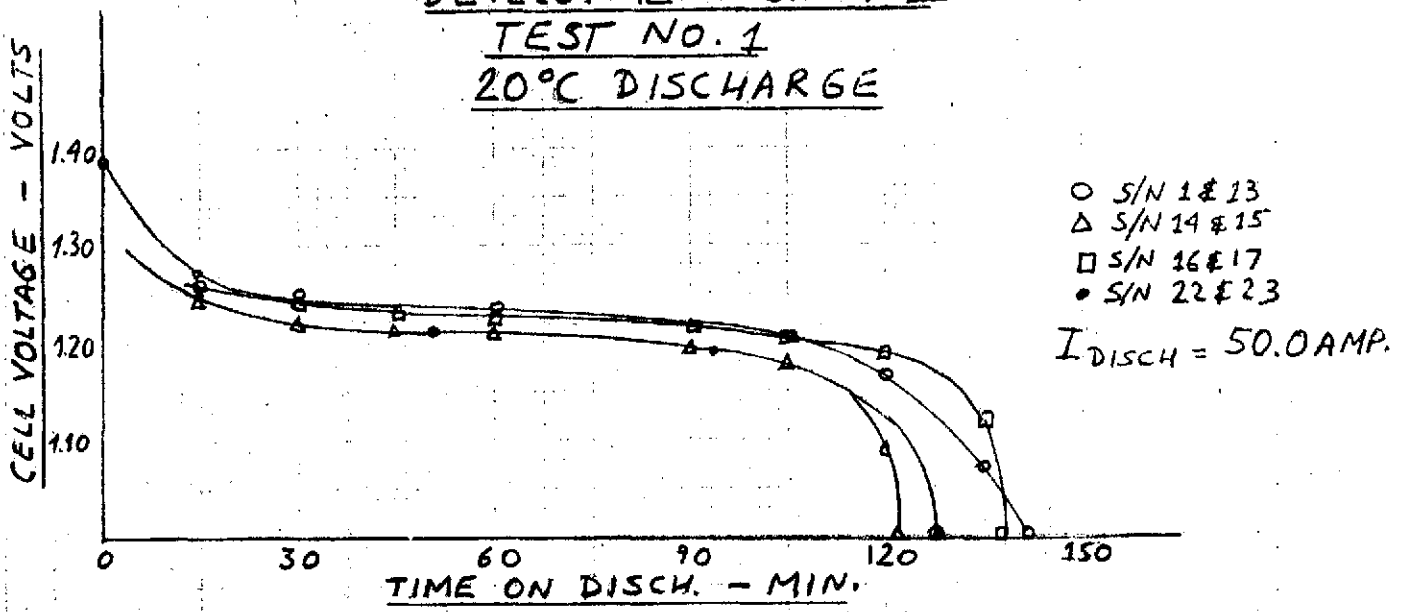
TABLE 5.2-15

60°C TEST CHARGE INPUT, AMPERE HOURS

DEVELOPMENT GROUP II

CELL NO.	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	50 AMP CHARGE	15 AMP CHARGE	OVERCHARGE	FINAL DISCHARGE
13	113	--	--	101.5	90.5	77	93.5	92.8	109
14	100	89.5	91	91	90.5	85	95.3	110	109
15	100	89.5	91	91	90.5	85	95.3	110	109
16	112.5	101.5	101	101.5	100	95	105.5	168.5	109
17	--	101.5	99	101.5	100	95.	105.5	168.5	109
22	100	75	89	86.5	85	73	80.0	99.6	75
23	100	75	89	91	90.6	83.5	95.3	106.1	109

DEVELOPMENT GROUP I
TEST NO. 1
20°C DISCHARGE



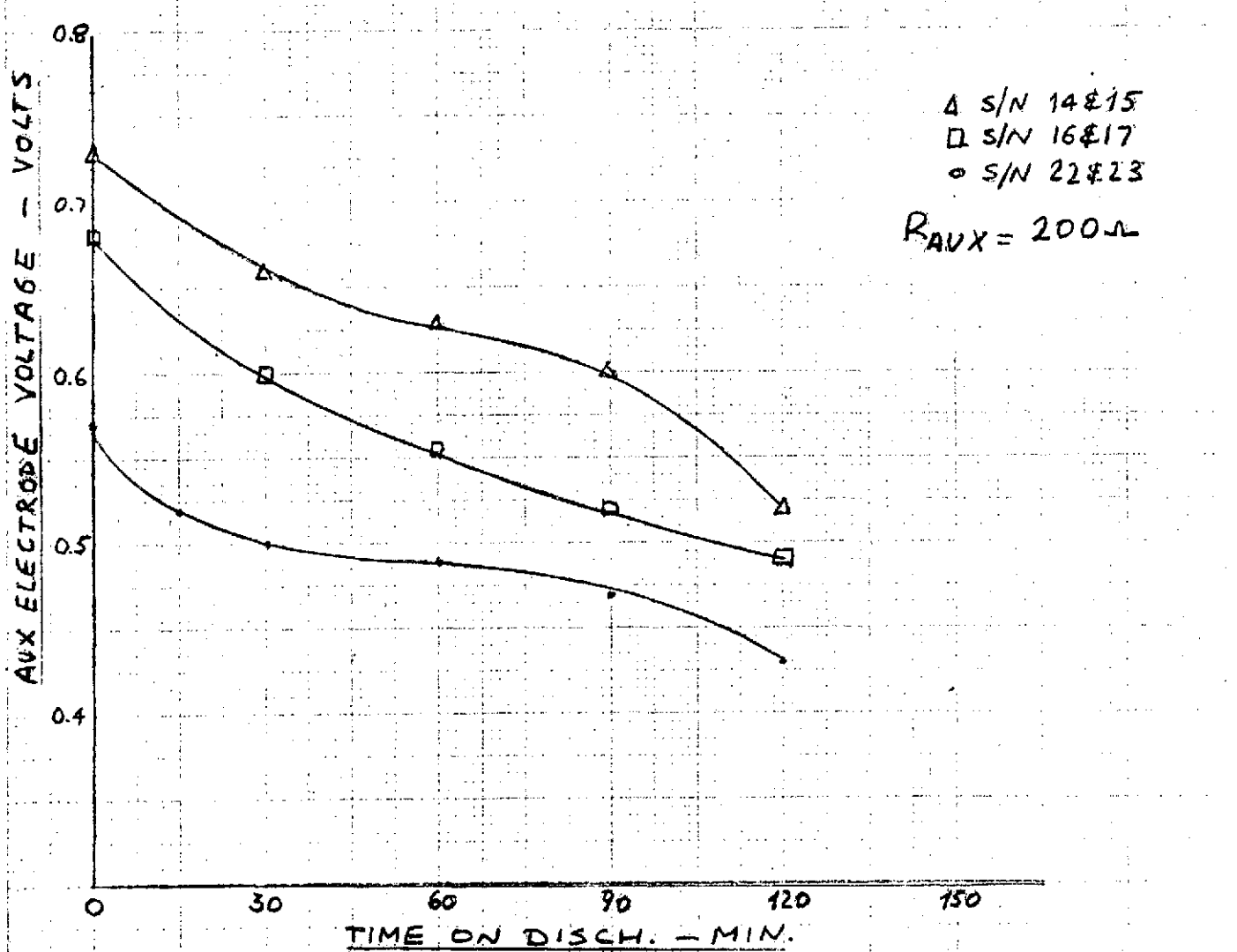
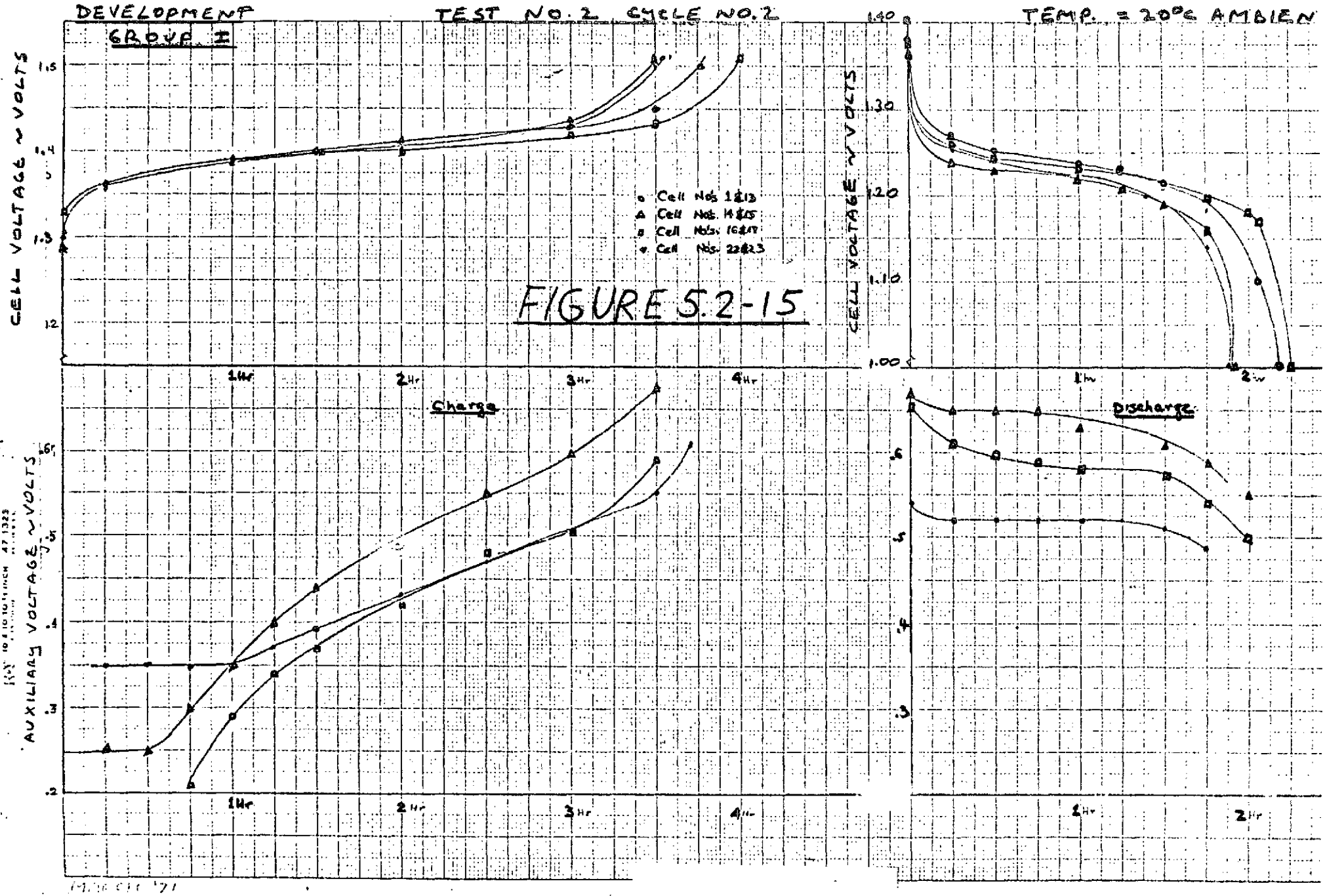
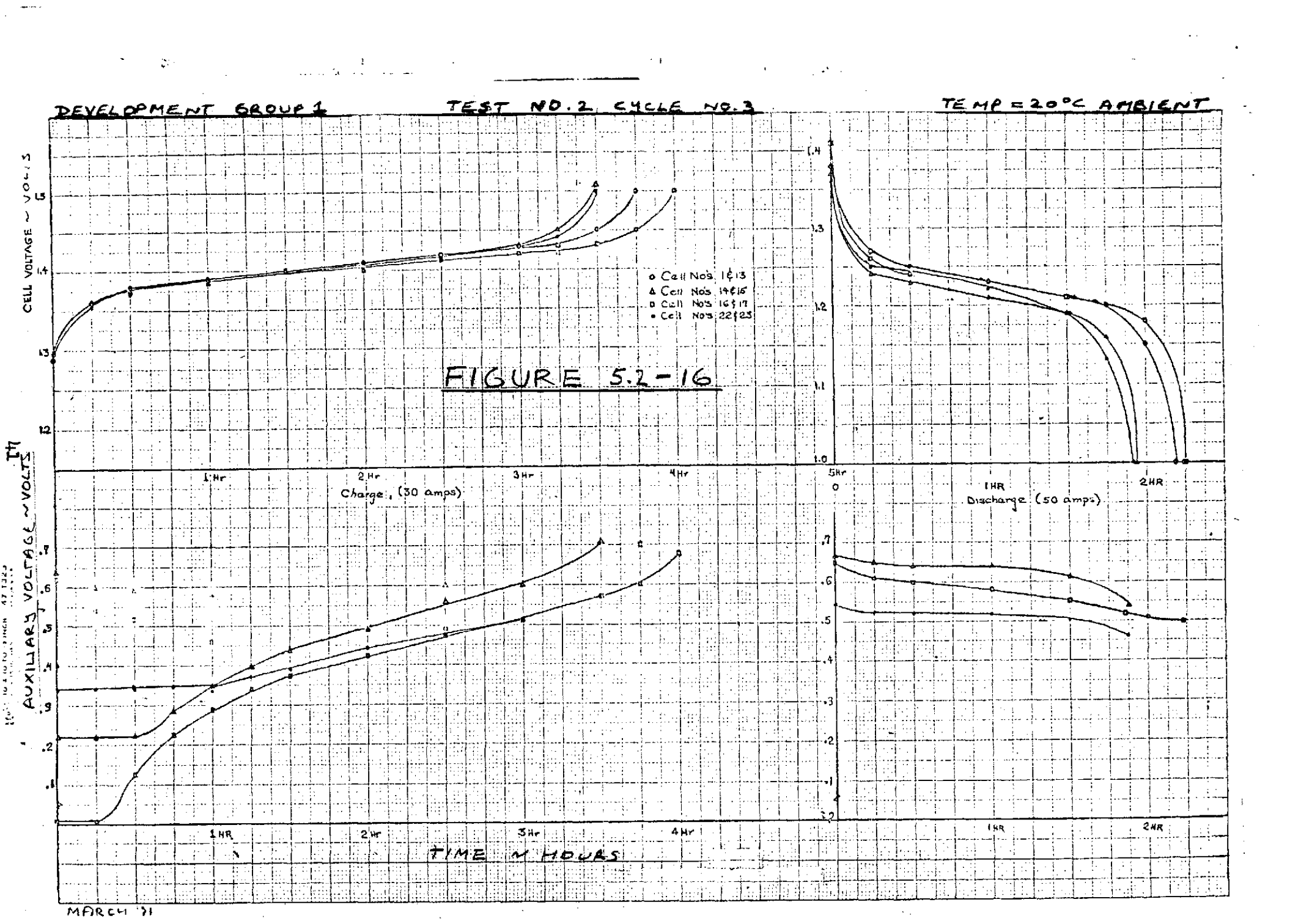


FIGURE 5.2-14


DEVELOPMENT
GROUP H
TEST NO. 2 CYCLE NO. 2
TEMP. = 20°C AMBIEN
CELL VOLTAGE ~ VOLTS
AUXILIARY VOLTAGE ~ VOLTS
Cell Nos 1 & 13
Cell Nos. 14 & 15
Cell Nos. 16 & 17
Cell Nos 22 & 23
FIGURE 5.2-15
Charge
Discharge
1Hr
2Hr
3Hr
4Hr


DEVELOPMENT GROUP 1
TEST NO. 2 CYCLE NO. 3
TEMP = 20°C AMBIENT
CELL VOLTAGE ~ VOLTS
AUXILIARY VOLTAGE ~ VOLTS
o Cell Nos 1 & 13
Δ Cell Nos 14 & 15
□ Cell Nos 16 & 17
• Cell Nos 22 & 23
FIGURE 5.2-16
Charge (30 amps)
Discharge (50 amps)
1HR
2Hr
3Hr
4Hr
5Hr
TIME IN HOURS
MARCH '71

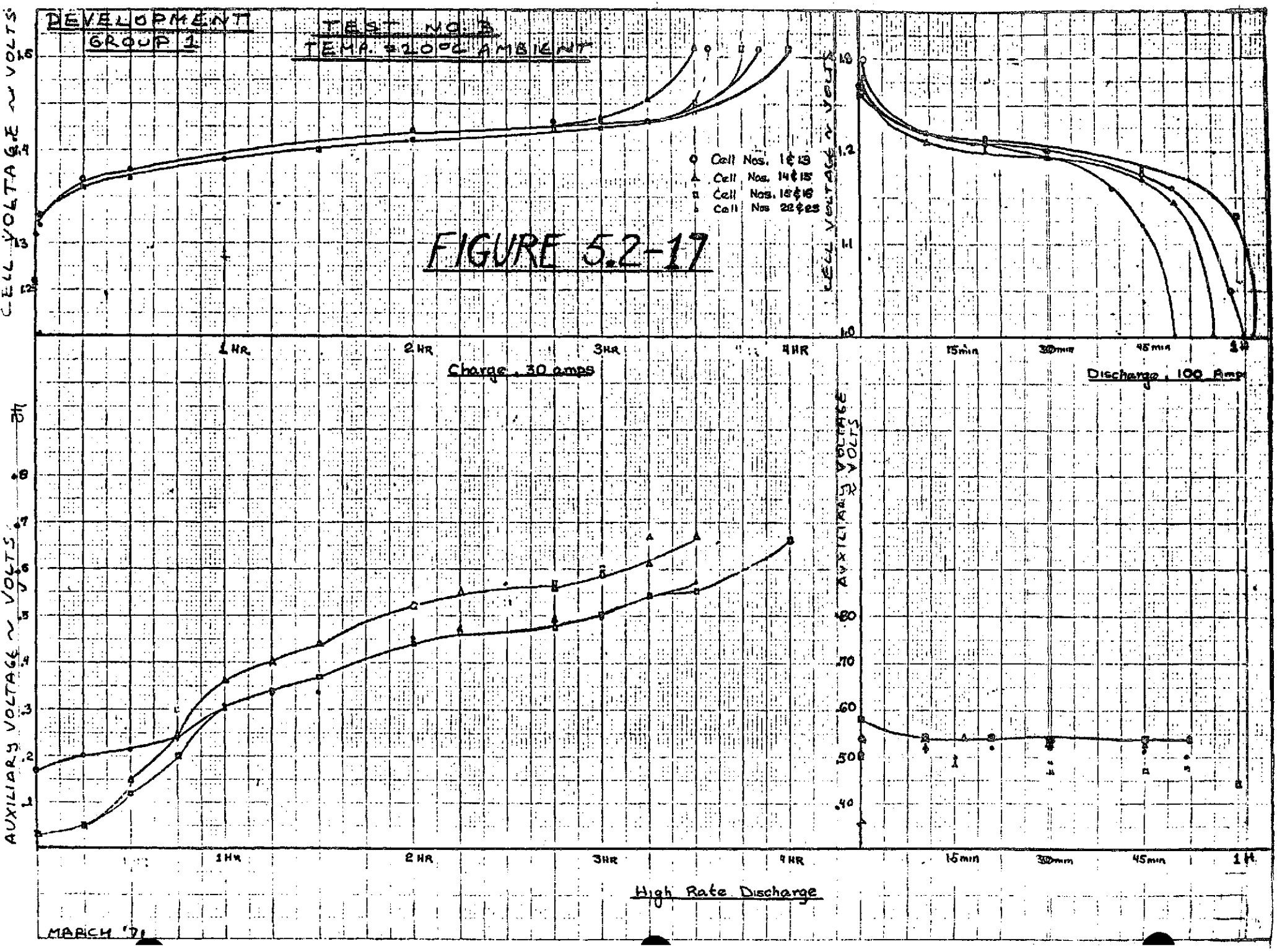
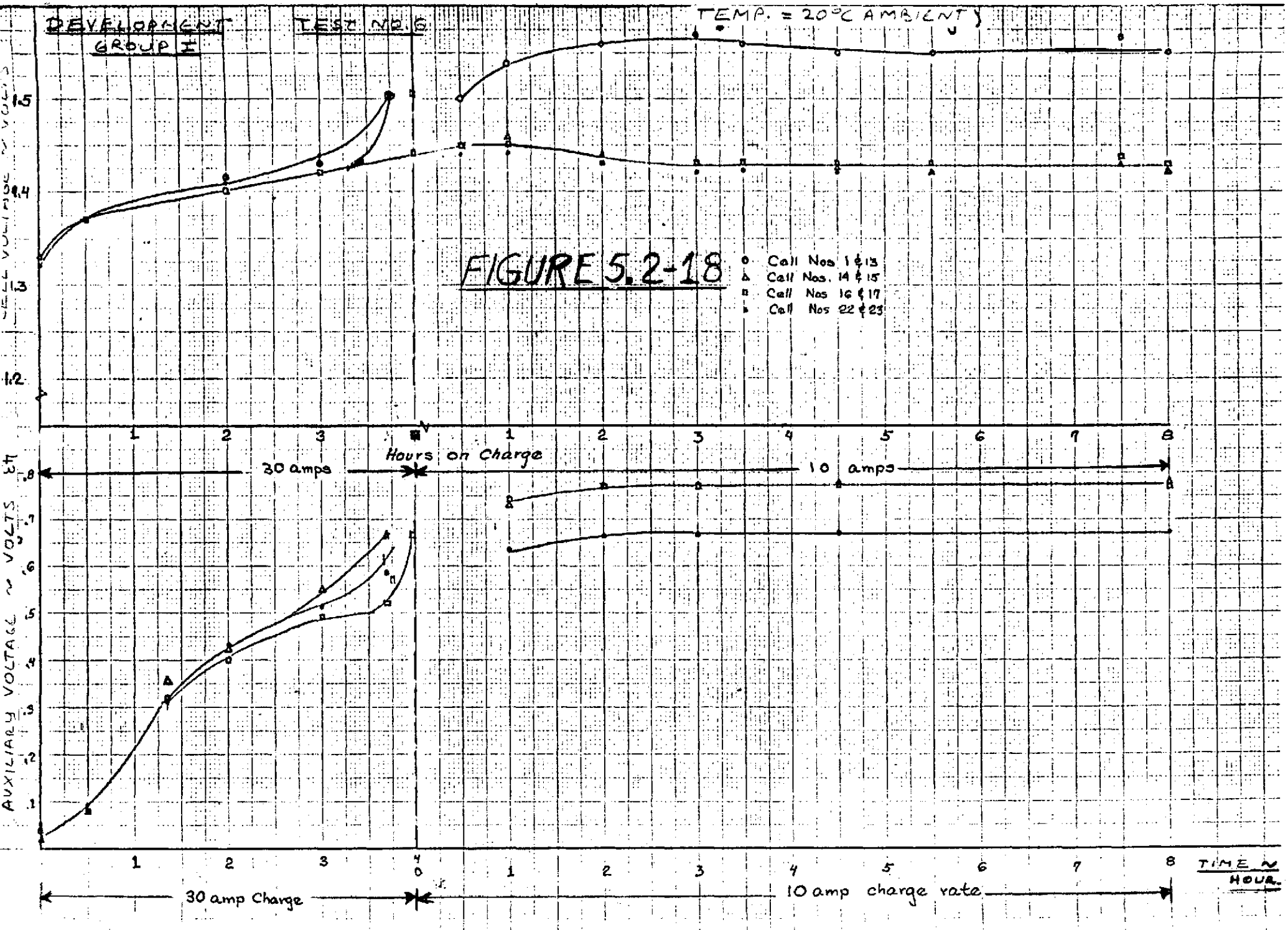

DEVELOPMENT
GROUP 1
TEST NO. 3
TEMP. +20°C AMBIENT
Cell Nos. 1 & 13
Cell Nos. 14 & 15
Cell Nos. 18 & 16
Cell Nos 22 & 23
CELL VOLTAGE ~ VOLTS
1 HR
2 HR
3HR
4 HR
Charge . 30 amps
15min
30min
45min
1 H
Discharge . 100 Amps
AUXILIARY VOLTAGE ~ VOLTS
High Rate Discharge
MARCH '71

FIGURE 5.2-17


DEVELOPMENT TEST NO. 6
GROUP H
TEMP. = 20°C AMBIENT
FIGURE 5.2-18
Cell Nos 1 & 13
Cell Nos. 14 & 15
Cell Nos 16 & 17
Cell Nos 22 & 23
Hours on Charge
30 amps
10 amps
AUXILIARY VOLTAGE IN VOLTS
TIME IN HOURS
30 amp Charge
10 amp charge rate

CONTRACT NAS9-11674

CELL DEVELOPMENT TESTS - GROUP 2

OVERCHARGE DATA AT ±20°C

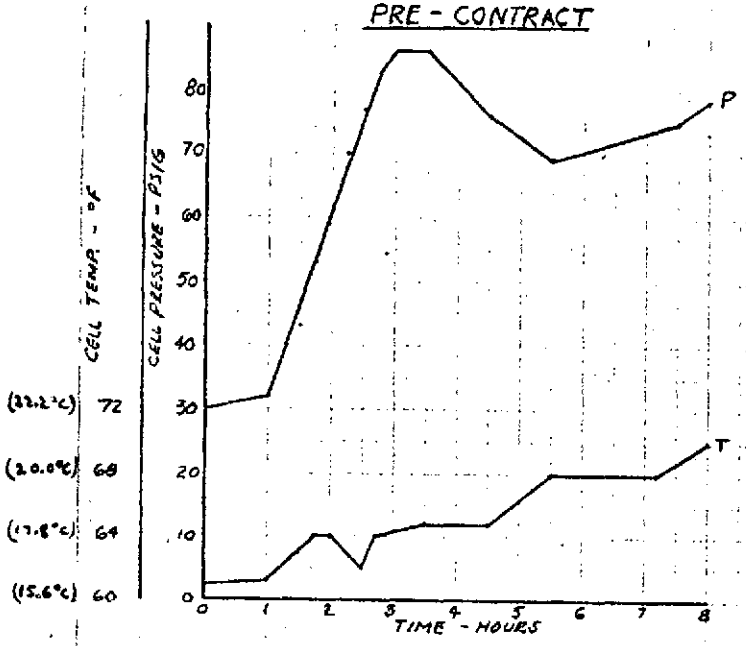
REFERENCES:

1. TEST PROGRAM PLAN, REV. B, TABLE I, TEST CONDITION 6
2. E-P TEST DATA SHEETS, 6/8/71

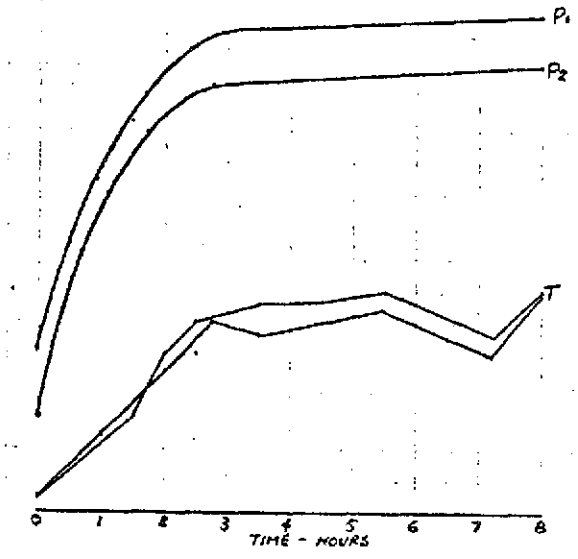
CELL S/N	DESIGN DESCRIPTION
1371	PRE-CONTRACT
1415	BASELINE
1617	THIN PLATES
2242B	OPPOSITE TERMINALS

3. OVERCHARGE CURRENT = 10.0 AMP. FOR 8.0 HOURS

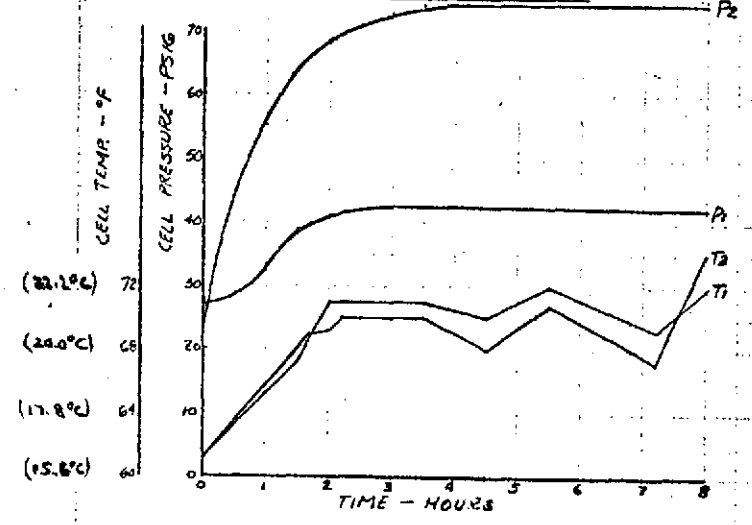
PRE - CONTRACT



BASELINE



THIN PLATES



OPPOSITE TERMINALS

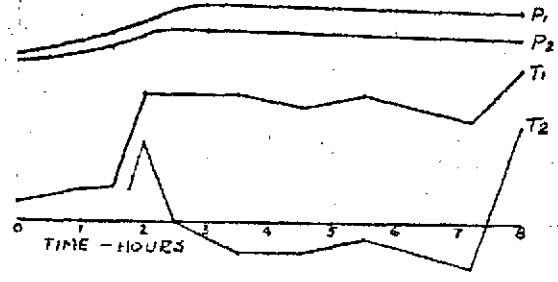


FIGURE 5.2-19

S.G/JAM 3/4/71

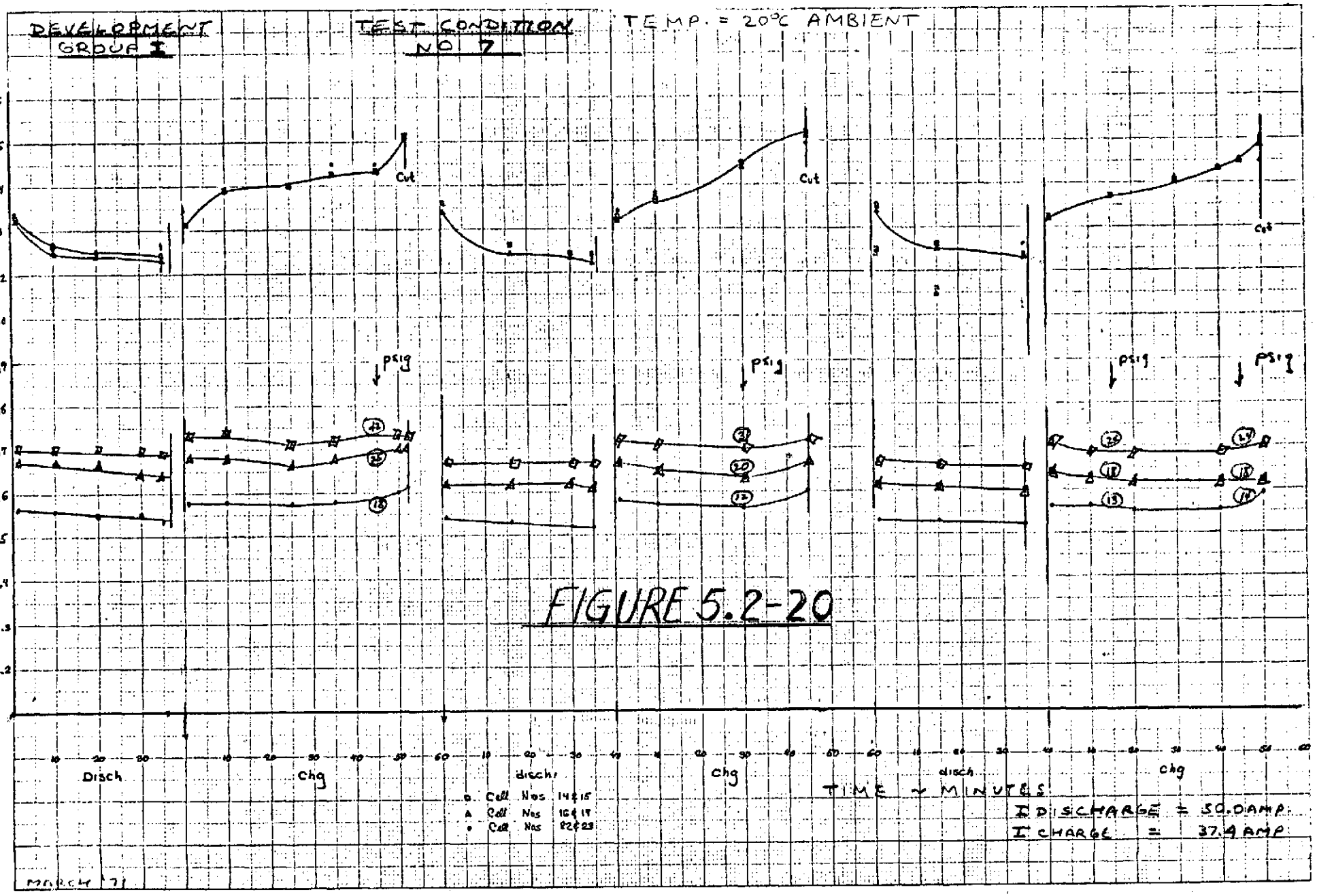

DEVELOPMENT
GROUP I
TEST CONDITION
NO 7
TEMP. = 20°C AMBIENT
CELL VOLTAGE ~ VOLTS
AUXILIARY
Cut
Cut
Cut
psig
psig
psig
psig
Disch
Chg
dischr
Chg
disch
Chg
TIME ~ MINUTES
Cell Nos 14 & 15
Cell Nos 16 & 17
Cell Nos 22 & 23
I DISCHARGE = 50.0 AMP
I CHARGE = 37.4 AMP
MARCH '71

FIGURE 5.2-20

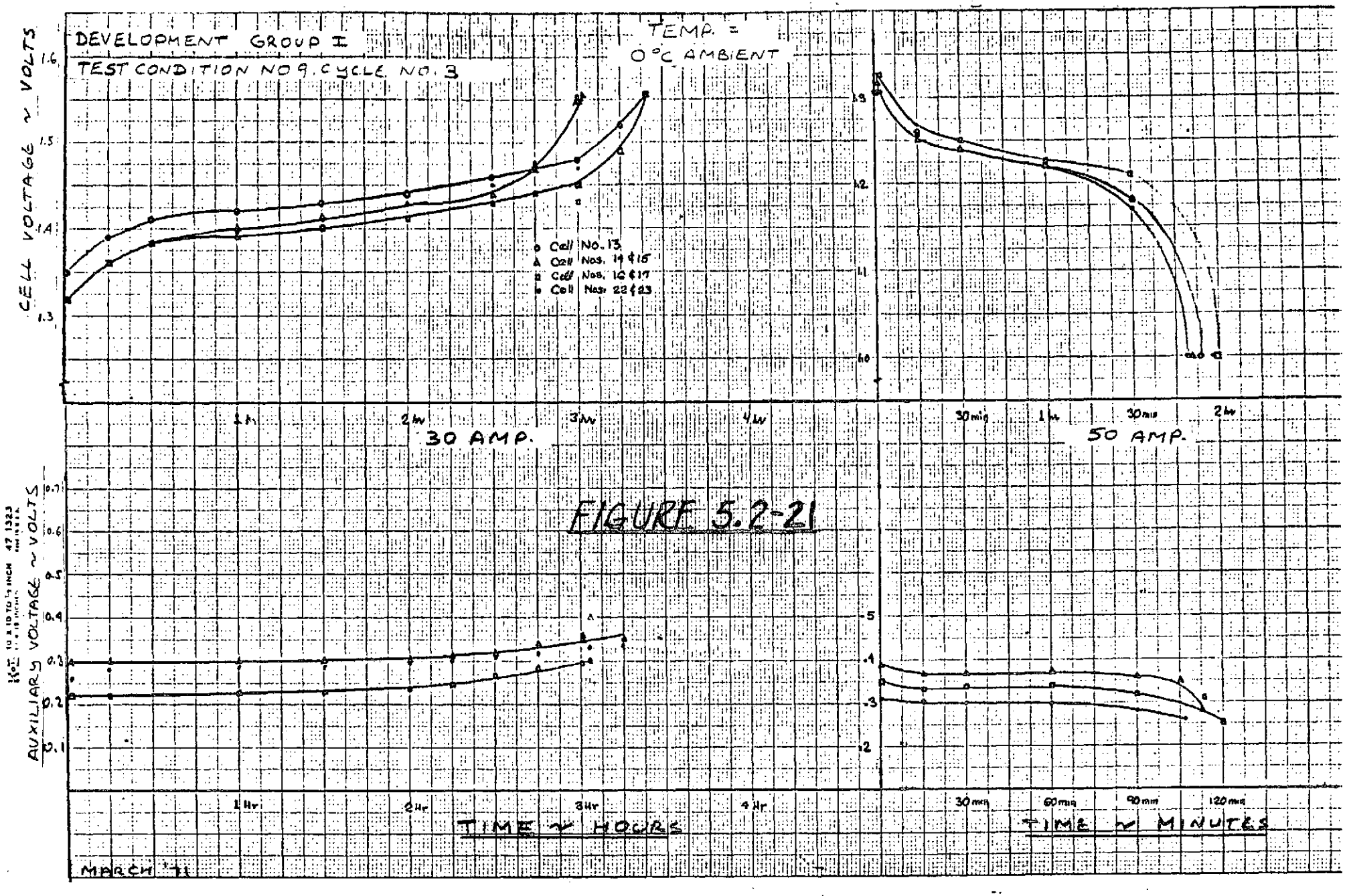

DEVELOPMENT GROUP II
TEST CONDITION NO 9. CYCLE NO. 3
TEMP. = 0°C AMBIENT
CELL VOLTAGE ~ VOLTS
AUXILIARY VOLTAGE ~ VOLTS
o Cell No. 13
Δ Cell Nos. 14 & 15
□ Cell Nos. 16 & 17
◇ Cell Nos. 22 & 23
30 AMP.
50 AMP.
TIME ~ HOURS
TIME ~ MINUTES
MARCH '71

FIGURE 5.2-21

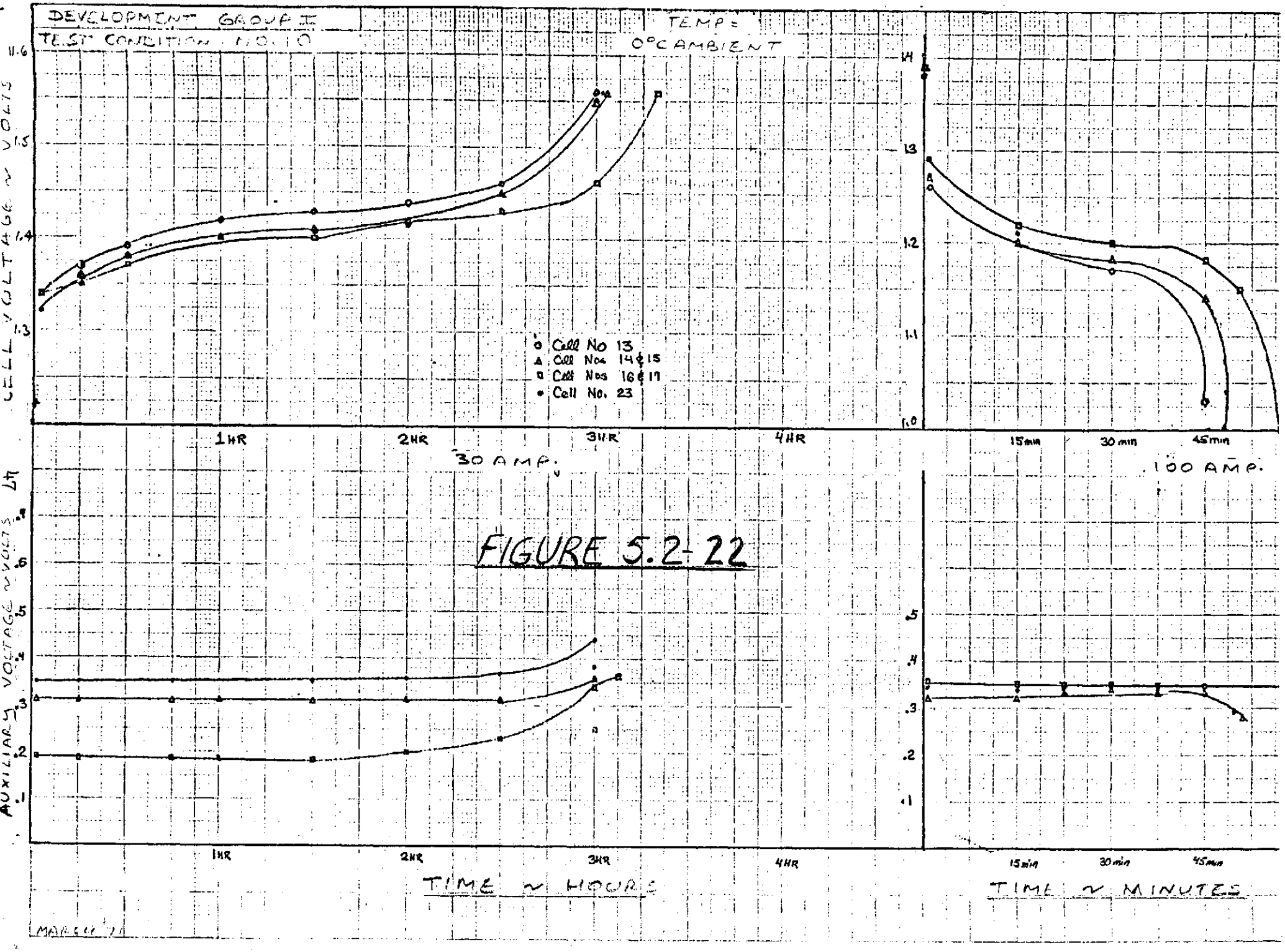

DEVELOPMENT GROUP II
TEST CONDITION NO. 10
TEMP = 0°C AMBIENT
CELL VOLTAGE ~ VOLTS
AUXILIARY VOLTAGE ~ VOLTS
Cell No 13
Cell Nos 14 & 15
Cell Nos 16 & 17
Cell No. 23
1HR
2HR
3HR
4HR
30 AMP.
100 AMP.
15min
30 min
45min
TIME ~ HOURS
TIME ~ MINUTES
MARCH '71

FIGURE 5.2-22

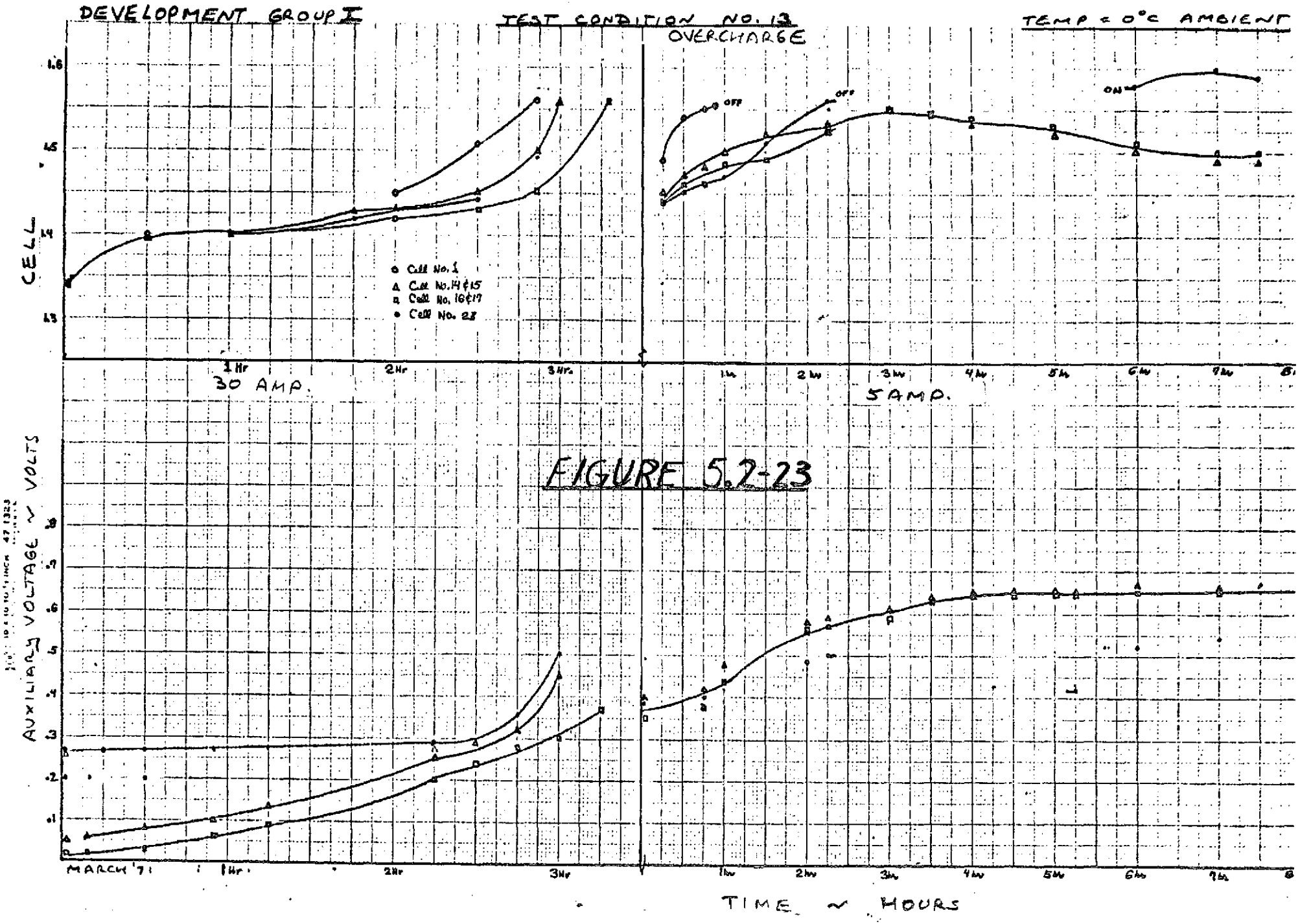

DEVELOPMENT GROUP I
TEST CONDITION NO. 13
OVERCHARGE
TEMP = 0°C AMBIENT
CELL
AUXILIARY VOLTAGE ~ VOLTS
Cell No. 1
Cell No. 14 & 15
Cell No. 16 & 17
Cell No. 23
OFF
OFF
ON
30 AMP.
5 AMP.
MARCH '71
TIME ~ HOURS

FIGURE 5.2-23

DEVELOPMENT GROUP I

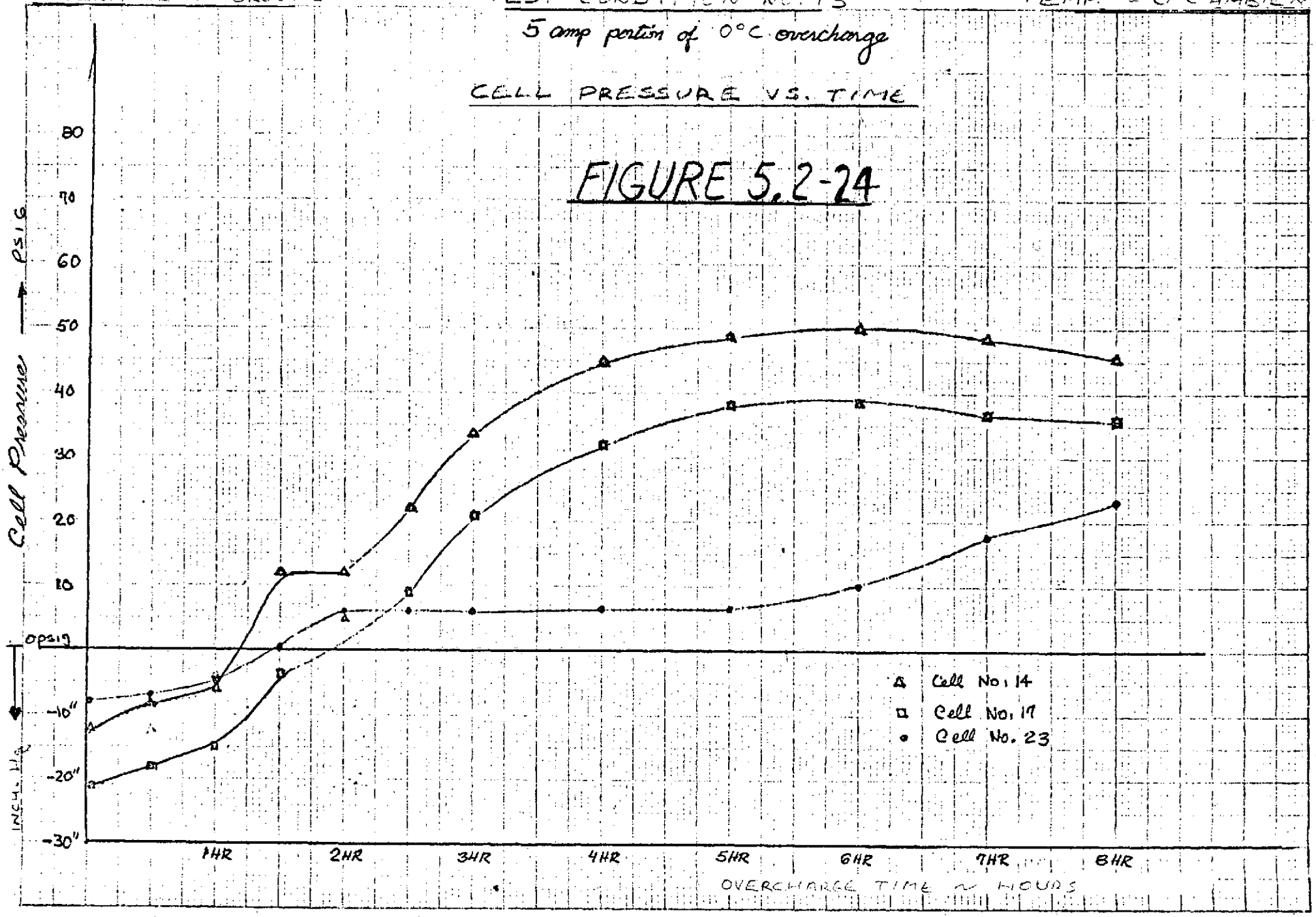
TEST CONDITION NO. 13

TEMP. = 0°C AMBIENT

5 amp portion of 0°C overcharge

CELL PRESSURE VS. TIME

FIGURE 5.2-24



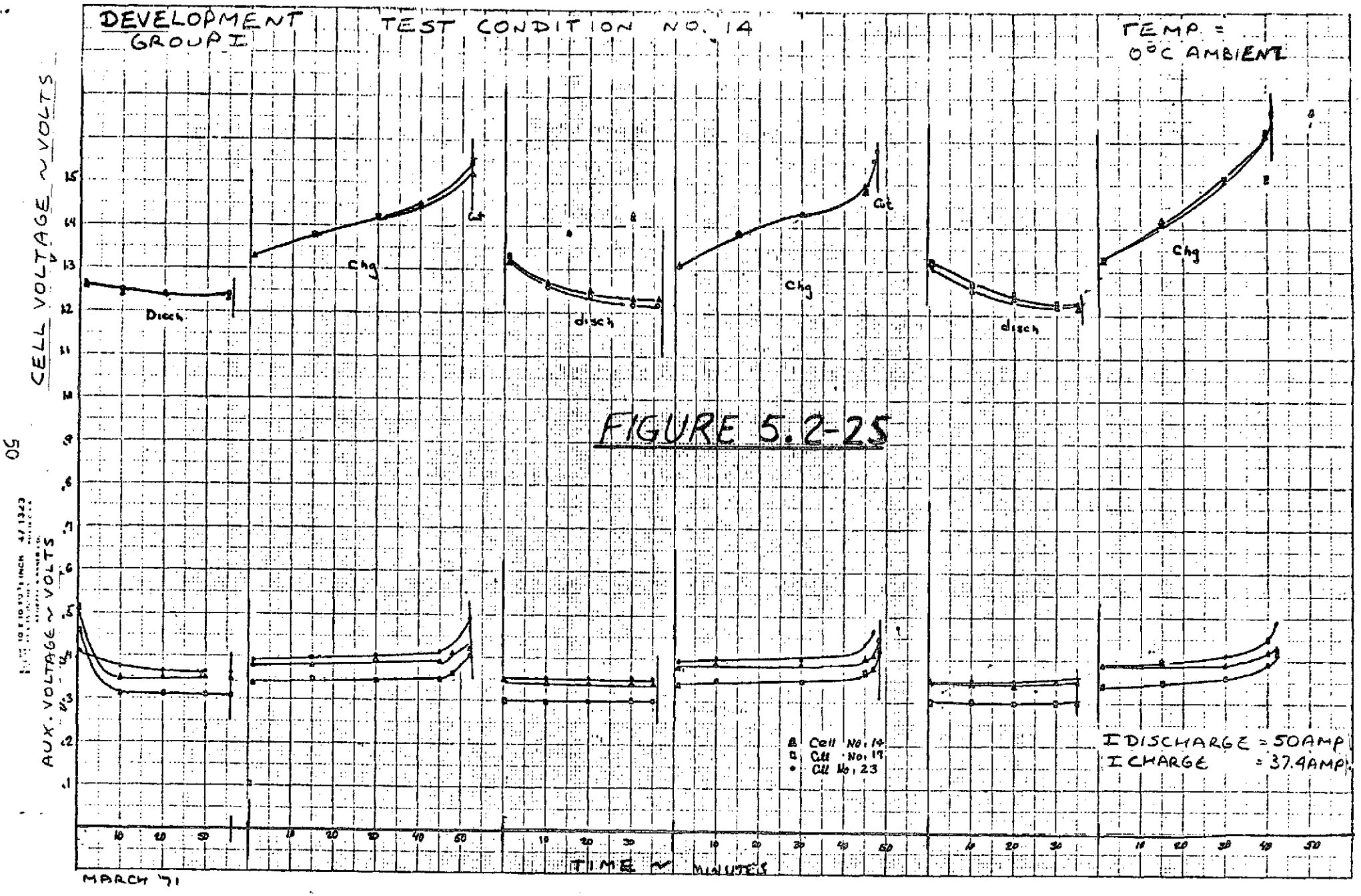

DEVELOPMENT GROUP I
TEST CONDITION NO. 14
TEMP. = 0°C AMBIENT
CELL VOLTAGE ~ VOLTS
AUX. VOLTAGE ~ VOLTS
Chg
Disch
Cut
B Cell No. 14
□ Cell No. 17
• Cell No. 23
I DISCHARGE = 50AMP
I CHARGE = 37.4AMP
TIME ~ MINUTES
MARCH '71

FIGURE 5.2-25

5.2.1.4.2.2 Development Group II

5.2.1.4.2.2.1 Capacity

Capacity data for the Group II cell tests are shown in Table 5.2-16.

5.2.1.4.2.2.2 Pressure

Maximum cell pressure changes on charge, and at end of discharge, are shown in Table 5.2-17.

5.2.1.4.2.2.3 Cell Discharge Voltage - 50 and 75 AH Removal

The cells' voltages after 50 and 75 AH discharges, respectively, at 0°C are shown in Tables 5.2-18 and 5.2-19. Voltages after 75 AH discharge at 20°C are shown in Table 5.2-20.

5.2.1.4.2.2.4 Ampere-Hour Input

The inputs for all charges are shown in Table 5.2-21.

5.2.1.4.2.2.5 Cell Performance Curves

The following cell performance curves are included in this report.

Figure 5.2-26 - Test Cond. #6 - Overcharge cell pressure profiles

Figure 5.2-27 - Test Cond. #8 - Cell press. and aux. signal volt. profiles at 30% D.O.D.

Figure 5.2-28 - Test Cond. #16 - Cell pressure and aux. signal voltage profiles at 30% D.O.D.

5.2.1.4.2.3 Development Group I Retest

Cells S/N 1, 14, 17 and 23 were retested, during Group II tests, after adjustment of electrolyte quality.

5.2.1.4.2.3.1 Capacity

Table 5.2-22 shows the output capacity for these cells when tested as Group I cells, and later during the retest. Also shown are capacity changes from original Group I to retest with Group II. Finally the electrolyte quantity adjustment and percent change are given.

Test Description	S/N 24	S/N 25	S/N 26	S/N 27	S/N 28	S/N 29
Cell Type	WEX 1242		2505 Pellon-Shims		FT 2140 + Woven Polypro	
Electrolyte cc	350	350	346	346	354	354
% Ratio=Gr. of Electro. / Gr. of Cell Core	19.2	19.2	19.1	19.1	19.1	19.1
20°C Capacity - AHo						
Conditioning	96	96	99	100	81	84
Cycle #1	95	94	98	99	78	83
Cycle #2	92	92	99	100	75	81
Cycle #3	93	99	99	99	71	78
Hi Rate	89	88	95	97	75	78
Low Rate	93	93	102	103	75	80
Overcharge	103	102	104	108	82	80
Final Disch.	102	100	104	105	83	86
"C" rate Disch.	73	73	83	85	65	63
Av. Capacity = Σ/N	93	93	98	100	76	79
Av.AHo/gm pos.act.mat.	0.208	0.208	0.219	0.223	0.170	0.176
0°C Capacity - AHo						
Conditioning	92	90	91	94	80	81
Cycle #1	82.5	81	88.5	91.5	75	76.5
Cycle #2	81	80	86	87.5	77.5	77
Cycle #3	80	77.5	83	87	74	74
Hi Rate	79	77	83	86	74	72.5
Low Rate	87.5	86	90	91	79	79
Overcharge	89	88.5	94	91	78	78
Final Disch.	85	82	90	90	78	78
"C" Rate Disch.	70	66	82	82	68	68
Av. capacity = Σ/N	83	81	88	89	76	76
Av.AHo/gm pos.act.mat.	0.185	0.181	0.196	0.199	0.170	0.169
Av. AHo (20 + 0°C)	88	87	93	95	76	78
Av. AHO/gm (0 & 20)	0.197	0.195	0.207	0.211	0.170	0.173
% chg AHo/gm (20→0)	-11	-6.3	-11	-6.0	0	-0.4
Av.AHo/gm ÷ Elect. Rat.	1.026	1.016	1.084	1.105	0.890	0.906

TABLE 5.2-16
CAPACITY TO 1.0 VOLT
DEVELOPMENT GROUP II

TABLE 5.2-17

PRESSURE CHANGE (PSI) AT CHARGE
DEVELOPMENT GROUP II

Test Description	S/N 24	S/N 25	S/N 26	S/N 27	S/N 28	S/N 29
20°C Conditioning	+42	+41	+31	+15	+53	+45
Cycle #1	21	15	12	14	16	15
Cycle #2	11	6	9	12	14	9
Cycle #3	17	15	10	10	17	25
High Rate	7	3	8	7	8	4
Low Rate	35	26	44	44	20	21
Overcharge	25	33	35	22	36	*
Final Dischg.	38	44	49	23	36	-
"C" Rate	27	20	30	21	29	26
Average = Σ/N	25	23	25	25	25	21
Av. Δ P / Elect. Ratio	1.30	1.20	1.31	1.31	1.31	1.10
0°C Conditioning	+12	+9	+4	+4	+6	+7
Cycle #1	0	+1	-1	+3	-3	-1
Cycle #2	0	-1	0	-1	-1	-1
Cycle #3	+2	-1	+2	+1	+1	+1
High Rate	+2	0	+1	+1	+1	+1
Low Rate	+8	+5	+3	+3	+6	+3
Overcharge	+16	+13	+28	+7	+13	+11
Final Disch.	+4	0	+3	+1	+2	+3
"C" Rate	-1	0	-1	0	-1	-3
Average = Σ/N	5	3	4	2	3	2
Av. Δ P / Elect. Ratio	.26	.16	.21	.11	.16	.11
Av. Δ P (0° + 20°)C	15	13	15	14	14	12
Av. ΔP (0° + 20°)/Elect. Ratio	0.78	0.68	0.79	0.73	0.73	0.63

DEVELOPMENT GROUP II

0°C TEST VOLTAGE AFTER REMOVAL OF 50 A-H

TABLE 5.2-18

CELL NO.	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CHARGE	15 AMP CHARGE	OVERCHARGE	3 ORBITAL CYCLES
24	1.199	1.196		1.195		1.214	1.202	1.196	1.190
25	1.195	1.191		1.191		1.211	1.199	1.191	1.186
26	1.194	1.191		1.193		1.211	1.197	1.192	1.185
27	1.203	1.199		1.200		1.216	1.204	1.199	1.193
28	1.180	1.177		1.178		1.199	1.183	1.175	1.173
29	1.161	1.158		1.157		1.178	1.164	1.157	1.151

TABLE 5.2-19

0°C TEST VOLTAGE AFTER REMOVAL OF 75 A-H

CELL NO.	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CHARGE	15 AMP CHARGE	OVERCHARGE	3 ORBITAL CYCLES
24	1.155	1.123	1.112	1.095		1.098	1.146	1.145	1.133
25	1.144	1.103	1.093	1.057		1.028	1.135	1.130	1.109
26	1.145	1.124	1.128	1.119		1.123	1.140	1.146	1.139
27	1.161	1.145	1.144	1.141		1.144	1.155	1.153	1.147
28	1.096	0.904	1.026	1.184		0.860	1.083	1.069	1.087
29	1.092	0.983	0.988	1.182		0.775	1.068	1.070	1.064

20°C TEST VOLTAGE AFTER REMOVAL OF 75 A-H

TABLE 5.2-20

CELL NO.	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CHARGE	15 AMP CHARGE	OVERCHARGE	3 ORBITAL CYCLES
24	1.170	1.171	1.174		1.191	1.168	1.168	1.180	
25	1.169	1.170	1.175		1.180	1.169	1.166	1.168	
26	1.120	1.180	1.183		1.192	1.182	1.178	1.177	
27	1.179	1.189	1.192		1.178	1.190	1.185	1.186	
28	1.102	1.024	0.997		1.048	0.900	0.904	1.106	
29	1.136	1.138	1.197		1.123	1.088	1.103	1.102	

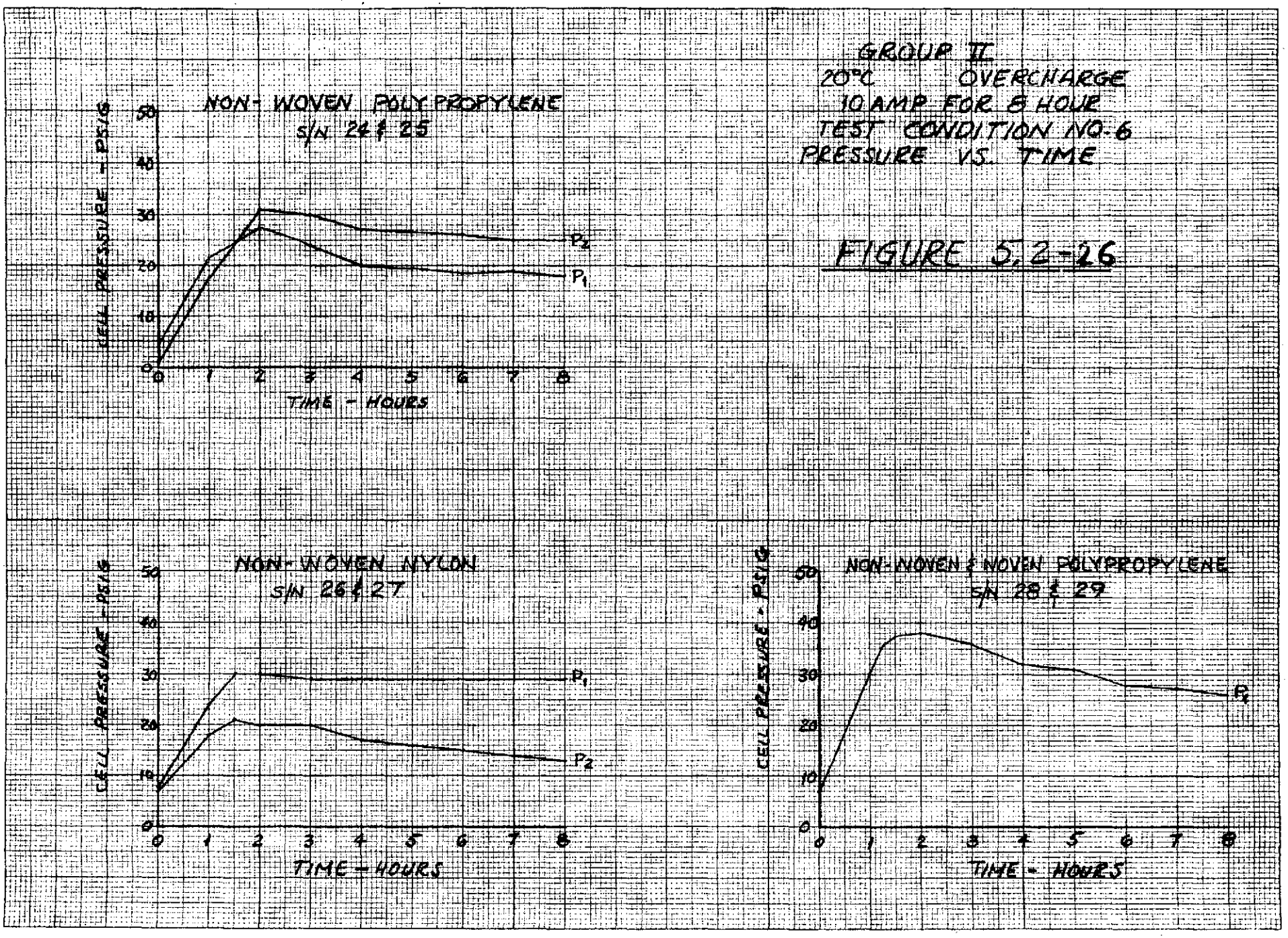
Test Description	S/N 24	S/N 25		S/N 26	S/N 27		S/N 28	S/N 29					
20°C Conditioning	160	160		160	160		160	160					
Cycle #1	100	100		105	106		83	91					
Cycle #2	96	96		101	102		79	83					
Cycle #3	93	93		102	103		75	83					
Hi Rate	88	94		101	105		76	81					
Low Rate	104	104		150	150		85	90					
Overcharge	172 x	171 x		182 x	184 x		155 x	*					
Final Disch.	160	160		160	160		160	160					
"C" Rate	87	84		94	94		82	83					
Average = Σ/N	111	111		122	123		100	104					
0°C Conditioning	112	110		112	115		96	99					
Cycle #1	83	83		86	90		75	76					
Cycle #2	83	86		90	90		78	77					
Cycle #3	75	76		82	85		74	73					
Hi Rate	79	76		83	86		75	73					
Low Rate	88	87		91	92		83	83					
Overcharge	109* x	111* x		225 x	114 **		95 ** x	95 ** x					
Final Disch.	107	108		120	114		95	97					
"C" Rate	69	68		85	86		64	60					
Av. = Σ/N	87	87		94	95		80	80					
Av. AHi (0 + 20°C)	99	99		108	109		90	92					

TABLE 5.2-21
INPUT AHi
DEVELOPMENT GROUP II

* was terminated prematurely
x excluded from average values

GROUP II
20°C OVERCHARGE
10 AMP FOR 6 HOUR
TEST CONDITION NO-6
PRESSURE VS. TIME

FIGURE 5.2-26



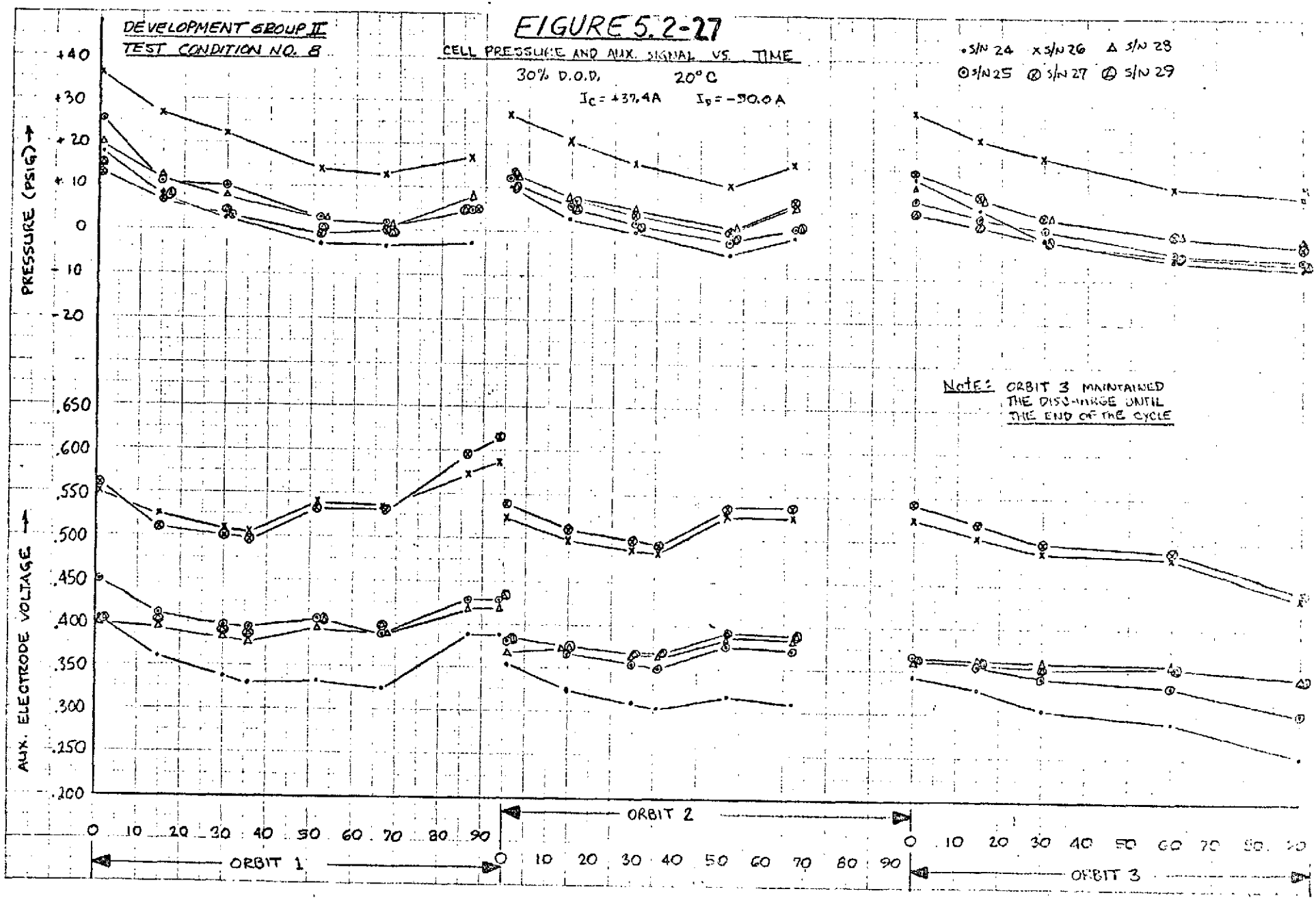

DEVELOPMENT GROUP II
TEST CONDITION NO. 8
FIGURE 5.2-27
CELL PRESSURE AND AUX. SIGNAL VS. TIME
30% D.O.D. 20°C
I_C = +37.4A I_D = -30.0A
•S/N 24 ×S/N 26 Δ S/N 28
⊙S/N 25 ⊗ S/N 27 Ⓓ S/N 29
PRESSURE (PSIG) →
+40
+30
+20
+10
0
-10
-20
AUX. ELECTRODE VOLTAGE →
.650
.600
.550
.500
.450
.400
.350
.300
.250
.200
Note: ORBIT 3 MAINTAINED THE DISCHARGE UNTIL THE END OF THE CYCLE
ORBIT 1
ORBIT 2
ORBIT 3
0 10 20 30 40 50 60 70 80 90

FIGURE 5.2-28

CELL PRESSURE AND AUX. SIGNAL VS. TIME

30% D.O.D. 0°C

I_C = +37.4A I_D = -50.0A

DEVELOPMENT GROUP II

TEST CONDITION NO. 16

• S/N 24 x S/N 26 Δ S/N 28

⊙ S/N 25 ⊗ S/N 27 Ⓒ S/N 29

PRESSURE (PSIG) →

+12 +10 +8 +6 +4 +2 0 -2 -4 -6 -8 -10 -12

AUX. ELECTRODE VOLTAGE →

.360 .340 .320 .300 .280 .260 .240 .220 .200 .180 .160

0 10 20 30 40 50 60 70 80 90

ORBIT 1

ORBIT 2

ORBIT 3

TABLE 5.2-22
OUTPUT CAPACITY TO 1.0 VOLT
DEVELOPMENT GROUP I RETEST

Test Descripton	Cell S/N 1 Grp. I	Cell S/N 1 Retest Grp. II	Cell S/N 1 % Inc./ Decrease	Cell S/N 14 Grp. I	Cell S/N 14 Retest Grp. II	Cell S/N 14 % Inc./ Decrease	Cell S/N 17 Grp. I	Cell S/N 17 Retest Grp. II	Cell S/N 17 % Inc./ Decrease	Cell S/N 23 Grp. I	Cell S/N 23 Retest Grp. II	Cell S/N 23 % Inc./ Decrease
Cell type	Pre-	Contract		Baseline			Thin	Elect.		Opposed Term.		
Electrolyte cc	433	405	-6	390	388.5	-1	386	371	-4	410	450	+10
Ratio=Gr. of electroly.	24.2	22.6	-6.6	21.1	20.9	-1	21.0	20.2	-3.8	21.1	23.2	+10
Gr. of cell core												
Capacity AHo												
20°C conditioning	117	105	-10	101	90	-11	114	91	-20	107	107	0
Cycle #1	116	104	-10	97	93	-4	113	89	-21	104	103	-1
Cycle #2	113	101	-11	98	92	-6	112	84	-25	98	100	+2
Cycle #3	110	104	-6	95	94	-1	112	87	-22	94	95	+1
High Rate	106	100	-6	93	88	-5	107	82	-23	91	89	-2
Low Rate	107	105	-2	94	93	-1	113	89	-21	96	89	-7
Overcharge	123	105	-15	99	92	-7	113	86	-24	97	88	-9
Final Disc.	113	106	-6	93	95	+2	108	87	-19	94	89	-5
"C" Rate Disc.	105	94	-10	93	87	-6	105	75	-29	86	83	-3
Average = Σ/N	112	103	-8	96	92	-4	111	86	-23	96	94	-3
Av. AHo/gram pos. act. mat.	.226	.208		.219	.210		.241	.187		.219	.215	
0°C Conditioning		99		91	89	-2		79		91	86	-6
Cycle #1		103		91	84	-7	96	77	-20	89	104	+17
Cycle #2		106		89	84	-6	97	79	-19	89	86	-3
Cycle #3		96		92	78	-15	100	73	-27	91	82	-10
High Rate		98		90	81	-10	99	76	-23	91	82	-10
Low Rate		99		90	89	-1	101	83	-18	83	85	+2
Overcharge		104		98	89	-9	110	78	-29	91	89	-2
Final Disc.		103		91	87	-5	103	80	-22	88	88	0
"C" Rate		98		92	68	-26	96	63	-34	91	83	-9
Average = Σ/N		101		92	83	-11	100	76	-24	89	87	-2
Av. AHo/gram pos. act. mat.		.204		.210	.189		.217	.165		.203	.199	
Av. AHo (0 + 20°)		102		94	88		106	81		93	91	
Av. AHo (0 + 20°C)		.206		.215	.200		.229	.176		.211	.207	
% chg. AHo/gm (20→0)		-1.9		-4.1	-10.0		-10.0	-11.8		-7.3	-7.4	
Av. AHo/gm elect. ratio		.912		1.02	.957		1.09	.871		1.00	.892	
% chg. av. AHo/gm (GP I→ GP II)						-7.0			-23.1			1.9

5.2.1.4.2.3.2 Pressure

Maximum pressure change for each cell during each charge, and at end of discharge, both as Group I cells and during the retest are shown in Table 5.2-23

5.2.1.4.2.3.3 Ampere-Hour Input

The inputs for each cell for each charge, both as Group I cells and for the retest, are shown in Table 5.2-24.

