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Final Report

STUDY OF PROCESS VARIABLES ASSOCIATED WITH MANUFACTURING HERMETICALLY-SEALED NICKEL-CADMIUM CELLS

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GREENBELT, MARYLAND 20771

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FINAL REPORT

FOR

STUDY OF PROCESS VARIABLES ASSOCIATED WITH MANUFACTURING HERMETICALLY-SEALED NICKEL-CADMIUM CELLS

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ABSTRACT

This final report summarizes a two year program to study the major process variables associated with the manufacturing process for sealed, nickel-cadmium, aerospace cells. Effort was directed toward identifying the major process variables associated with a manufacturing process, experimentally assessing each variable's effect, and imposing the necessary changes (optimization) and controls for the critical process variables to improve results and uniformity.

A critical process variable associated with the sintered nickel plaque manufacturing process was identified as the manual forming operation. Variability from this source was demonstrated in plaque thickness, porosity and weight variations. The design, development and imposition of a semi-automatic plaque forming system, 1) reduced plaque thickness variation to ± 0.001 inches anywhere on a plaque and from plaque to plaque, 2) reduced porosity variation to ± 0.3% anywhere on a plaque and ± 0.5% from plaque to plaque, and 3) reduced weight variation to ± 2.0% from plaque to plaque.

Critical process variables identified with the positive electrode impregnation/polarization process were impregnation solution temperature, free acid content, vacuum impregnation, and sintered plaque strength. The selection of high impregnation solution temperatures (200°F), low free acid content (1.0 gram nitric acid/liter), 0 vacuum during impregnation, and high strength sintered plaques (600-800 lb/in^3 compared to 200-400 lb/in^3 suitable for the negative electrode impregnation/polarization process) resulted in superior positive electrodes. Uniform

impregnation (0.8 - 0.9 grams/in^2, 0.028" thick plaque) positive electrodes were produced requiring a minimum number of impregnation cycles (4-5 cycles), exhibiting high active material utilization (95% contributed to electrical capacity), and were free of surface defects such as cracks, blisters, indication of flaking material, etc.

Positive and negative electrodes were identified as a major source of carbonate contamination in sealed cells. Without taking special precautions during processing, storage and cell assembly, electrodes could be assembled into cell with carbonate content in excess of 5% of electrode weight. However, it was determined contamination levels could be controlled below 2% of electrode weight by: 1) maintaining electrode materials under de-ionized water during process stand times, 2) thoroughly washing electrodes for a 16-24 hour period (pass sensitive phenolphthalein test), 3) sealing of electrode materials in polyethylene bags for both storage and shipment, and 4) storing electrodes and electrode assemblies in inert atmosphere chambers during cell assembly stand times.

Parametric cells were manufactured to investigate process variables at the cell level. This effort identified electrode active material loading and additional electrode formation cycles as critical process variables. Significantly reduced overcharge voltages were recorded for the parametric group incorporating 10 additional formation cycles (1.465 versus typical 1.500 volts at 32°F) and for the parametric group incorporating the low loading levels of 0.5 - 0.6 gms/in^2 positive and 0.7 - 0.8 gms/in^2 negative active material (1.486 versus typical 1.500 volts at 32°F). Both parametric groups also exhibited improved oxygen recombination rates.

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I. INTRODUCTION/CONCLUSIONS

The primary objective of the following program was to study the major process variables associated with manufacturing procedures for the purpose of improving the reliability of the sealed nickel-cadmium aerospace cell. The specific goals established were: (1) to identify the major process variables associated with manufacturing procedures, (2) to experimentally determine their effect upon the manufacturing process and cell performance, and (3) to improve the overall manufacturing process by the optimization and increased control of the cirtical process variables. This latter step is to be implemented by the preparation and imposition of manufacturing control documentation.

To facilitiate achievement of the above objective and goals, the overall manufacturing process was divided into its major phases. These areas were then individually subjected to study.

To summarize the areas selected for study, the more important conclusions resulting from the separate studies are presented below.

A. Sintered Plaque Study

In this study, a statistical experiemntal design technique (this technique is used in several studies of the program) was used to assess the effects of the major process variables for the purpose of increasing control where necessary to improve uniformity of product. The process variables were evaluated with respect to sintered plaque strength and void (porosity or free volume).

1. Dewpoint (a measure of the strength of the sintering furnace reducing atmosphere) exhibited the greatest effect upon the process of the variables studies. Lower dewpoints (increasing reducing atmosphere strength) increased plaque strength and reduced void. A dewpoint temperature setting of 25°F (versus 50°F) produced strong plaques (500-800 lbs/in^3) exhibiting 82-85% void.
2. Sintering furnace temperature exhibited the next greatest effect upon the process. Higher temperatures increased plaque strength and reduced void. A furnace temperature setting of 1850°F (versus 1600°F) produced plaques in the strength and void range indicated above.
3. The volume of reducing atmosphere passed through the sintering furnace exhibited the next greatest effect after furnace temperature. Greater volumes (800 versus 400 cu. ft./hr.) increased plaque strength and reduced void.
4. Furnace belt speed (carry plaques through furnace) and final cooling zones exhibited small effect upon the process.

B. Semi-Automatic Plaque Forming System

Variability in sintered plaque thickness, void (porosity), and weight observed in the above study was attibuted to the manual plaque forming operation. The design, development, and incorporation of a semi-automatic plaque forming system into the manufacturing process resulted in the following improvements in sintered plaque uniformity:

1. Plaque thickness of ±0.001 inch anywhere on a plaque and from plaque to plaque.
2. Plaque void (porosity) of ±0.3% anywhere on a plaque and ±0.5% from plaque to plaque.
3. Plaque weight ±2.0 grams (typical plaque weight 90 grams) from plaque to plaque.

C. Impregnation/Polarization Process Study

Utilizing statistical design experiments, a total of 21 process variables were evaluated with respect to plaque impregnated pick-up weight, electrical capacity, and physical characteristics (strength and appearance). In an optimization of this process with respect to the above three responses, the following critical process variable values were demonstrated preferred:

1. High nickel nitrate solution specific gravity (1.800 versus 1.700)
2. Low cadmium nitrate solution specific gravity (1.800 versus 1.900)
3. Low nickel nitrate free acid content (1 gram versus 4 grams/liter)
4. High nickel nitrate solution temperature (200°F versus 140°F)
5. High cadmium nitrate solution temperature (140°F versus 110°F)
6. Longer impregnation time (one hour versus 15 minutes)
7. No vacuum during impregnation (0 inch versus 30 inches)

8. NaOH as polarization solution (NaOH versus KOH)
9. High NaOH solution specific gravity (1.300 versus 1.200)
10. High NaOH solution temperature in positive process (150°F versus 80°F)
11. Low NaOH solution temperature in negative process (80°F versus 150°F)
12. High polarization current (0.4 versus 0.1 amp/in^2)
13. Short polarization time in positive process (15 minutes versus one hour)
14. Longer polarization time in negative process (one hour versus 15 minutes)
15. High strength plaques in positive process (500-800 versus 200-400 lbs/in^3)
16. Low strength plaques in negative process (200-400 versus 500-800 lbs/in^3)

D. Formation Study

The statistical design experiment technique also found application in the study of the impregnated plaque formation (electrochemical cleaning) process. Three process variables were evaluated with respect to final plaque impregnated pick-up weight, electrical capacity, and physical characteristics (strength and appearance). Again, optimizing this process with respect to the above three responses, the following process variable values were demonstrated preferred:

1. A 200% (100% overcharge) charge cycle introduced over a shorter period of time (4 hours versus 24 hours) is preferred in the positive formation process.
2. A 110% (10% overcharge) charge cycle introduced over a longer period of time (24 hours versus 4 hours) is preferred in the negative process.
3. No significant effect could be attributed to a variation in the specific gravity of the formation solution (1.200 versus 1.400 KOH).

In addition to the statistical design experiments, an attempt was made to evaluate the cleaning effect of the formation process by subjecting plaque samples to emission spectrometry. However, no variation in detected impurity levels could be discerned.

Finally, an evaluation of the formed plaque washing operation demonstrated a period of 16 to 24 hours of continuous washing was required to remove the residual caustic.

E. Single Plate Processing For Improved Process Control and Traceability

The single plate processing concept (versus normal plaque processing where a plaque contains a multiple of plates which are cut from the plaque at the completion of the manufacturing process) offered improved process control and traceability. The concept considered small batch processing under laboratory type controls and non-reuse of process chemicals. Individual plates would be serialized at the sintering process stage and complete traceability with respect to all plate characteristics would be maintained throughout the manufacturing process. This record of individual plate characteristics (active material weight, electrical capacity, etc.) would eventually be computerized for precise plate matching for cell assembly.

Initial test runs on prototype equipment, however, revealed the following mechanical problem which resulted in the termination of this effort:

1. Regardless of the care taken, plate edges were damaged during the manufacturing process.
2. Wherever the process holding fixture touched a plate, it interfered with the subsequent impregnation/polarization/formation processes. (In the normal process, the holding fixture grips a plaque on its unused edges which are subsequently trimmed.)
3. The necessity of permanently attaching (resistance welding) the plate's electrical contact tab prior to processing resulted in concern for the integrity of this connection. (Electrical contact for normal processing is again made to the plaque's unused edge with final plate tab attachment being made after completion of processing.)

F. Separator Material Test Method Study

This area of study was concerned with various test methods which may be effective in determining the suitability of a separator material for use in sealed nickel-cadmium cells. The effectiveness of a test method was evaluated with respect to its ability to distinguish the measured parameter and the degree of confidence which could be attached to its results.

The following test methods demonstrated merit and are recommended for inclusion in manufacturing control documentation.

1. Unit weight determination (density).
2. Thickness variations.
3. Tensile strength.
4. Wetting agent determination.
5. Wettability (wicking rate).
6. Electrolyte retention and absorbency.
7. Extractable organic content.
8. Inorganic analysis (emission spectrometry).

The following test methods were not recommended for inclusion in manufacturing control documentation.

1. Scanning electron microscopy.
2. Organic analysis (infrared spectrometry).
3. Electrical resistance (DC method).
4. Classical wet chemical analyses.

G. Carbonate Contamination Study

A series of experiments demonstrated a major source of carbonate contamination of sealed nickel-cadmium cells is associated with the positive and negative electrodes (carbonate contents as high as 5% of total electrode weight were observed). These experiments further indicated the most probable mechanism for contamination of electrodes is by conversion of the respective active materials by the following reactions.

$$Ni(OH)_2 + CO_2 \rightarrow NiCO_3 + H_2O$$

$$Cd(OH)_2 + CO_2 \rightarrow CdCO_3 + H_2O$$

Experiments conducted to reduce carbonate demonstrated contamination in electrodes could be controlled below 2% of total electrode weight by incorporation of the following steps into the manufacturing procedure:

1. Maintaining electrode materials under de-ionized water during any process stand time prior to final drying.
2. Washing electrodes during the final wash to pass the sensitive phenolphthalein test (described in the Formation Process Study).
3. Immediate heat sealing of electrode materials in polyethylene bags for both storage and shipment after the final drying procedure.
4. Storing electrode and electrode assemblies in inert atmosphere chambers during cell assembly stand times.

H. Auxiliary Assembly and Process Study

This area of investigation included three small studies of cell auxiliary assemblies and processes. These studies were concerned with ceramic-to-metal seal assemblies, the electrolyte activation process, and cell gauge and valve assemblies.

1. To improve the reliability of the ceramic-to-metal seal assemblies used in sealed nickel-cadmium cells, a comprehensive procurement specification controlling major manufacturing parameters was prepared and incorporated into the manufacturing control documentation. In addition, a joint effort was undertaken with a vendor to improve his basic seal design. Changes were made in the area of design geometry, mating surface tolerance reduction, and selection of superior materials.

2. An improved cell electrolyte activation system was successfully designed and developed. The system is fast and clean, offers a reproducible accuracy greater than ± 0.05%, and prevents contamination of the electrolyte from CO_2 in the atmosphere.
3. Testing of gauge and valve assemblies (these assemblies are subsequently attached to cell for evaluation tests) utilizing teflon tape as a connection sealant have typically demonstrated a 25% unit leak attrition. An evaluation of alternate sealants resulted in the selection of a "Loctite" sealant, Grade AVV. Use of this sealant reduced the gauge and valve assembly leak attrition from 25% to 5%.

I. Signal (Auxiliary) Electrode Study

A problem encountered with the use of the oxygen sensing, teflonated, non-noble signal electrodes (signal used for charge control purposes) is described as hysteresis of the signal produced (residual increase with cycling). In this study, modifications of the basic signal electrode design (design modifications were primarily concerned with different teflonation processes) were evaluated to determine if the hysteresis effect could be eliminated.

The results were not encouraging, the modifications evaluated either depressed the signal produced to a level it would not be useful or testing indicated the hysteresis effect was still present.

J. Parametric Cell Study

In this final study of the program, process variables were evaluated on the cell level by the introduction of manufacturing parameter change associated with the cell electrodes. The following parametric cell electrode parameter levels were selected for this study:

Group I	Low electrode loading. (Active material loading, 0.5-0.6 gms/in^2 positive and 0.7-0.8 gms/in^2 negative; normal formation cycles, three cycles)
Group II	One formation cycle. (Moderate active material loading, 0.7-0.8 gms/in^2 positive and 0.9-1.0 gms/in^2 negative)
Group III	Ten formation cycles. (Moderate active material loading)
Group IV	Vacuum dried electrodes. (Moderate active material loading; normal formation cycles)
Group V	High electrode loading. (High active material loading, 0.9-1.0 gms/in^2 positive and 1.1-1.2 gms/in^2 negative; normal formation cycles)
Group VI	Formation cycle reversal. (Moderate active material loading; three formation cycles discharged past active material exhaustion into reserved gas evolution)

Primary characterization of the parametric cells will result from cycle life testing at the (NAD) Crane test facility, Crane Indiana. However, a few preliminary evaluation cycles prior to cell shipment permitted the following observations:

1. Cell charge voltage and pressure benefited from ten formation cycles.

(Test Temperature 32°F)

	PV	PP	AH Capacity
Group II	1.515	80	25.4
Group III	1.465	9	22.5

However, additional formation cycles appeared to be detrimental to high temperature charge efficiency.

(Test Temperature 95°F)

	AH Capacity
Group II	21.7
Group III	12.5

2. Low loading of electrodes also appears to benefit cell charge voltage and pressure.

(Test Temperature 32°F)

	PV	PP
Group I	1.486	30
Group V	1.520	55

3. Vacuum drying of electrodes (after final washing operation) adversely effected this parametric cell group's oxygen recombination ability.

(Test Temperature 75°F)

	PV	PP	AH Capacity
Group IV	1.442	100	26.5
Group V	1.432	35	26.4

4. The charge efficiency associated with the level of electrode active material loading appears to exhibit an optimum range. Little or no additional capacity was achieved by pushing the loading level up in Group V and the loss in capacity associated with the low electrode loading level in Group I is greater than that which could be attributed to reduction in active material.

(Test Temperature 75°F)

	AH Capacity
Group I	17.5
Group II	27.2
Group V	27.3

II. SINTERED PLAQUE STUDY

A. Introduction

The study of the major process variables associated with the nickel-cadmium cell manufacturing process was initiated with a study of the sintered plaque manufacturing process. To identify the major process variables, evaluate their process influence, and evolve information useful for control and product improvement, designed experiments were devised and implemented investigating the various manufacturing steps.

The designed experiments were formulated around two standard statistical techniques. A fractional factorial procedure was utilized to design the experiments with respect to selection of variables, order of performance, and magnitude of variable values. The data resulting from the experiments was then treated to a regression analysis to evaluate the results. Details of these statistical procedures are presented in Appendix A of this report.

B. Background

The high energy density levels achieved with present nickel-cadmium systems are primarily the result of sintered plaque technology. This technology permits the formation of electrodes which exhibit an effective or active surface area many times greater than the apparent surface area (that area defined by the over all electrode dimensions).

High porosity sintered plaques are produced by either the "slurry" process, in which the process material (pure nickel filiments) is mixed with a carrier media and applied in a slurry form or the "dry" process in which the process material is applied directly. The work reported here is concerned with the dry process.

In the dry process, a high porosity sintered plaque is formed by the application of the pure nickel filiment material (controlled particle size distribution) to a flat shallow mold in which is previously introduced a current collecting substrate (nickel grid). Excess material is manually raked off the mold leaving a thin sheet of material within the mold and containing the substrate. The mold assembly is transferred to a controllable speed belt which moves the assembly through a reducing atmosphere, sintering furnace and subsequent cooling zones. The sintering operation effects bonding of the individual nickel filiments to each other and to the substrate forming a strong, high porosity, highly conductive sintered plaque. A reducing atmosphere is required to prevent oxidation of the plaque material at the elevated temperatures.

C. Design Experiments

Table I lists the process variables selected along with the levels used in the study.

Variable 3 may require additional explanation. Dewpoint, which is a measure of water content in an atmosphere, determines the strength of the sintering furnace reducing atmosphere. The higher the dewpoint, the weaker the reducing atmosphere. As will be seen, this variable exhibits a significant effect upon the manufacturing process.