5.2.1.4.2.3.4 Cell Performance Curves

The following cell performance curves are included in this report:

Figure 5.2-29 - Test Cond. #8 - Cell and aux. signal volt. profiles at 30% D.O.D.

Figure 5.2-30 - Test Cond. #16 - Same as 5.2-29, except at $0^{\circ}C$.

5.2.1.4.2.4 Development Group III

5.2.1.4.2.4.1 Capacity

Capacity data for Group III tests, conduct both at $+20^{\circ}C$ and $0^{\circ}C$ are shown on attached Table 5.2-25.

5.2.1.4.2.4.2 Pressure

The cell pressure change at charge are shown on attached Table 5.2-26.

5.2.1.4.2.4.3 Ampere-Hour Input

The inputs for all charges are shown in attached Table 5.2-27.

5.2.1.5 Test Results

5.2.1.5.1 Capacity

A review of positive and negative active material quantities for the various designs shows substantial differences. Normalizing capacity data among the designs is thus required. Since all types were to be positive electrode capacity limiting, during both charge and discharge, only the positive active material information need be so treated. Positive active material weight, as described in this report, is defined as the material weight gain during the impregnation of the positive electrode plaque.

Test Description	CELL S/N 1 Grp. I	CELL S/N 1 Retest Grp. II	% Inc./ Decr.	CELL S/N 14 Grp. I	CELL S/N 14 Retest Grp. II	% Inc./ Decr.	CELL S/N 17 Grp. I	CELL S/N 17 Retest Grp. II	% Inc./ Decr.	CELL S/N 23 Grp. I	CELL S/N 23 Retest Grp. II	% Inc./ Decr.
20°C Conditioning	-	115	-	-	87	-	-	91	-	-	12	-
Cycle #1	-	9	-	-	23	-	-	18	-	-	8	-
Cycle #2	13	7	-45	40	16	-60	37	11	-70	23	7	-59
Cycle #3	8	9	+13	33	24	-27	31	19	-39	27	7	-74
High Rate	-	3	-	-	4	-	-	1	-	-	5	-
Low Rate	-	15	-	-	45	-	-	27	--	-	23	-
Overcharge	91	7*	-	89	43*	-	89	21*	-	47	16*	-
Final Disch.	-	28	-	-	56	-	-	48	-	-	33	-
"C" Rate Disch.	-	19	-	-	32	-	-	32	-	-	25	-
Average = Σ/N	37	24	-35	54	37	-31	52	30	-42	32	15	-53
Av. ΔP/Elect.Ratio	1.53	1.09	-	2.56	1.77	-	2.48	1.49	-	1.52	.647	-
0°C Conditioning	-	-	-	15	7	-53	0	1	-	0	0	0
Cycle #1	-	-	-	5	1	-20	3	1	-67	2	2	0
Cycle #2	-	-	-	4	6	+50	3	1	-67	3	1	-66
Cycle #3	-	-	-	5	1	-20	4	2	-50	3	2	-33
High Rate	-	-	-	4	2	-50	4	1	-25	1	2	+100
Low Rate	-	-	-	9	4	-55	6	4	-33	4	1	-75
Overcharge	60	17	-	60	17	-71	24	8	-66	13	3	-77
Final Disch.	-	-	-	30	7	-77	9	0	-100	2	4	+100
"C" Rate Disch.	-	-	-	7	+2	-	-	3	-	2	1	-
Average = Σ/N	-	-	-	15	5	-66	7	2	-71	3	2	-33
Av. ΔP Elect. Ratio	-	-	-	.71	.24	-	.33	.10	-	.14	.09	-
Av. ΔP (0+20°C)	-	-	-	35	21	-40	30	16	-46	18	9	-50
Av. ΔP (0+20°C)/ Elect. Ratio	-	-	-	1.66	1.00	-	1.43	0.79	-	0.85	.39	-

NOTES: * Overcharge was terminated prematurely

TABLE 5.2-23
PRESSURE CHANGE (PSI) AT CHARGE
DEVELOPMENT GROUP I RETEST

Test Description		CELL S/N 1 Grp. I	CELL S/N 1 Retest Grp. II	CELL S/N 1 % Inc./ Decr.	CELL S/N 14 Grp. I	CELL S/N 14 Retest Grp. II	CELL S/N 14 % Inc./ Decr.	CELL S/N 17 Grp. I	CELL S/N 17 Retest Grp. II	CELL S/N 17 % Inc./ Decr.	CELL S/N 23 Grp. I	CELL S/N 23 Retest Grp. II	CELL S/N 23 % Inc./ Decr.
20°C	Conditioning	150	120	-20	160	120	-25	160	120	-25	160	120	-25
	Cycle #1	127	105	-17	121	92	-24	138	93	-33	133	105	-21
	Cycle #2	124	102	-18	115	95	-17	128	90	-30	119	102	-14
	Cycle #3	114	105	-8	105	94	-10	120	87	-28	108	103	-5
	High Rate	105	94	-10	98	88	-10	113	83	-26	93	89	-4
	Low Rate	109	120	-10	150	105	-30	150	100	-33	150	97	-4
	Overcharge	190X	X110*	-	190X	X105*	-	X200	X100*	-	X190	X93*	-
	Final Disch.	155	120	-22	160	115	-28	160	120	-25	160	107	-33
	"C" Rate	115	106	-	105	95	-	102	84	-	105	94	-
Average = Σ/N		125	109	-	127	101	-	136	97	-	129	102	-
0°C	Conditioning	113	120	+6	100	114	+14	113	115	+2	100	110	+10
	Cycle #1	-	-	-	90	83	-8	102	74	-28	75	83	+11
	Cycle #2	-	100	-	91	84	-8	99	76	-23	89	84	-6
	Cycle #3	102	-	-	91	76	-17	102	71	-30	91	79	-13
	High Rate	77	122	+58	85	101	+19	95	94	-1	91	109	+20
	Low Rate	94	102	+9	95	88	-7	105	85	-19	95	88	-7
	Overcharge	-	-	-	-	-	-	-	-	-	-	-	-
	Final Disch.	109	110	+1	-	107	-	100	105	-	-	106	-
	"C" Rate	91	97	-	91	70	-	-	85	-	91	83	-
Average = Σ/N		97.7	109	-	92	90	-	102	88	-	90	93	-
Av. AHi (20+0°C)		112	109	-	110	96	-	119	93	-	110	98	

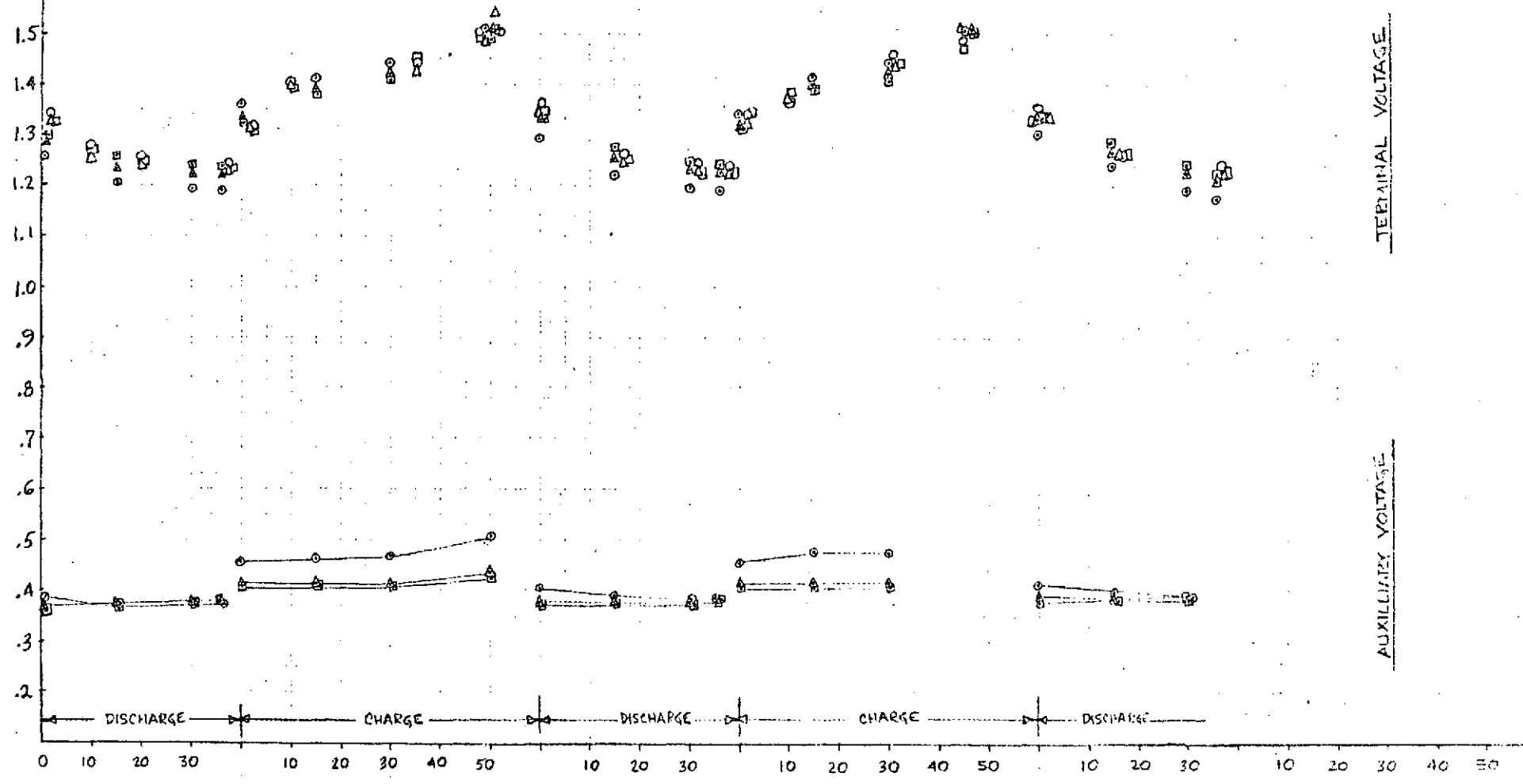
NOTES: * was terminated prematurely
X excluded from average values

TABLE 5.2-24
INPUT AHi

DEVELOPMENT GROUP I RETEST

DEVELOPMENT GROUP I RETEST
TEST CONDITION NO. 8

FIGURE 5.2-29



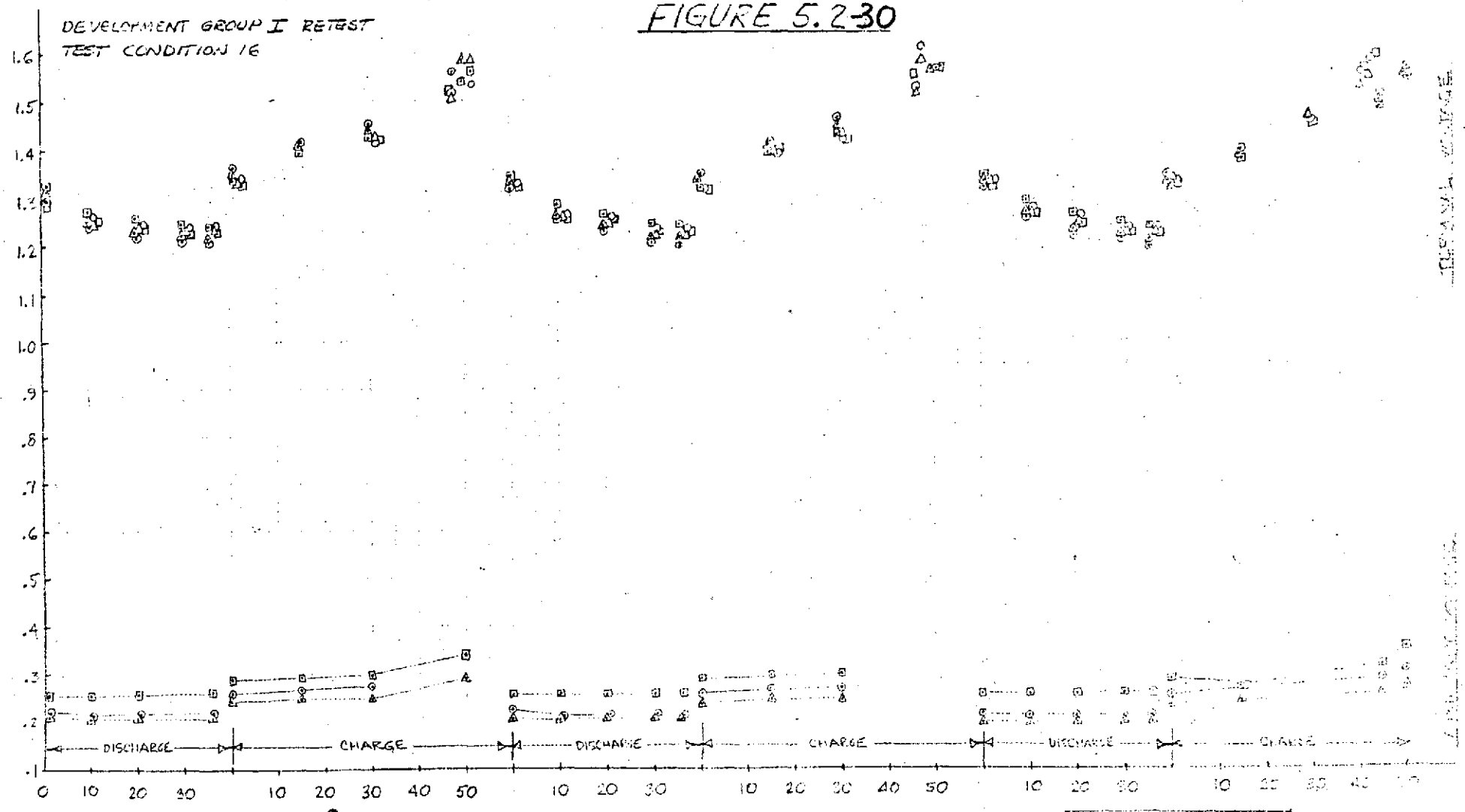
BEFORE KOH REMOVAL *
S/N 14 △
S/N 17 ○
S/N 23 □

AFTER KOH REMOVAL
S/N 14 ◬
S/N 17 ⊙
S/N 23 ⊡

30% D.O.D 20°C
CYCLING

* NOTE: CELL VOLTAGES SHOWN SLIGHTLY ADVANCED IN TIME

FIGURE 5.2-30



* NOTE: CELL VOLTAGES SHOWN SLIGHTLY ADVANCED IN TIME

TEST DESCRIPTION	CELL S/N 32	33	34	35	36	37	38	39	40	41
Cell Type										
Electrode Type	Thin →								→ Baseline	
No. of Pos/Neg	19/20 →								→ 20/21 →	
Separator	Pellon(P2505 W) →						→ Hercules	MF	Pellon (W)	
Hold Down	X			X		X		X		X
Aux. Wrap	1	1	2	2	Isolated Term.		2	→	→	→
Electrolyte	375 →						→ 374	→	→ 394	→
20°C Capacity-AHo										
Conditioning	115.0	116.6	116.6	115.0	113.3	113.3	92.5	80.8	120.8	120.0
Cycle #1	116.6	116.6	116.6	115.0	111.0	111.0	75.0	79.0	122.4	122.4
Cycle #2	114.0	116.0	116.0	111.8	113.3		75.0	75.0	125.0	125.0
Cycle #3	114.0	114.0	114.0	111.5	108.4	108.4	79.0		121.6	120.8
"C" Rate Disch.	116.8	116.8	116.8	116.8	115.0	115.0	-	-	-	123.3
High Rate	110.0	110.8	110.0	110.0	106.6	106.6	-	-	-	111.7
Low Rate	118.2	118.2	119.0	118.2	111.7	111.7	-	-	125.8	125.6
Overcharge	117.5	118.4	119.2	116.6	116.6	115.0	-	-	121.6	119.2
Final Disch	113.3	113.3	115.0	113.3	113.3	111.6	-	-	121.0	120.0
Average	115.1	115.6	116.0	114.2	112.1	111.5	80.3	78.2	120.5	120.8
Pos. Act. Mat.	497 →								→ 524 →	
AV. AHo g pos.act.mat.	.232	.233	.234	.230	.226	.224	.162	.158	.230	.231
AHo/g/Design	→	→	.232	→	→	.225	→	.160	→	.231 →
0°C Capacity-AHo	111.6	112.5	113.3	111.6	111.6	108.3	-	-	111.6	112.5
Conditioning										
Cycle #1	108.3	108.3	110.0	104.2	104.2	100.8	49.1	-	111.6	111.6
Cycle #2	102.5	102.5	103.3	100.8	100.8	100.0	50.8	-	109.2	109.2
Cycle #3	105.0	105.8	103.8	104.16	104.2	100.0	50.8	-	111.6	109.2
"C" Rate Disch	105.0	105.0	106.6	101.6	101.6	96.6	45.0	-	111.6	111.6
High Rate	107.5	107.5	108.3	105.0	104.2	100.0	36.0	-	114.2	113.3
Low Rate	107.5	108.3	109.2	105.8	105.8	102.5	56.6	-	108.3	114.2
Overcharge	116.6	117.4	119.1	116.6	114.1	114.1	83.3	-	126.6	125.7
Final Disch.	109.9	110.7	110.7	108.2	108.2	104.9	64.9	-	119.2	119.2
Aver.	108.2	108.7	109.6	106.4	106.0	103.2	54.5	-	113.8	114.0
AV. AHo g pos.act.mat.	.217	.218	.220	.214	.213	.207	.109		.217	.217
AV. AHo/g/Design	→	→	.217	→	→	.210	→	→	.217	→

TABLE 5.2-25
DEVELOPMENT
GROUP III

CAPACITY TO
1.0 VOLT

TEST DESCRIPTION	CELL S/N 42	43	44	45
Cell Type				
Electrode Type	Thin →		Baseline →	
No. of Pos/Neg	20/21 →		17/18	
Separator	T 2104 (W)		Pellon (W)	
Hold Down	X			X
Aux. Wrap	2 →			
Electrolyte cc	394 →		408 →	
20° Capacity-AHo				
Conditioning	117.5	113.3	128.3	127.5
Cycle #1	112.5	110.0	129.0	129.0
Cycle #2	113.4	109.2	126.0	126.0
Cycle #3	111.6	108.3	129.0	128.2
"C" Rate Disch.	110.0	110.0	123.3	123.3
High Rate	107.3	105.0	112.8	112.8
Low Rate	115.0	107.5	130.0	130.8
Overcharge	109.2	105.0	133.4	133.4
Final Disch	108.4	103.3	127.5	127.5
Average	111.6	107.9	126.5	126.5
Pos. Act. Mat.	524 →		538 →	
AV. AHo/g pos.act.mat.	.213	.206	.236	.236
AHo/g/Design	→	.210	→	.236
0°C Capacity-AHo	110.0	110.0	106.6	108.3
Conditioning				
Cycle #1	108.3	104.2	112.5	115.8
Cycle #2	103.3	100.8	110.0	118.3
Cycle #3	104.16	104.2	113.3	115.0
"C" Rate Disch	103.3	101.6	111.6	111.6
High Rate	105.8	104.2	115.0	116.6
Low Rate	106.6	105.8	115.0	120.0
Overcharge	107.4	103.3	126.6	130.7
Final Disch.	102.5	99.2	114.16	120.8
Aver.	105.7	103.7	113.9	117.4
AV.AHo/g Pos. Act.Mat.	.201	.197	.211	.218
AV. AHo/g/Design	→	.199	→	.214

CONTINUATION
OF TABLE 5.2-25

DEVELOPMENT GROUP III
CAPACITY TO 1.0 VOLT

TEST DESCRIPTION	S/N 32	33	34	35	36	37	38	39	40	41	42	43	44	45
20°C														
Conditioning	42	30	27	27	40	29	27	39	44	45	77	83	12	16
Cycle #1	3	2	3	3	2	3	7	3	0	1	23	27	1	0
Cycle #2	4	5	5	4	4	3	6	6	1	2	2	5	1	0
Cycle #3	6	5	5	7	6	25	15	-	3	3	8	9	2	1
High Rate	13	17	23	35	19	16	-	-	14	16	32	29	6	8
Low Rate	78	68	61	79	76	62	-	-	45	87	77	53	47	51
Overcharge	62	60	49	64	56	49	-	-	75	34	65	65	60	71
Final Disch.	67	60	52	72	64	53	-	-	99	96	84	80	57	64
"C" Rate	18	16	11	23	20	17	-	-	23	24	27	29	20	14
AV. $=\Sigma/N$	33	29	26	35	32	29	-	-	34	34	44	42	23	25
AV.ΔP% Elect. Ratio														
0°C														
Conditioning	12	14	12	6	14	8	-	-	1	2	7	5	0	0
Cycle #1	1	1	1	0	1	2	2	-	2	2	0	1	7	4
Cycle #2	1	1	6	0	1	1	5	-	0	3	1	1	1	5
Cycle #3	4	2	5	2	2	1	1	-	3	3	2	2	1	1
High Rate	0	1	1	0	0	0	2	-	0	1	1	0	0	0
Low Rate	9	8	8	6	9	4	1	-	10	8	6	6	2	3
Overcharge	49	45	39	14	46	10	8	-	84	72	74	6	47	48
Final Disch.	30	26	22	13	25	12	2	-	5	9	40	62	5	3
"C" Rate	5	4	4	3	4	3	1	-	5	4	3	4	1	1
AV. $=\Sigma/N$	12	11	11	5	13	5	-	-	12	12	15	10	7	7
AV.ΔP% Elect. Ratio														
AV.ΔP(0+20°C)														
AV.ΔP)0+20°C)														
1% Electr. Ratio														

TABLE 5.2-26

DEVELOPMENT GROUP III

PRESSURE CHANGE AT CHARGE

TEST DESCRIPTION	CELL S/N32	33	34	35	36	37	38	39	40	41	42	43	44	45
20°C														
Conditioning	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0
Cap. Cycle#1	125.0	125.0	125.0	122.5	117.5	117.5	80.0	80.0	127.5	127.5	120.0	117.5	135.0	135.0
" " #2	122.5	122.5	122.5	120.0	110.0	110.0	78.0	78.0	126.0	126.0	110.0	107.0	140.0	140.0
" "3	124.0	122.5	122.5	121.0	120.0	-	85.0	-	131.5	131.5	130.0	117.5	132.5	132.5
"C"Rate Disch	123.0	121.0	121.5	120.5	115.5	115.5	-	-	128.0	127.5	118.0	115.0	131.5	130.0
High Rate Ch.	123.3	121.5	121.5	121.5	110.5	110.5	87.0	-	-	142.5	107.5	107.5	142.5	142.5
Low Rate Ch.	150.0	150.0	150.0	150.0	150.0	150.0	-	-	150.0	150.0	130.0	130.0	150.0	150.0
Overcharge(*)	217.0	205.0	206.0	206.0	202.0	202.0	-	-	163.5	153.5	140.0	193.5	209.5	209.5
Final Disch.	160.0	160.0	160.0	160.0	160.0	160.0	-	-	160.0	160.0	160.0	160.0	160.0	160.0
Average = Σ/N	136.0	135.3	135.4	134.4	130.4	131.9	-	-	140.4	140.6	129.4	126.9	143.9	143.8
0°C														
Conditioning	160.0	160.0	160.0	160.0	160.0	137.5	-	-	160.0	160.0	160.0	160.0	160.0	160.0
Cap. Cycle #1	109.5	109.5	111.5	107.5	107.5	107.5	57.0	-	112.5	112.5	106.0	106.0	115.0	120.0
" " #2	107.5	107.0	108.0	101.0	101.0	97.5	90.0	-	101.0	112.0	106.5	115.5	111.5	115.5
" " #3	107.0	106.5	107.0	106.0	105.0	103.0	51.0	-	113.0	112.0	105.0	103.5	115.0	118.5
"C" Rate Disch	107.5	107.5	107.5	106.5	106.5	101.5	49.0	-	114.5	112.5	109.0	106.5	116.5	118.5
High Rate Ch.	107.0	108.0	110.0	105.0	104.0	99.0	47.5	-	114.0	113.5	106.0	109.5	111.0	117.5
Low Rate Ch.	114.3	114.3	114.3	112.0	112.0	109.0	108.8	-	121.3	118.8	111.8	109.8	123.0	121.8
Overcharge(*)	148.5	146.5	147.5	144.0	144.0	139.5	91.5	-	154.0	152.0	144.0	144.0	152.0	157.0
Final Disch.	120.0	120.0	120.0	120.0	120.0	120.0	120.0	-	120.0	120.0	120.0	120.0	120.0	120.0
Average = Σ/N	116.6	116.6	117.3	114.8	114.5	109.4	74.8	-	119.5	120.2	115.5	116.4	121.5	124.0
AV.AHi(0+20°C)	126.3	126.0	126.4	124.6	122.5	120.7	-	-	130.0	130.4	122.5	121.7	132.7	133.9

NOTES: (*)Excluded from Average values.

TABLE 5.2-27

DEVELOPMENT GROUP III

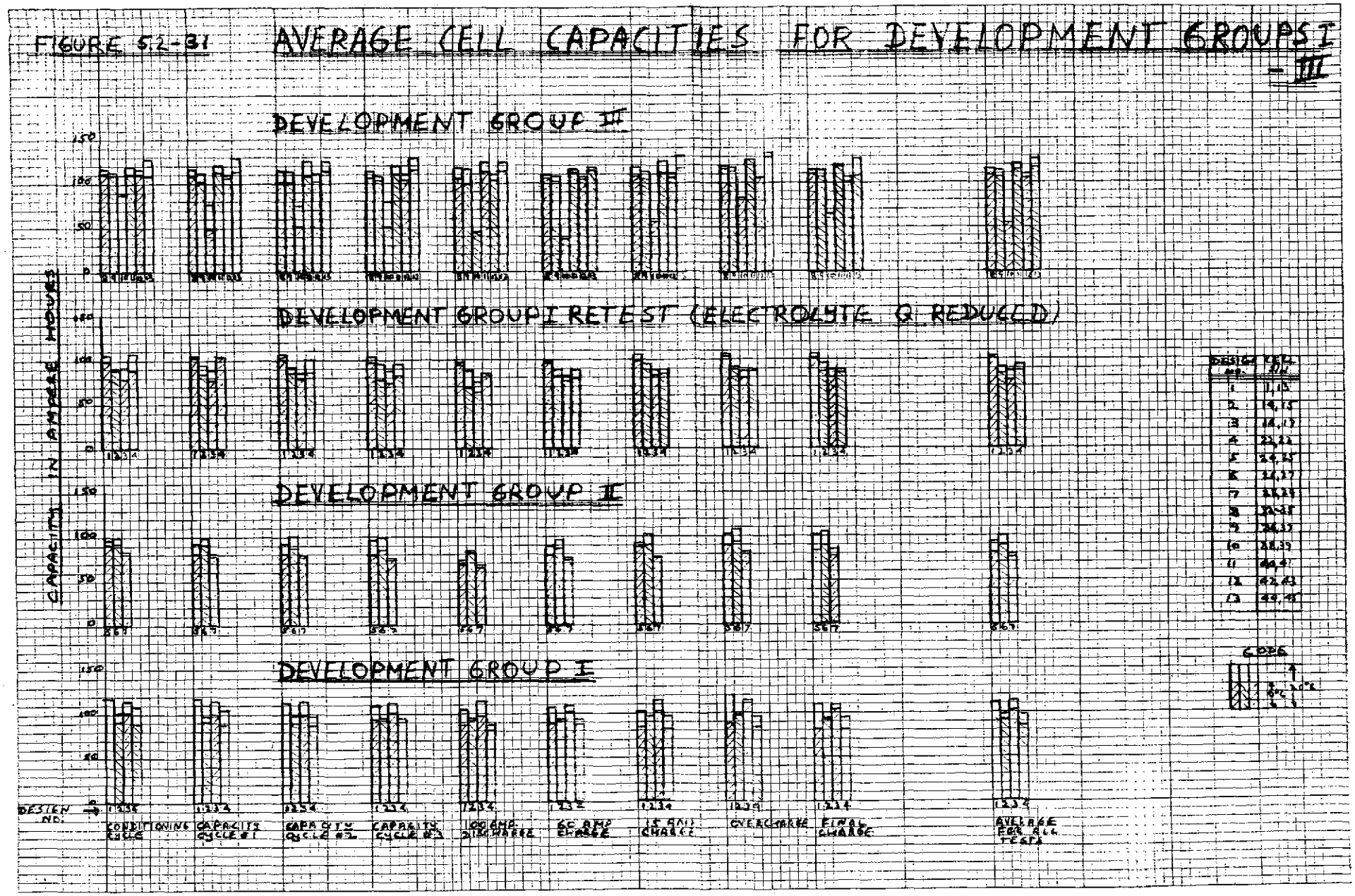
INPUT A.H.

Normalized capacity data is then defined as each cell's discharge capacity (at the specified current) to 1.0 volt, divided by the cell's positive active material weight. The resulting figure is usually described as "material utilization". The higher the material utilization number, the better the cell design. The lower this figure is, the less desirable the design.

Figure 5.2-31 shows the average cell capacity obtained for each design of development Groups I - III when tested under conditions shown. The following can be noted:

- A general trend of a capacity decrease exists when ambient temperature was changed from +20°C to 0°C.
- The Group I and II cell designs show a very pronounced capacity decrease for the "C"-rate (100 ampere) discharges as compared with "C/2" - rate (50 ampere) discharges. This trend cannot be observed on the Group III cells.
- The 100 A.H. minimum specified capacity was not met by any design of Group I and II under all conditions. However the thin electrode yielded 100 A.H. for all but three test conditions. Even there, the minimum capacity was 98 ampere hours, only 2% below specified goal. Most cells from Group III met this 100 A.H. minimum capacity under all conditions.
- Substantial capacity losses were observed when the Group I cells were retested after electrolyte removal.
- A general capacity increase after application of an overcharge was observed as anticipated.
- The Group III cells appear to show lower capacities at +20°C when charged at 60 amperes.

FIGURE 5.2-31 AVERAGE CELL CAPACITIES FOR DEVELOPMENT GROUPS I - III



- Comparison of average capacity among cell designs within each group shows the following:

  Group I - The thin electrode cells (design 3) showed highest average capacities. The pre-contract cells (design 1) showed next to the highest average capacities at +20°C temperature only. The poorest average capacities at 0°C was obtained from the opposed terminal cells (design 4).

  Group II - The shimmed cells (design 6) showed highest average capacities. The FT 2140(W) and woven polypropylene cells (design 7) showed lowest average capacities.

  Group I Retest - The pre-contract cells (design 1) showed highest average capacities.

  Group III - The baseline cells (design 13) showed highest average capacities, followed by the thin electrode design with additional electrodes (design 11). The lowest average capacities were obtained by the cells with Hercules MF polypropylene (design 10).

5.2.1.5.2 Positive Active Material Utilization

Positive active material utilization for Groups I - III is given in Tables 5.2-28 to 5.2-31 and are plotted in Figure 5.2-32. The following points can be made:

- All designs yielded higher average material utilizations at +20°C than at 0°C. (There was one exception on one cell at one test condition).
- The thin electrode cells (design 3) had shown the highest material utilization results in Group I. However, in the Group III tests this electrode design yielded nearly identical results as the baseline electrode cells (comparing designs 8, 9, & 11 with 13).

TABLE 5.2-28

DEVELOPMENT GROUP I

POSITIVE ACTIVE MATERIAL UTILIZATION IN A-Ho/g x 10^{-3}

CELL DESIGN DESCRIPTION	CELL S/N	CALC. POSITIVE ACTIVE WT. G.	CONDI-TIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CAPACITY	15 AMP CAPACITY	CAPACITY AFTER OVERCHG.	CAPACITY AFTER 3 ORBIT CYCLES	AVG. FOR ALL TESTS
+20°C												
Pre-Contract	1											
Pre-Contract	13	495	236	237	228	218	208	212	208	238	234	224
Baseline	14	438	231	222	222	217	213	213	224	226	211	
Baseline	15	438	231	222	222	217	213	213	226	226	212	
	AV.		231	222	222	217	213	213	225	226	212	220
Thin Plate	16	460	252	253	248	245	236	239	250	251	239	
	17	460	248	246	244	244	228	233	246	246	234	
	AV.		250	250	246	245	232	236	248	249	237	244
Opposed Terminals	22	438	244	238	222	215	196	212	222	222	218	
Opposed Terminals	23	438	244	238	224	215	196	208	218	222	214	
	AV.		244	238	223	215	196	210	220	222	216	220
0°C												
Pre-Contract	1											
Pre-Contract	13	495	-	-	-	189	177	177	169	179	164	176
Baseline	14	438	207	207	202	209	209	205	206	224	208	
	15	438	207	207	202	209	209	206	206	222	210	
	AV.		207	207	202	209	209	206	206	223	209	209
Thin Plate	16	460	221	218	219	220	211	220	223	246	228	
Thin Plate	17	460	-	210	211	220	209	216	220	239	225	
	AV.		221	214	215	220	210	218	222	243	227	221
Opposed Terminals	22	438	201	199	199	206	162	192	181	177	171	
	23	438	207	204	202	208	208	206	191	208	200	
	AV.		204	202	201	207	185	199	186	193	186	196

TABLE 5.2-29

DEVELOPMENT GROUP II

POSITIVE ACTIVE MATERIAL UTILIZATION IN A-Ho/g x 10^{-3}

CELL DESIGN DESCRIPTION	CELL S/N	CALC. POSITIVE ACTIVE WT. G.	CONDI-TIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CAPACITY	15 AMP CAPACITY	CAPACITY AFTER OVERCHG.	CAPACITY AFTER 3 ORBIT CYCLES	AVG. FOR ALL TESTS
+20°C												
WEX 1242 Polyprop.	24	448	214	212	205	206	164	197	207	229	227	
	25	448	214	210	205	206	164	196	207	227	223	
	AV.		214	211	205	206	164	197	207	228	225	206
2505 Pellon + Shims	26	448	222	219	220	220	186	212	227	233	233	
	27	448	223	222	223	220	190	216	229	240	235	
	AV.		223	221	222	220	188	214	228	237	234	221
FT 2140 + woven polyprop.	28	448	180	173	167	158	145	167	167	182	186	
	29	448	188	186	180	175	141	173	179	179	192	
	AV.		184	180	173	167	143	170	173	181	189	173
0°C												
WEX 1242 Polyprop.	24	448	204	184	189	179	156	177	195	199	190	
	25	448	201	182	187	173	149	171	192	197	182	
	AV.		203	183	188	175	153	174	194	198	186	184
2505 Pellon + Shims	26	448	203	197	191	186	182	186	201	210	201	
	27	448	210	204	195	194	182	191	202	203	201	
	AV.		207	201	193	190	182	189	202	207	201	197
FT 2140 + woven polyprop.	28	448	179	167	181	166	152	166	177	175	177	
	28	448	180	171	180	166	152	162	177	175	177	
	AV.		180	169	181	166	152	164	177	175	177	171

TABLE 5.2-30

DEVELOPMENT GROUP I RETEST

POSITIVE ACTIVE MATERIAL UTILIZATION IN A-Ho/g x 10^{-3}

CELL DESIGN DESCRIPTION	CELL S/N	CALC. POSITIVE ACTIVE WT. G	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CAPACITY	15 AMP CAPACITY	CAPACITY AFTER OVERCHG.	CAPACITY AFTER 3 ORBIT CYCLES	AVG. FOR ALL TESTS
+20°C												
Pre-Contract Cell	1	500	210	208	202	208	188	200	210	210	212	205
Baseline	14	438	205	211	209	214	199	201	211	209	217	208
Thin Plate	17	460	198	192	181	189	209	177	192	187	188	190
Opposed Terminal	23	438	242	234	228	216	190	204	202	200	202	213
0°C												
Pre-Contract Cell	1	500	199	207	211	192	196	195	198	209	205	201
Baseline	14	438	202	192	191	177	185	184	204	202	198	192
Thin Plate	17	460	172	167	179	159	165	165	181	170	174	169
Opposed Terminal	23	438	196	238	195	186	187	186	194	202	202	198

TABLE 5.2-31A

POSITIVE ACTIVE MATERIAL UTILIZATION IN A-Ho/g x 10^{-3}

DEVELOPMENT GROUP III

CELL DESIGN DESCRIPTION	CELL S/N	CALC. POSITIVE ACTIVE WT. G	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CAPACITY	15 AMP CAPACITY	CAPACITY AFTER OVERCHG.	CAPACITY AFTER 3 ORBIT CYCLES	AVG. FOR ALL TESTS
+20°C												
Thin Pl. Pellon	32	497	231	235	229	229	235	221	238	236	227	232
" "	33	"	235	235	233	220	235	223	238	238	228	233
" "	23	"	235	235	233	220	235	223	239	240	231	233
" "	35	"	231	231	225	224	235	221	238	235	228	230
	AV.		232	234	230	228	235	222	238	237	229	230
Ditto Iso. Aux.	36	497	228	223	228	218	231	215	225	235	228	226
	37	"	228	223	-	218	231	215	225	231	224	224
	AV.		228	223	228	218	231	215	225	233	226	225
Thin Pl. Herc. MF	38	497	186	151	151	159	-	-	-	-	-	226
	39	"	163	159	151	-	-	-	-	-	-	224
	AV.		174	154	151	159	-	-	-	-	-	225
Thin PL. Pellon 20/21	40	524	231	234	239	232	-	-	240	232	232	162
	41	"	229	234	239	231	235	213	239	227	227	157
	AV.		230	234	239	232	235	213	240	230	230	160
Thin PL. T21047	42	524	224	214	216	213	210	205	219	208	208	230
	43	"	216/220	210/212	208/212	207/210	210/210	200/203	205/212	200/204	200/204	231/231
B:L. PL. Pellon	44	538	238	240	234	240	229	210	242	248	248	213
	45	"	237/238	240/240	234/234	238/239	229/229	210/210	243/243	248/248	248/248	206/210
	AV.											

TABLE 5.2-31B

POSITIVE ACTIVE MATERIAL UTILIZATION IN A-Ho/g x 10^{-3}

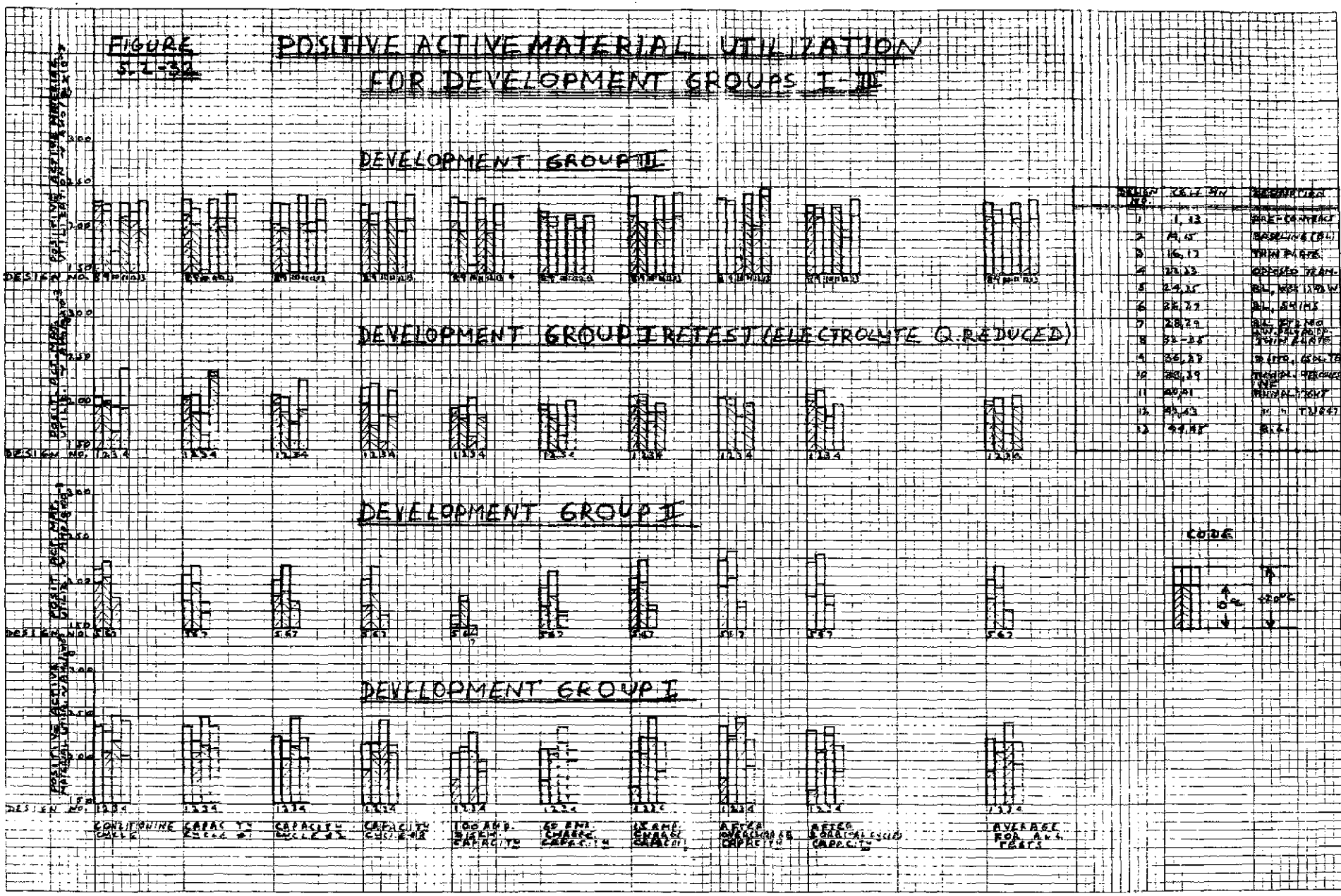
DEVELOPMENT GROUP III

0°C

CELL DESIGN DESCRIPTION	CELL S/N	CALC. POSITIVE ACTIVE WT. G	CONDITIONING CYCLE	CAPACITY CYCLE #1	CAPACITY CYCLE #2	CAPACITY CYCLE #3	100 AMP CAPACITY	60 AMP CAPACITY	15 AMP CAPACITY	CAPACITY AFTER OVERCHG.	CAPACITY AFTER 3 ORBIT CYCLES	AVG. FOR ALL TESTS
Thin PL. Pellon	32	497	225	218	206	211	211	216	216	235	221	218
	33	"	226	218	206	213	211	216	218	236	223	219
	34	"	228	221	208	213	215	218	221	240	223	221
" "	35	"	225	210	203	210	204	211	213	235	218	214
	AV.		226	217	206	211	210	215	217	236	221	217
Ditto Iso. Aux.	36	497	225	209	203	209	204	209	213	230	218	212
	37	"	218	203	201	201	194	201	206	230	211	208
	AV.		222	206	202	205	198	205	210	230	214	210
Thin Pl. Herc. MF	38	497	-	99	102	102	90	72	112	168	131	110
	39	"	-	-	-	-	-	-	-	-	-	-
	AV.		-	99	102	102	90	72	114	168	131	110
Thin PL. $^{20}/_{21}$	40	524	213	213	208	213	213	218	207	242	227	217
	41	"	215	213	208	208	213	216	219	240	227	218
	AV.		214	213	208	211	213	217	213	241	227	218
Thin PL. T21047	42	524	210	207	197	199	197	202	203	205	196	202
	43	"	210	199	192	199	194	199	202	197	190	198
	AV.		210	203	195	199	196	200	203	201	193	200
B:L. PL. Pellon	44	538	198	209	204	211	207	214	214	235	212	212
	45	"	201	215	220	214	207	217	223	243	225	218
	AV.		200	212	212	213	207	215	219	239	214	215

FIGURE 52-32

POSITIVE ACTIVE MATERIAL UTILIZATION FOR DEVELOPMENT GROUPS I-III



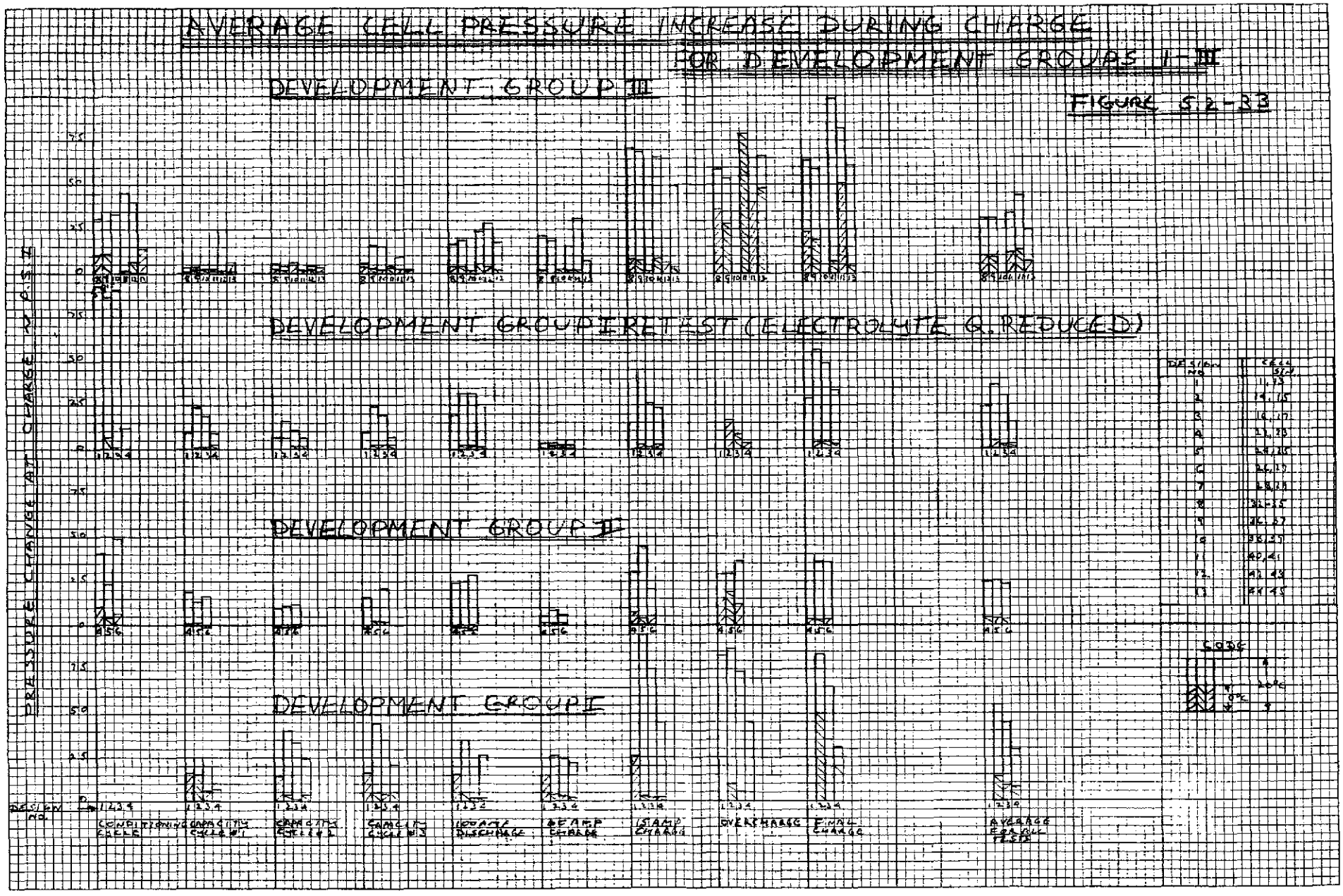
- The opposed terminal cells (design 4) showed nearly identical material utilizations as the baseline cells (design 2) at +20°C, but performed considerably more poorly at 0°C.
- All polypropylene separator cells (designs 5, 7, 10 & 12) showed poorer utilizations than the nylon separator cells. The highest material utilization among the polypropylene group was observed from cells with the T21047 (washed) material (design 12).
- All more tightly stacked cells (design 6 & 11) did not show any improvement in material utilization over the designs with normal compression.

5.2.1.5.3 Average Cell Pressure Increase During Charge

Average cell pressure increase during charge for Groups I - III is shown in Figure 5.2-33. The following can be noted:

- All cells, with one exception, showed higher pressure rises during the charge at +20°C than at 0°C. However, since end of charge voltages were pre-selected for each temperature and pressure increase is a function of this voltage, the observation is a resultant of the voltage values selected.
- The pre-selected charge cut-off voltage value for the low rate conditions at +20°C (15 ampers and final charge) was too high and resulted in large pressure rises.
- The overcharge pressures data is only applicable in very general terms due to variation in cell manufacturer's test conditions between groups. In some instances cells were kept at rest overnight between full charge and overcharge, without a clear entry in the data sheet. Thus, only intragroup (since each group received identical conditions) rather than intergroup evaluation is possible.

  Group I - The opposite terminal cells (design 4) showed the least


AVERAGE CELL PRESSURE INCREASE DURING CHARGE
FOR DEVELOPMENT GROUPS I-III
FIGURE 5.2-23
DEVELOPMENT GROUP III
DEVELOPMENT GROUP II RETEST (ELECTROLYTE Q. REDUCED)
DEVELOPMENT GROUP II
DEVELOPMENT GROUP I
PRESSURE CHANGE AT CLARKE
CONDITIONING CHARGE CYCLE #1
CHARGING CYCLE #2
CHARGING CYCLE #3
HOVARC DISCHARGE
REAMP CHARGE
STACK CHARGE
OVERCHARGE
FINAL CHARGE
AVERAGE FOR ALL TESTS
DESIGN NO.
EUGENE DIETZGEN CO. MADE IN U. S. A.
NO. 340DR-10 DIETZGEN GRAPH PAPER 10 X 10 PER INCH

pressure rise for this and all other tests in this group. This is expected due to their larger free volume. The thin electrode cells showed next to the lowest and the baseline cells showed the highest pressure rise. Again this was anticipated due to the larger surface area in the thin electrode cells.

Group II - The tighter (shimmed) cells (design 6) showed the highest pressure rise, as anticipated.

Group III - Again the thin electrode cells exhibited the lowest pressure rise (design 8 & 9). The thin electrode tighter cells showed the highest pressure rise at +20°C. The Hercules MF cells (design 10) showed such high pressure rises that they were removed from the overcharge prematurely.

5.2.1.5.4 Percent Coulometric Efficiency

Percent coulometric efficiency for Groups I - III is shown in Tables 5.2-32 to 5.2-35 and plotted in Figure 5.2-34. All overcharge condition values have been excluded from these data since they have no real meaning for this purpose. The following points can be made:

- Occasionally more than a 100% value was obtained. This can only be explained by either a recording error, or by residual capacity from the previous cycle.
- In general the 0°C charge efficiency was higher than the +20°C values.
- Comparing the Group III average values with those of Group I a general increase in efficiency for the +20°C values and a slight decrease for the 0°C values can be noted.
- Using the Group III average values of 90% and 94% for +20°C and 0°C respectively and taking their reciprocal values we obtain a charge return (Input A.H. divided by Output A.H. times 100) of 111% and 106% respectively. These values compare very favorably with earlier reported values for small size sealed nickel cadmium cells.

TABLE 5.2-32

DEVELOPMENT GROUP I

PERCENT COULOMETRIC EFFICIENCY (AHo/AHi x 100)

	CELL S/N											
Test Description	1	13	AV.	14	15	AV.	16	17	AV.	22	23	AV.
+20°C												
Conditioning	78	78	78	63	64	64	72	71	72	67	67	67
Cycle #1	92	93	93	81	81	81	84	82	83	78	78	78
Cycle #2	91	91	91	85	85	85	89	88	89	82	82	82
Cycle #3	97	95	96	91	91	91	94	93	94	87	87	87
"C" Rate Disch.	91	90	91	89	89	89	90	88	89	82	82	82
High Rate	101	98	100	95	95	95	98	95	97	100	98	99
Low Rate	98	95	97	63	67	65	77	75	76	65	64	65
Average Σ/N			92			81			86			80
0°C												
Conditioning	-	-	-	91	91	91	90	85	88	88	91	90
Cycle #1	-	-	-	101	102	102	99	95	97	116	118	117
Cycle #2	-	-	-	98	98	98	100	100	100	93	100	97
Cycle #3	-	92	92	101	101	101	100	97	99	104	100	102
"C" Rate Disch.	-	97	97	101	101	101	97	96	97	83	100	92
High Rate	-	114	114	106	106	106	107	106	107	115	100	107
Low Rate	-	89	89	95	95	95	98	105	102	100	87	94
Average Σ/N			98			99			99			100
Average (20 + 0°C)			95			90			93			90

TABLE 5.2-33

DEVELOPMENT GROUP II

PERCENT COULOMETRIC EFFICIENCY (AHo/AHi x 100)

Test Description	CELL S/N 24	25	AV.	26	27	AV.	28	29	AV.
+20°C									
Conditioning	60	60	60	62	63	63	51	53	52
Cycle #1	95	94	95	93	93	93	94	91	93
Cycle #2	96	96	96	98	98	98	95	98	97
Cycle #3	100	106	103	97	96	97	95	94	95
"C" Rate Disch.	84	87	86	88	91	90	79	76	78
High Rate	99	94	97	94	92	93	99	96	98
Low Rate	89	89	89	68	-	68	88	89	89
Average = Σ/N			89			86			86
0°C									
Conditioning	92	90	91	91	94	93	80	81	81
Cycle #1	83	81	92	89	92	91	75	77	76
Cycle #2	81	80	81	86	88	87	78	77	78
Cycle #3	80	78	79	83	87	85	74	74	74
"C" Rate Disch.	101	97	99	96	94	95	106	113	110
High Rate	79	77	78	83	86	85	74	73	74
Low Rate	88	86	87	90	91	91	79	79	79
Average = Σ/N			87			90			82
Average (20 + 0°)			88			88			84

TABLE 5.2-34

DEVELOPMENT GROUP I RETEST

PERCENT COULOMETRIC EFFICIENCY (AHo/AHi x 100)

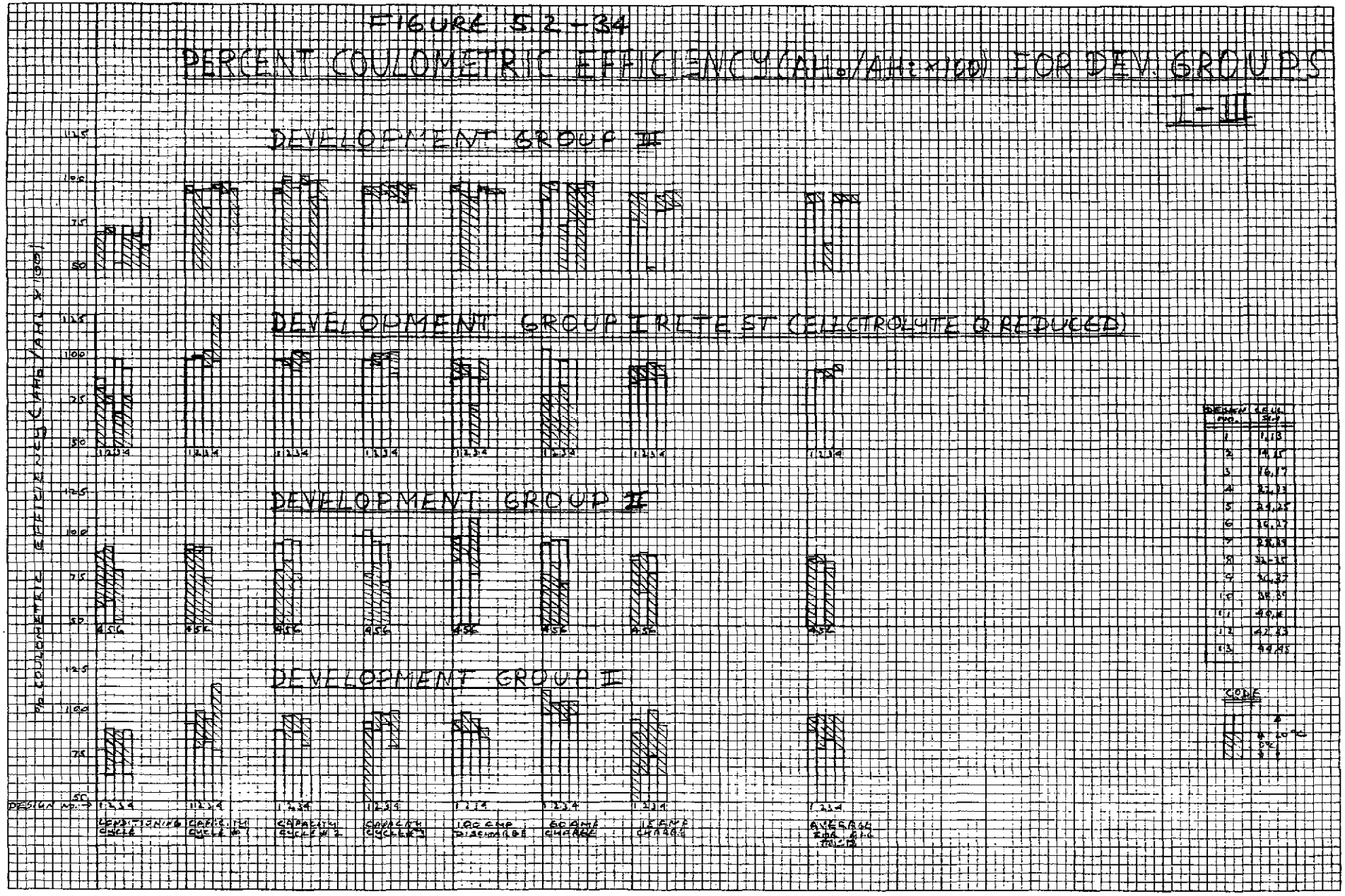
Test Description	CELL S/N 1 Group 1	CELL S/N 1 Group 2	CELL S/N 14 Group 1	CELL S/N 14 Group 2	CELL S/N 17 Group 1	CELL S/N 17 Group 2	CELL S/N 23 Group 1	CELL S/N 23 Group 2
+20°C								
Conditioning	78	88	63	75	71	99	67	89
Cycle #1	92	99	81	101	82	96	78	98
Cycle #2	91	99	85	97	88	93	82	98
Cycle #3	97	99	91	100	93	100	87	92
"C" Rate Disch.	91	89	89	92	88	89	82	88
High Rate	101	106	95	100	95	99	98	100
Low Rate	98	87	63	89	75	89	64	92
Average = Σ/N	93	95	81	93	85	95	80	94
0°C								
Conditioning	-	83	91	78	85	69	91	78
Cycle #1	-	-	101	101	95	104	118	125
Cycle #2	-	-	98	100	100	104	100	102
Cycle #3	-	-	101	103	97	103	100	104
"C" Rate Disch.	-	100	101	97	96	74	100	100
High Rate	-	80	106	80	106	81	100	75
Low Rate	-	97	95	97	105	98	87	97
Average = Σ/N	-	-	99	94	98	91	99	97
Average (20 + 0°C)	-	-	90	94	92	93	90	96

TEST DESCRIPTION	CELLS S/N 32-35	S/N 36+37	S/N 38+39	S/N 40+41	S/N 42+43	S/N 44+45							
Cell Design No.	8	9	10	11	12	13							
20°C													
Conditionign	72	71	54	75	72	80							
Cap. Cycle #1	93	95	96	96	94	96							
" " #2	94	103	97	99	102	90							
" " #3	93	90	93	92	89	97							
"C" Rate Disch.	96	100	-	96	94	94							
High Rate Ch.	91	97	-	78	99	79							
Low Rate Ch.	79	75	-	84	86	87							
Average = Σ/N	88	90	-	89	91	89							
0°C													
Conditioning	70	74	-	70	69	64							
Cap. Cycle #1	98	95	86	99	100	97							
" " #2	97	101	56	103	92	101							
" " #3	98	98	100	98	100	98							
"C" Rate Disch.	98	95	92	98	95	95							
High Rate Ch.	100	101	76	100	97	101							
Low Rate Ch.	95	94	52	93	96	96							
Average = Σ/N	94	94	77	94	93	93							
Average(20 + 0°C)	91	92	-	92	92	91							

TABLE 5.2-35
DEVELOPMENT GROUP III
AVERAGE PERCENT EFFICIENCY
(AHo/AHi x 100)

FIGURE 5.2-34

PERCENT COULOMETRIC EFFICIENCY (AH_o/AH_i × 100) FOR DEV. GROUPS I - III



5.2.1.5.5 Cell Terminal Development

5.2.1.5.5.1 Early Program Review

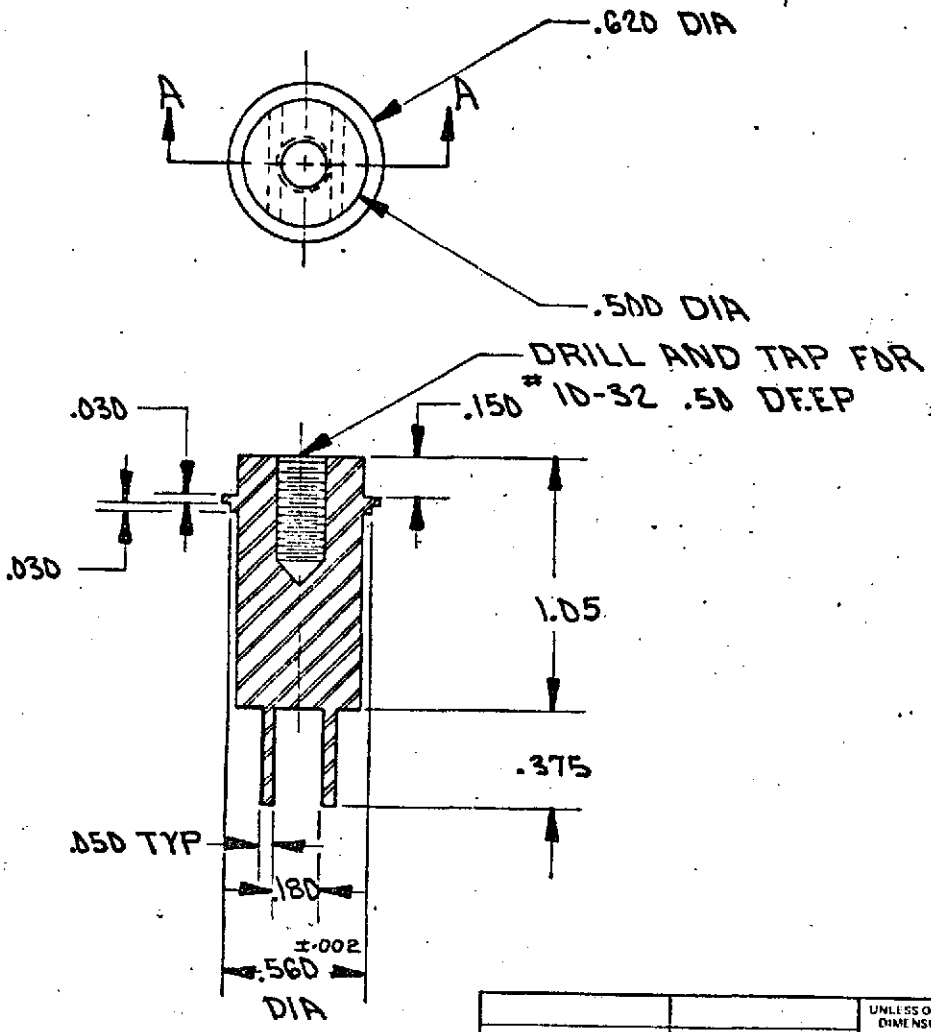
An existing Eagle-Picher terminal was selected for use on the early development cells (groups I-III). Long manufacturing lead periods of 4 to 6 months influenced this decision. The terminal is shown in figure 5.2-3 and the stud is shown in figure 5.2-35. This header was manufactured by Ceramaseal, Inc., New Lebanon Center, New York.

Concurrently this design was reviewed at Grumman to improve its function and reliability. Each terminal component was scrutinized and findings are summarized below:

5.2.1.5.5.2 Terminal design - A cell impedance review as a function of the terminal geometry is described in Grumman Project Interoffice Memo D-559-0-2, dated 20 October 1970 shown in Appendix K-1. It was concluded therein that a number of design changes are mandatory. The internal terminal flags were reinforced to improve the conductivity. The flat base terminal top, to which the intercell connector is fastened by means of a bolt, had inherent problems due to stresses exerted on the relatively brittle ceramic sleeve. Frequently cracks either developed or extended into the ceramic sleeve when torque stresses were applied which could lead to leakage paths. As a remedy to this potential problem, the terminal top was redesigned as shown in figure 3.2-36. A slot was added to the upper terminal to insert the intercell connector and provide a weld joint. The bottom portion shows an increased contact area between the electrode tabs and terminal when compared to the Eagle Picher terminal shown in figure 5.2-3. The bottom terminal portion design is very similar to that used by Gulton on their 100 ampere-hour cell with opposite side terminals, supplied to NASA, Langley (Gulton cell P/N 552-8047-86 using Ceramaseal terminal P/N 808B6350). This terminal design did resolve the concern expressed in the Grumman document, Appendix K-1.

The above design was subsequently modified as shown in figure 5.2-37. The upper slot was replaced by a lug which eliminates weld joints. This avoids possible cell heat damage which is difficult to inspect on a completed cell. Such a design is also more readily adaptable for quick intercell and intermodule connections. The connector is again bolted in place but torque stresses to the ceramic are drastically reduced. This lug type terminal was used on all parametric and life test group cells.

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROV



PRINT ISSUED
DATE MAR 19 1971
ALL PRINTS ISSUED
PRIOR ARE OBSOLETE

85-40-138-5	RSN 110
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON FRACTIONS ±1/32 DECIMALS 2PL ± .03 3PL ± .010 ANGLES ±2°

MATERIAL: NICKEL 270 COLD DRAWN RND STOCK

CONTRACT NO.

DATE

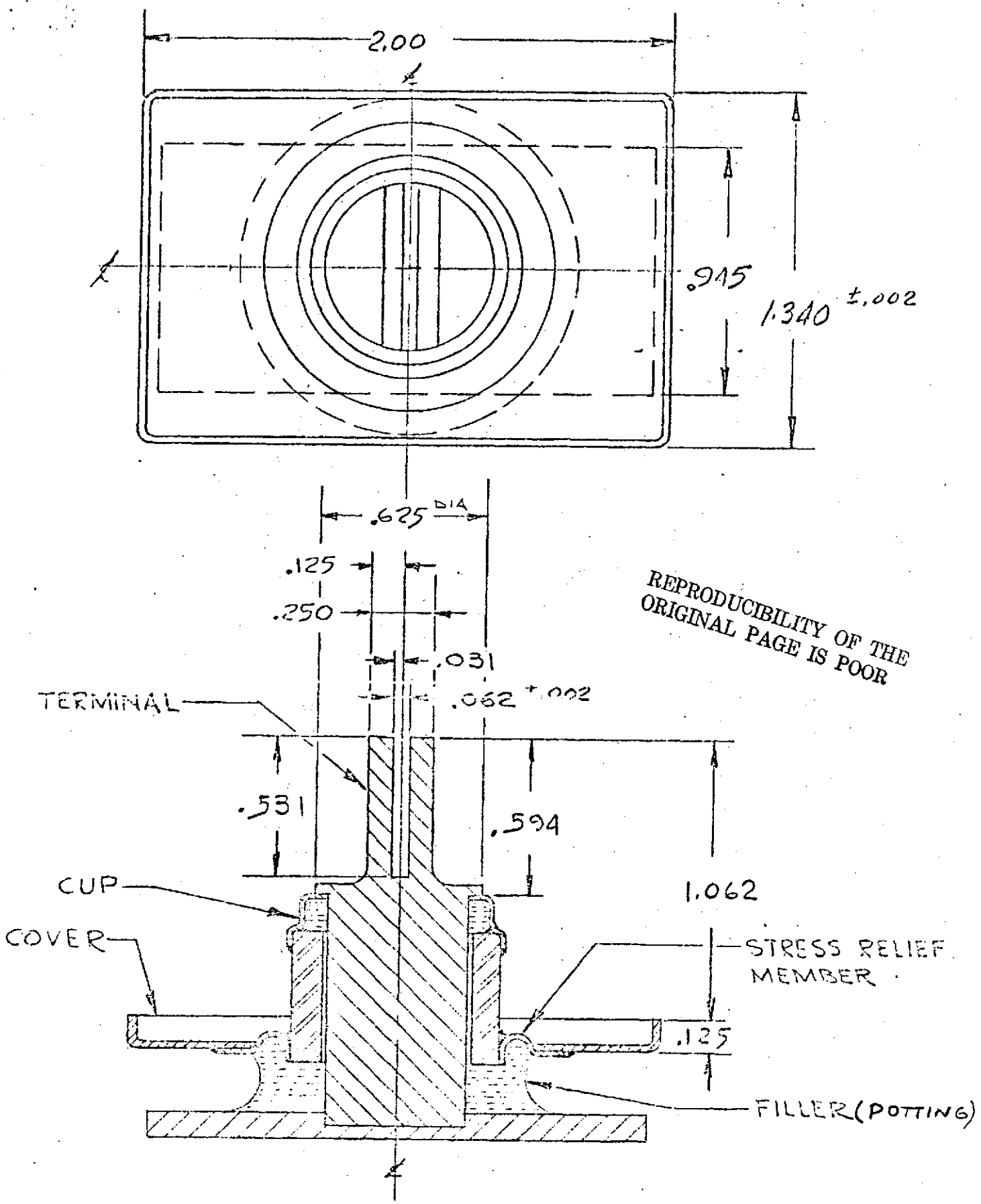
PREPARED	D.G.C.	13MAR70
CHECKED	[illegible]	[illegible]
ENGINEER	D.S.	22APR70

EAGLE PICHER INDUSTRIES, INC.
COUPLES DEPARTMENT
JOPLIN, MISSOURI

STUD TERMINAL

SIZE	CODE IDENT NO.	
B	81855	85-40-138-0
SCALE 2/1		SHEET

FIGURE 5.2-35

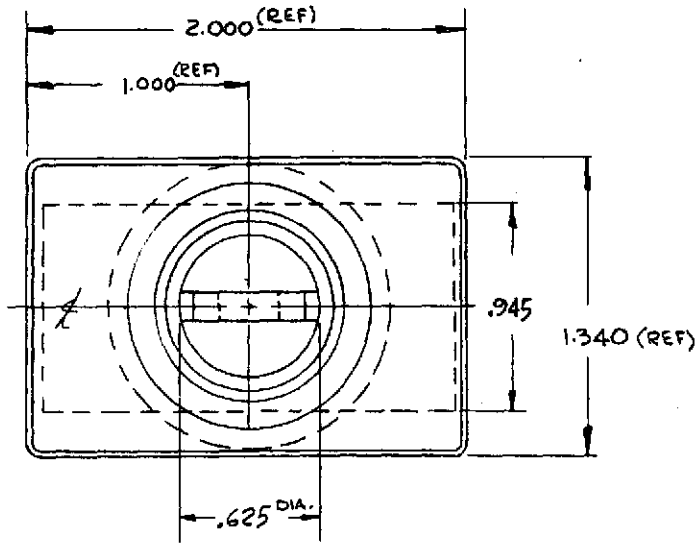


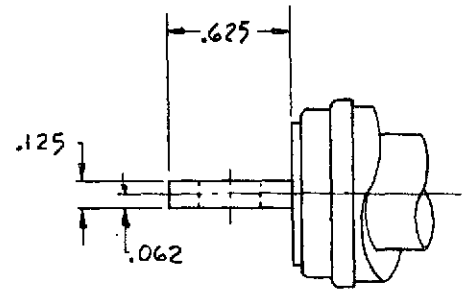
PROPOSED MODIFICATION FOR CELL TERMINAL

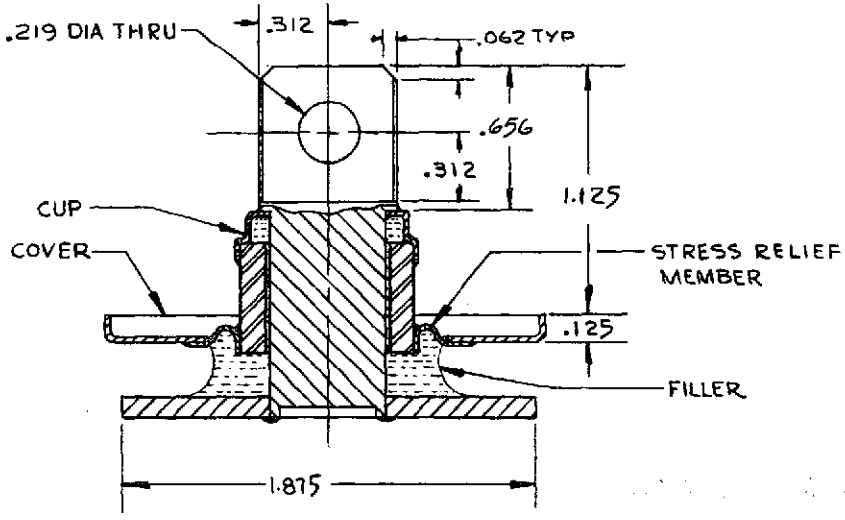
FIGURE 5.2-36

SCALE 3/1

"GRUMMAN SKETCH 559-101AV"







06

FIGURE 5.2-37

CONTRACT NO.	GRUMMAN AIRCRAFT ENGINEERING CORPORATION BETHPAGE, NEW YORK 11714
DRAWN BY B. Lijoi 1-22-71 LAYOUT BY B. Lijoi 1-22-71 CHECKED BY B. Lijoi 1-22-71 GR LEADER REL GROUP PROJ ENGR S Gaston 1-22-71	TERMINAL SEAL CERAMIC - TO METAL (FLAT LUG)
SIZE	CODE IDENT NO. 26512 — 559-104 AV
SCALE 2:1	SHEET OF

5.2.1.5.5.3 Terminal Retainer Material Alloy 42 vs. Alloy 52 - Alloy 42 terminal retainer material was used successfully on nickel-cadmium cells. It was selected to achieve thermal expansion characteristics close to that of the ceramic material. Ceramaseal's experience has shown that a copper plating of the collar is required prior to the brazing operation to obtain a satisfactory joint. From the chemical point of view an exposure of copper to the cell's interior is undesirable since copper oxide is partially soluble in the electrolyte. An epoxy coating will somewhat retard this effect but will not stop it completely for long durations. It was therefore desirable to eliminate this copper plating. Ceramaseal found that no copper plating is required if alloy 52 is used. However, the thermal expansion of this material is slightly higher than alloy 42. Alloy 52 was selected after a thorough analysis and evaluation testing.

5.2.1.5.5.4 Choice of Alumina Purity - In the past Ceramaseal has used a 94% minimum (96% nominal) alumina content ceramic material for sealed nickel cadmium cells. Gulton, who manufactures their own terminals, has used 99.4% minimum alumina content ceramic materials. Since a large percentage of the balance in the ceramic is silica, and since silica is attacked by the electrolyte, it appears desirable to use the highest purity available for long life nickel-cadmium cells.

A review of the available ceramic materials had shown that Coors (Coors Porcelain Company, Golden, Colorado) can supply a 99.9% alumina. This material, in addition to its high purity, has a smaller crystal size and, consequently, is stronger. No working experience with this material for cell terminal use was available at that time.

Experience had shown that 94% minimum alumina content material could readily be utilized for cell terminals. The 99.9% material appeared to be the best choice but required an experimental evaluation prior to incorporating it in this design.

5.2.1.5.5.5 Choice of Braze Materials - In the past Ceramaseal has successfully used a copper-silver-palladium alloy for cell terminals. Gulton has used a copper-silver eutectic alloy successfully for their cell terminals. A nickel-gold alloy is now available but it has not been experimentally evaluated. From the chemical inertness point of view, the nickel-gold appears very desirable. However, preliminary information shows that it will result in a poor bond. At present this item requires further investigation before a final choice can be made.

5.2.1.5.5.6 May 1971 Terminal Design Finalization for Parametric Cells

In May 1971 a decision was made on the materials to be used for the cell terminals for the parametric cell group. This was based on past performance information of the various candidate materials and program economy. 95% minimum purity alumina ceramic material and alloy 42 retainer material was selected. A configuration change to a stud shown in figure 5.2-38 was made.

5.2.1.5.5.7 July 1971 - Large Ceramaseal Terminal Problem Observed At Other User

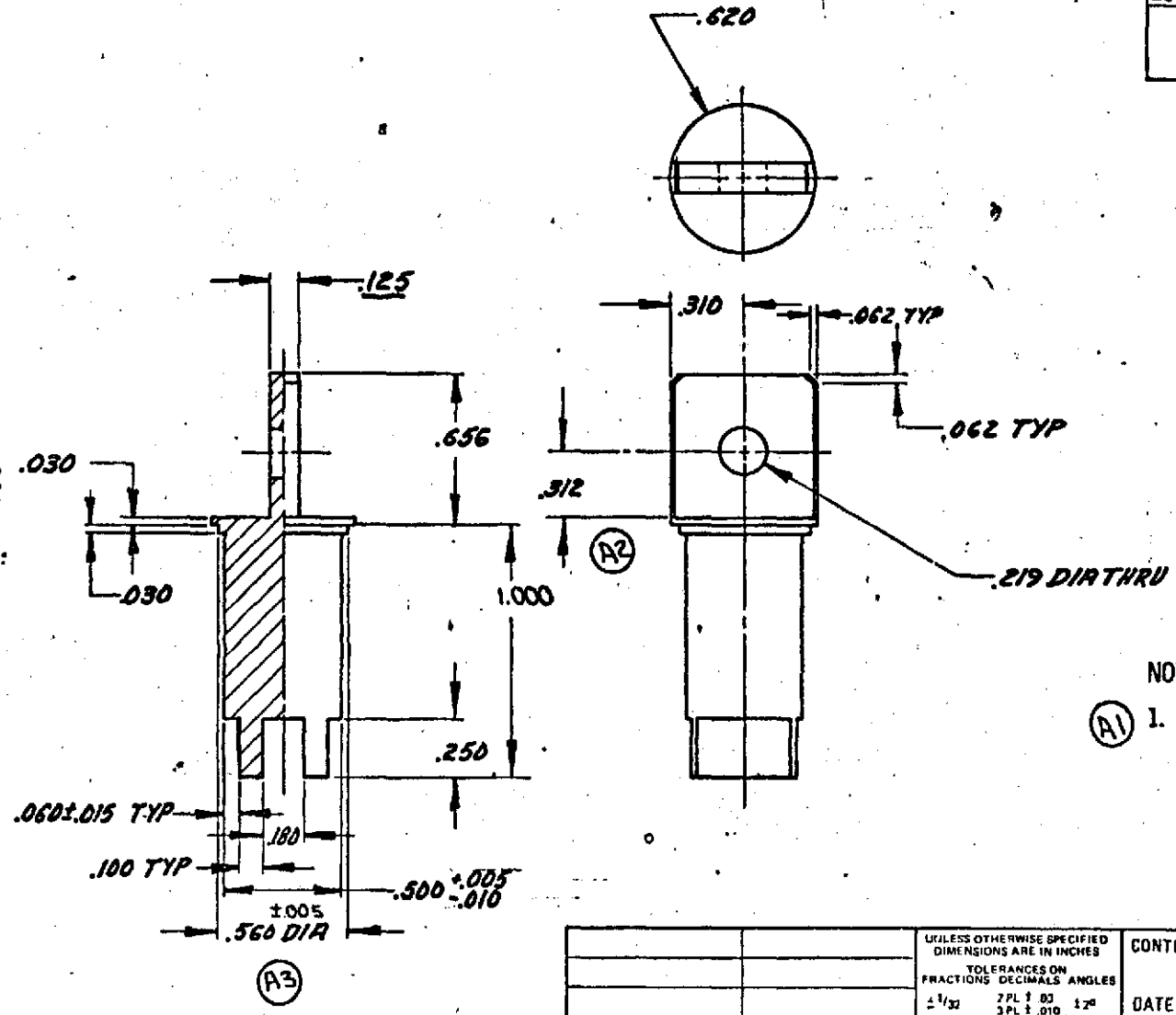
In July 1971, Hughes Aircraft reported a seal problem on the large Ceramaseal terminals on their 50 A.H. cells (Hughes Aircraft July 1971 Monthly Progress Report on U.S.A.F. Contract F33615-70-C-1710).
Specifically, leaks around the terminal seal areas were observed. Their metallurgical analysis had shown that, "this type of leakage path is a direct result of improper jigging with regard to heat distribution --". They also concluded that large terminals require much closer controls in the braze operation than smaller size terminals.

As a result of this finding, Grumman made an immediate request to Eagle Picher to send two of the ratio test cells to Grumman for a terminal metallurgical analysis, even though none of the cells constructed under this program had shown any signs of leakage.

5.2.1.5.5.8 November 1971 Meeting on Large Size Terminal Problem

The potential leak problem on large size terminals was discussed at the NASA/GSFC Battery Workshop meeting held in November 1971. This discussion occurred both at the general meeting and separately between Grumman, Eagle Picher and Ceramaseal. This review is summarized in Appendix K-2. It was decided there that a number of immediate steps must be taken to eliminate this potential problem, and should be

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	(1-3) REVISED PER ED. 26812	30 DEC 71	JSC



PRINT ISSUED
DATE DEC 30 1971
ALL PRINTS ISSUED
PRIOR ARE OBSOLETE

NOTES:

A1 1. SULFUR BEARING CUTTING OIL SHALL NOT BE USED DURING MACHINING.

FIGURE 5.2-38

		UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON FRACTIONS ±1/32 DECIMALS 2PL ±.03 3PL ±.010 ANGLES ±2°	CONTRACT NO.	EAGLE PICHER INDUSTRIES, INC. COUPLES DEPARTMENT JOPLIN, MISSOURI
		MATERIAL: NI-270 COLD DRAWN STOCK	DATE	STUD, TERMINAL
			PREPARED P.C. Logan 24 JUN 71	
			CHECKED S.C. Hall 29 oct 71	
005313	RSN 110		ENGINEER J. Hawkins 29 oct 71	SIZE B / CODE IDENT NO. 81855 / 85-40-175-0
NEXT ASSY	USED ON			SCALE 2/1 / SHEET 1 OF 1
APPLICATION				

incorporated in the parametric group cells. These were:

a) Increase in the alumina purity level to 99.5% minimum.

b) Elimination of the surface glaze on the ceramic.

c) Change in retainer material to 52% nickel alloy.

d) Tighter component tolerances.

e) Greater control of braze material.

f) Application of the Quality Assurance provisions for the manufacture of ceramic to metal seals shown in the Third Quarterly Report of the "Study of Process Variables Associated with Manufacturing Hermetically Sealed Nickel Cadmium Cells" (Contract NAS 5-21159), and issued as Eagle Picher Specification EP-MS-122. (document is shown in Appendix K-3)

The alternate terminal designs, listed in Appendix K-2 were rejected based on considerations of cost, schedule and availability of sufficient design evaluation data.

5.2.1.5.5.9 Grumman Metallurgical Analysis Results of Development Group I Cell Terminals - Grumman conducted a metallurgical analysis on terminals of a development group I cell. Its purpose was to determine if inherent seal weaknesses are present in this design. Grumman AVO 559-2-8 (Appendix L-4) summarizes the findings. Hairline cracks in the ceramic under the braze joint and voids in the braze were observed. These cracks centered around the outer diameter of the ceramic sleeve, but did not extend to the inner diameter. Thus a leakage path from the cells interior to the exterior was avoided. However, the joint integrity was questionable due to this condition.

5.2.1.5.5.10 May 1972 Meeting with Ceramaseal on Terminal Problems

On May 4, 1972, Messrs. W. Harsch (Eagle Picher) and S. Gaston (Grumman) visited Ceramaseal in New Lebanon, New York, to monitor the progress of cell terminal redesign. Changes described above, as shown in figure 5.2-39 were reviewed with Mr. R. Turner and A. M. Bredbenner of Ceramaseal. All sample terminals seen contained hairline cracks. The 96% purity alumina ceramic samples showed fewer and shorter cracks than the 99.5% samples. For neither purity did the crack extend enough to result in a leakage path. However, since units were dissected without prior encapsulation some cracks might have formed then. (Ceramaseal used this technique since the potting material fouled their cutting wheel.) Ceramaseal contended that all terminals produced in the past could show these fine cracks, if examined as closely as those in question. This requirement for a total absence of any cracks thus appeared unrealistic, being probably unachievable at that time. However they could not indicate the nature of more "realistic" criteria, except to state that the terminal must pass a fine leak rate (helium) test. As alternate solutions for future applications, "butt-type" terminal seals and large terminals using tapered ceramic sleeve were under development.

Based on available information, Grumman and Eagle Picher representatives decided to have one complete cover assembly constructed immediately. This contained one terminal with 96% purity alumina and one with 99.5% purity. It was constructed using standard production techniques to represent the batch to be produced shortly thereafter. This sample was sent to Grumman for metallurgical examination. Based thereon, Grumman and Eagle Picher would decide on the terminal construction for the parametric cells.

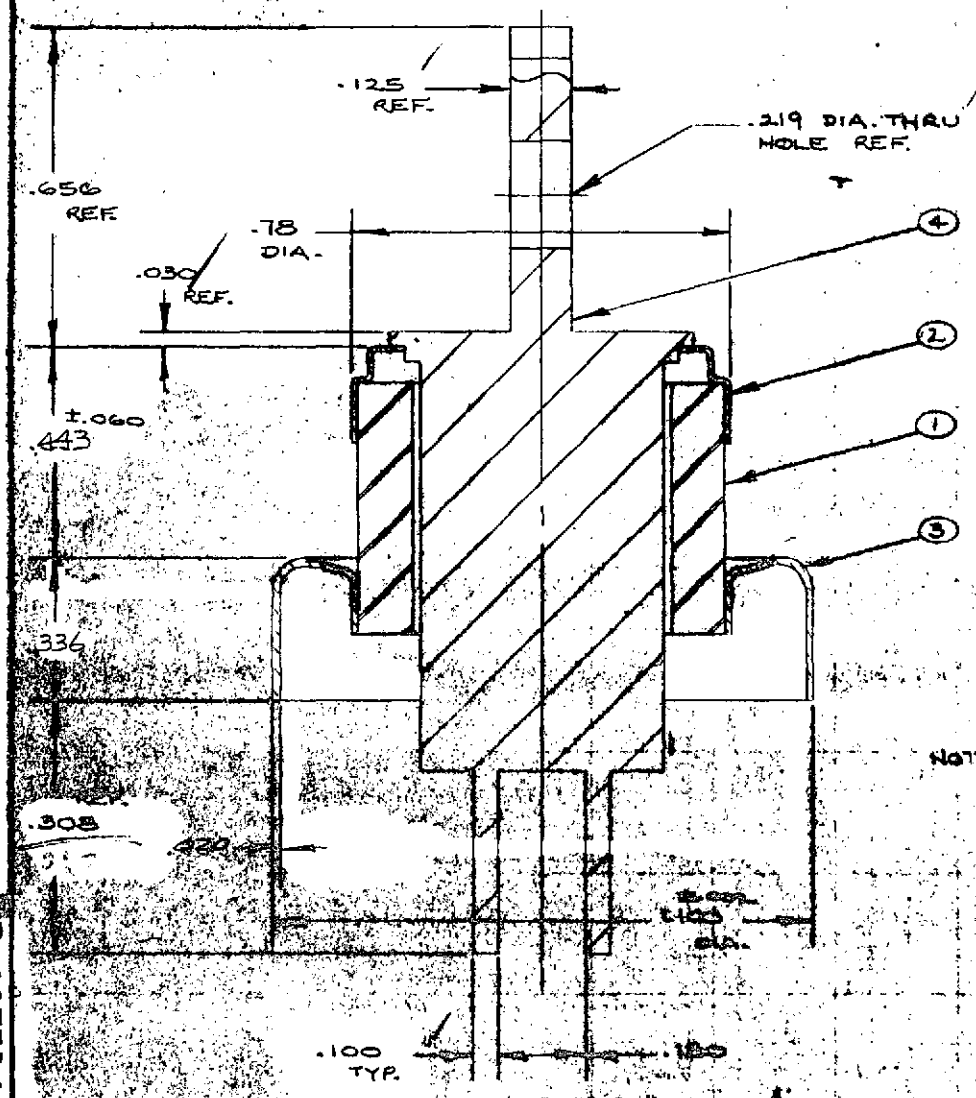
This sample was mailed to Grumman the following day, and was examined during the week of May 8, 1972. The following results were obtained.

1. The 96% alumina showed better structural integrity than the 99.5% piece. One fine hairline crack, however, was noted in each seal -- with the shorter in the 96% alumina. There was no cause to question seal integrity.
2. The potted and polished cross-sections showed good braze joints on both terminals.

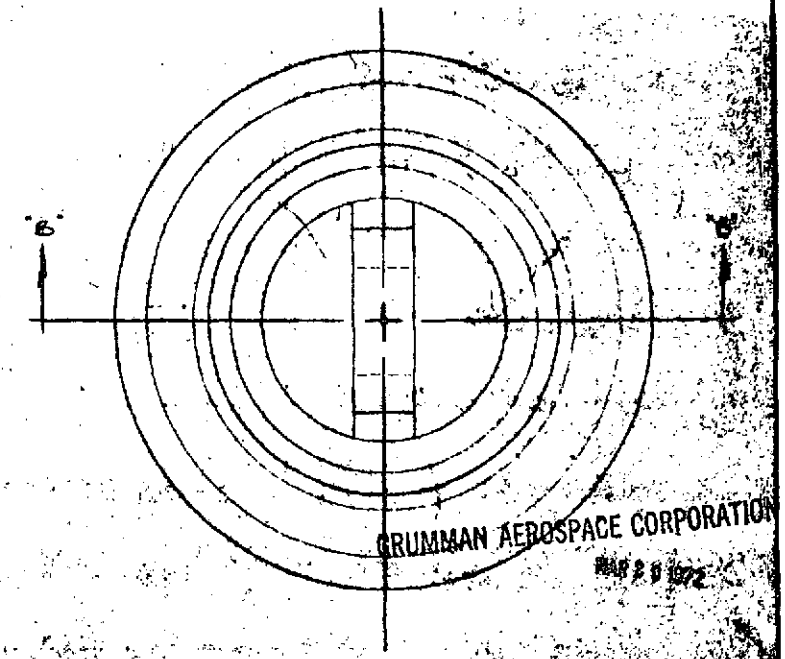
Ceramaseal was thus told, on May 9, 1972, to construct terminals for the parametric cells using 96% purity alumina, provided that production techniques identical to those for the above samples were used.

MATERIAL	FINISH	PLATING	SPECIFICATION	USED ON
SEE DESCRIPTION	WELDABLE ADAPTER	———	———	C7720-1

ITEM		DESCRIPTION	QTY.	DRAWING
	BOND MATERIAL	AG CU Pd.		
1	INS.	99.5 ALUMINA		810A7185-1
2	CAP	52% NIFE		821A7722-1
3	FLANGE	52% NIFE		P831A7721-1
4	STUD	NICKEL 270		862A7738-1
5				
6				



Section "B"-"B"



GRUMMAN AEROSPACE CORPORATION

MAR 2 9 1972

NOTES:
1.) LEAK TEST @ 1×10^{-9} ATM. CC/ SEC. H.T.R. HELIUM.
2.) MANUFACTURE TO S.I. 469 & VISUAL INSPECT TO S.I. 678.
3.) PROCURE MATERIAL PER S.I. 675.
4.) E.P. SPEC. GR-MS-122 APPLIES.
5.) MATERIAL VERIFICATION REQUIRED ON ALL CERAMASEAL SUPPLIED PARTS PRIOR TO BRAZING.

FIGURE 52-39

TERMINAL	CERAMASEAL, INC. NEW LEBANON CENTER, NEW YORK, U.S.A.
	DRAWN 1 PR; CHECKED; DATE 12-16-71; P807B7734

96

P807B7734

5.2.1.5.5.11 May 1972 Meeting with General Electric

On the afternoon of May 4, 1972, Messrs. W. Harsch and S. Gaston visited the General Electric Tube Department, Microwave Tube Operation, in Schenectady, New York to obtain information on the G.E. "Butt-Seal" for possible future use in this program. This was discussed with Messrs. A. Michaelson (Manager) and R. Bristow (Senior Ceramist). They appear to have found a 97% purity alumina well-suited to this application. They had tooling for studs up to 0.352" diameter, but none for the 0.500" diameter required for 100 A-H cells. At best, delivery would range from several weeks to several months depending upon the design selected. G.E. promised to quote cost and delivery schedule for a few alternate approaches, such as various stud diameters, and whether G.E. or E.P. will supply the terminal stud.

5.2.1.5.5.12 Seal Problem on Some Cells of the Parametric Group

In September 1972, after construction completion of the parametric cell group, cell terminal leak problems were detected on some cells. (These cells had used terminals described in above paragraphs 5.2.1.5.5.8 & 5.2.1.5.5.10.) As a consequence all terminal seal areas were externally coated with epoxy. This temporary measure had to be resolved life test group terminals which were immediately placed on a "production hold". Grumman offered immediate assistance to Eagle Picher and Ceramaseal to resolve this problem. Also the Ceramaseal "Butt" design was considered as an alternate if it appeared that no quick and satisfactory solution could be found.

5.2.1.5.5.13 Ceramaseal "Butt Seal Terminal" Design Sample Review

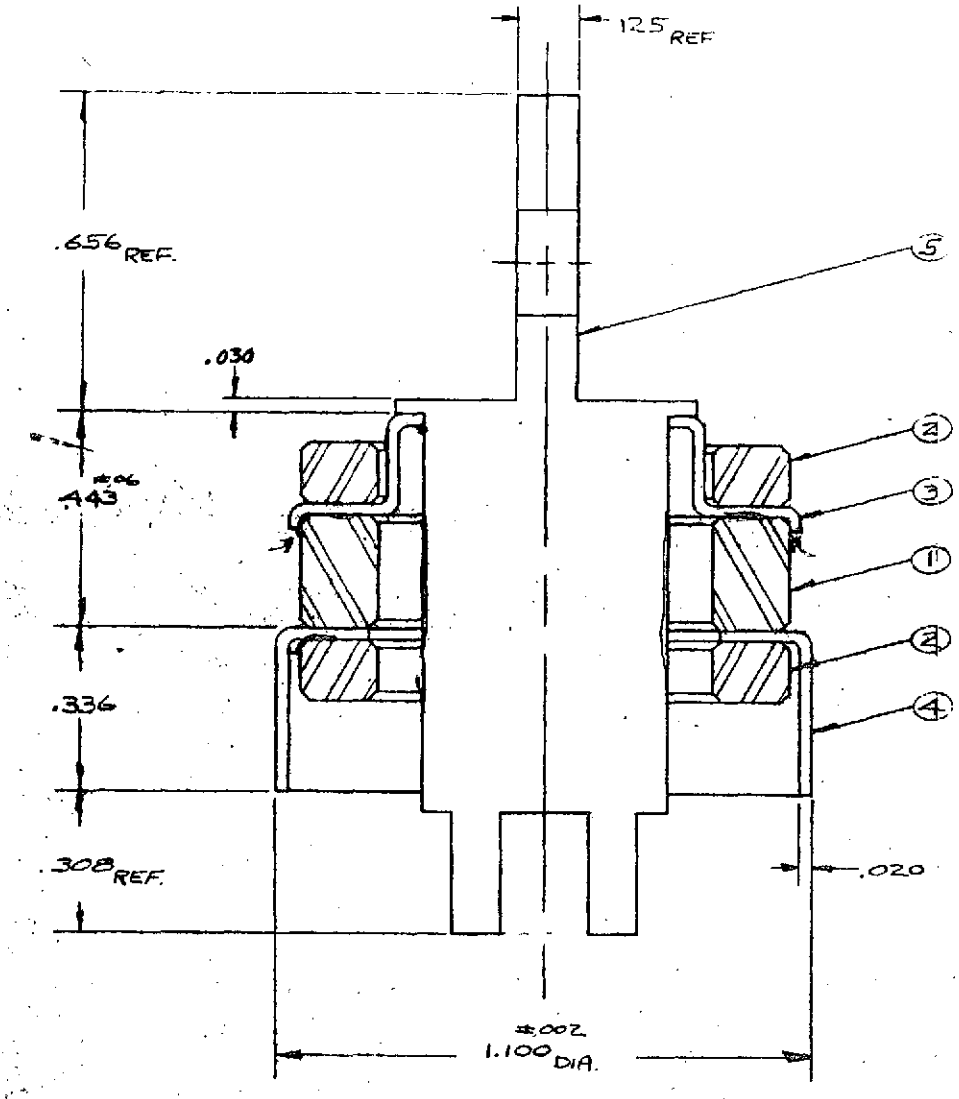
In October 1972, it became apparent that further effort on the above described terminal would be unsuccessful in resolving its inherent problems. Consequently the Ceramaseal "Butt Seal" terminal was examined more closely. A sample cell cover was received from Eagle Picher on November 10, 1972. This cover was welded to a case at Grumman for a mass spectrometer leak test. These terminals have successfully passed a leak test of 2.6×10^{-8} cc per second of helium (the value was the minimum detectable with the standard sample used). The cover sample was then given to the Grumman Metallurgical laboratory for dissection and examination of the seal areas. This showed that this terminal looks superior to those designs supplied previously. The design is shown in figure 5.2-40. A few improvements were indicated in the following areas:

1. Better cleaning at bottom weld to cover - a burr was left at the cup - and weld penetration could be improved.
2. Incomplete braze penetration - braze material flows toward the perimeter leaving less material near the inner diameter.

To strengthen this design in the areas outlined above, and to expedite delivery of the life cells with this terminal, Eagle Picher was contacted to arrange a meeting with Ceramaseal at the Grumman Metallurgical laboratory as soon as possible.

MATERIAL	FINISH	PLATING	SPECIFICATION	USED ON
	WELDABLE FLANGE			C7720-1

	ITEM	DESCRIPTION	QTY.	DRAWING
	BOND MATERIAL	Ag CU EUT		
1	INSULATOR	99.5% ALUMINA	1	810A7923-1
2	INSULATOR	" "	2	810A7923-2
3	CAP	52% NIFE	1	921A7932-1
4	FLANGE	" "	1	931A7933-1
5	STUD	NICKEL 270	1	962A7934-1
6				



NOTE
1. LEAK TEST @ 1×10^{-9} ATM CC/SEC STR HELIUM
2. MFG TO S1469 & VISUAL INSP. TO S1.375
3. PROCURE MATL PER S1475
4. E.P. SPEC. EP-MS-122 APPLIES
5. MATL VERIFICATION REQ. ON ALL CERAMASEAL SUPPLIED PARTS PRIOR TO BRAZING

FIGURE 5.2-40

TITLE: TERMINAL	CERAMASEAL, INC. NEW LEBANON CENTER, NEW YORK, U.S.A. A SUBSIDIARY OF ITT CANNON ELECTRIC CORPORATION
DO NOT SCALE DRAWING — WORK TO DIMENSIONS. ALL DIMENSIONS IN INCHES EXCEPT AS NOTED. TOLERANCES BELOW APPLY UNLESS OTHERWISE SPECIFIED.	SUPERSEDES: / REVISED TO: 7734
FRACTIONS ± 1/32 · 2 PLACE DEC. ± .02 · 3 PLACE DEC. ± .015 · ANGLES ± 1°	DRAWN: K.B. · SCALE: 4:1 · CHECKED: · DATE: 5-8-72 · APP'D: · DRAWING NO. 80787931 · REV.

80787931

5.2.1.5.5.14 Finalization of the Cell Terminal Design for the Life Test Cells

On 12 December 1972, a meeting was held at Grumman concerning the cell-terminal seal. It was attended by W. Harsch (Eagle Picher); R. Turner, M. Bredbenner (Ceramaseal); S. Gaston, M. Wertheim(Grumman) and J. Greenspan, J. Winn, P. Dent Grumman Metallurgical Laboratory). The results obtained from the sample cover were viewed and discussed. Ceramaseal indicated that additional manufacturing modifications were made after the sample in question was supplied. These were done to improve seal integrity. They felt Grumman's comments were valuable, and that this design can meet requirements.

As a result of this meeting, Grumman issued an action item document (AVO D-559-2-39, shown in Appendix K-5) to Eagle Picher to expedite delivery of the Life Test Cells. These are summarized below:

a) The "Butt Seal terminal" appears superior to previous designs and was to be used on the life test cells .

b) The Quality Assurance specification for the manufacture of ceramic-to-metal seals, E.P.-MS-122 and comments listed in Grumman AVO-D-559-1-33 (shown in Appendix K-3) was to be reviewed quickly for specified terminal material and dimensional changes. Actual changes were to be transmitted to Grumman immediately for approval. Thenceforth, this specification must be enforced.

c) A number of production sample units were to be examined metallurgically for for good braze integrity, and copies of results were to be furnished to Grumman quickly for review and approval.

d) Finalized terminal design and cover drawings were to be furnished to Grumman for information.

e) Application of Non-Destructive Terminal Braze uniformity Detection Technique

Subsequent to this meeting, the Grumman Metallurgical Laboratory radiographically examined one "Butt Seal" terminal mounted on a cover. A top view and one angular view, using standard X-ray techniques can detect small internal voids in the braze material. These views are shown in enclosure 2 to Addendum to AVO-D559-2-39 (see Appendix K-5).

Eagle Picher was requested to review this technique with respect to incorporation in the process requirements for life test cell terminals. Acceptance/Rejection criteria were to be established thereafter.

All life cell terminals were then constructed and examined as described above.

5.2.1.5.6 Auxiliary Electrode Signal Review

5.2.1.5.6.1 Development Group Cell Manufacturer's Test Results - The results of the group I development cells had shown that the auxiliary electrode signal changes were too low to provide usable control. A more careful review of the data in April 1971 showed the following performance characteristics of the group I auxiliary electrode design, as reported in the April 1971 Monthly Progress Reports.

a) The residual voltage at 0 psia was high compared to the change in voltage with increasing pressure. This characteristic showed up at all load resistance values measured. In general, the range of signal-to-residual-level ratio was 1.3 to 1.6/1. This is in contrast to the performance of OAO 20 Amp-Hr. cells (6 to 7/1 ratio), 6 Amp-Hr cell reported in January 1968 on NAS 5-10261 (> 5:1), and ATM 20 Amp-Hr. cells reported in June 1970 on NAS 8-20055 (~3.5:1).

b) The voltage-pressure data indicated a fairly large temperature sensitivity ~ 3-5%°C.

c) The apparent maximum power load resistor indicated -- 1 ohm -- showed a large variation as a function of pressure and temperature -- from approximately 0.5 ohm to 1.5 ohm.

It was concluded from the above that some phenomena, not well-understood, are occurring. Among the possibilities (see Appendix K-1 for a thorough discussion of the investigation of auxiliary electrode design and performance) suggested were:

a) Electrode area insufficient for total oxygen volume (mass) generated.

b) Electrode is improperly located in the plate stack.

c) Use of non-woven (Pellon) can liner rather than polyvinyl chloride (PVC) causes oxygen molecule entrapment and/or other deleterious electrochemical action.

While any or all of the above possibilities could be true, it was felt that no definitive conclusion could be reached based on the existing level of understanding of auxiliary electrode operation. Accordingly, the decision was made to investigate design and performance parameters with the express goals of:

a) Deriving design data and rules for the geometry, location and material requirements of auxiliary electrodes.

b) Deriving design data and rules for optimization of auxiliary electrode load circuitry. Optimization shall be taken to include individual and mutual effects of the following:

1) Maximization of signal change to residual level ratio.

2) Minimization of temperature sensitivity of both levels and signal ratios.

3) Minimization of cell-to-cell differences to permit standard design techniques and parameters to be used for sensing circuitry.

Initial results of this effort, as reported in Appendix L-1, indicated the probability that the above-cited goals were achievable. The following were noted tentatively:

a) The relationships describing electrode performance appear to be very similar to those used to characterize thermodynamic phenomena. If verified by tests, these relationships would permit the achievement of most of goal b. above by means of a paper prediction once the geometry, location and material data of an electrode are known.

b) Utilizing the above described relationships, it may be possible to construct meaningful experiments which would yield parametric data for use in the electrode design. Such data may also result in insights regarding the design criteria as functions of such things as negative electrode construction, electrolyte quantity, cell size, and so forth.

It should be noted that achievement of either goal above, or any significant part thereof, would represent a major advance in state-of-the-art of cell design and charge control.

The Test Program to understand the interelationships among basic auxiliary electrode parameters, as described in paragraph 3 of Appendix L-1, was not conducted due to lack of program funds. The Eagle Picher effort described in Appendix L-2 was carried out at their own expense. Grumman requested five (5) selected development group I & II cells from Eagle Picher for tests here to obtain auxiliary electrode characteristics under continuously orbiting conditions (not done previously at Eagle Picher).

5.2.1.5.6.2 Results of Special Tests to Investigate Auxiliary Electrode Problem- In July 1971, Eagle Picher reported the findings of their tests to investigate auxiliary electrode performance problems. These results are shown in Appendix L-3. A total of 18 cells of 36 A.H. size (RSN-36) instead of the planned 12 A.H. size were constructed. The previously suggested use of a larger area auxiliary electrode was not included and all had areas of 10 square centimeters. Variations evaluated were:

a) Wrap 1 - a gas spacer was placed between electrode and container.

b) Wrap 2 - no gas spacer, but electrode was wrapped in non-woven nylon P2505 (washed).

c) Teflon was placed on a nickel screen.

d) Teflon was placed on a raw plaque.

e) Uncoated raw plaque.

f) Recombination type electrode with platinum.

g) Cell electrolyte to core weight ratios of 19, 21 & 23%.

The results may be summarized as follows:

1. Auxiliary electrode signal values are inconsistent with cell pressures and vary widely among cells of identical designs.
2. The following trends, however, were observed:
   a. Cells with less electrolyte show higher electrode voltage peaks and greater oxygen sensitivity.
   b. Cells with auxiliary electrode wrap 2 have less oxygen sensitivity.
   c. Cells without teflon on the auxiliary electrode have lower signals.
   d. The maximum power resistance for all signal electrodes appears to be less than one (1) ohm.

5.2.1.5.6.3 Auxiliary Electrode Evaluation Testing at Grumman - The test plan shown in Appendix L-4 (Grumman AVO-559-2-3) was followed. However, tests were terminated prematurely since consistent repeatable signal results were not obtained in cycling, and no technique for selecting an optimum resistor load was found. From the data it appeared that one or more of the following seemed to be true:

- The electrodes were completely saturated, even at pressures as low as zero (0) PSIG.
- The variations in negative electrode-to-case (as neutral) voltage were sufficiently greater than the auxiliary signal to completely swamp out any effect from oxygen presence.
- Cells S/N 24 and 42 may have generated some hydrogen.

5.2.1.5.6.4 Discovery of Design Weakness in Auxiliary Electrode Tab-to-Can Welds - In January 1972 Grumman discovered a design weakness in the tab-to-can welds of the auxiliary electrode. This problem was found when development cell S/N 14 (from development group I) was dissected. These results are shown in Appendix L-5 (Grumman AVO-D559-2-2). The auxiliary electrode tab formed a bend touching several layers of main separator in the plate stack. This is undesirable since a short could be induced. In addition, two (2) nicks across the tabs' width, in close proximity to the tab-to-can weld area were observed. Since, during the cells assembly, the cover is forced onto the can while this tab is sandwiched between, tab damage can occur (tab material is..005" soft nickel).

Two alternate solutions to eliminate the above described problems were proposed and are also shown in Appendix L-5.

5.2.1.5.6.5 Auxiliary Electrode Modifications for the Group III Cells - Most of the group III cells were constructed with the auxiliary wrap 2 (as defined in paragraph 5.2.1.1.3). Only two cells (S/N32 & 33) of this group had the type 1 wrap for use as a control. Two cells (S/N 36 & 37) had their auxiliary electrode terminal insulated in the housing.

Again the results had shown no substantial performance improvement useful for repeatable charge control.

5.2.1.5.6.6 Final Attempt to Correct Auxiliary Electrode Performance Defects - In April 1972 it was decided to make one final attempt to correct the auxiliary electrode performance problem. It was to utilize three (3) different designs in nine (9) cells of the parametric group, These were:

a) 10 square centimeter nickel mesh with teflonated gas side surface.

b) 30 square centimeter nickel mesh with teflonated gas side surface.

c) "U" shaped nickel mesh, teflonated, running down one narrow face, across the bottom and up the other narrow face.

Each design used a tab welded to the underside of the cover. Wrap 1 was used (as defined in paragraph 5.2.1.5.6.2.a).

The above decision was subsequently modified to expand the number of auxiliary electrode types to be evaluated. All of the 25 delivered parametric cells contained an auxiliary electrode. A total of six (6) different types of auxiliary electrodes were used. These were:

- Type I (cells S/N 47, 57 & 67) - Grumman supplied, Teflonated one side, 1.6 sq. inches X .010".
- Type II (Cells S/N 48, 49, 58, 68 & 69) - Sintered Teflon one side, 1.6 sq. inches X .010".
- Type III (cells S/N 51, 60, 61 & 72) - Standard as previously used, no teflon, 1.6 sq. inches X .025".
- Type IV (cells S/N 52, 53, 62, 73 & 74) - Both sides Teflonated. 1.6 sq. inches X .025".
- Type V (cells S/N 54, 56, & 75) - One side Teflon film and teflon dispersion on the other, 1.6 sq. inches X .025".
- Type VI (cells S/N 55, 65 & 76) - One side teflon film, larger size 4.1 sq. inches X .025". Two electrodes, one on each narrow face.

The "U" shaped design, as proposed in above, was not readily adaptable to the cell design without causing possible internal cell shorts. It was therefore not incorporated.

Even though the larger size auxiliary electrodes had shown somewhat better signal changes than those of standard size, many signals were still inconsistent with pressure changes, varied between cells of identical designs and were therefore unsuitable for charge control. Thus, all further work on auxiliary electrodes was terminated.

Other testing demonstrated this point and although associated with auxiliary electrode effort and stemming from its failures, this conclusion logically must be stated separately in that portion reporting the pressure characteristic effort. The results have shown that a direct sensing of cell pressure can yield a practical and reliable charge back up control. As a consequence, life test cells were constructed without auxiliary electrodes.

5.2.1.5.7 Cell Pressure Sensor Investigation & Selection

5.2.1.5.7.1 Early Program Review - The field of pressure sensors, other than the auxiliary electrode, was reviewed early in the program for automatic recording of cell pressures, or for alternate use for charge control. This review led to two suitable pressure transducers. These were:

a) Servonic Instruments (Costa Mesa, California), One Million Series, unit cost = $210.

b) Computer Instruments Corp. (Hempstead, New York), Model 3000, unit cost = $150.

The cost for either of the above units for use on all or some of the test cells, although less than many available devices, was still prohibitive to this program.

5.2.1.5.7.2 Pressure Switch Selection - In May 1972, it became apparent that a pressure sensitive device as a possible replacement for the auxiliary electrode was required. The lowest cost device among them is a pressure sensitive switch. A review of existing switches of this kind had shown that a unit manufactured by Hydra Electric (Burbank, California), P/N 12213, appears well-suited for this purpose. This part was previously used by the U.S. Army Electronics Command on a number of batteries without any problems. The unit cost is $65.00 but has not yet been space qualified.

A total of ten (10) of these units were purchased with preset pressure settings permitting an evaluation from 1.0 to 40.0 PSI.

They were scheduled to be included in the parametric characterization tests at Grumman in case unsuitable auxiliary electrode signals were obtained. However, due to delivery delays these tests came to completion and program had exhausted its funds before evaluation testing of these units could be conducted.

5.2.1.5.8 Cell Free Volume Determination, Equations and Application of Volumetric Electrolyte Filling Technique

5.2.1.5.8.1 Cell Free Volume Measurement and Apparent Core Density Calculations - The cell's free volume was measured on eight (8) selected cells from development groups I - III. The cell internal free volume is defined as the unoccupied volume inside the cell after it is filled with its internal components and electrolyte.

It was determined by filling each cell with dry nitrogen gas at constant temperature and volume and measuring the pressure rise. The summarized free and electrolyte volumes, and core (stack) weight data are shown on Table 5.2-36. Reviewing these data it becomes readily apparent that planned variations in the previously applied "electrolyte weight to core weight ratio" filling technique can in some instances result in identical free volume values. For example, cell S/N 16 was filled using a 21% and cell S/N 32 was filled using a 19% weight ratio, yet nearly identical free volume ratios of 50.4% and 50.9% respectively were measured. The average electrolyte volume to initial free volume (prior to filling) was 51.7%. A normalizing factor, called "apparent core density", was calculated to correct for variations in core weight for the different designs. This value was found to be 6.13g/cc.

5.2.1.5.8.2 Free Volume Equations - Table 5.2-37 shows the derived free volume equations applicable for a volumetric filling technique. Equation 1 is a general case and is self-explanatory. Equations 2-4 are specifically applicable to these 100 A.H. cell designs. They utilize the inside cell volume (empty) and the "average apparent core density" as described above. Using these two constants, measuring the cell core weight and selecting the desired free volume one can calculate the electrolyte volume by means of equation 3. Equation 4 shows a special case in which the electrolyte volume equals the free volume; that is the remaining free volume (after filling) equals to 50% of the initial free volume (prior to filling).

5.2.1.5.8.3 Application of Volumetric Electrolyte Filling Technique - The above described volumetric electrolyte filling technique was subsequently applied on all parametric and life test cells rather than the previously used "core weight filling". Equal electrolyte volume to free volume ratios were selected. The electrolyte filling procedure applied is shown in appendix G and quantities used are shown in appendix N.

5.2.1.5.9 Cell Ratio Testing

5.2.1.5.9.1 Philosophy - The purpose of the first portion of the ratio test is to determine the negative electrode precharge capacity after the positive electrode capacity has been exhausted. The purpose of the second portion of the cell ratio test is to determine the total cell capacity, where the positive electrodes are capacity limiting on charge, the negative electrodes cannot be fully charged, due to oxygen recombination. Therefore, the cell must be flooded with electrolyte to reduce oxygen recombination to a very small value.

TABLE 5.2-36

100 A.H. CELL FREE VOLUME DATA

DESIGN DESCRIPTION	CELL S/N	DESIGN GRP. NO.	NO. +/-	ELECTROL. VOLUME	FREE VOLUME	COMB. ELECTROL + FREE VOLUME	% ELECTROL. VOLUME OF COMB. ELECTROL. + FREE VOL.	CELL INSIDE VOLUME	VOL. INSIDE CELL V-(COMB. ELECTROL.	CORE WEIGHT	CORE WEIGHT VOL.	% ELECTROL. WEIGHT TO CORE WEIGHT
UNIT	-	-	-	cc MEAS.	cc MEAS.	cc CALC.	% CALC.	cc CALC.	cc CALC.	g MEAS.	g/cc CALC.	% CALC.
THIN PLATE P2505	16	1	19/20	387	381	768	50.4	1164	396	2410	6.09	21
BASELINE WEX 1242	24	2	17/18	350	429	779	44.9	1164	385	2389	6.21	19
THIN PLATE P2505	32	3	19/20	375	362	737	50.9	1164	427	2580	6.06	19
THIN PLATE P2505	35	3	19/20	375	381	756	49.6	1164	408	2580	6.32	19
THIN PLATE ISO AUX.	37	3	19/20	375	362	737	50.9	1164	427	2580	6.04	19
THIN PLATE ISO AUX.	41	3	20/21	394	331	725	54.3	1164	439	2710	6.17	19
THIN PLATE T21047	42	3	20/21	394	314	707	55.7	1164	457	2710	5.93	19
BASELINE P2505	45	3	17/18	408	303	711	57.4	1164	453	2805	6.19	19

$\bar{x}$ = 6.13

STD. DEV. = 0.096

APPARENT CORE DENSITY = 6.13 g/cc

TABLE 5.2-37

EQUATIONS FOR VOLUMETRIC FILLING

Definitions:

Inside Volume (IV) = Free Volume (FV) + Electrolyte Volume (EV) + Core Volume (CV)

1. OR $IV = FV + EV + CV$

For This 100 AH Cell

IV = Calculated cell inside volume = 1164 cc
CW = Core weight in grams
CV = Core weight in grams divided by 6.13 g/cc

6.13 = Apparent density of core material. This value was calculated from the development cell free volume and core weight measurements - see attached table 1.

2. Therefore eq. 1. becomes:

$$1164 = FV + EV + \frac{CW}{6.13}$$

3. For a free volume goal = 100x %

$$1164 = FV + (1-x)\,EV + \frac{CW}{6.13}$$

$$(1-x)\,EV = 1164 - FV - \frac{CW}{6.13}$$

$$EV = \frac{1164 - FV - \frac{CW}{6.13}}{1 - x}$$

$$EV = \frac{1164 - FV - 0.163CW}{1 - x}$$

4. For a 50% free volume goal, EV = FV
Then equation 2. becomes

$$1164 = 2\,EV + \frac{CW}{6.13}$$

$$2\,EV = 1164 - \frac{CW}{6.13}$$

$$EV = 582 - \frac{CW}{12.26}$$

The first portion of the ratio test is not repeatable since, after negative electrode precharge has been removed, no additional precharge is left. It has been Grumman's experience that the second portion of the ratio test is also not repeatable since later cycles have yielded large unexplainable differences in results from the first cycle (see Table 5.2-39).

Due to the "destructive" nature of ratio tests then, not every cell constructed can be subjected to them. Therefore, a sampling technique must be applied using a small number of cells. Each sample result is thus of great value and extreme care must be exercised to obtain meaningful and reliable results. Since nickel-cadmium cell performance is very much dependent on both previous history and test conditions, it is of critical importance to keep these conditions identical for each test and between tests.

5.2.1.5.9.2 Procedure - The ratio test procedure shown in appendix I was followed with the exception of the earlier sample cells. (These cells did not receive electrolyte additions during the flooded full charge and spewed electrolyte which was not replaced resulting in incomplete full charge of the negative electrodes due to recombination.)

5.2.1.5.9.3 Results - The ratio test results summary for groups 1, 2, 3 and parametric cells is shown in Table 5.2-38. All positive electrode capacities exceeded the minimum required 100 A.H. All negative to positive capacity ratios exceeded 1.50. The negative precharge values were somewhat erratic. All precharge values were high due to insufficient power discharges. The early sample cells up to cells S/N 29 had lost large electrolyte quantities during the flooded charge preventing them from reaching full charge. Repeated test cycles generally resulted in increased positive and negative electrode capacities.

5.2.1.5.9.4 Precharge Setting for Parametric and Life Cell Groups - Two sample test cells received ratio tests; one full size cell (S/N 46) and two 12 A.H. size cells cut from the 100 A.H. plaque lot. These data are shown in Table 5.2-38. Table 5.2-39 shows the precharge prediction for the parametric test group from the sample cell results. Based on these results the power discharge was increased to 68.0 A.H. for the thin electrode group. The power discharge settings for all other cells of the parametric and life groups were determined in the same fashion according to their positive and negative active material contents. A goal to achieve a 20% precharge of the excess negative electrode was applied.

CELL S/N	DESIGN DESCRIPTION		DEV. GROUP NO.	POWER DISCH.	I_o T N1	I_o T N2 (*)	I_o T P3	POSITIVE ACTIVE MATERIAL	I_o TP3 ÷ POS. ACT. MAT.	I_o TN3	NEGATIVE ACTIVE MATERIAL	I_o TN3 ÷ NEG. ACT. MAT.	RATIO $= \frac{I_o TN3}{I_o TP3}$	
UNIT →				A.H. MEAS.	A.H. MEAS.	A.H. CALC.	A.H. MEAS.	GRAM MEAS.	A.H./G. CALC.	A.H. MEAS.	GRAM MEAS.	A.H./G. CALC.		
14	BASELINE	(**)	1	26.0	54.3	9.7	118.5	432	.274	182.5	624	.292	1.54	
17	THIN ELECT.	(**)	1	26.0	22.5	66.5	126.0	455	.277	215.0	673	.319	1.71	
26	BASELINE + SHIMS		1	26.0	37.5	45.0	112.5	462	.244	195.0	594	.328	1.73	
29	BASELINE, FT2140 + W. POLYPROP.		2	26.0	37.5	26.0	112.5	462	.244	176.0	594	.296	1.56	
34	THIN ELECT. 19/20	CYCLE 1	3	40.0	92.0	13.0	103.0	495	.208	182.0	704	.259	1.77	
		CYCLE 2		-	-	-	133.0	495	.269	215.0	704	.305	1.62	
		CYCLE 3		-	-	-	131.0	495	.265	225 (***)	704	.370+	1.72+	
40	THIN ELECT. 20/21	CYCLE 1	3	55.0	66.4	7.6	110.0	525	.209	184.0	739	.249	1.67	
		CYCLE 2		-	-	-	140.0	525	.267	220.0	739	.298	1.57	
		CYCLE 3		-	-	-	142.0	525	.271	225 (***)	739	.305+	1.58+	
43	THIN ELECT. 20/21 T21047	CYCLE 1	3	50.0	120 (***)	-	105.0	525	.200	300 (***)	739	.406+	2.86+	
		CYCLE 2		-	-	-	138.0	525	.263	***	739	-	-	
35	THIN ELECT. 19/20		3	45.0	71.7	-	127.0	495	.257	190.0	704	.270	1.50	
41	THIN ELECT. 20/21		3	45.0	104.1	-	131.0	525	.250	215.0	739	.291	1.64	
46	THIN ELECT.		PARAMET.	45.0	39.5	6.5	124.0	459	.270	208.5	642	.325	1.68	
RSN12 (EQUIV. TO 100 A.H.)		CELL 1	PARAMET.	← NO POWER DISCH. →			115.5	459	.252	215.4	642	.335	1.86	
		CELL 2	PARAMET.	33.3	75.2	27.7	100.9	459	.270	206.7	642	.322	2.05	

NOTES: (*) $I_o TN2 = I_o \left[(TN2) - (TP3) - (TN1) \right]$ ALL SYMBOLS ARE AS DEFINED IN GAC CELL SPEC. AV-D559CS-1

(**) ELECTROLYTE REMOVAL ON THESE CELLS COULD HAVE RESULTED IN PRECHARGE VALUE CHANGES

(***) CELL VOLTAGE DID NOT REACH -1.00 VOLTS. DISCHARGE WAS, THEREFORE, TERMINATED

TABLE 5.2-38
RATIO TEST SUMMARY

TABLE 5.2-39 PRECHARGE PREDICTION FOR PARAMETRIC TEST GROUP CELLS (BASED ON SAMPLES)

Cell S/N	Design Description	Dev. Group No.	Power Disch.	Precharge (-) I_oTN1	Unch. (-) I_oTN2	Total Excess $I_oTN1 + I_oTN2$	% Precharge $\frac{I_oTN1}{I_oTN1 + I_oTN2} \times 100$	Power Disch. Efficiency $\frac{I_oTN2}{\text{Power Disch.}} \times 100$
			Measured A.H.	Measured A.H.	Calc. A.H.	Calc. A.H.	Calc. %	Calc. %
46	Thin. Elect.	Para.	45.0	39.5	45.0	84.5	47	100
*	Thin. Elect.	Para.	33.3	75.2	30.6	105.8	71	92

NOTES: * 12 A.H. SIZE CELL WAS CONSTRUCTED FROM PARAMETRIC GROUP ELECTRODE PLAQUES. RESULTS SHOWN WERE MADE EQUIVALENT TO A FULL SIZE 100 A.H. CELL.

111

GOAL = 20% PRECHARGE OF TOTAL EXCESS NEG. ELECT. CAPACITY = $.20\left(\frac{I_oTN1}{I_oTN1 + I_oTN2}\right)$

① UNCHARGED EXCESS NEG. ELECT. CAP = $.80\left(\frac{I_oTN2}{I_oTN1 + I_oTN2}\right)$

SINCE POWER DISCHARGE (P.D.) EFF. WAS 100%, IT FOLLOWS THAT

② $P.D. = I_oTN2$

THEREFORE EQ. 1 EQUALS TO:

③ $.80\left(\frac{P.D.}{I_oTN1 + P.D.}\right)$

SINCE CELL S/N 46 CELL RESULTS SHOW THAT TOTAL NEG. ELECT. EXCESS CAP. = 84.5A.H. IT FOLLOWS THAT:

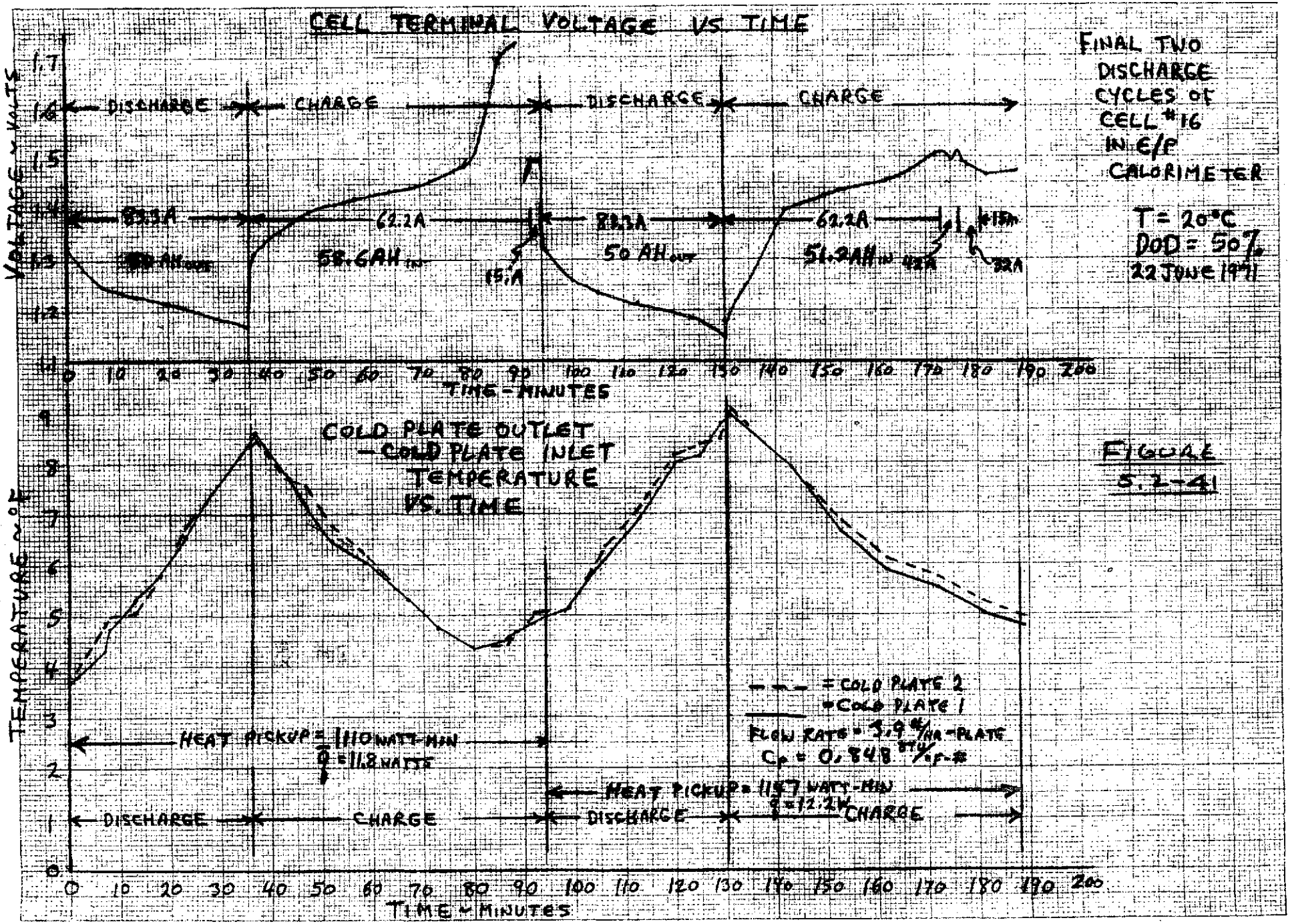
④ P.D. = .80 (84.5 A.H.) = 68 A.H.

5.2.1.5.10 Mechanical Tests - Two cells (S/N 33 & 44). Selected from development group III, received mechanical tests in accordance with Eagle Picher "Qualification Test Procedure," Q.T.P. - 169, and comments thereto, shown in Appendix M-1. Cell S/N 33 exhibited signs of damage during the 30g sinusoidal vibration (details are described in Appendix M-2). Subsequently, with the change in launch vehicle for the space station, the specified vibration levels were reviewed and revised to reflect anticipated Shuttle launch conditions. These revised levels are shown in Appendix M-3 (Grumman AVO D559-2-29). Cells S/N 35 (with holdown) and S/N 36 (without holdown) were selected and received these revised mechanical tests. The vent tube plug on cell S/N 35 loosened and fell off during the sinusoidal vibration and subsequent tests on this cell were terminated. (The electrical and mechanical data for this cell are shown in Appendix M-4). Cell S/N 36 received and successfully completed all scheduled mechanical tests. Its results are shown in Appendix M-5.

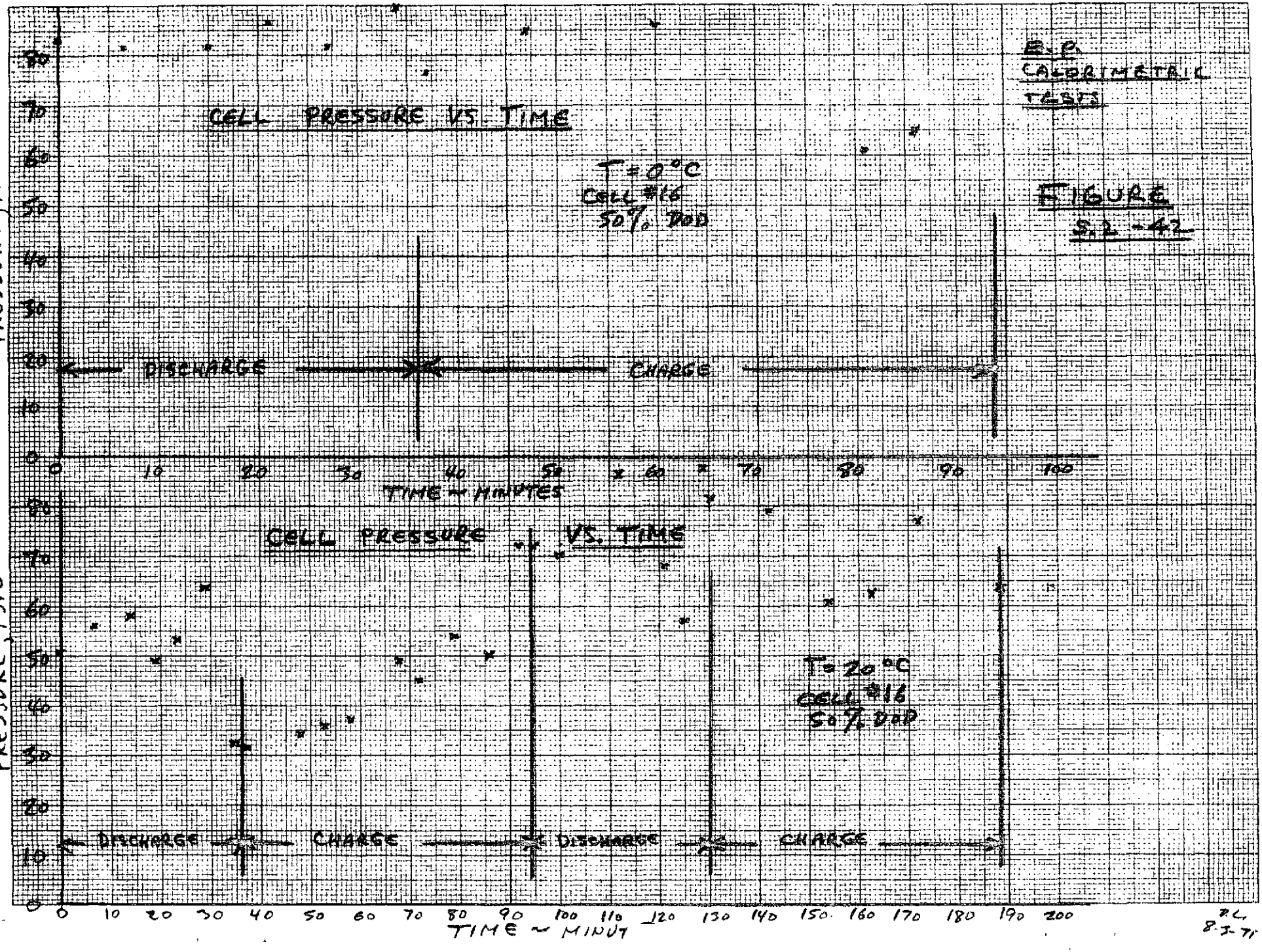
5.2.1.5.11 Thermal Tests

5.2.1.5.11.1 Purpose - A calorimetric cell test program was included in the scope of the 100 A.H. cell development effort to provide heat generation rate data for the final cell design and to optimize the Battery Module Package design. These thermal tests were conducted at two separate facilities, Eagle Picher and NASA/GSFC.

5.2.1.5.11.2 Tests at Eagle Picher - Two cells, S/N 16 with thin electrodes and S/N 22 with opposed terminals, were selected for these tests. Eagle Picher constructed a special calorimeter for this purpose. The equipment, theory of operation, planned calibration and test runs are described in Appendix O-1. Unfortunately, after a limited number of test runs the calorimeter was damaged beyond repair due to an uncontrolled cell overcharge and test runs had to be terminated. A typical run for a 50% depth of discharge (worst case heat generation) is shown in figures 5.2-41 and 5.2-42. The heat generated in cell S/N 16 for two stabilized orbits were 11.8 and 12.2 watts per orbit respectively.



D.C
8-2-71


B.P.
CALORIMETRIC
TESTS
FIGURE
S.2-42
CELL PRESSURE VS TIME
T = 0°C
CELL #16
50% DOD
DISCHARGE
CHARGE
PRESSURE, PSIG
TIME ~ MINUTES
CELL PRESSURE VS. TIME
T = 20°C
CELL #16
50% DOD
DISCHARGE
CHARGE
DISCHARGE
CHARGE
PRESSURE, PSIG
TIME ~ MINUTES
RC
8-3-71

5.2.1.5.11.3 Tests at NASA/GSFC - Subsequent to the tests at Eagle Picher the above cell (S/N 16) and cell S/N 15 were shipped to NASA/GSFC for thermal testing in their large conduction heat flow calorimeter, constructed by Rocketdyne under contract NAS5-21514.

The planned test procedure for these two cells is shown in Appendix 0-2. Again tests had to be terminated prematurely due to an observed crack in the epoxy of the center conduction rod limiting its intended function severely.

A typical worst case stabilized run at 50% depth of discharge for cell S/N 16 is shown in figure 5.2-43. A value of 7.44 watts per orbit was obtained.

5.2.1.5.11.4 Thermal Test Summary - The NASA determined heat value of 7.44 watts differs considerably from the E.P. determined values of 11.8 and 12.2 watts for the 50% D.O.D., +20°C runs. In addition the NASA monitored electrical data seem inconsistent with the thermal data. They were as follows:

Integrated Watt - hr. input = 74.66
Integrated Watt - hr. output = 61.29
Watt - hr. loss = 13.37
Watt loss per orbit = W.H (loss)/1.567 H. = 8.53

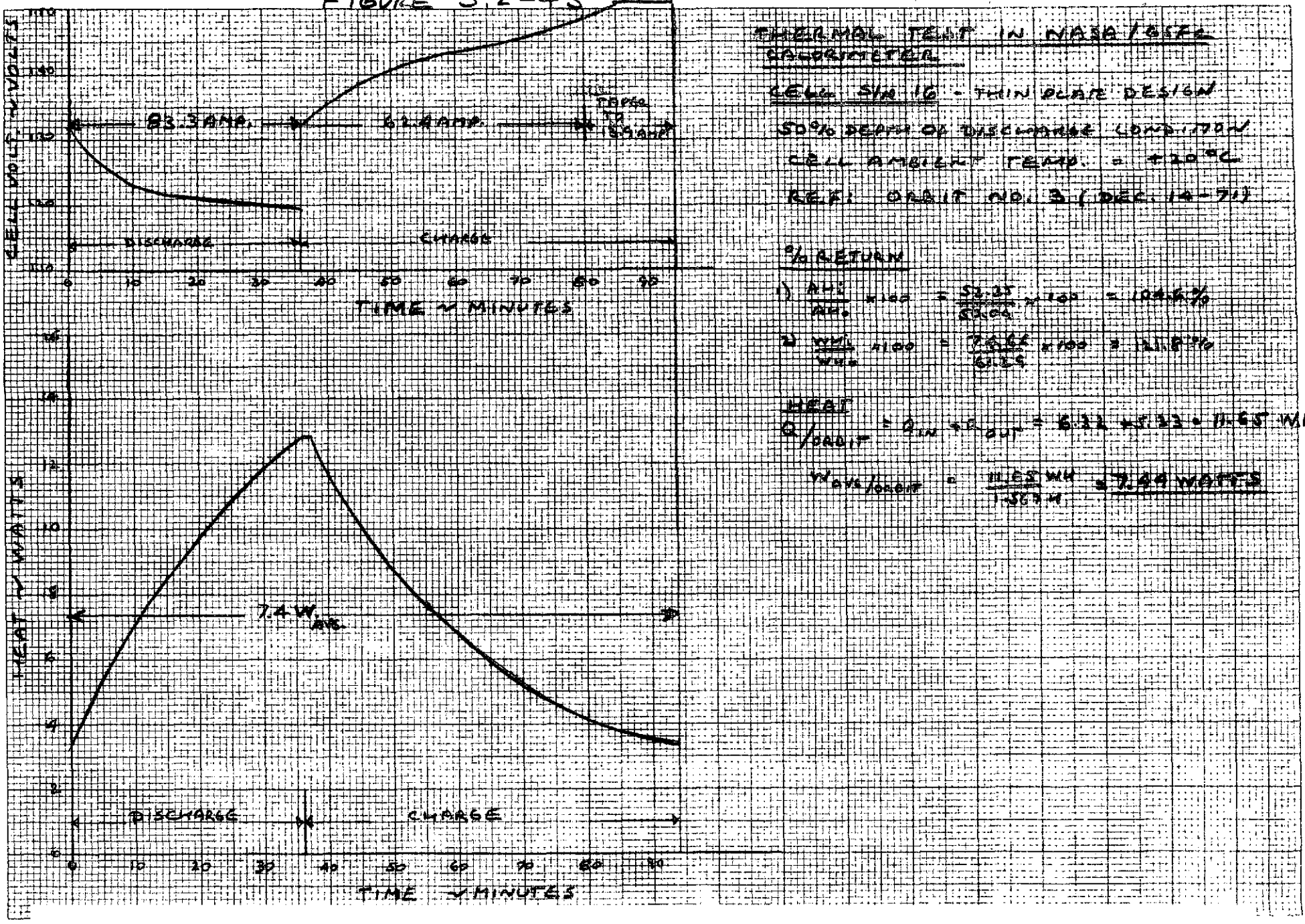
If, indeed, such a difference exists, there would be an additional energy absorbing mechanism in the cell -- one not accounted for by heat generation.

Another attempt was made to obtain cell heat generation data during the parametric characterization testing, whereby the inflow and outflow temperatures of the circulating fluid through the cell stack at a preadjusted rate was monitored. These results will be reported in a later section of this report.

5.2.1.6 Parametric Characterization Group

5.2.1.6.1 Cell Design Finalization - Based on all of the results of the development group I - III cells the design for the 100 ampee-hour cell was finalized for the parametric characterization group. (A short summary as shown in figure 5.2-44). However, since none of the early design group cells had received long term cycling evaluation it would have been risky to select

FIGURE 5.2-43



THERMAL TEST IN MASA / GSFC CALORIMETER

CELL SIM 16 - THIN PLATE DESIGN

50% DEPTH OF DISCHARGE CONDITION

CELL AMBIENT TEMP. = +20°C

REF: ORBIT NO. 3 (DEC. 14-71)

% RETURN

1) $\frac{AH_i}{AH_o} \times 100 = \frac{52.37}{50.00} \times 100 = 104.6\%$

2) $\frac{WH_i}{WH_o} \times 100 = \frac{74.66}{61.25} \times 100 = 121.8\%$

HEAT

$Q_{ORBIT} = Q_{IN} + Q_{OUT} = 6.32 + 5.33 = 11.65$ WH.

$W_{AVG/ORBIT} = \frac{11.65 \text{ WH}}{1.575 \text{ H}} = 7.40$ WATTS

DEVELOPMENT GROUPS 1-3 SUMMARY

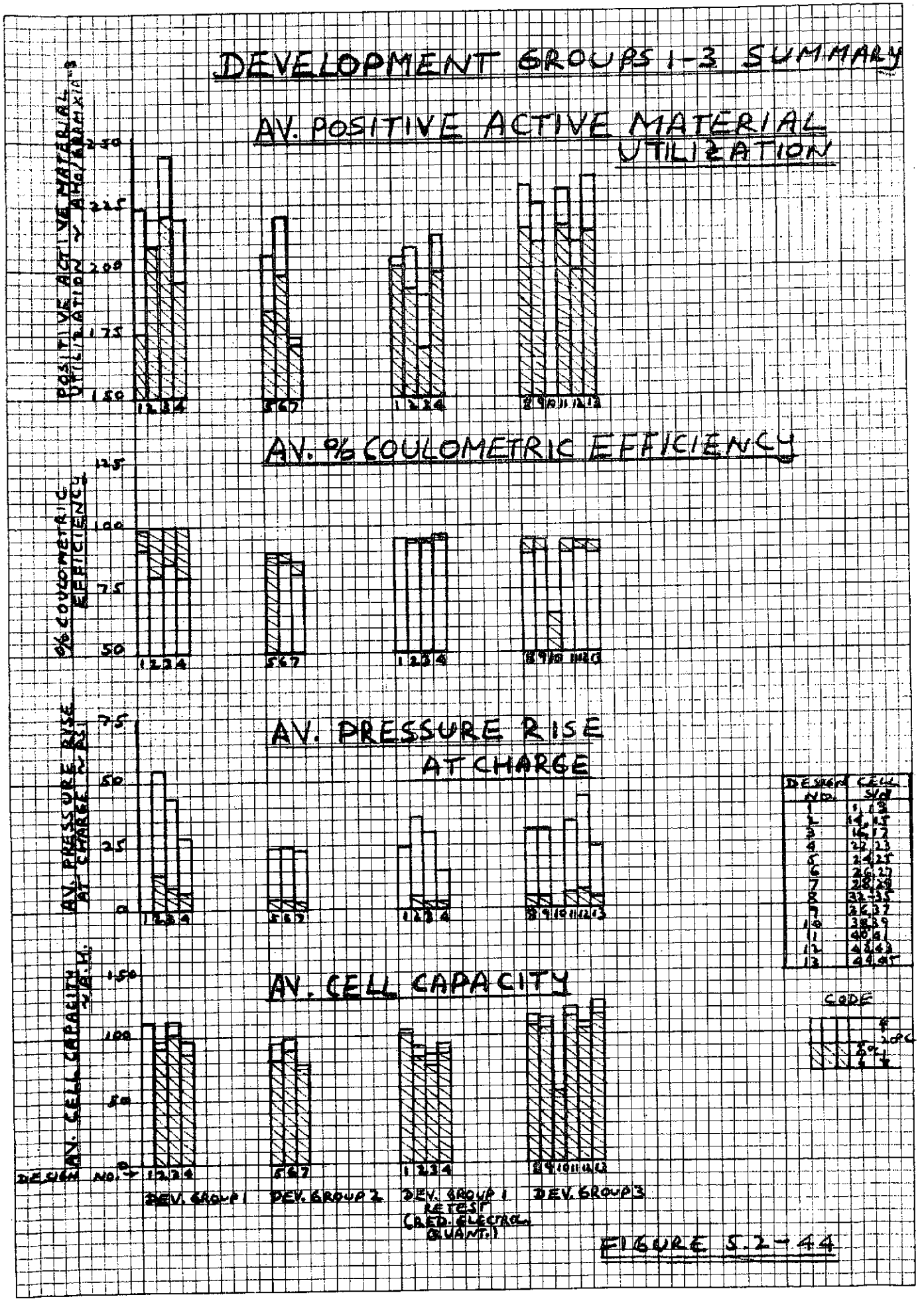


FIGURE 5.2-44

only that cell design with the best initial characteristics without regard to long term performance. For example, the best initial results were obtained from the nylon separator cells as compared with the polypropylene separator cells tested. A design finalization on this basis would have eliminated polypropylene separators completely. Thus three (3) finalized cell designs were selected for the parametric characterization group. All cells had two insulated terminals (Ceramaseal design) located on the same face, as described in paragraph 5.2.1.5.5.12. They also had auxiliary electrodes, as described in paragraph 5.2.1.5.6.6. The active material and electrolyte quantities used are shown in Appendix N. The typically used stack holdown device was removed since it could lead to internal shorting if plates expand in this direction during cycling. Mechanical tests in this program have shown that cell can meet its requirements without a holdown device. All separator material used was washed as described previously to remove organic impurities, such as wetting agents.

The following cells were constructed:

a) Group P-1, cells S/N 47-49, 51-56, total of 9 cells with thin electrodes and nylon P2505 (washed) separator.

b) Group P-2, cells S/N 57-62, 64 & 65, total of 8 cells with thin electrodes and polypropylene WEX1242 (washed) separator.

c) Group P-3, cells S/N 67-69, 72-76, total of 8 cells with baseline electrodes and nylon P2505 (washed) separator.

5.2.1.6.2 Acceptance Testing at Eagle Picher - All cells of this group received acceptance with the E.P. Acceptance Test Plan, A.T.P. - 251, shown in Appendix P-1. These test results are summarized as follows:

a) Table 5.2-40 "Capacity to 0.9 Volts" - The average capacity for the polypropylene group for the 20°C and 0°C tests was 99 + 94 A.H. respectively. The thin electrode and the baseline electrode cells with nylon for the identical tests showed 109 and 107 and 121 and 115 A.H. respectively.