Two responses were considered in this design experiment. First, the finished sintered plaque strength which was determined on the "four point" bend tester shown in Figure 1.(1) This instrument applies a continuously increasing load upon a plaque sample to measure a

SINTERED PLAQUE DESIGN EXPERIMENT

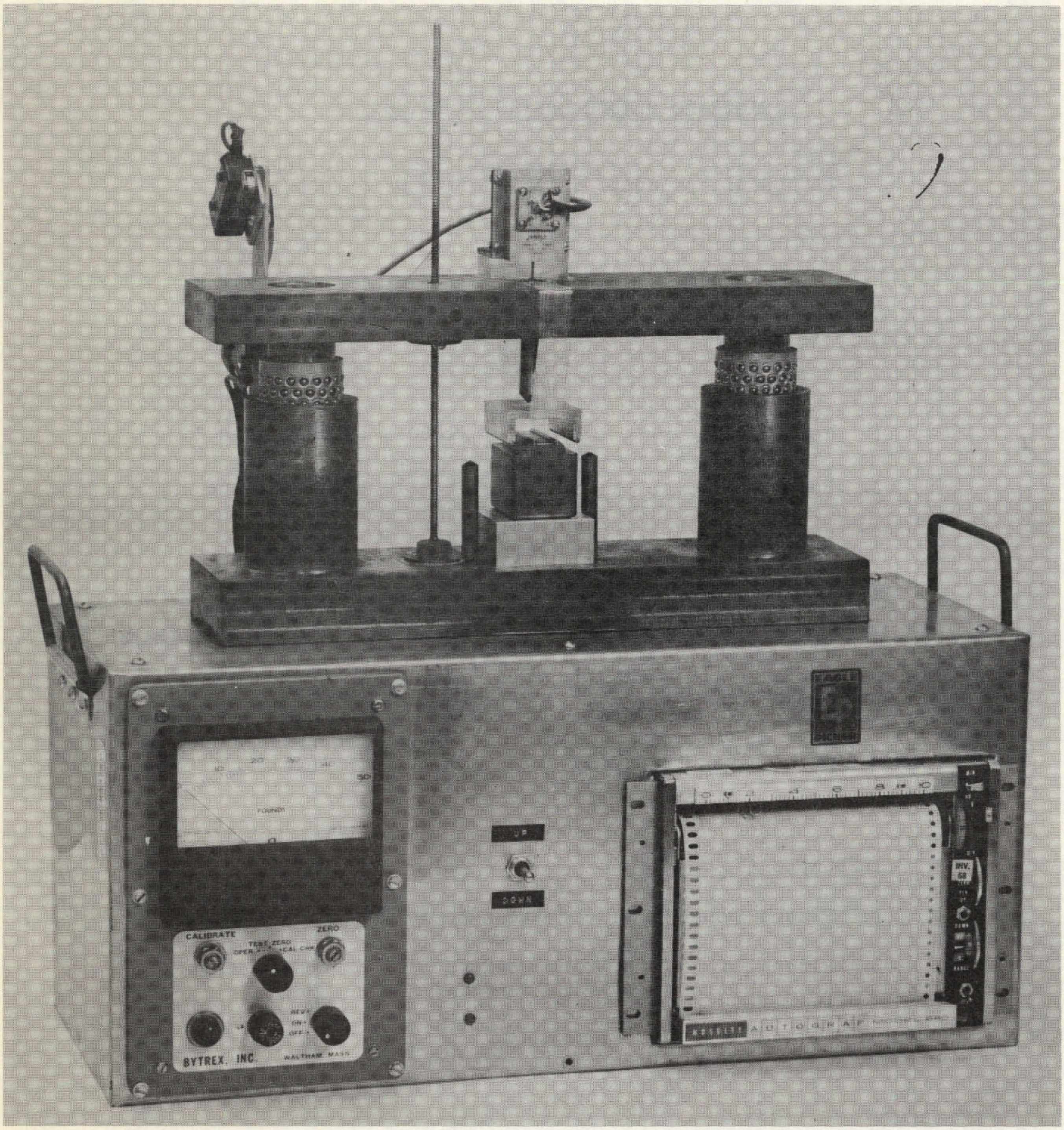
FACTORIAL VARIABLES & DESIGNATION OF LEVELS

VARIABLES (X Values)	LEVEL AND DESIGNATION
1. Temperature	1600 - 1850 Degrees F
2. Belt Speed	6 - 12 Inches/Minute
3. Dewpoint	25 - 50 Degrees F
4. Atmosphere Amount	400 - 800 Cubic Feet/Hour
5. Bulk Density	Measured, .870 ± .006 gms/cc
6. Plaque Spacing	0 - 16 Inches
7. Cooling Zone	75 - 175 Degrees F

RESPONSES (Y VALUES)

1. Plaque Strength (Yield Strength in lbs/in^3)
2. Plaque Void (Free Volume or Porosity Expressed as a Percent of Total Plaque Volume)

TABLE I



FOUR POINT BEND TESTER
FIGURE 1

yield or break point. The second response, plaque void, is a measure of the free volume or porosity of the finished sintered plaque. This value was determined by subtracting from the total volume occupied by a plaque (plaque thickness x plaque area), the volume consumed by the actual nickel matrix (plaque weight x density of nickel).

D. Results

Table II presents the results of the regression analysis of the design experiment data. The dewpoint variable exhibited an unexpected strong effect upon the manufacturing process; this variable was closely followed by the furnace temperature and reducing atmosphere volume variables.

As a first step in the implementation of the results of the Process Variable Program, the first three process variables listed in Table II were the subject of increased manufacturing process control.

To supplement the regression evaluation, samples of the finished sintered plaques were subjected to a scanning electron photomicrographic examination. This technique permitted a visual evaluation of the sintered plaque quality and revealed a number of interesting features.

Figures 2 and 3 are examples of the above effort. Figure 2 presents a well sintered plaque which exhibited both high strength (525 lbs/in^3) and high porosity (83.3% void) qualities. Figure 3 presents a plaque in which the process variable levels selected resulted in insufficient sintering or bonding of individual filiments. This plaque exhibited very low strength (250 lbs/in^3, porosity 86.0%).

SINTERED PLAQUE PROCESS STUDY

CONCLUSIONS

(1) Dewpoint exhibited greatest effect. Lower dewpoint (25°F), higher strength (500-800 lbs/in^3) and lower void (82-85% void). Incorporate increased control.

(2) The next greatest effect was exhibited by sintering temperature. Higher temperature (1850°F), greater strength and lower void. Incorporate increased control.

(3) Reducing atmosphere volume exhibited effect next in magnitude. Higher volume (800 cu. ft./hr.), increased strength and decreased void. Incorporate increased control.

(4) Slow belt speed (6 in/min) produced plaques with high strength and low void. High speed (12 in/min), just the opposite.

(5) Cooling zone temperatures exhibited little effect upon strength and void.

(6) Strength and void appear to be inverse linear functions.

TABLE II

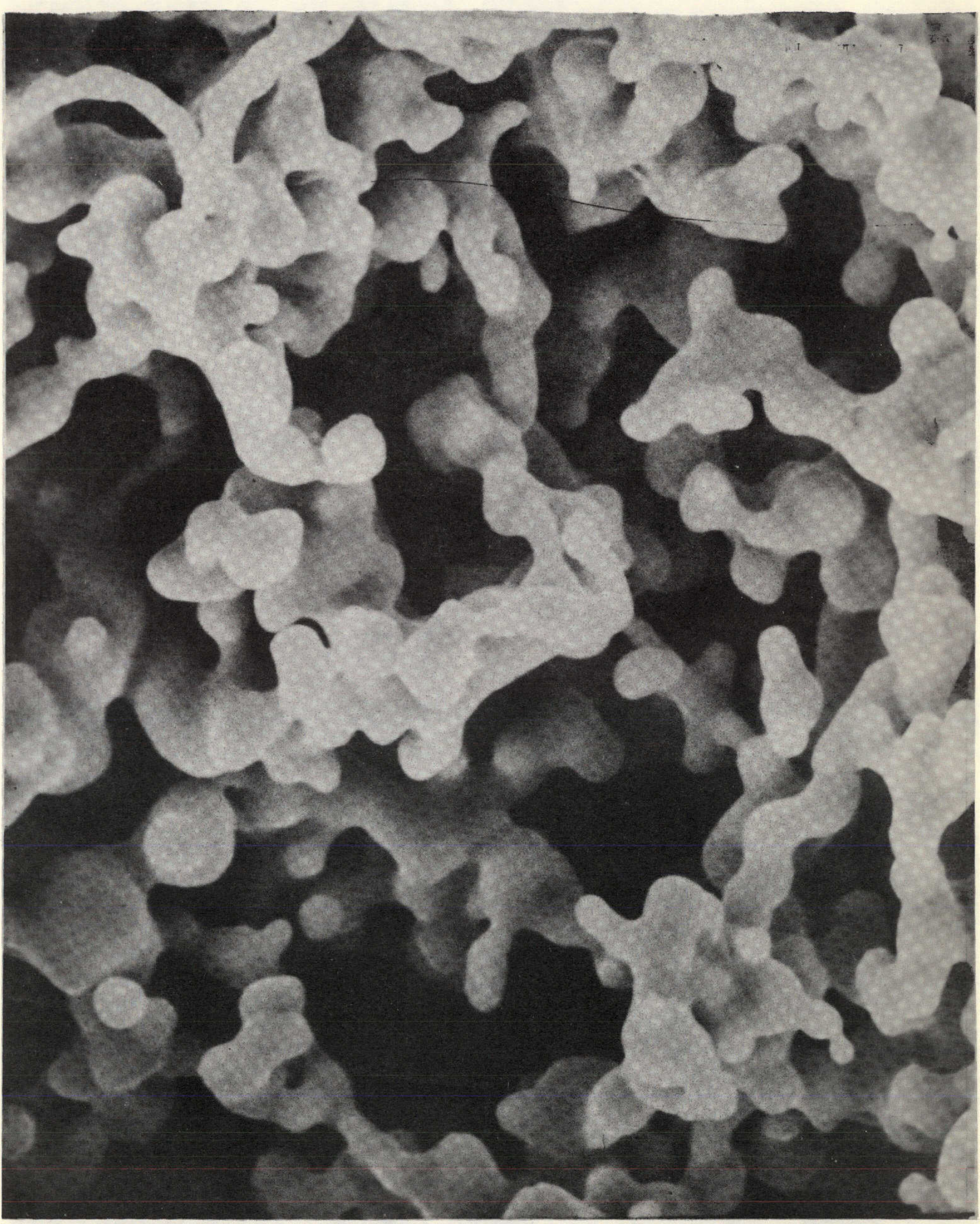


FIGURE 2
RAW PLAQUE LOT 151
5000X MAGNIFICATION

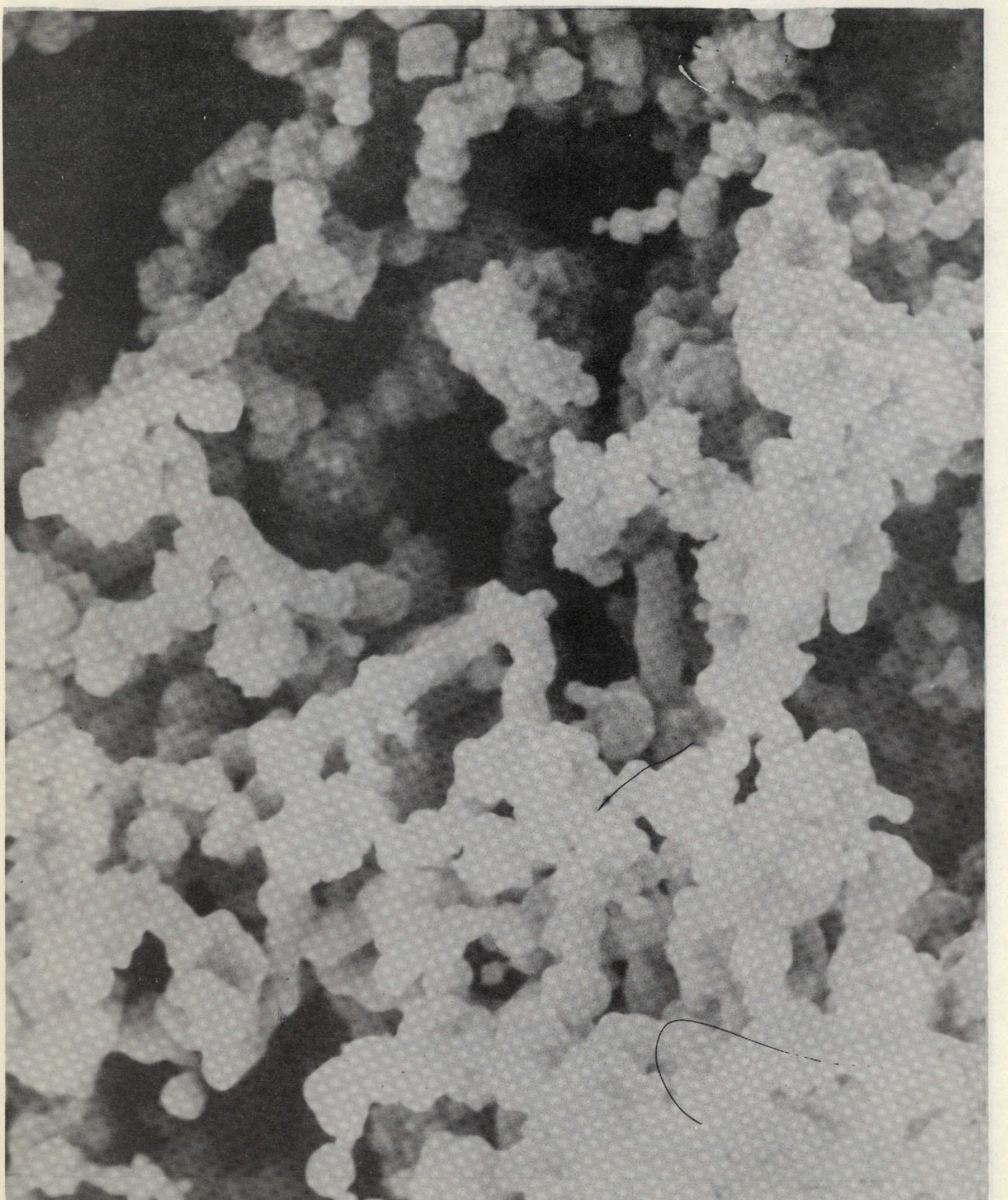


FIGURE 3.
RAW PLAQUE LOT 152
5000X MAGNIFICATION

III. SEMI-AUTOMATIC PLAQUE FORMING SYSTEM

A. Introduction

In the preceding study, the strength and porosity of a plaque was determined by punching out uniform 1 in. x 2 in. rectangular sections (the sample size required by the four point bend tester) from various areas of a plaque. The data resulting from the measurement of these smaller samples was averaged and used to characterize the parent plaque.

Significant variation was, however, observed between the samples from a single plaque. A comparison of a number of plaque samples indicated an inherent variability within any individual plaque up to 2% with respect to strength and porosity. This variability was primarily attributed to the manual plaque forming operation with its reliance upon the human element.

To reduce this source of variability, the following program was undertaken to design and develop a semi-automatic plaque forming system.

B. Design Concept

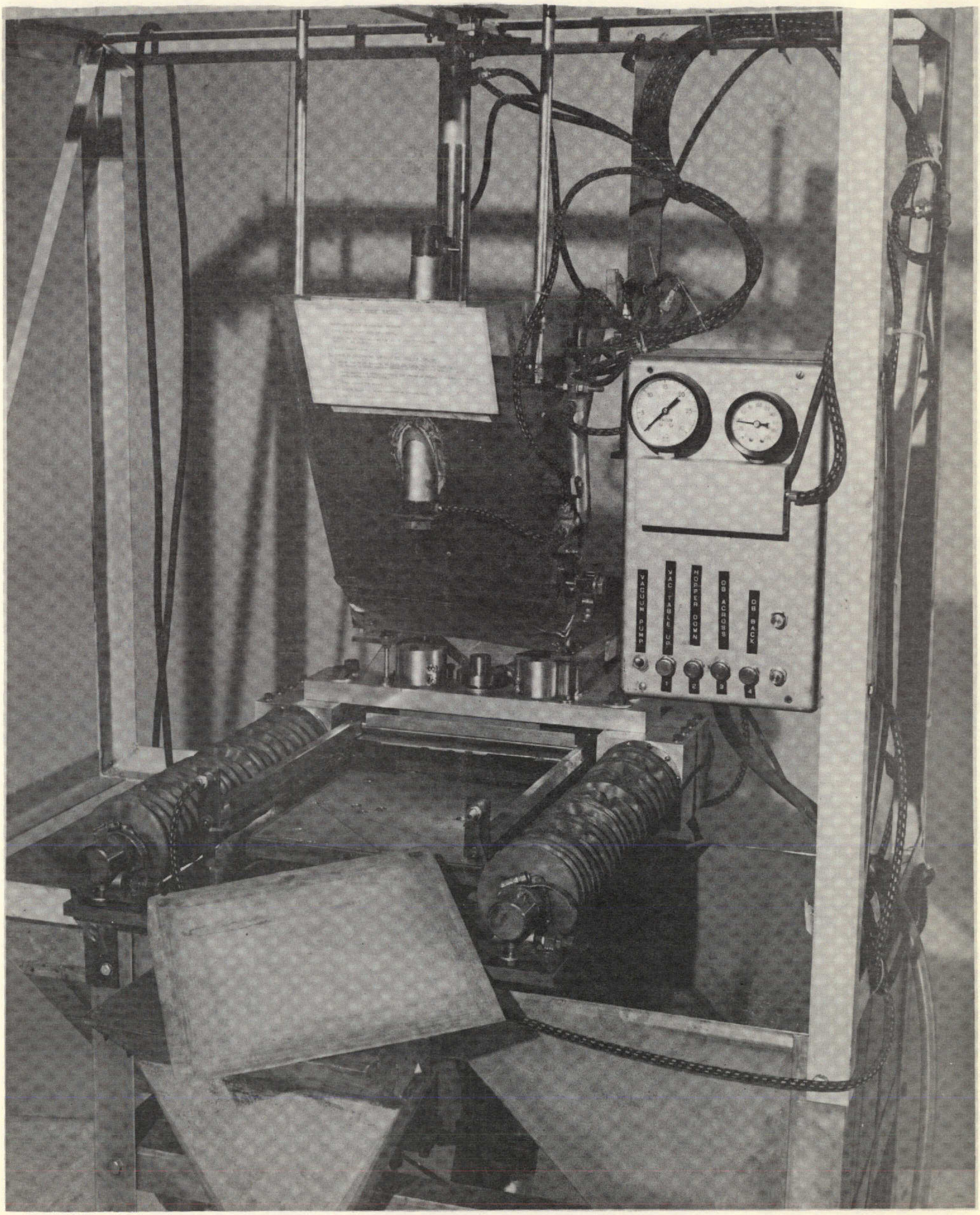
The design concept basic to the subject program was to develop a system to manufacture dry sintered nickel plaques to close reproducible specifications. The target specifications were: 1) plaque thickness of ±.001 inch anywhere on a plaque and from plaque to plaque, 2) plaque porosity of ±.3% anywhere on a plaque and ±.5% from plaque to plaque; and, 3) yield weights where 85% of all plaques produced are within ±2.0 gm from plaque to plaque.

The above requirement dictated close machine tolerances, machine stability, reproducibility of machine operations, and no manual labor which would directly influence the manufacturing of the dry plaque. These requirements lead immediately to semi-automated system wherein only minimal handling was left to a human operator.