ITEM NO.	DESIGN NO.	CELL S/N		CAP. CYCLE #1	CAP. CYCLE #2	CAP. CYCLE #3	CAP. AFTER 3 ORBIT CYCLES	AFTER OVER-CHARGE	FINAL CAP. CYCLE	CAP. CYCLE #1	CAP. CYCLE #2	CAP. CYCLE #3	CAP. AFTER 3 ORBIT CYCLES	AFTER OVER-CHARGE	
1	P-1	47		115.8	111.6	108.3	109.2	106.7	107.5	110.0	105.9	110.0	110.0	113.3	
2	"	48		115.8	112.5	109.2	110.0	108.3	108.3	107.4	104.1	108.3	108.3	114.2	
3	"	49		115.8	111.7	108.3	108.3	106.7	107.5	107.4	103.3	106.6	106.7	113.3	
4	"	51		114.2	112.5	109.2	109.2	107.5	108.3	107.6	104.1	105.0	106.3	113.3	
5	"	52		114.2	113.3	110.0	110.0	107.5	109.2	105.0	102.5	105.8	106.7	114.2	
6	"	53		113.3	111.7	109.2	105.9	106.7	107.5	103.2	102.5	105.8	106.7	113.3	
7	"	54		113.3	111.7	109.2	108.3	106.7	106.7	105.0	101.7	105.8	106.7	114.2	
8	"	55		115.8	114.2	110.8	110.8	108.3	110.0	105.0	101.7	105.8	106.7	114.2	
9	"	56		106.7	97.5	105.0	100.0	105.8	105.0	103.3	98.5	98.3	95.0	107.5	
Average = Σ/N				113.9	110.7	108.8	108.3	107.1	107.8	106.0	102.7	105.7	105.9	113.1	
Av. for all tests						109.4						106.7			
10	P-2	57		104.2	95.0	101.7	97.5	105.8	100.0	96.7	91.9	91.7	90.0	108.3	
11	"	58		103.3	92.5	98.3	94.5	104.2	98.3	88.3	87.3	85.8	88.3	108.3	
12	"	59		103.3	90.8	100.0	96.7	102.5	99.2	91.7	91.7	91.7	91.7	106.7	
13	"	60		100.8	87.5	98.3	94.2	102.5	97.5	88.3	89.6	90.0	90.0	105.0	
14	"	61		103.3	90.0	99.2	95.0	100.0	99.2	90.8	90.8	89.2	90.0	105.0	
15	"	62		103.3	92.5	100.0	95.8	97.5	99.2	92.5	91.9	91.7	90.8	105.0	
16	"	64		105.0	94.2	102.5	97.5	99.2	99.2	92.5	93.7	93.3	92.5	100.8	
17	"	65		104.2	95.0	101.7	97.5	100.8	100.0	89.2	88.7	87.5	89.2	104.7	
Average = Σ/N				103.4	92.2	100.2	96.1	101.6	99.1	91.2	90.8	90.1	90.3	105.5	
Av. for all tests						98.8						93.6			
18	P-3	67		124.2	120.0	125.0	115.8	112.5	120.8	113.3	110.0	109.2	106.7	126.7	
19	"	68		125.8	121.7	125.0	117.5	113.3	122.5	115.0	114.2	112.5	111.7	128.3	
20	"	69		125.0	123.3	125.8	120.0	113.3	123.3	115.0	114.2	112.5	111.7	130.0	
21	"	72		127.5	123.3	126.7	114.2	113.3	122.5	115.8	112.2	110.8	106.7	129.2	
22	"	73		124.2	123.3	125.8	120.0	126.7	125.0	115.8	112.9	112.5	109.2	128.3	
23	"	74		127.5	120.0	125.0	116.7	111.7	119.2	114.2	112.2	110.8	109.2	126.7	
24	"	75		120.8	113.3	120.0	115.0	106.7	116.7	-	110.8	110.0	106.7	121.7	
25	"	76		127.5	122.5	127.5	117.5	110.8	121.7	113.3	112.9	110.0	109.2	126.7	
Average = Σ/N				125.3	120.9	125.1	117.1	113.5	121.5	114.6	112.4	111.0	108.9	127.2	
Av. For all tests						120.6						114.8			
Temp						+20°C						0°C			

G316 REV. 2
3-72 2000P

TABLE 5.2-40

GRUMMAN

PARAMETRIC TEST GROUP (E.P. DATA)

CAPACITY TO 1.0 VOLT EN AMP. HRS

b) Table 5.2-41 shows the "Positive Active Material Utilizations" for these tests. The polypropylene cells showed average values of 0.215 and 0.203 AH_o/g. for the 20°C and 0°C tests respectively. The thin electrode and baseline electrode cells with nylon showed average values of 0.238 and 0.232 and 0.239 and 0.228 AH_o/g. respectively.

c) Table 5.2-42 shows the Input in ampere hours for all tests for these 3 groups.

d) Table 5.2-43 shows the pressure rise during charge for all tests for these 3 groups.

e) Figure 5.2-45 shows the Acceptance Test Summary, such as average values for capacities, positive active material utilizations, coulometric efficiency and pressure rise during charge for each group at the two test temperatures. The polypropylene cells showed substantially lower capacities and positive active material utilizations when compared with the nylon separator cell groups. The coulometric efficiencies for the 3 groups are nearly identical. The average pressure rise at charge for the polypropylene cells at 20°C was somewhat lower than that for the other 2 groups, indicating that increased capacities might have been obtained if charge would have been continued to a slightly higher cut-off voltage.

Appendix P-2 shows voltage, pressure and auxiliary signal voltage profile curves for the 3 orbital cycles at 20°C and 0°C. Figures 1-3 shows the voltages for cells of the three cell designs at 20°C and figures 4-6 show the corresponding pressures and auxiliary signal voltages. Figures 7-12 show similar profiles for the 0°C tests.

After successful completion of their acceptance tests all above cells were shipped to Grumman for parametric characterization testing.

DESIGN NO.	CELL S/N		CAP. CYCLE #1	CAP. CYCLE #2	CAP. CYCLE #3	CAP. AFTER 3 ORBIT CYCLES	AFTER OVER-CHARGE	FINAL CAP. CYCLE		AV. FOR ALL TESTS		REMARKS		
+20°C														
P-1	47-49,51-56		248	241	237	235	233	234		238	460g.	Pos. act. material		
P-2	57-62,64,65		225	200	218	209	221	215		215	"	"	"	"
P-3	67-69,72-76		248	239	248	232	225	241		239	505g.	"	"	"
0°C														
P-1	47-49,51-56		230	223	230	230	246	-		232				
P-2	57-62,64,65		198	197	196	196	229	-		203				
P-3	67-69,72,76		227	223	220	216	252	-		228				

NOTES: 1) Design P-1 = Thin Plate + Nylon P2505W
P-2 = " " + Polypropylene WEX 1242W
P-3 = Baseline Plate + Nylon P2505W

TABLE 5.2-41

PARAMETRIC TEST GROUP - E. P. DATA

POSITIVE ACTIVE MATERIAL UTILIZATION

IN A Ho/g x 10^{-3}

ITEM NO.	DESIGN NO.	CELL S/N		CAP CYCLE #1	CAP CYCLE #2	CAP CYCLE #3	OVER-CHARGE	FINAL CAP CYCLE	CAP CYCLE #1	CAP CYCLE #2	CAP CYCLE #3	OVER-CHARGE		AV. FOR TESTS EXCEPT OVERCHARGE	ALL
1	P-1	47		150.0	120.0	120.0	170.0	126.-	135.0	112.5	110.5	182.0		+20°C	0°C
2		48		140.1	"	"	"	"	133.5	110.0	112.5	"			
3		49		150.0	"	"	"	"	133.5	110.0	109.5	"			
4		51		143.0	"	"	"	"	133.5	110.0	111.0	"			
5		52		139.0	"	"	"	"	128.5	105.0	111.0	"			
6		53		137.5	"	"	"	"	128.5	105.0	111.0	"			
7		54		139.5	"	"	"	"	130.0	105.0	110.5	"			
8		55		137.5	"	"	"	"	130.0	105.0	111.0	"			
9		56		112.0	174.5	111.5	182.5	116.5	115.0	107.5	92.5	-			
Average = Σ/N				138.2	126.0	119.1	171.4	124.9	129.7	107.8	108.8	182.0		127.2	115.4
10	P-2	57		105.0	107.5	103.5	182.5	107.5	101.5	97.0	92.5	132.5			
11		58		105.0	104.5	101.5	181.5	106.0	97.5	095.0	87.5	130.0			
12		59		105.0	104.0	101.5	182.5	106.0	100.0	97.0	92.5	134.0			
13		60		105.0	100.5	101.5	181.5	103.5	97.0	96.0	90.0	132.5			
14		61		105.0	103.0	101.5	162.5	105.5	97.5	97.0	90.0	132.5			
15		62		105.0	105.5	102.5	141.5	105.5	100.0	97.0	92.5	134.0			
16		64		105.0	107.5	104.0	185.5	104.0	100.0	97.5	94.0	135.0			
17		65		105.0	108.0	105.0	184.0	104.0	95.0	95.5	92.5	131.0			
Average = Σ/N				105.0	105.1	102.6	175.2	105.3	98.6	96.5	91.4	132.7		104.5	95.5
18	P-3	67		132.0	134.5	129.5	121.0	126.5	124.5	119.0	111.5	150.5			
19		68		136.0	137.5	132.0	142.5	131.0	128.5	123.5	116.0	155.0			
20		69		136.0	138.5	134.0	142.5	131.5	128.5	123.0	116.0	155.0			
21		72		135.0	138.5	134.0	142.5	131.0	128.5	122.0	115.0	151.5			
22		73		136.0	139.0	133.5	212.5	131.0	131.0	123.5	114.0	152.5			
23		74		132.0	135.0	131.0	142.5	127.5	125.0	121.0	114.0	152.5			
24		75		130.0	135.0	128.5	142.5	125.5	-	129.0	114.0	153.0			
25		76		128.5	138.5	134.0	142.5	127.5	135.0	127.0	114.0	155.0			
Average = Σ/N				133.2	137.1	132.1	148.6	128.9	128.7	122.9	114.3	153.1		132.8	122.0
Temp				◀		20°C						0°C			▶

G316 REV. 2
3-72 2000P

TABLE 5.2-42

GRUMMAN

PARAMETRIC TEST GROUP - E.P. DATA
INPUT IN AMPERE - HOURS

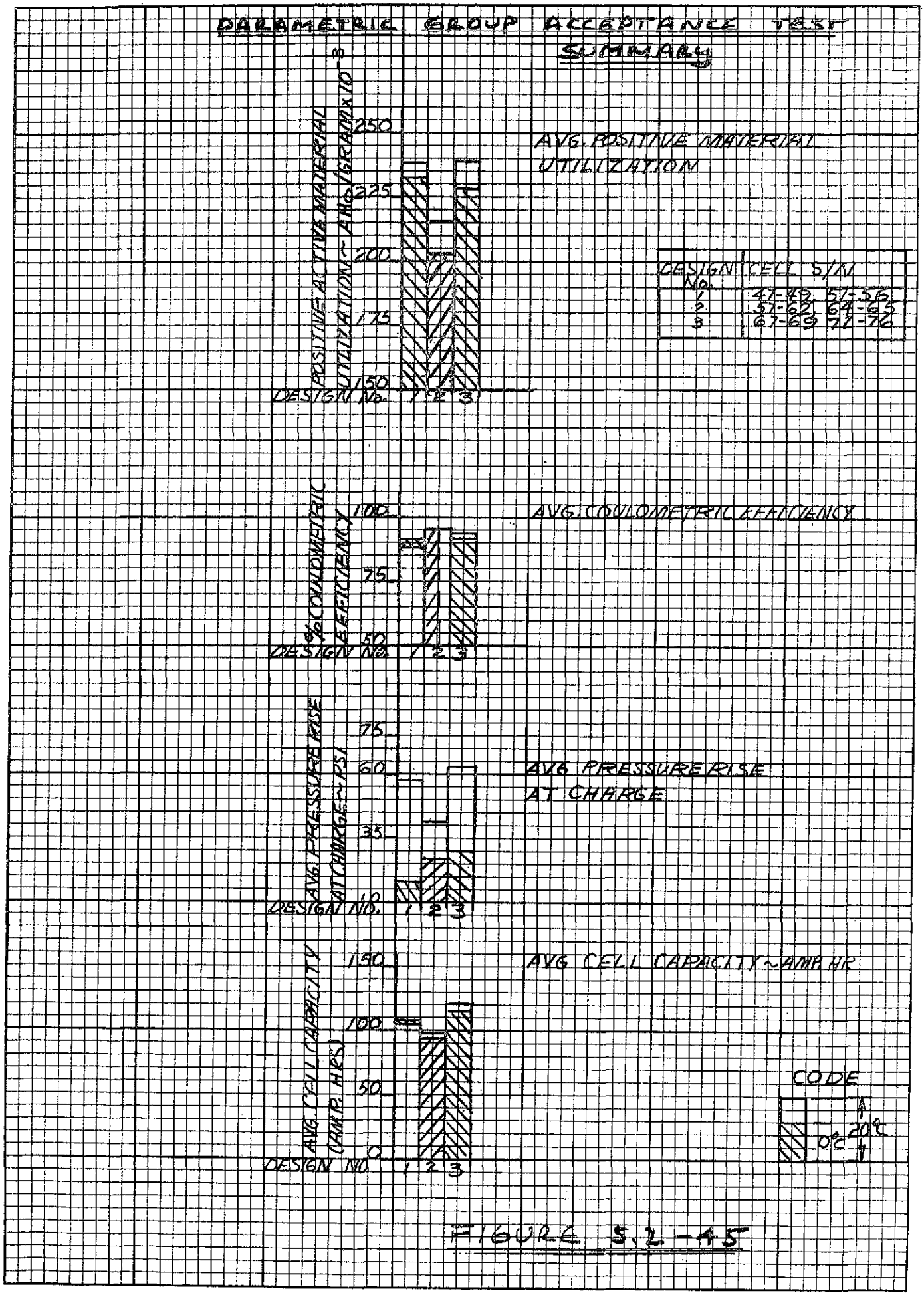
ITEM NO.	DESIGN NO.	CELL S/N		CAP CYCLE #1	CAP CYCLE #2	CAP CYCLE #3	OVER-CHARGE	FINAL CAP CYCLE	CAP CYCLE #1	CAP CYCLE #2	CAP CYCLE #3	OVER-CHARGE			
1	P-1	47		73	40	34	98	66	5	4	16	53			
2		48		49	37	32	84	54	5	5	6	48			
3		49		87	41	35	95	58	6	4	4	46			
4		51		45	49	34	107	73	6	7	6	59			
5		52		30	33	32	99	61	2	8	7	48			
6		53		34	46	33	103	73	3	9	7	53			
7		54		41	49	40	101	66	5	11	8	43			
8		55		35	36	27	103	61	4	6	7	55			
9		56		31	26	31	98	60	13	22	1	56			
Average = Σ/N				47	40	33	99	64	5	9	7	51			
AV. for all tests				←		57			←	18		→			
10	P-2	57		17	15	20	109	38	14	28	2	73			
11		58		20	10	16	103	39	6	13	2	73			
12		59		27	9	19	114	39	6	28	2	75			
13		60		30	8	21	108	38	4	33	3	75			
14		61		34	9	24	115	33	7	31	3	82			
15		62		29	12	22	114	43	8	28	3	81			
16		64		38	12	22	105	46	0	26	2	64			
17		65		28	16	22	91	44	8	25	6	69			
Average = Σ/N				28	10	21	107	40	7	27	3	72			
Av. for all tests				←		41			←	27		→			
18	P-3	67		54	47	51	95	72	11	11	6	98			
19		68		55	49	51	99	77	9	11	4	92			
20		69		40	50	49	95	63	11	11	3	93			
21		72		57	46	31	93	70	8	12	5	103			
22		73		66	45	49	-	-	10	10	5	94			
23		74		54	48	49	95	59	10	14	6	94			
24		75		53	46	40	96	-	1	13	17	90			
25		76		71	48	54	98	70	5	12	3	83			
Average = Σ/N				56	47	47	96	69	8	12	6	94			
AV. for all tests				←		63			←	30		→			
Temp						+200C				0°C					

G316 REV. 2.
3-72 2000P

TABLE 5.2-43

GRUMMAN

PARAMETRIC TEST GROUP - E.P. DATA
PRESSURE RISE AT CHARGE IN PSI



5.2.1.7 Life Test Group -

5.2.1.7.1 Cell Design - The construction of the life test cells was started shortly after completion of the parametric characterization group. A total of 54 cells were constructed for this purpose. All auxiliary electrodes were eliminated from these cells due to inconsistent and poor performance results achieved on all earlier cells. These cells were identical in design to the parametric characterization group and details are shown in Appendix N. The design breakdown is as follows:

a) 6 cells - S/N 77 - 82, polypropylene WEX 1242 (washed) separator, baseline electrodes.

b) 42 cells - S/N 83 - 124, nylon P2505 (washed) separator, thin electrodes.

c) 6 cells - S/N 125 - 130, polypropylene WEX 1242 (washed) separator, thin electrodes.

5.2.1.7.2 Acceptance Testing at Eagle Picher - All cells received an identical acceptance test as the parametric characterization cell group, per acceptance test plan shown in Appendix P-1.

5.2.1.7.2.1 Acceptance Test Results - The acceptance capacity results are summarized in Table 5.2 - 44 (A & B). It can be noted that all cells yielded 100 ampere-hours or better, except those cells containing thin electrodes with polypropylene separator and discharged at 0° C. The average capacity and average positive active material utilizations are shown in figure 5.2 - 46. The thin plate, nylon and the baseline, polypropylene cell groups showed nearly identical capacity results at both temperatures. However, the positive active material utilizations for the thin plate, nylon group is substantially higher than that for the baseline electrode, polypropylene group.

5.2.2 Phase II - Parametric Characterization

5.2.2.1 Test Matrix - A parametric characterization test matrix was established to obtain maximum amount of test data for the minimum amount of test runs.

The following independent test variables were selected:

- Cell Design (3)
  P1 = Thin electrodes, nylon separator.
  P2 = Thin electrodes, polypropylene (WEX 1242w) separator.
  P3 = Baseline electrodes, nylon separator.

DESIGN DESCRIPTION	CELL S/N	COND. CYCLE	CAP. CYCLE #1	CAP. CYCLE #2	CAP. CYCLE #3	OVER-CHARGE	AV.	CAP. CYCLE #1	CAP. CYCLE #2	CAP. CYCLE #3	OVER-CHARGE	AV.	
TEMP °C		R.T.	0	0	0	0		20	20	20	20		
I CHARGE AMP		10	30	30	30	10+5		30	30	30	10+8		
I DISCHARGE AMP		50	50	50	50	50		50	50	50	50		
BASELINE POLYPROP	77	111	112	113	104	107		113	109	109	118		
BASELINE POLYPROP	78	111	112	113	104	107		113	109	109	118		
BASELINE POLYPROP	79	111	112	113	104	107		113	109	109	118		
BASELINE POLYPROP	80	111	112	113	104	107		113	109	109	118		
BASELINE POLYPROP	81	111	112	113	104	107		113	109	109	118		
BASELINE POLYPROP	82	111	112	113	104	107		113	109	109	118		
AVERAGE		111	112	113	104	107	109(*)	113	109	109	118	112	
THIN PL. NYLON	83	111	114	115	108	108		113	104	104	116		
"	84	111	114	115	108	108		113	104	104	116		
	85	111	114	115	108	108		113	104	104	116		
	86	120	101	106	108	104		113	108	104	113		
	87	120	103	106	108	104		113	108	104	115		
	88	120	107	106	108	104		113	108	104	116		
	89	120	107	106	108	104		113	108	104	113		
	90	120	105	106	108	104		113	108	104	116		
	91	120	105	106	108	104		113	108	104	115		
	92	120	108	106	108	104		113	108	104	115		
	93	120	105	106	108	104		113	108	104	113		
	94	120	102	106	108	104		113	108	104	115		
	95	120	101	100	100	104		106	105	100	113		
	96	120	101	106	108	104		113	108	104	113		
	97	120	103	106	108	104		113	108	104	114		
	98	120	103	106	108	104		113	108	104	115		
	99	120	102	106	108	104		113	108	104	114		
	100	120	101	106	108	104		113	108	104	113		
	101	111	114	115	108	108		115	100	100	115		
	102	111	114	115	108	108		115	104	104	116		
	103	111	114	115	108	108		115	104	104	116		
	104	111	114	115	108	108		115	104	104	116		
	105	111	114	115	108	108		115	104	104	116		
	106	111	113	115	108	108		115	104	104	116		

G316 REV. 2
8-70 2000P

TABLE 5.2-44A

GRUMMAN

LIFE TEST GROUP -
ACCEPTANCE TEST CAPACITY RESULTS
TO 1.0 VOLTS

DESIGN DESCRIPTION	CELL S/N	CONDIT CYCLE	CAP. CYCLE #1	CAP. CYCLE #2	CAP. CYCLE #3	OVER-CHARGE	AV.	CAP. CYCLE #1	CAP. CYCLE #2	CAP. CYCLE #3	OVER-CHARGE	AV.	
TEMP °C		R.T.	0	0	0	0		20	20	20	20		
I CHARGE AMP		10	30	30	30	10+5		30	30	30	10+8		
I DISCHARGE AMP		50	50	50	50	50		50	50	50	50		
THIN P. NYLON	107	112	105	109	104	108		122	115	109	124		
"	108	112	102	109	104	108		122	115	110	124		
	109	112	102	109	102	108		122	116	110	124		
	110	112	102	108	104	108		122	116	110	124		
	111	112	105	108	103	108		100	113	109	124		
	112	112	102	109	106	108		122	116	110	124		
	113	112	102	110	102	108		121	115	109	124		
	114	112	102	108	102	108		122	116	110	124		
	115	112	102	108	102	108		122	116	110	124		
	116	112	102	108	101	108		121	115	108	124		
	117	112	112	109	108	108		121	115	108	124		
	118	112	112	109	108	108		121	115	108	124		
	119	112	112	109	108	108		121	115	108	124		
	120	112	112	109	108	108		121	115	108	124		
	121	93	-	-	-	-		-	-	-	-		
	122	112	112	109	108	108		121	115	108	124		
	123	112	102	107	100	108		121	114	108	124		
	124	112	102	109	102	108		121	115	108	124		
AVERAGE		114	107	109	106	107	107(*)	116	110	106	119	113	
THIN PL. POLYPROP.	125	102	94	90	97	89		104	93	103	113		
"	126	104	94	90	97	89		100	94	105	113		
	127	104	94	90	97	89		101	94	103	113		
	128	106	94	90	97	89		102	93	103	113		
	129	105	94	90	97	89		101	92	104	113		
	130	106	94	90	97	89		101	92	103	113		
AVERAGE		105	94	90	97	89	93(*)	102	93	103	113	103	
	NOTES:	(*)	CONDITIONING CAPACITY IS EXCLUDED FROM THIS AVERAGE VALUE										

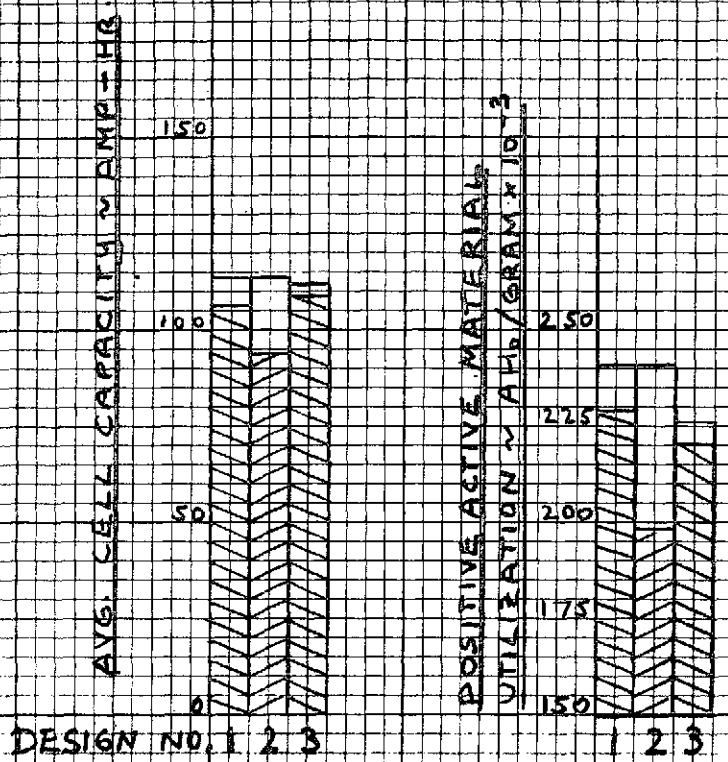
G316 REV. 2
8-70 2000P

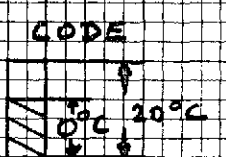
TABLE 5.2-44B

GRUMMAN

CONT. LIFE TEST GROUP -
ACCEPTANCE TEST CAPACITY
RESULTS TO 1.0 VOLTS

LIFE TEST GROUP -- ACCEPTANCE TEST SUMMARY





DESIGN NO.	DESCRIPTION	CELL S/N
1	THIN PL. NYLON	83 - 124
2	THIN PL. POLYPROP.	125 - 130
3	BASELINE PL. "	77 - 82

FIGURE 5.2-46

- Temperature (3)
  T1 = 0°C
  T2 = 10°C
  T3 = 20°C
- Depth of Discharge (3)
  D1 = 12%
  D2 = 30%
  D3 = 50%
- Charge Voltage/Temperature Limit (3)
  L1 = Low level
  L2 = Medium level
  L3 = High level
- Charge Pressure (Auxiliary Electrode Signal) Limit (3)
  L1 = Low level
  L2 = Medium level
  L3 = High level

A total of nine (9) cell groups were selected consisting of three (3) groups from each design. Each group was to consist of three (3) identical cells resulting in a total requirement of 27 cells for these tests (actually only a total of 25 cells were delivered to Grumman which resulted in that two (2) groups contained only two (2) cells each). One group of each design was kept at each of the three temperatures throughout the entire test. This test matrix is shown in Table 5.2-45. Two out of the three possible conditions were selected for testing as indicated by a circle. The number inside each circle shows the applied test sequence and order which was established to minimize test equipment adjustments and re-calibration. Each group received a minimum of 25 orbital burn-in cycles (or until characteristics were stabilized) prior to the characterization cycles. Each characterization test was conducted until cell characteristics had stabilized before going into the next condition.

5.2.2.2 Test Equipment

5.2.2.2.1 Battery/Cell Test Controller Design and Construction - A test controller, with functions as described in the Program Summary of paragraph 3.0 was designed. A total of nine (9) independently operating units were constructed for these tests. Each unit in conjunction with a Sorensen type SRL 10/100 Power Supply is capable of automatically cycling three 100 A.H.

STRING NO	BURN IN *	TEMP	DESIGN	M1 - VOLT/TEMP LIMIT						M2 - PRESS OR AUX LIMIT					
				L1			L2			L3			L1			L2			L3		
				D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3
1	①	T1	P3	①	②		④	③		⑤	⑥		⑦	⑧		⑨	⑩		⑪	⑫	
2	①		P2	①	②		③		④		⑤	⑥	⑦	⑧		⑨		⑩		⑪	⑫
3	①		P1	①		②		④	③	⑥	⑤		⑦	⑧			⑨	⑩	⑪		⑫
4	①	T2	P1		①	②	④		③	⑤	⑥			⑦	⑧	⑨		⑩	⑪	⑫	
5	①		P2	①		②		④	③	⑤		⑥	⑦		⑧		⑨	⑩	⑪		⑫
6	①		P3	①	③		②		④		⑤	⑥	⑦	⑧		⑨		⑩		⑪	⑫
7	①	T3	P1	①	②		④	③		⑤		⑥	⑦		⑧	⑨	⑩		⑪	⑫	
8	①		P3		②		③	①	④	⑤	⑥			⑦	⑧	⑨		⑩	⑪	⑫	
9	①		P2	①		②		④	③	⑤	⑥		⑦	⑧			⑨	⑩	⑪		⑫

* ACHIEVEMENT OF ORBITAL PERFORMANCE STABILITY (ELECTRICAL, THERMAL, PRESSURE RANGE) AFTER A MINIMUM OF 25 ORBITS, COMPLETES BURN-IN AND TEST CONDITION D.

NOTES:

1. EACH TEST CONDITION SHALL BE RUN TO ORBITAL PERFORMANCE STABILITY OR A MINIMUM OF 13 ORBITS.
2. T1 = 0°C (32°F) INLET; T2 = 8°C (46°F) INLET; T3 = 18°C (64°F) INLET, ALL TEMPS ± 2.5°F.
3. L1 = 4.44V @ 20°C, 4.59V @ 0°C (FOR 3 CELLS) D1 = 12% DOD
   L2 = 4.53V @ 20°C, 4.63V @ 0°C D2 = 30% DOD
   L3 = 4.62V @ 20°C, 4.77V @ 0°C D3 = 50% DOD
4. CAPACITY TESTS SHALL BE RUN AS FOLLOWS (AT C/2 DISCH. RATE TO 0.90V FIRST CELL)
   a. AFTER INITIAL CONDITIONING
   b. AFTER BURN-IN STABILITY, THEN RUN TO STABILITY AGAIN
   c. AFTER TEST CONDITION (6)
   d. AFTER TEST CONDITION (12)

TABLE 5.2 - 45

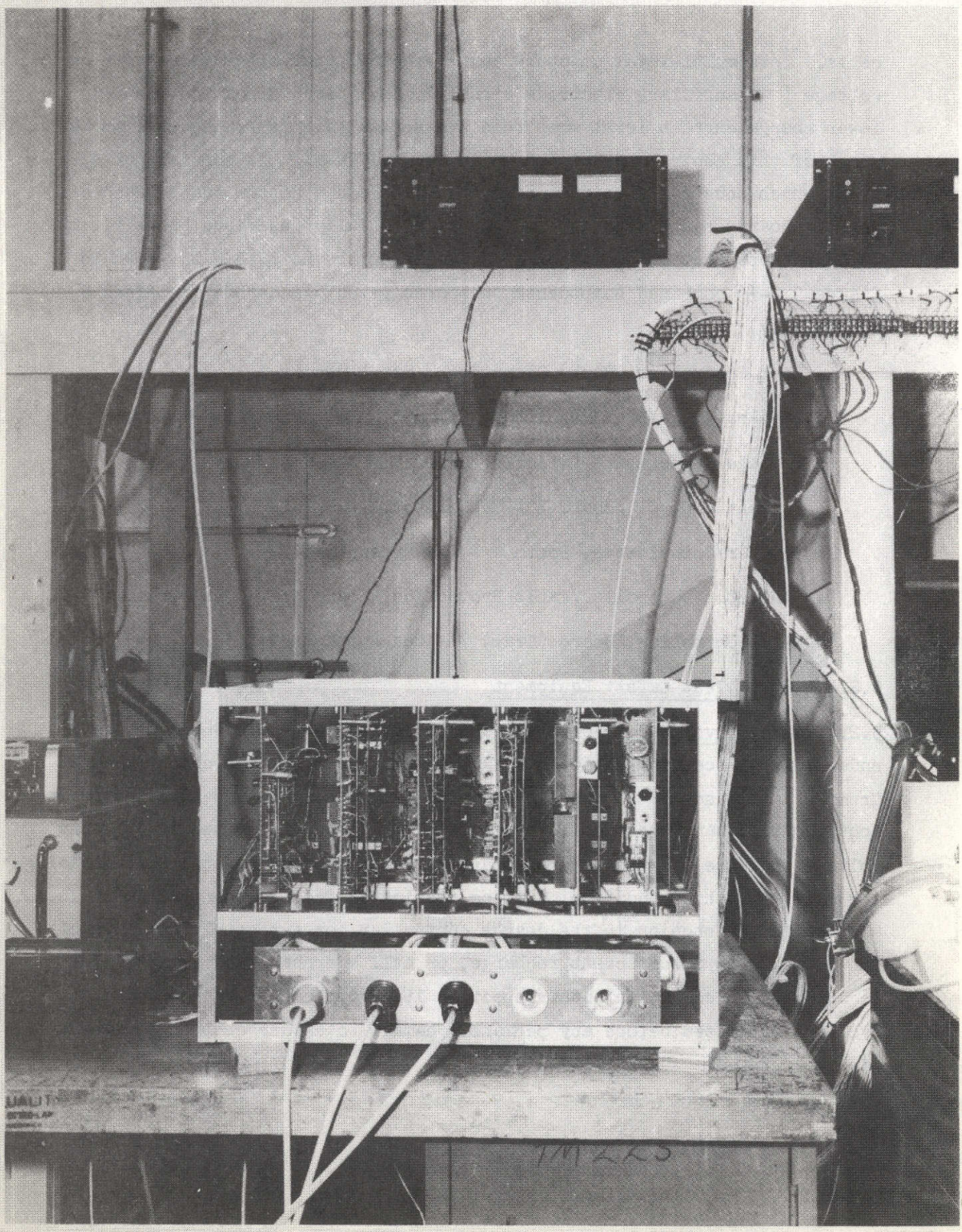
CELL/CHARGER PARAMETRIC TEST MATRIX

cells. This multi-level constant current charge controller senses string voltage (or auxiliary electrode signal voltage) and "fires" to the next lower charge current level when this pre-set voltage is reached. A photograph of this control rack is shown in figure 5.2-47. It consists of a frame which houses six printed circuit boards and a bottom tray. Each of the six boards has a separate function and is fully described below (it must be noted here that all units constructed after the unit (S/N 1) shown in figure 5.2-47 combined components on boards 5 and 6 and thus contained 5 boards only):

- Test Controller (Rack) Operation - See Appendix Q-1.
- Pre-Regulator/Bias Regulator, Board 1 - See Appendix Q-2.
- Voltage/Temperature Detector, Board 2 - See Appendix Q-3.
- Current Control, Board 3 - See Appendix Q-4.
- Counter/Coincidence, Board 4 - See Appendix Q-5.
- Contactor Controller/Fault Protection, Board 5/6 - See Appendix Q-6.
- Mode Controller, Board (Tray) 7 - See Appendix Q-7.

5.2.2.2.2 Test Safety Equipment

5.2.2.2.2.1 Over/Under Voltage Scanning Detector - An independent over/under voltage scanning detector was conceived, designed and constructed at Grumman. (Its schematic and layout details are shown in Appendix Q-8). It continuously scans every cell at a rate of one channel per second. If any voltages outside the pre-set range are detected the entire string, containing the cell with this condition, will be terminated from further cycling. Thus a possible malfunction in the charge controller, or a possible cell capacity run-down due to insufficient recharge, or cell overcharge or reversal due to out-of-step condition with respect to its group can be detected and cycling terminated before any permanent damage to either cell or equipment has occurred.



GAC PN 559-121AV

FIGURE 5.2 - 47

BATTERY/CELL TEST CONTROL RACK

5.2.2.2.2.2 Cell Pressure Gauge Safety Switch - Since each cell was tested with an attached pressure gauge, Grumman installed an in-house developed and constructed switch inside the gauge assembly. The switch was installed in such a manner that it closes at approximately +85 PSIG sending a signal to the charge controller and terminating all cycling for that string. This switch formed another independent safety feature preventing extremely high cell pressure buildup with possible case distortion, rupture and/or damage to the test equipment.

5.2.2.2.3 Test Instrumentation - A Hewlett-Packard Model 2012B Digital Data Acquisition System with magnetic and paper tape readout monitored all test data, except pressure. Table 5.2-45 shows a channel assignment for the parametric tests. For a quick data trend review two Bristol 24 channel recorders were operated continuously. The Bristol recorder channel assignment is shown in Table 5.2-46.

5.2.2.2.4 Test Laboratory Layout - The photograph (Figure 5.4-48) shows the battery test laboratory layout prior to completion. The test controllers, with the power supplies located behind them, are sitting on a large shelf. Below it are the constant temperature baths (Labline No. 3324-x) and benches on which the insulated cells stacks were to be located. The right side of the photograph shows a rear view of the Data Acquisition System, which is in the center of the room. Figures 5.2-49 and 5.2-50 show the floor plan and the upper tier plan views of the area. Figure 5.2-51 shows the location of the various fused test and instrumentation terminal boards of the test set-up. A typical block diagram of the cables is shown in Figure 5.2-52

5.2.2.2.5 Cell Group (Stack) Mechanical Design - The 3 cell group, 2 cell group and planned 5 cell group (for life tests) stack mechanical assemblies are shown in Appendix Q-9. The philosophy for this type of cell temperature control is described in the Grumman Project Memorandum D559-1-1 (shown in Appendix Q-10). A view of the "Cell String Constant Temperature Package" is shown in Figure 5.2-53. The cooling flow rate for each string was controlled by a flow valve permitting circulating fluid flow rate adjustments necessary for the cell heat generation calculations.

DATA ACQUISITION SYSTEM CHANNEL ASSIGNMENT FOR PARAMETRIC TESTS

TABLE 5.2-46

CHAN.	0	1	2	3	4	5	6	7	8	9	SEE NOTES
00	SPARE	BATT. 10 CELL 1 VOLTAGE	BATT. 10 CELL 2 VOLTAGE	BATT. 10 CELL 3 VOLTAGE	BATT. 11 CELL 1 VOLTAGE	BATT. 11 CELL 2 VOLTAGE	BATT. 11 CELL 3 VOLTAGE	BATT. 12 CELL 1 VOLTAGE	BATT. 12 CELL 2 VOLTAGE	BATT. 12 CELL 3 VOLTAGE	
10	BATT. 13 CELL 1 VOLTAGE	BATT. 13 CELL 2 VOLTAGE	BATT. 13 CELL 3 VOLTAGE	BATT. 13 CELL 4 VOLTAGE	BATT. 13 CELL 5 VOLTAGE	BATT. 13 CELL 6 VOLTAGE	BATT. 13 CELL 7 VOLTAGE	BATT. 13 CELL 8 VOLTAGE	BATT. 13 CELL 9 VOLTAGE	BATT. 13 CELL 10 VOLTAGE	
20	BATT. 13 CELL 11 VOLTAGE	BATT. 13 CELL 12 VOLTAGE	BATT. 13 CELL 13 VOLTAGE	BATT. 13 CELL 14 VOLTAGE	BATT. 14 CELL 1 VOLTAGE	BATT. 14 CELL 2 VOLTAGE	BATT. 14 CELL 3 VOLTAGE	BATT. 14 CELL 4 VOLTAGE	BATT. 14 CELL 5 VOLTAGE	BATT. 14 CELL 6 VOLTAGE	
30	BATT. 14 CELL 7 VOLTAGE	BATT. 14 CELL 8 VOLTAGE	BATT. 14 CELL 9 VOLTAGE	BATT. 14 CELL 10 VOLTAGE	BATT. 14 CELL 11 VOLTAGE	BATT. 14 CELL 12 VOLTAGE	BATT. 14 CELL 13 VOLTAGE	BATT. 14 CELL 14 VOLTAGE	SPARE	SPARE	
40	SPARE	SPARE	SPARE	SPARE	SPARE	BATT. 10 CURRENT	BATT. 11 CURRENT	BATT. 12 CURRENT	BATT. 13 CURRENT	BATT. 14 CURRENT	
50	T. C. ROOM AMB	T. C. BATT. 1 IN	T. C. BATT. 1 STACK	T. C. BATT. 1 OUT	T. C. BATT. 2 IN	T. C. BATT. 2 STACK	T. C. BATT. 2 OUT	T. C. BATT. 3 IN	T. C. BATT. 3 STACK	T. C. BATT. 3 OUT	
60	T. C. BATT. 4 IN	T. C. BATT. 4 STACK	T. C. BATT. 4 OUT	T. C. BATT. 5 IN	T. C. BATT. 5 STACK	T. C. BATT. 5 OUT	T. C. BATT. 6 IN	T. C. BATT. 6 STACK	T. C. BATT. 6 OUT	T. C. ROOM AMB.	
70	BATT. 1 SPARE CELL 1	BATT. 1 SPARE CELL 2	- CAL	BATT. 1 SPARE CELL 3	BATT. 2 SPARE CELL 1	BATT. 2 SPARE CELL 2	BATT. 2 SPARE CELL 3	BATT. 3 CELL 1 AUX	BATT. 3 CELL 2 AUX	BATT. 3 CELL 3 AUX	
80	BATT. 4 SPARE CELL 1	BATT. 4 SPARE CELL 2	BATT. 4 SPARE CELL 3	BATT. 5 SPARE CELL 1	BATT. 5 SPARE CELL 2	BATT. 5 SPARE CELL 3	BATT. 6 CELL 1 AUX	BATT. 6 CELL 2 AUX	BATT. 6 CELL 3 AUX	SPARE	
90	BATT. 7 SPARE CELL 1	BATT. 7 SPARE CELL 2	BATT. 7 SPARE CELL 3	BATT. 8 SPARE CELL 1	BATT. 8 SPARE CELL 2	BATT. 8 SPARE CELL 3	BATT. 9 CELL 1 AUX	BATT. 9 CELL 2 AUX	BATT. 9 CELL 3 AUX	SPARE	
100	SPARE	BATT. 1 CELL 1 VOLTAGE	BATT. 1 CELL 2 VOLTAGE	BATT. 1 CELL 3 VOLTAGE	BATT. 2 CELL 1 VOLTAGE	BATT. 2 CELL 2 VOLTAGE	BATT. 2 CELL 3 VOLTAGE	BATT. 3 CELL 1 VOLTAGE	BATT. 3 CELL 2 VOLTAGE	BATT. 3 CELL 3 VOLTAGE	
110	BATT. 4 CELL 1 VOLTAGE	BATT. 4 CELL 2 VOLTAGE	BATT. 4 CELL 3 VOLTAGE	BATT. 5 CELL 1 VOLTAGE	BATT. 5 CELL 2 VOLTAGE	BATT. 5 CELL 3 VOLTAGE	BATT. 6 CELL 1 VOLTAGE	BATT. 6 CELL 2 VOLTAGE	BATT. 6 CELL 3 VOLTAGE	SPARE	
120	BATT. 7 CELL 1 VOLTAGE	BATT. 7 CELL 2 VOLTAGE	+CAL	BATT. 8 CELL 1 VOLTAGE	BATT. 8 CELL 2 VOLTAGE	BATT. 8 CELL 3 VOLTAGE	BATT. 9 CELL 1 VOLTAGE	BATT. 9 CELL 2 VOLTAGE	BATT. 9 CELL 3 VOLTAGE	SPARE	
130	SPARE	BATT. 1 CURRENT	BATT. 2 CURRENT	BATT. 3 CURRENT	BATT. 4 CURRENT	BATT. 5 CURRENT	BATT. 6 CURRENT	BATT. 7 CURRENT	BATT. 8 CURRENT	BATT. 9 CURRENT	
140	CH/DISC FLAG BATH 1	CH/DISC FLAG BATH 2	CH/DISC FLAG BATH 3	SPARE	SHORT	HI CAL	LO CAL	SHORT	SPARE	SPARE	
150	T. C. BATT. 7 IN	T. C. BATT. 7 STACK	T. C. BATT. 7 OUT	T. C. BATT. 8 IN	T. C. BATT. 8 STACK	T. C. BATT. 8 OUT	T. C. BATT. 9 IN	T. C. BATT. 9 STACK	T. C. BATT. 9 OUT	T. C. SPARE	
160	T. C. BATH # 1	T. C. BATH # 2	T. C. BATH # 3	T. C. BATT. 10 IN	T. C. BATT. 10 STACK	T. C. BATT. 10 OUT	T. C. BATT. 11 IN	T. C. BATT. 11 STACK	T. C. BATT. 11 OUT	T. C. SPARE	
170	T. C. BATT. 12 IN	T. C. BATT. 12 STACK	T. C. BATT. 12 OUT	T. C. BATT. 13 IN	T. C. BATT. 13 STACK 1	T. C. BATT. 13 STACK 2	T. C. BATT. 13 STACK 3	T. C. BATT. 13 STACK 4	T. C. BATT. 13 STACK 5	T. C. BATT. 13 OUT	
180	T. C. SPARE	T. C. SPARE	T. C. SPARE	T. C. BATT. 14 IN	T. C. BATT. 14 STACK 1	T. C. BATT. 14 STACK 2	T. C. BATT. 14 STACK 3	T. C. BATT. 14 STACK 4	T. C. BATT. 14 STACK 5	T. C. BATT. 14 OUT	
190	SPARE	SPARE	SPARE	SPARE	SPARE	SPARE	SPARE	SPARE	SPARE	SPARE	
CHAN.	0	1	2	3	4	5	6	7	8	9	SEE NOTES

TABLE 5.2-47

T BRISTOL RECORDER CHANNEL I.D.

RECORDER #1

CHART CHANNEL NUMBER	INST CHAN	FUNCTION
1	101	Bat 1 Cell 1 voltage
2	102	Bat 1 Cell 2 voltage
3	103	Bat 1 Cell 3 voltage
4	104	Bat 2 Cell 1 voltage
5	105	Bat 2 Cell 2 voltage
6	106	Bat 2 Cell 3 voltage
7	107	Bat 3 Cell 1 voltage
8	108	Bat 3 Cell 2 voltage
9	109	Bat 3 Cell 3 voltage
10	110	Bat 4 Cell 1 voltage
11	111	Bat 4 Cell 2 voltage
12	112	Bat 4 Cell 3 voltage
13	113	Bat 5 Cell 1 voltage
14	114	Bat 5 Cell 2 voltage
15	115	Bat 5 Cell 3 voltage
16	116	Bat 6 Cell 1 voltage
17	117	Bat 6 Cell 2 voltage
18	118	Bat 6 Cell 3 voltage
19	131	Bat 1 current
20	132	Bat 2 current
21	133	Bat 3 current
22	134	Bat 4 current
23	135	Bat 5 current
24	136	Bat 6 current

RECORDER #2

CHART CHANNEL NUMBER	INST CHAN	FUNCTION
1	120	Bat 7 Cell 1 voltage
2	121	Bat 7 Cell 2 voltage
3	129	Bat 7 Cell 3 voltage
4	123	Bat 8 Cell 1 voltage
5	124	Bat 8 Cell 2 voltage
6	125	Bat 8 Cell 3 voltage
7	126	Bat 9 Cell 1 voltage
8	127	Bat 9 Cell 2 voltage
9	128	Bat 9 Cell 3 voltage
10		
11	77	Bat 3 Cell 1 Aux
12	78	Bat 3 Cell 2 Aux
13	79	Bat 3 Cell 3 Aux
14	86	Bat 6 Cell 1 Aux
15	87	Bat 6 Cell 2 Aux
16	88	Bat 6 Cell 3 Aux
17	96	Bat 9 Cell 1 Aux
18	97	Bat 9 Cell 2 Aux
19	98	Bat 9 Cell 3 Aux
20		
21		
22	137	Bat 7 current
23	138	Bat 8 current
24	139	Bat 9 current

NOTE: (1) Wire is two conductor twisted shielded; Blue conductor is "HI". White is "LO".

(2) Shields are connected at the Inst. Terminal Boards; not at the Chart Recorders. Shields at the Chart Recorders are endcapped.

BATTERY LABORATORY LAYOUT (EARLY VIEW)

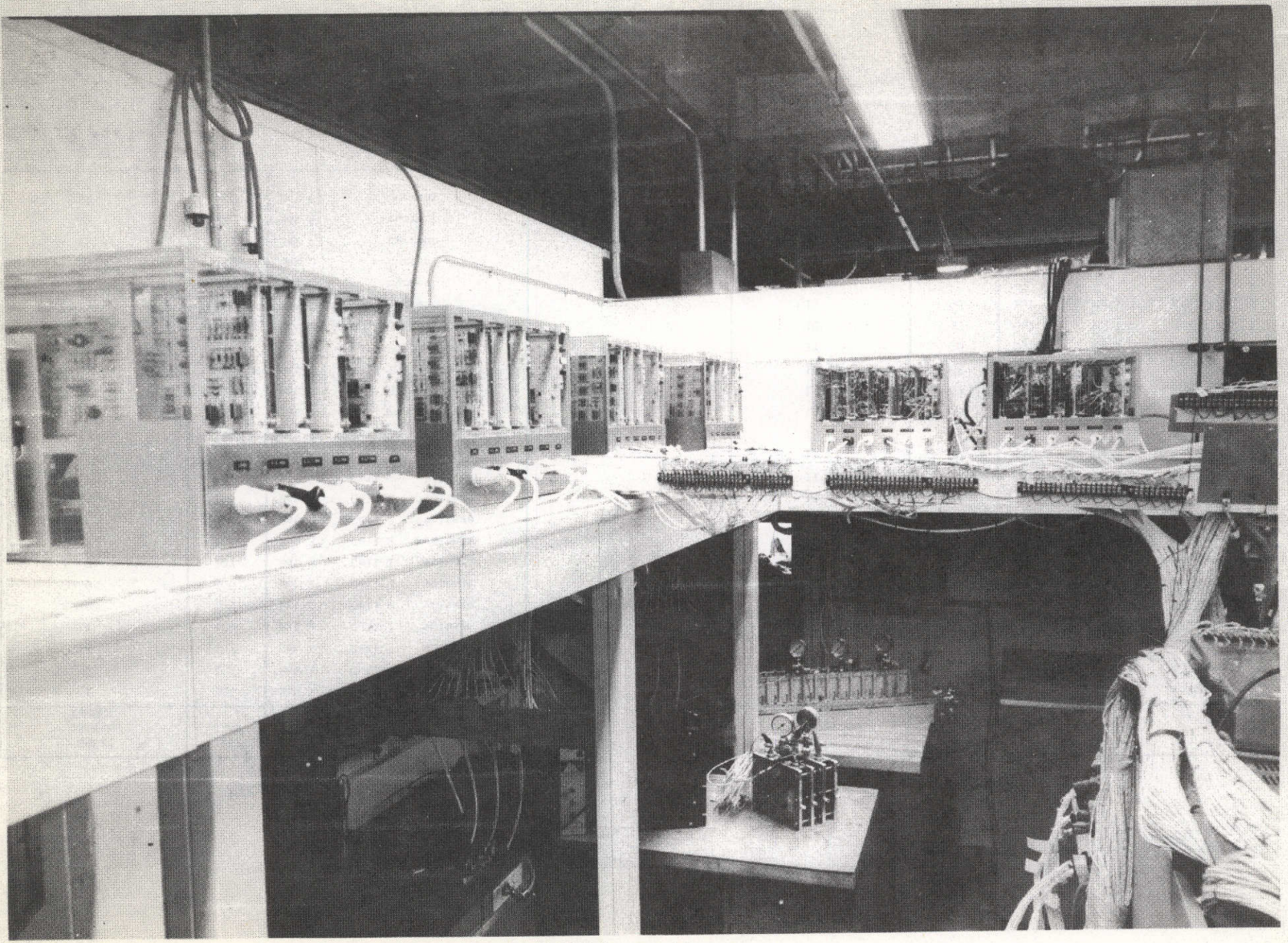
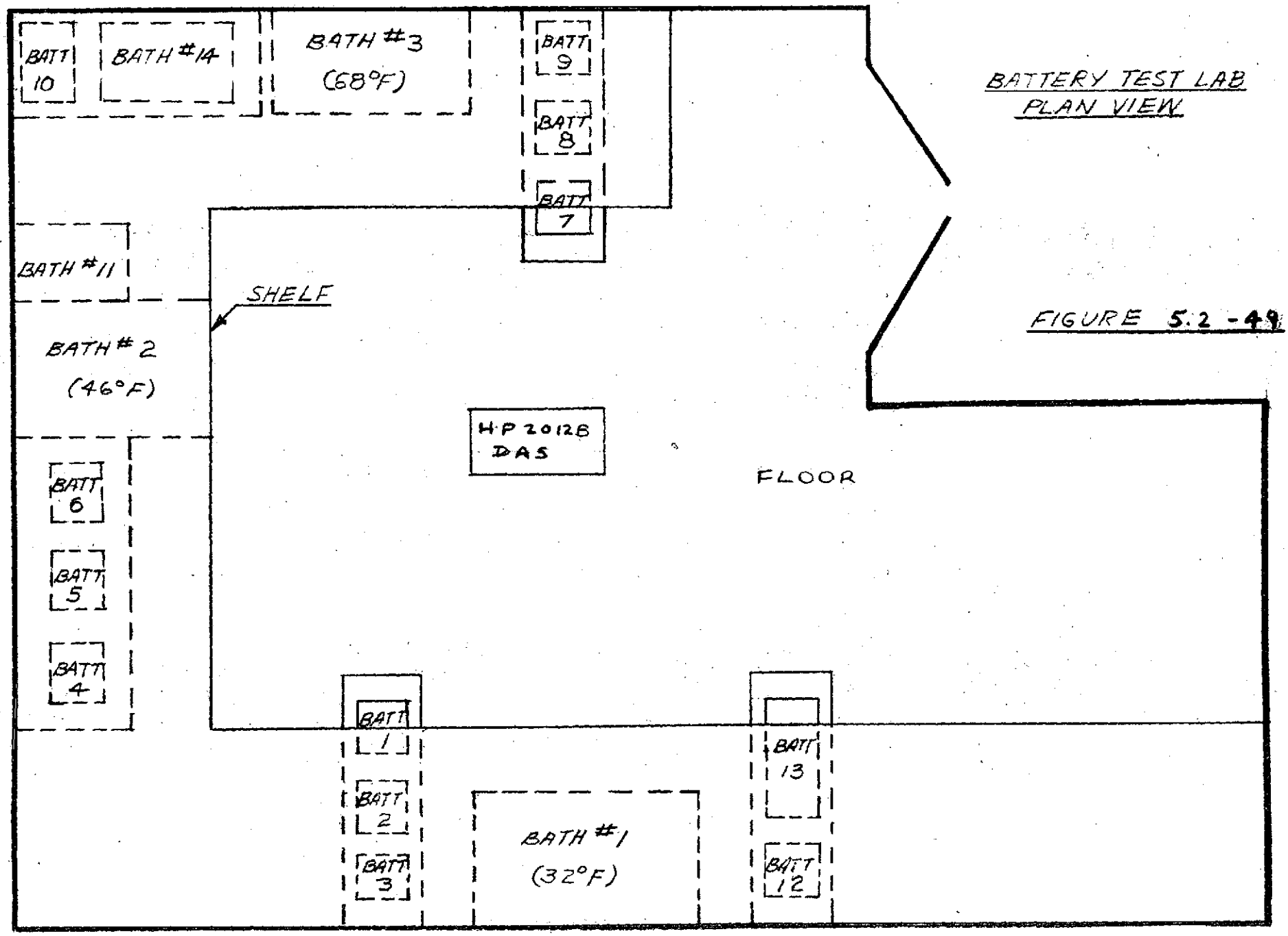
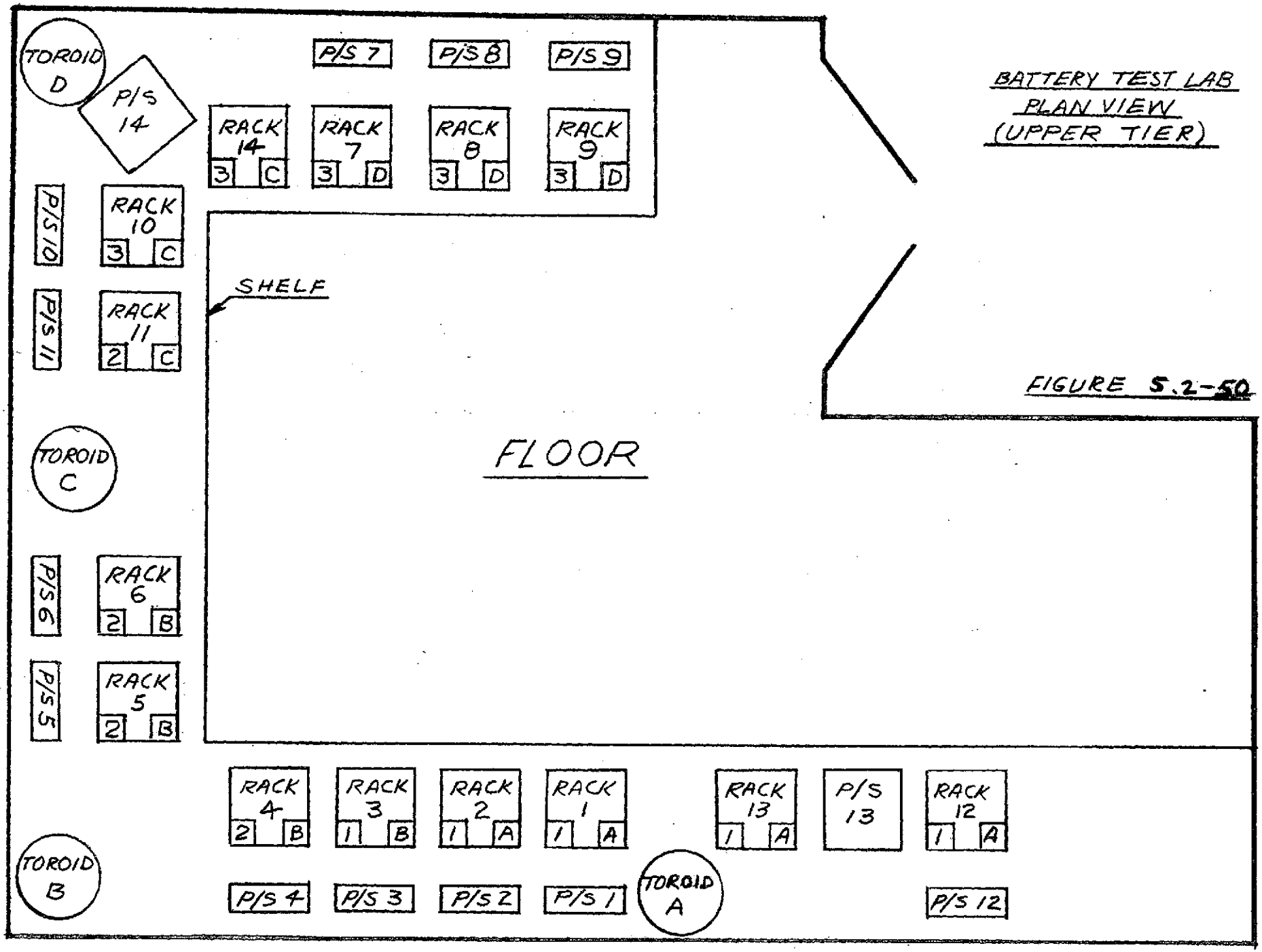


FIGURE 5.2-48


BATT 10
BATH #14
BATH #3
(68°F)
BATT 9
BATT 8
BATT 7
BATTERY TEST LAB
PLAN VIEW
BATH #11
SHELF
BATH #2
(46°F)
FIGURE 5.2 - 49
HP 2012B
DAS
FLOOR
BATT 6
BATT 5
BATT 4
BATT 1
BATT 2
BATT 3
BATH #1
(32°F)
BATT 13
BATT 12


BATTERY TEST LAB
PLAN VIEW
(UPPER TIER)
FIGURE 5.2-50
FLOOR
SHELF
TOROID D
P/S 14
P/S 7
P/S 8
P/S 9
RACK 14 3 C
RACK 7 3 D
RACK 8 3 D
RACK 9 3 D
P/S 10
RACK 10 3 C
P/S 11
RACK 11 2 C
TOROID C
P/S 6
RACK 6 2 B
P/S 5
RACK 5 2 B
RACK 4 2 B
RACK 3 1 B
RACK 2 1 A
RACK 1 1 A
RACK 13 1 A
P/S 13
RACK 12 1 A
TOROID B
TOROID A
P/S 4
P/S 3
P/S 2
P/S 1
P/S 12

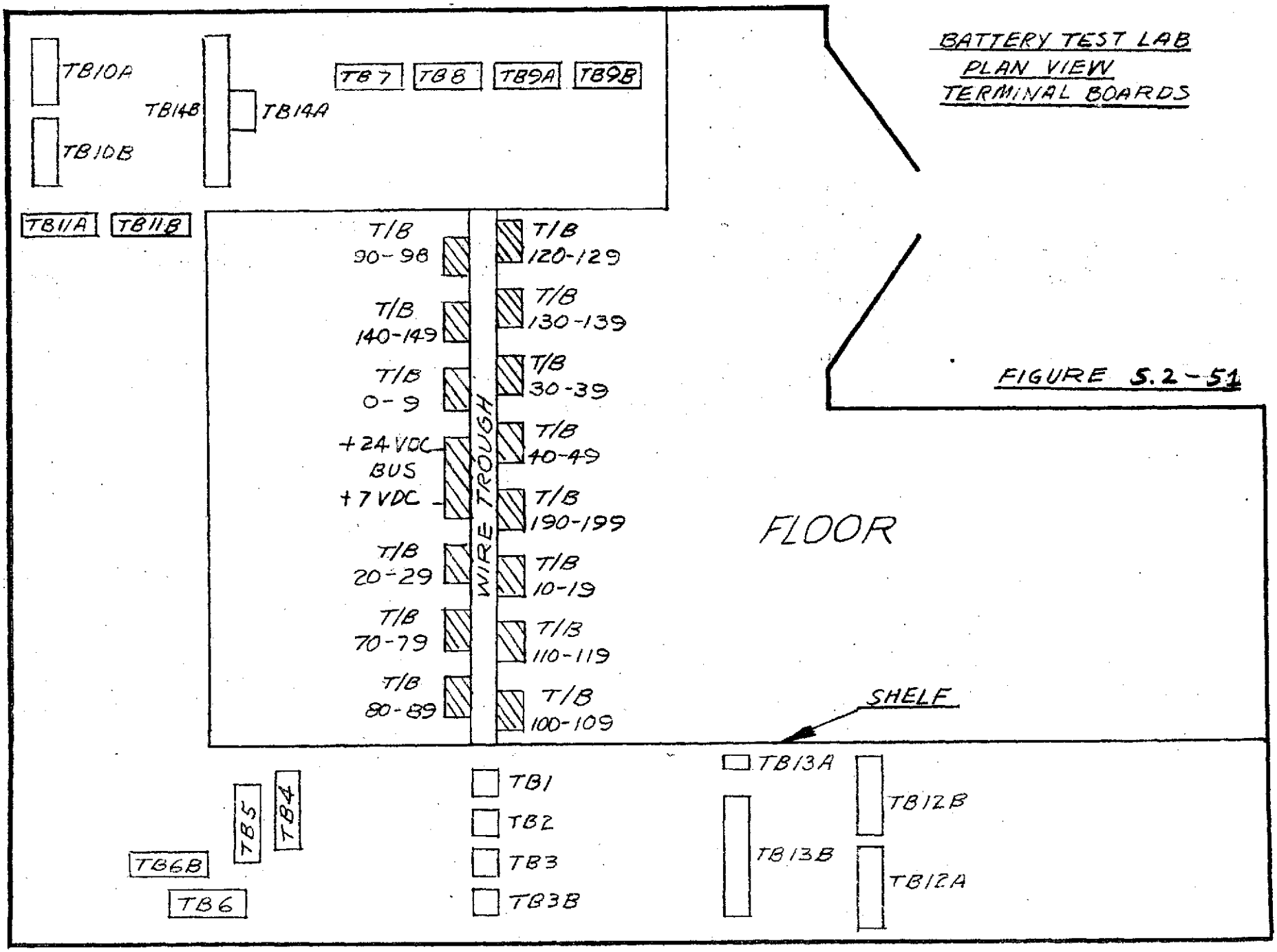
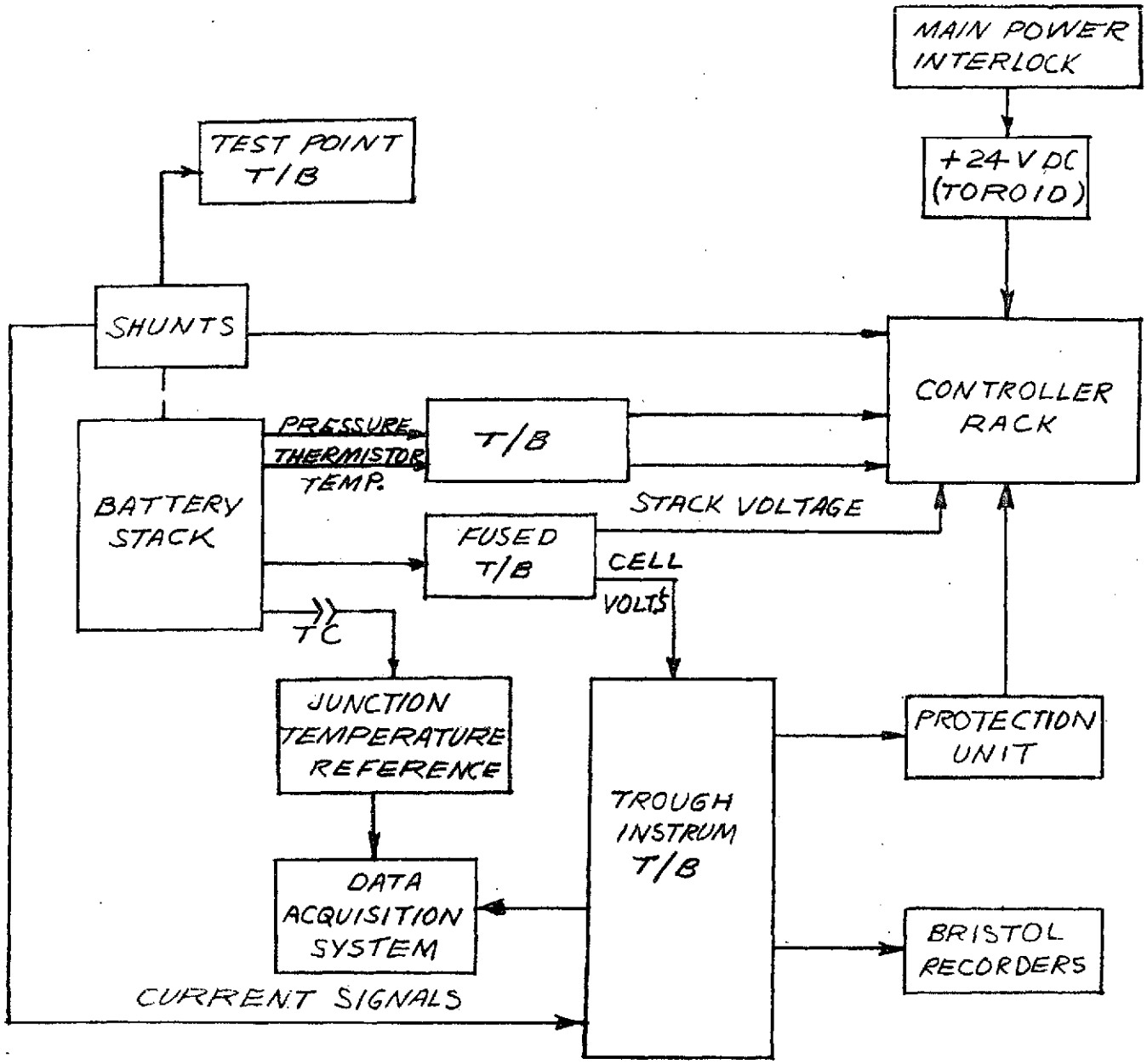

BATTERY TEST LAB
PLAN VIEW
TERMINAL BOARDS
TB10A
TB10B
TB14B
TB14A
TB7
TB8
TB9A
TB9B
TB11A
TB11B
T/B 90-98
T/B 120-129
T/B 140-149
T/B 130-139
T/B 0-9
T/B 30-39
+24 VDC BUS
T/B 40-49
+7 VDC
T/B 190-199
T/B 20-29
T/B 10-19
T/B 70-79
T/B 110-119
T/B 80-89
T/B 100-109
WIRE TROUGH
FLOOR
SHELF
TB5
TB4
TB6B
TB6
TB1
TB2
TB3
TB3B
TB13A
TB13B
TB12B
TB12A

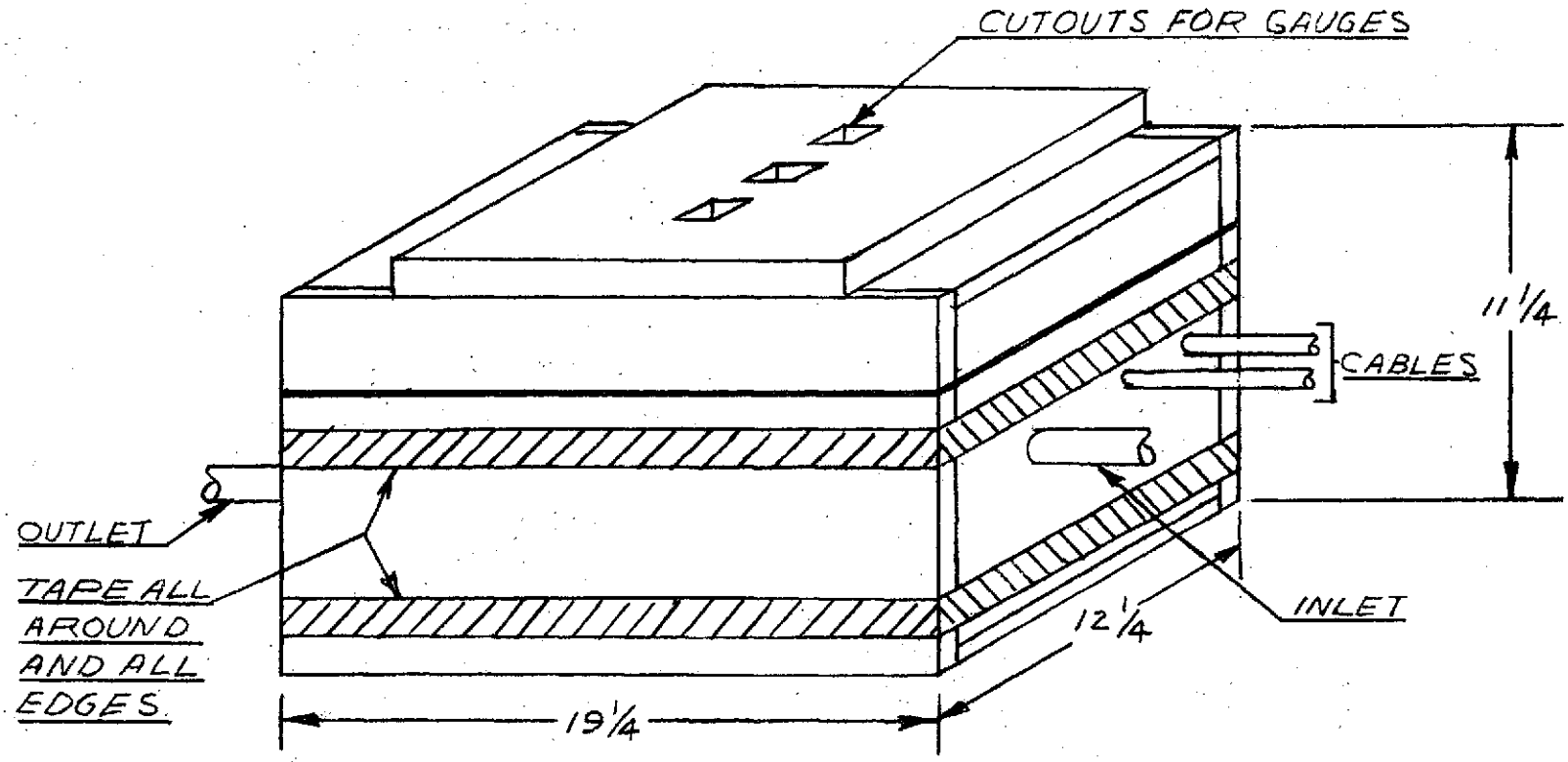
FIGURE 5.2-51



TYPICAL
BLOCK DIAGRAM
SHOWING CABLES

FIGURE 5.2 -52

CELL STRING
CONSTANT TEMPERATURE PACKAGE
(CONDITIONED COOLANT CIRCULATED)



NOTES:

1. MATERIAL ~ 1 INCH TH. POLYSTYRENE FOAM
2. INSIDE VOID VOLUME FILLED WITH VERMICULITE
3. ALL GAUGES BAGGED IN CLEAR POLYETHYLENE

FIGURE 5.2-53

5.2.2.3 Computerized Data Reduction/Analysis Program

5.2.2.3.1 Program Development - The initial data reduction/analysis program for the parametric characterization and life cycle tests was written in Fortran IV for use on the IBM Computer using the magnetic tape output from the Hewlett Packard Data Acquisition System. The program could be used for either the time sharing (360/67) or batch processing (360/75) operations. (A sample output was reported in the January 1972 Monthly Progress Report and is shown in Appendix Q-11.) Due to frequent errors by the tape reader converting the 7 track instrumentation tape, a premature output termination resulted. Consequently, the program was revised for use on a CDC-3200 Computer. All parametric characterization test data was processed by the Grumman LMDRS (LEM Data Reduction System) group using a NASA owned CDC-3200 Computer, which was purchased under NAS 9-1100. The main program revisions to incorporate major functions are described in Grumman AVO's D559-2-20 and D559-2-26 (shown in Appendix Q-12).

5.2.2.3.2 Finalized Computer Program - The finalized computerized data reduction/analysis program was subdivided into two separate sequentially run programs.

Program 1 - Battery Data Reduction, "BDR". - It processes variable record length binary coded instrumentation tapes. To permit more operational flexibility all data references were generalized by creation of a descriptor array using channel assignment cards. It produces a tab listing for each string for each orbit. A summary file of all error messages is provided and listed when all data are processed.

Program 2 - Designated "ORBPLOT" for the orbital plotting routine. It uses a binary (E.U. formated) tape produced in program 1 as input to a selective data plot program. The computer produces these plots on microfilm by means of a movie camera taking pictures of an oscilloscope screen. A complete "BDR" and "ORBPLOT" source program printout is

shown in Appendix Q-13. A listing of all channel assignments for input cards for both programs is shown in Appendix Q-14. A typical tab listing sample is shown in Table 5.2-48. The abbreviations used therein are as follows:

C1, C2, C3	- Voltage for cells 1, 2, 3 in string
Test Data	- Shows Julian day
Time	- Real-Test Time
OLT	- String outflow temperature in ^{o}F
TSR	- Temperature sensing resistor temperature in ^{o}F (located on restraining plate inside the insulated battery package)
SCV	- String voltage
AMP	- Current in amperes
A1, A2, A3	- Auxiliary electrode signal voltage in volts for cells 1, 2, 3 in string
P1, P2, P3	- Auxiliary electrode power output for cells 1, 2, 3 in string - this function was not used and is shown as zero.