C. Development Program

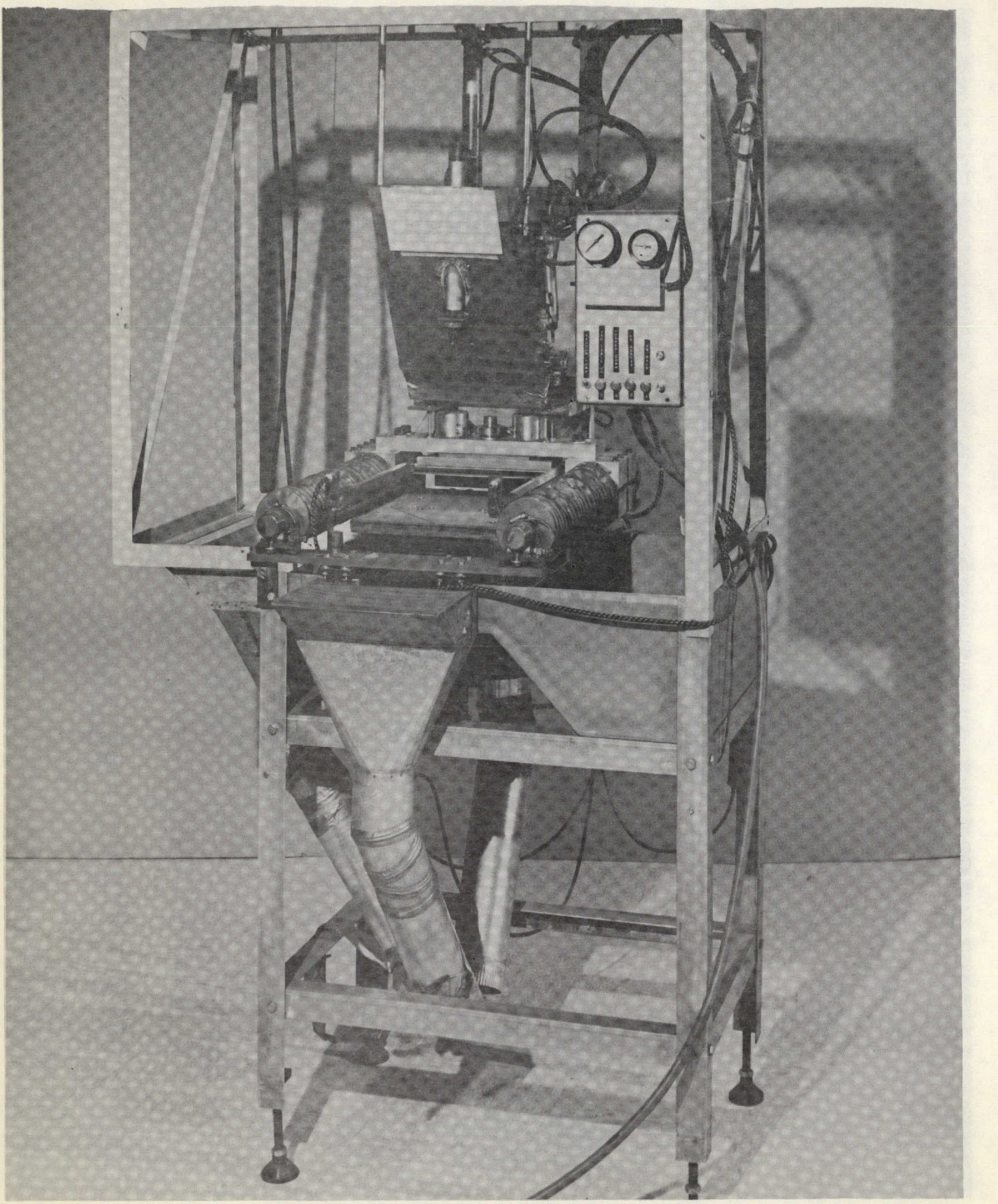
At the onset of the development program the following design goals were established: 1) the critical machine parts must be within a tolerance of ± .001 inch, 2) adjustment capability must be to within ± .0005 inch, 3) the supporting structure of the critical parts must be non-flexing and isolated from vibration, 4) the moving precision parts must be protected from nickel-powder, 5) the machine should not be subject to environmental changes in temperature; and, 6) the operation of the critical forming steps must be automatic, free of human influence to the greatest extent possible.

Figures 4 and 5 presents a photograph of the final configuration of the plaque forming machine. To the right, beneath the control panel, is shown a typical carrier platen which is used in conjunction with the machine. The platen is approximately one foot square and is fabricated from 0.031 inch thick 200 nickel sheet. Located in the center of the platen is the nickel substrate screen. The screen is cemented at the top with a fast setting glue. Prior to joining the screen to the platen, the platen is flattened in an impact press with automatic feed. The screen is processed through a neoprene faced press during which a series of 60 1/8 inch diameter embossed studs are formed into the screen. The embossings hold the screen approximately .007 inch above the platen thus



AUTOMATIC PLAQUE FORMING SYSTEM (VIEW #1)

FIGURE 4



AUTOMATIC PLAQUE FORMING SYSTEM (VIEW #2)

FIGURE 5

assisting in positioning the screen in the center of the sintered plaque. The platen with the screen is inserted into the machine underneath the two parallel bars. A ground steel table possessing a circumferential O-ring seal is activated upward and firmly holds the carrier platen against the underneath side of the parallel bars. The ground table is connected to a vacuum pump. A vacuum is pulled over the entire lower side of the carrier platen. This vacuum leads to flattening the platen against the vacuum table. Next, the storage hopper containing the nickel powder is lowered and a predetermined quantity of nickel powder is automatically dispensed at the upper end of the platen. The hopper automatically retracts. There is now a narrow pile of nickel powder immediately in front of the cross bar shown in the figures. This cross bar is mounted at each end to bushing blocks which are carried on precision ground shafting. The shafting is protected by shaft boots and each shaft is positioned on adjustable waymounts. The shafts, cross bar, parallel bars and vacuum table are thus located precisely to one another ensuring the required dimensional control. Carried beneath the cross bar are two semi-circular polished rods mounted parallel to one another. The rear bar (not visible) determines the final thickness of the unsintered plaque. The front bar is positioned 0.003 inch higher. On command of the machine operator, the cross bar assembly is actuated forward. This motion pushes the nickel powder across the platen and screen forming the unsintered plaque. After the plaque is formed, the vacuum table drops. The operator removes the carrier platen with the plaque and places it on the belt of a three-zone sintering furnace. The cross bar is returned to its rear position and the operator removes any nickel powder from the vacuum table with a vacuum cleaner.

The machine is controlled employing a pneumatic logic system which is interlocked with the various mechanical motions of the machine. The machine is housed in a temperature controlled room adjacent to the sintering furnace.

Several problems were encountered during the development, three of which deserve comment. Ground alumina ceramic plates were first tried as carrier platens. These lead to an excellent quality of plaque, but repeated passes through the sintering furnace resulted in grain growth and eventual fracture. A durable silicon carbide platen would have eliminated this problem but such platens were prohibitively expensive. The ultimate solution was the nickel plates used in conjunction with the vacuum table. Dimensional control is as good as that determined in the early use of ceramic platens.

The first method of distributing the nickel powder was to sift it onto the carrier platen and substrate screen. This procedure resulted in porosity variations as high as ± 2% and a non-reproducible weight of nickel powder layed down per unit area. The present method of drawing a pile of nickel powder across the substrate screen proved to solve both of the above problems and with interesting results. Figure 6 presents a comparison of the "sift" method and the "pile and draw" method. Shown is the thickness of the final sintered plaque as a function of the net weight of nickel powder layed down in a 2 inch^2 sample. The results reveal a clear linear correlation between thickness and net weight of nickel powder layed

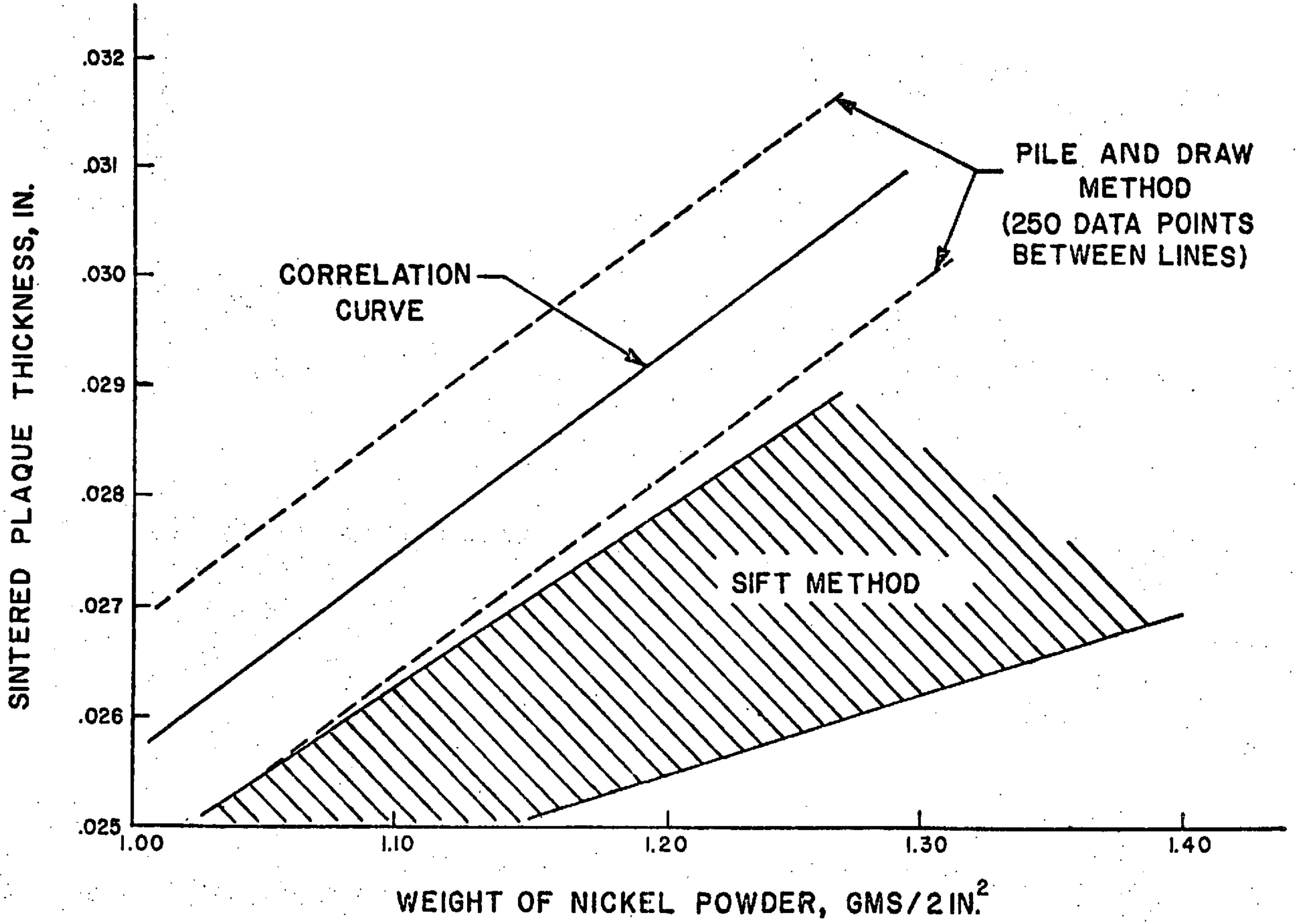


FIGURE 6

COMPARISON OF THE SIFT METHOD & THE PILE & DRAW METHOD down for the pile and draw method. The sift method has no clear correlation. Further, the sift method gives a denser plaque for a given weight of nickel powder as evidenced by the thinner plaque for a given weight of nickel powder. Not shown in the figure is the fact that the pile and draw method results in plaques having a narrow porosity variation as well.

The necessity of embossing the substrate screen arose because of too much of the screen being to one side of the finished plaque. This situation caused the nickel sinter to easily delaminate from the screen. Several ways were attempted to correct the problem; however, the embossing procedure proved most successful.

D. Results

Visually the plaques produced by the machine look much the same from plaque to plaque. The upper surface carries faint streaks which are the result of the interaction of the long grain nickel powder and the micro-characteristics of the surface of the semicircular bars. These streaks are not, however, thickness variations. The back side of the plaques reveal the position of the emboss studs. Most of the substrate screen is surrounded by nickel sinter as desired.

Figure 7 presents the number of plaques (cut to 10.5 in. x 9.5 in.) as a function of plaque weight for two groups of plaques produced on the machine. Of 1010 0.029 inch plaques, 89% were within ± 2.0 gms. Of 403 0.021 inch plaques, 97% were within ± 2.0 gms. This uniform weight characteristic is a direct result of the mechanics of the pile and draw method previously discussed.

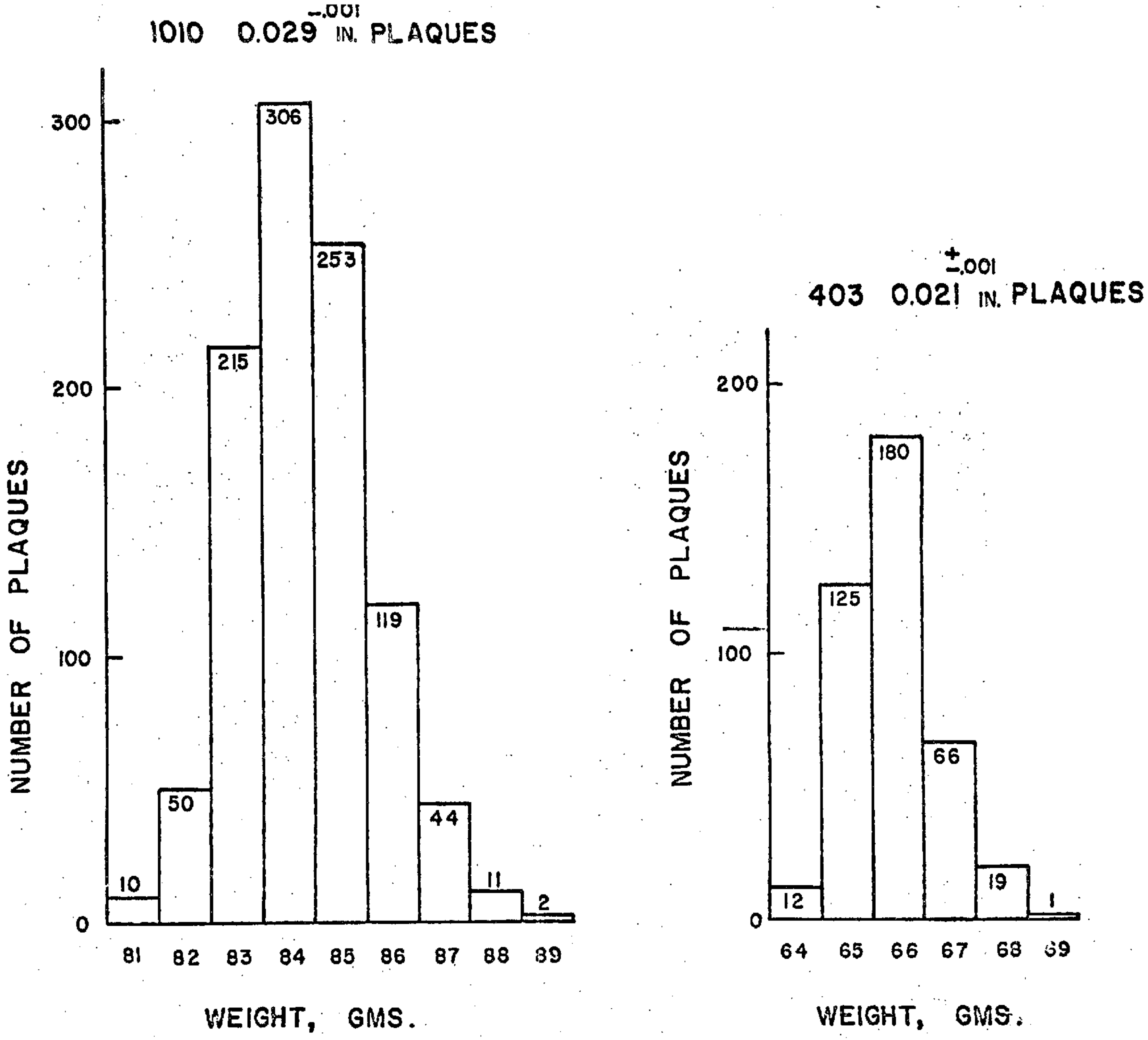


FIGURE 7 NUMBER OF PLAQUES AS A FUNCTION OF PLAQUE WEIGHT

Plaque strength is determined by the four point bending test which provides a relative measure of sinter strength against an arbitrary standard. Of the samples taken from 10 plaques designated as negative plaques, the yield strength values ranged from 350 to 450 lbs/in^3 against a desirable basic value of 200 lbs/in^3. Similarly, plaques designated as positive plaques showed a yield strength ranging from 650 to 850 lbs/in^3, where 600 lbs/in^3 is the desirable basic value. The ranges were the result primarily of different selected thicknesses rather than non-uniformity of the plaque itself.

The day-to-day production yield of plaques within ± .001 inch of a desired thickness is approximately 90%. The porosity variation of the 1010 0.029 inch plaques previously mentioned was from 85.0 to 85.7% for the particular furnace conditions of the sintering process. The strength of the plaques as determined by a standardized break test exceeds the nominal requirements applied to similar plaques manufactured by the manual method.

IV. IMPREGNATION/POLARIZATION PROCESS STUDY

A. Introduction

The impregnation/polarization of the sintered plaques in the process of forming electrodes was the next manufacturing area subjected to study. In addition to the numerous process variables selected for investigation which are normally associated with this process, sintered plaque strength and porosity variables were introduced into the study by the following procedure.

Three groups of sintered plaques were manufactured featuring three strength and porosity levels. (See Section II, Third Quarterly Report(3))

	Lot 151	Lot 152	Lot 153
Strength (lbs/in^3)	525	250	400
Porosity (%)	83.3	86.0	85.7

Plaque samples from all three groups were then utilized in each impregnation/polarization experiment.

B. Background

An impregnation/polarization process is the means by which the active material of the nickel-cadmium couple is impregnated in the porous sintered nickel plaque. In the Eagle-Picher process, impregnation is accomplished by immersion of the unimpregnated plaques in a hot, slightly acidic solution of either nickel or cadmium nitrate. This operation is normally performed under a vacuum. Polarization or the conversion of the electrically inactive nitrate form of nickel or cadmium to the electrically active hydroxide form is accomplished by immersion of the impregnated plaques in a strong caustic solution (normally sodium hydroxide) accompanied by the passage of a polarizing cathodic current. The plaques are then washed in deionized water to remove the caustic solution.

The above operation is repeated until a predetermined amount of active material impregnation is achieved. The impregnated plaques are then subjected to an electrochemical cleaning or formation operation in preparation to their fabrication into cells.

C. Experimental Procedure

To facilitate the study of this manufacturing phase, a scaled-down production facility was established. Figure 8 presents a portion of this facility including the impregnation/polarization tanks (foreground), heated nitrate and caustic reservoirs (floor) and rectifier banks (background). Care was exercised to assure a representative scale-down in order that actual production parameters could be evaluated.

Again, to evaluate the large number of process variables associated with this manufacturing operation, the statistical techniques described previously were used. Fractional factorial experiments were designed investigating the selected process variables at two (2) levels. Table III lists the selected variables and their levels of investigation; in addition, the Table lists the three (3) responses to be measured.

The impregnated pick-up weight (Response 1) is determined by simply subtracting from the finished plaque weight the starting unimpregnation sintered plaque weight. The electrical capacity (Response 2) of plate samples removed from plaques was determined by a standardized procedure. Individual plates were charged at

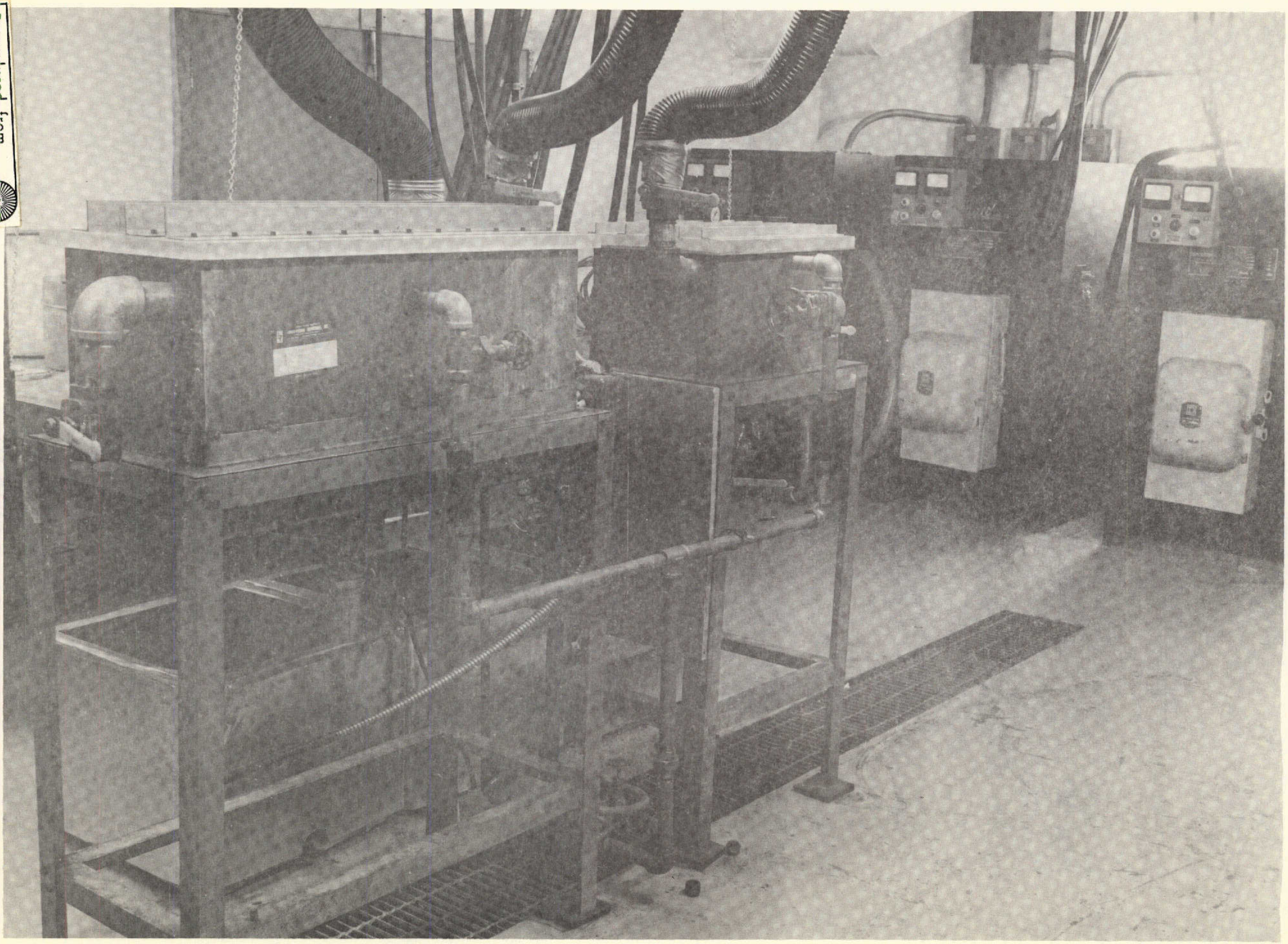


Figure 8
Scaled-Down Production Facilities

IMPREGNATION/POLARIZATION DESIGN EXPERIMENT

FACTORIAL VARIABLES	DESIGNATION	LEVELS NEGATIVE	LEVELS POSITIVE
(X Values)			
1	Specific Gravity of Nitrate	1.800-1.900	1.700-1.800
2	Free Acid	.2-.5 gm/liter	1-4 gm/liter
3	Temperature of Nitrate	110°F-140°F	140°F-200°F
4	Time of Impregnation		15 Minutes - 1 Hour
5	Vacuum		0-15 Inches
6	Wash Time		10-30 Minutes
7	Wash (Number of Cycles)		1-3
8	Wash Water Temperature		R.T. - 150°F
9	pH of Wash Water		Measured
10	Type of Caustic		KOH-NaOH
11	Specific Gravity of Caustic		1.200-1.300
12	Temperature of Caustic		80°F-150°F
13	Amount of NH_3 in Caustic		Measured
14	Amount of CO_2 in Caustic		Measured
15	Amount of OH in Caustic		Measured
16	Polarization Current		.1-.4 Amps/sq.in.
17	Polarization Time		15 Minutes-1 Hr.
18	Voltage of Plaque to Ref. Electrode		Measured
19	Amount of Cycles with Same Caustic		1-5
20	Number of Total Cycles		Measured
21	Type of Plaque		3 Types

RESPONSES (Y Values)

1	Impregnated Pick-up Weight (Finished Weight-Starting Weight)
2	Electrical Capacity (C/2 Rate Discharge Capacity of Plate Samples)
3	Plaque Characterization (Strength and Physical Appearance)

TABLE III

a C/3 rate for 4 hours and discharged at a C/2 to a potential of 1.00 volts in a flooded condition against sheet nickel counter electrodes. Plaque characteriaation (Response 3) involved rating plaques with respect to their physical attributes. High strength plaques exhibiting a smooth uniform surface free of cracks or blisters received a high rating. Plaques exhibiting one or more of the above defects received a lower rating.

D. Results

With the completion of the required number of experiments, the resulting data was subjected to a regression analysis. The subsequent interpretation applied to the regression results was similar to that used in the previous (sintered plaque process) study; however, the emphasis in this case was on optimization. Instead of concentrating on process variables which exhibit the greatest effects for increase control and uniformity purposes (although this information was determined and used), the regression data was utilized to establish an optimized manufacturing process.

The following goals were established in the optimization of the manufacturing process.

1. A manufacturing process which would result in the greatest amount of impregnation for number of cycles.
2. A manufacturing process which would result in the highest electrical capacity (efficiency) for impregnated material.
3. A manufacturing process which would result in high strength plaques exhibiting uniform surface texture free of pits, cracks and blistering.

Table IV summarizes the regression analysis results. Process variables not included in this summary did not, within the limits of experimentation, exhibit a significant effect upon the process. Incorporation of the indicated changes into the actual production process proved so successful that they have become an integral part of the manufacturing specifications.

Supplementing the above statistical efforts, the scanning electrons photomicrographic technique was again utilized. The following photomicrographs are representative of this effort.

Figures 9 and 10 represent positive plaques in which the dominant process variable is the temperature of the nitrate or impregnation solution. The smooth uniform impregnation associated with Figure 9 was achieved with a high (200°F) nitrate temperature. The rough, very nonuniform impregnation associated with Figure 10 resulted from the use of a low (150°F) nitrate temperature. Figure 11 presents plates hand cut from the above plaques (Figure 9 plaque on left, Figure 10 on right) showing the very visible difference. This visual analysis technique then supports and helps explain why the regression analysis indicated a higher nitrate temperature would improve both Response 1 (impregnation amount) and Response 3 (plaque physical characteristics).

Figures 12 and 13 represent negative plaques in which the dominant process variable is polarization time. The large crystalline structure associated with Figure 12 is the result of a shorter (15 minutes) polarization time. The small crystalline structure associated with Figure 13 is attributed to a longer

IMPREGNATION/POLARIZATION PROCESS STUDY

CONCLUSIONS

Preference indication in optimization process:

Variables

1 High specific gravity (1.800) preferred in positive process, low (1.800) preferred in negative process.

2 Low free acid (1 gm/L) preferred in positive process.

3 High nitrate temperature (200°F pos/140°F neg) preferred.

4 Longer impregnation time (1 hour) preferred.

5 0 vacuum preferred.

10 NaOH preferred caustic.

11 High NaOH specific gravity (1.300) preferred.

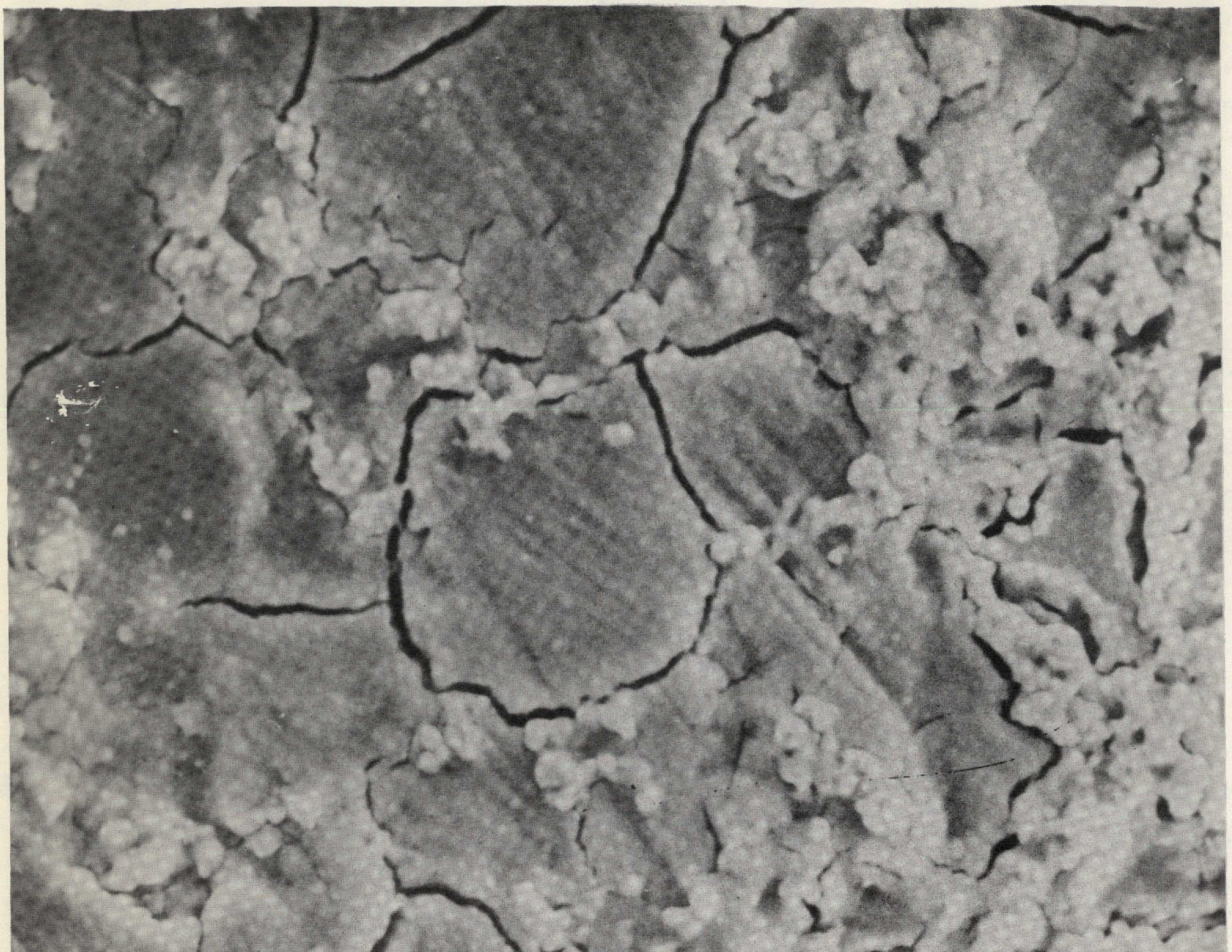
12 High NaOH temperature (150°F) preferred in positive process, low temperature (80°F) preferred in negative process.

16 High polarization current (0.4 amp/in^2) preferred.

17 Short polarization time (15 min) preferred in positive process, longer time (1 hour) preferred in negative process.

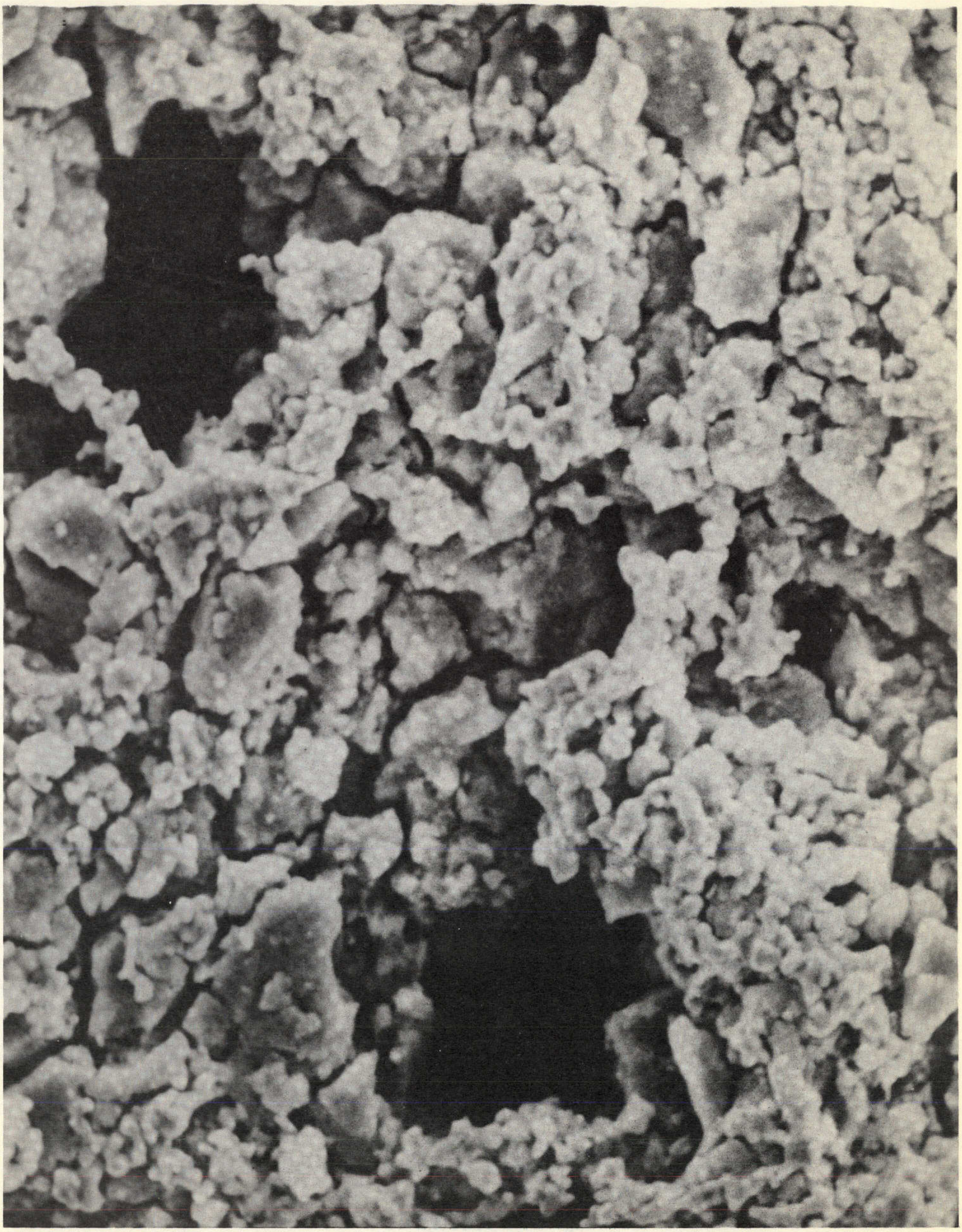
21 High strength (500-800 lbs/in^3), low void (82-84%) plaques preferred in positive process; low strength (200-400 lbs/in^3), high void (85-88%) plaques preferred in negative process.

TABLE IV



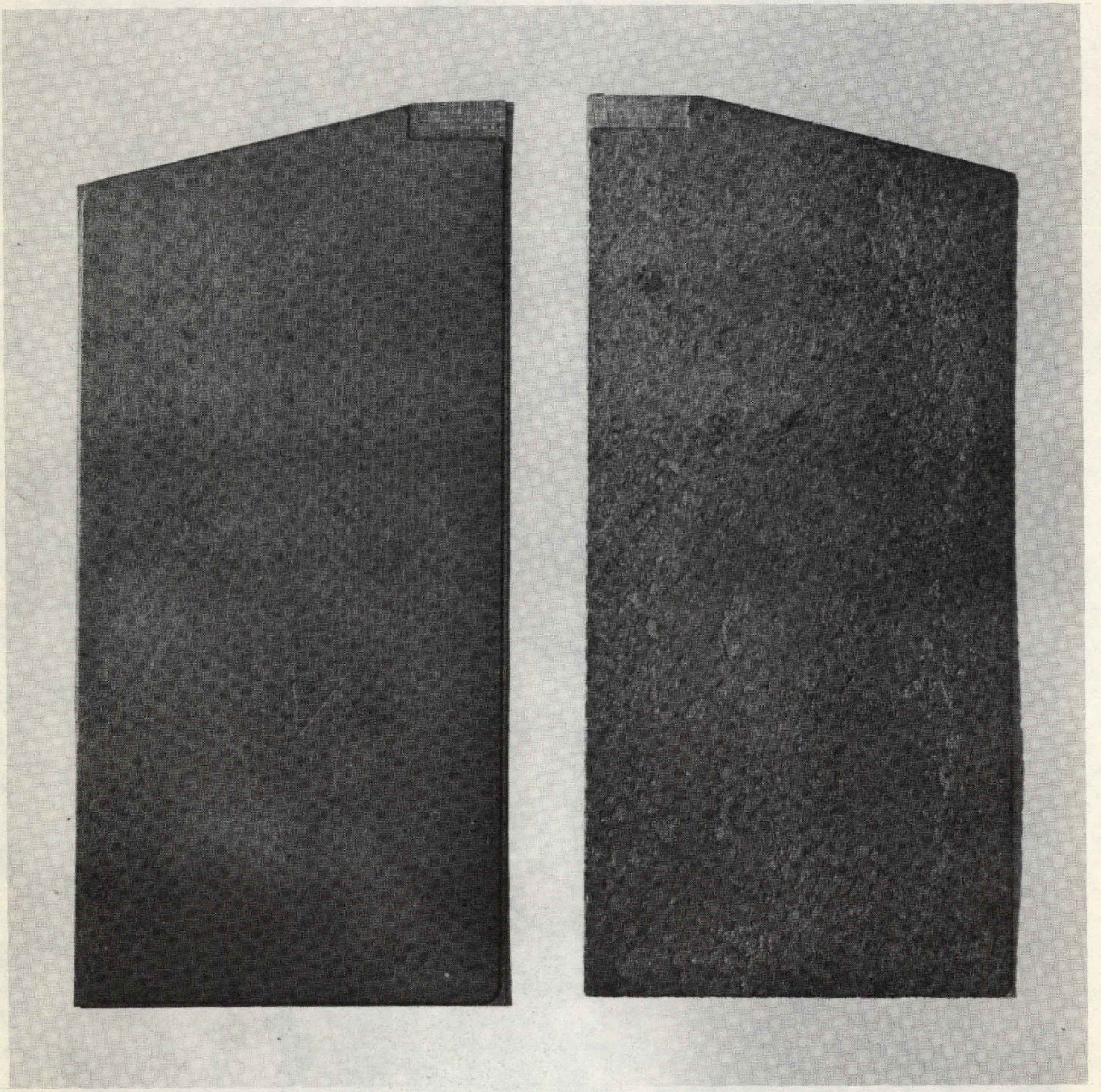
POSITIVE PLAQUE, HIGH NITRATE TEMPERATURE, 1250 x MAGNIFICATION