Typical orbital plot samples are presented in figures 5.2-54 and 5.2-55. They show orbital time profiles of each cell voltage, currents, average stack temperature, calculated heat generated from thermal data and auxiliary electrode signal voltages.

5.2.2.4 Parametric Characterization and Life Cycle Test Plans

5.2.2.4.1 Electrical Operation - The parametric/life cycle set-up and operation test plan is shown in Appendix R-1 (Grumman AVO D559-3-1). It describes the step-by-step operation starting with incoming inspection through string assembly, test set-up, conditioning, capacity discharge and orbital cycling. The parametric test cell grouping into nine (9) test strings is shown in Table 5.2-49.

5.2.2.4.2 Circulating Fluid Flow Rate Plan - The circulating fluid flow rate plan for use in conjunction with the electrical operations to obtain cell heat generation information is shown in Appendix R-2.

MODT 46 PARAMETRIC TEST-DATE 155 STATISTICS FOR ORBIT NUMBER 71

STRING NUMBER 3

DISCHARGE		C1	C2	C3	TIME	OLT	TSR	SCV	AMP	A1	P1-MV	A2	P2-MV	A3	P3-MV
START		1.4[illegible]	1.417	1.409	52300.	41.239	40.658	4.224	20.070	.5875	0	.4743	0	.3299	0
END		1.267	1.259	1.258	55800.	41.975	41.697	3.775	20.059	.5218	0	.4339	0	.2957	0
CHARGE															
START	I1	1.382	1.377	1.373	55900.	41.927	41.697	4.132	82.326	.5967	0	.4855	0	.3308	0
END	I1	1.522	1.491	1.478	60100.	41.975	41.697	4.491	82.322	.6920	0	.5454	0	.3655	0
START	I2	1.468	1.458	1.450	60200.	41.975	41.743	4.375	49.692	.6508	0	.5256	0	.3528	0
END	I2	1.586	1.498	1.483	60300.	41.327	41.749	4.487	49.688	.6742	0	.5453	0	.3649	0
START	I3	1.430	1.430	1.426	60400.	41.975	41.789	4.286	20.740	.6173	0	.5054	0	.3395	0
END	I3	1.493	1.516	1.523	61500.	41.927	41.651	4.531	20.744	.6462	0	.5351	0	.3720	0
START	I4	1.472	1.491	1.499	61600.	41.927	41.626	4.462	4.424	.6365	0	.5276	0	.3672	0
END	I4	1.457	1.459	1.461	65600.	41.284	40.734	4.377	4.482	.6192	0	.4994	0	.3484	0

WATT-HOURS OUT	WATT-HOURS IN.	PERCENT RETURN
47.41	55.26	116.56

AMP-HOURS OUT	AMP-HOURS IN .	PERCENT RETURN
12.04	12.68	105.38

WATT-HOURS OUT		WATT-HOURS IN.	PERCENT RETURN
7	15.81	18.45	116.73
8	15.81	18.43	116.60
9	15.80	18.38	116.34

THERMAL INFORMATION - INLET TEMPERATURE IN DEG F

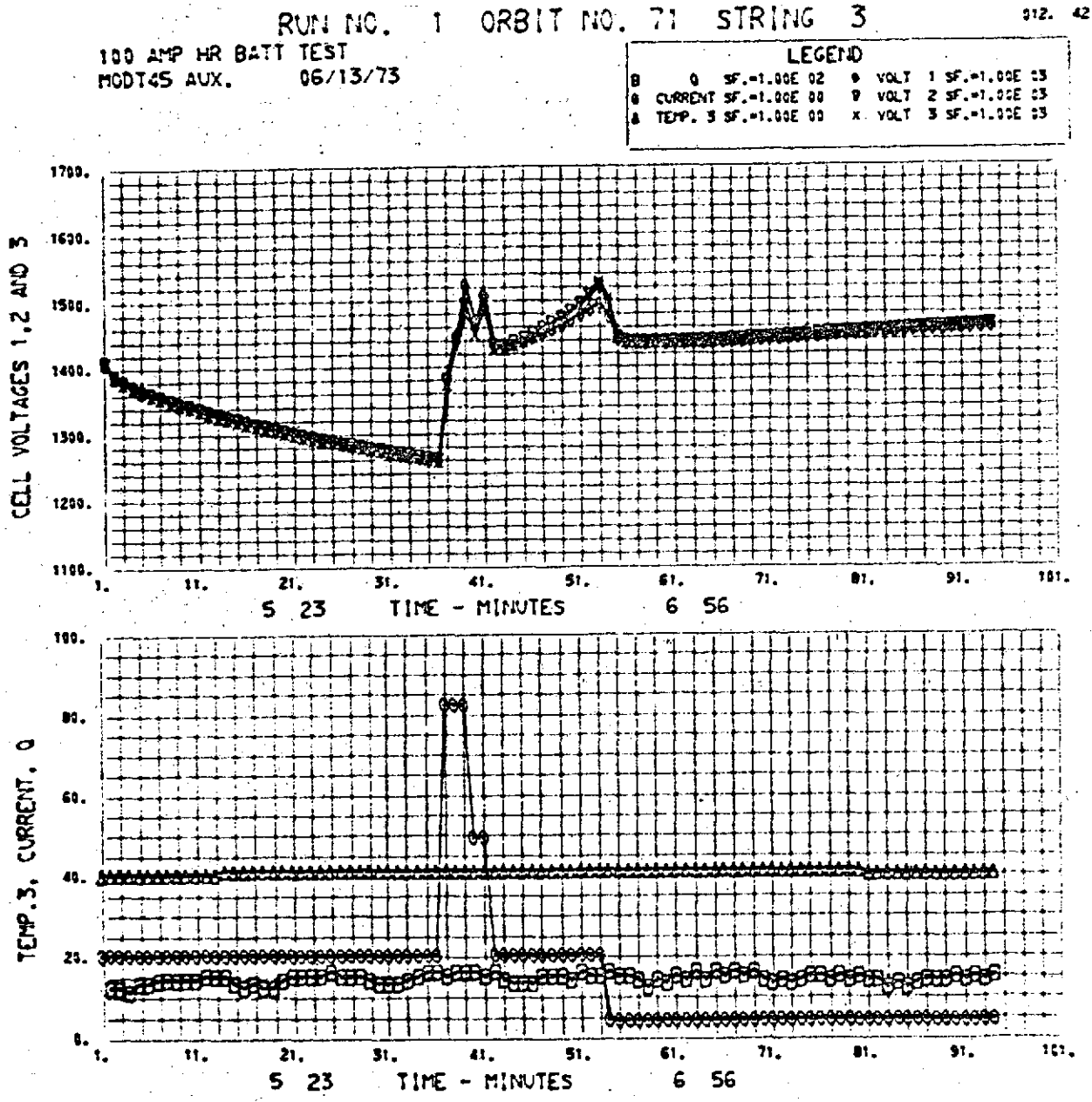
LOW	HIGH	AVER
38.822	39.757	39.228

TOTAL HEAT IN WATT-HRS= 13.49 AMBIENT CORRECTION= .7500 DEGREES F

SAMPLE

COMPUTER TAB LISTING

TABLE 5.2-48



SAMPLE

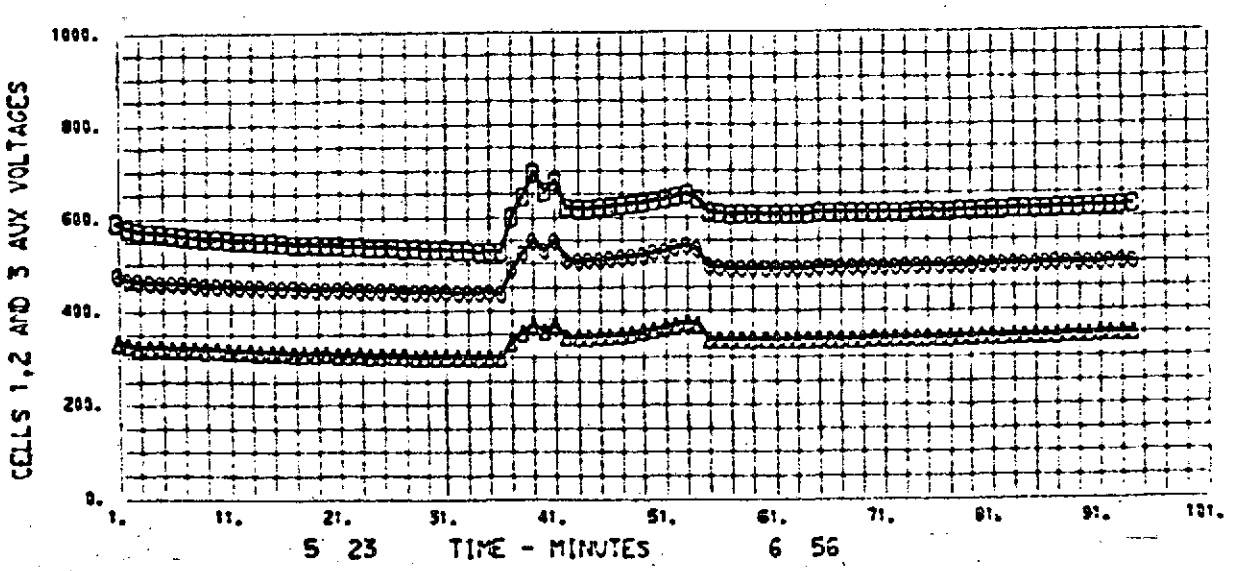
FIGURE 5.2-54

RUN NO. 1 ORBIT NO. 71 STRING 3

012. 43

100 AMP HR BATT TEST
MODT45 AUX. 06/13/73

LEGEND
B AUX. 1 SF.=1.00E 03
G AUX. 2 SF.=1.00E 03
A AUX. 3 SF.=1.00E 03



SAMPLE

FIGURE 5.2-55

STRING NO.	CELL NO.	CELL S/N	ELECTRODES THIN	ELECTRODES BASEL.	SEPARATOR NYLON	SEPARATOR POLYPR.	AUX. ELECT.			COMMENTS			
					(*)	(**)	(***)		NOTES:	(*) TYPE P2505 (WASHED)			
1	1	59	✓			✓	II			(**) TYPE WEX1242 (WASHED)			
	2	61	✓			✓	III			(***)AS DESCRIBED IN PARAGRAPH 5.2.1.5.6.6			
	3	--											
2	1	69		✓	✓		II						
	2	72		✓	✓		III						
	3	74		✓	✓		IV						
3	1	55	✓		✓		VI						
	2	52	✓		✓		IV						
	3	48	✓		✓		II						
4	1	53	✓		✓		IV						
	2	51	✓		✓		III						
	3	49	✓		✓		II						
5	1	67		✓	✓		I						
	2	75		✓	✓		V						
	3	--											
6	1	58	✓		✓		II						
	2	62	✓		✓		IV						
	3	65	✓		✓		VI						
7	1	47	✓		✓		I						
	2	54	✓		✓		III		-	AUX. ELECTRODE MALFUNCTION			
	3	56	✓		✓		V						
8	1	57	✓			✓	I						
	2	60	✓			✓	III						
	3	64	✓			✓	V						
9	1	68		✓	✓		II						
	2	73		✓	✓		IV						
	3	76		✓	✓		VI						

G316 REV. 2
8-70 2000P

TABLE 5.2-49

GRUMMAN

PARAMETRIC CHARACTERIZATION

CELL GROUPING

5.2.2.4.3 Test Equipment Turn-On-Procedures - The Test Controller turn-on-procedures are shown in Appendix R-3.

5.2.2.5 Parametric Characterization Test Data Summary

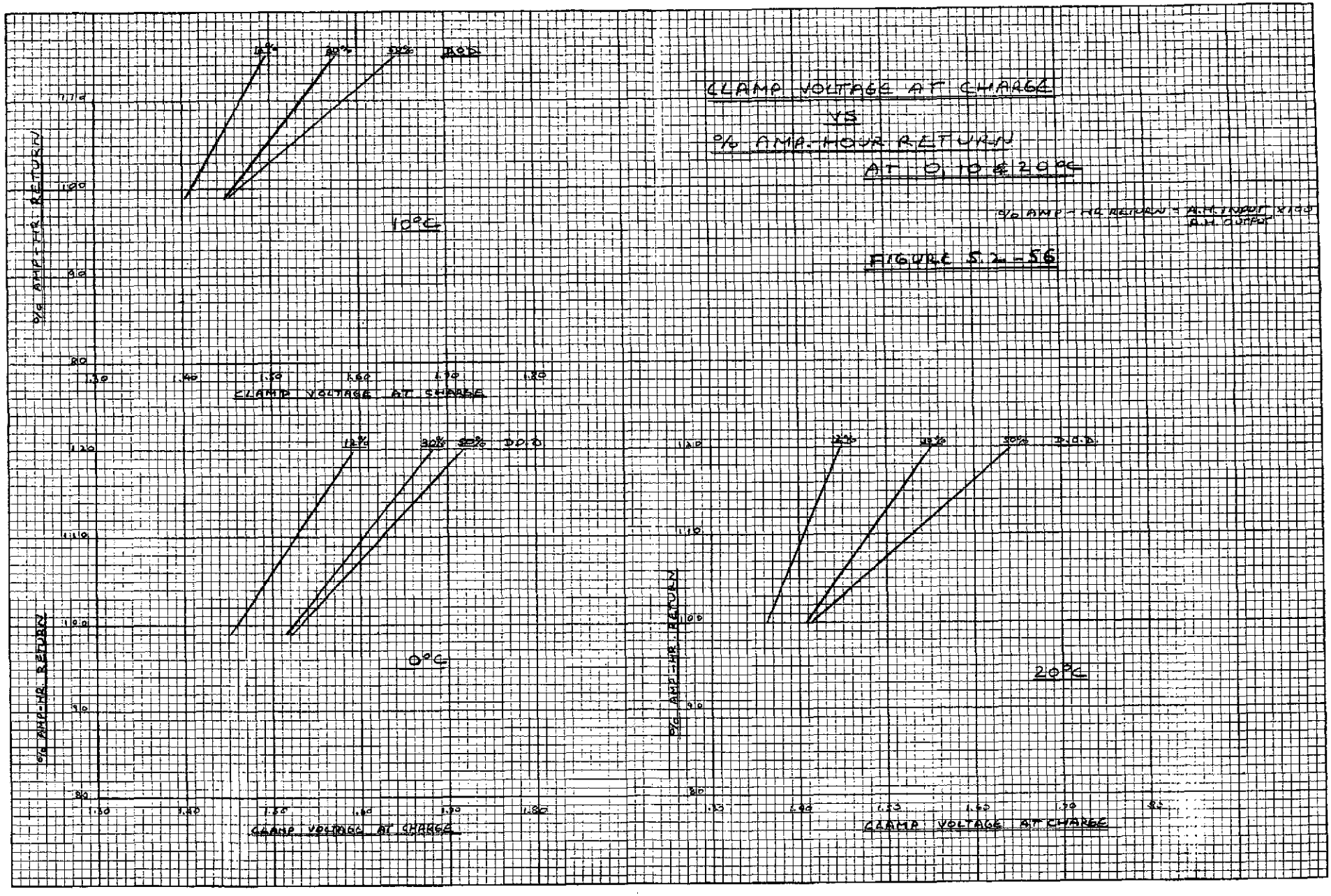
5.2.2.5.1 Characterization Test Runs - The parametric characterization test runs were conducted after conditioning, capacity determination and completion of about 274 orbital burn-in cycles for most cell strings. Most of those test conditions for the voltage/temperature limit, shown in Table 5.2-44, were conducted. The second postion of the planned tests, pressure or auxiliary electrode signal limit characterization (conditions 7-12), could not be conducted due to poor auxiliary signal responses and late delivery of pressure switches. Table 5.2-50 shows a test condition summary for all orbital runs conducted after the burn-in cycles. It also shows an assigned MODT run number and the number of orbital cycles conducted at each test condition (each generated test tape was assigned a consecutive "MODT" number and could contain as much as four days of continuous test run data). Appendix R-4 shows the computer printouts of selected stabilized cell characteristics for each string at each test condition Appendix R-5 shows the computer plots (ORBPLOTS) of stabilized cell characteristics for each string at each test condition.

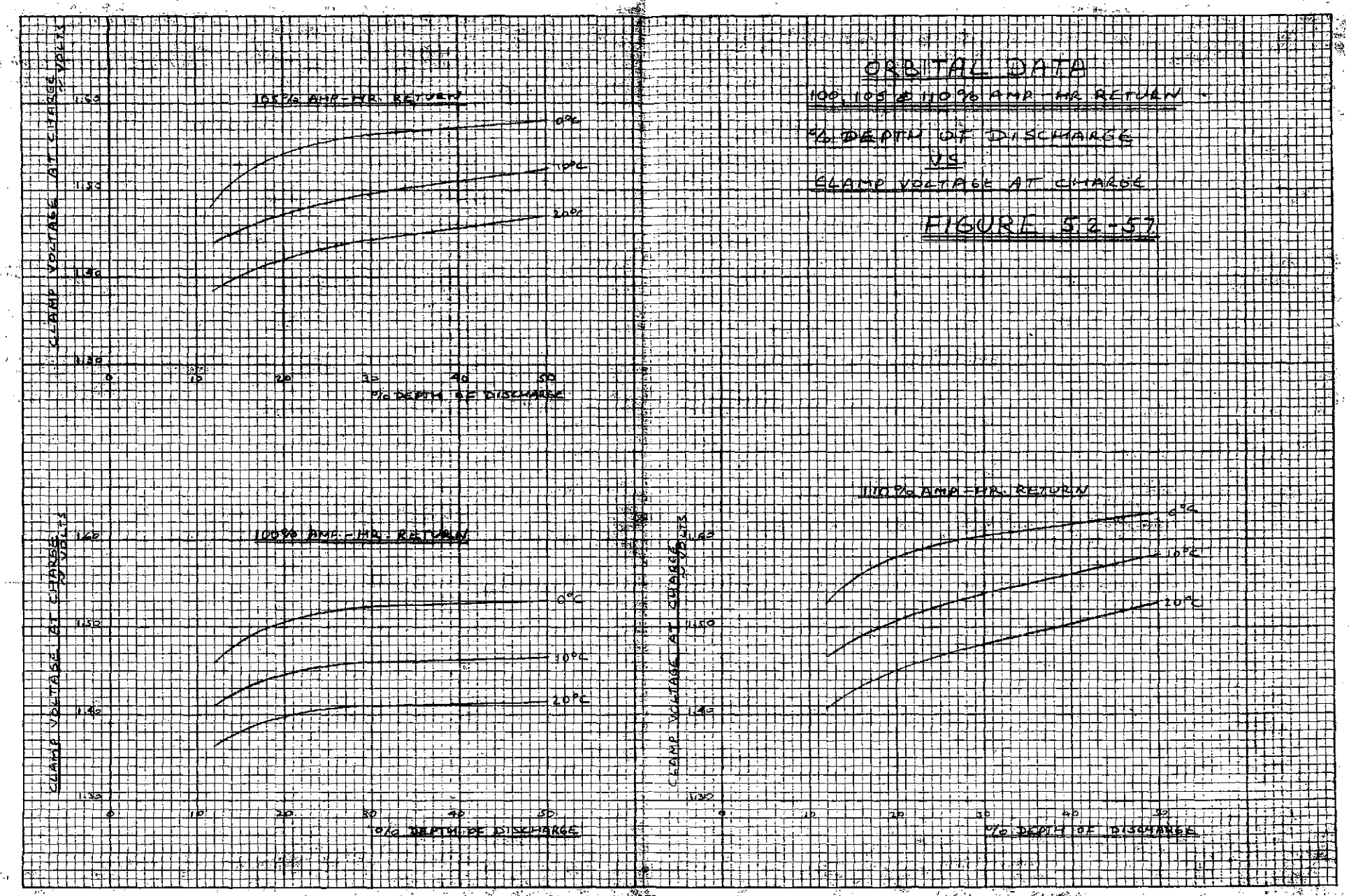
The initial cycle life cell characteristics based on these tests are summarized as follows:

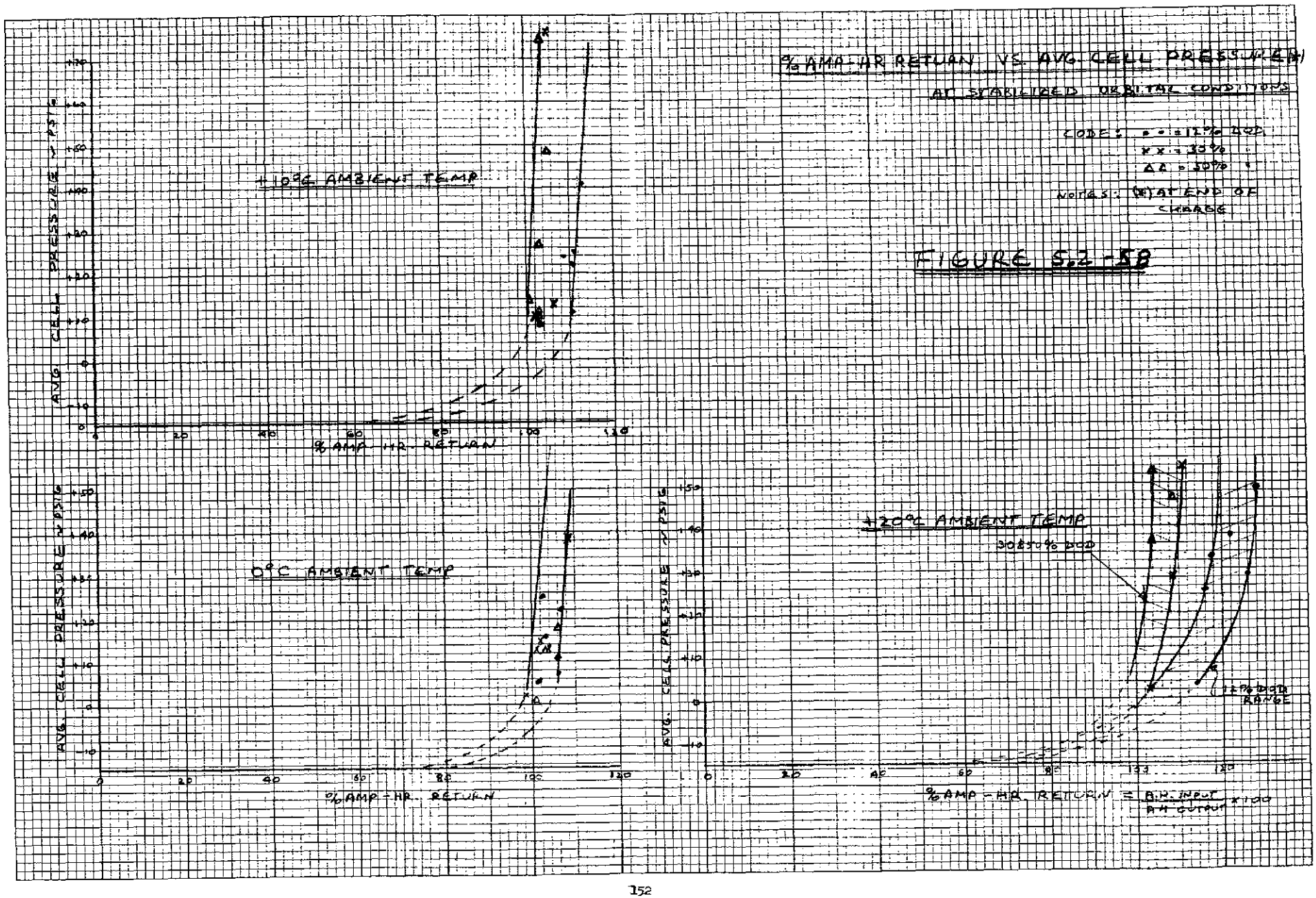
- The clamp voltage at charge as a function of percent ampere-hour return at 0°, 10°, & 20°C ambient temperatures and for 12, 30 & 50% D.O.D. (depth of discharge) is presented in figure 5.2-56. The three different cell designs showed no significant differences in the percent returns for identical conditions and are, therefore, presented together. As anticipated, a steeper slope for lower depth of discharge and a shallower slope for a higher depth of discharge can be noted. A direct correlation between charge voltage decrease with temperature increase for identical percent return can be observed.
- Figure 5.2-57 presents the percent depth of discharge as a function of clamp voltage for 100, 105 & 110% ampere-hour return.
- Figure 5.2-58 shows the percent ampere-hour return as a function of average cell pressure at end of charge for stabilized orbit at conditions at 0°, 10°, & 20°C ambient temperature. At 0°C the point of inflection for the gassing curve appears to occur in the 100 - 106% charge return range. The depth of discharge appears to have little or no effect on this curve. At 10°C ambient temperature the gassing curve inflection point for the 50% and

ASSIGNED STRING NO. / MOD T NO.	1	2	3	4	5	6	7	8	9		COMMENTS
45 COND. NO.	1	1	1	1	1	1	1	1	1		ORBITS 275-346
LEVEL NO.	1	1	1	1	1	1	1	2	1		(COMPUTER DATA SHOWS
D.O.D.	12	12	12	30	12	12	12	30	12		ORBITS 1-72)
SPEC. FLOW RATE	11.66	17.50	17.50	43.61	11.63	17.45	19.42	43.54	17.42	LBS/HR.	
46 COND. NO.	2	1	2	2	2	1	2	2	2		ORBITS 347-395
LEVEL NO.	1	2	1	1	1	1	1	2	1		
D.O.D.	30	12	50	50	50	12	30	30	50		
SPEC. FLOW RATE	29.03	19.50	72.84	72.56	48.37	17.45	43.61	72.44	17.42	LBS/HR.	
47 COND. NO.	3	2	3	2	3	2	3	2	3		ORBITS 396-414
LEVEL NO.	2	2	2	1	2	2	2	2, 3	1, 2		
D.O.D.	30	12	50	50	50	12	30	50	50		
SPEC. FLOW RATE	29.03	17.50	72.84	72.56	48.37	17.45	43.61	72.44	73.89	LBS/HR.	
48 COND. NO.	4	3	4	3	4	3	4	3	3		ORBITS 415-432
LEVEL NO.	2	1	2	2	2	1	2	2	2		
D.O.D.	12	30	30	50	30	30	12	12	50		
SPEC. FLOW AIR	11.65	43.54	43.54	72.56	29.08	43.61	43.61	43.61	73.89	LBS/HR.	
49 COND. NO.	5	4	5	3	5	4	5	4	3		ORBITS 433-479
LEVEL NO.	3	2	3	2	3	2	3	3	2		
D.O.D.	12	50	30	50	12	50	12	12	50		
SPEC. FLOW RATE	11.65	72.84	43.54	72.56	11.63	72.56	17.45	17.45	73.89	LBS/HR.	

TABLE 5.2-50 PARAMETRIC CHARACTERIZATION TEST CONDITION SUMMARY





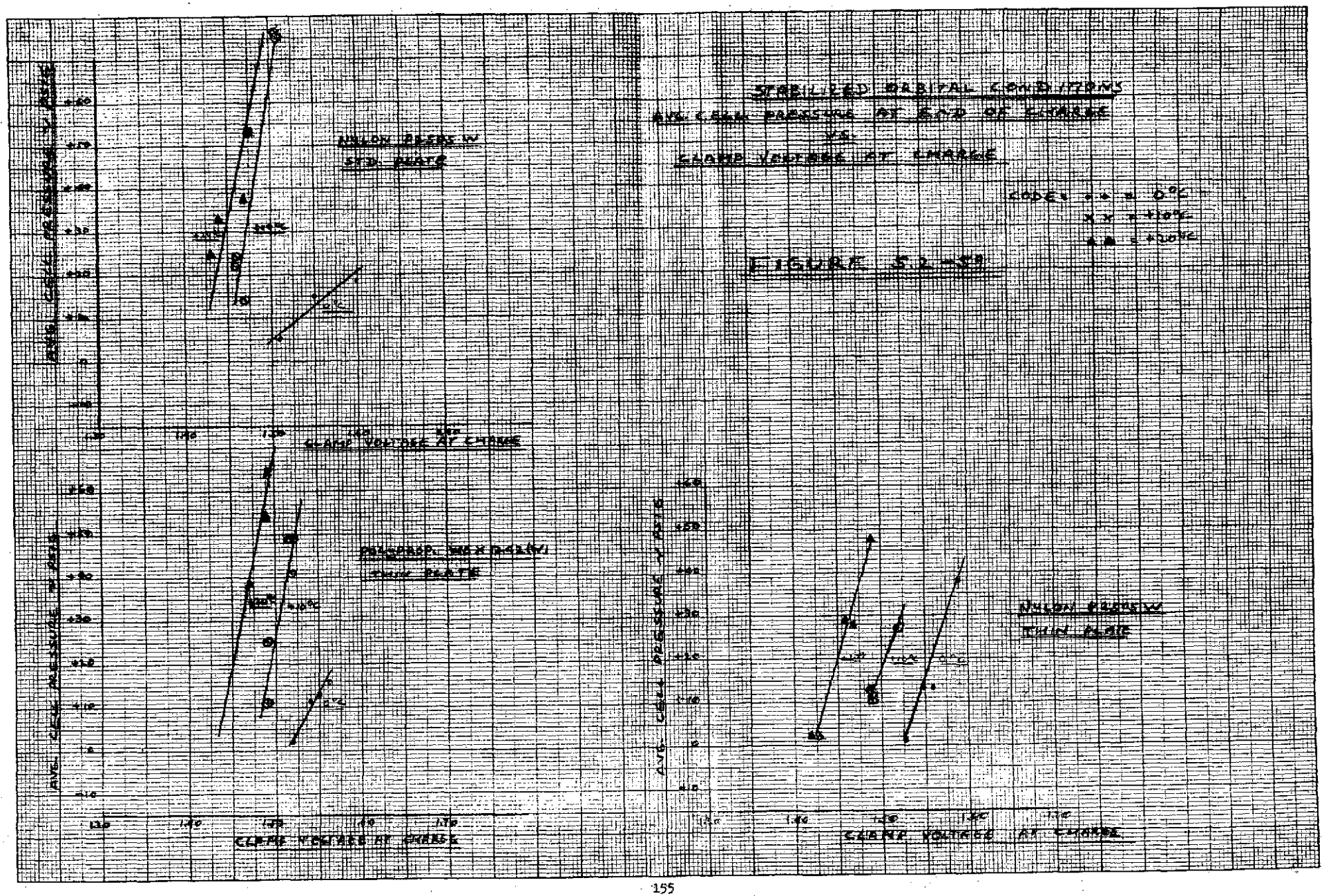


30% D.O.D. appears to range from 103 - 110%. Thus, there is a definite trend of a higher charge return requirement for the lower depth of discharges at the higher temperatures.

- Figure 5.2-59 presents the average cell pressure at end of charge as a function of clamp voltage at charge for each of the three designs at 0°, 10°, & 20°C. Comparing the 10°C & 20°C curves for the three designs one can note that the lowest pressures for identical clamp voltages were observed on the thin plate, nylon, cells. The 0°C data for the standard (baseline) plate, nylon, and thin plate polypropylene cells show a considerable shallower slope than those for the other test conditions.
- Figure 5.2-60 shows the capacity data after completion of the parametric testing as a function of the discharge current at 0, 10 & 20°C. These capacities were obtained at the last parametric test run condition (described in Table 5.2 -49) and do not necessarily represent a full state of charge. However, the data show it at under the test conditions applied the thin plate, nylon cell yielded the highest capacities of the three designs and showed approximately 100 ampere-hours to discharge currents up to about 50 amperes at all three temperatures. The polypropylene cells (WEX1242, washed, yielded consistantly the lowest capacities.
- Figure 5.2-61 shows plots of temperature and discharge current as a function of positive active material utilization obtained prior and after burn-in and parametric-testing. The thin plate, nylon cells yielded the highest post parametric positive material utilization for all discharge current for the entere temperature range tested. The standard (baseline) plate nylon yielded the second highest utilization values for the higher discharge current ranges (about 30 amperes and above).

5.2.2.6 PROPOSED CYCLE LIFE/MEMORY EFFECT TEST

- The proposed cycle life/memory effect test is outlined on Table 5.2-51. None of these scheduled tests were started.



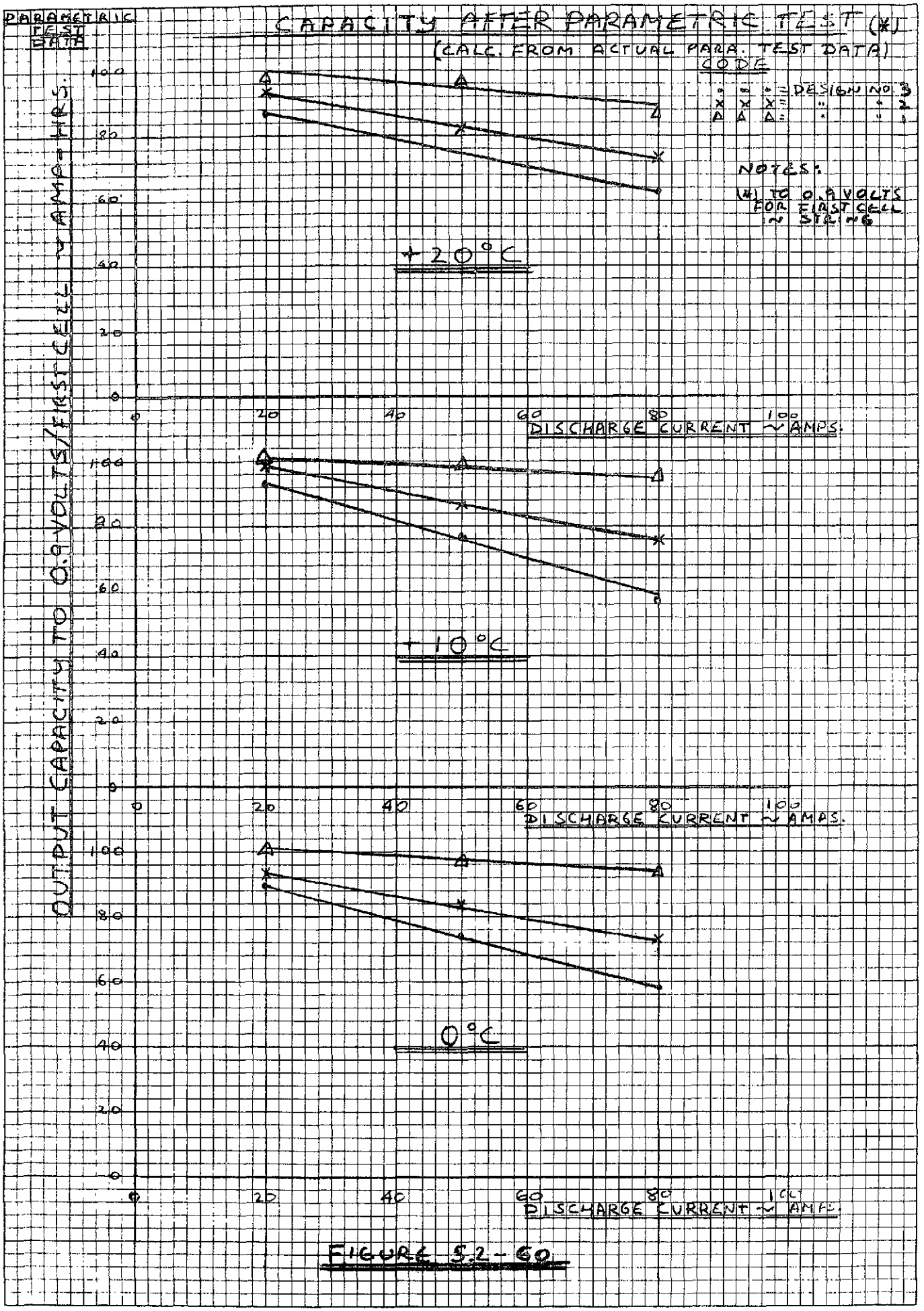

PARAMETRIC TEST DATA
CAPACITY AFTER PARAMETRIC TEST (*)
(CALC. FROM ACTUAL PARA. TEST DATA)
CODE
X = DESIGN NO. 3
A = " " 2
NOTES:
(*) TO 0.9 VOLTS FOR FIRST CELL IN STRING
+20°C
+10°C
0°C
OUTPUT CAPACITY TO 0.9 VOLTS/FIRST CELL ~ AMP-HRS.
DISCHARGE CURRENT ~ AMPS.
0
20
40
60
80
100
120

FIGURE 5.2-60

PROPOSED CYCLE LIFE/MEMORY EFFECT TEST

P = PRESSURE CUT-OFF AS DEFINED FROM PARAMETRIC TESTS
L = VOLTAGE LIMIT AS DEFINED FROM PARAMETRIC TESTS
T1 = 0°C
T2 = 10°C
T3 = 20°C
D1 = 12% DOD
D2 = 30% DOD
D3 = 50% DOD
P1 = LOW PRESS.
P2 = MED. PRESS.
P3 = HIGH PRESS.

PREFERED C_P

		T1		T2		T3	
		LL	LH	LL	LH	LL	LH
P1	D1		14	3			3
	D2						
	D3						
P2	D1						3
	D2	3			3		
	D3						
P3	D1						
	D2						
	D3	3			3	14	

TOTAL 3 CELL STRINGS 2 1 2 2
TOTAL 14 CELL STRINGS / /
1 D.V.T. MODULE
STORAGE TESTS (SEE BELOW)

ALTERNATE C_A

		T1		T2		T3	
		LL	LH	LL	LH	LL	LH
P1	D1	3					
	D2						
	D3					3	
P2	D1						
	D2			3			
	D3						
P3	D1						
	D2						
	D3		3				3

/ / / / /

TOTAL CELLS

REQUIRED	AVAILABLE
=36	54 LIFE TEST CELLS + PARA. CELLS
=28	
=4	
=4	
72	

STORAGE TESTS		
GROUP	STAND PERIOD	TEMP
CP (2)	6 MONTHS	0°C
	+6 MONTHS	25°C
CP (1)	12 MONTHS	0°C
(1)	12 MONTHS	25°C

TABLE 5.2-51

GRUMMAN AEROSPACE CORPORATION

Bethpage, L. I., N. Y.
Code Ident. No. 26512

Specification No. AV-D559CS-1

SPECIFICATION

Release Date 8-24-73

100 AMPERE-HOUR

NICKEL-CADMIUM STORAGE CELLS

POWER SUPPLY SUBSYSTEM

MANNED ORBITING SPACE STATION

SPECIFICATION FOR

C. Monaco — Specifications Engr

Thermal Design Engineer

Stephen J. Gaston

S. Gaston — Mechanical Engineer

Power Electronics Engineer

Stephen J. Gaston

Project Engineer

Program Manager

APPENDIX A

Grumman Specification

AV-D559CS-1,

100 Ampere-Hour Sealed

Nickel-Cadmium

Storage Cell

SPECIFICATION

No. AV-D559CS-1

TABLE OF CONTENTS

SPECIFICATION

No. AV-D559CS-1

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

SPECIFICATION

No. AV-D559CS-1

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

SPECIFICATION

No. AV-D559CS-1

TABLE OF CONTENTS (Continued)

SPECIFICATION

No. AV-D559CS-1

100 AMPERE-HOUR

NICKEL-CADMIUM STORAGE CELLS

POWER SUPPLY SUBSYSTEM

MANNED ORBITING SPACE STATION

SPECIFICATION FOR

1 SCOPE

1.1 General. - This specification establishes the requirements for a hermetically sealed, 100 Ampere-Hour Nickel-Cadmium Storage Cell (Storage Cell) which is to be used in the fabrication of the Storage Battery Module for the Manned Orbiting Space Station.

2 APPLICABLE DOCUMENTS

2.1 General. - The following specifications, standards, drawings and publications, of current issue, form a part of this specification to the extent specified herein:

Grumman	
GSS 7011	Safety Solvents - Cleaning
Federal	
MIL-S-4043B	Steel: Corrosion resisting (Extra Low Carbon Type 304), Plate, Sheet, and Strip
Military	
MIL-R-5031	Rods and Wire, Welding, Corrosion and Heat Resistant Alloys

SPECIFICATION

No. AV-D559CS-1

2.1 (Continued)

MIL-B-7883B	Brazing of Steels, Copper, Copper Alloys, and Nickel Alloys, Aluminum and Aluminum Alloys
MIL-W-8611A	Welding, Metal Arc and Gas, Steels, and Corrosion and Heat Resistant Alloys, Process for
MIL-S-5002B	Surface Treatments and Metallic Coatings for Metal Surfaces of Weapons Systems

STANDARDS

Military

MIL-STD-202D	Military Standard, Test Methods for Electronic and Electrical Component Parts
MIL-STD-271D	Military Standard, Nondestructive Testing Requirements for Metals
MIL-STD-454 REQ. 15	Ferrous Alloys, Corrosion Resistance

DRAWINGS

Grumman

TBD	100 Amp-Hr Nickel-Cadmium Storage Cell

HANDBOOKS

Aero Propulsion Lab, Wright Patterson AFB, Ohio

Screening Method, Edited by: J. E. Cooper and A. Fleischer	Characteristics of Separators for Alkaline Silver Oxide-Zinc Secondary Batteries

SPECIFICATION

No. AV-D559CS-1

2.2 Precedence. - When the requirements of the purchase order, this specification or subsidiary specifications are in conflict, the following precedence shall apply:

(a) Purchase Order - The Purchase Order shall have precedence over any specification.

(b) This Specification - This specification shall have precedence over all referenced subsidiary specifications.

2.3 Availability of Documents. - Copies of this specification and other Grumman specifications and documents referenced herein may be obtained, upon request from Grumman Aerospace Corporation, Bethpage, Long Island, New York, 11714, Attention: Specification Group. Requests for Military documents listed herein should be addressed to the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

3 REQUIREMENTS

3.1 Qualification. - The storage cells furnished under this specification shall be products which have been tested and have passed the Qualification Tests listed in Section 4.

3.2 Reliability and Operating Life. -

3.2.1 Reliability. - Each storage cell shall be designed and constructed so that a 99.8 percent probability of successful operation during the launch and orbital life as defined in 3.2.2 is achieved.

3.2.2 Operating Life. - All cells purchased under this specification shall have a minimum life of 11,000 orbital cycles. (An orbital cycle is defined in 3.2.2.1.) 30,000 orbital cycles shall be considered a design goal. The operating life shall be defined as wearout, deterioration, or catastrophic failure to an extent which causes the cells to deviate from the performance limits specified herein. Environmental test conditions representative of ground

SPECIFICATION

No. AV-D559CS-1

3.2.2 (Continued)

operations, launch and orbital operations shall be as specified herein. The storage cell surface temperature shall range between 0°C and 20°C. The average required Depth Of Discharge (DOD) is 30 percent. The minimum DOD is 12 percent, and the maximum DOD is 50 percent. Orbital life shall be defined as that period following ground and launch operations.

3.2.2.1 Orbital Cycle. - An orbital cycle shall be defined as having 94 minutes duration. The longest dark (discharge) period shall be 36 minutes duration.

3.3 Materials. - Materials used in the manufacture of storage cells shall be of high quality, suitable for the purpose intended, and shall be selected in accordance with the requirements specified herein and those contained in the final statement of work, negotiated as part of the Purchase Order.

Plates, separator and electrolyte are the only items to be installed in a storage cell. Any other materials must be approved by Grumman prior to their being used. A list of materials shall be supplied by the seller for Grumman approval.

3.4 Design and Construction. - Individual storage cells shall be hermetically sealed to permit operation within the environmental requirements of this specification. Storage cells shall contain the necessary plates and terminal posts and shall be secured so that no motion of the plates, relative to the container or hold-down arrangement, can occur. The detailed mechanical and electrical design of the storage cells shall be accomplished by the Seller subject to the requirements of this specification.

3.4.1 Interchangeability. - All storage cells of a given Seller's part number shall be dimensionally and functionally interchangeable with each other. The Seller's part number shall be identical with the Seller's drawing number for the same storage cells.

SPECIFICATION

No. AV-D559CS-1

3.4.2 Storage Cell Lot. - Storage cells to be purchased under one lot shall use components from one specific batch only and shall be assembled as one batch under identical production techniques. Components from one batch are mandatory for all active components such as; separator material, electrolyte, plates (one batch = one melange or 2 randomized melanges (See NOTE)). For all other storage cell components, one batch is desirable. This requirement must be strictly adhered to. Complete records must be kept of each component batch and be made available to Grumman upon request. Each storage cell shall be serialized with a non-recurring number.

NOTE: A melange shall be used to fabricate the storage cell order. In the event one melange is not adequate to manufacture the storage cell order, two or more melanges may be used if mixed and randomized prior to storage cell production.

3.4.3 Separators. - Separators shall be of an approved type for space application, free from flaws, cracks, or other imperfections likely to permit short circuits. They shall be fabricated from materials which are physically and chemically stable in the presence of potassium hydroxide. They shall have a low electrical resistance and shall be capable of absorbing and retaining large quantities of potassium hydroxide electrolyte when subjected to the environmental conditions specified herein. Separators shall also be capable of withstanding without damaging the thermal tests (See 4.5.9, 4.5.10 and 4.5.11) which are representative of environmental conditions anticipated during the 11,000 orbital cycles of minimum Storage Battery Module life.

3.4.3.1 Separator Quality Assurance Provisions. - The following tests shall be conducted on the separator which are to be used for storage cells purchased under this specification. Sample Data Sheets as shown in the attached (Appendices I, II and III) shall be prepared by the seller. Two copies of each Data Sheet and a separator sample of 100 square inch minimum size shall be furnished to Grumman prior to start of further processing. Material traceability shall be required.

3.4.3.1.1 Separator Manufacturer's Information. - The information requested under 10.1 on sample Data Sheets of Appendix I shall be recorded.

3.4.3.1.2 Electrolyte Absorption, Dimensional Change, Electrolyte Retention and Porosity. - Six samples of each material shall be cut (in the machine direction) to 6.50 cm. by 2.50 cm. and individually measured using a standard die. The thickness of each sample shall be measured using an Ames gauge Model 262 platform dial micrometer with a 0.5 in. diameter stainless steel anvil. The dial shall be graduated in 0.001 mm. An equivalent thickness measurement system is acceptable, but must be submitted for Grumman approval. Each sample shall be weighed to the nearest one milligram on an analytical balance and then immersed in approximately 100 cc of aqueous potassium hydroxide (KOH) solution in non-corrosive containers with air tight covers. The concentration of the KOH solution shall be the same percent as used in the storage cell filling and shall be of the same quality. Dimensional changes shall be measured after three hours of equilibration. The samples shall be returned to their individual containers for an additional hour. At the end of one hour, the equilibrated samples shall be wiped across a clean methyl methacrylate plate until no droplets are left on plate. Then the sample shall be re-weighed.

(a) Electrolyte Absorption - Electrolyte absorption is the difference between the wet equilibrated samples and the dry sample weights. Dimensions, dimensional changes and absorption shall be recorded in a manner similar to that delineated under 10.5 of the sample Data Sheets of Appendix I.

(b) Electrolyte Retention - Electrolyte retention shall be measured on the same samples after draining for 15 + 5 minutes on a clean methyl methacrylate plate positioned at a 45 ± 2 degree angle. The samples shall be re-weighed. During draining, the samples shall be enclosed in an inert atmosphere. Data on electrolyte retention shall be recorded in a manner similar to that delineated under 10.6 of the sample Data Sheets of Appendix I.

(c) Porosity - Porosity shall be calculated in a manner similar to that delineated under 10.7 of the sample Data Sheets of Appendix I.

3.4.3.1.3 Separator Resistance - DC Method. - The resistance of three samples of separator material shall be measured. Each sample shall be cut from a different roll. This method is essentially that described by Lander in Chapter 6a of the Cooper-Fleischer Handbook.

The storage cell used is a modification of that used in the AC method. The platinized platinum current electrodes are replaced by disc cadmium electrodes (capacity 0.7 A-hr) which are maintained in a partially discharged state. The voltage drop across the membrane is measured using two Hg/HgO reference electrodes which fit into ports in either storage cell half. The bottom of each port is connected by a diagonally drilled capillary to the membrane surface.

Equilibration technique and sample size are the same as in the AC method. The sample is introduced between the storage cell halves and the storage cell promptly filled with electrolyte and the reference electrodes placed. Current is passed by means of a constant current source to give 50 ma/cm^2. The voltage drop is measured between the two reference electrodes using either an electrometer or a potentiometer. A blank determination is made and subtracted from the storage cell resistance with the membrane in the path.

(a) Calculations -

(1) Separator Resistance

$$R'' = \frac{E_r - E_b}{I} A$$

R'' = Separator resistance ohm-cm^2

E_r = Voltage drop between Hg/HgO electrodes with separator in path - volts

E_b = Voltage drop between Hg/HgO electrodes with separator out of path - volts

I = Current - amperes

A = Separator area exposed - cm^2

3.4.3.1.3 (Continued)

(b) Separator Specific Resistivity -

$$P'' = \frac{R''}{t_w}$$

P'' = Separator specific resistivity ohm-cm

R'' = Separator resistance ohm-cm^2

t_w = Equilibrated separator thickness cm

The Calculations above shall be performed and data recorded in a manner similar to that delineated under 10.8 of the sample Data Sheets of Appendix I.

3.4.3.1.4 Separator Wettability. - Separator wettability of three samples of separator material shall be measured. Each sample shall be cut from a different roll. Separator wettability shall be measured by placing the dry separator sample in the resistivity storage cell, filling the cell with electrolyte, and recording the time required to attain a stable resistance. Measurements shall be made at five second intervals. The data of the three determinations shall be plotted on one graph, 10 x 10 to the inch.

3.4.3.1.5 Tensile Strength at Break. - Tensile strength at break shall be measured on at least six samples, each two samples cut from a different roll. Separator tensile strength measurements shall be made on die cut specimens 12.7 cm by 2.5 cm, cut in the roll direction, each of which must be carefully examined for flaws. Samples containing cracks, nicks or inclusions must be discarded. At least five samples of each material shall be run and the mean value reported. The tensile strength at break shall be measured on samples which are conditioned both at 72 ± 5°F, 50 + 5% relative humidity for 24 hours, and after 24 hour immersion in 34 percent KOH. A cross head speed of 2 inches

SPECIFICATION

No. AV-D559CS-1

3.4.3.1.5 (Continued)

per minute shall be used and the specimens positioned in rubber faced jaws so that the grip separation is 3 in. Elongation measurements can be obtained by measuring the grip separation as the test progresses using the value at break to calculate percent elongation. For the tensile measurement, the load in pounds shall be measured at the breaking point. Samples breaking outside the area between the jaws are not included.

Temperature and humidity at the test site shall be recorded on the sample Data Sheet. Perform calculations as follows:

Calculations -

$$\text{Tensile Strength at Break} = \frac{\text{Breaking Load lbs.}}{\text{C.S.A.}}$$

C.S.A = sample cross sectional area

$$\% \text{ Elongation} = \frac{L - L_o \times 100}{L_o}$$

L = Sample lenth at break

L_o = Original length

Record data in a manner similar to that delineated under 10.9 of the sample Data Sheets of Appendix I. Also record the appearance of break, (i.e., clean or fuzzy). Repeat the test on six samples that have been stored for 24 hours at 70°C in storage cell electrolyte. The surrounding atmosphere shall be free of CO_2. Data shall be recorded in a manner similar to that delineated under 10.9 of the sample Data Sheets of Appendix I. The Seller may suggest alternate methods to Grumman for approval.

SPECIFICATION

No. AV-D559CS-1

3.4.3.1.6 Extractable Organic Content. - At least three samples, each from a different roll, shall be analyzed for soluble organic material. The sample size shall be a 10 cm. square. The following method of extraction of organics is recommended. If a different method is used, it shall be submitted to Grumman for approval.

(a) Weigh the separator sample on an analytical balance.

(b) Determine volume of separator sample.

(c) Put the sample in a weighed container with methanol, reagent grade. Use a volume ratio of 20 of solvent to one of separator. Cover the container.

(d) Stir with a magnetic stirrer for a minimum of 16 and a maximum of 24 hours.

(e) Remove separator sample and weigh after drying.

(f) Evaporate solvent.

(g) Determine weight of residue and weight loss of separator.

(h) Perform IR analysis of residue. Submit copy of IR trace to Grumman and indicate major organic constituents. (If a larger residue sample is required to perform this task, a proportionally larger sample is permissible.)

(i) Record data in a manner similar to that delineated on the sample Data Sheets of Appendix I.

The extractable organic residue shall be less than 2.0 percent by weight of total organics.

3.4.3.1.7 Inorganic Content. - At least three samples, each from a different roll, shall be analyzed for inorganic materials. The sample size from which inorganics are to be extracted shall be a 10 cm. square. Quantitative analysis of the following will be determined:

3.4.3.1.7 (Continued)

Carbonate, silica, zinc, chloride, nitrate, nickel and titanium. A description of the method used shall be submitted to Grumman for approval. Data shall be recorded in a manner similar to that delineated under 10.11 on the sample Data Sheets of Appendix I.

The extractable inorganic content shall be less than 0.25 percent by weight of total inorganics.

3.4.3.1.8 Discoloration of Samples in Electrolyte. - During testing of samples requiring equilibration in electrolyte, any discoloration of the sample shall be reported in a manner similar to that delineated under 10.12 of the sample Data Sheets of Appendix I.

3.4.3.1.9 Thickness Variation. - The separator thickness shall be measured at minimum intervals of one measurement for each 20 storage cells constructed. Each measurement shall be made on samples of two feet in length, taking 10 thickness readings at approximately two inch intervals. The gauge described in 3.4.3.1.2 shall be used. Data shall be recorded in a manner similar to that delineated under 10.13 of sample Data Sheets of Appendix I.

3.4.3.1.10 Materials Used In Storage Cell Formation or Electrochemical Cleaning. - The sampling criteria and test procedures specified in 3.4.3.1.6 and 3.4.3.1.7 for the separator used in the storage cell formation shall apply. Data shall be recorded in a manner similar to that delineated under 10.10 and 10.11 of the sample Data Sheets of Appendix I. Where applicable, information similar to that delineated on 10.1 of sample Data Sheet of Appendix I shall be furnished.

3.4.4 Metal Container. -

3.4.4.1 Storage Cell Case. - The storage cell case shall be Type 304 or 304L stainless steel per MIL-S-4043, Condition b. Material thickness shall be 0.031 ± 0.002 inch. The container shall either be welded or deep drawn. Internal and/or external taper shall not exceed 0.010 inch for total measured dimensions after drawing. Storage cell case

3.4.4.1 (Continued)

surface flatness shall not exceed 0.040 inch Total Indicator Reading (TIR) on the broad faces. On the narrow faces and end face, flatness shall not exceed 0.010 inch TIR. Flatness requirements are for finished storage cell with cover welded in place. Other dimensions shall be held to tolerance of ± 0.010 inch for finished storage cells.

3.4.4.2 Cover. - The storage cell cover shall be made from class 304 or 304L stainless steel per MIL-S-4043, cond. b and passivated per MIL-S-5002 and MIL-STD-454 REQT 15.

3.4.4.3 Storage Cell Case Quality Assurance Provisions. - The Seller shall provide Grumman, with each shipment of storage cells, data regarding the metal supplier, alloy designation, batch number and certified chemical composition analysis of raw material. Two copies of these data shall be provided. Each can shall be visually examined for blemishes, pits, cuts, cracks, burrs, file marks, weak points, poor wetting of braze joints, incomplete penetration of weld seams or any other visual defect prior to further processing or test. Such defects shall be cause for rejection and/or rework. Cases shall not be reworked for any cause more than twice. Cases requiring more than two reworks shall be permanently rejected.

3.4.4.4 Storage Cell Case Assembly. - Storage cell covers shall be assembled to storage cell cases using electric arc welding with inert gas shielding per Specification MIL-W-8611. The cell case shall be passivated in accordance with Specification MIL-S-5002 and MIL-STD-454, REQ'T 15. Completed case assemblies shall conform to Grumman Drawing TBD.

3.4.5 Electrodes and Electrode Assemblies. -

3.4.5.1 General. - The electrode materials shall be identical to those used in storage cells used for the Qualification Program as stated herein. No changes in material quality, contents and manufacturing technique shall occur without written approval by Grumman.

3.4.5.2 Electrode Quality Assurance Provisions. - Two copies of either the electrode purchasing specifications or the manufacturing process specifications delineating the process from raw materials through impregnation and storage for use on storage cells as specified herein shall be furnished to Grumman prior to start of further processing. Two copies of the electrode suppliers certification for both positive and negative electrodes used herein shall be furnished to Grumman prior to start of further processing. This certification shall also contain the following minimum information:

(a) Assigned plate batch number (melange).

(b) Assigned lot number.

(c) Dates of impregnation.

(d) Percent porosity.

(e) Weight of active material per plate.

(f) Positive capacity obtained.

(g) Negative capacity obtained.

NOTE: Sample results based on a reasonable sample from each positive and negative spiral are acceptable for items (d) through (g) above and tolerances are to be supplied by the Seller.

3.4.5.3 Electrode Assembly Quality Assurance Provisions. - Manufacturing and inspection operations on completed positive and negative plates shall be controlled as follows prior to their formation:

(a) Inspection of cutting, coining and other operations affecting the integrity of the sinter and grid.

SPECIFICATION

No. AV-D559CS-1

3.4.5.3 (Continued)

(b) Edges shall be coined to prevent flaking of sinter material.

(c) Visual inspection of plates. (100 percent inspection on positive and negative plates prior to assembly into formation pack).

NOTE: Inspection criteria shall be established by the Seller reflecting items listed in (d)(1) through (9) and (e) as follows. Sample plates showing each type defect shall be posted at inspection station.

(d) Plates shall be rejected if defects as listed as follows are found:

(1) Crack detected in sinter exceeds 0.50 inch in length, 0.005 inch in depth, or 0.001 inch in width.

(2) Rough edges, burrs and snags exceeding 0.0005 inch. (Inspection shall be made with nylon gloves to feel for pulls on fibers of glove. Inspection shall include the entire electrode surface).

(3) Pimples, blisters, and peeling of sinter material. Pimples and blisters in excess of 0.002 inch above electrode surfaces or evidence of sinter material breaking away from grid.

(4) Electrodes shall be of uniform thickness over entire surface area (± 0.001 inch). A 10 percent random sample shall be selected for thickness determination. If all samples can meet this thickness requirement then all plates are acceptable. If one or more plates from this sample cannot meet this thickness requirement, then a 100 percent sample is required in order to eliminate all electrodes which cannot meet this thickness. Rejection shall be final.

3.4.5.3 (Continued)

(d) (Continued)

(5) Tab shall be free of sinter material.

(6) Coining of edges shall be uniform, (i.e., within ±0.015 inch).

(7) Grid support for sinter material shall be free of any breaks or cracks.

(8) Cut edges of plates shall be coated with polystyrene to prevent flaking of sinter material.

(9) Dimensional checks shall show that plates are in accordane with applicable drawings.

NOTE: The Seller may submit an alternate procedure subject to Grumman approval. Two copies of the specifications and documentation for use shall be furnished go Grumman prior to application.

(e) Plate Weight Screening - Establish the average weight of the positive electrode and negative electrode by a screening method. Then each plate shall be screened by a GO-NO GO technique. Each plate weight shall be within 3.5 percent of the average established plate weight. As an alternate, the Seller may weigh and record each plate weight of each electrode for each storage cell and measure each electrode thickness at a minimum of four (4) locations. Electrode traceability is required. The Seller shall establish detail procedures and submit to Grumman for approval prior to start of task.

SPECIFICATION

No. AV-D559CS-1

3.4.5.3 (Continued)

(f) Plate Samples - The Seller shall supply Grumman with 10 unformed acceptable positive electrodes and 10 unformed acceptable negative electrodes from each plate lot (melange) used in the production of the storage cell lot. Each electrode type shall be placed in a polyethylene bag, heat sealed, and permanently marked with the plate lot (melange) number.

3.4.5.4 Quality Assurance Provisions for Production Processing of Electrode Assemblies. - Production processing and test operations on storage cell electrode assemblies consisting of initial inspection of plates, through formation, addition of KOH and sealing of storage cell with gauge assembly shall be controlled as follows:

3.4.5.4.1 General. -

3.4.5.4.1.1 Atmospheric Environment. - The environment of the formation facility shall be monitored with respect to humidity and temperature.

3.4.5.4.1.2 Handling of Materials. - All plates, separators and materials shall be handled with gloves and shall be sealed in clean room grade plastic bags when not being processed.

3.4.5.4.2 Storage Cell Formation. - If the formation step on the processes plaques occurs prior to cutting to finished size, or if the Seller finds the requirements stated as follows in compatible with his production process, the Seller may submit an alternate procedure for Grumman approval. Two copies of such submission, including all specifications and documentation shall be furnished prior to use.

3.4.5.4.2.1 Formation Pack Identification. - Sufficient numbers of previously inspected positive and negative electrodes constituting a storage cell pack shall have a formation pack identification number assigned. Formation pack identification numbers shall be referred to for all data recording during formation. Numbers shall be visible on each formation pack.

3.4.5.4.2.2 Separator Material (or Materials). - Separator material or materials used to wrap plate groups for formation shall be inserted such that the outside surface of the two outer electrodes is covered with separator material.

3.4.5.4.2.3 Formation Storage Cell Fabrication. - All formation storage cells shall be fabricated from alkali resistant materials such as nylong, plexiglass, etc. The adhesive or epoxy used to assemble the containers shall also be alkali resistant.

3.4.5.4.2.4 Electrical Clips and Leads. - Electrical clips and leads must be stainless steel, nickel or nickel plated steel. Means for attaching leads to clips must be alkali resistant.

3.4.5.4.2.5 Formation Pack Connectors. - The connectors holding the plates together in the formation storage cells shall be constructed of 316 or 304 stainless alloy, and shall be washed and rinsed in deionized water prior to installation.

3.4.5.4.2.6 Addition of Electrolyte and Water to Formation Storage Cells. - Electrolyte bubbling out of the storage cell during formation shall be avoided. At the end of the first formation cycle, electrolyte shall be added to a preset mark. Use 34 percent KOH to maintain preset mark.

3.4.5.4.2.7 Formation, Electrochemical Cleaning, Capacity Determination, and Setting Relative State-of Charge of Electrodes. -

3.4.5.4.2.7.1 Assembled Formation Packs. - Assembled formation packs shall be soaked in KOH (concentration as specified by the Seller) ± 0.5 percent for a minimum of 16 hours and a maximum of 24 hours prior to first electrical operation of formation.

3.4.5.4.2.7.2 Operational Conditions. - The following conditions shall be observed during operations associated with 3.4.5.4.2.7:

(a) KOH level in formation container shall be maintained above the top of the plate stack.

3.4.5.4.2.7.2 (Continued)

(b) Charge and discharge times shall be maintained as specified by the Seller within ± 4 percent of designated time periods.

NOTE: (1) Exact time of each charge and each discharge shall be recorded to nearest minute. Deviation from periods specified shall be subject to immediate Grumman notification and joint material review board action.

(2) In case of power failure, a notation shall be made and shall be clearly visible in a manner similar to that delineated on the sample Data Sheets.

(c) Where constant currents for charge or discharge are specified, and/or current measurements are used for calculations of ampere hour capacity, currents shall be regulated within ± 2.0 percent of specified value.

(d) Positive and negative current leads of each formation series circuit shall have an ammeter inerted in series with each lead. One ammeter shall be marked "control"; the second ammeter marked "monitor". Readings of two meters shall always match within ± 2.0 percent.

(e) Voltage of each formation storage cell, and current of series formation circuit measurements shall be made not more than five minutes prior to end of all charge or end of all discharge periods.

3.4.5.4.2.7.3 Storage Cell Formation. - Formation shall be performed in accordance with seller's schedule. Exceptions to certain operations are listed below and apply to all storage cells manufactured. The following steps shall be adhered to during the final capacity determination of positive electrodes and setting of relative state-of-charge of cadmium electrodes. The cell stack shall consist of 18 negative and 17 positive electrodes.

SPECIFICATION

No. AV-D559CS-1

3.4.5.4.2.7.3 (Continued)

(a) Last formation discharge to determine capacity of positive electrodes shall be made at the C/2 constant current rate (50.0 amps) to a storage cell voltage of 0.70 ± 0.1 volt.

(b) Voltage of each storage cell and discharge current shall be recorded at 15 minute intervals during capacity discharge. More frequent voltage monitoring is required to obtain a discharge time to an accuracy of one minute. Positive electrodes shall be verified as limiting electrodes by sampling one storage cell from each series formation group. (Series formation group may consist of up to 26 storage cells). Time for each storage cell to reach a voltage of +0.7 ± 0.1 volt shall be recorded.

(c) Each storage cell shall be removed from the discharge circuit at the specified voltage and individually placed under a 0.1 ohm ± 10 percent resistive load such that the voltage decreases to 0.1 ± 0.1 volt. The resistor may be removed from the storage cell as soon as it reaches its specified voltage range.

(d) Ampere hour capacity of positive electrodes as determined in paragraph (a) shall be a minimum of 110.0 ampere hours. Any storage cell exhibiting capacities below this value shall be permanently rejected.

(e) Formation discharge shall be continued at 10.0 ampere rate when all storage cell voltages in a series formation circuit are less than +0.1 ± 0.1 volt. Each storage cell voltage shall be recorded before starting the 10-ampere discharge.

(f) Positive electrodes shall be verified as limiting electrodes by sampling one storage cell from each series formation circuit. Series formation circuits may consist of up to 26 storage cells.

3.4.5.4.2.7.3 (Continued)

(g) Discharge time at the 10-amp rate shall be such that the negative plate capacity of storage cells in the series formation circuit are discharged by a minimum of 1.50 times the average of the positive plate capacity of the storage cells in the series formation circuit as determined in paragraph (a), and each storage cell shall be discharged to -0.20 $^{+0.00}_{-0.02}$ volt. Any storage cell to be acceptable must show a minimum capacity ratio of 1.50:1.00. This capacity ratio is defined as the ratio of the negative ampere-hour capacity obtained, divided by the positive ampere-hour capacity obtained for each respective storage cell.

(h) Storage cell voltage and series string current shall be recorded at least every 15 minutes during the 10-ampere discharge. More frequent voltage monitoring is required to obtain a discharge time to an accuracy of one minute. Total time that each storage cell is on 10-ampere discharge shall be recorded.

(i) Any storage cell exhibiting a voltage more negative than -0.25 volt during or at the end of the 10-ampere discharge period shall be rejected.

3.4.5.4.2.7.4 Wash, Rinse and Drying of Plates. -

3.4.5.4.2.7.4.1 Plate Stacks. - Plate stacks shall be removed from formation packs and immediately submerged in deionized water having the initial required resistivity measurement per 3.4.6.3.1. Plates from a series formation circuit shall not be mixed with plates from other circuits. Wash and rinse shall be completed when a Ph reading of 8.0 or less is demonstrated from the last dripping taken from plate samples pulled from wash container. Ph reading shall be recorded.

3.4.5.4.2.7.4.2 Drying. - Drying of plates shall be accomplished in air at 50 ± 5°C. Drying time shall be a minimum of 16 hours and a maximum of 24 hours. Oven temperature not exceeding the maximum limit

3.4.5.4.2.7.4.2 (Continued)

specified during drying operation shall be demonstrated. "Time in" and "time out" of oven on each group of plates shall be recorded. All internal storage cell components shall be handled with lint-free gloves in an area designated for aerospace storage cells. Good housekeeping procedures are required at all times.

3.4.5.4.2.8 Inspection and Weighing of Electrode Assemblies. - Inspection on each electrode shall be performed in accordance with 3.4.5.3. Particular attention shall be given to bent corners on grid and blisters on sintered material. Positive, negative and auxiliary electrodes for each storage cell shall be grouped and their weight per storage cell shall be recorded to the nearest 0.1 gram.

3.4.5.4.2.9 Weld Plates to Combs. - Plates shall be stacked and welded. Welds shall be in accordance with Specification MIL-W-8611A as applicable and shall be reasonably free of oxidation upon visual inspection. Welds shall be inspected for burn through of plate grid or comb and inspected for loose materials. The Seller shall supply weld procedures used and rejection criteria to Grumman for approval prior to use.

3.4.5.4.2.10 Plate Stack Wrap (Separator Material). - Separator material shall be tested in accordance with 3.4.3.1. Lot number and type of separator material shall be recorded on Data Sheets. Alignment of plate edges utilizing an alignment gage shall be performed.

3.4.5.4.2.11 Resistance Test of Plate Stack Assembly. - Electrode assemblies shall be compressed to the minimum equivalent final stack thickness of 1.363 inches ± 0.010 inch.

NOTE: Controlled periodic calibration required if conducted on a test jig.

While under compression, minimum resistance, (at 50 VDC) shall be 100 megohms. Storage cells not meeting this criteria shall be identified on Data Sheet and not reworked more than once.

3.4.5.4.2.12 Radiographic Examination. - Radiographs shall be taken of each storage cell for inspection of workmanship, foreign metallic particles and drawing compliance. Three radiographic views shall be provided for each storage cell. Prior to welding the cover to case, one edge view along the Zc axis (as defined in Figure 6) and one flat view along the Xc axis (as defined in Figure 6) shall be provided. After welding of cover to case and pinch-off, one flat view along the Xc axis shall be provided. No more than three storage cells shall be included in each radiograph taken of the flat view and no more than four storage cells shall be included in each radiograph taken of the edge view. As a minimum, each radiograph shall contain, storage cell serial number, positive or negative terminal location, view number, suitable control number, date radiograph was taken and an image quality indicator. All radiographs shall have good clarity. Prior to the performance of this task, the Seller shall submit to Grumman for review and approval a Radiographic Examination Procedure. Radiographs of all storage cells purchased shall be submitted to Grumman prior to shipment of the storage cells.

3.4.5.4.2.12.1 Rejection Criteria. - Storage cells shall be rejected if the following is observed:

(a) Foreign particles greater than 0.010 inch in any direction.

NOTE: The exception shall be those storage cells which have completed one rework cycle and still show foreign particles greater than 0.010 inch in any direction. These storage cells are permissible for use as test storage cells, provided that they can successfully pass all electrical and mechanical requirements specified herein. These storage cells shall be tagged and prior to shipment they shall be marked FOR TEST USE ONLY.

(b) Tab bends greater than 90 degrees.

(c) Poor workmanship and nonconformance to drawings.

3.4.5.4.2.12.2 Rework. - One rework cycle on defects detected prior to welding of cover to case is permissible. Additional rework requirements are:

(a) Workmanship - Each storage cell stack shall be closely re-examined, prior and during re-insertion in the container, for quality workmanship standards. Any degradation in workmanship standards, after or during rework, from those existing at the time of original manufacture shall be cause for rejection.

(b) Complete replacement of the stack wrapper is required if the stack was completely removed from its container during the rework.

(c) Each storage cell, if the stack was completely removed from its container during the rework, shall be subjected to the resistance test requirements of 3.4.5.4.2.11 and shall meet the requirements specified therein.

(d) A complete rework log shall be maintained and submitted to Grumman.

(e) A complete radiographic re-examination shall be conducted on the reworked unit.

(f) No rework shall be permitted on units where defects are detected after cover weld and/or pinch-off is completed.

3.4.5.4.2.13 KOH Fill. - KOH shall be prepared and tested in accordance with 3.4.6.3.3. Data from batch card on Data Sheet shall be recorded. Each storage cell with dust cap shall be weighed to the nearest 0.1 gram before KOH is added. Contamination of KOH shall be prevented by utilizing pre-weighed, bottled allotment while filling and by minimizing KOH exposure to atmospheric conditions. The amount of KOH shall be specified by the Seller. The exact procedure shall be submitted for Grumman approval.

SPECIFICATION

No. AV-D559CS-1

3.4.5.4.2.14 Storage Cell Weight. - Each storage cell shall be weighed immediately after fill and the dust cap installed to fill tube. Storage cell weight with dust cap shall be recorded to the nearest 0.1 gram. Weight gain must be within ± 3 percent of nominal value specified by the Seller. Pre-tested gage assemblies shall be installed within 10 minutes of filling operation. Storage cells left unsealed longer than 10 minutes shall be rejected. Immediately after installation of gage assembly, storage cells shall be evacuated to 25 inches minimum gage vacuum. All fittings, gages and associated components of the gage assembly shall be of non-corrosive material in a KOH environment. Jackets must be put on storage cells to assure surface of plates are parallel, and then torqued to a specified value. This torque value, and the restraining procedure shall be submitted for Grumman approval.

3.4.5.4.2.15 Leak Test of Storage Cell and Gauge Assembly. - After the cover has been welded to the storage cell case, and prior to filling with KOH electrolyte (as specified in 3.4.5.2.13), the storage cell shall be filled to 2.0 psia ±0.2 psia with Research Type, Zero Grade helium having the following impurities composition:

CO_2 = 0.5 PPM by volume

CH_4 = 0.5 PPM by volume

N_2 = 5.0 PPM by volume

Total Hydrocarbon Content (THC) = 1.0 PPM by volume

O_2 = 4 PPM by volume

H_2O = 4 PPM by volume

DEW Point = -89°F.

The pinch tube shall then be sealed.

SPECIFICATION

No. AV-D559CS-1

3.4.5.4.2.15.1 Helium Soak. - The storage cell under test shall be placed in a chamber which shall be pressurized to 2.0 ± 0.1 atmospheres using Research Type, Zero Grade helium as described above. The storage cell shall soak at this condition at an ambient temperature 77 ± 10°F, and with the pressure maintained within the above noted limits for a period of not less than 48 hours, or more than 72 hours.

3.4.5.4.2.15.2 Leak Test. - At the termination of the soak period, the pressure in the chamber shall be reduced to 1.0 ± 0.05 atmosphere, and the storage cell shall be removed to the helium detection mass spectrometer bell jar. No more than 2 minutes shall elapse between removal from the pressure chamber and sealing of the mass spectrometer bell jar. While handling the storage cell under these conditions, contact with welded or sealed surfaces shall be avoided. White lint-free gloves shall be worn and the room atmosphere shall be that of a Class I Clean Room.