FIGURE 9



POSITIVE PLAQUE, LOW NITRATE TEMPERATURE, 1250 x MAGNIFICATION

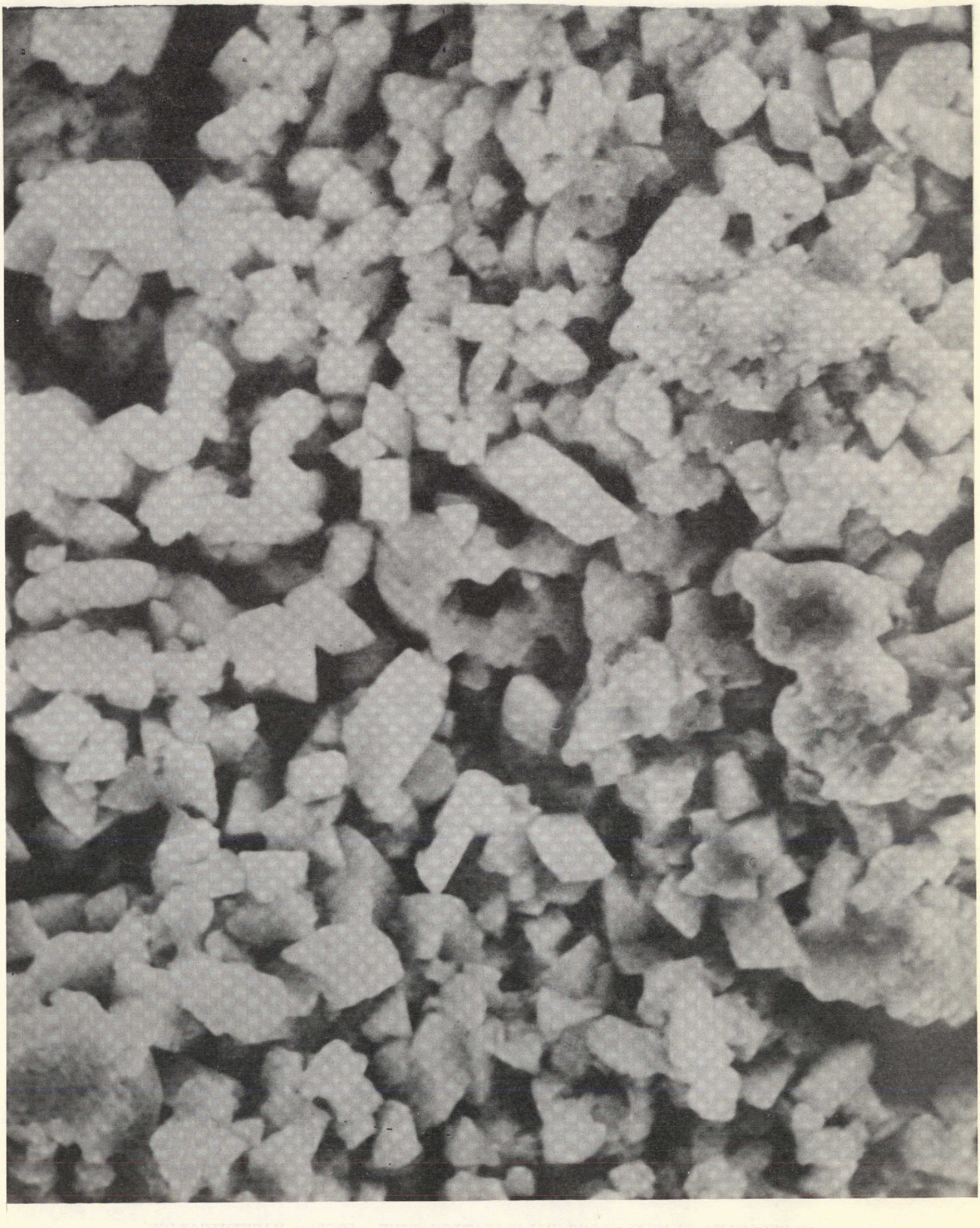
FIGURE 10



POSITIVE PLATE
HIGH NITRATE TEMPERATURE

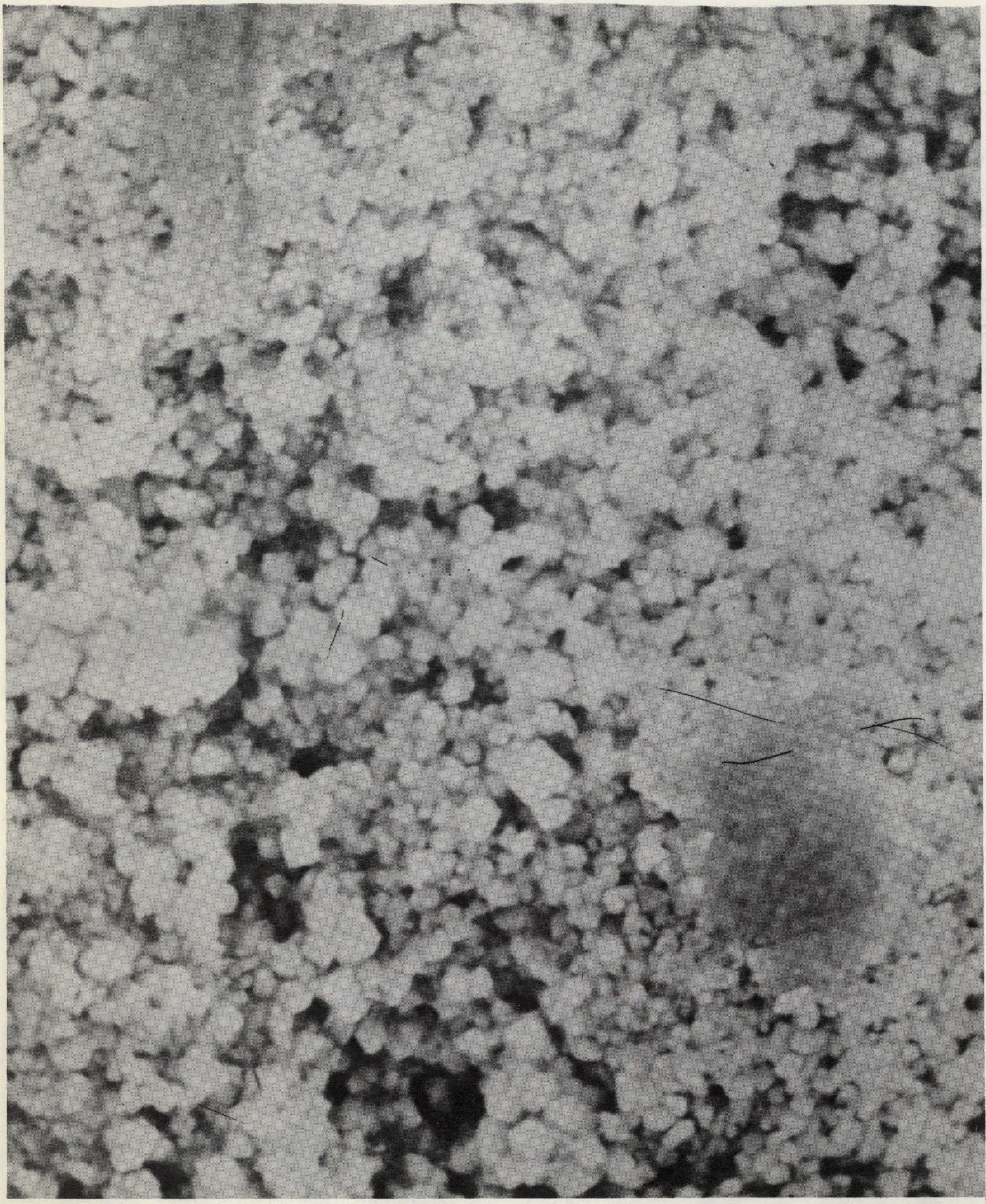
POSITIVE PLATE
LOW NITRATE TEMPERATURE

FIGURE 11



NEGATIVE PLAQUE, SHORT POLARIZATION TIME, 5000 x MAGNIFICATION

FIGURE 12



NEGATIVE PLAQUE, LONG POLARIZATION TIME, 5000 x MAGNIFICATION

FIGURE 13

(60 minutes) polarization time. The electrical capacity (efficiency) per impregnated material for plates produced by longer polarization process time normally exhibits a 10-15% advantage over plates produced by shorter polarization times. This advantage may be attributed to the increased surface area exhibited by the smaller crystalline structure.

The observations again support the regression analysis selection of a desired process variable level. In this case, longer polarization times result in an improvement in Response 2 (plate electrical capacity).

V. FORMATION STUDY

A. Introduction

The formation process is the last stage in the positive and negative electrode manufacturing operation and was selected as the next area of study. Reliance was again placed upon fractional factorial design experiments and regression analysis techniques to design experiments and evaluate the major process variables associated with this manufacturing process. In addition, the electrochemical cleaning effect of the process and the final plaque washing procedure were evaluated.

Information presented in this section has not previously been published in the Quarterly Reports associated with the program and will be covered in greater detail.

B. Background

After the impregnated plaques complete the impregnation/polarization process (the former to deposit the respective nickel and cadmium salts within the sintered plaques and the latter to precipitate the electrically active hydroxide forms of the material), the plaques are then normally subjected to a formation procedure. The formation process primarily functions as an electrochemical cleaning procedure. The impregnated plaques, normally in a group, are subjected to a specified amount of overcharge in a fresh KOH caustic solution; the subsequent evolution of gas results in a cleaning effect on the plaque surfaces and pores. The plaques are finally subjected to a very thorough deionized water wash procedure.

C. General Experimental Approach

The basic equipment used in the study is the same scaled down production equipment utilized in the impregnation/polarization study phase of the subject program. Photographs and a description of this equipment are presented in Section III, C., Second Quarterly Report (2).

The experimental approach for the formation process study proceeded in the following four phases:

1. A fractional factorial design experiment was formulated to study the selected process variables. The formation process variables selected for study and their levels are as follows:
    a. Percent Charge - The levels selected are 110 and 200 percent charge (this corresponds to a 10 percent and a 100 percent overcharge of test plaques). In all phases of this work, the assumed capacity of both plaques and individual plates is based upon total grams of active material impregnated utilizing an efficiency factor of 90% of theoretical for the positive material and 60% of theoretical for negative material.
    b. Specific Gravity - The levels of specific gravity (concentration) of the KOH solution were set at 1.20 and 1.40.
    c. Formation Time - The levels of time selected for the introduction of the required percent charge (or amount of over-charge) are 4 and 24 hours.

All experiments were performed at room temperature. Table V lists the process variable levels and responses to be measured.

Three (3) responses were selected for measurement in this phase of the subject effort to characterize the formation process.

a. Grams Active Material - This is simply a measure of the amount of active material remaining in the plaques after completion of a formation experiment. The data is obtained by subtracting the initial unimpregnated sintered plaque weight from the final formed impregnated plaque weight.

b. Plate Capacity - One plate was randomly selected from each plaque in an experiment and its electrical capacity determined in a flooded condition against sheet nickel counter electrodes. A photograph of the equipment set-up and the operating procedure is presented in Section V., Third Quarterly Report (3). Basically, the procedure consists of charging a single plate, immersed in an electrolyte solution between two counter electrodes, at a C/3 rate for four (4) hours and then discharging at a C/2 rate to a specified potential at which the useful active material contained in the plate is assumed exhausted.

c. Efficiency - This measurement is a direct function of the previous two measurements, but expresses the data in another form. The value is the ampere-hour capacity per gram of active material or the practical efficiency of the impregnated active material.

FORMATION PROCESS STUDY

DESIGN EXPERIMENT

FACTORIAL VARIABLES (X VALUES)	LEVEL 0	LEVEL 1
1. Percent Charge	110	200
2. Specific Gravity	1.20	1.40
3. Formation Time (Hours)	4	24

RESPONSES

(Y VALUES)

1. Final Pick-Up Weight (Finished weight - starting weight)
2. Electrical Capacity (C/2 Rate discharge capacity of plate samples)
3. Plaque Characterization (Strength and physical appearance)

TABLE V

2. The second phase of the experimental approach consisted of a general physical characteriaation of the plaques resulting from the above experiments. Of concern in this effort, were plaque surface appearance, color, strength, etc.
3. In an attempt to evaluate the degree of cleaning effected by the various formation experiments, samples of the resulting plaques were subjected to a chemical analytical procedure. A semi-quantitative spectrographic analysis procedure was selected as this instrument was readily available and lent itself to the performance of a large number of experiments. It was believed the detection of various elements in different concentration and their subsequent reduction in the formation process would render comparative formation experiment data.
4. The last experimental approach involved a study of the final plaque washing procedure. Adequacy of the washing process is normally ascertained by a measurement of the pH of the wash water (a pH of 7.0 is the usual target). In this work, several pH indicating materials were evaluated, relative to their sensitivity in this function. With the selection of an optimum indicator, the time dependent relationship of washing to residual electrolyte concentration in the wash water was investigated.

D. Positive Formation Experiments

1. Sample Preparation - In order to produce a uniform group of impregnated positive plaques from which to select samples for the various formation experiments, a sufficient number of plaques were impregnated and polarized under identical process conditions. The process conditions used corresponds to a selected experiment performed during the previous impregnation/polarization study (positive experiment 5A, see Fourth Quarterly Report(4)). Table VI lists the process variables controlled and their respective values for the subject experiment. The plaques were subjected to four (4) impregnation/polarization cycles and the nominal unformed impregnation level was determined to be approximately 60 grams of active material per plaque. This value was used for determination of the various formation current levels.
2. Experiments - A sample of three (3) impregnated plaques were utilized in each formation experiment. Table VII summarizes the results of performance of four (4) positive plaque formation experiments. The positive plaque samples were characterized physically in the discharged state.

POSITIVE EXPERIMENT NUMBER 5A

	VARIABLE	LEVEL
1.	Specific Gravity of Nitrate	1.70
2.	Free Acid (Controlled By Addition of HNO_3)	1.0 gms/liter
3.	Temperature of Nitrate (In I/P Tank)	200°F
4.	Time of Impregnation	1 Hour
5.	Vacuum	0 Inches
6.	Wash Time	10 Minutes
7.	Wash (Number of Cycles)	3 Cycles
8.	Wash Water Temperature	Room Temperature
9.	Type of Caustic	NaOH
10.	Specific Gravity of Caustic	1.30
11.	Temperature of Caustic (In I/P Tank)	150°F
12.	Polarization Current	0.4 $amps/in^2$
13.	Polarization Time	1 Hour
14.	Amount of Cycles with Same Caustic	4 Cycles
15.	Number of Total Cycles	4 Cycles
16.	Type of Plaque	Lot 151

TABLE VI

TABLE NUMBER VII

POSITIVE FORMATION EXPERIMENTS

	PROCESS VARIABLES				RESPONSES				
EXPERIMENT	PERCENT CHARGE	CAUSTIC SP.GR.	PROCESS TIME (HRS)	CURRENT AMPS/IN^2	PLAQUE	GRAMS ACTIVE MATERIAL	PLATE CAPACITY AMP/HRS.	EFFICIENCY A-H/GRAM	PHYSICAL APPEARANCE
1	200	1.20	24	0.014	1	67.8	3.10	0.244	Uniform black color, no evidence of blistering or flaking material.
					2	59.6	2.41	0.215	
					3	57.2	2.55	0.238	
2	110	1.20	4	0.044	1	56.7	2.40	0.261	Uniform black color, no evidence of blistering or flaking material.
					2	63.2	3.00	0.272	
					3	61.5	3.00	0.277	
3	110	1.40	24	0.008	1	59.6	2.47	0.250	Scattered greenish areas mixed with normal black color; no blistering or flaking material.
					2	60.3	2.47	0.250	
					3	60.7	2.55	0.252	
4	200	1.40	4	0.078	Severe blistering and flaking of material resulted in the loss of the plaques in this experiment.				

E. Negative Formation Experiments

1. Sample Preparation - As was done with the positive plaques, to produce a uniform group of impregnated negative plaques from which to select samples, a sufficient number of plaques were impregnated and polarized under identical process conditions. The process conditions used again corresponded to a selected experiment performed during the previous impregnation/polarization study (negative experiment 3, see Fourth Quarterly Report(4)). Table VIII lists process variables controlled and their respective values for the subject experiment. The plaques were subjected to three (3) impregnation/polarization cycles and the nominal unformed impregnation level was again determined to be approximately 60 grams of active material per plaque.

2. Experiments - In this second half of the formation process study, three (3) impregnated plaques were also used in each formation experiment. Table IX summarizes the results of performance of four (4) negative plaque formation experiments. The negative plaques were physically characterized in the discharged state.

NEGATIVE EXPERIMENT NUMBER 3

	VARIABLE	LEVEL
1.	Specific Gravity of Nitrate	1.80
2.	Free Acid (Controlled By Addition of HNO_3)	0.5 gms/liter
3.	Temperature of Nitrate (In I/P Tank)	140°F
4.	Time of Impregnation	1 Hour
5.	Vacuum	0 Inches
6.	Wash Time	10 Minutes
7.	Wash (Number of Cycles)	3 Cycles
8.	Wash Water Temperature	Room Temperature
9.	Type of Caustic	NaOH
10.	Specific Gravity of Caustic	1.30
11.	Temperature of Caustic (In I/P Tank)	80°F
12.	Polarization Current	0.4 amps/in^2
13.	Polarization Time	1 Hour
14.	Amount of Cycles with Same Caustic	3 Cycles
15.	Number of Total Cycles	3 Cycles
16.	Type of Plaque	Lot 151

TABLE VIII

TABLE NUMBER IX

NEGATIVE FORMATION EXPERIMENTS

	PROCESS VARIABLES				RESPONSES				
EXPERIMENT	PERCENT CHARGE	CAUSTIC SP.GR.	PROCESS TIME (HRS)	CURRENT AMPS/IN^2	PLAQUE	GRAMS ACTIVE MATERIAL	PLATE CAPACITY AMP/HRS.	EFFICIENCY A-H/GRAM	PHYSICAL APPEARANCE
1	200	1.20	24	0.014	1	70.2	3.23	0.256	Light gray or whitish color, no evidence of blistering or flaking material.
					2	70.5	3.18	0.243	
					3	69.0	3.31	0.262	
2	110	1.40	24	0.008	1	62.7	2.76	0.251	Very light whitish color, rough surface, no blistering or flaking material
					2	58.9	2.90	0.268	
					3	61.1	2.92	0.278	
3	110	1.20	4	0.004	1	68.7	2.67	0.226	Uniform gray, no evidence of blistering or flaking material.
					2	71.8	3.12	0.232	
					3	72.4	2.95	0.236	
4	200	1.40	4	0.078	1	54.3	2.30	0.247	Patchy light and dark gray areas. No evidence of blistering or flaking material.
					2	52.0	2.17	0.255	
					3	50.0	2.25	0.230	

F. Results of Positive and Negative Formation Experiments

As in previous studies, the data resulting from performance of the design experiments was subjected to a regression analysis to determine the main effects of the selected process variables. Using interpretive procedures similar to those previously described, the results of the analysis were evaluated with respect to producing desired response values. The following preselected response values or preferences were selected for this study:

1. Parameter values which minimize the loss of active material during formation are preferred.
2. Parameter values which maximized electrical capacity (efficiency) of resulting electrodes are preferred.
3. Parameter values which maximize plaque physical characteristics (see impregnation/polarization discussion) are preferred.

The major results of the regression analysis are summarized in Table X.

G. Electrochemical Cleaning Effect

1. To obtain a measure of the cleaning effect of the various formation experiments, samples removed from the resulting plaques were subjected to a semi-quantitative spectrographic analysis. Table XI presents the results of this effort.

   The letter A associated with the plaque number designates the spectrographic sample was removed from the raw sintered plaque before impregnation/polarization. The letter B designates the sample was removed after impregnation,

FORMATION PROCESS STUDY

CONCLUSIONS

1. High percent charge (200) introduced over short period of time (4 hours) is preferred with respect to electrical capacity in the positive process; however, the potentially destructive effect upon final pick-up weight and plaque characterization limits this procedure and requires strict control.

2. Low percent charge (110) introduced over a longer period of time (24 hours) is preferred with respect to electrical capacity in the negative process; in this case, plaque characterization or electrochemical cleaning effect is the limiting factor.

3. No significant effect could be attributed to specific gravity of caustic.

TABLE X

TABLE NUMBER XI

POSITIVE PLAQUE SEMI-QUANTITATIVE SPECTROGRAPHIC ANALYSIS (%)

EXPERIMENT	PLAQUE	Fe	Mg	Si	Cu	Al	Ti	Co	Ca	Cr	Mn	Cd
1	1A	0.002	0.001	0.003	0.0003	0.001	ND	0.0005	0.002	ND	0.0001	ND
	1B	0.010	0.010	0.500	0.003	0.001	0.006	2-3	0.040	0.030	0.0002	ND
	1C	0.010	0.003	0.040	0.003	0.002	0.006	2-3	0.010	0.002	0.0002	ND
	2A	0.002	0.001	0.003	0.0005	0.001	ND	0.0005	0.010	ND	0.0001	ND
	2B	0.010	0.004	0.001	0.002	0.003	0.006	2-3	0.010	0.030	0.0002	ND
	2C	0.010	0.001	0.020	0.002	0.003	0.006	2-3	0.010	0.002	0.0002	ND
	3A	0.002	0.001	0.001	0.0005	0.003	ND	0.0005	0.010	ND	0.0001	ND
	3B	0.010	0.004	0.001	0.002	0.001	0.006	2-3	0.010	0.030	0.0002	ND
	3C	0.010	0.004	0.040	0.002	0.003	0.006	2-3	0.010	0.002	0.0002	ND
2	1C	0.005	0.005	0.020	0.002	0.002	0.006	2-3	0.010	0.002	0.0002	ND
	2C	0.002	0.003	0.020	0.002	0.002	0.006	2-3	0.010	0.0005	0.0001	ND
	3C	0.005	0.004	0.020	0.002	0.002	0.006	2-3	0.010	0.0005	0.0002	ND
3	1C	0.010	0.005	0.001	0.002	0.002	0.006	2-3	0.030	0.002	0.0002	ND
	2C	0.010	0.005	0.001	0.002	0.003	0.006	2-3	0.030	0.002	0.0002	ND
	3C	0.010	0.005	0.003	0.002	0.003	0.006	2-3	0.030	0.002	0.0002	ND

but before formation. The letter C designates the sample was removed after the completion of the formation experiment.

Observing the spectrographic data, it is difficult to detect any significant trends (contaminate reduction) associated with the various formation experiments. It appears this particular analytical technique is of little value for evaluating the cleanliness of the positive plaques resulting from the formation experiments.

2. To obtain a measure of the cleaning effect of the various negative formation experiments, samples were again removed from the resulting plaques and subjected to a semi-quantitative spectrographic analysis. Table XII presents the results of the effort for the negative formation experiments plaques. Again, the letters A, B, and C designate where samples were removed from the process.

   Observing the spectrographic data, it is again difficult to detect any significant trends (contaminate reduction) associated with the various formation experiments. As was evident in the positive formation phase of this work, this particular analytical technique is of little value in evaluating the cleanliness of the negative plaques resulting from the formation experiments.

TABLE NUMBER XII

NEGATIVE PLAQUE SEMI-QUANTITATIVE SPECTROGRAPHIC ANALYSIS (%)

EXPERIMENT	PLAQUE	Fe	Mg	Si	Cu	Al	Ti	Co	Ca	Cr	Mn	Cd
1	1B	0.010	0.060	0.003	0.003	0.002	ND	0.001	0.007	0.002	0.0002	10-20
	1C	0.010	0.060	0.500	0.003	0.002	ND	0.001	0.010	0.010	0.0002	10-20
	2B	0.010	0.060	0.003	0.003	0.002	ND	0.001	0.010	0.004	0.0002	10-20
	2C	0.010	0.060	0.300	0.002	0.002	ND	0.001	0.010	0.004	0.0002	10-20
	3B	0.010	0.080	0.003	0.003	0.003	ND	0.001	0.002	0.004	0.0002	10-20
	3C	0.010	0.080	0.300	0.003	0.003	ND	0.001	0.030	0.004	0.0002	10-20
2	1B	0.020	0.080	0.010	0.003	0.003	ND	0.001	0.005	0.010	0.0002	10-20
	1C	0.020	0.080	0.100	0.003	0.003	ND	0.001	0.040	0.010	0.0002	10-20
	2B	0.020	0.080	0.020	0.003	0.003	ND	0.001	0.003	0.007	0.0002	10-20
	2C	0.020	0.080	0.100	0.003	0.003	ND	0.001	0.010	0.010	0.0002	10-20
	3B	0.020	0.080	0.010	0.003	0.003	ND	0.001	0.003	0.0005	0.0001	10-20
	3C	0.020	0.080	0.100	0.003	0.003	ND	0.001	0.010	0.010	0.0001	10-20
3	1B	0.010	0.080	0.003	0.003	0.003	ND	0.001	0.002	0.004	0.0007	10-20
	1C	0.010	0.080	0.005	0.003	0.003	ND	0.001	0.030	0.004	0.0002	10-20
	2B	0.010	0.080	0.003	0.003	0.003	ND	0.001	0.002	0.004	0.0002	10-20
	2C	0.010	0.080	0.005	0.003	0.003	ND	0.001	0.030	0.010	0.0002	10-20
	3B	0.010	0.080	0.003	0.003	0.003	ND	0.001	0.003	0.002	0.0002	10-20
	3C	0.010	0.080	0.005	0.003	0.003	ND	0.001	0.020	0.002	0.0002	10-20
4	1B	0.010	0.080	0.100	0.003	0.003	ND	0.001	0.002	0.030	0.0005	10-20
	1C	0.010	0.080	0.100	0.003	0.003	ND	0.001	0.020	0.030	0.0005	10-20
	2B	0.020	0.080	0.100	0.003	0.003	ND	0.001	0.007	0.010	0.0002	10-20
	2C	0.020	0.080	0.050	0.003	0.003	ND	0.001	0.030	0.010	0.0002	10-20
	3B	0.020	0.080	0.100	0.003	0.003	ND	0.001	0.007	0.010	0.0005	10-20
	3C	0.020	0.080	0.050	0.003	0.003	ND	0.001	0.030	0.010	0.0005	10-20

H. Formed Plaque Washing Study

1. Indicator Evaluation - Normally to determine the adequacy of the washing procedure, the pH of the wash water is periodically measured. If the pH value can be lowered to approximately 7.0 (neutral), it is assumed the basic electrolyte solution used in the previous formation process has been removed from the plaques.

   It is common to effect this measurement with "pH paper" possessing the desired pH transitional range (normally pH range 7.0 - 9.0). Both this type of indicator plus a liquid indicator of approximately the same pH transitional range (phenolphthalein, pH range 8.0 - 10.0) were used in the preceding formation experiments to evaluate the adequacy of wash.

   After the first test of the two indicators, it was readily apparent the liquid indicator was far more sensitive than "pH paper". After washing plaques for a period of 4 - 6 hours, the pH paper used gave a negative indication (indication pH of solution has been lowered past indicator range); it required approximately 20 more hours of washing of the same plaques to obtain a negative indication with the liquid indicator. In addition, the sensitivity of the "pH paper" appeared to be function of its physical condition (age, exposure to the atmosphere, etc). It was decided to use phenolphthalein indicator in all further work.

2. Quantitative Wash Study - The following experiment was devised to quantitatively measure the reduction in caustic content of impregnated plaques with respect to the degree of wash (length of time). The wash operation selected for investigation is the wash cycles following the formation process. This particular operation is important for, at this point, the finished impregnated sintered plaques are dried and stored exposed to the atmosphere until ready for use in cells. If residual caustic remains, it rapidly absorbs carbon dioxide from the atmosphere with the production of the corresponding carbonate.

$$CO_2 + 2\ OH \rightarrow CO_3 + H_2O$$

Carbonate has been reported to exhibit a deleterious effect when present in sealed nickel-cadmium cells (6).

The final plaque washing operation associated with Negative Formation Design Experiment No. 3 and 4 (see Section V, E, this report) was used in this investigation. After completion of the formation process, the plaques normally remain in the formation tank. Deionized water is then introduced and allowed to over-flow continuously (flow rate 0.1 gpm) until washing is complete.

During the above washing operations, samples for analysis were collected on an hourly basis by the "last drippings method" from a randomly selected plaque. In this procedure, a plaque is removed from the wash and held at an angle which results in one corner of the plaque being the lowest point. The wash water run off is allowed to continue until it has been reduced to a slow drip. A 2 ml sample is then collected in a pharmaceutical 15 ml graduate. One drop of phenolphthalein indicated (pH range 8.0 - 10.0) is added to the collected sample. A quantitative determination of the caustic content of the sample is then conducted by means of a neutralization tritration method. The 2 ml sample is titrated with a 0.01N HCl standard solution. The accepted end point is determined by the last drop of standard solution required to change the red colored sample solution to the colorless state.

The results of the analysis are calculated in normality and are represented graphically in Figure No. 14.

In observing the graph, it is noticed there is a rapid decrease in the content of the caustic within the first few hours of the wash operation. For example, based on a starting normality of approximately 7.0, there is a 99.98% reduction in the caustic content of the plaque within the first hour of wash. It is further observed that associated with the graph, there is a sharp break in the slope of the curve at approximately four (4) hours of wash. Washing beyond this point resulted in a very gradual reduction in the residual caustic content. It was necessary to continue the wash operation for 24 hours to reach a point where the addition of indicator to a 2 ml sample resulted in no color change. The sample is assumed to have a pH of 8.0 or less under these conditions.

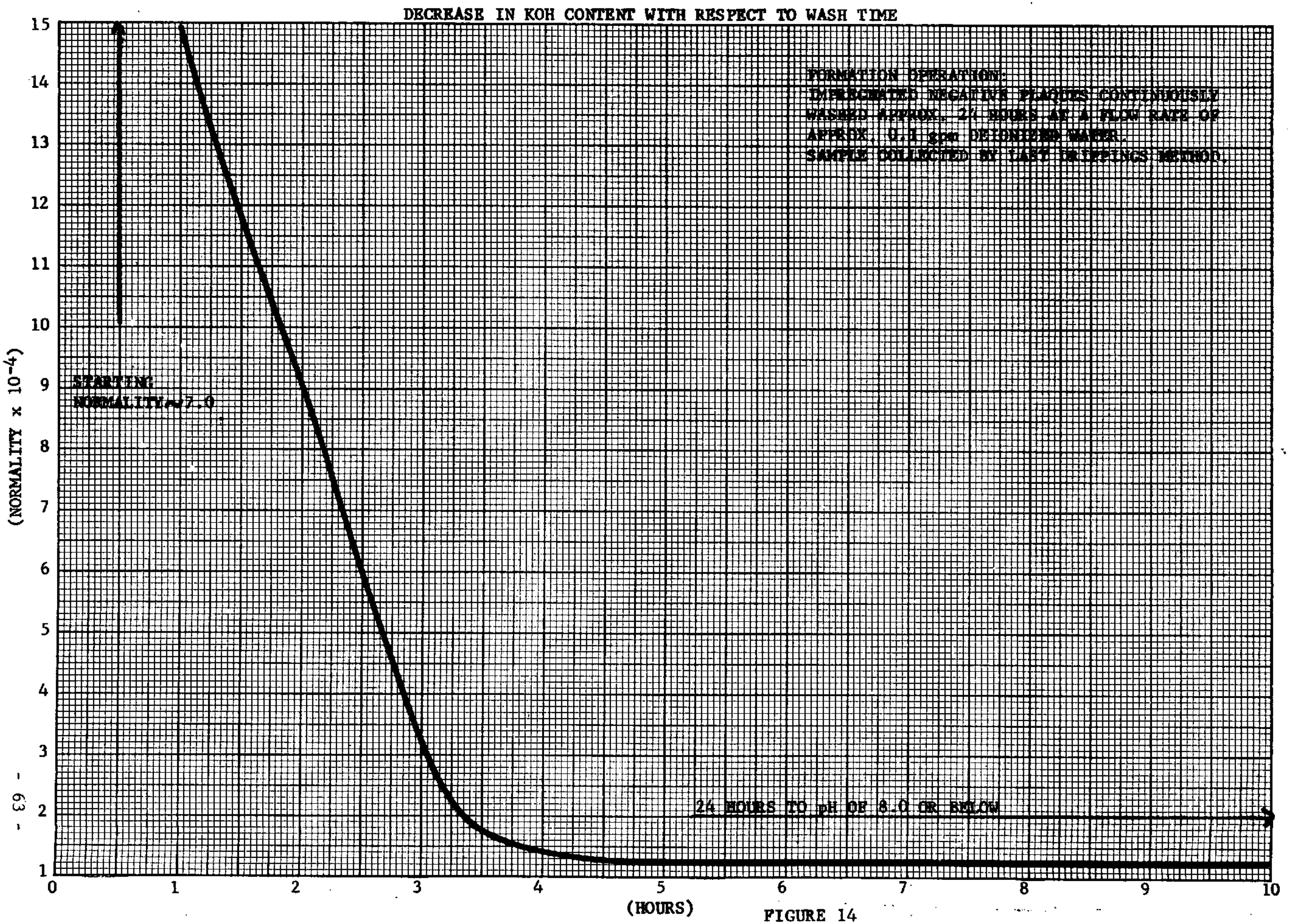

DECREASE IN KOH CONTENT WITH RESPECT TO WASH TIME
FORMATION OPERATION:
IMPREGNATED NEGATIVE PLAQUES CONTINUOUSLY
WASHED APPROX. 24 HOURS AT A FLOW RATE OF
APPROX. 0.1 gpm DEIONIZED WATER.
SAMPLE COLLECTED BY LAST DRIPPINGS METHOD.
STARTING
NORMALITY ≈ 7.0
24 HOURS TO pH OF 8.0 OR BELOW
(NORMALITY x 10^{-4})
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10
(HOURS)

FIGURE 14

It might seem feasible, based upon these experimental results, that since the residual caustic has been tremendously reduced in the first few hours of washing, the extended period of wash to pass the phenolphthalein test would not be necessary. However, there is a question, unanswered by this experiment, as to whether the reduction in pH represents an actual reduction of the caustic content of the plaques or reflects a reduction in the diffusion rate of the caustic from the interstices of the plaque matrix. It is possible a considerably higher volume of caustic is present in the plaques than is indicated by subject analytical procedures, and is only removed by diffusion into the wash water at a very low rate (the very gradual reduction or graphic plateau observed after 4-5 hours of washing in Figure 14 may be evidence of a low diffusion rate equalibrium). It is believed that a conservative approach to the selection of a procedure to evaluate the adequacy of the formation washing process dictates the requirements of passing the phenolphthalein test.

I. Summary of Results

1. In the positive plaque formation (electrochemical cleaning) process, a superior active material electrical efficiency factor and cleaning effect was obtained with a low charge percent (110% of the active material capacity versus 200%) introduced in a short period of time (4 hours versus 24). The improved results are attributed to the cleaning and

activation effect of the higher gas evolution associated with the higher formation current density (0.044 amps/in^2) imposed by the above combination.

2. The improvement in the positive plaque characteristics by use of higher formation current densities is severely limited. A formation current density of 0.078 amps/in^2 (200% charge introduced in a 4 hour period) resulted in the destruction of the positive plaques.
3. There does not appear to be any advantage in the use of more concentrated caustic solutions (1.20 specific gravity KOH versus 1.40 specific gravity) in the positive plaque formation process.
4. With respect to active material efficiency, superior results were obtained in the negative plaque formation process by the use of a lower charge percent (110% versus 200%) introduced over a longer period of time (24 hours versus 4). However, the low formation current density (0.008 amp/in^2) associated with this combination did not appear to effect sufficient plaque cleaning.
5. The use of a higher formation current density (0.044 amp/in^2, combination of 110% charge for 4 hours) resulted in a significant improvement of the cleaning effect of the process. But, as was the case in the positive process, although not to the same extent, there is a somewhat low limit to the current density which may be employed. A formation current density of 0.078 amp/in^2 (200% charge, 4 hours) resulted in a considerable loss of impregnation active material from the negative plaques.

6. The use of a more concentrated caustic solution (1.40 specific gravity KOH versus 1.20 specific gravity) in the negative plaque formation process appears to result in the increased solubility of the active material and a subsequent small loss of the impregnated material in the negative plaques.
7. The use of liquid "phenolphthalein" pH indicator offers a considerably more sensitive test for the evaluation of the adequacy of the positive and negative plaque washing procedure in comparison to the use of "pH paper".
8. A quantitative measurement of the degree of wash (pH reduction of the wash water, "last drippings" method) indicates the bulk of the residual caustic content of the plaques is removed in approximately the first four (4) hours of washing. A long plateau in the reduction curve is then experienced requiring a total wash period of approximately 24 hours to achieve a negative phenolphthalein indication.

VI. SINGLE PLATE PROCESSING FOR IMPROVED PROCESS CONTROL AND TRACEABILITY

A. Introduction

The concept of single plate processing to improve process control and traceability evolved from the previous related manufacturing process studies under the subject program, and was considered for application in an on-going design and development program for a large (100 ampere hour) nickel-cadmium cell. The large plate size used in this design made the single plate processing concept practical.

The concept involved a relatively new and improved process which was not an original part of the Process Variable Study Program Plan.

B. Background

In the normal manufacturing process, a sintered plaque (approximate dimensions 10" x 11" x 0.030") is coined forming a multiple of plates on a single plaque. The coining die is designed so the plate area does not extend to the edge of the plaque. An approximate 0.5" deep strip is left around the plaque to which an electrical connection and a plaque holding fixture is secured for the subsequent processing operation. This strip area is eventually discarded.

After the plaque completes the impregnation/polarizations/formation processes (plaques are processed in large groups), the individual plates are cut from the parent plaque leaving a small (0.030") coined edge around the plate for strength. To make an electrical connection to the individual plates, a small tab area on the plate (introduced during the coining operation) is cleaned of impregnated active material and a nickel lead resistance welded to this cleaned area. The plate assembly is then ready for fabrication into a cell.

C. Single Plate Processing Concept

The single plate processing concept considers a large individual serialized plate rather than multi-plate plaque as the processing entity. This procedure would permit complete traceability and identification of pertinent plate characteristics from sintering furnace to cell assembly.

The final plate is punched from a sintered plaque prior to the impregnation process and a permanent nickel lead resistance weld to the tab area. The ability to perform this resistance weld at this point to a pure nickel surface is an additional advantage of the single plate process. The plate assembly, with its initial weight recorded, is then carried through the impregnation/polarization/formation processes.

Formation of individual plates rather than plaques results in other important advantages for the single plate process system. The charge and discharge cycles associated with this operation permits determination of individual plate electrical capacities. This information would then be recorded and identified with the plate. The finished weight of the plate assembly after completion of the formation process minus the recorded initial weight renders an exact record of the amount of active material contained in each plate.