NOTE: The above constraints may be avoided if the mass spectrometer bell jar is modified for use as a pressure chamber. However, handling of the storage cell prior to placement in the bell jar shall be subject to the constraints listed above.

The mass spectrometer bell jar shall be evacuated to a pressure of $\leq 1.0 \times 10^{-6}$ mmHg. The mass spectrometer shall be activated within 1 minute after the pressure has stabilized. Since the high pressure soak may cause helium to become entrapped on rough surfaces, the initial readings may be very high. Continuous leakage rate readings shall be taken at least once every 5 seconds until the readings are stable. (Stability is considered to be change of less than 1 percent in any 3 sequential readings.) The stable readings shall indicate a leakage rate of $\leq 1.0 \times 10^{-8}$ std cc/sec. per cubic inch of free volume. The readings shall stabilize within less time than that required for 10 percent of the helium backfill (by volume) to be emitted through the seal at the leakage rate limit. In the event that stable readings are not

3.4.5.4.2.15.2 (Continued)

obtained within this time, or that the stable readings are $\geq 1.0 \times 10^{-6}$ std cc/sec. per cubic inch, or $\leq 1.0 \times 10^{-10}$ std cc/sec. per cubic inch, the storage cell shall be subjected to the gross leak bubble test of Standard MIL-STD-202D, Method 112A, Test Condition B before proceeding to the next step in fabrication. If the storage cell passes this test, no further leak testing other than KOH leakage per 4.5.15 shall be performed. If the storage cell fails the bubble test, it shall be permanently rejected. (Note that the above test is a modified form of Standard MIL-STD-202D, Method 112A, Test Condition C, Procedure IIIA).

3.4.5.4.2.16 State of Charge Adjustment. - The Seller shall provide for a procedure to adjust the charge on the negative electrodes of each storage cell. The procedure used shall include sufficient quantitative measurement of storage cell parameters during the charge adjustment such that calculations can be made to determine exact charge adjustment on negative electrodes. The procedure is subject to Grumman approval prior to use.

The excess negative capacity as measured in 3.4.5.4.2.7.3(g) shall be distributed in a finished storage cell as follows:

(I_oTN1) shall show a value between 20 percent and 30 percent of (I_oTN3), as defined in 3.4.5.5.3.5.

The distribution of the negative electrode capacity shall be determined in accordance with 3.4.5.5. If any storage cell of a formation lot fails to meet the requirements of this paragraph, or cannot yield a negative to positive capacity ratio $\frac{(TN3)}{(TP3)}$ of $\geq 1.50:1.00$, as defined in 3.4.5.5.3.5, for the total storage cell stack, the entire formation lot shall be rejected.

3.4.5.5 Quality Assurance Provisions for Electrode Capacity Test. - The electrode capacity test shall provide a measure of the discharge capacity of the positive (nickel) electrode and of the

3.4.5.5 (Continued)

negative (cadmium) electrode of storage cells as separate data under a standard set of conditions. This test shall be run in a manner such that the excess negative capacity beyond complete discharge of the positive (or excess positive beyond the negative in case of storage cells that may be negative limited on discharge) may be determined in addition to the total capacities of the electrodes. These data may be used to establish one or more of the following:

(a) Range and distribution of positive capacities.

(b) Range and distribution of negative capacities.

(c) Difference between and/or ratio of total negative and positive capacities.

(d) Excess negative (or positive) on discharge.

(e) Excess negative on charge.

A total negative/positive capacity ratio of 1.50:1.00 minimum is required. Any ratio less than 1.50:1.00 obtained under the following conditions specified is subject to rejection of the entire storage cell group it represents.

3.4.5.5.1 Sampling Rate. -

(a) A minimum number of storage cells, as shown in the table as follows, from each formation group of 52 storage cells (or less) shall be random selected at the conclusion of the electrical formation cycles. The test storage cell(s) shall be selected prior to further processing. Electrolyte level shall be adjusted to a minimum of 1/4 inch above the separator. Tests shall start as soon as possible, but not more than two days after formation.

SPECIFICATION

No. AV-D559CS-1

3.4.5.5.1 (Continued)

(a) (Continued)

NOTE: Electrodes of a smaller size may be used for this sample, but minimum size shall be 12.0 ampere-hour capacity. Such electrodes shall be taken from the same plaques as those for the formation group, and plaque uniformity shall be demonstrated. Plaque uniformity criteria, and other processing and test criteria relating to this test under the following conditions shall be submitted for Grumman approval.

(b) A minimum number of storage cells as shown in the table as follows, from each formation group of 52 storage cells (or less) shall be random selected at the conclusion of the plate neutralization and drying operation. The test storage cell(s) shall be fabricated with formation hardware to standard storage cell core configurations (i.e.: 17 positive electrodes, 18 negative electrodes). The storage cell(s) shall be flooded with 34 percent KOH solution to a level 1/4 inch minimum above the separator. Tests shall be performed as soon as possible, but prior to activation of storage cells of this particular formation group.

(c) A minimum number of storage cells, as shown in the table as follows, from each formation group of 52 storage cells (or less) shall be random selected at the completion of the standard capacity test. (Discharge capacity immediately prior to pinch tube closure). Following the standard 0.2 ohm and dead short periods, the test sample(s) shall be opened by removal of the gage assembly and flooded with 34 percent KOH. Tests shall be performed on sample storage cells prior to any pinch-off tube closure of formation groups from which the sample was taken.

3.4.5.5.1 (Continued)

TABULATION OF SAMPLING RATE

Paragraph	Development Storage Cell Group	27-Storage Group	74-Storage Cell Group
3.4.5.5.1(a)	2	1	2
3.4.5.5.1(b)	-	-	-
3.4.5.5.1(c)	2	1	2

3.4.5.5.2 Applicable Conditions. - The following conditions are applicable:

(a) Storage cell temperature shall be between 75 ± 5°F.

(b) Storage cell terminal voltage shall be recorded.

(c) Voltage from both positive and negative terminals to the reference electrode shall be recorded continuously or at intervals not to exceed 15 minutes.

(d) Since material purity is of utmost importance to the performance, life and reliability of these storage cells, no contamination by foreign materials is permissible. The following precautions are those considered minimally adequate to assure fulfillment of this requirement during all handling and storage:

(1) Electrode plaques, and stored electrodes shall be kept in inert atmosphere in sealed containers.

(2) If the same facility, manufactures or processes silver and/or zinc electrodes, complete separation of the area in which these storage cells are handled is mandatory.

3.4.5.5.2 (Continued)

(d) (Continued)

(3) No smoking, eating or food storage shall be permitted in the electrode processing and/or storage cell assembly areas.

(4) Lint-free gloves and clothing shall be worn at all times by personnel handling plaques, electrodes and storage cell assembly. Hair covering are strongly recommended.

(5) As a minimum, atmosphere in the plaque, electrode processing and storage cell assembly area shall be conditioned to maintain temperatures of 75 ± 5°F, 50 ± 5% relative humidity. Air exchange techniques and filtering shall be used with exchange flow rates of not less than 75 linear feet/minute to avoid settling of dust and other foreign contamination particles. A Class I Clean Room is preferred.

NOTE: Since the storage cell is in a stainless steel container, and both electrode terminals are insulated from the container, the container itself may be used as a rough substitute for a reference electrode. Even though the container potential is a function of the pressure O_2 or H_2 in the storage cell, the changes in electrode voltage at end of capacity are relatively large and usually can be clearly identified using the container as a reference.

3.4.5.5.3 Test Procedure. -

3.4.5.5.3.1 Residual Negative Electrode Capacity. - A 0.20 ohm ± 5% resistor shall be placed across the storage cell terminals for 16 hours. Then discharge at 10.0 amperes until terminal voltage indicates -1.0 volt. Terminal (storage cell) voltage and voltage from both positive and negative terminals to reference electrode shall be recorded.

3.4.5.5.3.2 Filling. - Storage cells shall be filled until flooded with 34 percent KOH solution. KOH quantity required and additional electrolyte added during entire test shall be recorded.

3.4.5.5.3.3 Charge. - Storage cells shall be charged at 10.0 amperes for a minimum period of 40 hours until a storage cell voltage of 1.51 volts is reached. A maximum period of 64 hours shall not be exceeded. Storage cell and reference storage cell voltages shall be recorded continuously or at intervals not to exceed 1 hour.

3.4.5.5.3.4 Discharge. - Storage cells shall be discharged at 50.0 amperes until terminal voltage indicates -1.0 volt. Positive and negative terminal to reference voltages shall be time recorded when the storage cells terminals reach:

(a) +1.0 volt

(b) +0.5 volt

(c) 0.0 volt

(d) -0.5 volt

(e) -1.0 volt

NOTE: The storage cells shall be protected from further contact with the atmosphere in the event further testing is required.

3.4.5.5.3.5 Calculations. -

Let

(T_{N_1}) = time to -1.0 V (as delineated in 3.4.5.5.3.2)

= time to discharge precharged negative

3.4.5.5.3.5 (Continued)

(T_{P_3}) = time from start of discharge (full charge) to +0.5 V (as delineated in 3.4.5.5.3.4(b)).

= time to discharge positive electrode

(T_{N_3}) = time to -1.0 V as delineated in 3.4.5.5.3.4(e).

= time to discharge total negative electrode

I_O = discharge current = 50.0 amps.

Then

$I_O \left[(T_{N_3}) - (T_{P_3}) \right]$ = excess capacity of total negative over positive

$I_O (T_{N_1})$ = precharged negative capacity

$I_O \left[(T_{N_3}) - (T_{P_3}) - (T_{N_1}) \right]$ = excess (discharged) negative capacity at the charged end

$\frac{(T_{N_3})}{(T_{P_3})}$ = negative-to-positive ratio

3.4.5.5.3.6 Submittal of Data. - Two copies of all information obtained shall be submitted to Grumman. Storage cell fabrication and/or testing may continue, at the seller's own risk, provided that the storage cells have met the criteria established above.

3.4.6 Terminals. - Terminals provided for positive and negative electrodes shall be rated at not less than 100 amperes continuous duty. The terminals shall be made from pure, non-porous nickel, number 270 cold-drawn rod stock. Both terminals shall be insulated from the storage cell cover by means of a ceramic insulator having an alumina content of 96 percent nominal but not less than 94 percent. The insulator-to-cover junction shall employ a stress-relief configuration such that

3.4.6 (Continued)

relative motion between the terminal assembly and the cover applies minimum stress to the insulator and to the metal-to-insulator bonds. The collar-to-insulator and insulator-to-terminal bonds shall be made using a metal-to-ceramic bonding process subject to approval by Grumman.

3.4.6.1 Control and Testing of Feedthrough Terminals and Seals. - Materials, manufacturing and test operations on the storage cell feedthrough terminals, seals and related hardware shall be controlled by the following criteria. Two copies of all data obtained herein shall be furnished to Grumman prior to further processing.

3.4.6.1.1 Ceramic Material. - The ceramic material shall be alumina of 94 percent purity minimum.

3.4.6.1.2 Mechanical Inspection. -

(a) Dimensions - Sampling 2.5 A.Q.L.

(b) Chips, cracks, grain structure (uniform density), voids - 100% inspection, visual & radiographic

3.4.6.1.3 Cleaning. - Components shall be cleaned by ultrasonic bath using freon.

3.4.6.1.4 Lot Tensile Test. - Each new lot of active metal and each new lot of ceramic shall be subjected to an ASTM tensile specimen test. A minimum of three sets shall be treated identical to standard production processes, then vacuum brazed using an iron-nickel alloy 52 washer. Sample tensile strength must exceed 6000 psi. The Seller may propose an alternate test, subject to approval by Grumman.

3.4.6.1.5 Braze Alloy. - The braze alloy shall consist of silver-copper - 5 percent palladium, and shall contain a minimum of carbon. Each new lot of active metal shall be subjected to a semi-quantitative spectographic analysis. In addition to the expected

3.4.6.1.5 (Continued)

elements, the carbon content shall be measured. Allowable impurity limits shall be established by the storage cell seller and made available to Grumman. A braze flag test shall be run on each lot to determine solidus and liquidus points, or supplier's certification on each lot used herein shall be furnished to Grumman. Immediately after completion, a 2 percent sample or one(1) piece, whichever is greater, of brazed headers shall be supplied to Grumman for metallurgical studies.

3.4.6.1.6 Cover Assembly. -

3.4.6.1.6.1 Metal Parts. - Metal parts shall be inspected for conformance to drawings, physical dimensions, surface defects, and burrs that may interfere with intended function.

3.4.6.1.6.2 Cleaning. - Chemical cleaning shall be utilized on all parts and a combination of chemical cleaning and furnace firing shall be utilized on cup and collar to prepare them for vacuum brazing.

3.4.6.1.6.3 Welding of Pinch Tube to Cover. - Welding of pinch tube to cover shall be controlled by a process specification to insure adequate weld strength and seal integrity or may be tested as an integral part of the cover.

3.4.6.1.7 Inspection. - Cracks, porosity, excessive burning, oxidation and foreign inclusions shall be inspected 100 percent. 100 percent inspection shall be performed on all pinch tube cover welds and they shall be capable of passing a helium leak test (leak rate in accordance with 3.4.5.4.2.15). Samples shall be tested periodically for weld quality by metallurgical sectioning.

3.4.6.1.7.1 Assembly Fixturing. - Mechanical fixturing shall be adequate to insure maintenance of part positions during brazing operation. Self-jigging features shall be included where possible. Particular attention shall be paid to alignment of terminal post and ceramic to maintain concentricity. Provision for periodic cleaning of fixture shall be made.

SPECIFICATION

No. AV-D559CS-1

3.4.6.1.8 Vacuum Braze Operations. - Processes shall be established which ensure clean handling of parts and fixtures. A brazing inspection plan shall be submitted by the Seller for Grumman approval.

3.4.6.1.9 Visual Inspection. - All units shall receive inspection of terminal location, seal junction continuity, braze joint quality, pinholes, and flowout shall be visually inspected using magnification aids where required.

3.4.6.1.10 Insulator Resistance. - All units shall receive an insulation check. Each unit must exhibit resistance above 100 megohms at 50 VDC.

3.4.6.1.11 Leak Check. - Each complete cover assembly shall receive a leak test to assure braze-joint integrity in accordance with 3.4.5.4.2.15 with the following exceptions:

(a) The leak test process shall be done in accordance with Standard MIL-STD-271, paragraph 6.1.2 through 6.5 as amended for the actual hardware, and by 3.4.5.4.2.15 herein.

(b) The helium soak shall be done in the mass spectrometer's bell jar, with the under side of the cover exposed to the vacuum, and the upper side exposed to the helium at 1.0 $\pm$ 0.05 atmosphere. The soak period shall be 1 to 2 hours.

(c) Following the soak period, the maximum leak rate shall be 1.0×10^{-8} std. cc/sec.

(d) There shall be no bubble test for assembled covers.

The above test shall be performed on a 100 percent sample basis at the Seller's cover assembly facility. The storage cell seller shall perform the same test as part of his incoming inspection procedure on an AQL basis TBD. The storage cell seller shall be cause for rejection of the cover lot.

SPECIFICATION

No. AV-D559CS-1

3.4.6.1.12 Insulator Resistance. - Insulator resistance shall be tested by 100 percent sampling. The resistance across each insulator shall exceed 100 megohms when 50 VDC is applied. After completion of storage cell assembly, but prior to filling, the resistance shall be measured, using a megohmmeter applying 50 VDC as follows:

(a) (+) terminal to (-) terminal, resistance shall be 100 megohms or greater.

(b) (+) terminal to case
(c) (-) terminal to case
} Resistance shall be 100 megohms or greater.

3.4.6.2 Control and Testing of Water and Electrolyte. - The electrolyte solutions and wash water used for storage cells specified herein shall be of high purity. Two copies of all data obtained herein shall be submitted to Grumman prior to further processing.

3.4.6.2.1 Deionized Water. - Deionized water used in all wash water, dilutant, or additive shall have a resistivity of greater than 1.0 megohm-cm. In the event the resistivity drops below 1.0 megohm-cm, the process shall be stopped until the resistivity is restored to the specified limits. The resistivity is to be determined prior to each operation in which the water is used. A suitable conductivity storage cell calibrated less than two weeks prior to start of water requirement tests used on storage cells constructed under this specification shall be used. Criteria for calibration shall be as follows:

(a) The conductivity storage cell shall be re-calibrated at two week intervals (maximum) until completion of the water requirement tasks.

(b) The calibration shall be conducted in a 0.1 percent potassium chloride solution and shall record a conductivity of 1410 ± 20 micromhos at 25°C (a temperature correction as per the hanbook of Chemistry and Physics may be used). If conductivity is not within these tolerances, the conductivity storage cell must be replaced or replatinized.

3.4.6.2.1 (Continued)

(c) The silica content in the water shall not exceed 1 ppm.

(d) The solids content of the water must be determined by the Seller. The maximum solids content shall not exceed 50 PPM, and shall be recorded as data for submission to Grumman.

3.4.6.2.2 Distilled Water. - Distilled water used either as wash water, dilutant or additive shall be tested, and shall meet the requirements of 3.4.6.2.1(c) and (d).

3.4.6.2.3 Electrolyte. - The supplier, batch number, grade, analysis, date of purchase and data container is opened must be recorded. The potassium hydroxide "mercury cell" grade electrolyte concentrate as defined by Allied Chemical Company or equivalent, shall be mixed with the distilled water to make-up a solution with a tolerance of ±0.5 percent. Each batch of electrolyte shall be analyzed for carbonate content and hydroxyl ion concentration using the double titration method of phenolphthalein end point followed by methl purple or orange end point. Carbonate concentration must be less than 0.01 gm/liter. The hydroxyl ion concentration shall be determined by analytical methods. The concentration tolerance to KOH shall be +20 mg/cc. The electrolyte shall be analyzed for nitrate content. The tolerance level is 1 mg/liter nitrate or less, using a colorimetric analysis technique. The Seller shall prepare procedure details and submit them to Grumman for approval. The shelf life of the standard acid used in the titration shall not have been exceeded.

The completed solution shall be stored in sealed, pre-weighed containers until used for storage cell fill. Each such container shall be identified with the original concentrate batch data noted above, the date of dilution, the date of test, the test data sheet and the storage cell serial number for which it will be used. During storage process, minimum exposure to ambient air shall be required.

3.4.6.2.31 Sample. - The Seller shall supply Grumman with an electrolyte sample of each electrolyte batch (after dilution to the proper concentration) used in the storage cell construction. The quantity of electrolyte sample shall be approximately 1 oz. It shall

3.4.6.2.31 (Continued)

be supplied in capped polyethylene bottle(s) permanently marked to identify the storage cell serial numbers this electrolyte batch was used for.

3.4.6.2.4 Spectrochemical Analysis. - A spectrochemical analysis shall be performed on the electrolyte from each batch used for storage cells. The content of the following impurities shall be determined and reported:

(a) Silver

(b) Cobalt

(c) Copper

(d) Iron

(e) Sulfur

(f) Zinc

Any other impurity found to be present in concentrations greater than 100 ppm shall also be reported.

3.4.7 Cover-to-Case Junction. - The cover shall be electric-arc welded to the container using inert gas shielding. No welds beyond dimensional limits shall be permitted. Weld joints shall not be ground or polished. Weld beads shall be smooth and free of folds. Repair welds are acceptable provided repair areas meet the above weld requirements and the repair is accomplished by using filler wire conforming to Specification MIL-R-5031, Class I or II.

Prior to case to cover weld and prior to complete insertion of the storage cell stack, the exterior of the storage cell container shall be permanently serialized. Any technique other than electro-etch requires prior Grumman approval.

3.4.8 Electrolyte Leakage. - The storage cell shall show no evidence of electrolyte leakage whenever subjected to the test of 4.5.13 up to four (4) years after completion of the storage cell manufacture.

SPECIFICATION

No. AV-D559CS-1

3.4.9 Size and Weight. - The size and weight of the storage cell shall not exceed the limitations specified in Specifications Control Drawing TBD. The seller shall establish such weight control procedures as are necessary to insure meeting this guarantee.

3.4.10 Operating Position. - The storage cell shall operate normally in any position and under any gravity conditions from zero "g" to 11.3 "g". (See 4.5.7)

3.4.11 Operating Temperature. - Each storage cell shall be capable of functioning normally, shall have dimensional stability, and shall deliver at least 80 percent of its respective rated capacity within the above specified voltage, when operating at temperature extremes of 30°F to 110°F. (See 4.5.9 and 4.5.10).

3.4.12 Thermal Vacuum. - The storage cell shall be capable of operating in a pressure of 1.0×10^{-6} mm Hg without evidence of mechanical or electrical failure or electrolyte leakage.

3.4.13 Vibration. - The storage cell shall be capable of operating under vibration as specified in 4.5.6 without internal storage cell mechanical failure or leakage.

3.4.14 Mechanical Shock. - The storage cell shall be capable of operating under shock as specified in 4.5.8 without showing evidence of mechanical or electrical failure.

3.4.15 Gas Tightness of Storage Cells. - The storage cell suitably restraining, shall be hermetically sealed and shall be capable of withstanding an internal gas pressure of at least 225 psia at 145°F without leakage for 30 minutes at any ambient pressure from one atmosphere down to a pressure of 1.0×10^{-6} mmHg or less. In order to permit satisfactory leak detection procedures to be used on sealed equipment, all such items shall contain between 8 percent and 12 percent of helium gas by volume. The design objective for each item shall be zero leakage at the expected pressure differential. The maximum allowable leak-rate of the sealed storage cell shall be as defined in 3.4.5.4.2.15.

SPECIFICATION

No. AV-D559CS-1

3.4.16 Acceleration. - The storage cell shall be capable of withstanding accelerations as specified in 4.5.7 without mechanical or electrical failure.

3.4.17 Container Finish. - See paragraph 3.4.4

3.4.18 Identification of Product. - The manufacturer shall identify each storage cell by branding or stamping a serial number plus date of activation on an accessible area. In addition, storage cells that are delivered to Grumman shall be stamped or tagged as follows:

Weight_____ A.H. at 1-Hour Rate_____

Date of Activation_____ Type Nickel-Cadmium

Manufacturer Mode No._____

Manufacturer Serial No._____

GAC Specification Control Drawing No. and Dash No. _____

3.4.19 Polarity Markings. - The polarity of the positive terminal shall be plainly indicated on the container cover by electro-etch.

SPECIFICATION

No. AV-D559CS-1

3.4.20 Manufacturing Data. - The manufacturer shall maintain a log on the history of each storage cell by recording the following data:

(a) Serial number of storage cell

(b) Date of manufacture (date of pinch-off)

(c) Date of activation (addition of electrolyte)

(d) Type and duration of electrical tests performed on the storage cells

(e) Charge and discharge method and rate used in electrical tests

(f) End of charge and discharge voltages

(g) Test conditions

(h) Test results including features

(i) Material traceability (consisting of complete records of storage cell components including batch numbers and components)

This log shall be maintained on all storage cells manufactured for the Manned Orbiting Space Station Storage Battery Module development program and shall be available to Grumman on request.

3.4.21 Workmanship. - The storage cells, including all parts and accessories, shall be manufactured in a thorough workmanlike manner. Particular attention shall be paid to neatness and cleanliness.

3.4.21.1 Neatness. - Neatness shall include thoroughness of soldering, wiring, impregnation of coils, potting, conformal coating, marking of parts, and assemblies, plating, painting, riveting, machine screw assemblage, welding, brazing and freedom of parts from burrs and sharp edges.

3.4.21.2 Cleanliness. - Each part, component of the equipment shall be free from residual contaminants such as corrosion inhibiting oils, cutting oils, forming oil lubricants, greases, dyes, wire clippings, solder balls, non-metallic shim stock, extraneous debris and dirt.

Precautions shall be taken to prevent contamination of the equipment during manufacturing, handling and shipping. The seller shall maintain adequate controls to assure consistency in maintaining acceptable workmanship and cleanliness levels. Quality workmanship and cleanliness standards, including any required visual aids, shall be established and submitted to Grumman for approval.

3.5 Performance. -

3.5.1 Capacity. - The storage cell shall meet the following capacity requirements:

Condition	Temp °C	Discharge Current Amp	Discharge Time Hrs.	Min. Cut-Off Volt.	Min. Reqd. Capacity A.H.
1	20	83.5	1.20	1.00	100.0
2	20	50.0	2.10	1.00	105.0
3	20	20.0	5.50	1.00	110.0
4	0	83.5	1.20	1.00	100.0
5	0	50.0	2.10	1.00	105.0
6	0	20.0	5.25	1.00	105.0

3.5.2 Life. - The storage cell shall be capable of withstanding an 11,000 cycle charge-discharge test as specified in 4.5.3. Thirty-thousand cycles shall be a design goal.

3.5.3 Retention of Capacity. - The storage cell shall be designed to meet the retention of capacity after tests specified in 4.5.4.

SPECIFICATION

No. AV-D559CS-1

3.5.4 Storage. -

3.5.4.1 In Dry (Unfilled) Condition. - The fully assembled, dry (unfilled) storage cell, when stored for periods up to 5 years, shall show no detrimental performance effects. After activation, the storage cell shall be capable of meeting all performance requirements stated herein and shall show no performance deviations.

3.5.4.2 In Filled (Sealed) Condition. - The storage cell shall be designed to meet the storage test of 4.5.5 in filled (sealed) condition.

3.5.5 Thermal Requirements. - The internal thermal design of the storage cell shall be such that satisfactory operation of the storage cells is assured under all operating conditions when the storage cell case surface temperature is maintained at 32°F to 68°F. All operation, performance and reliability requirements specified herein shall be met within these extremes.

3.5.6 Charging. - All storage cells shall be capable of being charged at a maximum charge rate of 62.2 amperes. Charging shall be accomplished within the maximum limiting voltage constraint specified in Figure 1. Each storage cell shall be capable of being fully charged from 50 percent to 100 percent state of charge in a maximum of 58 minutes without exceeding the limiting voltage value specified in Figure 1. (This charge shall include the overcharge necessary to account for the ampere-hour efficiency value of the storage cell at a particular temperature.) (See Figure 2.) All storage cells shall be capable of accepting continuous overcharge currents up to the maximum values shown in Figure 4 without exceeding 75 psig internal storage cell gas pressures and the limiting voltage value specified on the lowest curve in Figure 1.

3.5.7 Retention of Charge. - Each storage cell shall be free of short circuiting paths between negative and positive terminals and shall maintain an open circuit voltage of no less than 1.15 volts when tested in accordance with the provisions of 4.5.11.

3.5.8 Internal Impedance. - Each storage cell shall have internal impedance parameters within the range shown below when measured under the specified conditions:

Parameter	Range of Value(s)	Measurement Condition
TBD	TBD	4.5.1.3.TBD
TBD	TBD	4.5.1.3.TBD
TBD	TBD	4.5.1.3.TBD
TBD	TBD	4.5.1.3.TBD
TBD	TBD	4.5.1.3.TBD
TBD	TBD	4.5.1.3.TBD

4 QUALITY ASSURANCE PROVISIONS

4.1 Classification of Tests. - The inspection and testing of the 100 ampere-hour Nickel-Cadmium Storage Cells and component parts shall be classified as follows:

(a) Development Tests

(b) Qualification Tests

(c) Quality Assurance Tests

4.2 Development Tests. - Development tests shall be conducted in two parts as follows:

(a) Storage Cell Testing

(b) Thermal Testing

The results of these tests shall be used to provide design data for the 100 ampere-hour Nickel-Cadmium Storage Cell.

4.2.1 Storage Cell Testing. - Each storage cell of the Development Test Group as defined in the Purchase Order shall be subjected to the following tests:

Test No.	Test Type	Temp.	CHARGE Rate	CHARGE Time*	CHARGE End Volt*	DISCHARGE Rate	DISCHARGE Time	DISCHARGE End Volt
1	Conditioning	+20°C	10 Amp	16 Hr	1.51 V Max.	50 Amp	Data	1.0 V Min.
2	Cap., C/2	+20°C	30 Amp	5 Hr	1.51 V Max.	50 Amp	Data	1.0 V Min.
			3 CYCLES					
3	Cap., High Rate	+20°C	30 Amp	5 Hr	1.51 V Max.	100 Amp	Data	1.0 V Min.
4	Cap., High Chg	+20°C	60 Amp 30 Amp	2 Hr 1 Hr	1.51 V Max.	50 Amp	Data	1.0 V Min.
5	Cap., Low Chg	+20°C	15 Amp	10 Hr	1.51 V Max.	50 Amp	Data	1.0 V Min.
6	Overchg	+20°C	30 Amp 10 Amp	5 Hr 8 Hr	1.51 V Max.	50 Amp	Data	1.0 V Min.
7	30% DOD Cycle	20°C	37.4 Amp	58 Minutes	1.51 V Max.	50 Amp	36 Minutes	Data
			3 CYCLES					
8	Conditioning	0°C	10 Amp	16 Hr	1.56 V Max.	50 Amp	Data	1.0 V Min.
9	Cap., C/2	0°C	30 Amp	5 Hr	1.56 V Max.	50 Amp	Data	1.0 V Min.
			3 CYCLES					
10	Cap., High Rate	0°C	30 Amp	5 Hr	1.56 V Max.	100 Amp	Data	1.0 V Min.
11	Cap., High Chg	0°C	60 Amp 30 Amp	2 Hr 1 Hr	1.56 V Max.	50 Amp	Data	1.0 V Min.
12	Cap., Low Chg	0°C	15 Amp	10 Hr	1.56 V Max.	50 Amp	Data	1.0 V Min.
13	Overchg	0°C	30 Amp 5 Amp	5 Hr 8 Hr	1.56 V Max.	50 Amp	Data	1.0 V Min.
14	30% DOD Cycle	0°C	37.4 Amp	58 Minutes	1.56 V Max.	50 Amp	36 Minutes	Data
			3 CYCLES					

* Stop charge at indicated time or End Voltage, whichever occurs first.

SPECIFICATION

No. AV-D559CS-1

4.2.1.1 Test Conditions and Data Acquisition. -

(a) The tests of 4.2.1 shall be performed under the following conditions:

(1) Temperature Tolerance: ± 1°C

(2) Current Tolerance: ± 2%

(3) End Voltage Tolerance: ± 10 millivolts

Data shall be taken on a continuous sampled basis to four significant figures, and at a sampling rate of no slower than four readings per second. Data acquisition shall be by means of a 200-channel automatic recording system with either punched paper tape or magnetic tape readout. The system, which will be furnished by Grumman, will have a printer readout as well which can be commanded to observe trends. Grumman will supply data reduction computer programs and will provide copies of the reduced data to the seller.

(b) The following data shall be taken:

(1) Storage Cell Series String Current

(2) Individual Storage Cell Voltage

(3) Auxiliary Electrode Signal Voltage

(4) Two Individual Storage Cell Case Temperatures per Figure TBD

(5) Environmental Temperature

(6) Time to the nearest minute

The seller shall provide a detailed test plan covering these items for Grumman approval at least 45 days prior to the start of any test.

4.2.2 Thermal Testing. - Two selected storage cells of different designs shall be subjected to thermal tests in a calorimeter whose construction is TBD. At least three days shall be devoted to testing each storage cell at a storage cell case temperature of 20°C, and the same time to testing at a storage cell case temperature of 0°C. One-third of each test period shall be devoted to orbital cycling at 12 percent, 30 percent and 50 percent DOD, respectively, using the orbital cycle definition of 3.2.2.1.

The following charge and discharge parameters shall be used:

	CHARGE		DISCHARGE	
Depth of Disch. (DOD)	Rate	Time (Min.)	Rate	Time (Min.)
12%	14.5 Amp	58	20 Amp	36
30%	37.4 Amp	58	50 Amp	36
50%	62.2 Amp	58	83 Amp	36

End-of-charge and end-of-discharge voltage limits shall be the same as those shown in 4.2.1. If end-of-charge voltage limit is reached before charge time expires, charging shall continue at constant potential (tapered charge).

The seller shall submit a detailed test plan for Grumman approval which shall contain at least the following information:

(a) Test Data to be taken and Measurement Techniques

(b) Calorimeter construction and test set-up.

This plan shall be submitted at least 45 days prior to the start of testing.

SPECIFICATION

No. AV-D559CS-1

4.3 Qualification Tests. - Qualification Tests are those tests conducted on prototype units of the storage cells. The units are "prototype" only in the sense that they are intended for evaluation and test purposes; they are to be identical in manufacture to production units. Qualification tests shall consist of two parts:

(a) Performance Tests

(b) Environmental Tests

4.3.1 Performance Tests. - Performance Tests shall be conducted under laboratory conditions for the purpose of demonstrating that the electrical performance and container characteristics of the storage cells meet the requirements of this specification. Performance Tests shall include but not necessarily be limited to the following:

(a)	Examination of Product	4.5.1
(b)	Capacity	4.5.2
*(c)	Life-Cycling	4.5.3
*(d)	Retention of Capacity	4.5.4
*(e)	Storage	4.5.5
(f)	Modified Constant Potential	4.5.6
(g)	Operating Position	4.5.7
**(h)	Electrolyte Leakage Test	4.5.15
(i)	Retention of Charge	4.5.16

* To be performed at Grumman
** May not be performed prior to Leak Detection Test per 3.4.5.4.2.15 and 4.5.12.

SPECIFICATION

No. AV-D559CS-1

4.3.2 Environmental Tests. - Environmental Tests shall be conducted in accordance with the requirements specified herein, and those contained within the Final Statement of Work, for the purpose of demonstrating that the storage cells can withstand the environmental requirements specified for the Manned Orbiting Space Station Storage Battery Module. Since the storage cells are required to operate during launch, they shall be operated during all Environmental Tests as indicated herein. Environmental Tests shall include but not necessarily be limited to the following:

(a)	Sinusoidal and Random Vibration	4.5.6
(b)	Acceleration	4.5.7
(c)	Shock	4.5.8
*(d)	Leak Detection	3.4.5.4.2.15 & 4.5.9

* Must be performed before performance of Electrolyte Leakage Tests.

4.3.3 Qualification Test Plans. - Qualification tests are those tests conducted on the test samples specified in 4.3.3.1, for the purpose of demonstrating that the storage cells meet all the requirements of this specification. The seller shall propose complete qualification testing of the storage cells and provide the necessary facilities for accomplishing this task. Available facilities for environmental testing shall be described. Testing procedure and equipment shall be subject to Grumman approval. Qualification tests shall be proposed to Grumman in the form of test plans submitted 45 days prior to the start of the tests. These plans shall contain details as to the scope and purpose of the tests, the determination of the test conditions, a description of the test setup and procedures, and other pertinent data. Upon approval of the test plan by Grumman, the tests shall be conducted in accordance with the approved test procedure. Grumman shall be advised when tests are to be conducted so that a representative may be designated to witness the tests when so desired. Photographs shall be obtained wherever practicable and test logs shall be maintained to record all significant observations and events during the test. Qualification test plans shall be in accordance with the requirements specified herein and those contained in the Final Statement of Work.

4.3.3.1 Sampling Instructions. - Qualification test samples shall consist of a specified number of storage cells identical in manufacture to production units. Samples shall be identified as such and they shall be used as follows:

(a) A specified number of storage cells shall be subjected to Capacity and Life tests. Life tests shall be conducted at Grumman.

(b) A specified number of storage cells shall be subjected to all the Qualification Storage Cell tests of this specification except Life tests.

NOTE: The Purchase Order will specify the number of test samples to be used for each test.

4.4 Quality Assurance Tests. - The seller shall conduct a Performance Test on each production unit of the storage cell to demonstrate the continuance of quality of each unit intended for orbit.

4.4.1 Performance Tests. - Performance tests shall be conducted under laboratory conditions for the purpose of demonstrating that the electrical performance of the storage cells meets the requirements of this specification. Performance tests shall include but not necessarily be limited to the following:

(a)	Examination of Product	4.5.1
(b)	Capacity	4.5.2
(c)	Leak Detection	4.5.12
(d)	Electrolyte Leakage Test	4.5.13
(e)	Retention of Charge	4.5.14
(f)	Storage Cell Electrical Operations Requirements	6.

4.4.2 Data Approval. - Two copies of all data obtained on the tests described in 4.4.1 shall be furnished to Grumman for approval prior to further processing.

SPECIFICATION

No. AV-D559CS-1

4.5 Test Methods. -

4.5.1 Examination of Product. - Each complete storage cell, submitted for qualification and acceptance under contract, shall be inspected as Grumman may deem necessary to determine compliance with this specification and the applicable drawing with respect to workmanship, construction, interchangeability, sealing storage cell container, weight, dimensions, identification marking, packaging and packing and terminals.

4.5.1.1 Inspection of Storage Cell Assembly. - The final storage cell assembly shall be witnessed by a Grumman quality assurance representative to verify the integrity of internal and external component parts.

4.5.1.2 Hermetic Seal. - The storage cell shall be tested for seal leakage (Helium) in accordance with 3.4.5.4.2.15.

4.5.1.3 Internal Impedance. - The storage cell shall meet the internal impedance requirements of 3.5.8 when subjected to the following tests:

TBD

4.5.2 Capacity. - Each storage cell shall be subjected to the tests detailed in 4.2.1 as test numbers 1, 2, 6, 7, 8, 9, 13 and 14. The conditions of 4.2.1.1 shall apply. Each storage cell shall meet the capacity requirements conditions 2 and 5, respectively, of 3.5.1 following the last change cycle of tests 2, 6, 7, 9, 13 and 14 of 4.2.1.

4.5.3 Life. - All storage cells shall have a minimum operational life of 11,000 orbital cycles in accordance with 3.2.2 and 3.2.2.1 life cycle tests shall be performed at Grumman.

4.5.4 Retention of Capacity. - These tests shall be performed at Grumman.

4.5.5 Storage Tests. - These tests shall be performed at Grumman.

4.5.6 Vibration. - Qualification test storage cells shall be subjected to the sinusoidal and random vibration requirements specified in Tables I and II. During these vibration tests, test storage cells shall be discharged at frequent intervals at the one-hour rate for periods of 30 seconds. The current and voltage values observed during these discharges shall show no fluctuations. Visual inspection of the storage cells, upon completion of the test, shall show no mechanical failure. During vibration tests, the storage cells shall be under a "clamp up" load of 6000 pounds applied through stiff metal plates.

4.5.7 Acceleration, Centrifugal. - Qualification test storage cells shall be mounted on the test apparatus (centrifuge) in the applicable positions defined in TBD to produce the required acceleration in the direction specified. The centrifuge shall be brought up to the rotational speed required to produce the radial acceleration specified. During the above test, acceleration shall be 11.3 g's, 3 perpendicular axes, 2 directions per axis per Figure 6, 5 minutes per direction, and the test storage cells shall be discharged at frequent intervals at the one-hour rate for periods of 30 seconds. The acceleration gradient across the storage cell shall not exceed 15 percent. The current and voltage values observed during these discharges shall show no fluctuations, and visual inspection of the storage cells upon completion of the test shall show no mechanical failure.

4.5.8 Shock. - Qualification test storage cells shall be subjected to the Shock Test specified herein and in the Final Statement of Work. The storage cell shall be discharged at the one-hour rate during the test, and the discharge voltage monitored on a recording voltmeter with a resolution capability of four significant figures. If a sampled data system is used, the sampling rate shall be at least three orders of magnitude faster than the rise or fall time, whichever is shorter, of the Shock Pulse to avoid missing a voltage discontinuity. During the period of each Shock Test, any discontinuity in the voltage resulting from a shock in any direction shall be cause for rejection.

SPECIFICATION

No. AV-D559CS-1

4.5.9 High Temperature Operation. - A fully charged storage cell shall be discharged at the one-hour rate at 50 ± 3°F, recharged and then placed in an oven at a temperature of 68 ± 3°F. This temperature shall be maintained for 24.5 hours. The storage cell shall then be discharged at this temperature at the 2-hour rate and its capacity measured to 1.0 volts. The storage cell shall then be returned to room temperature and charged at the 2-hour rate. Following this charge, the storage cells shall again be discharged at the 2-hour rate. The capacity of this second discharge shall be 100 percent of the capacity specified in 3.5.1, Condition 2.

4.5.10 Low Temperature Operation. - A fully charged storage cell shall be discharged at the one-hour rate at 50 + 3°F, recharged and then placed in a chamber at a temperature of 32 ± 3°F. This temperature shall be maintained for 24.5 hours. The storage cell shall be discharged at this temperature at the two-hour rate and its capacity measured to 1.0 volts. The storage cell shall then be returned to room temperature and then charged at the two-hour rate. Following this charge, the storage cells shall again be discharged at the two-hour rate. The capacity of this second discharge shall be 100 percent of the capacity specified in Drawing _____, paragraph 3.5.1, Condition 5.

4.5.11 Thermal Vacuum. - Two fully charged storage cells shall be discharged at the one-hour rate at 50 ± 3°F, recharged and then placed in a vacuum chamber. One surface of each storage cell shall be adjusted to a high temperature of 68 ± 2°F and the chamber shall be evacuated to 1.0×10^{-6} mm Hg or less. This condition shall be maintained for a period of 24.5 hours. During this period each storage cell shall be cycled sequentially for a minimum of one cycle of charge and discharge as specified in 4.5.3. The above procedure shall be repeated except that one storage cell surface shall be maintained at a low temperature of 32 ± 3°F. The above procedure shall be repeated a third time at 50 ± 3°F except that the test time shall be for four hours. The storage cells shall show no evidence of failure following these tests.

SPECIFICATION
No. AV-D559CS-1

4.5.12 Leak Detection. - To permit satisfactory leakage detection, all storage cells shall be sealed with 8 percent to 12 percent of helium gas by volume. A fully charged storage cell shall be allowed to cool to 50 ± 3°F, at which time a leakage test shall be made. Storage cells shall have a leakage rate of less than the limits specified in 3.4.5.4.2.15.

4.5.13 Electrolyte Leakage. - This test shall occur immediately after completion of charge, during which the storage cell must have received some overcharge to assure a positive storage cell pressure with respect to atmospheric pressure. The storage cell shall be thoroughly cleaned with distilled water and alcohol, prior to start of charge. All mechanically sealed areas on the storage cell cover shall be swabbed with phenolphthalien solution (see Note). A red indication on the swab is evidence of electrolyte leakage. In the event of a positive indication, the storage cell shall be again cleaned and the test repeated. If a positive indication of leakage is present during the second test, the storage cell shall be rejected.

NOTE: 0.5 percent phenolphthalein in 50 percent alcohol and 50 percent distilled water solution. All areas where phenolphthalein was applied shall be subsequently rinsed with distilled water; then all areas shall be rinsed with acetone and the storage cell shall be placed in a vacuum chamber for one hour at a pressure of 1 mm Hg or less.

4.5.14 Retention of Charge. - This test shall occur if the storage cell was discharged to 1.00 volt. Drain the storage cell for $16\ ^{+1}_{-0}$ hours at 68 ± 3°F ambient temperature using a 0.20 ± 5% ohm resistor. Let the storage cell stand at open circuit for 24 ± 0.5 hours at 68 ± 3°F ambient temperature. The storage cell voltage at the end of this open-circuit stand shall be 1.15 volts or higher.

4.6 Rejection and Retest. - When any test sample fails to meet the requirements outlined herein, the product shall be rejected. If for any reason the storage cells of the lot represented have already left the contractor's plant, they shall be subject to return to correct the defects and resubmitted for all the specified tests. Before resubmitting,

4.6 (Continued)

full particulars concerning previous rejection and the action taken to correct the original defects shall be furnished to Grumman. Units rejected after retest shall not be resubmitted without the specific approval of Grumman. This retest, however, is only permissible if doubt exists with respect to the test equipment employed, test procedure applied or incomplete storage cell conditioning is suspected.

4.6.1 Failure Reporting and Analysis. - When failures occur during test operations, the reporting and analysis procedures specified in the Final Statement of Work shall apply.

4.7 Equipment Changes. - After successful completion of the qualification test, no changes shall be incorporated in the storage cell design or manufacturing techniques unless approved in writing by Grumman.

5 PREPARATION FOR DELIVERY

5.1 Application. - The requirements of Section 5 apply to direct purchases by or direct shipments to Grumman.

5.2 Preservation, Packaging and Packing. - After completion of tests each unit shall be preserved within one week by performing the following:

(a) Each unit shall be discharged below 0.1 volt by clipping a 0.20 ± 5% ohm resistor across the storage cell terminals.

(b) Remove the resistor and short the storage cell terminals by wrapping a copper wire around the storage cell terminals.

(c) Each unit shall be placed in a polyethylene bag and an inert drying agent shall be added to exclude moisture. Bag shall be heat sealed.

NOTE: Storage cell serial number shall be clearly visible from the outside of the bag.

(d) Each unit shall be packaged in a manner to avoid damage during shipment.

SPECIFICATION
No. AV-D559CS-1

5.3 Marking of Shipments. - Interior packages and exterior shipping containers shall be marked in accordance with Grumman instructions.

6 NOTES

6.1 Intended Use. - The storage cells covered by this specification, after assembly into Storage Battery Modules, are intended for continuous duty in electrical systems of Manned Orbital Space Stations. They will be used in combination with a solar cell array or other primary power source to provide energy storage and furnish peak power demands.

6.2 Storage Conditions. - All storage cells which are kept on long term storage (periods in excess of one week) shall be stored as follows:

(a) Each unit shall be preserved and packaged as specified in 5.2(a) through (d).

(b) Each unit shall be stored in a clean dry area at a temperature between 50°F to 70°F.

6.3 Definitions. -

6.3.1 Storage Cell Capacity. - Storage cell capacity is the discharge measured quantitatively in ampere hours at the specified discharge rate to the specified cutoff voltage.

6.3.2 Cutoff Voltage. - The cutoff voltage of a storage cell is defined as that discharge voltage which represents the complete discharge condition of the storage cell for a particular rate. Discharge beyond this voltage would yield an insignificant amount of useful energy.

6.3.3 Constant Current Discharge. - The discharge made at the rate specified until the final voltage reaches the specified cutoff value.

6.4 Charging Instructions. - The seller shall furnish with the storage cells, one reproducible printed copy of charging instructions.

SPECIFICATION

No. NV-D559-C5-1

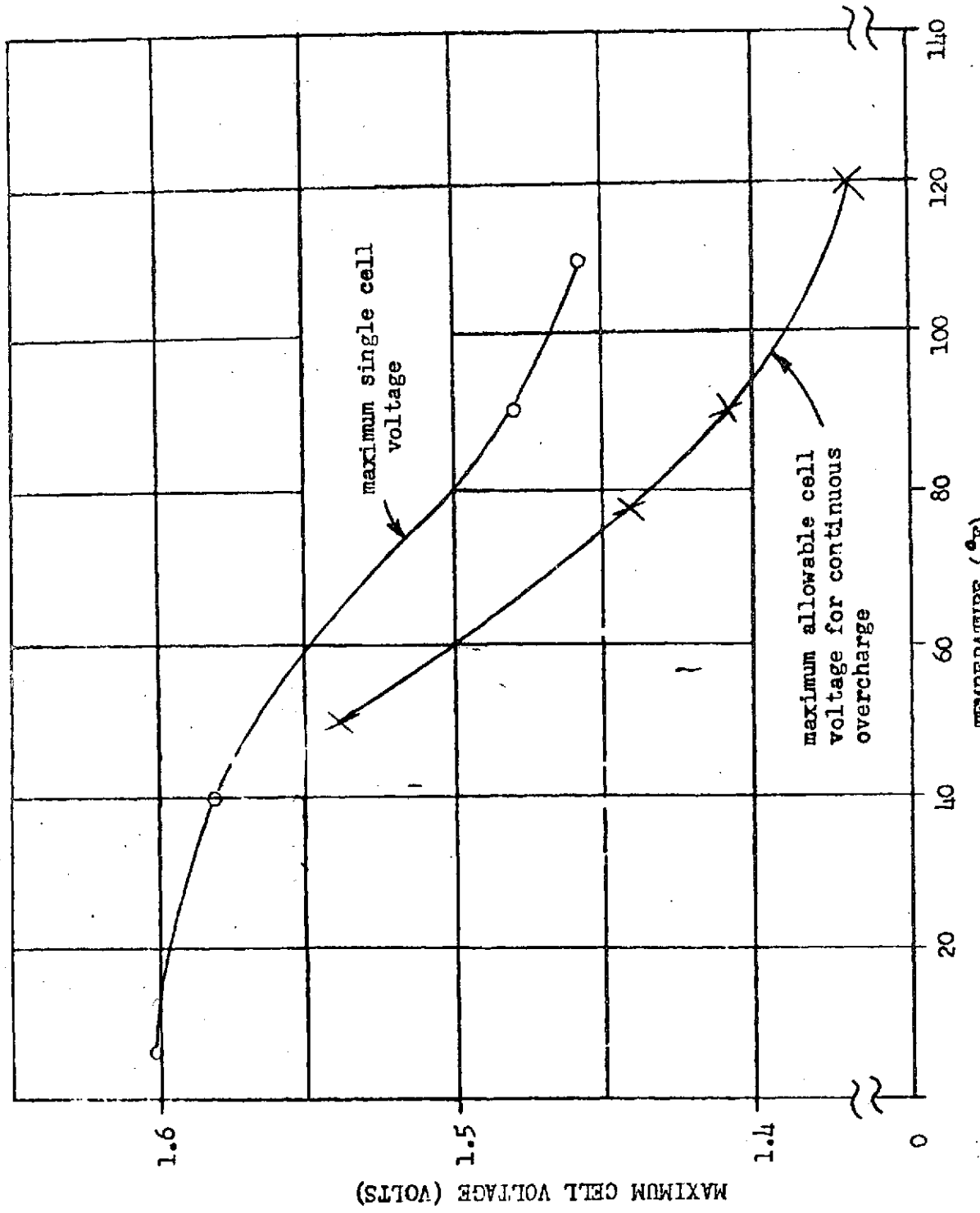
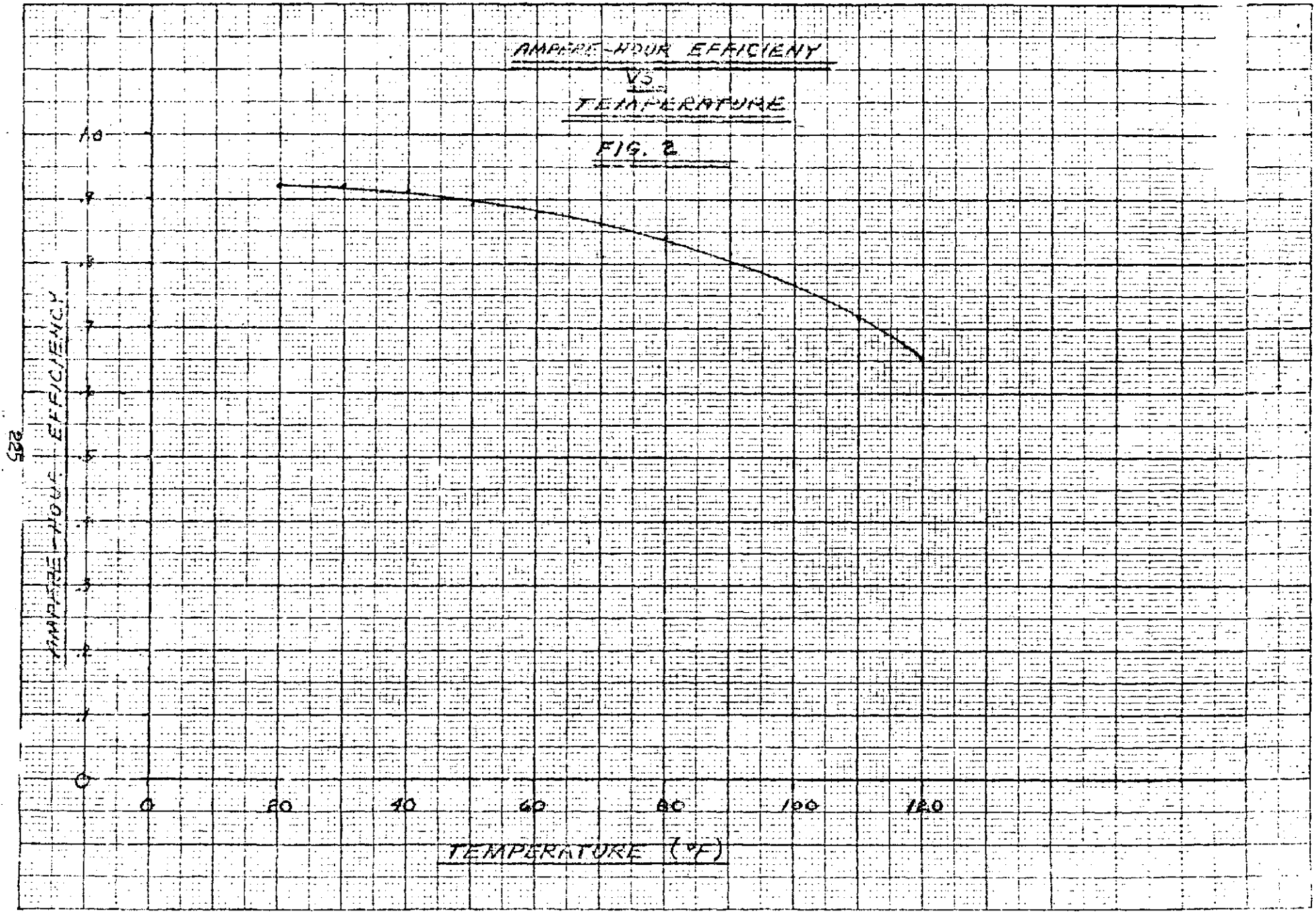


FIGURE 1. MAXIMUM LIMITING VOLTAGE FOR CHARGE CONTROL OF HERMETICALLY SEALED NICKEL-CADMIUM CELLS


AMPERE-HOUR EFFICIENY
VS.
TEMPERATURE
FIG. 2
AMPERE-HOUR EFFICIENCY
10
0
0
20
40
60
80
100
120
TEMPERATURE (°F)

TBD

INTERNAL IMPEDANCE
CIRCUIT

FIGURE 3

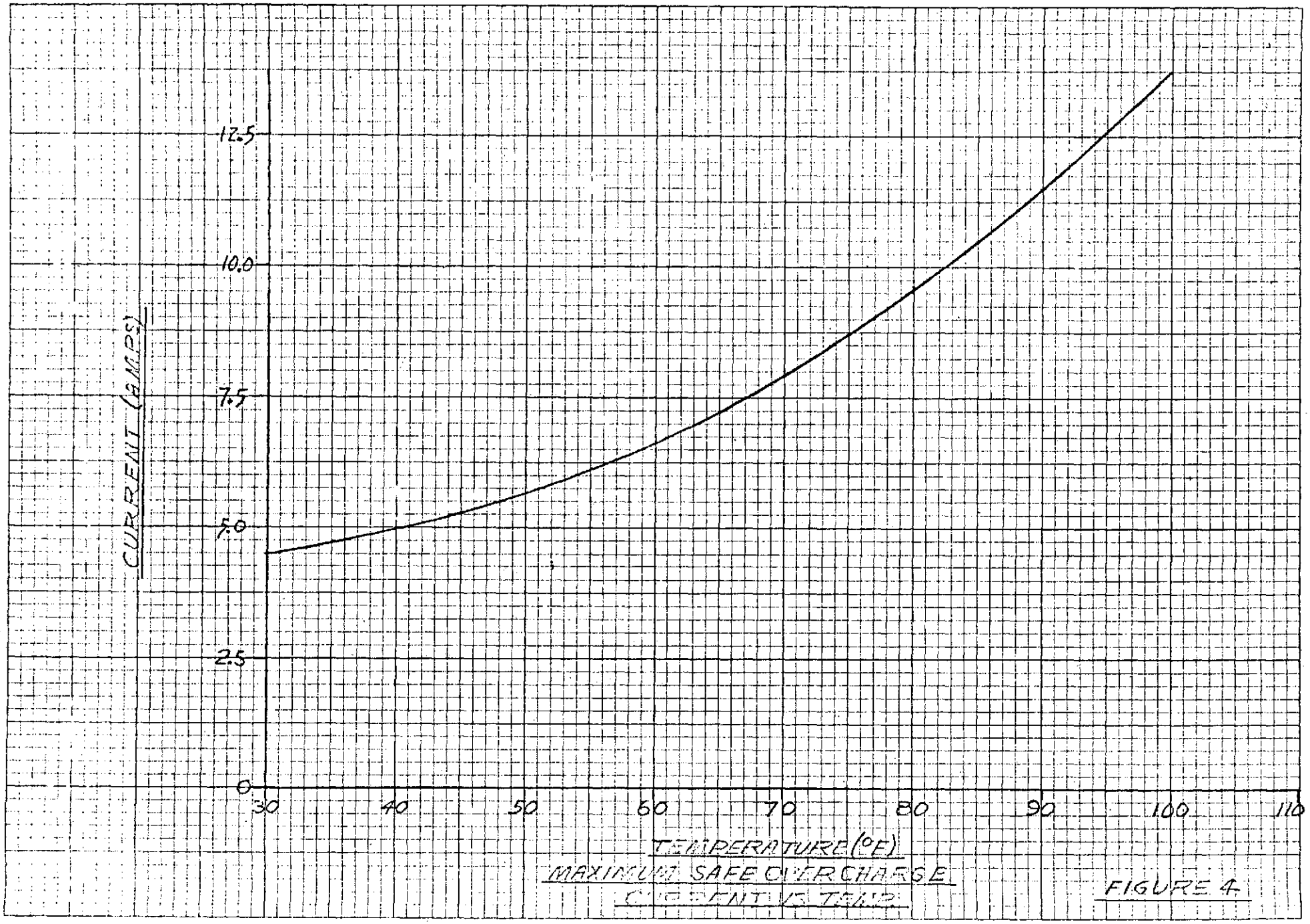
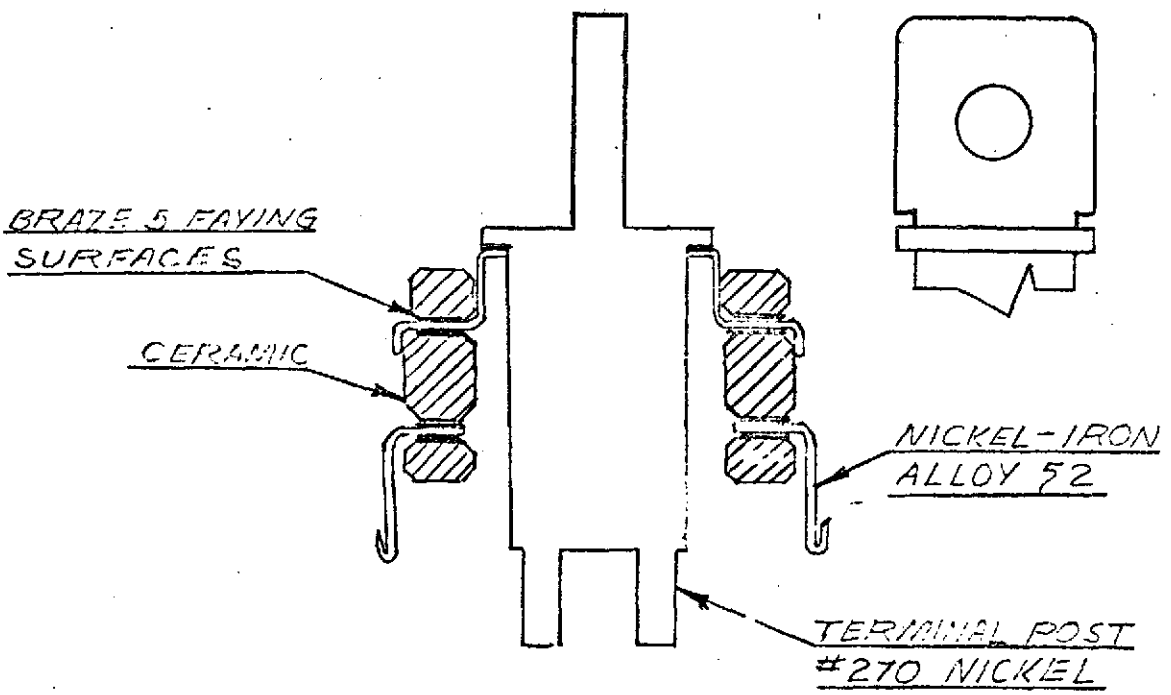


FIGURE 4



CERAMIC-TO-METAL SEAL TERMINAL
CROSS SECTION VIEW
(SEE APPLICABLE DRAWING FOR DIMENSIONS)

FIGURE 5

AXES FOR VIBRATION – STORAGE CELLS

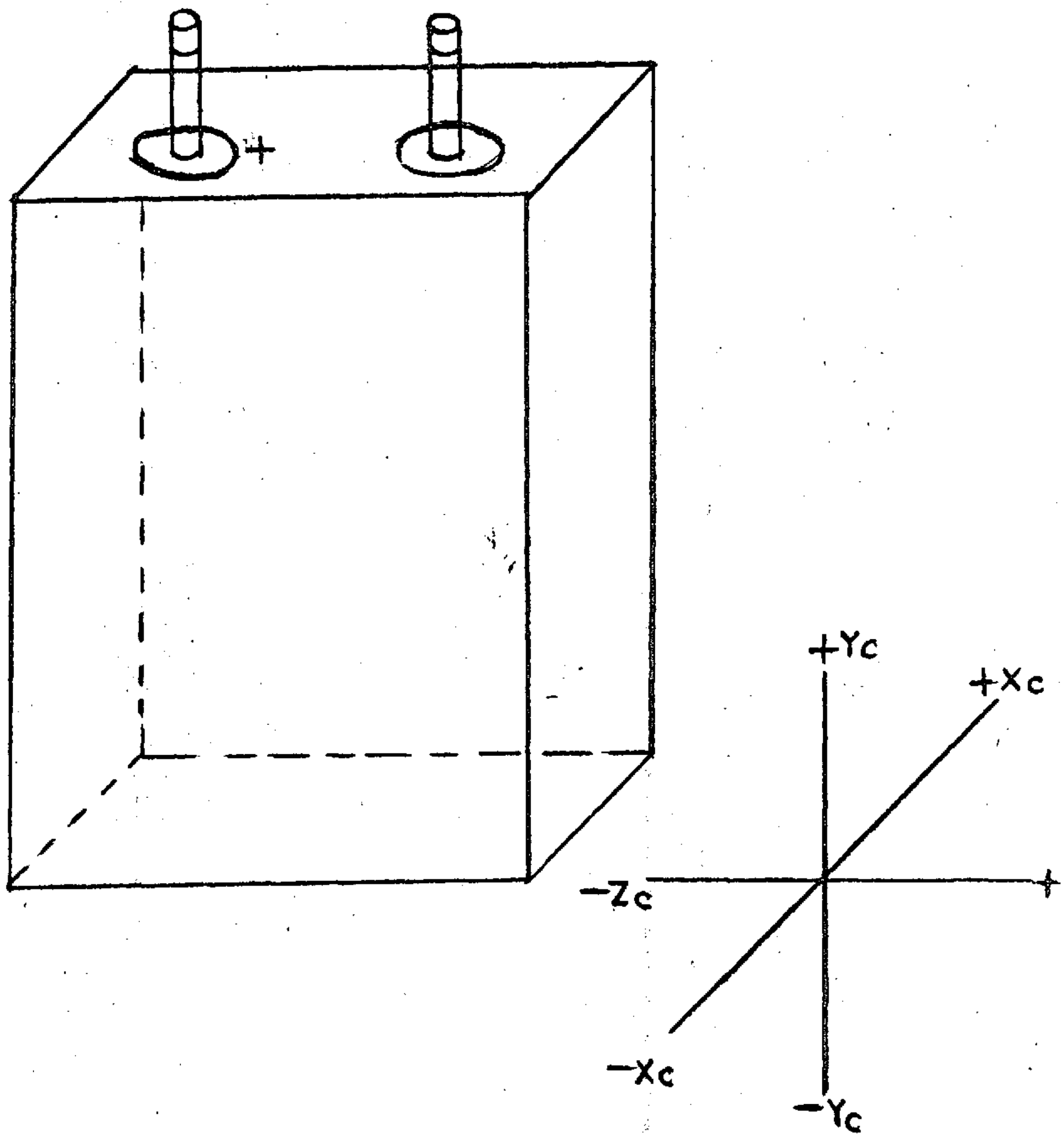


FIGURE 6

SPECIFICATION
No. AV-D559CS-1

TABLE I

QUALIFICATION VIBRATION TEST REQUIREMENTS FOR

100 AMPERE-HOUR

NICKEL-CADMIUM STORAGE CELLS

SINUSOIDAL VIBRATION
SWEEP AT 2 OCTAVES PER MINUTE

x_c, y_c and z_c axes

Frequency	Level
5-14 Hz	1/2" DA
14-100 Hz	5 g
100-200 Hz	10 g
200-2000 Hz	15 g

RANDOM VIBRATION
RUN FOR 4 MINUTES PER AXIS

x_c, y_c and z_c axes

Frequency	Level
20-200	9 db/oct increase
200-500	0.13 g^2/Hz
500-2000	3 db/oct decrease

+ 4 db 30 sec/axis

NOTE: Sine levels to be applied using tracking filter control.

SPECIFICATION
No. AV-D559CS-1

TABLE II

QUALIFICATION VIBRATION REQUIREMENTS

Sinusoidal Vibration. - The control signal shall be filtered for sinusoidal testing, if harmonic distortion is evident this can be determined by viewing the control signal on an oscilloscope during the fixture survey.

MAXIMUM TOLERANCES

Sinusoidal Vibration Amplitude:	± 10%
Sinusoidal Vibration Frequency:	± 2%
Random Vibration:	± 3 db (The overall rms-g applied shall be maintained within a tolerance of $^{+15}_{-5}$%

Sinusoidal Vibration. - The vibration input levels shall be measured at or near the test unit mounting location. Whenever more than four mounting locations exist, only four points need be monitored. Any accelerometer fastened at any one of the mounting locations can be used as the servo control input provided that:

(a) The control input maintains levels at the test frequency within ± 1 db of the requirements.

(b) The level at any input location is within ± 4 db of the requirements at the test frequency.

(c) The average of all inputs at the test frequency is within ± 2 db of the requirements.

SPECIFICATION
No. AV-D559CS-1

TABLE II (Continued)

Exceeding the lower limits of the above tolerances shall be cause for rejection of the delinquent portion of the test and shall necessitate rerunning only that portion of the vibration test. Selection of the control point shall be subject to Grumman approval.

Random Vibration. - The vibration input for this test shall be controlled from the same accelerometer as used to control the sinusoidal vibration test.

Vibration Fixtures. - The fixture, and its connection to the shaker head, shall be capable of transmitting the vibrations specified herein. It shall be a design objective that the fixture be free of resonances within the test frequencies. In any event, the fundamental resonance of the fixture compensated for test unit mass shall be above 750 Hz. The transverse motion (crosstalk) in any direction produced by these fixtures shall not exceed the vibration levels in the transverse direction specified herein. The requirements outlined above shall be verified by a sinusoidal vibration sweep at test frequencies using a mass simulated dummy test item. The vibration input for this sweep shall be monitored with tri-axial accelerometers.

X-Y Plots. - X-Y plots of vibration test control accelerometers shall be made and included in the test report. For sinusoidal vibration tests, the following ground rules shall be used:

(a) The control signal shall be filtered if harmonic distortion is evident. This can be determined by viewing the control signal on an oscilloscope during the fixture survey.

(b) If a filtered control signal is used, then the X-Y plots shall be filtered.

SPECIFICATION

No. AV-D559CS-1

TABLE II (Continued)

X-Y plots for sinusoidal tests shall show peak "g" vs Hz. For random tests, the plots shall show the Spectral Density (PSD) analysis in g^2/Hz vs Hz. Parallel filter or tracking filter analysis can be used. Both sinusoidal and random X-Y plots should be made using on-line or taped signals from the control accelerometer and reduced using automatic X-Y plotters. Plotting of meter readings by hand is not acceptable.

NOTE: If track filter PSD analysis is used, the analyzing filter bandwidths should not exceed 20 Hz for frequencies below 200 Hz and should not exceed 50 Hz for frequencies between 200 and 2000 Hz. Analyzing constants such as averaging time, sweep rate and tape loop length should be consistent with good analysis practice. It is recommended that the statistical quality of the analysis be equivalent to 60 degrees of freedom minimum.

A copy of the X-Y vibration test plots shall be submitted to Grumman within 5 days of the completion of the vibration portion of the environmental test.

SPECIFICATION
No. AV-D559CS-1
Appendix I

Sample Data Sheet 1

APPENDIX I

SEPARATOR TEST PROCEDURE

NOTE: The following information shall be supplied for each storage cell lot production.

10.1 General. -

Separator Material Supplier:

Base Material:

Fiber Manufacturer:

Part No.
Lot No.
Date of Manufacturing (mo/yr)

Separator Suppliers Style No.

Lot No.
Date of Manufacturing

Material Slitted By:

(Do not use Anti-Static Agent)

Finishes or Wetting Agents Added by Separator Supplier

Yes _____
No _____

Finishes or Wetting Agents Added by Storage Cell Manufacturer

Yes _____
No _____

State type of wash and number of times separator washed.

Applicable Grumman Purchase Order No. _____

Prepared by _____ Date _____

SPECIFICATION

No. AV-D559CS-1

Appendix I

Sample Data Sheet 2

10.2 Thickness. -

Nominal Thickness
Maximum Thickness
Minimum Thickness

10.3 Weight. - Weight in gm/m^2

Sample 1 _____ Sample 2 _____ Sample 3 _____

10.4 Dimensions and Dimensional Changes. -

	Length (cm)		Width		Thickness	
	Dry	Wet	Dry	Wet	Dry	Wet
Sample 1						
2						
3						
4						
5						
6						

	% Change in Thickness	Wet Volume (V_w)
Sample 1		
2		
3		
4		
5		
6		

Applicable Grumman Purchase Order No. _____

Above Tests Conducted By _____ Date _____

Prepared By _____ Date _____

SPECIFICATION

No. AV-D559CS-1
Appendix I

Sample Data Sheet 3

10.5 Electrolyte Absorption. -

	Dry Weight (gm) W_D	Wet Weight (gm) W_W	Grams of Electrolyte Absorbed ($W_W - W_D$) W_A
Sample 1			
2			
3			
4			
5			
6			

Applicable Grumman Purchase Order No. _____

Above Tests Conducted By _____ Date _____

Prepared By _____ Date _____

SPECIFICATION

No. AV-D559CS-1

Appendix I

Sample Data Sheet 4

10.6 Electrolyte Retained. -

	Dry Weight (gm)	Wet Weight (gm)	Grams of Electrolyte Retained ($W_r - W_D$)
Sample 1			
2			
3			
4			
5			
6			

Calculate percent electrolyte retained from the following:

$$\frac{W_R}{W_A} \times 100 = \text{Percent Electrolyte Retained}$$

W_R = Grams of Electrolyte Retained

W_A = Grams of Electrolyte Absorbed

Percent Electrolyte Retained

Sample 1	
2	
3	
4	
5	
6	

Applicable Grumman Purchase Order No. _____

Above Tests Conducted By _____ Date _____

Prepared By _____ Date _____

SPECIFICATION

No. AV-D559CS-1

Appendix I

Sample Data Sheet 5

10.7 Porosity. - Porosity or internal void volume is calculated by the following:

$$\frac{W_W - W_D}{V_W \times p} = \text{Percent Porosity}$$

Where:

W_W = Wet weight or separator (gm)

W_D = Dry weight of separator (gm)

V_W = Wet volume of separator (cc)

p = Density of absorbed electrolyte. The density of the absorbed electrolyte is taken to be the same as the density of the equilibrating electrolyte.

Percent Porosity

Sample 1

2

3

4

5

6

Applicable Grumman Purchase Order No. _____

Above Tests Conducted By _____ Date _____

Prepared By _____ Date _____

SPECIFICATION

No. AV-D559CS-1
Appendix I

Sample Data Sheet 6

10.8 Separator Resistance. -

	Separator Resistance ohm-cm^2	Separator Specific Resistivity ohm-cm
Sample 1		
2		
3		

10.9 Tensile Strength at Break. - Record temperature in °F and % humidity.

	Tensile Strength at Break lbs/cm^2	Percent Elongation	Appearance Of Break
Sample 1			
2			
3			
4			
5			
6			
Sample 1			
2			
3			
4			
5			
6			

Applicable Grumman Purchase Order No. _____

Above Tests Conducted By _____ Date _____

Prepared By _____ Date _____

SPECIFICATION

No. AV-D559CS-1

Appendix I

Sample Data Sheet 7

10.10 Determination of Organics. -

	Sample 1	2	3
Weight of separator before extraction (gm)			
Weight of separator after extraction (gm)			
Weight loss (gm)			
Weight of container plus residue (gm)			
Weight of container (gm)			
Weight of residue (gm)			
Percent organics (Weight of residue divided by weight of separator after extraction) X100			

10.11 Determination of Inorganics. -

	Inorganic	Percent
Sample 1		
2		
3		

10.12 Discoloration of Samples in Electrolyte. - Describe color change and in which test discoloration occurred.

Applicable Grumman Purchase Order No. _____

Above Tests Conducted By _____ Date _____

Prepared By _____ Date _____

SPECIFICATION

No. AV-D559CS-1

Appendix I

Sample Data Sheet 8

10.13 Thickness Variation. -

Reading	Sample 1	2	3	4	5
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Average					

Circle maximum and minimum value for each sample.