The single plate processing system then, in addition to producing the normal record of information including processing data, plate thickness, and total plate weight, would produce a record of exact amount of active material and electrical capacity for each plate. It was envisioned this data would eventually be computerized and used for plate selection and matching to produce highly uniform cell plate groups.

Finally, in the planning stage for the above system, it was elected to take the process one step further and introduce small batch processing. This concept included the design of specialized equipment which would accommodate small batches of plates (approximately 100 plates) and minimize the amounts of process solutions required in each operation. The solutions would then be discarded after each cycle eliminating the potential of contamination from reuse (the relatively expensive active material impregnation solution are normally used repeatedly).

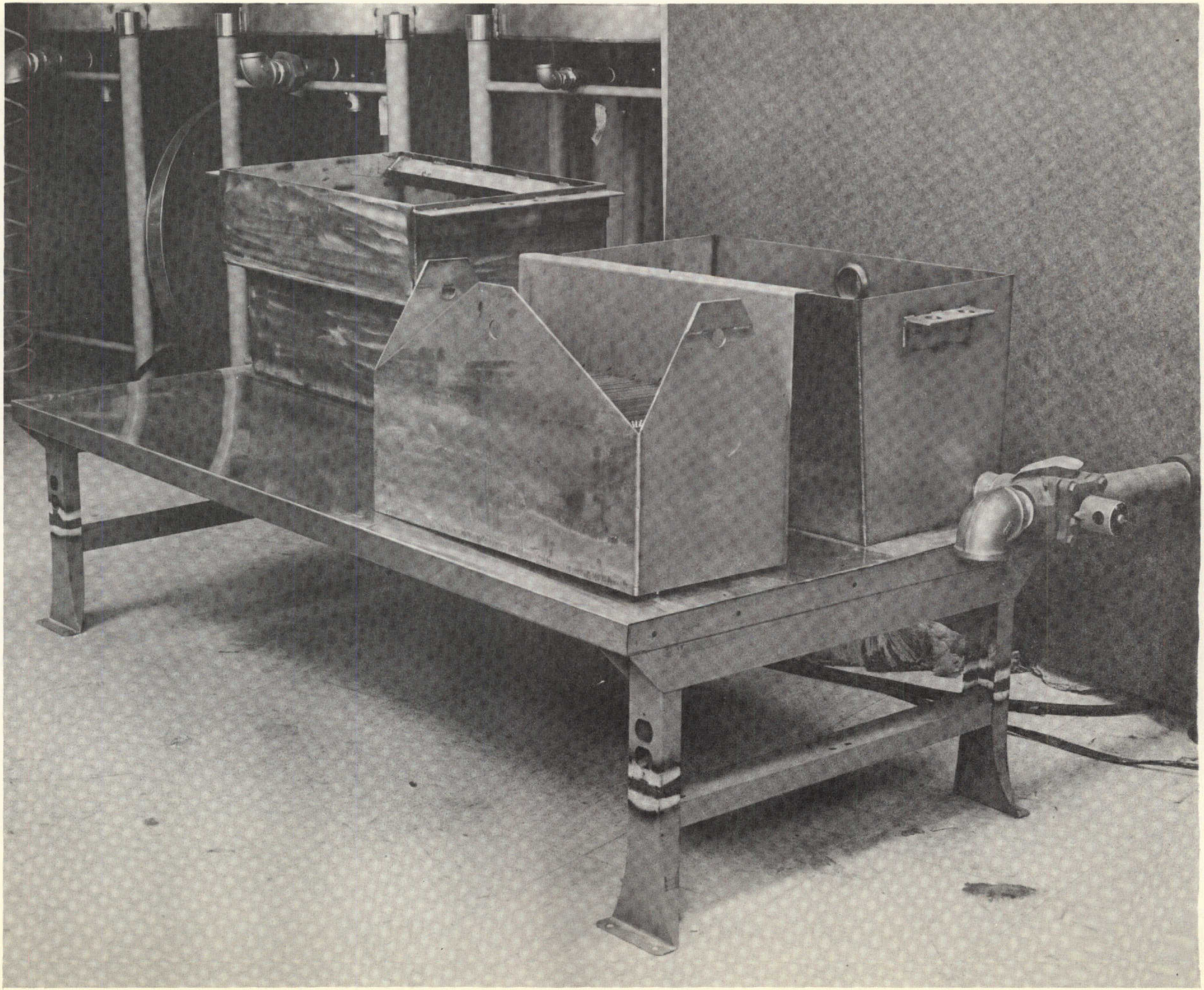
D. Single Plate Processing Equipment

A die was developed that would coin and cut a plate in a two-stage, single operation. The plate produced in this manner was uniformly spaced within the coined edges and was of an exact size so that unit weight comparisons could be made and the plate could be processed with the tab that would stay with it in the cell.

The plate processing equipment was setup with a monorail hoist facilitating intra-tank material transfers for eventual automated operation. The preliminary equipment (shown in Figures 15 and 16) consisted of a vacuum impregnation tank (on table, second tank foreground), polarizing tank (on table, background), formation

SINGLE PLATE PROCESSING SYSTEM

FIGURE 15



SINGLE PLATE PROCESSING TANK

FIGURE 16

and wash tank (not shown), and batch storage tanks (background). A processing rack (on table, first item foreground) designed to provide individual control of each electrode is used to transfer plate groups from tank to tank for processing. The equipment was designed to use a master batch of nitrate for impregnation and master batches of caustic for polarization and formation. All parameters that are controllable would be controlled and identical for all plates in a run. The materials used would not be returned to the storage tank so that the purity and consistency could be maintained. Polarization and formation was to have been performed with a recording monitor on the individually adjustable current and voltage inputs to each plate to improve uniformity and facilitate measurement of electrical capacities.

E. Results of Initial Experiments

Initial trial runs performed to evaluate the system revealed several severe problems. Regardless of the care exercised in handling the individual plates during processing, damage still frequently occurred to plate edges. The advantage of having an unused strip around the plaque (multi-plate process) which is discarded after completion of the process appears to be very important.

Several plate holding fixture designs were evaluated, but a recurring problem could not be resolved. Wherever a fixture touched or gripped a plate, an outline or shadow was left on the finshed product indicating the member interfered with one or more of the manufacturing processes.

Finally, the extensive handling to which the plate assembly is subjected during the various processes resulted in some reservation about the early attachment of the permanent nickel lead. The resistance welded connection could be weakened by the excessive handling and the plate assembly fabricated into a cell without knowledge.

Solutions considered for the above problems incorporated one or more features of the original multi-plate plaque process system and nullified the advantages of the single plate processing concept. A decision was made to discontinue the expenditures of resources and funds for the single plate processing program.

VII. SEPARATOR MATERIAL TEST METHOD STUDY

A. Introduction

Leaving the electrode process phases of the nickel-cadmium manufacturing process, the next area selected for study is concerned with the separator materials used in the fabrication of cells. The specific objective of this area of study was the evaluation of separator material test methods which may be effective in determining the suitability of a material for use in sealed nickel-cadmium cells. To determine the effectiveness of the various test methods, the tests were evaluated with respect to their ability to distinguish the measured parameter and the degree of confidence which may be attached to the results.

Approximately half of the planned effort for this study was completed and published in a Quarterly Report. The remaining unpublished half will be emphasized in the following sections.

B. Background

The first half of the separator study was published in detail in the Fifth Quarterly Report(5). During this phase, the following list of separator materials was compiled from which separator materials were selected for the subsequent test evaluation.

NON-WOVEN NYLON

1. Pellon 2505 ML; (0.013-0.017 thickness) supplied by Pellon Corporation, 221 Goshson Street, Lowell, Massachusetts, 01852.
2. "Lyonel" (unit weight 2 ounces/sq. yard) supplied by Howard Textile Mills, Inc., 65 West 36th Street, New York, New York, 10018.

NON-WOVEN POLYPROPYLENE

1. FT-2140, supplied by Pellon Corporation.
2. WEX-1242, supplied by GAF Corporation, Industrial Products Division, Glenville Station, Greenwich, Connecticut, 06830.
3. "Microweb" Micropolypropylene, supplied by Hercules Incorporated, Fiber and Film Department, Post Office Box 12145, Research Triangle Park, North Carolina, 27709.

WOVEN POLYPROPYLENE

1. "100% Woven Cloth Polypropylene", supplied by Howard Textile Mills, Inc.

Three test methods were evaluated during the first phase of the study.

1. Scanning electron microscopy was used in a detailed visual examination of several separator materials. The technique revealed considerable simularity in structure and filiment size for both the non-woven nylon and polypropylene materials with one exception. The Hercules "microweb" material exhibited an unusually different structure and filiment size (see Figures 18, 19 and 20). A form of contaminate associated with the filiments of the Pellon 2505 ML nylon material was also observed.

   As a separator material test method, scanning electron microscopy would appear to be of limited value. Little difference could be discerned between most of the separator material examined.

2. Infrared spectrometry was utilized in an attempt to identify extractable organic constituents associated with the different separator materials. An extraction performed on the Pellon FT-2140 material using carbon tetrachloride as the solvent produced an absorption band identifying an organic constituent similar to a fatty acid such as soybean oil or linseed oil. Methanol extractions performed on this and several other separator material did not produce an identifiable absorption band.

   This test method was further evaluated during the following second half of the separator material study and comment will be reserved until that section.

3. Classical wet chemical analyses and emission spectrometry methods were used in attempt to identify both qualitatively and quantitatively inorganic impurities associated with the various separator materials. The results of the analyses performed indicated a rather high Zn and Ti impurity level (1000 and 500 ppm respectively) associated with the Pellon 2505 ML material and a high Ti impurity level (500 ppm) associated with Howard Textile Mills "100% Woven Cloth Polypropylene".

   Additional use of these test methods is also made in the following second half of the study and comment will again be reserved until that section.

In addition to the above test method evaluation, consideration was given to the gas permeability of the various separator materials. For adequate recombination of oxygen gas in the sealed nickel-cadmium overcharge operational mode, the gas permeability of the separator material is believed to be an important attribute. To evaluate this test method, the instrument presented in Figure 17 was purchased.

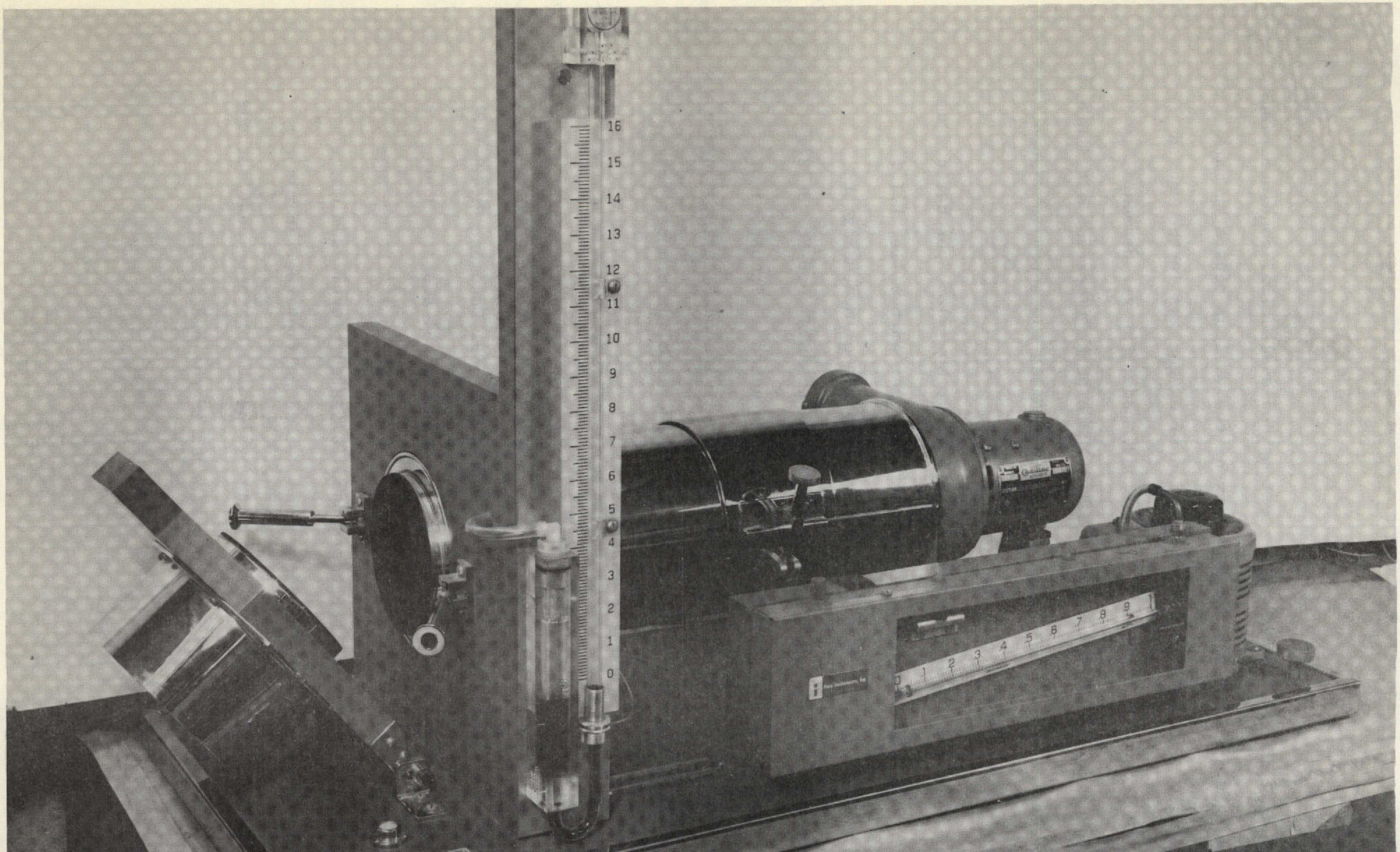
The instrument is an Air Flow Tester, No. 9025, purchased from Testing Machines, Inc., 400 Bayview Avenue, Amityville, L.I., New York, 11701. The instrument is capable of measuring the permeability of fabrics in accordance with ASTM Test No. D-737. Delay in receipt of this instrument prevented a discussion of evaluation in this report; however, it is intended to incorporate the instrument into our normal quality control procedures for acceptance of separator materials.

C. Separator Material Test Methods

The Third Quarterly Report (3) under the subject program contained a separator material specification (EPI Document EP-MS-118) which defined a number of physical and chemical tests methods suggested by NASA/GSFC Specification S-716-P-23 (7) to be conducted on separator materials used in sealed nickel-cadmium cells for spacecraft applications. The second half of the separator material study was consumed in an evaluation of these test methods.

The following test were performed in the order listed:

1. Unit Weight Determination
2. Thickness Variation



AIR FLOW TESTER NO. 9025
FIGURE 17

3. Tensile Strength
4. Wetting Agent Determination
5. Wettability (Wicking Rate)
6. Electrolyte Retention and Absorbency
7. Electrical Resistance
8. Extractable Organic Content
9. Organic Analysis (Infrared Spectrometry)
10. Inorganic Analysis (Emission Spectrometry)

In the evaluation of the above test methods, the original lists of separator materials was reduced to three. The new list included Pellon 2505 ML, Lyonel, and Microweb. At least two of these materials were selected in the evaluation of each test method.

D. Test Procedures and Results

1. Unit Weight Determination

a. Procedure: Cut Samples 10 cm x 10 cm such that no feathered edges are included. Weigh each sample to the nearest tenth of a milligram. Compute weight for one square meter.

b. Results:

1. Lyonel

Sample 1	0.6722 gm
Sample 2	0.7774 gm
Sample 3	0.6630 gm
	Mean gm/m^2 69.4

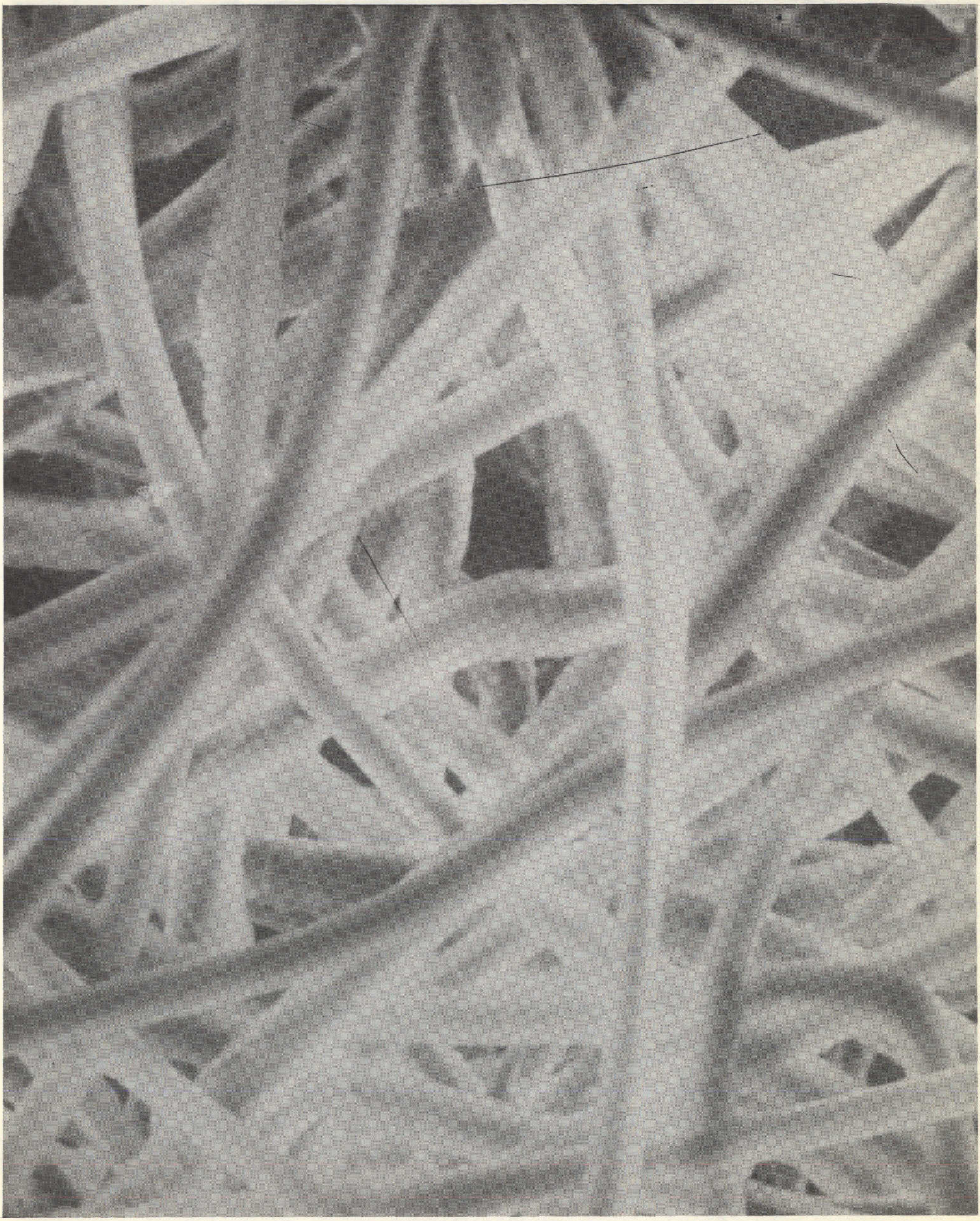
2. Pellon 2505 ML

Sample 1	0.06505 gm
Sample 2	0.06509 gm
Sample 3	0.06492 gm
	Mean gm/m^2 64.2

c. Discussion: In spite of the similarity in unit weight, the materials are quite different in appearance. The fibers of Lyonel are more coarse and "swirled" in orientation. Individual filaments are visible to the unaided eye. Fibers of Pellon 2505 ML appear smaller and are apparently more randomly oriented. Figures 18, 19 and 20 present scanning electron photomicrographs of the three separator materials contained in the reduced list (note also difference between Microweb and the two materials discussed above).