Reading	6	7	8	9	10
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Applicable Grumman Purchase Order No. _____

Above Tests Conducted By _____ Date _____

Prepared By _____ Date _____

SPECIFICATION

No. AV-D559CS-1
Appendix I

Sample Data Sheet 9

10.14 Dimensions and Dimensional Changes. -

	Length (cm)		Width		Thickness	
	Dry	Wet	Dry	Wet	Dry	Wet
Sample 1						
2						
3						
4						
5						
6						

	% Change in Thickness	Wet Volume (V_W)
Sample 1		
2		
3		
4		
5		
6		

10.15 Electrolyte Absorption. -

	Dry Weight (gm) W_D	Wet Weight (gm) W_W	Grams of Electrolyte Absorbed ($W_W - W_D$) W_A
Sample 1			
2			
3			
4			
5			
6			

Applicable Grumman Purchase Order No. _____
Above Tests Conducted By _____ Date _____
Prepared By _____ Date _____

SPECIFICATION

No. AV-D559CS-1

Appendix I

Sample Data Sheet 10

10.16 Electrolyte Retained. -

	Dry Weight (gm)	Wet Weight (gm)	Grams of Electrolyte Retained (W_T-W_D) W_R
Sample 1			
2			
3			
4			
5			
6			

Calculate percent electrolyte retained from the following:

$$\frac{W_R}{W_A} \times 100 = \text{Percent Electrolyte Retained}$$

W_D = Grams of Electrolyte Retained

W_A = Grams of Electrolyte Absorbed

Percent Electrolyte Retained

Sample 1

2

3

4

5

6

Applicable Grumman Purchase Order No. _____

Above Tests Conducted By _____ Date _____

Prepared By _____ Date _____

SPECIFICATION

No. AV-D559CS-1
Appendix I

Sample Data Sheet 11

10.17 Porosity. - Porosity or internal void volume is calculated by the following:

$$\frac{W_W - W_D}{V_W \times p} = \text{Percent Porosity}$$

Where:

W_W = Wet weight of separator (gm)

W_D = Dry weight of separator (gm)

V_W = Wet volume of separator (cc)

p = Density of absorbed electrolyte. The density of the absorbed electrolyte is taken to be the same as the equilibrating electrolyte.

Plot data of the three determinations on one graph 10 x 10 to the inch.

10.18 Tensile Strength at Break. -

	Tensile Strength at Break lbs/cm^2	Percent Elongation	Appearance Of Break
Sample 1			
2			
3			
4			
5			
6			

Pore Volume 0.38 cc/GM
Aminco-Winslow Mercury Intrusion Porosity Meter

Applicable Grumman Purchase Order No. _____

Above Tests Conducted By _____ Date _____

Prepared By _____ Date _____

SPECIFICATION

No. AV-D559CS-1

Appendix II

TBD

SPECIFICATION

No. AV-D559CS-1

Appendix III

TBD

APPENDIX B

Cell Leak Check

Procedures

EP-MP-152

LEAK CHECK PROCEDURES
FOR
EAGLE-PICHER NICKEL-CADMIUM
RSN-110 TYPE CELLS

Prepared for:

GRUMMAN AEROSPACE CORPORATION
Bethpage, Long Island, New York

SPEC AV-D559 CS-1

12 March 1971

Original

Prepared by:

EAGLE-PICHER INDUSTRIES, INC.
Electronics Division
Couples Department
Joplin, Missouri

Bill Hawkins
Engineering

Quality Assurance

1.0 SCOPE

This document contains the Leak Test Procedure for a sealed one-hundred ampere-hour nickel-cadmium secondary cell, Eagle-Picher RSN-110 type cell.

2.0 APPLICABLE DOCUMENTS

2.1 Eagle-Picher

EP-QC-782 RSN-110 Flow Sheets

2.2 Other Specifications

992249-008; C.E.C. Leak Detector Manual

3.0 REQUIREMENTS

3.1 Maximum Leak Rate

Leakage rate higher than 1×10^{-6} cc's per second shall be cause for rejection.

3.2 Equipment

3.2.1 Helium Gas - as supplied by Linde, Bureau of Mines Grade A

3.2.2 Cell Pressurizing Port - as manufactured by Eagle-Picher

3.2.3 Mass Spectrometer - No. 24-120A as manufactured by Consolidated Electrodynamics Corporation

3.2.4 Cell Pressurizing Chamber

SPECIAL NOTE: After receipt cell cases shall have a non-recurring serial number vibro-etched on the bottom. Cases shall then be degreased. From this time, cell cases and cells shall be handled with lint-free gloves. No further immersion or exposure to liquids is allowed prior to helium leak check. Do not perform gross leak check in water and do not liquid hone prior to helium leak test.

3.3 Leak Check Procedure

3.3.1 Insure that internal cell pressure is no greater than -28" Hg as indicated by the cell gage.

3.3.2 Connect He source and back fill cell to a maximum internal pressure of -24" Hg pressure with He. Record cell pressure.

3.3.3 Seal cells in pressurizing chamber and increase pressure in approximately 5 minutes to 30 $^{+5}_{-0}$ psig with Helium.

3.3.4 At the end of one hour, release pressure from chamber and record pressures. If pressure has increased by more than 2" Hg, remove the individual cell and hold for screening (see 3.3.9).

3.3.5 Replace all satisfactory cells and repressurize for an additional 48-72 hours. Record pressure.

3.3.6 At the end of the He soak, remove cells to the leak check area. Leak test shall be performed within 8 hours.

3.3.7 Perform the leak test on each cell in accordance with C.E.C. Leak Detector Manual 992249-008, Section 3-30 through 3-33. Record calculated leak rate and mark EP-QC-782 as pass/fail for each cell.

3.3.8 Cells which fail the leak test may have fittings of gage assemblies tightened where applicable and be retested per paragraph 3.3.7.

3.3.9 At any step through paragraph 3.3.3, cells suspected to have a gross leak may be tested as follows:

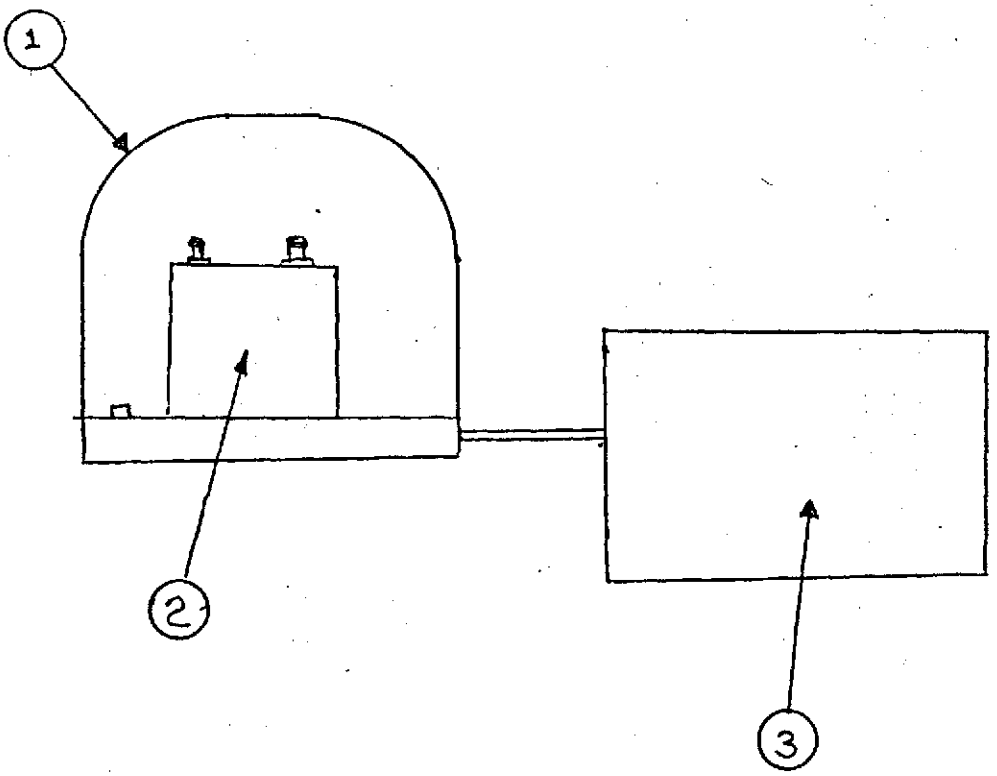
a) Connect helium source and pressurize to 5 $^{+2}_{-0}$ psig.

b) Attach C.E.C. "sniffer" to unit and locate leak if possible. If leak is at ceramic seal, or through case wall, the cell shall be permanently rejected. If leak is at a threaded joint, it may be tightened and the cell evacuated, and paragraphs 3.3.1-3.3.7 repeated. If leak is at cover to case weld, the weld may be repaired per EP-MP-13 and resubmitted for leak test.

4.0 QUALITY ASSURANCE AND TEST WITNESSING

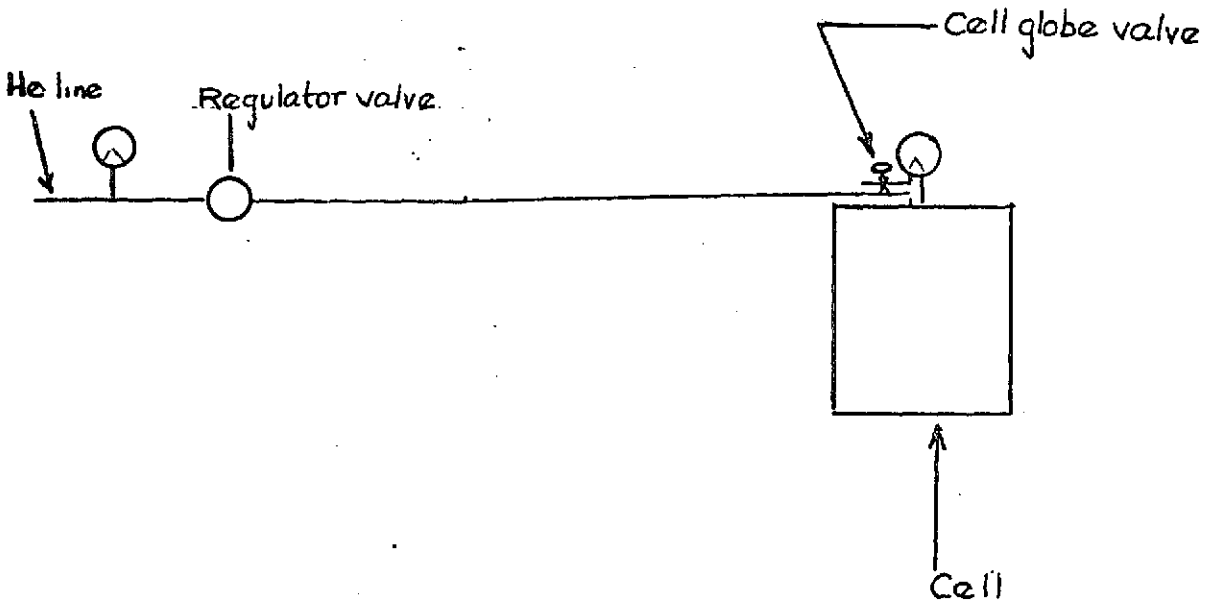
At the time of testing per paragraph 3.3.7, DCAS personnel and the GAC Inspector shall be notified by Eagle-Picher Quality Assurance personnel. Leak test data shall be recorded on the proper flow sheets (EP-QC-782).

FIGURE NO. 1



1 Test Port
2 CELL
3 MASS SPECTROMETER

FIGURE NO. 2



EAGLE-PICHER INDUSTRIES, INC.

Precision Products Department, Joplin Plant

Industrial Test Laboratories

Joplin, Missouri

RSM-110 Radiographic Procedures

IT-QC-8

(Issue Original)

January 26, 1971

Prepared By: R. A. Moss — Date: 1/27/71
R. A. MOSS
(Testing Engineer)

Approved By: L. D. Barbee — Date: 1/27/71
L. D. BARBEE
(Laboratory Manager)

Approved By: Bill Hawkins — Date: 1/27/71
BILL HAWKINS
(Couples Engineering Department)

Approved By: Kenneth Krueger — Date: 1/27/71
KENNETH KRUEGER
(Couples Quality Assurance)

Approved By: S. Gaza — Date:
GRUMMAN AEROSPACE CORPORATION
Bethpage, Long Island, New York

Copy No.: 4

Issued: 3/2/71

Assignee: Bill Hawkins

APPENDIX C

Cell Radiographic Procedure

Section 1.0 Purpose

This specification establishes the controls, techniques, limitations and acceptance criteria for the radiographic inspection of RSN-110 hermetically sealed nickel cadmium cells for the battery of the same nomenclature.

Section 2.0 Scope

Radiographs complying with the requirements of this procedure shall be used for inspection of hermetically sealed cells for workmanship, foreign metallic particles and drawing conformance. It is not the function of these radiographs to provide detailed weld quality analysis.

Section 3.0 References

Mil-Std-453, Inspection Radiographic, 4 September, 1963

Grumman Aerospace Corporation, AV-D5596-1, Paragraph 3.4.5.4.2.13 Radiographic Examination

Grumman Aerospace Corporation, AV-D5596S-1, Paragraph 3.4.5.4.2.13.1 Rejection Criteria

Section 4.0 Procedure

4.1 Cell Handling and Preparation for Radiographic Inspection

4.1.1 All exterior surfaces of the cell shall be clean, dry, and free of contamination. Handling care will be taken to maintain cleanliness during radiography.

4.2 Radiographic Views

There will be three radiographs taken of each cell. The first and second radiographs will be made prior to welding cover case to case. The first shot will be a flat shot along the X_c axis from $-X_c$ to $+X_c$ (Ref. Appendix, Page 2). The battery will be laid flat on a high contrast, fine grained, industrial radiographic film. A maximum of three units will be included in each radiograph

of the flat view. As the battery cell is placed on the film the negative terminal will be on the left, and the positive terminal on the right. The second radiograph will be an edge view along the Z_c axis (Ref. Appendix, Page 3). A maximum of four units will be included in each radiograph of the edge view. The cells will be placed on the film with the negative terminal up, and the positive terminal nearest the film. After installation of the cover case and pinch off, the third radiograph will be taken. This radiograph will be a flat view along the X_c axis (Ref. Appendix, Page 4), with the negative terminal on the left, and the positive terminal on the right. A maximum of three units will be included in each radiograph of the flat view. All radiographs taken will include the cell serial number, the positive or negative terminal location, the view number, the transfer document number or other means of control, the date of radiograph, and an image quality indicator. The image quality indicator used will be penetrameters which comply with Mil-Std-453.

4.3 Radiographic Interpretation

Radiographs will be interpreted by an individual qualified to determine the extent and character of any possible rejectable discontinuities. The following rejectable criteria will be used: foreign particles greater than 0.010 inch in any direction, tab bends sharper than 90 degrees (excluding radius formed stress loops), poor workmanship and nonconformance to drawings. All rejectable criteria will comply with Grumman Aerospace Corporation, AV-D55908-1, Paragraph 3.4.5.4.2.13.1.

4.4 Rework

Cells found defective prior to welding of the cover case may be repaired and reexamined by radiographic inspection. After said reexamination, no repairs will be made, nor will any repairs be made on units following welding of the cover case to case. Units repaired will be noted in a repair log that is maintained and submitted to Grumman Aerospace Corporation. All cells repaired prior to welding of cover case, will be thoroughly examined utilizing complete radiographic inspection.

4.5 Documentation

Records of control settings will be maintained by the radiographic inspection facility. The operator, X-ray unit, amount of filtration, focal length, voltage, and exposure time will be recorded in a log, maintained by the radiographic testing facility. Records of radiographs will be maintained for one year unless otherwise requested by the customer. Any change in procedure, settings, or parameters shall be submitted to the customer prior to implementation. Records of radiographs are maintained on Certification Inspection Report, PP-QC-161 (Ref. Appendix, Page 1). This record gives the name of the Eagle-Picher customer, the date, the customer purchase order number, the nomenclature of the part and its description, the drawing number and the quantity received, accepted and rejected. The serial number will be utilized in identifying the acceptable and rejectable units. The Certification Inspection Report is signed by the radiographer who has completed the nondestructive testing. Following completion of the testing, the testing facility

will retain one copy of the Certification Inspection Report which will be filed according to Eagle-Picher customer name and date. The copy of the Certification Inspection Report is retained in file for one year unless otherwise requested by the customer.

Section 5.0 Radiographic Facility

5.1 Qualifications

Radiographic inspections will be completed in a laboratory that complies with MIL-Std-453 and shall be subject to approval of Eagle-Picher and its customers as required.

Section 6.0 Personnel

6.1 Qualifications

Radiographers conducting nondestructive testing of these units will be qualified according to MIL-Std-453. Operator experience and training allow the Radiographers to distinguish the extent and character of discontinuities.

Section 7.0 Radiographic Materials

7.1 Film

The film used will be high contrast, fine grained industrial X-ray film, type D, of size to meet dimension requirements of the cells.

7.2 Film Identification

Lead numbers will be used to identify radiographs of each unit as per Paragraph 4.2. The location of lead numbers will be in accordance with customer requests.

APPENDIX

CERTIFICATION INSPECTION REPORT

Eagle-Picher Industries, Inc.
PRECISION PRODUCTS DEPARTMENT
INDUSTRIAL TEST LABORATORIES
20th and Iron Gates (417) 624-5115 P.O. Box 2215 Joplin, Missouri 64801

CUSTOMER: P. O. NO.

DATE:

PART NUMBER and DESCRIPTION	QUANTITY RECEIVED	QUANTITY ACC'D	QUANTITY REJECTED	REASON FOR REJECTION

I CERTIFY THAT THESE PARTS WERE:

☐ Fluorescent Penetrant Inspected in accordance with Mil-I-6866 _____

and per _____

☐ Magnetic Particle Inspected in accordance with Mil-I-6868 _____

and per _____

☐ Radiographic Inspected in Accordance with Mil-Std.-453 _____

and per _____

☐ Other _____

_____

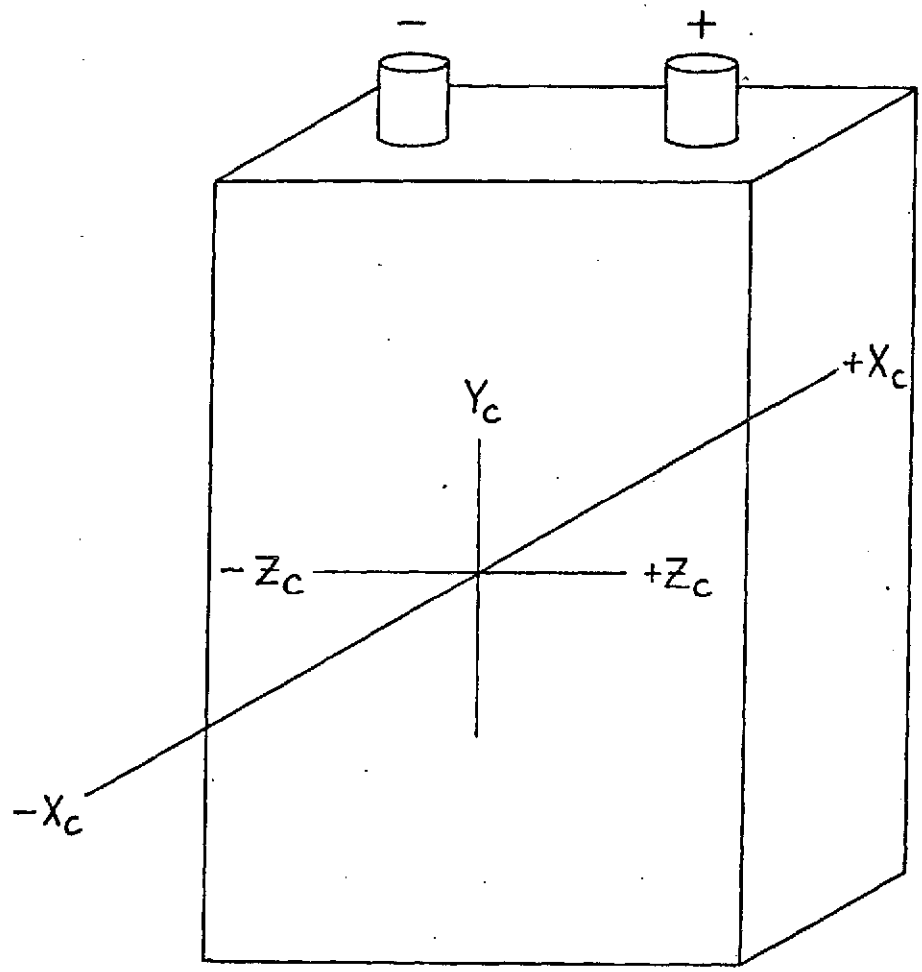
_____

By _____
CERTIFIED INSPECTOR

PP-QC-161
Musselman's Litho Service-Joplin Mo

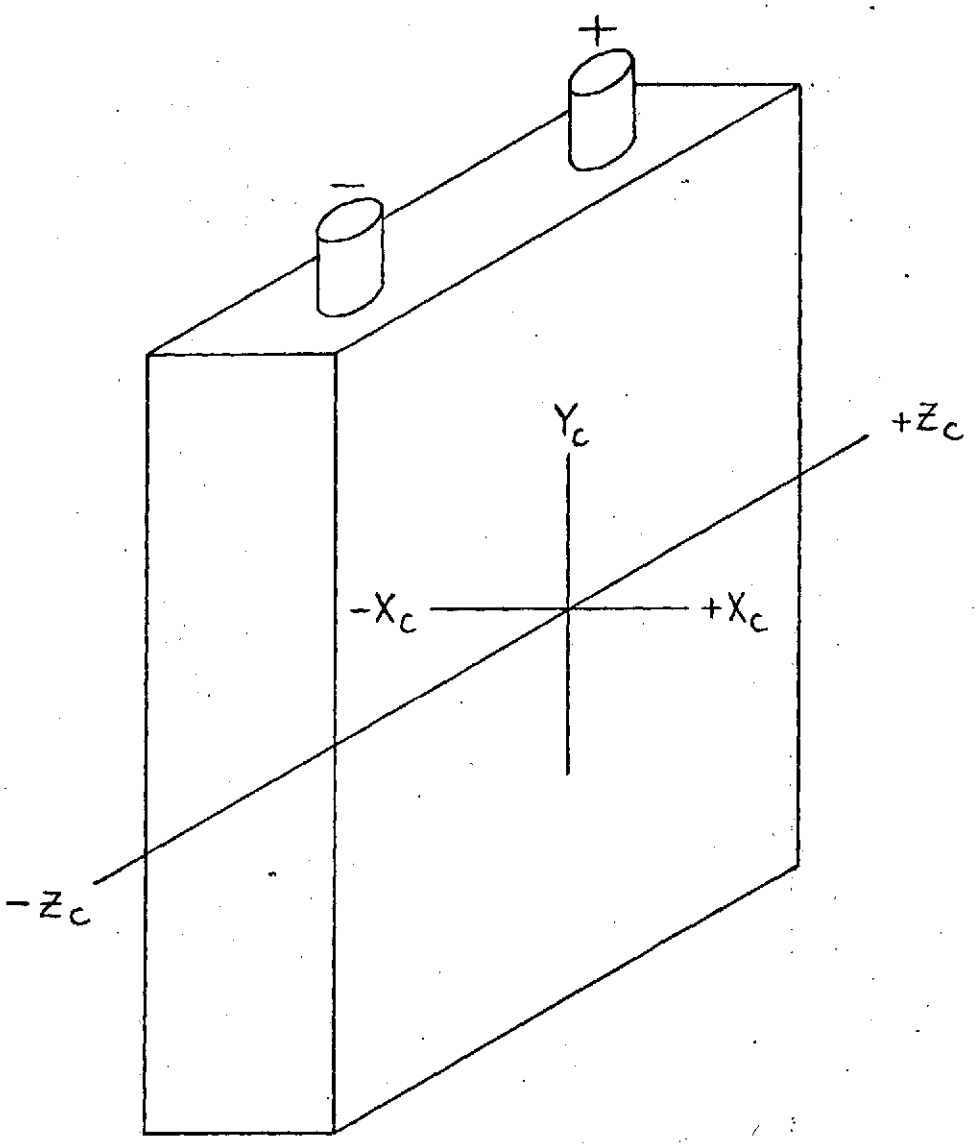
RSN-110 RADIOGRAPHIC INSPECTION TECHNIQUE

SHOT # 1



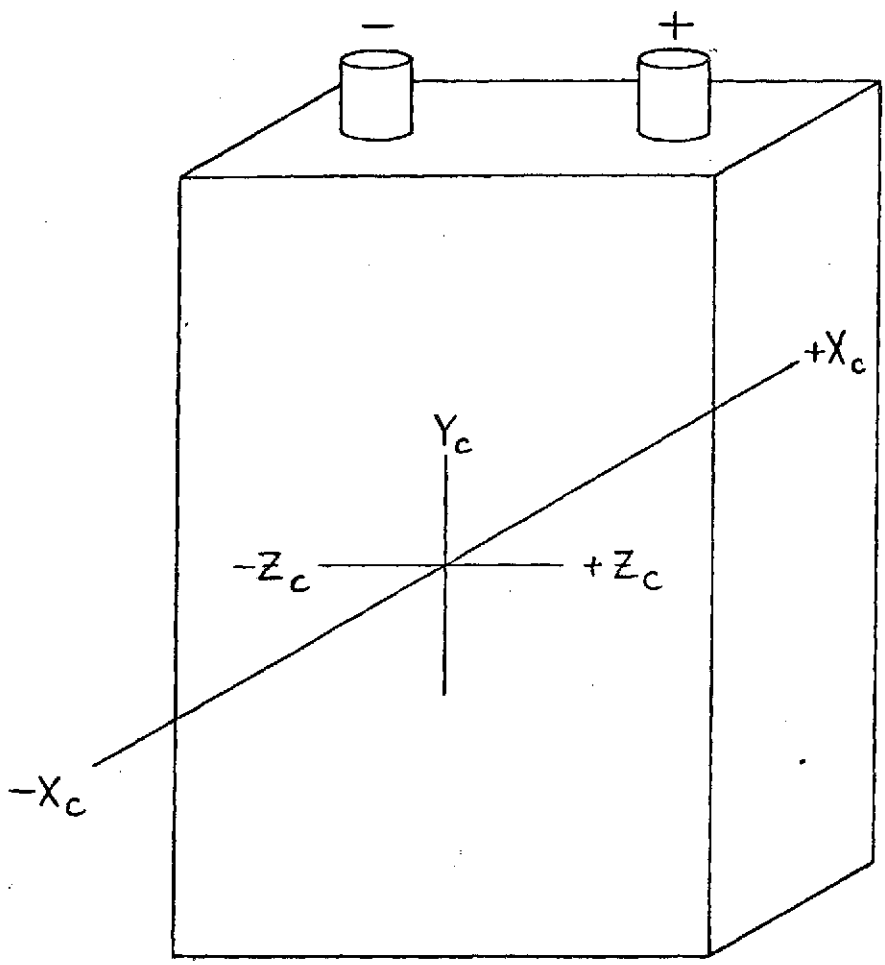
RSN-110 RADIOGRAPHIC INSPECTION TECHNIQUE

SHOT # 2



RSN-110 RADIOGRAPHIC INSPECTION TECHNIQUE

SHOT #3



NOTE: SHOT #3 COMPLETED AFTER INSTALLATION OF COVER CASE & PINCH-OFF

APPENDIX D

Non-woven nylon Specification

EP-MS-118

NON-WOVEN NYLON SPECIFICATION NICKEL-CADMIUM SPACECRAFT CELLS

1.0 SCOPE

This specification defines acceptance criteria for non-woven nylon materials used as separator materials in Eagle-Picher nickel-cadmium spacecraft batteries.

This document is intended for use in procuring raw materials. Certain tests are required of the seller and certain tests are required by Eagle-Picher receiving inspection. In addition, it is intended that individual separators be tested to various paragraphs of this specification after cutting. The piece part separator drawing shall require these tests. In this manner, necessary quality control shall be maintained for the raw material and subsequent operations.

2.0 DOCUMENTATION

The following documents of the issue, in effect on the date of this specification, are applicable to the extent outlined herein.

2.1 EP-QC-1100 Quality Assurance Manual, Policies & Procedures

2.2 EP-QC-1157 Calibration Procedures

3.0 REQUIREMENTS

3.1 General

Materials will be uniform in texture, color and appearance. They will be free of holes, tears and inclusions of foreign materials.

3.1.1 The components shall be capable of meeting the requirements of this document after an indefinite period of time in their primary packaging container.

3.1.2 Each roll shall be supplied with data sufficient to complete applicable portions of Data Sheet No. 1, Appendix I. Each roll shall be supplied with an identification tag which supplies the following minimum information:

a) Separator Manufacturer's Style or Type

b) Manufacturer's Lot Number

c) Roll Number

This identification tag shall be placed within the hollow paper core of each roll. Individual rolls shall consist of one (1) continuous sheet. Spliced rolls are not acceptable and lots may be made-up of more than one (1) roll.

3.2 Physical Characteristics

3.2.1 Wetting agents or antistatic agents which cause foaming or are unstable in strong alkali shall not be used in the manufacture of the material or be added to the material prior to delivery to Eagle-Picher.

3.2.2 The various materials controlled by this specification shall meet the specific requirements of attached data sheets for each manufacturer. See Appendix II.

3.2.2.1 Weight in grams per yard shall be determined by direct measurement, that is, the weight of a sample of one yard with no feathered edges shall be measured. See Appendix II for specific weight requirements.

3.2.3 Additional Requirements

Such additional requirements as noted in the remainder of this specification shall be met. See Appendix II for specific

permeability, electrical resistance, etc.

3.3 Chemical Characteristics

3.3.1 Total extractable organics shall be less than 2.0% by weight.

3.3.2 Total inorganic content shall be less than 1.0% by weight with 0.25% as target maximum as determined by chemical analysis or ignition residue.

3.4 Eagle-Picher shall be noted in writing of changes to dimensions, tolerances, materials, addition agents, finishes and of the materials listed in this specification.

4.0 QUALITY ASSURANCE

4.1 Certified Test Data

Certified test data shall be required in accordance with Table No. 1 and shall indicate results of specific tests performed by or under the supervision of the vendor. Actual test data of specific tests as applicable shall accompany the shipment.

4.2 Qualification Tests

Each material is considered qualified for use in each battery which has used this material in its successful qualification program.

4.3 Acceptance Tests

The tests of this specification shall be performed under the supervision of the Eagle-Picher Quality Assurance Department as denoted in Table 1. Actual testing may be performed by Receiving Inspection, E-P Chemical Laboratories or other test facility as determined by the nature of the test. Tests shall be conducted as per this specification, the purchase order or the applicable drawing.

4.3.1 Identification

The shipment shall be inspected to verify that the data required by 3.1.2 and Data Sheet No. 1 of Appendix I are complete.

4.3.2 Weight

4.3.2.1 Procedure A

One (1) square meter from each roll shall be cut with no feathered edges to demonstrate compliance with Appendix II. Record results on Data Sheet 2, Appendix I.

4.3.2.2 Procedure B

Three samples 10 cm x 10 cm shall be cut across the width of the roll. The samples shall be weighed and grams/m^2 calculated. The calculated value shall be in accordance with Appendix II.

4.3.3 Thickness Variation

4.3.3.1 Procedure A

Thickness and variation of thickness shall be determined and recorded for each roll using a CADY gage Model DW-1. Measurement shall be made on a sample two (2) feet in length. Individual determinations shall be made at intervals of approximately two (2) inches for a total of ten (10) measurements per sample. Record data on Data Sheet No. 2.

4.3.3.2 A thickness gage similar to CADY gage, Model M, standard TAPPI 9/16" diameter pressure foot shall be used. Ten (10) specimens are tested and three (3) measurements are taken on each. Pressure applied 8 psi.

4.3.4 Electrolyte Absorption, Dimensional Change, Electrolyte Retention

4.3.4.1 Equipment

a) Die for cutting sample

b) Cady Gage DW-1 or Ames 262 platform dial micrometer

c) Non-corrosive containers with air tight covers

d) Lucite Plate

e) Balance

f) Vernier calipers

g) 1.30 specific gravity electrolyte

h) Gas tight sample box

i) Nitrogen Supply

j) Beaker

4.3.4.2 Procedure (A)

(1) Die cut two (2) samples 6.50 cm x 2.50 cm from each roll (or a minimum of six (6) samples from each lot). Sample size is 6.5 cm by 2.5 cm with fibers running in the length dimension, if applicable.

(2) Measure dry length, width and thickness of each sample and record on Data Sheet No. 2.

(3) Weigh each sample to the nearest milligram. Record dry weight of each sample on Data Sheet No. 2.

(4) Cover each sample with electrolyte in non-corrosive container. Cover individual container or enclose in secondary container, cover and flush with nitrogen.

(5) At the end of three (3) hours, remove one (1) sample and determine dimensions. Record on Data Sheet No. 2.

(6) Wipe sample across dry lucite plate until no droplets remain, then determine weight and absorption per Data Sheet No. 3.

(7) Place samples on slanted (45 ± 2°) lucite plate for 15 ± 5 minutes such that direction of flow is along the 6.5 cm dimension.

(8) Weigh each sample and record retention per Data Sheet No. 4.

4.3.4.3 Procedure (B)

Test is performed on samples taken from each roll of each shipment by personnel in the Receiving Inspection Section of the Quality Control Department.

(1) Cut a minimum of two (2) samples from the stock in roll form. Each sample size is 4" x 4".

(2) Weigh the 4" x 4" sample of pellon to the nearest hundredth gram = (W_1)

(3) Place 100 cc's of 1.300 ± 0.02 specific gravity KOH solution in the 100 ML beaker.

(4) Immerse the weighed test sample in the KOH solution (reference 4.2.2) for a period of one (1) hour.

(5) Remove test sample from the KOH solution and allow excess electrolyte (KOH) to drain while

sample is held in a vertical position for a period of ten (10) plus three (3) minus zero (0) ($10\ ^{+3}_{-0}$) seconds.

(6) Weigh the saturated sample of pellon to the nearest hundredth gram = (W_2)

(7) Calculate percent of KOH absorption using the formula as follows:

$$\frac{W_2 - W_1}{W_1} \times 100 = \%\ \text{KOH absorption}$$

(8) Discoloration of 1.3 sp.gr. KOH solution shall be noted.

NOTE: Percent of KOH retention (absorption) must meet requirements of Appendix II.

4.3.4.4 Electrolyte Absorption - 30% KOH (Specific Weight 1.29)

Three (3) specimens 45 x 70 mm are weighed. The specimens are immersed in a Kubelka jar. After one (1) hour, the test specimens are removed and allowed to "drip off" for one (1) minute. The electrolyte retention is determined by recording the difference of the electrolyte level in cc's as per the following formula:

KOH Absorption in %: $\frac{\text{Retained Electrolyte Volume x Wt. of Test Specimen}}{\text{Density x 100}}$

KOH Absorption in g/m^2:

$$\frac{\text{Retention in \% x gms/m}^2\text{ of 45 x 70 mm Specimens}}{100}$$

No. of Tests: 1 per Sample.

4.3.5 Electrolyte Wicking (Wettability)

4.3.5.1 Samples - One (1) per manufacturer roll, cut 12.75 x 2.5

4.3.5.2 Equipment

a) 250 ml beaker

b) 1.30-1.35 specific gravity KOH

c) Rule

4.3.5.3 Procedure

4.3.5.3.1 Place approximately 100 cc's electrolyte in a 250 ml beaker.

4.3.5.3.2 Position sample lengthways vertically so that the lower end is immersed one (1) inch minimum in electrolyte.

4.3.5.3.3 Note and record the time for electrolyte to attain a stable resistance, or for 2 minutes. Measurements shall be taken approximately each 5 seconds and the results graphically plotted.

4.3.6 Resistance

4.3.6.1 Sample - One (1) sample from each manufacturer's lot.

4.3.6.2 Equipment

a) Sample Holder and Test Fixture

b) Ammeter, DC

c) Null Potentiometer

d) 1.30 specific gravity electrolyte

e) Power Supply, DC

4.3.6.3 Procedure

(1) Adjust constant current power supply to 50 ma/cm^2 exposed separator area.

(2) Fill fixture with electrolyte above the level of the sample.

(3) Connect power supply to sample holder and start current.

(4) Record three (3) potentiometer readings at five (5) second intervals and record a final value after stabilization.

(5) Remove sample and record voltage for blank run.

(6) Calculate resistance and resistivity as follows:

a) $R'' = \frac{Er - Eb}{I} A$

R'' = Separator Resistance, ohm-cm^2

Er = Voltage across reference electrodes with separator in path-volts

Eb = Voltage drop during blank run, volts.

I = Current, Amperes

A = Separator Area Exposed - cm^2

b) $P'' = \frac{R''}{T_W}$

P'' = Separator Resistivity, ohm-cm

R'' = Separator Resistance, ohm-cm^2

(7) Record calculated values on Data Sheet 5. Graph resistance values on one (1) graph (10 x 10 per inch).

4.3.7 Tensile Strength at Break

4.3.7.1 Samples

Two (2) samples from each roll or six (6) from each manufacturer's lot.

4.3.7.2 Equipment

Tensile Tester

Vernier Calipers

CADY Gage

Temperature Regulated Chamber

Corrosion Resistant Containers

4.3.7.3 Procedure A

(1) Cut specimens 12.7 x 2.5 cm. Examine for cracks, nicks and foreign material inclusions.

(2) Condition specimens at 72 ± 5°F at 80% maximum relative humidity.

(3) Position sample in tester with grip separation of three (3) inches.

(4) Apply load, noting grip separation and load at break as well as thickness.

(5) Calculate tensile strength at break.

$$\text{Tensile Strength} = \frac{\text{Breaking Load, Pounds}}{\text{Cross Section Area}}$$

$$\% \text{ Elongation} = \frac{L - Lo}{Lo} (100)$$

L = Grip Sepration at Break

Lo= Original Grip Separation

(6) Record results on Data Sheet No. 5.

(7) Repeat preceding four (4) steps on samples conditioned @ 70 ± 2°C for 24 hours in cell electrolyte under a CO_2 - free atmosphere.

4.3.7.4 Procedure B

A testing machine similar to the Scott Tester Model X-3 is used. The size of the specimen is 50 x 260 mm. The distance between the clamps at the start of the test shall be 225 mm (8"). The speed of the pulling clamp shall be 12 1/2" per minute. The load at the moment of breaking is read in pounds. (For the 50 mm wide specimens, the elongation at break is read in %).

No. of Tests: 5 for each direction

4.3.8 Air Permeability

4.3.8.1 Sample Required

One (1) per manufacturers lot

4.3.8.2 Apparatus - air permeability tester (essentially same as ASTM D737-46 See Figure No. 1), or Gurley Sensometer, or the method of Schiefer and Baylord, J. Res. Nat. Bur. Standards 28, 637 (1942).

4.3.8.3 Procedure

Place test specimen across sample holder. Open regulator valve until pressure drops across sample 0.5" H_2O. Read pressure drop across standardized orifice. Convert manometer to $ft^3/ft^2/min$ using calibration chart.

4.3.9 Wetting Agent Test

4.3.9.1 Sample Required

One (1) 4" x 4" sample from each roll.

4.3.9.2 Equipment

One pint glass container with cover 1.300 specific gravity electrolyte deionized water.

4.3.9.3 Procedure A

Place approximately one-half pint 1.3 sp. gr. KOH electrolyte in a glass container with a separator sample and close. After 15 minutes, shake the container vigorously for a minimum of 20 seconds. Allow the sample to sit in the container for a minimum of one minute. At the end of this period, make the determination for the presence of foam on the surface. Presence of foam will cause rejection of the roll represented by the sample. Note any discoloration of the electrolyte.

4.3.9.4 Procedure B

Repeat the above test with water.

4.3.9.5 Procedure C

Repeat the above test with 1.3 sp.gr. KOH and allow to remain in the caustic for one (1) week, then repeat shake test.

4.3.10 Extractable Organic Content

4.3.10.1 Samples

One required per manufacturers lot (10 x 10 cm)

4.3.10.2 Equipment

a) Analytical Balance

b) Beaker or other container with cover

c) Solvent: Methanol, Reagent Grade

d) Magnetic Stirrer

4.3.10.3 Procedure A

(1) Weigh separator sample to nearest tenth milligram.

(2) Determine volume of separator sample.

(3) Place sample in container of methanol. Use a volume ratio of approximately 20 solvent to one separator.

(4) Cover container and stir 16-24 hours. Note any discoloration of sample.

(5) Remove sample; dry at 50°C (125°F) maximum; weigh sample.

(6) Evaporate Solvent - Obtain weight of residue.

(7) Submit residue for IR analysis of major organic constituents.

NOTE: Proportionally larger separator sample may be used if residue is inadequate for analysis.

4.3.10.4 Procedure B

Repeat 4.3.10.3 using trichloroethylene.

4.3.11 Inorganic Content

4.3.11.1 Samples Required

A minimum of one (1) per manufacturer's lot.

4.3.11.2 Apparatus

a) Beaker and magnetic stirrer

b) Distilled water

c) Hot plate

4.3.11.3 Procedure A

(1) Weigh sample of separator to nearest milligram.

(2) Place sample in 50 cc's distilled water.

(3) Extract solubles using magnetic stirrer for 16-24 hours.

(4) Conduct wet chemical analysis on aliquot of extract and record results on Data Sheet .

Analysis shall include:

a) Nitrate - Taylor Method with phenoldisulfonic acid.

b) Silica - Taylor Method with color reagent one and two.

c) Carbonate - Barium chloride method.

d) Nickel)
e) Zinc) Atomic absorption method

f) Titanium Sulfuric Acid Peroxide Calorimetric Method

g) Chloride - Mohr Method

NOTE: The above methods are cited for reference only.

4.3.11.4 Procedure B

Perform semi-quantitative spectrographic analysis on one (1) sample per lot.

4.3.11.5 Procedure C

Completely ignite sample and burn. Weigh ignition residues. Requirement of 3.3.2 shall be met.

4.3.11.6 Procedure D

1) Cut four 4 x 4" samples across the width of the material.

2) Weigh on analytical balance.

3) Dry at 104°C to a constant weight.

4) Remove and cool in desiccator.

5) Weigh - (Dry weight).

6) Place samples in extraction thimbles in Soxhlet Extraction apparatus.

7) Extract with distilled water at the boil for 4 to 5 hours.

8) Remove sample and dry at 104°C to a constant weight.

9) Cool in desiccator.

10) Weigh sample for extracted weight.

4.3.12 Burst Strength

The bursting strength shall be measured on an approved type of diaphragm burst tester such as the Model C Mullen Tester. The sample shall be at least 3 x 3" in area. The specimen is clamped in position and is subjected to the pressure of a fluid activated diaphragm. The pressure at burst will be read on a gauge in pounds.

5.0 SHIPPING INFORMATION

5.1 Labeling

Each roll shall be clearly labeled in accordance with Para. 3.1.2.

5.2 Packaging for Shipment

Materials shall be packaged in a manner so that damage does not occur during shipment by normal modes of transportation and handling.

TABLE NUMBER 1

TEST	PARAGRAPH	APPENDIX I DATA SHEET NUMBER	CERTIFIED TEST DATA REQUIRED BY SELLER	R & I TESTS	RECOMMENDED PIECE PART TESTS
IDENTIFICATION PHYSICAL MEASUREMENTS	4.3.1	1	1	Each Roll	100%
Weight A	4.3.2	2		Each Roll	
Weight B			3/Roll		
Thickness A	4.3.3			Each Roll	Sample
Thickness B			30/lot		
PHYSICAL ANALYSES					
Absorption (A)	4.3.4.2			6 min/lot	
Absorption (B)	4.3.4.3			2/Roll	
Absorption (C)	4.3.4.4			2/Roll	Sample
Wettability (Wicking)	4.3.5		3/Roll		
Electrical Resistance	4.3.6			1/Roll	
Tensile Strength (A)	4.3.7			1/Lot	
Tensile Strength (B)				2/Roll	
Permeability	4.3.8		10/Lot	6 Min/Lot	
Burst Strength			1/Lot	1/Lot	
			1/Lot		
TESTS FOR ADDITIVES/ WETTING AGENTS					
KOH Procedure A	4.3.9.3			1/Roll	
Water Procedure B	4.3.9.4			1/Roll	Sample
KOH Procedure C	4.3.9.5			1/Lot	Sample
CHEMICAL ANALYSES					
Spectrographic Nickel Cloride & Silica)	4.3.11.4			1/Lot	
Zinc Nitrate Carbonate) Titanium)	4.3.11.3			1/Lot	
Extractables				1/Lot	
Tricloroethylene	4.3.10.4			1/Lot or	
Methanol	4.3.10.3			1/Lot	
W[redacted]er			4/Lot		

IR Analysis	4.3.10.3 or 4	1/Lot

OTHER RECOMMENDED TESTS

Retained Samples	Sample
Compressed Thickness (As Applicable)	Sample

(This side of page is blank)

APPENDIX E

Potassium Hydroxide Specification

EP-MS-36

POTASSIUM HYDROXIDE K1020 (45B)

(EP P/N KOH 101)

February 6, 1964

Revision B

29 April 1964

PRECEDING PAGE BLANK NOT FILMED

All procedures shall be changed by E.O. and are to be referred to as said revision from that time on. Current revision letters will be placed in the upper right corner of each page.

Date Completed 2-6-64

REVISION LETTER	REVISION DATE	E.O. NUMBER	OPERATION OR PAGE	APPROVAL
A	4-14-64	6409, 6421, 6425	1, 2	
B	4-29-64	6974	3	

EP MS 36 Approved by: F.D. Gerde

Potassium Hydroxide K1020 (45B) Date: February 6, 1964

(EP P/N KOH 101) **Revision A**

1.0 SCOPE

This specification covers a potassium hydroxide solution used in the formulation of electrical battery plates and as an electrolyte for the same.

2.0 REFERENCES

2.1 Not applicable.

2.2 Not applicable.

3.0 REQUIREMENTS

3.1 Form

3.1.1 The K1020 (45B) solution shall be supplied in liquid form.

3.2 Special Identification

3.2.1 Not applicable

3.3 General

3.3.1 Not applicable

3.4 Lot Definition

3.4.1 A lot shall consist of the material produced by one manufacturer in not more than 24 consecutive hours under essentially the same manufacturing conditions and with no change in materials, providing the operation is continuous. In the event the process is a batch operation, each batch shall constitute a lot.

3.5 Chemical Analysis

3.5.1 The K1020 (45B) solution shall contain the following chemical parameters.

1.	KOH	45% Minimum
2.	Sodium as Na_2O	0.10% Maximum
3.	Chloride as KCl	0.004% Maximum
4.	Carbonate as K_2CO_3	0.20% Maximum
5.	Iron as Fe	5 parts/million Maximum
6.	Water (H_2O)	Remainder

4.0 TEST METHOD

4.1 Qualification

4.1.1 This material is considered qualified for use in each battery which has used this material in its successful battery qualification program.

4.2 Acceptance Test

4.2.1 Chemical Analysis (Requirements per Paragraph 3.5)

4.2.1.1 An analysis shall be performed as to the chemical constituents of the material using any acceptable standard analytical method which provides the desired accuracy.

5.0 QUALITY CONTROL

5.1 The manufacturer shall provide a certified test report or certificate of compliance stating that test data is on file and is available for Eagle-Picher inspection upon request with each shipment showing that each lot conforms to the acceptance requirements of this specification, or Eagle-Picher shall do so.

5.2 Eagle-Picher reserves the right to conduct the tests prescribed in paragraph 4.2 of this document.

5.3 No changes in material formulation or method of manufacturing may be made without prior approval of the purchaser.

5.4 Tests in accordance with paragraph 4.2 of this specification shall be conducted on each incoming lot.

5 5 Receiving Inspection Control shall perform the following inspections at receipt of each shipment and lot of material.

1. Verify that all information is as stated in paragraph 6.0 and conduct the chemical analysis of paragraph 4.2.1.

2. Cross check the purchase order with the shipping bill to verify correct procurement.

3. Review the certified test report to verify all required tests have been performed and passed.

6.0 Shipping Information

6.1 Each tank car shipped to Eagle-Picher shall be completely identified with:

1. Manufacturers part number
2. Date of manufacture
3. Lot number

7.0 SOURCE

Pennsalt Chemical Company
Three Penn Center
Philadelphia 2, Pennsylvania

CODE IDENT NO. 86460

Vendor P/N K1020 (45B)

APPENDIX F

Electrolyte Handling

and

Processing Procedure

EP-MP-151

ELECTROLYTE HANDLING AND
PROCESSING PROCEDURES FOR
THE RSN-110 TYPE CELL

Prepared for:

GRUMMAN AEROSPACE CORPORATION
Bethpage, Long Island, New York

SPEC AV-D559 CS-1

15 March 1971

Original

Prepared by:

EAGLE-PICHER INDUSTRIES, INC.
Electronics Division
Couples Department
Joplin, Missouri 64801

Bill Hawkins

Bill Hawkins
Engineering

Ken Kruger
Quality Assurance Manager

PRECEDING PAGE BLANK NOT FILMED

1.0 SCOPE

The purpose of this document is to establish the procedures and controls for treatment, mixing and bottling of electrolyte for hermetically-sealed nickel-cadmium RSN-110 Type Cells.

2.0 APPLICABLE DOCUMENTS

EP-MS-36	Potassium Hydroxide K1020 (45B)
EP-QC-468	Production and Inspection Record

3.0 REQUIREMENTS

3.1 Raw Materials

3.1.1 45% Potassium Hydroxide

45% potassium hydroxide "mercury cell" grade shall be procured in sealed polyethylene lined drums per EP-MS-36. In addition to Quality Control Tests performed per EP-MS-36, the electrolyte shall be analyzed for nitrate content of one (1) milligram per liter, or less.

The supplier batch number, grade, analysis, date of purchase and the date that the container is opened shall be recorded.

3.1.2 Distilled Water

Distilled water shall be used for diluting the 45% potassium-hydroxide before barium hydroxide treatment. The silica content in the water shall not exceed one (1) part per million (ppm). The solids content of the water shall not exceed 50 ppm. The electrolyte shall be tested using a suitable conductivity cell for a level of 350,000 ohm-cm^2.

3.1.3 Barium Hydroxide

Barium hydroxide used for treatment of electrolyte shall be reagent grade.

3.2 Mixing to Desired Specific Gravity

Upon successful completion of the tests of paragraphs 4.1 and 4.2, the treated 45% potassium hydroxide shall be diluted to a specific gravity of 1.300 ± 0.02 using distilled water per paragraph 3.1.2.

3.3 Barium Hydroxide Treatment

3.3.1 Carbonate Determination

Determine percent CO_2 by standard analysis.

3.3.2 Procedure

A. Using the CO_2 percent as determined by the standard analysis for a container of electrolyte, calculate the weight of CO_2 present in the electrolyte.

B. Calculate based on the following equation the amount $Ba(OH)_2$ which is required to react with the calculated weight of CO_2 as K_2CO_3.

$$Ba(OH)_2 + K_2CO_3 = BaCO_3\downarrow + 2\ KOH$$

Add the required amount of $Ba(OH)_2$ to the electrolyte solution. The CO_2 will be put out as $BaCO_3$.

C. Allow the precipitate to decant for 30 minutes. Filter the electrolyte in a sealed container.

D. Rerun carbonate content determination to assure the level is below .01 grams per liter as CO_2.

The electrolyte mix shall be tested for the hydroxyl concentration as determined by analytical methods and the carbonate concentration shall be determined by the double titration method of phenolphthalein end point followed by methyl orange end point. Carbonate concentration must be less than 0.01 grams per liter.

3.3.2 Procedure (Continued)

If the electrolyte does not meet this requirement of carbonate concentration, it shall be treated and tested per paragraphs 3.3 and 4.2.

3.4 Bottling of Electrolyte

Upon successful completion of tests of paragraph 4.3, the electrolyte shall be bottled for individual cell allotments. Each bottle shall contain _____cc's of 1.30 specific gravity of electrolyte.

A. Rinse glass container with distilled water and dry.

B. Fill glass container with 1.300 ± 0.02 specigic gravity potassium hydroxide.

C. Weigh empty poly bottle (with cap and diaphragm) for tare weight determination. Record tare weight on the bottle label.

D. Fill bottle to _____cc (by weight). Determine weight (with cap and diaphragm) by a Mattler 0-1000 gram scale or equivalent. Record gross weight on the bottle label.

E. Place the sealing diaphragm (polyethylene disc approximately .015 inch thick x the outside diameter of the applicable bottle neck) into the sealing cup. NOTE: Put a trace of DOW grease in cup to prevent diaphragm from sticking to the cup when heated.

F. Place sealing cup on the bottle and place the bottle with the sealing cup installed under the sealing ring of the induction heater with the sealing cup extending through the sealing ring. The heater shall be a high frequency induction heater, Lapel Model T-1-B-1-KC-A-B or equivalent.

G. Perform seal operation by the following steps:

1) Turn all switches to the "on" position.

3.4 Bottling of Electrolyte (Continued)

2) Set the "power" knob between 80-90.

3) Set the "grid" knob between 80-90.

4) Depress the foot switch for approximately 5 seconds. Remove sealing cap and visually check for a proper diaphragm-to-bottle seal. If seal is not acceptable, replace sealing cap and repeat step 4.

H. Remove bottle from the sealing ring and remove the sealing cup from the bottle. Allow the seal to cool for a minimum of two (2) minutes.

I. Place a strip of litmus paper on top of the bottle seal and screw the cap down snugly on the bottle.

J. Place the sealed bottles in an inverted position in an altitude chamber and set chamber at 60,000 ft. After the 60,000 ft. pressure is attained leave the bottles at this pressure for a minimum of 5 minutes.

K. Lower chamber to zero and remove the electrolyte bottles from the chamber.

L. Visually check the litmus paper through the bottle cap for any indication of seal leakage. If a seal is leaking, the litmus paper shall have a bluish discoloration. If no leakage is present, the litmus paper shall be a light red color. Seal leakage is cause for rejection.

M. Verify that bottle labels contain the following information:

1) Specific Gravity
2) Tare Weight
3) Gross Weight
4) Lot Number
5) Mix Number
6) Battery Type
7) Date
8) Number cc's or oz.

3.4 Bottling of Electrolyte (Continued)

N. 2 samples of electrolyte shall be prepared and identified per the above paragraphs for each lot. This shall be a sample of approximately one ounce (22 cc's) for each.

3.5 Filling Procedures for RSN-110 Type Cells

3.5.1 Requirement

A vacuum activation system should be used to introduce a premeasured quantity of electrolyte into each cell. Such a system is pictured schematically in Figure No. 1. This system consists of a vacuum pump, vacuum chamber including one or more cavities each capable of holding a volume approximately 50% greater than that required for a cell (to prevent spatter loss).

3.5.2 Procedure

A. Insure filling apparatus has been cleaned.

B. Weigh each cell to nearest gram and record on flow sheet.

C. Connect individual cell gage exhaust from each cell to the corresponding cell fill line until the desired number of cells are prepared for activation.

D. With activation chamber lid in place, open globe valve of each cell and each fill tube valve.

E. Evacuate the chamber to approximately 16 inches Hg at a rate of approximately 5 inches per minute and close main valve to vacuum line.

F. Monitor gauge for approximately two minutes to insure that there are no leaks in the system.

3.5.2 Procedure (Continued)

G. Open chamber equalization valve and close individual fill line valves.

H. Remove chamber lid and close chamber vent valve.

I. Remove cap from electrolyte bottle, remove sealing diaphragm with a clean sharp knife.

J. With the aid of a polyethylene funnel, carefully pour the contents of one bottle of electrolyte into the proper cavity.

K. Repeat the above step until the desired number of cavities are filled.

L. Replace the chamber lid and open individual cell fill valve tubes at a rate of approximately 2 inches per minute to sixteen (16) inches vacuum. Close the vacuum line valve.

M. Re-evacuation of the chamber may be necessary to complete transfer of all electrolyte from each cavity to the corresponding cell.

N. When all electrolyte cavities and fill tubes are empty, close the vacuum line valve and open the chamber vent. Close individual fill tube valves and cell globe valves.

O. Disconnect cell fill tubes and close cell globe valves.

P. Seal each cell immediately upon filling.

Q. Clean filling apparatus using deionized water. The system is to be purged a minimum of three times with deionized water.

3.5.2 Procedure (Continued)

R. Weigh each cell to the nearest gram and record cell wet weight on appropriate flow sheet.

4.0 QUALITY ASSURANCE

4.1 Testing of Raw Materials

4.1.1 45% Potassium Hydroxide Tests

This material shall be tested in accordance with EP-MS-36 and, in addition, shall be analyzed for nitrate content to demonstrate compliance with paragraph 3.1.1.

4.1.2 Distilled Water

4.1.2.1 Conductivity

A suitable conductivity cell calibrated less than two weeks prior to start of water requirement tests used on cells constructed under this specification shall be used. Criteria for calibration shall be as follows:

(a) The conductivity cell shall be recalibrated at two week intervals (maximum) until completion of the water requirement tasks.

(b) The calibration shall be conducted in a 0.1% potassium chloride solution and shall record a conductivity of 1410 ± 20 mhos at 25°C (a temperature correction as per the Handbook of Chemistry and Physics may be used). If conductivity is not within these tolerances, the conductivity cell must be replaced or replatinized.

4.1.2.2 The water shall be analyzed for total solids content in accordance with paragraph 3.1.2.

4.1.3 Barium Oxide

Certified analysis shall be obtained for each lot of barium oxide.

4.2 Testing of Mixed Electrolyte

Testing of mixed electrolyte shall be for carbonate content and hydroxyl ion concentration using the double titration method of phenolphthalein end point followed by methyl orange end point as follows:

Determination of Total Alkalinity, Actual Alkalinity and Carbon Dioxide -

Reagents: 0.6 N Hydrochloric Acid
Phenolphthalein
Methyl Purple Indicator

Procedure:

Weigh to the nearest milligram, 10 grams of solid or 20 grams liquid in glass stoppered weighing bottle. Cool and dilute to 250 ml with CO_2 free water.

Pipette 25 ml. aliquot into beaker, add 100 ml. distilled water and 2-3 drops phenolphthalein. Titrate to end point with .6 N HCl. Record volume (A). Add 2-3 drops methyl purple and titrate to first tinge of purple end point. Record volume (B).

Calculations:

% KOH Total Alkalinity =

$$\frac{(A + B) \text{ ml. HCl} \times \text{Normality} \times 0.056 \times 100}{\text{Sample Weight}}$$

% KOH Actual Alkalinity =

$$\frac{(A - B) \text{ ml. HCl} \times \text{Normality} \times 0.056 \times 100}{\text{Sample Weight}}$$

% CO_2 =

$$\frac{2\ B \text{ ml. HCl} \times \text{Normality} \times 0.022 \times 100}{\text{Sample Weight}}$$

Reference: N. H. Furman, "Scott's Standard Methods of Chemical Analysis," D. Van Nostrand, Fifth Edition, page 2256.

4.3 Testing of Bottled Electrolyte

EP-QC-468 form shall be used to record bottled electrolyte data.

A. Verify that hydrometer and graduated cylinder are rinsed clean and dried prior to use.

B. Check specific gravity of each container of KOH and record on Good Material Tag. Use conversion table to determine specific gravity.

C. Verify lot number is recorded on Good Material Tag.

D. Verify batch number is recorded on Good Material Tag.

E. Verify empty bottles are free from contamination prior to use.

F. Verify bottles are filled with the proper amount of KOH and proper specific gravity as per battery specification.

G. Verify that litmus paper is placed in bottle cover and leak test is performed per paragraph 3.4, Section L.

H. Inspect bottle labels for the following information:

1. Specific Gravity
2. Tare Weight
3. Gross Weight
4. Lot Number
5. Batch Number
6. Battery Type
7. Date
8. Number cc's/oz.

I. Verify that the specific gravity of the container of which KOH was bottled from, and the specific gravity on the bottle labels correspond.

J. After final acceptance is made of the bottling operation, place a Good Material Tag with the acceptable material with the following information:

4.3 Testing of Bottled Electrolyte (Continued)

1. Battery Type
2. Type KOH
3. Batch Number
4. Lot Number
5. Number of Bottles

4.4 Retained Samples

One retained sample of 3.4 shall be submitted to GAC with the appropriate lot of delivered cells.

The second retained sample shall be tested by spectro-chemical analysis for:

(a) Silver
(b) Cobalt
(c) Copper
(d) Iron
(e) Sulfur
(f) Zinc
(g) Any other impurity present in concentration greater than 100 ppm.

4.5 Cell Filling

4.4.1 Verify that filling apparatus has been thoroughly cleaned.

4.4.2 Inspect bottles of electrolyte for indication of leakage per paragraph 3.4, Section I.

4.4.3 Verify that correct filling procedures are followed per paragraph 3.5.

4.4.4 Verify cell dry and activated weights.

ELECTROLYTE FILL SETUP

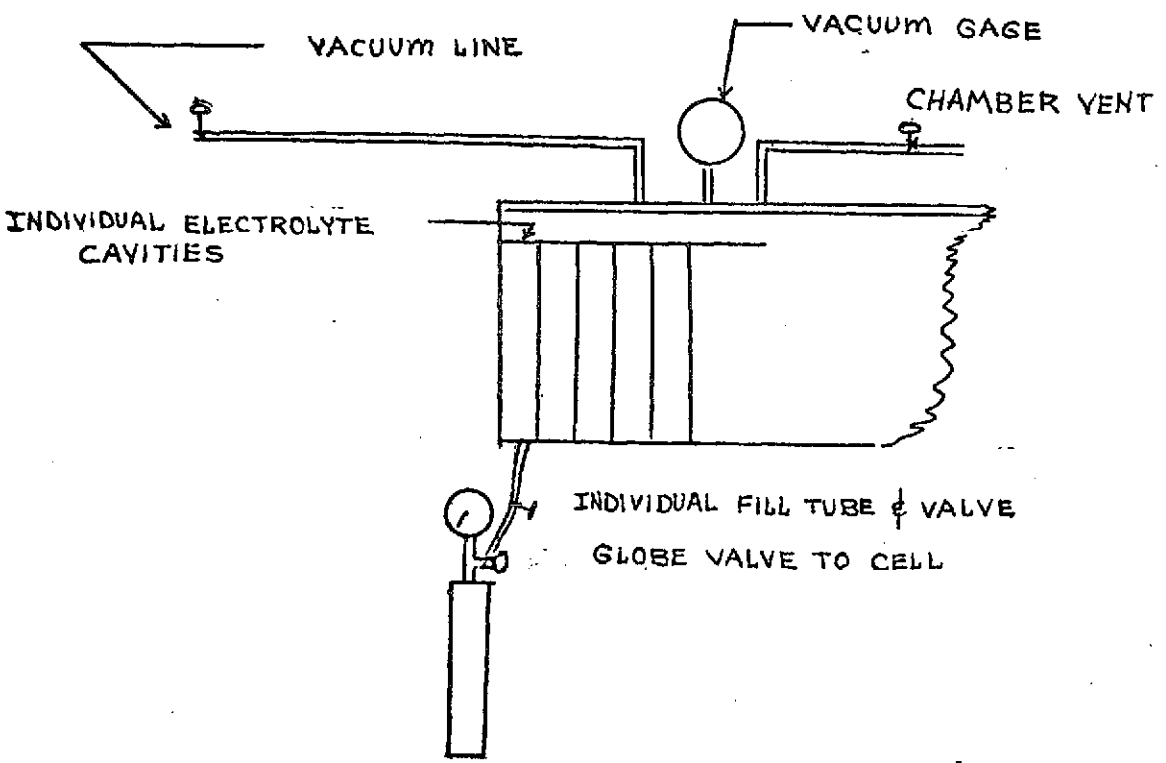


Figure No. 1

APPENDIX G

EP-MP-146-1

ACTIVATION AND CONDITIONING FOR RECHARGEABLE NICKEL-CADMIUM CELL (RSN-110)

1.0 SCOPE

This document defines the procedures, requirements and quality assurance provisions for proprietary Eagle-Picher Cell Activation and Conditioning Procedures for RSN-110 type sealed nickel-cadmium cells.

2.0 REFERENCED DOCUMENTS

005264	Cell Assembly Drawing (RSN-110 Type)
EP-WS-8	Cell Welding Spec.
EP-MP-152	Leak Test Procedure for RSN-110 Type Cells
EP-MP-151	Electrolyte Handling & Processing Procedures for RSN-110 Type Cell
IT-QC-8	X-Ray Procedure for RSN-110 Type Cells
AV-D559-CS-1	Specifications for 100 Ampere Hour Nickel-Cadmium Storage Cell

3.0 REQUIREMENTS

3.1 Test Conditions

3.1.1 Room Ambient Tests

Tests shall be performed at room ambient conditions, except for the Retention of Charge Test.

3.1.2 Filling Procedure for RSN-110 Cells

3.1.2.1 Requirement

A vacuum activation system shall be used. All electrolyte handling shall be conducted in a glove box in an inert dry atmosphere.

3.1.2.2 Procedure

a) Place cells which have been evacuated to -30" of Hg into the glove box.

b) Place large bulk of previously analyzed electrolyte into the glove box.

c) Inspect filling device for cleanliness and place into glove box.

d) Seal glove box and remove air and replace with dry inert gas (N_2).

e) Measure exact amount of electrolyte into a filling bottle (polyethylene) and attach to cell as shown in Figure 1.

f) Open cell's valve and squeeze until all electrolyte has entered the cell.

g) Close the cell's valve tightly and remove filling device.

h) After removal of cell from the glove box re-weigh it to the nearest gram and record on appropriate flow sheet.

i) All cells must stand for at least 16 hours prior to start of the first electrical test.

3.1.3 Cell Grouping

Series-connected cells in groups of 20-30 whenever possible. Non-conducting insulators shall be placed between all cells. Restraining plates shall consist of sheet aluminum (electrically insulated with .005" mylar, nylon, kapton or equal) 3/8" minimum thickness approximately 1" wider than the cell.

Approximately 4 cells shall be constrained in each group. The cell group shall be restrained by 1/2" insulated aluminum plates connected by threaded rods with nuts torqued to 5-6 inch pounds. Alternately, cells may be

3.1.3 (Continued)

individually restrained between 1/2 inch aluminum plates approximately 1" wider than the cell. Extreme care shall be taken handling cells, especially when in the charged condition. Transporting of cells when in the charged condition. Transporting of cells shall be accomplished using a cart equipped with styrofoam or wood cut-outs for each cell.

3.1.4 Temperature Measurement

A thermocouple of small gauge shall be affixed to one (1) cell in each group of 4-30 cells (or one thermocouple for each cell element design). The thermocouple shall be located as close to the center of the wide side of the cell case as possible.

The cell group thermocouple shall be located on the middle cells in the test group and shall be positioned approximately in the middle of the wide cell side. A narrow slot shall be cut in the insulator and the thermocouple shall be insulated from the cell and test fixture by approximately .005" thick electrical tape.

3.1.5 Data Recording

During electrical testing data shall be recorded at the intervals indicated by the appropriate data sheets. Data may be acquired by printout of the GAC-supplied NLS system. Temperature may be acquired automatically or by reading an instrument such as a Thermo-electric "Minimite" potentiometer pyrometer.

3.1.6 General

All ammeter and voltmeter calibration data shall be recorded. Voltmeter correction shall be recorded. If a meter is changed during a test, it shall be so noted.

Ammeters shall be continuously monitored and calibration shall be "used".

Open circuit voltages shall be recorded prior to each charge and discharge.

3.2 Conditioning Requirements

NOTE: The following requirements define the general procedures necessary to reach the goal of satisfactory cell performance. They are deliberately intended to provide the test engineer enough freedom to treat individual cell,

Specifically, portions of tests may be rerun, such as power discharge, followed by additional sealed cycles as necessary to develop the rated capacity of the cell. All such repeat testing shall be noted and documented.

3.3 Preferred Conditioning Procedure

3.3.1 Record dry weight of each cell on Q.C. Flow Sheet to the nearest gram. The cell shall next be X-Rayed per the above referenced procedure (See Section 2). After X-Ray acceptance, the unactivated cell shall be helium leak checked per the Leak Test Procedure (EP-MP-152).

Activate cells per paragraph 3.1.2. Each cell shall be activated with the number of cc's called for on the cell assembly drawing or the design requirement in accordance with the applicable purchase order.

3.3.1 (Continued)

Cells shall be equipped with the following items:

a) Stainless Steel Fittings such as a "Tee" etc.
b) Stainless Steel Bourdon Tube Compound Cage.
c) Globe Valve or Plug
d) Adaptor and low pressure Bunson valve;
All cells shall be provided with a valve to prevent entrance of CO_2 during discharge.

Record each cell activated weight with and without hardware on the battery Q.C. Flow Sheet.

3.3.2 Discharge each cell at a rate of 25 ± 2 amps to 1.00 volt. Note and record the time to 1.00 volt. Continue discharge to 0.7 ± 0.1 volt per cell, remove from circuit and short out for a minimum period of 8 hours with a 0.20 ohm resistor.

Verify that cell voltage is less than 0.4 volts.

3.3.3 Remove shorting resistors and series-connect cells to a constant current source. ASSURE THAT THE GLOBE VALVE IS IN THE OPEN POSITION WHEN POSITIVE CELL PRESSURE EXISTS SO CHARGING GASES WILL VENT. Place on charge at 30 amperes for 4.5 hours. Close cell valve immediately at either termination of charge or as soon as no positive cell pressure with respect to atmospheric exists.

3.3.4 Discharge

Connect cell group to a variable resistor of suitable wattage rating and discharge at a rate of 50 ± 2 amperes. Record time for each cell to reach 1.0 volt. Cells shall be allowed to remain in the circuit until voltage reaches 0.7 ± 0.1 volt. Each cell should be removed at this minimum voltage and shall be externally shorted for a period of four (4) hours minimum.

3.3.5 Repeat Steps 3.3.3 and 3.3.4 one (1) additional time.

3.3.6 Charge as in 3.3.3 above.

3.3.7 Leave valve or plug open only to conduct the power discharge as per Figure 2 at room ambient conditions. Discharge from the negative terminal of one (1) cell to the cell case of the adjacent cell at a rate of 13.0 ± 0.1 amps for 2 ± .01 hours.

3.3.8 Discharge and short out per 3.3.4. Install pressure gages on cells as required. Thoroughly clean and wash cell free of traces of electrolyte.

3.3.9 After the power discharge cycle, weigh each cell (with hardware to the nearest gram and record this weight.

3.3.10 Scrub cell weld and seal areas with deionized water. Dry with a clean dry air blast.

3.3.11 Charge at 10 amps for 16 hours or maximum of 1.51 volts, whatever occurs first.

3.3.12 Discharge at 50 amps to 1.00 volts per cell and remove from circuit at 1.0 volt. Discharge data shall be recorded at open circuit and at 15 minute intervals. The time to 1.00 volt shall be recorded for each cell.

3.3.13 Phenolphthalein Leak Check using a 1% solution. If the preliminary indication is positive, remove all traces of coloration using deionized water; dry weld and seal areas and retest. Appearance of a pink or red coloration in a ten minute period shall be cause for rejection.

3.4 Retention of Charge Test

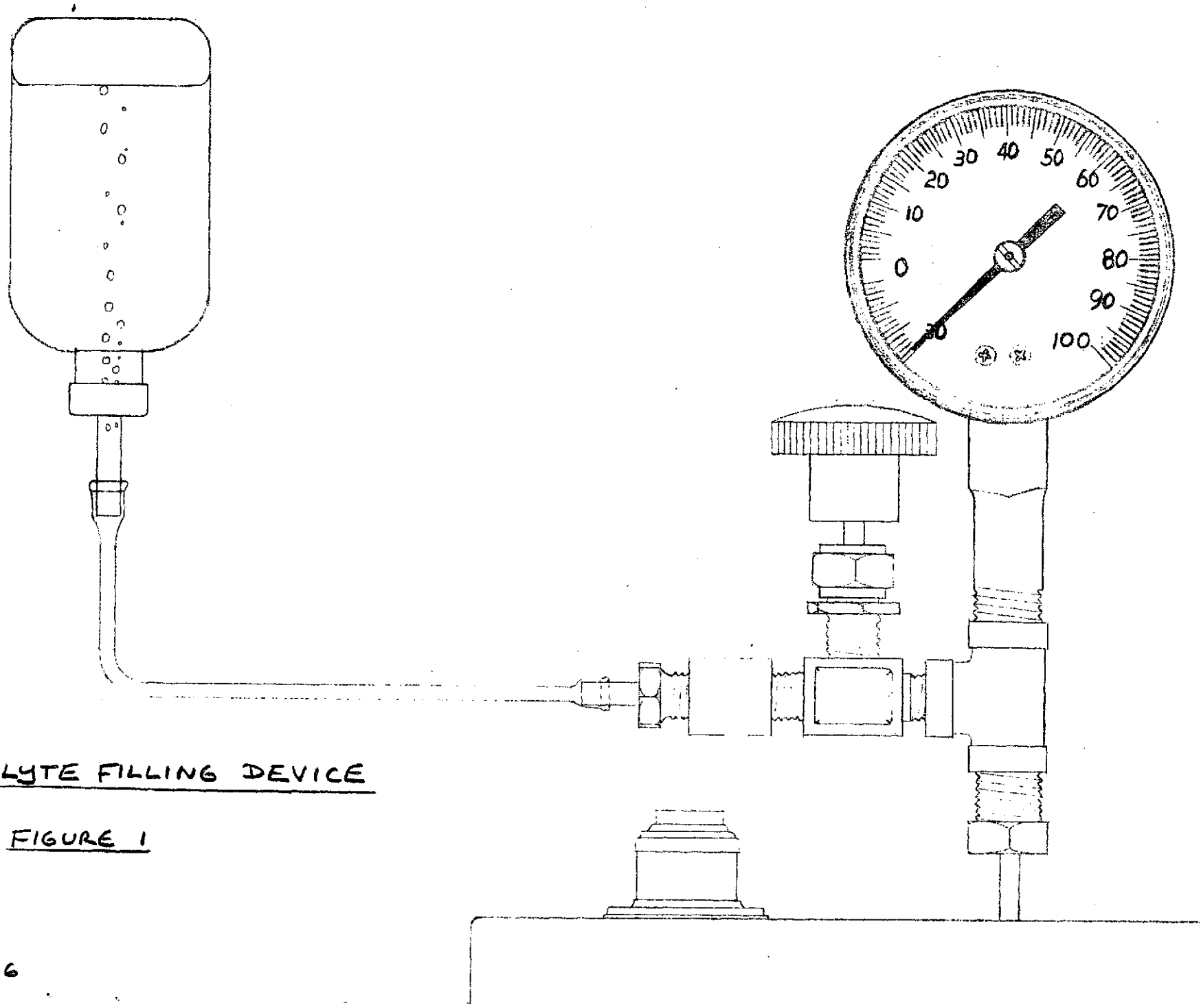
After discharge to 1.0 volt, connect a 0.20 ± 5% ohm resistor and store at 68° ± 5°F for 16 $^{+1}_{-0}$ hours. Next, remove the 0.2 ohm load 24 ± 0.5 hours at 68°F ± 5°F. The cell voltage at the end of this open-circuit stand shall be 1.15 volts or higher.

4.0 QUALITY ASSURANCE

4.1 Quality Assurance personnel shall audit and monitor activities during testing.

4.2 Test data shall be reviewed for completeness.

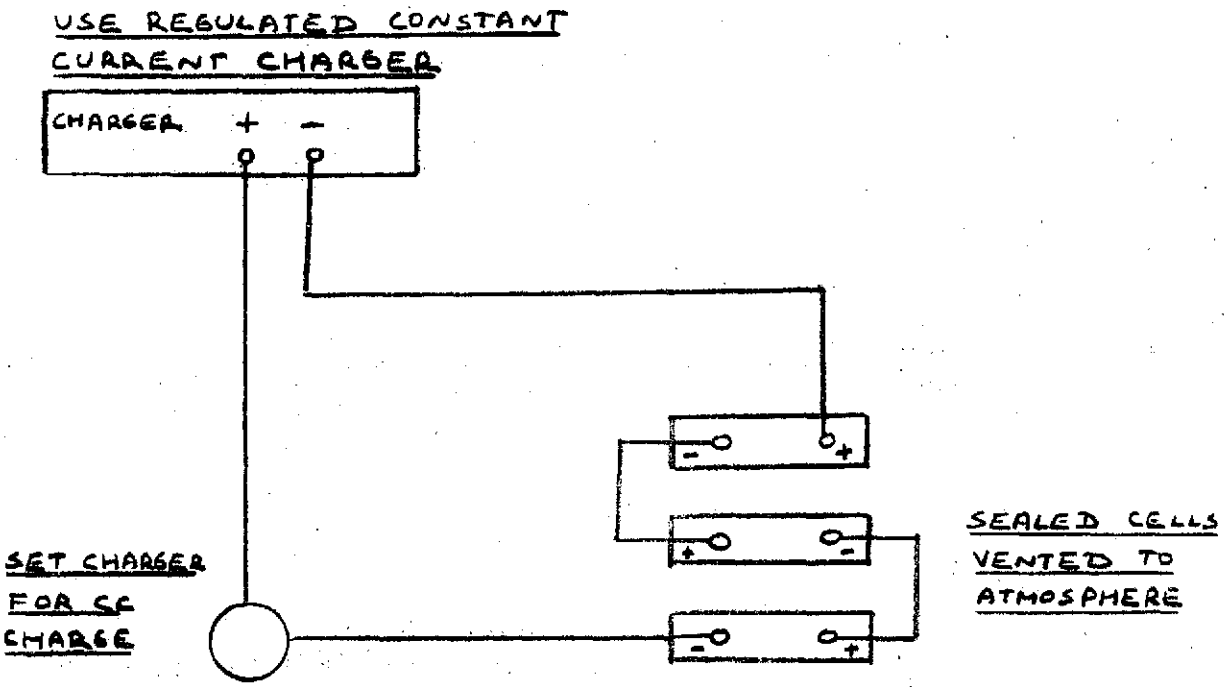
4.3 Inability of a cell to meet the 100 ampere-hour requirement shall be cause for a "withhold" disposition for that cell, as is the occurrence of a leak or failure on Retention of Charge Test.



ELECTROLYTE FILLING DEVICE

FIGURE 1

OBJECTIVE : TO DISCHARGE THE NEGATIVES 26 AMPERE-HOURS WHILE LEAVING THE POSITIVES FULLY CHARGED



POWER DISCHARGE CIRCUIT

FIGURE 2

NOTE: Reproduction, return original and repro order to Corporate Forms Control, Plant 30.

Customer Grumman

Customer Spec. AV-D5596S-1

Cell Activation Data Sheets

SELLER DOCUMENT EP-MP-146

308

PAGE 1 OF 1

CELL # POS.	DRY WT.	LEAK RATE	MEG OHMS	CC'S KOH	WET WT.	W/GAGE WT.	DATE TIME	INSP. BY
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								

TEST AND REFERENCE PARAGRAPH NUMBER	
WEIGH DRY CELL TO NEAREST GRAM. Q.C. VERIFY	
RADIOGRAPH PER DOCUMENT #___ _____.	
PERFORM HELIUM LEAK CHECK PER _____. RECORD LEAK RATE	
PERFORM ELECTROLYTE ANALYSIS PER (RECORD RESULTS ON D.S.#) Q.C. VERIFY KOH ACCEPTABILITY	
PERFORM DRY RESISTANCE INSULATION CHECK PER _____. RECORD RESISTANCE	
FILL CELLS PER _____. RECORD DATE, START TIME AND KOH AMOUNT	
WEIGH WET CELL WITH FILL TUBE CAP. RECORD WEIGHT TO NEAREST GRAM	
INSTALL HARDWARE (GAGE). REWEIGH EQUIPPED CELL. RECORD TO NEAREST GRAM.	
NOTE: LET CELLS SOAK MIN. 16 HRS. BEFORE PROCEEDING WITH ELEC. TESTING Q.C. VERIFY	
RECORD TIME AT END OF 16 HR. MIN. GO TO CELL CONDITIONING FLOW SHEETS	

GAC 2792
1-59

NOTE: Reproduc[illegible], return original and repro order to [illegible]orate Forms Control, Plant 30.

CONDITIONING (PRE-CHARGE) CYCLES - Initial Dischg.

TEST AND REFERENCE PARAGRAPH NUMBER	CELL # / POS.	DATE	TIME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	INSP. BY
ASSURE ACTIVATION DATA SHEETS COMPLETED AND STAMPED BY Q.C. BEFORE PROCEEDING																													
DISCHARGE CELLS AT 25±2 AMP RATE TO 0.7±0.1 VOLT PER CELL WITH VENTS CLOSED																													
RECORD TERMINAL VOLTAGE PRIOR TO PLACING ON CHARGE (O.C.V.)	O.C.V.																												
RECORD CURRENT RATE AT TIME OF APPLICATION (T=0)	T=0 AMPS																												
RECORD TERMINAL VOLTAGE AT T=0+	T=0 VOLTS																												
RECORD AUX. VOLTAGE AT T=0+	T=0 AUX.																												
RECORD PRESSURE AT T=0+	T=0 PSIG.																												
RECORD CELL TEMP. AT T=0+	T=0 °F																												
T=1 MINUTE CURRENT	T=1 AMPS																												
T=1 MINUTE TERMINAL VOLTAGE	T=1 VOLTS																												
T=1 MINUTE AUX. VOLTAGE	T=1 AUX.																												

DVTP-153-2

TEST PLAN - PART 1
CELL DEVELOPMENT TESTS

CONTRACT NO. NAS 9-11074

MARCH 1971

FOR

GRUMMAN AEROSPACE CORPORATION
BETHPAGE, L. I., NEW YORK

EAGLE-PICHER INDUSTRIES, INC.
ELECTRONICS DIVISION
COUPLES DEPARTMENT
JOPLIN, MISSOURI
64801

PREPARED BY: _____

Bill R. Hawkins
Design Engineer

_____

William C. Harsch
Project Engineer

APPROVED BY: S Gaston

Steve Gaston, Project Engineer
Grumman Aerospace Corporation

1.0 SCOPE

This document describes the detailed test procedures to be used for the Development Test Program of 26,100 ampere-hour nickel-cadmium sealed cells. The objective of this Development Test Program is to evaluate cell construction variables in RSN-110 type cells which are constructed as part of the 100 ampere-hour cell Improvement Program, GAC Purchase Order 0-15161 and Prime Contract No. NAS9-11-074. Data from these Development Tests will be used to establish the final design for additional cells to be manufactured for Grumman for parametric testing.

2.0 APPLICABLE DOCUMENTS

2.1 GAC

Purchase Order 0-15161

AV-D559CS-1; 100 A-H Ni-Cd Storage Cells Specification

2.2 Conference Minutes

2-3 September 1970; GAC, E-P

12-13 October 1970; GAC, NASA, E-P

2.3 Eagle-Picher Industries

EP-MP-146, Activation & Conditioning Procedures For RSN-110 Type Cells

EP-QC-1157, Calibration Procedure Manual

3.0 REQUIREMENTS

3.1 Equipment

ITEM	MFG.	MODEL NUMBER
Grumman Supplied Data Acquisition System	Non-Linear Systems	200 Channel Type, Punched Paper Tape & Digital Printer Readout
Temp. Controlled Chamber	Missimers	FT8-100x350
Power Supply, DC	Harrison	6268A
Ammeter	Weston	Model 1
Voltmeter	Weston	931
Thermocouple Switching Box	Omega - E-P	Not Applicable
Charger-Cycler Combination	E-P	CGR 2002-2006 Combination or Equivalent
Thermocouple Bridge	Thermo-Electric	70200

Equivalent equipment is allowed. This refers to the ability of the function of specified equipment with respect to magnitude, accuracy, etc. Specified equipment lists are only included to advise test personnel of acceptable equipment.

3.2 Test Conditions

Except when otherwise noted, Test Conditions shall be as follows:

3.2.1 Temperature (Monitored and Recorded)

20°C ± 3°C (68°F ± 5°F), and 0°C ± 3°C (32°F ± 5°F)

3.2.2 Barometric Pressure

Except as otherwise noted - 28-31 inches mercury

3.2.3 Relative Humidity

Ambient

3.3 Accuracy of Test Apparatus

As a minimum, measurement of accuracy of equipment shall be as follows:

3.3.1 Visually - Read Ammeters - ± 0.5% Full Scale (With Anti-Parallax Scales)

3.3.2 Visually - Read Voltmeters - ± 0.5% Full Scale (With Anti-Parallax Scales)

3.3.3 Digital Recorded Voltage - x.xxx

3.3.4 Temperature - ± 0.5°C

3.3.5 200 Channel Data Acquisition System, x.xxx

3.3.6 Meters or other instruments of less accuracy shall be used as "Indicator Only."

3.4 Test Sequence

Cells shall be subjected to the tests in the sequence listed by Table No. 1, following conditioning cycles per EP-MP-146.

3.5 Cell Test Constraints

3.5.1 Cell Restraint

Cells shall be tested as series-connected individual cells. Each cell shall be restrained between aluminum plates of $\frac{1}{2}$" minimum thickness approximately one (1)

inch wider than the cell. Each side of the cell shall be insulated from the adjacent aluminum plate by an approximate .005" layer of mylar, vinylite, Kapton, or other electrical insulator. Restraint shall be provided by six (6) low-carbon steel bolts ($\frac{1}{4}$ - 20) with nuts torqued to 5-6 in. lb.

3.5.2 Provisions for Temperature Monitoring

For temperature data acquisition purposes, each cell shall have a small gage copper-constantan thermocouple junction located at the approximate geometric center of the plate pack in the broad face of the cell. This junction shall be insulated on either side from the metal cell case by a material such as Teflon "Tempr-Tape". Provision for space required by the junction and leads may be made by cutting a narrow slot approximately 1/16" wide in the insulating shim.

3.5.3 Auxiliary Electrodes

One-half watt, 1 ohm ($\pm$ 5%) resistors shall be connected between each cell reference electrode and the respective cell negative electrode. The potential across each resistor shall be monitored by the 200-channel data acquisition system.

3.5.4 Frequency of Recordings

3.5.4.1 Punched Tape

Open circuit readings shall be taken before and after all charges and discharges. Charge readings (all channels monitored) shall be taken at time = one (1) minute and 15 minutes and 15 minute intervals thereafter except during overnight charging periods.

It is desired to have one (1) hour readings during overnight low rate charges. Discharge values (all channels monitored) shall be taken at time = one (1) minute and 15 minutes and fifteen minute intervels thereafter.

3.5.4.2 Tape Printout and Hand Recording

Tape printout shall be at intervals of 15 minutes on charge in addition to open circuit voltages and one minute voltages. Voltages shall be recorded for each cell and its auxiliary electrode. Pressure readings shall be taken at 15 minute intervals except during overnight charging periods. Temperature measurement shall be recorded for a control cell and the temperature chamber. Temperature readings shall be taken each 15 minutes except during overnight charging periods.

3.6 Test Procedure

3.6.1 Preparation

Place series-connected cells in chamber. Verify that all necessary connections to monitoring equipment have been made and that all electrical cell connections are torqued to 15 $\pm$ 3 inch lbs (#10-32 terminal screws).

3.6.2 Temperature Stabilization

Testing may begin when temperature of the cells are within tolerance (20 $\pm$ 3°C) for three (3) successive readings. These readings shall be taken at intervals of 15 minutes minimum.

3.6.3 Conditioning Test (1)

3.6.3.1 Cells shall have been connected to 0.2 ohm resister for 16 hours prior to this test. Verify cells have been drained below 0.4V prior to removal. Record voltage.

3.6.3.2 Begin charging at ten (10) emperes. Continue charge for 16 hours. When cell voltage reaches 1.510 or pressure exceeds 100 psig, terminate charge for that cell. Note and record time of termination of charge.

3.6.3.3 At termination of charge of all cells, turn-off and disconnect power supply and conduct a 50 ampere discharge. Note the time for each cell to reach 1.000 volt and remove from the circuit at 0.9 $\pm$ 0.1 volt.

3.6.4 Capacity C/2 (Test 2)

3.6.4.1 Stabilize cells at +20°C as per Paragraph 3.6.2 above.

3.6.4.2 Connect cell group to power supply and charge at 30 amperes for 5 hours. If cell voltage reaches 1.510 volts for a cell or pressure reaches 100 psig, remove that cell from charge.

3.6.4.3 Conduct discharge at 50 amperes.

3.6.4.4 Record time for each cell to a voltage of 1.000 volt.

3.6.4.5 Remove each cell from circuit at a voltage of 0.9 $\pm$ .1 volt per cell.

3.6.4.6 Repeat steps 3.6.4.1-3.6.4.5 two (2) additional times for a total of three (3) cycles.

3.6.5 Capacity - High Rate (Test 3)

3.6.5.1 Stabilize cells at +20°F as per Paragraph 3.6.2 above.

3.6.5.2 Charge at 30 amperes for five (5) hours. If voltage exceeds 1.510 volts for cells prior to acceptance of five (5) hours charge, or if pressure exceeds 100 psig, remove the cell from the circuit.

3.6.5.3 Conduct discharge at 100 ampere rate.

3.6.5.4 Record time for each cell to a voltage of 1.000 volt.

3.6.5.5 Remove each cell from the circuit at a voltage of 0.9 ± 0.1 volt.

3.6.5.6 After all high-rate capacities have been determined, reconnect cells and discharge at 50 amperes to 0.9 ± 0.1 volt per cell. Record time to 1.000 volt at 50 amps.

3.6.6 Capacity - High Charge Rate (Test 4)

3.6.6.1 Stabilize cell temperature as per Paragraph 3.6.2.

3.6.6.2 Charge at 60 amperes for two (2) hours and decrease charge rate to 30 amps for 1 hour. If voltage for cells exceeds 1.510 volt or if pressure exceeds 100 psig, remove that cell from the circuit.

3.6.6.3 Conduct discharge as in Paragraph 3.5.4 above.

3.6.7 Capacity - Low Charge Rate (Test 5)

3.6.7.1 Stabilize cell temperature as per Paragraph 3.6.2

3.6.7.2 Charge cells at 15 amperes for ten (10) hours. If cell voltage should exceed 1.510 volts for a cell prior to 10 hours charge, remove that cell from the circuit.

3.6.7.3 Conduct discharge as in Paragraph 3.6.4 above.

3.6.8 Overcharge (Test 6)

3.6.8.1 Stabilize cell temperature as per Paragraph 3.6.2 above.

3.6.8.2 Charge cells at 30 amperes for five (5) hours. Lower charge rate to 10 amps and continue charging for an additional eight (8) hours. If voltage of a cell should exceed 1.510 volts, remove from the circuit. Similarly, if a cell pressure should exceed 100 psig, remove that cell from the circuit.

3.6.8.3 Discharge as in Paragraph 3.6.4 above.

3.6.9 Phenolphthalein Leak Check (Test 7)

Prior to the overcharge test, cells shall have weld and ceramic seal areas swabbed with boric acid solution. Areas shall be observed for color changes (from colorless to pink (red).

If such coloration occurs, clean the affected area of all traces of coloration, and assure that a positive pressure exists in the cell. This may be done by charging the cell at 10 amperes. Retest with phenophthalein. Recurrence of red coloration within ten minutes is to be considered a positive leak test and the cell shall be discharged and placed on a "withhold" status, followed by notification of GAC and failure analysis per spec. AV-D559CS-1.

3.6.10 Three Orbital Cycles (Test 8)

3.6.10.1 Connect cell group to charger-cycler combination and begin cycling at 50 amps for 36 minutes and charge at 37.4 amps for 58 minutes.

TABLE NUMBER 1

RSN-110 DEVELOPMENT CELL TESTING

TEST CONDITION NUMBER	TYPE TEST	TEMP. °C	CHARGE RATE x TIME	DISCHARGE RATE
1	Conditioning	20°C	10 Amps x 16 Hours	50 Amps
2	3 Capacity Cycles	20°C	30 Amps x 5 Hours	50 Amps
3	Capacity, High-Rate	20°C	30 Amps x 5 Hours	100 Amps
4	Capacity, High Charge	20°C	60 Amps x 2 Hours 30 Amps x 1 Hour	50 Amps
5	Capacity, Low Charge	20°C	15 Amps x 10 Hours	50 Amps
6	Overcharge	20°C	30 Amps x 5 Hours) 10 Amps x 8 Hours)	50 Amps
7	Phenolphthalein Leak Test			
8	3 Cycles, 30% DOD	20°C	37.4 Amps x 58 Min.	50 Amps x 36 Min.
	Charge Voltage shall not exceed 1.51 volts at +20°C			
9	Conditioning	0°C	10 Amps x 14 Hours	50 Amps
10	3 Capacity Cycles	0°C	30 Amps x 4.5 Hours	50 Amps
11	Capacity, High Rate	0°C	30 Amps x 4.5 Hours	100 Amps
12	Capacity, High Charge	0°C	60 Amps x 1.75 Hours 30 Amps x 1 Hour	50 Amps
13	Capacity, Low Charge	0°C	15 Amps x 9 Hours	50 Amps
14	Overcharge	0°C	30 Amps x 4.5 Hours) 5 Amps x 8 Hours)	50 Amps
15	Phenolphthalein Leak Test			
16	3 Cycles, 30% DOD	0°C	34.2 Amps x 58 Min.	50 Amps x 36 Min.
	Charge Voltage shall not exceed 1.56 volts at 0°C			

3.6.10.2 Conduct three (3) cycles beginning with discharge.

3.6.10.3 Conduct discharge per Paragraph 3.6.4 above.

3.6.11 Repeat Test Series at $0^{\circ}C$

Test Nos. 9-16 shall consist of a repetition of Test Nos. 1-8, except that test temperature is $0^{\circ}C \pm 3^{\circ}C$ and allowable cell voltage is 1.560 volts. Phenolphthalein leak test shall again immediately follow overcharge. See Table I as rates and times are different because of the lower temperature.

3.6.12 Cell Impedance Test

All cells shall be subjected to an impedance test which shall not be required in excess of one (1) day. The nature of this test is to be determined.

3.7 Thermal Testing

Two (2) selected cells shall be subjected to thermal testing per Paragraph 4.2.2 of D559CS-1. The exact nature of this test sequence will be the subject of another Development Test Procedure to be finalized and submitted 45 days prior to its use.

3.8 Environmental Testing

Two (2) cells to be selected will be subjected to environmental tests per AN-D559CS-1 as follows:

Acceleration	-	Paragraph 4.5.7
Shock	-	Paragraph 4.5.8
Vibration	-	Paragraph 4.5.6 & Table No. 1

These tests will be conducted at room ambient conditions. The cells are to be charged per 3.6.3.2 prior to each of the above tests.and discharged per 3.6.3.3 during and after each environmental.test.

4.0 Quality Assurance and Test Witnessing

(a) Eagle-Pitcher engineering personnel shall advise Eagle-Picher Quality Assurance of development schedules so they may audit tests and data as required.

(b) Eagle-Picher shall continuously advise Grumman Aerospace Corporation of current development test schedules in order that Grumman quality assurance and/or engineering personnel may witness any of the testing.

(c) Eagle-Picher shall also advise resident DCAS personnel of development test schedules in order that they may review progress of any of the tests.

NOTE: Reproduct[illegible]eturn original and repro order to Corporate Forms Control, Plant 30.

TEST AND REFERENCE PARAGRAPH NUMBER

CELL POS.	CELL SERIAL NUMBER	INSP. BY	CELL SET-UP CONDITIONING
1			PLACE RESPAIRING JACKETS ON CELLS AND TORQUE TO 5-6 IN.-LBS.
2			ATTACH THERMOCOUPLES TO CELL AT APPROX. GEOMETRIC CENTER OF BROAD FACE.
3			SERIES CONNECT CELLS AND TORQUE ELECTRICAL CONNECTIONS TO 15 ±3 IN.LB.
4			PLACE CELLS IN CHAMBER. CHARILIZE TEMP.(TILL 3 SUCCESSIVE 15 MIN. READINGS ARE WITHIN 20 ±3°C)
5			CONNECT 0.2 RESISTORS TO EACH CELL FOR 16 ±0.1 HR.
6			RECORD CELL VOLTAGE BEFORE REMOVING 0.2 RESISTORS.
7			CHARGE CELLS AT 10 AMP RATE FOR 16.0 ±0.1 HRS. OR 1.51V/ CELL, WHICHEVER COMES FIRST
8			RECORD CELL OPEN-CKT. VOLTAGES
9			T=0+ CURRENT
10			T=0+ TERM. VOLT
11			T=0+ AUX. VOLT
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			

TYPICAL SAMPLE

323

PAGE 1 OF 79

GAC 2192 1-57

FOR INTERNAL NON-RECURRING USE ONLY

APPENDIX I

EP-QC- 686

RSN-110 TYPE CELL
NICKEL-CADMIUM CELL

ELECTRODE CAPACITY TEST PROCEDURE

ORIGINAL

MAY, 1971

PREPARED FOR

GRUMMAN AEROSPACE CORPORATION
BETHPAGE, L.I., NEW YORK

PREPARED BY

EAGLE-PICHER INDUSTRIES, INC.
ELECTRONICS DIVISION
COUPLES DEPARTMENT
JOPLIN, MISSOURI

William C Hancock
Engineering

Roger M. Amos
Quality Control

1.0 SCOPE

This test shall determine RSN-110 cell excess negative capacity beyond complete discharge of the positive in addition to the total capacities of the electrodes. These data may be used to establish one or more of the following:

(a) Range and distribution of positive capacities.

(b) Range and distribution of negative capacities.

(c) Difference between and/or ratio of total negative and positive capacities.

(d) Excess negative (or positive) on discharge.

(e) Excess negative on charge.

2.0 APPLICABLE DOCUMENTS

2.1 GAC

AV-D559CS-1 Spec. for 100 Ampere-Hour Nickel-Cadmium Storage Cells

2.2 Eagle-Picher

EP-MP-146, Activation and Conditioning Procedure for the RSN-110.

3.0 REQUIREMENT

3.1 A total negative/positive capacity ratio of 1.50:1 is required. Any ratio less than 1.50 obtained under the following conditions specified is subject to immediate notification of GAC.

3.2 Negative precharge as described below shall be 20-30% of total negative capacity.

3.3 Capacities of 12 ampere-hour plates, when corrected for area, (ratio of 39.1/8.12) shall indicate a positive capacity of a minimum of 100 ampere-hours.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Sampling Rate Test

A) A minimum of storage cells, as shown in the table as follows, from each formation group of 52 storage cells (or less) shall be selected.

Test cells may be constructed from 12 ampere-hour plates taken from the same plaques as the represented cell group.

Conditions for Substitution of 12 A-H Test Cells -

The following restrictions shall apply to the use of 12 ampere-hour plates in test cells in establishing quality assurance provisions for electrode capacity tests.

Plates shall be cut from plaques accepted in accordance with plaque drawings applicable at the time of construction.

Plates in one test cell shall be cut from plaques of the same lot used in 100 ampere-hour cells.

Test cells shall consist of the same number of positive and negative plates as the 100 ampere-hour cell which they represent. Plates shall be separated in the same manner as the cells which they represent.

Cells shall be flooded with 31% potassium-hydroxide electrolyte to a level 1/4" above the separator.

In order to assure full charge, cells may be subjected to two (2) formation cycles as follows:

a. Charge at 1.2 amps for 16 hours.

b. Discharge at 6 amperes to 1.00 volt.

c. Discharge across a 0.2 ± 5% ohm resistor for 16 hours.

d. Repeat Steps a and b.

Cells shall then be tested as described in Section 5.0.

B) A minimum number of storage cells, as shown in Table I, shall be selected from each formation group of 52 storage cells (or less) at the conclusion of testing per EP-MP-146 prior to pinch tube closure.

Following the standard 0.2 ohm and dead short periods, the test sample(s) shall be flooded with 31% KOH. Tests shall be performed on sample storage cells prior to any pinch-off tube closure of formation groups from which the sample was taken.

4.2 Test Conditions

A) Storage cell temperature shall be 75 ± 5°F.

B) Storage cell voltage shall be recorded at 15 minute intervals except with increased frequency as necessary to establish capacity values to the nearest minute.

C) Voltage from both the positive and negative terminals to the reference electrode shall be recorded at intervals not to exceed 15 minutes.

5.0 TEST PROCEDURE

5.1 Residual Negative Electrode Capacity

Place a 0.2 ± 5% resistor across the terminals for 16 hours. Discharge at the C/10 rate until the terminal voltage indicates -1.0 volt. Excess negative shall be measured from 0 volts to -1.0 volt.

5.2 Filling

Storage cells shall be filled until flooded with 31% KOH solution.

KOH quantity required and additional electrolyte or water added during entire test shall be recorded.

5.3 Charge at the C/10 rate for a minimum of 40 hours until cell voltage reaches 1.51 volts; charge time shall not exceed 64 hours. Record cell voltage continuously or at intervals not to exceed one (1) hour.

TABLE NUMBER I

TABULATION OF SAMPLING RATE

PARAGRAPH	DEVELOPMENT STORAGE CELL GROUP	27-STORAGE GROUP	74-STORAGE CELL GROUP
	2	1	2
	2	1	2

5.4 Discharge

Cells shall be discharged at the C/2 rate until terminal voltage indicates -1.0 volt. Positive and negative terminal to reference voltages shall be time recorded during discharge.

5.5 Calculations

Let

T_{N_1} = time to -1.0 V

= time to discharged precharged negative at C/10 discharge rate

T_{P_3} = time from start of discharge (full charge) to +0.5 v

= time to discharge positive electrode

T_{N_3} = time from full charge to -1.0 v as delineated

= time to discharge total negative electrode.

I_o = discharge current = 50 amps

Then

$I_o \left[\left(T_{N_3}\right) - \left(T_{P_3}\right)\right]$ = excess capacity of total negative over positive

$I_o \left(T_{N_1}\right)$ = precharged negative capacity

$I_o \left[\left(T_{N_3}\right) - \left(T_{P_3}\right) - \left(T_{N_1}\right)\right]$ = excess (discharged) negative capacity at the charged end

$\frac{\left(T_{N_3}\right)}{\left(T_{P_3}\right)}$ = negative-to-positive ratio

6.0 SUBMITTAL OF DATA

Two (2) copies of all information obtained shall be submitted to GAC with the shipment of cells.

ROM	NAME	GROUP NO. & NAME	PLANT NO.	EXT.	DATE
	S. Gaston	567/POD	35	9142	7/27/71

O: NO. D559-1-23

J. Rogers(*), LM Subcontracts

UBJECT: GRUMMAN COMMENTS TO THE EAGLE-PICHER SUBMITTED DOCUMENT, ENTITLED "RSN-110 TYPE CELL, ELECTRODE CAPACITY TEST PROCEDURE, EP-QC-686, DATED MAY 1971.

ference: a) Contract NAS 9-11074
b) Grumman PO #015161

closure: 1) Grumman comments on Eagle Picher document EP-QC-686, "Electrode Capacity Test Procedure".
2) Eagle-Picher EP-QC-686, RSN 110 Type Cell, Electrode Capacity Test Procedure, dated May 1971.

Please submit the attached Enclosure 1 to Eagle-Picher with the following comments:

1. The comments shown in attached Enclosure 1 must be incorporated in the EP submitted document entitled, : EP-QC-686 - Electrode Capacity Test Procedure", dated May 1971, and resubmitted to Grumman for approval.

2. Cell ratio testing or selected cells S/N's 14, 17, 26, 29, from the cell development group 1 and 2 cells, shall proceed as per telecon on 20 July 1971 between S. Gaston (Grumman) and W. Harsch (Eagle Picher).

S. Gaston
S. Gaston, Project Engineer

INFO cc:

J. Cioni, NASA/MSC
E. Carr/W. Harsch, EP
F. Ford, NASA/GSFC
R. Mallard, GAC at EP(*)
J. Benz
G. Foster (*)
V. Iacopelli (*)
E. Miller
R. Sablich (*)
Q. P. Sicardi, NAVPRO (*)
D. Lehrfeld (*)
R. Simendinger (*)
M. Wertheim (*)
A. Winegard/A. Zumpano (*)

Note: (*) Enclosure 2 attached.

27 July 1971

Grumman Comments on Eagle-Picher Document EP-QC-686, Entitled

"RSH-110 Type Cell, Nickel Cadmium Cell, Electrode Capacity

Test Procedure", Dated May 1971

Item No. 1

On paragraph 3.1, add to the end of the paragraph: "For all tests beyond those for the development groups 1 and 2 - any ratio less than 1.50:1.00 obtained under the following conditions specified is subject to rejection of the entire storage cell group it represents."

Item No. 2

On paragraph 3.2

a) After "negative precharge" - add "(IoTN1)".
b) After"total negative capacity - Add "(IoTN3)".
c) To the end of the paragraph - add "For all tests beyond those for development groups 1 and 2 - any negative precharge capacity (IoTN1) outside the 20-30% range of the lowest excess negative capacity [Io(TN3-TP3)] obtained under the following conditions specified is subject to the rejection of the entire storage cell group it represents."

Item No. 3

On paragraph 4.1

a) Add "I" after "Table"
b) Verification of the 8.12 plate area number shown in paragraph 3.3 is required. A submittal of a plate drawing to Grumman is desired. Plate drawing number shall be referenced in this document. Also the plaque uniformity must be demonstrated to assure that the 12 AH cell results are representative of the 100 AH cell results (see cell spec. requirements).
c) The substitution of the 12 AH size cell is only permitted for the formation sample (spec. paragraph 3.4.5.5.1(a)) not for the finished cell sample. This reference should be clarified.
d) The bottom paragraph requires clarification.
   1) Do you really need such conditioning cycles? Is this cycle identical to that applied when 100 AH size cells are tested. Both charge and discharge currents seem to be based on scaled down rated capacity rather than on identical current densities (e.g. 100 AH ÷ 12 AH = 8.3, resulting in a charge current of 10 A ÷ 8.3 = 1.2 amperes. Based on identical current densities the respective plate surface areas are 39.1 ÷ 8.12 = 4.8, or 10 amperes ÷ 4.8 = 2.1 amperes. For the discharge currents the 6 amperes should be 10.5 amperes. The 0.2 ohm resistor drain should then become 0.2 x 4.8 or approximately 1.0 ohm).
e) The initial electrolyte quantity and the final electrolyte quantity shall be measured and recorded.

Item No. 4

On paragraph 4.2, B - After "cell voltage", add "and cell temperature", using the data acquisition system."

Item No. 5

On paragraph 3.2 C, - Remove "intervals not to exceed [illegible] minutes" and substitute "same intervals as in paragraph 4.2 B, above".

Item No. 6

On paragraph 5.1 - To the end of the first sentence, add "record the cell voltage prior to the resistor removal." After negative, add "capacity (IoTN1)."

Item No. 7

On paragraph 5.2 - After first sentence, add "The electrolyte shall be analyzed for carbonate content prior to filling. Cells S/N 14, 17, 26 and 29 shall receive a carbonate content analysis after cells are flooded and mixing of the freshly added electrolyte with that previously present has occured."

Item No. 8

On paragraph 5.3 - After "cell voltage, add "reference cell voltage and cell temperature."

On "c/10 rate" - see above comment item 3, d, 1 on 12 AH size cells.

Item No. 9

On Table Number I - Location is wrong. It should either be part of paragraph 4.1 or at end of the procedure with a corresponding reference to it in paragraph 4.1.

The "paragraph heading" should either refer to the cell spec., or it should refer when sampling occurs. To the first group, cells shall be sampled after formation,the second group shall be sampled after cell construction and the standard electrical testing has been completed (see cell spec.,paragraph 3.4.5.5.1 for details).

Item No. 10

On paragraph 5.4 -

On "c/2 rate" see above comment item 3, d, 1 on 12 AH size cells

Add "The +1.0 volts; +0.5 volt cell voltage readings and its corresponding reference electrode readings shall be recorded as a function of discharge time.

Item No. 11

On paragraph 5.4 - Add a second paragraph "After completion of this discharge the cell shall receive a pressure tight plug in its filling tube and shall be stored in a cool clean area until a final disposition is made by Grumman."

Item No. 12

On paragraph 5.5 - on second line change "discharged" to discharge".
on eighth line, add "for 100 AH cell or - - - amperes for 12 AH cell.

Item No. 13

On paragraph 5.5, top of page 5 after "Then" add "calculate".

Item No. 14

On paragraph 5.5 at end of paragraph, add "review above data to determine if the requirements of paragraph 3.0 have been met. If sample cell(s) met all of these requirements then the cell lot represented by this sample shall be approved for further processing. If sample did not meet all of these requirements the cell lot represented by this sample shall be rejected and Grumman shall be immediately notified of this occurance.

Item No. 16

General Comments

a) Add - Electrical circuitry and equipment used for these tests to this procedure.
b) Add - Current tolerances.
c) What precautions will be taken to avoid atmospheric contamination during these tests?

APPENDIX I

EAGLE-PICHER INDUSTRIES, INC.
Electronics Division
Couples Department
Joplin, Missouri

EP-QC-781

QUALITY ASSURANCE PROGRAM PLAN

for

Eagle-Picher Part No. RSN-110
Sealed Nickel Cadmium Cell

GRUMMAN AEROSPACE CORPORATION

1 February 1972
Revision A

Contract No. 0-15161
Item 4 - Documentation
Sub-Item 3.1 & 3.2

PREPARED BY: Roger M. Amos
Quality Assurance Program
Administrator

APPROVED BY: William C Hanak
Engineering

EP-QC-781

Quality Assurance Program Plan

Revision Letter	Date	Description of Change	Approved
Orig	26 Oct 70	Preliminary Quality Assurance Plan	RA
"A"	1 Feb 72	Plan Up-Dated to Latest Changes	RA

GAC SIGNATURE PAGE

EP-QC-781

Quality Assurance Program Plan
for
Eagle-Picher Part No. RSN-110
Sealed Nickel-Cadmium Cell

GAC Approval Signature

1.0 SCOPE

1.1 The purpose of this document is to outline the quality plan to be followed by Eagle-Picher personnel during development, qualification, and production on the RSN-110 battery. This procedure shall be used in conjunction with the Eagle-Picher Quality Control Manual and documents referenced on purchase order or contract.

1.2 Applicability

This program is applicable to the function of the various departments specifically referenced herein.

1.3 Objectivity

The purpose of these procedures specified herein is to control the overall quality and reliability of the RSN-110 battery from procurement through fabrication, inspection and test, packaging and shipping.

2.0 REFERENCE DOCUMENTS

NASA

NPC 200-3	Inspection System Provisions for Suppliers of Space Materials, Parts, Components, and Services

Military

MIL-STD-105	Sampling Procedure and Tables for Inspection by Attributes
MIL-C-45662	Calibration Systems Requirements

Grumman Aerospace

WS July 1970	Work Statement
AV-252CS-25E	Specification dated 15 April 1969 (as applicable) and Amendments 1-5 (as applicable)

Eagle-Picher Ind.

EP-QC-1100	Quality Control Manual Policies and Procedures
EP-QC-1159	Supplier's Inspection Requirements for Parts, Components and Services
EP-QC-1157	Calibration Procedures

EP-WS-8	Welding Specification for RSN-110
EP-QC-3A	Battery Inspection Instructions
EP-QC-782	Battery Flow Sheets for RSN-110
ATP-251	Acceptance Test Procedure for RSN-110
EP-MP-146	Activation and Conditioning of RSN-110
EP-QC-510	Purchase Order Review

3.0 EAGLE-PICHER QUALITY CONTROL

3.1 Organization

3.1.1 Management

The quality control organization reports directly to the Couples Department Manager along with Manufacturing and Engineering. The quality control management is broken down into manager, quality control engineering, and quality control supervisors. It is the responsibility of quality control engineering to train and certify personnel for special processes, implement process and statistical controls, survey suppliers, perform failure analysis, and create inspection instructions and plans. The quality control supervisors are responsible for implementing, enforcing, and controlling procedures and policies established by the quality control organization. In addition, they direct Recieving Inspection, In-Process Inspection, and Final Inspection during development and production of all parts or assemblies.

3.1.2 Identification of Quality Personnel and Stamp Control

In order to identify quality control personnel, each quality control representative in the manufacturing area wears a quality

control badge. The stamps are controlled by the Quality Assurance Office where a complete history of all quality control stamps is available. A terminated stamp will not be re-issued for a period of six (6) months.

3.1.3 Quality Control Procedures Manual EP-QC-1100 , Revision A

This publication was created by the Quality Assurance Section of Eagle-Picher Industries for implementing controls in the manufacture of Space Systems Power Supplies and is capable of satisfying the quality requirements of publication NPC 200-3. A narrative description of the following functions is contained in publication EP-QC-1100 as referenced by section:

(a) Drawing and change control (Sections 3 & 4)
(b) Procurement Sources (Section 5)
(c) Receiving Inspection (Section 5)
(d) Raw Material Stock and Age Control (Sections 5 & 6)
(e) Handling and Storage of Material (Section 11)
(f) Fabrication and Assembly (Section 6)
(g) Training and Certification of Personnel (Section 2)
(h) Special Processes (Section 6)
(j) Nonconforming Material and Corrective Action (Section 8)
(k) Calibration of Measuring and Test Equipment (Section 9)
(l) Indication of Inspection Status (Sections 9 & 10)
(m) Preservation, Packaging and Shipping (Section 11)
(n) Sampling Plans (Section 12)
(p) Records of Inspections and Tests (Sections 5, 7, 9 & 10)
(q) Traceability (Section 4)
(r) Government Property Control (Section 13)
(s) Statistical Quality Control (Section 12)

3.1.3.1 Inspection Instruction Sheet: (Form No. EP-QC-3A)

This form is used by the Quality Assurance Section as written procedures to Inspection Personnel; indicating identification of the article to be inspected, objectives of the inspection or test, measuring and test equipment to be utilized, acceptance and rejection criteria,

and level of inspection per sampling procedures MIL-STD-105D. In the event other than ambient environmental conditions are required, the specific conditions will be covered in the procedures.

4.0 DRAWING AND CONFIGURATION CONTROL

4.1 Drawing and configuration control is maintained through the application of Eagle-Picher Process Standard EP-MP-87 or EP-QC-495. Drawings are originated by the Design Engineer during the initial design and development of a new battery. These drawings are reviewed for adequacy by Engineering, Production, and Quality Control during development, pre-production and by design review boards. All changes to drawings or procedures are made by an Engineering Order (E. O.) approved by Quality Control and Engineering.

4.2 Manufacturing Procedures and Material Specifications

Eagle-Picher Manufacturing Procedures (EP-MP's) and Eagle-Picher Material Specifications (EP-MS's) will be prepared and revised in the same manner as drawings. Quality Control Engineering approval is required on these documents. A listing of EP-MP's and EP-MS's applicable to fabrication of this battery will be available upon request. Review of proprietary documents will be restricted to in-plant review.

4.3 Quality Control Documentation

Quality Control documents and procedures generated by the Quality Control Department are under the direction and authorization of Quality Control Engineering and Supervision. Upon receipt of customer

specifications the Quality Control Department determines the adequacy of existing quality control documents and create any additional documents to comply with customer quality requirement. Battery flow sheets are prepared for the purpose of recording configuration, fabrication and inspection status and operator identification.

5.0 PROCUREMENT CONTROL

Procurement control is achieved by the Quality Control Department in the following manner. All customer requirements are imposed on our suppliers by the purchase order. Eagle-Picher maintains an approved vendor list based on surveys, trend charts, inspection history, and/or qualification of the purchased part. All purchase orders are reviewed by the Quality Control Department for conformance to requirements of EP-QC-510, Purchase Order Review.

6.0 RECEIVING INSPECTION

6.1 Material Inspection

All components and materials used in fabrication of battery assemblies are routed from the receiving area to Receiving Inspection where they are examined for compliance with and in accordance with the purchase order, control drawings, specific inspection instruction sheets, chemical and physical analysis when applicable and x-ray when applicable. History records for each item will be maintained for a minimum of six (6) years.

6.2 Lot Control and Traceability

The Quality Control Department assures component traceability and lot control, as required by contract or purchase order,

throughout receiving, fabrication and final assembly. This control is enforced per MIL-Q-9858A, NPC-200-3, and applicable sections of NASA NPC-200-2.

7.0 STOCK ROOM CONTROL

7.1 Stock Control

All materials used in fabrication of batteries are stored in areas specified as stores areas. All of this material is accompanied by a Good Material Tag or quality control inspection stamp as proof that it has been accepted by Receiving Inspection as having met all applicable requirements. Material is withdrawn from the stores area only with a Material Requisition by authorized personnel.

7.2 Audit Control

The Receiving Inspection Foreman performs monthly audits to determine that stock room control is maintained.

7.3 Shelf Life Control

A first in, first out shelving policy is utilized. Material having a shelf life is clearly marked as to expiration date, cure date, and/or other pertinate data required by drawing, specification, or purchase order.

8.0 IN-PROCESS INSPECTION

8.1 Inspection Control and Verification

Inspection Instruction Sheets will be written by quality control which coincides with assembly drawings and production flow of material. The describe in detail the inspections or tests to be performed at each phase of battery assembly. As verification and part

traceability a Battery Traveler of "Flow Sheet" is created which correlates production assembly and quality control inspection with the sequential assembly of the battery. On these flow sheets, the operator and inspector sign and/or stamp their completed work and indicate dates, part numbers and drawings used on a particular unit. These records are kept with their respective batteries from start to finish and then retained for a minimum of six (6) years.

8.2 Non-Conforming Material

When a battery, sub-assembly, or part is rejected for failure to meet the prescribed drawing requirements, it will be immediately removed from the production flow and tagged with an EP-QC-25 (Withhold Tag) and the Quality Control Supervisor notified. The discrepancy is immediately described on a Product Analysis Sheet. If the material is obviously reject, it will be tagged with an EP-QC-9 (Reject Material Tag) and the Quality Control Supervisor will make final disposition. If the material is doubtful as to status of acceptability, it will be processed through MRB. The Material Review Board will consist of the Design Engineer, Quality Control Supervisor or Engineer, the section's Production Supervisor, and the government or source inspector, if applicable.

9.0 FINAL INSPECTION

9.1 General

A final inspection will be conducted on all completed production batteries. This will consist of all the 100% non-destructive electrical, dimensional and mechanical tests required in the Acceptance Test

Procedure written as per the applicable customer's battery specifications.

9.2 Acceptance Procedure

The Acceptance Test Procedure is written by Engineering, approved by Engineering, Quality Control, and the customer. The complete acceptance test is conducted by Quality Assurance and the results are recorded on individual data sheets, copies of which accompany the shipped battery.

9.3 Qualification Testing

The qualification test procedures are written by Engineering and approved by Engineering, Quality Assurance, and the customer. These procedures are the destructive tests as specified by the customer specification. They are conducted by the Eagle-Picher environmental lab and witnessed by Quality Assurance, Engineering, and Source Inspector if applicable.

9.4 Calibration Control

Eagle-Picher maintains a Calibration Department backed by traceability to the National Bureau of Standards which assures confidence in measurements taken with meters, gages, instruments, and tools. Functioning of this laboratory is controlled by Quality Control Calibration Procedure Manual, EP-QC-1157. This procedure fulfills the requirements of MIL-C-45662. The function of this department is to calibrate, maintain and assure the accuracy of all instrumentation and the following: mechanical, tooling, fixtures, and gages used in research, development, production, inspection and environmental equipment testing. The environmental Lab Supervisor is directly responsible for the Calibration Laboratory, and reports to the Quality Assurance Manager.

10.0 PACKAGING AND SHIPPING

All battery packaging shall be in accordance with contract, battery specifications, or customer inspector instructions. Quality Control shall witness the packing operations and stamp all applicable paperwork.

EAGLE-PICHER INDUSTRIES, INC.
Electronics Division
Couples Department
Joplin, Missouri

RSN-110 Cells
Flow Sheets

Date_____
Positive Batch No._____
Negative Batch No._____

	Operator	Inspector

1.0 POSITIVE PLATE FABRICATION:

Positive Plaque Lot Nos._____, _____, _____

1.1	Clean Tab Area	_____
1.2	Cut Plates per Drawing 60-30-546-1	_____
1.3	Edge Plates	_____
1.4	Spotweld Plate Tabs per Drawing 005263, Rev.___.	_____
1.5	Pull Test Tab Welds, per EP-WS-8, Rev._____,	_____
1.6	Flatten Weld Area	_____
1.7	Inspect per IIS 30 and IIS 40	Date_____ Q.C

2.0 NEGATIVE PLATE FABRICATION:

Negative Plaque Lot Nos._____, _____, _____

2.1	Clean Tab Area	_____
2.2	Cut Plates per Drawing 60-30-546-2, Rev.___,	_____
2.3	Edge Plates	_____
2.4	Spotweld Plate Tabs per Drawing 005264, Rev.___.	_____
2.5	Pull Test Tab Welds, per EP-WS-8, Rev.____.	_____
2.6	Flatten Weld Area	_____
2.7	Inspect per IIS 10 and IIS 20	Date_____ Q.C

3.0 GROUPING OF PLATES, DRAWING NO._____, Rev.___.

3.1	Group Positive Plates into Groups of 19 plates	_____
3.2	Weigh Groups: Weight Range from_____to_____	_____
3.3	Group Negative plates into Groups of 20 plates	_____
3.4	Weigh Groups: Weight Range from_____to_____	_____
3.5	Measure & Record Thickness of:	
	Positive Group Tk. from_____to_____	_____
	Negative Group Tk. from_____to_____	_____
3.6	Weigh each plate and Record (p. 4)	_____
3.7	Inspect per IIS #50	Date_____ Q.C

EAGLE-PICHER INDUSTRIES, INC.
Electronics Division
Couples Department
Joplin, Missouri

RSN-110 Cells

Flow Sheet

Date_____
Positive Batch No._____
Negative Batch No._____
Block No._____

		Operator	Inspector
4.0	Group Assembly		
4.1	Shape tabs	_____	
4.2	Separate cell per Drawing 005051, Rev._____. Separation Lot No._____.	_____	
4.3	Trim tabs	_____	
4.4	Spotweld tabs	_____	
4.5	Inspect per IIS 60, Items A through C.	Date_____	Q.C.
4.6	Apply potting to top and bottom of cover assembly terminals.	_____	
4.7	Spotweld cell tabs to terminals per EP-WS-8, Rev._____.	_____	_____
4.8	Inspect per IIS 60, Item D.		_____
4.9	Install insulator jacket assembly on cell.	_____	
4.10	Weigh cell core & record weight & thickness on Page 3.	_____	
4.11	Install cell into case (also auxiliary electrode, if applicable).	_____	_____
4.12	Hypot cell 250 VDC one megohm minimum, terminal to terminal and terminal to case.		_____
4.13	Inspect per IIS 60, Items E through G.	Date_____	Q.C.
4.14	X-Ray cell per IT-QC-8.	_____	
4.15	Weld cell case and cover.	_____	
4.16	Hypot cell again as per Paragraph 4.12 above.		_____
4.17	X-Ray cell per IT-QC-8.		_____
4.18	Inspect per IIS 60, Items G through J.	Date_____	Q.C.

EAGLE-PICHER INDUSTRIES, INC.
ELECTRONICS DIVISION
COUPLES DEPARTMENT
JOPLIN, MISSOURI

RSN-110 CELL

Flow Sheet

Date_____
Block No._____
KOH Lot No._____

CELL S/N	POS. GROUP WT. (g)	POS. GROUP THICKNESS (IN.)	NEG. GROUP WT. (g)	NEG. GROUP THICKNESS	CORE WT.	CORE THICKNESS	CELL DRY WT.	KOH CC	WT. AFTER ACTIVATION	WT. AFTER CONDITIONI

EAGLE-PICHER INDUSTRIES, INC.
ELECTRONICS DIVISION
COUPLES DEPARTMENT
JOPLIN, MISSOURI

SEALED NICKEL CADMIUM CELL
Individual Plate Weights

DATE _____
POSITIVE BATCH NO. ___
NEGATIVE BATCH NO. ___

FLOW SHEET

Cell Type RSN-110

Cell S/N	Positive Plaque Lot	Positive Plate Weights	Negative Plaque Lot	Negative Plate Weights

EAGLE-PICHER INDUSTRIES, INC.
Electronics Division
Couples Department
Joplin, Missouri

5.0 FINAL CELL ASSEMBLY

5.1	Etch cell number on cell bottom.	_____
5.2	Install pressure gauge & glove valve.	_____
5.3	Perform helium leak test per IIS 80.	Date_____ Q.C.
5.4	Add KOH_____cc to cell assembly, per EP-MP-146.	_____
5.5	Record weights on Page three. KOH Lot No._____.	
5.6	Mark cell polarity with magic marker.	_____
5.7	Perform vented cycles per EP-MP-146.	_____
5.8	Perform power discharge cycle per EP-MP-146.	_____
5.9	Install valve or otherwise seal cell (valve torque 25 ± 5 in. lb.).	_____
5.10	Perform sealed cycles per EP-MP-146.	Date_____ Q.C.
5.11	Liquid hone cell case.	_____
5.12	Electro-etch polarity of cell (positive only) and cell identification. Cell Numbers_____to_____.	
5.13	Perform Acceptance Tests per ATP-251, Rev.___.	_____
5.14	Inspect per IIS 70.	Date_____ Q.C.

RSN-110 CELLS

FLOW CHARTS

B. H. Rucker
Reliability Engineer

Kenneth Kruger
Assistant Products Assurance Manager

Earl S. Carr
Engineering Manager
Nickel-Cadmium Batteries

GLOSSARY OF SYMBOLS

MANUFACTURING PROCESS

QUALITY CONTROL INSPECTION

PRODUCTION INSPECTION

DEFECTIVE MATERIAL

TEST LABORATORY

HOLD AREA

V - Visual Inspection

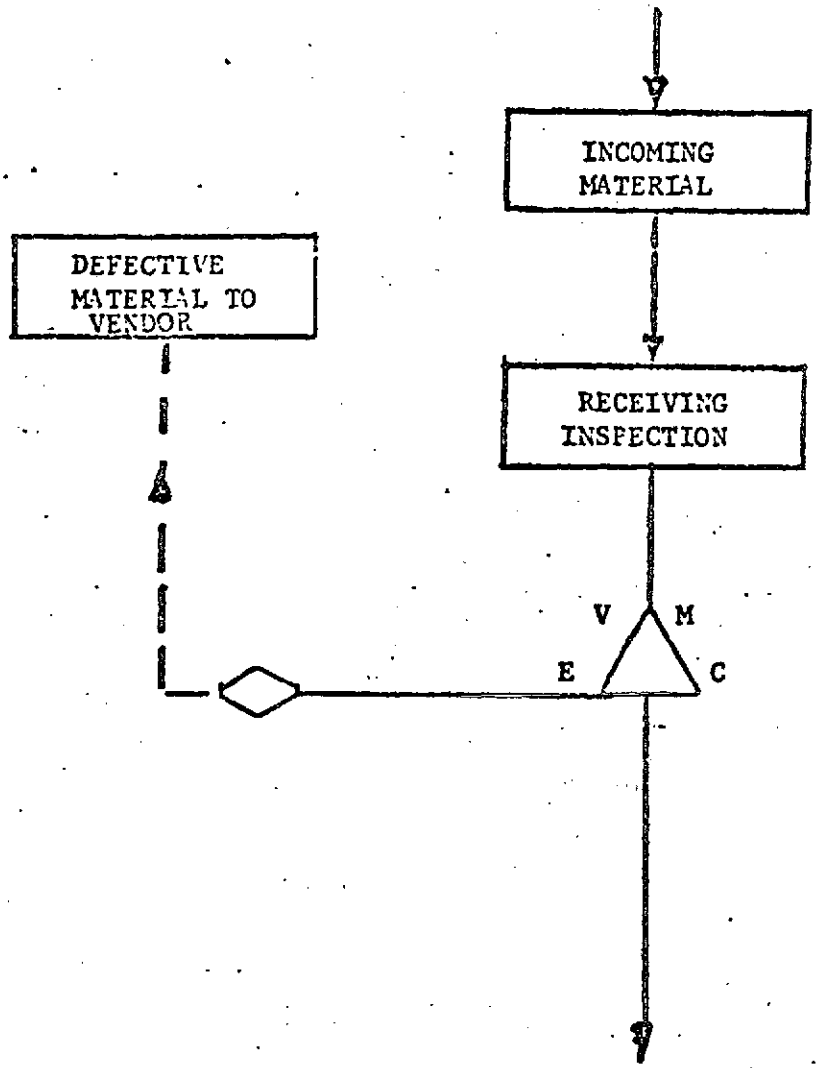
M - Mechanical Inspection

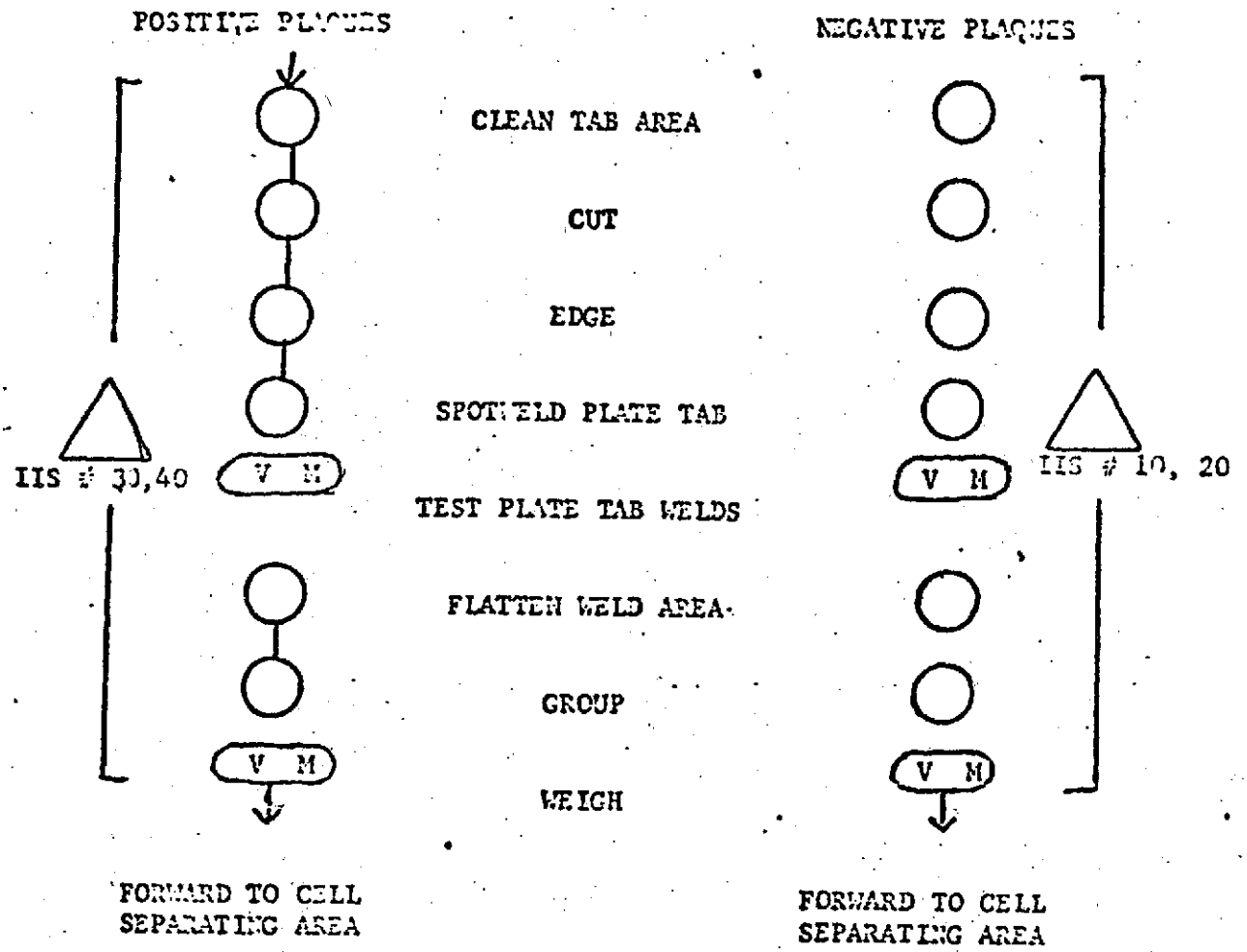
E - Electrical Inspection

C - Chemical Analysis

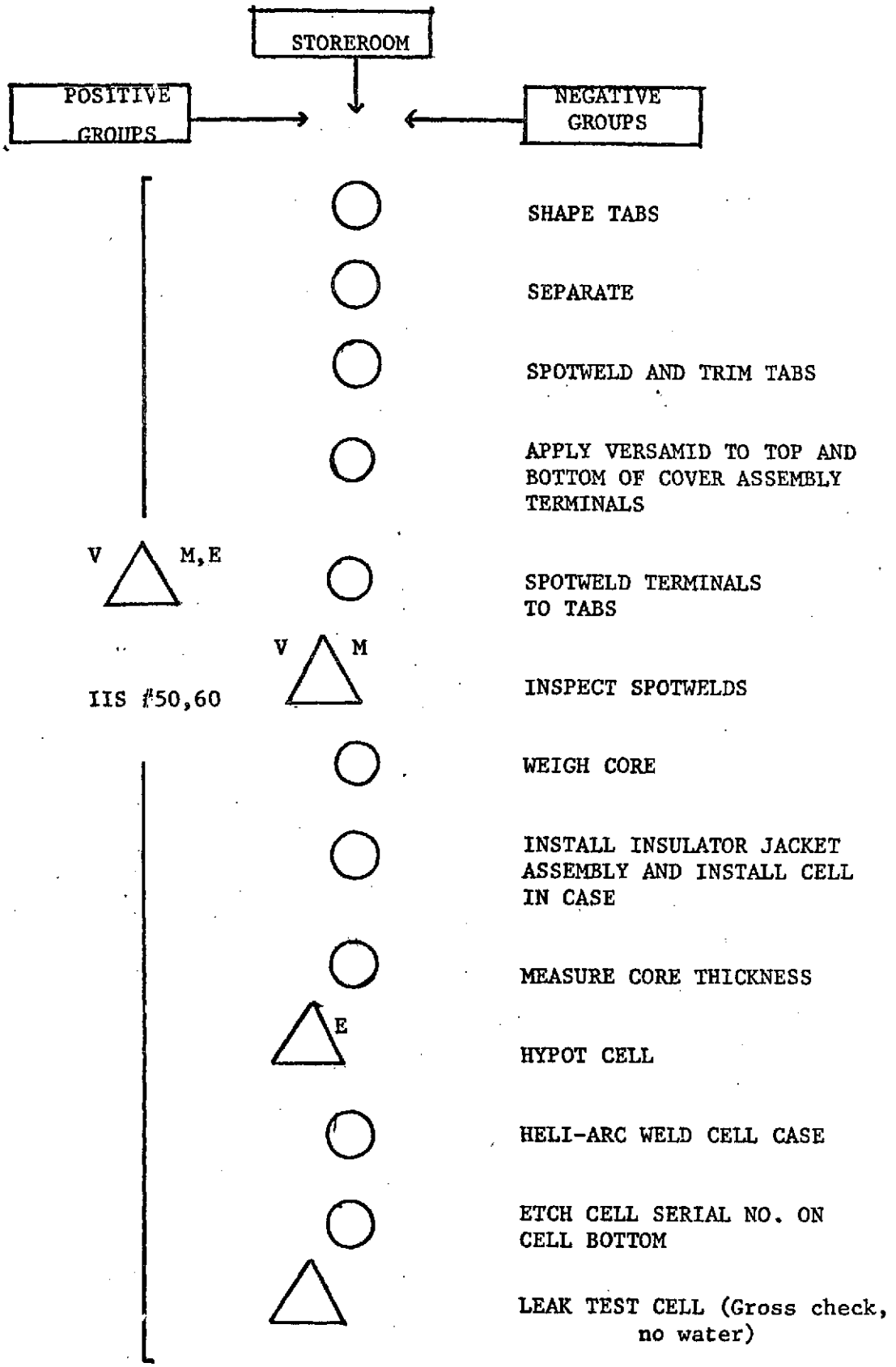
Source Inspection

Government Inspection


INCOMING MATERIAL
DEFECTIVE MATERIAL TO VENDOR
RECEIVING INSPECTION
V
M
E
C
ACCEPTABLE MATERIAL TO STOREROOM

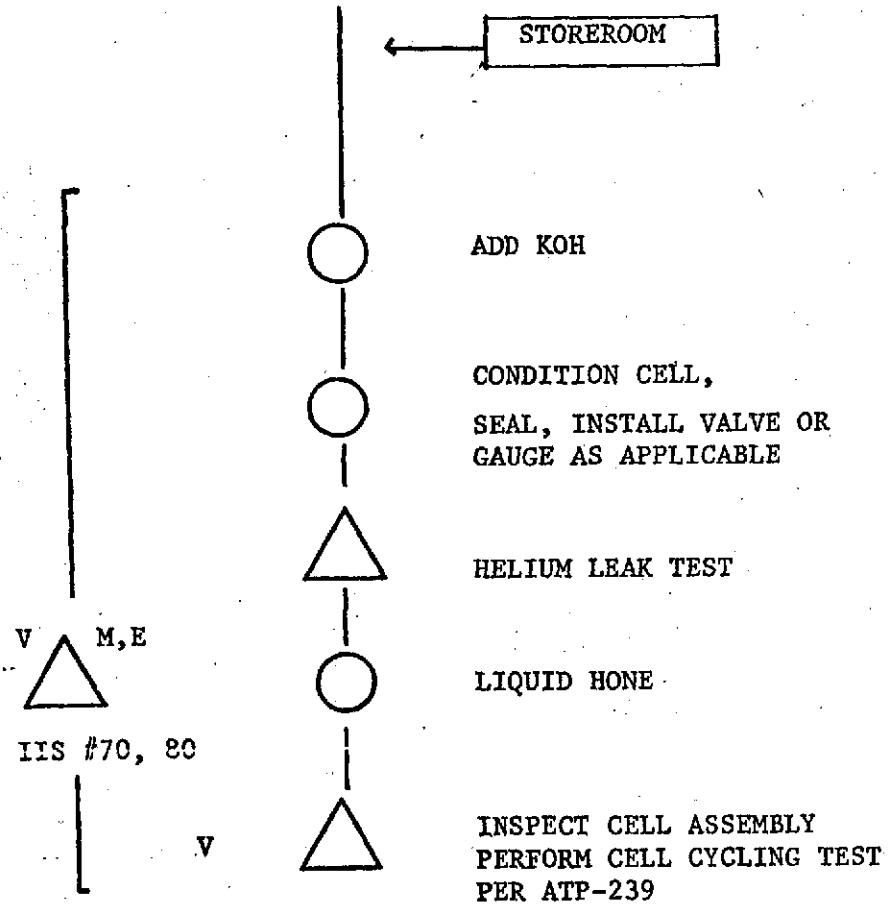

POSITIVE PLAQUES
NEGATIVE PLAQUES
CLEAN TAB AREA
CUT
EDGE
SPOT WELD PLATE TAB
TEST PLATE TAB WELDS
FLATTEN WELD AREA
GROUP
WEIGH
IIS # 30,40
V M
IIS # 10, 20
V M
V M
V M
FORWARD TO CELL SEPARATING AREA
FORWARD TO CELL SEPARATING AREA

CELL SEPARATING AREA



FORWARD TO CELL CONDITIONING AND FINAL INSPECTION

CELL CONDITIONING



APPENDIX F

INSPECTION INSTRUCTION

PLAN

for

RSN-110 CELLS

Date	Revision	Approved
1 Feb 72	"A"	R. Amos

ELECTRONICS DIVISION—COUPLES DEPARTMENT
JOPLIN, MO.

BATTERY TYPE RSN-110
IIS No. _____ REV. ____

INSPECTION INSTRUCTION SHEET

Part Name Negative Plate Part No 60-30-546-2

Written By R. Amos Approved E. Carr

Latest Drawing Issue _____ and Date _____

IIS Issue Date 1 Feb 72
IIS Rev. Date _____
Item Revised _____
Revised By _____
Approved By _____

ITEM	INSP. CODE	CHARACTERISTIC	GAGES
A	6	All dimensions except thickness	Vernier
B	4	Thickness	Dial Micrometer
C	4	Workmanship:	Visual
		A. Inspect plates for sharp edges, frayed wires,	
		loose active material, contamination on plates	
		B. Inspect for broken plates. Broken plates with	
		damage to grid wire are to be rejected.	
		C. Cracked plates without damage to active material	
		or grid are subject to Engineering and Quality	
		Assurance evaluation.	

Caution Notes _____

EAGLE-PICHER INDUSTRIES, INC.
ELECTRONICS DIVISION - SPECIALTIES DEPARTMENT
JOPLIN, MO.

BATTERY TYPE RSN-110

IIS No. _____ REV. ____ INSPECTION INSTRUCTION SHEET

Part Name Negative Plate Assembly Part No. _____ IIS Issue Date 1 Feb 72

Written By R. Amos Approved E. Carr IIS Rev. Date _____

Latest Drawing Issue _____ and Date _____ Issued By _____

Approved By _____

ITEM	INSP. CODE	CHARACTERISTIC	CLASS
A	4	Inspect spotwelding of plate to tab per drawing	Visual
B	1	Verify conformance to spotwelding procedure EP-WS-8	Visual
C	Ref: EP-WS-8	Sample test per EP-WS-8. Maintain EP-QC-1106A for all qualification and schedule testing.	
D	4	Inspect plate edging for a uniform application. Excessive edging on plates shall be returned to Production for rework.	Visual

Caution Notes _____

ELECTRONICS DIVISION—GOULD INC. DEPARTMENT
JOLIET, ILL.

Page 1 of 1

BATTERY TYPE RSN-110

IIS No. ____ REV. ____

INSPECTION INSTRUCTION SHEET

Part Name Positive Plate Part No. 60-30-546-1 IIS Issue Date 1 Feb 72

Written By R. Amos Approved E. Carr IIS Rev. Date

Latest Drawing Issue and Date Item Revised

Revised By

Approved By

ITEM	AQL % DEFECTIVE	CHARACTERISTIC	GAGES
A	6	All dimensions except thickness	Vernier
B	4	Thickness	Dial Micrometer
C	4	Workmanship:	Visual
		A. Inspect plates for sharp edges, frayed wires, loose active material, contamination on plates.	
		B. Inspect for broken plates. Broken plates with damage to grid wire are to be rejected.	
		C. Cracked plates without damage to active material or grid are subject to Engineering and Quality Assurance evaluation.	

Distribution Notes

BATTERY TYPE RSN-110

IIS No. _____ Rev. _____

ELECTRONICS DIVISION — JOPLIN, MO.

INSPECTION INSTRUCTION SHEET

Part Name Positive Plate Assembly Part No _____ IIS Issue Date 1 Feb 72

Written By R. Amos Approved E. Carr IIS Rev. Date _____

Latest Drawing Issue _____ and Date _____ Item Revised _____

Revised By _____

Approved By _____

ITEM	INSP CODE	CHARACTERISTIC	METHOD
A	4	Inspect spotwelding of plate to tab per drawing	Visual
B	1	Verify conformance to spotwelding procedure EP-WS-8	Visual
C	Ref:EP-WS-8	Sample test per EP-WS-8. Maintain EP-QC-1106A for all qualification and schedule testing.	
D	4	Inspect plate edging for a uniform application. Excessive edging on plates shall be returned to Production for rework.	Visual

Caution Notes _____

EP-C-5A

EAGLE-PICHER INDUSTRIES, INC.
ELECTRONICS DIVISION—CHEMICAL DEPARTMENT
JOPLIN, MO.

BATTERY TYPE RSN-110

IIS No. _____ Rev. _____

INSPECTION INSTRUCTION SHEET

Part Name Group Assembly Part No. _____

Written By R. Amos Approved E. Carr

Latest Drawing Rev. _____ Issued Date _____

IIS Issue Date 1 Feb 72
IIS Rev. Date _____
Date Revised _____
Revised By _____
Approved By _____

ITEM	INSP. CODE	CHARACTERISTIC	GAGES
A	4	Verify correct number of plates in positive groups	Visual
B	4	Verify correct number of plates in negative groups	Visual
C	4	Verify weight variation within positive groups does not exceed ± 5 grams	Gram Scales
D	4	Verify weight variation within negative groups does not exceed ± 5 grams	Gram Scales

Caution Notes _____

EAGLE-PICHER INDUSTRIES, INC.
ELECTRONICS DIVISION—COLORADO DEPARTMENT
JOPLIN, MO.

BATTERY TYPE RSN-110

IIS No. ____ Rev. ____ INSPECTION INSTRUCTION SHEET

Part Name Cell Assembly Part No. IIS Issue Date 1 Feb 72

Written By R. Amos Approved E. Carr IIS Rev. Date

Latest Drawing Issue Issued Date Item Released

Released By

Approved By

ITEM	CODE	CHARACTERISTIC	CAUSE
A	3	Inspection of cell separation per drawing	Visual
		A. Verify separation is placed properly on plates.	
		B. Verify separation is free of folds and wrinkles.	
B	4	Inspect cell cover assemblies for conformance to	Visual
C	3	Verify shaping of tabs with tab shaping jig and tabs	Visual
		are tack-welded per drawing.	
D	1	Verify conformance to spotwelding specification	Visual
		EP-WS-8 covering welding of terminals to tabs. Main-	
		tain EP-QC-1106A for all qualification and schedule	
		testing.	
E	1	Verify cell core weights and thicknesses are recorded	Visual
		on flow sheets.	
F	3	Inspect cell case for proper installation of cell	Visual
		insulator jacket.	
G	1	Perform insulation resistance on assembled cell;	Freed Megohmeter
H	1	Inspect fusion welding of cell cover to cases. Welds	Visual
		shall be free of irregularities, pin holes & burnouts.	
J	1	Verify etching of serial number on cell bottom	Visual

Caution Notes

BATTERY TYPE RSN-110

IIS No. _____ Rev. _____

[illegible] INDUSTRIES, INC.
[illegible] DIVISION - CONTROL DEPARTMENT
JOPLIN, MO.

INSPECTION INSTRUCTION SHEET

Part Name Final Cell Inspection Part No. _____

Written By R. Amos Approved E. Carr

Lot Marking Items _____ and Date _____

IIS Issue Date 1 Feb 72
IIS Rev. Date _____
Item Revised _____
Revised By _____
Approved By _____

ITEM	LOT SIZE	CHARACTERISTIC	GAGES
A	Q.C. Audit	Verify KOH is added per EP-MP-146	Visual & Record
B	1	Inspect cell conditioning to verify conformance to EP-MP-146	Visual & Record
C	1	Verify valve is torqued if applicable	Torque Wrench
D.	1	Perform helium leak check per EP-MP-152.	Spectrometer
E	4	Verify cell dimensions per drawing	Vernier
F	4	Verify cell container is liquid honed	Visual
G	1	Verify performance of cell cycling tests conform to ATP requirements.	Visual

Inspection Notes

EAGLE-PICHER INDUSTRIES, INC.
ELECTRONICS DIVISION—SOURCES DEPARTMENT
JOPLIN, MO.

BATTERY TYPE RSN-110

IIS No. ____ REV ____

INSPECTION INSTRUCTION SHEET

Part Name Spectrometer Leak Test Procedure Part No. ____

Written By R. Amos Approved E. Carr

Latest Drawing Issue ____ and Date ____

IIS Issue Date 1 Feb 72
IIS Rev. Date ____
Item Revised ____
Revised By ____
Approved By ____

ITEM	INSP. CODE	CHARACTERISTIC	GAGES
A	1	Place cell in test fixture and remove the pressure relief valve or pressure gage	Pressure test Fixture
B	1	Connect the test equipment and flush cell with helium	Helium
C	1	Immediately replace the pressure relief valve after the third flushing and remove cell from test fixture	
D	1	Connect CEC standard leak to test fixture on spectrometer	CEC Standard Leak Spectrometer
E	1	Perform leak test per CEC Manual No.992249-008 Section 3, Paragraph 3-30 through 3-33, and record leak detector meter indication.	CEC Manual #992249-000
F	1	Remove CEC standard leak and connect test cell.	
G	1	Perform leak test per CEC Manual No. 992249-0008 Section 3 and record	CEC Manual #992249-0008
H	1	Insert recorded indications into the following formula and calculate actual leak of test cell. $\frac{\text{Cell Leak Rate (Para. G)}}{\text{Std. Leak Rate (Para. E)}} \times \text{Helium Std. Leak Rate} = \text{Actual Test Cell Leak}$	
		NOTE: The above formula is calculated from CEC Manual, Type 24-120-A, Part 1, Reference F.	
J	1	The actual test cell leak calculated in Paragraph H shall not exceed 1×10^{-7} cc/sec.	

Caution Notes ____