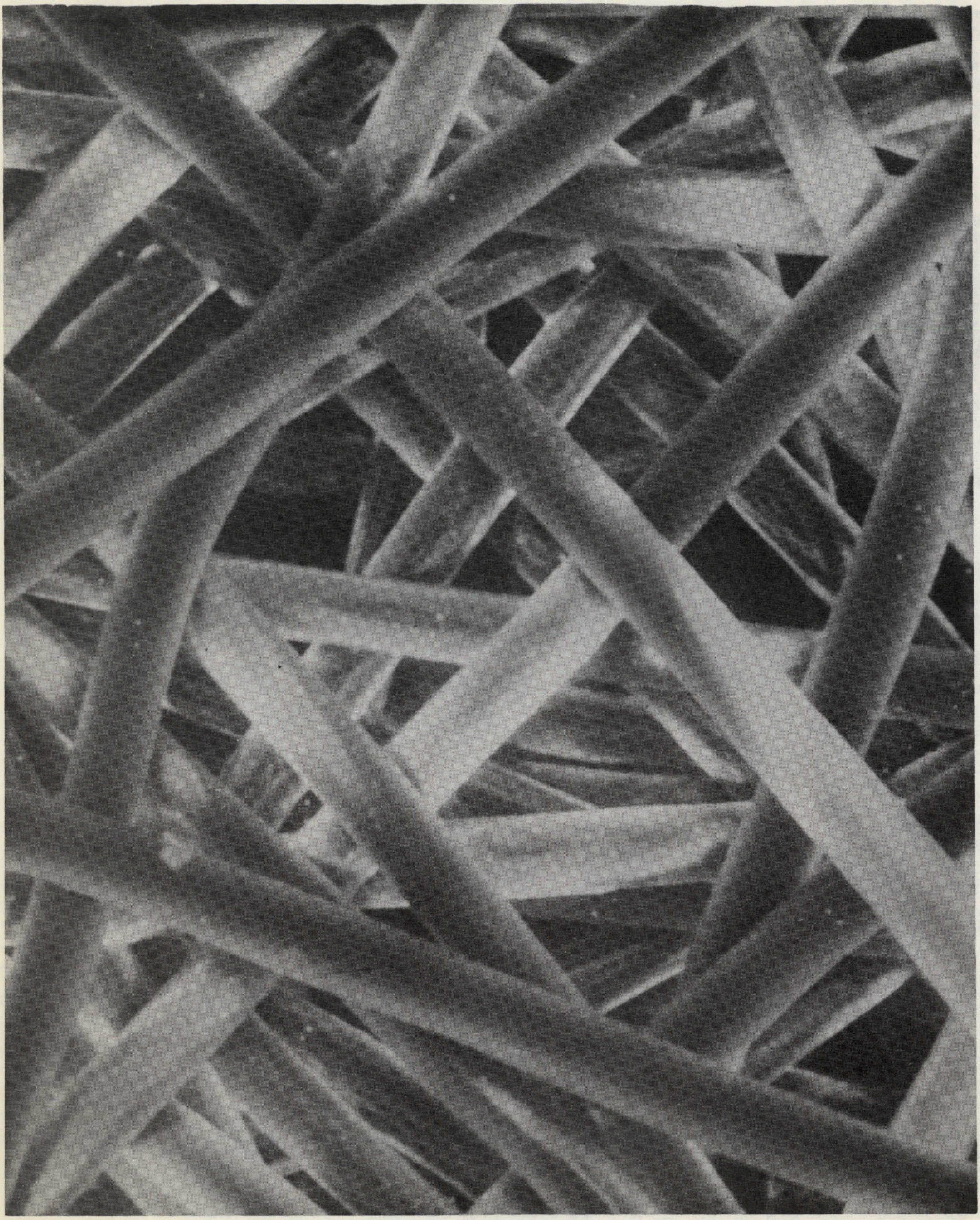
2. Thickness Variation

a. Procedure: Determine thickness at one (1) inch intervals along the roll direction for a total of ten (10) determinations, using an Ames Model 262 Dial Micrometer.



PELLON 2505 ML 750 X MAGNIFICATION

FIGURE 18



LYONEL 750 X MAGNIFICATION

FIGURE 19

MICROWEB 625 X MAGNIFICATION

FIGURE 20

b. Results:

THICKNESS VARIATION

	Pellon 2505 ML	Lyonel
1.	0.018 inch	0.012 inch
2.	0.018	0.011
3.	0.018	0.011
4.	0.017	0.012
5.	0.018	0.012
6.	0.018	0.011
7.	0.018	0.013
8.	0.018	0.012
9.	0.019	0.012
10.	0.019	0.012

Test Instrument: Ames Model 262 Dial Micrometer

c. Discussion: The values exhibited for Pellon 2505 ML are greater than the usual values of .013"-.017". Thickness of both materials was found to be consistent in the range of values presented.

3. Tensile Strength

a. Procedure: Cut test specimens 12.7 x 2.5 cm. Clamp specimen in tensile tester with an initial grip separation of three (3) inches. Apply load at constant rate of travel of three (3) in/minute. At break record load (lbs), grip separation (L_2), and sample thickness (T_2).

b. Results:

Sample No.	L_2(in)	T_2(in)	Load(lbs)	Tensile Strength PSI	Percent Elongation
1. Lyonel					
1	3.81	0.008	22.0	2750	27.0
2	4.87	0.010	26.0	2600	59.7
3	4.50	0.011	25.0	2270	50.0
4	4.37	0.010	23.0	2300	45.7
5	4.37	0.012	22.5	1875	45.7
2. Microweb					
1	4.00	0.0072	0.25	34.7	33.0
2	4.56	0.0083	0.25	30.1	52.0
3	4.16	0.009	0.50	55.6	38.7
4	3.97	0.010	0.25	25.0	32.3
5	3.84	0.009	0.50	55.6	28.0
6	3.91	0.008	0.50	62.5	30.3
3. Pellon 2505 ML					
1	4.37	0.011	9.00	813	12.3
2	4.94	0.009	7.75	861	31.3
3	4.28	0.009	8.75	923	8.8
4	4.41	0.009	9.25	1021	13.7
5	4.37	0.009	9.25	1021	12.3
6	4.44	0.009	8.75	923	14.7

4. Wetting Agent Determination

   a. Procedure: Place a standard sized sample of material in a pint glass jar. Fill the jar approximately one-half full with 1.30 specific gravity electrolyte. Seal the container and agitate. Allow jar to set for one (1) minute and examine for foam. Foam indicates the presence of wetting agent.

   b. Results and Discussion: Pellon 2505 ML, Lyonel, and Microweb displayed negative results. This test is for wetting agents as such and will not reveal the presence of several of the organic contaminants found in some separator materials.

5. Wettability (Wicking Rate)

   a. Procedure: Cut Samples 12.7 x 2.5 cm. Clamp specimen such that lower one inch immersed in 1.30 specific gravity electrolyte. Record electrolyte travel rate and plot to suitable scale on graph paper.

   b. Results: Figure No. 21 presents test data for Lyonel and Pellon 2505 ML. The wicking rate of Lyonel is minimal as compared to Pellon 2505 ML. This suggests that a much greater soak time would be required for a cell employing this separator. This subjective test does indicate gross differences in wettability of materials. It is noteworthy that it is now routine to require a minimum soak of 16 hours prior to any electrical testing of spacecraft cells.

6. Electrolyte Retention and Absorbency

a. Procedure: Cut test specimens 6.5 cm x 2.5 cm and weigh each to the nearest tenth of a milligram. Allow to soak for three (3) hours in a sealed pint glass jar. Remove sample and hold vertically, allowing a one-minute "drip off" period; determine and record total weight. Calculate percent retention or absorbency.

b. Results:

1. Lyonel

Sample 1		Sample 2	
Wet Weight	3.4625	Wet Weight	3.5765
Dry Weight	0.7274	Dry Weight	0.7201
KOH	2.7351		2.7564
Retention	379%		382%

2. Pellon 2505 ML

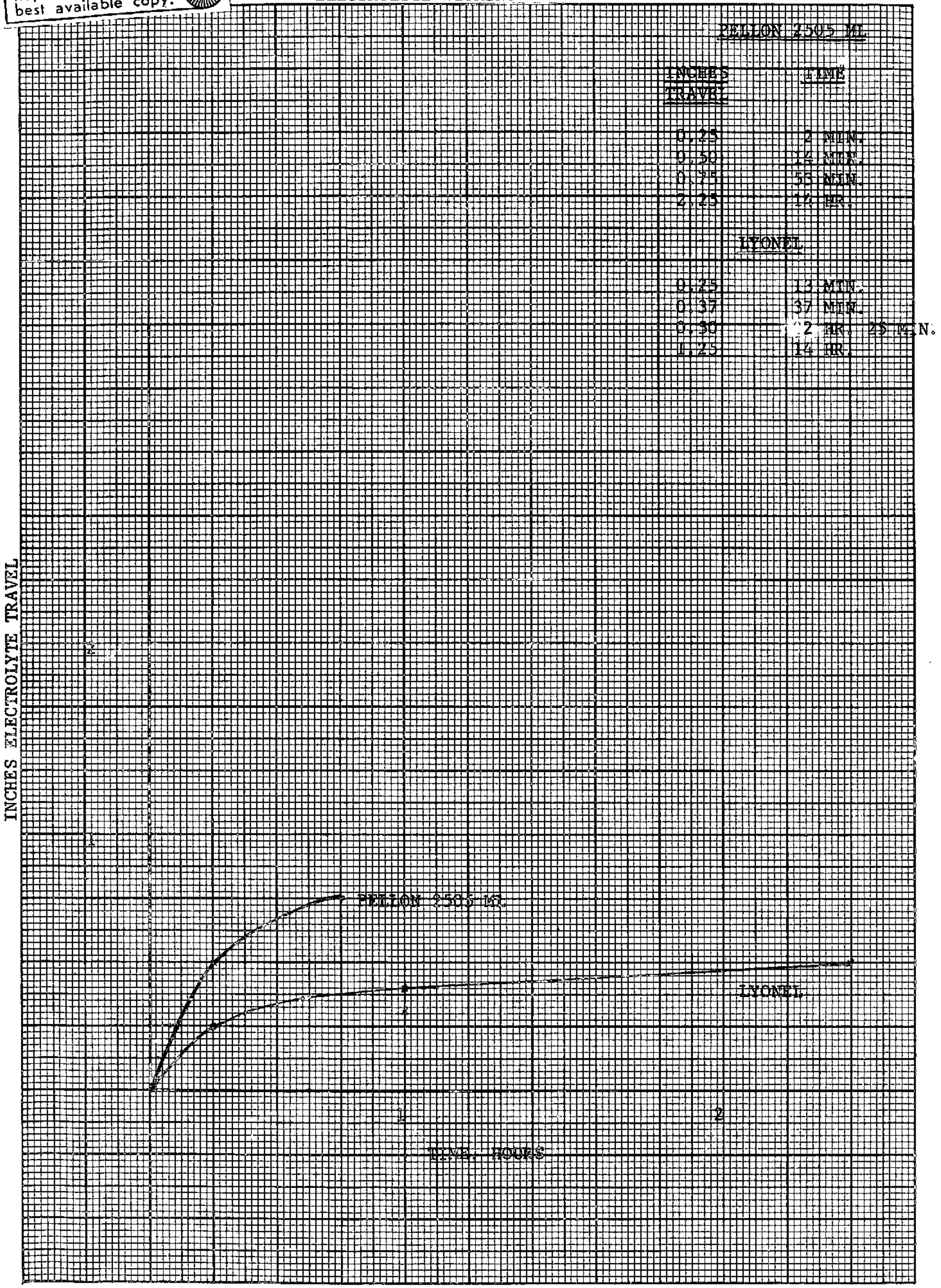
Sample 1		Sample 2	
Wet Weight	6.2726	Wet Weight	6.4200
Dry Weight	0.6362	Dry Weight	0.6664
KOH	5.5364	KOH	5.7536
Retention	865%		895%

7. Electrical Resistance

The electrical resistance test employs a test fixture described by Cooper and Fleisher(8) (direct current method). It consists of an electrolyte reservoir with a partially charged $Cd/Cd(OH)_2$ electrode at either end. The reservoir is divided into halves by a sample holder which has a circular opening through which ionic transfer may occur. The test consists of measuring the voltage differential across the electrodes

FIGURE NUMBER 21

ELECTROLYTE WICKING RATE



PELLON 2505 ML

INCHES TRAVEL	TIME
0.25	2 MIN.
0.50	14 MIN.
0.75	53 MIN.
2.25	14 HR.

LYONEL

INCHES TRAVEL	TIME
0.25	13 MIN.
0.37	37 MIN.
0.50	2 HR. 25 MIN.
1.25	14 HR.

during the passage of current (50 ma/cm^2 c.d.) through the fixture. A comparison of voltage with sample in place with a "blank" run yields a voltage drop attributable to the resistance of the separator resistance. Nominal units for resistance are ohm-cm^2.

Results of this test were found to be erratic and difficult to reproduce. It is noted, however, that stable voltages were reached almost immediately with Pellon 2505 ML, while Lyonel resistance decreased progressively over a period of five (5) minutes.

8. Extractable Organic Content
   a. Procedure: Weigh sample of separator to tenth of a milligram and determine volume. Place sample in weighed container with solvent (20/1 volume ratio of solvent to sample). Stir overnight, then remove and dry sample and evaporate solvent. Record weight loss of sample and weight of residue.
   b. Results: Table No. XIII displays the results of extractions performed using two common solvents. It appears that methonal is superior to trichloroethylene for removal of organic contaminants as evidenced by the greater weight loss.
9. Organic Analysis (Infrared Spectrometry)

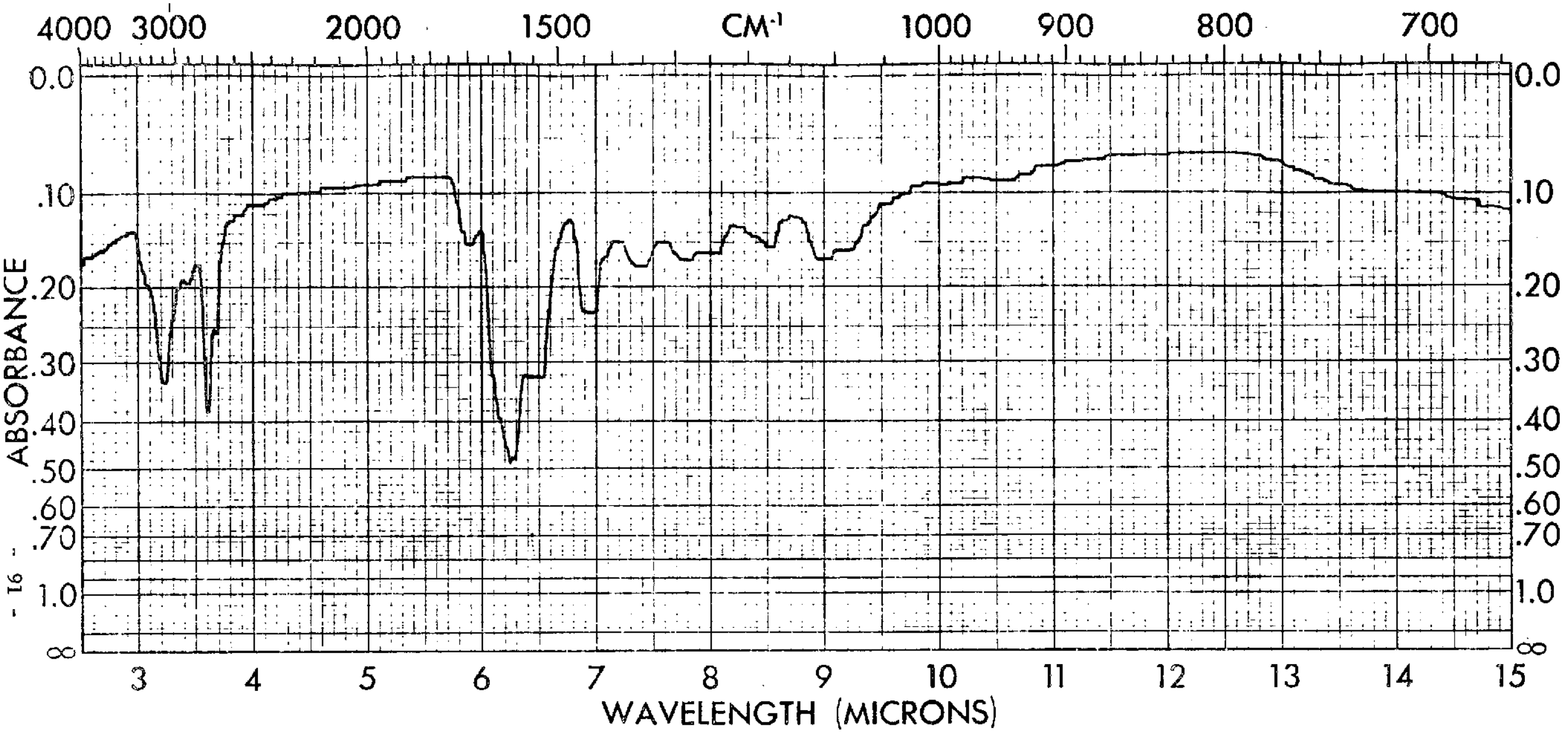
The residues obtained above were subjected to Infrared Analysis by Bruce Williams Laboratories, Joplin, Missouri. Figure Nos. 22 - 26 reveal the absorption bands for the samples described by Table No. XIII and includes the above laboratories

TABLE NUMBER XIII

SOLVENT EXTRACTION OF ORGANICS

MATERIAL	SOLVENT	SOLVENT (VOLUME)	SAMPLE WT. (GRAMS)	LEACHED SAMPLE (GRAMS)	WT. LOSS (GRAMS)	RESIDUE (GRAMS)
Pellon 2505 ML	Methanol	200 ml	4.9760	4.9145	.0525	.0558
Pellon 2505 ML	Trichloroethylene	200 ml	5.1698	5.1526	.0172	.0196
Lyonel	Methanol	200 ml	4.1698	4.1438	.0260	.0267
Lyonel	Trichloroethylene	200 ml	4.7851	4.7524	.0227	.0243
Microweb	Methanol	200 ml	5.7672	5.6244	.1428	.1462

NOTE: Residues were dissolved in 10 ml's of solvent for IR Analysis.



SPECTRUM NO. 1320

SAMPLE BLOL#944590
Methanol 2505 Pellon

99-923

ORIGIN Eagle Picher
Industries, Inc.
Couples Plant
Joplin, Mo

PURITY

PHASE liquid

THICKNESS Film

LEGEND

1.

2.

DATE 4-11-72

OPERATOR J. Douglas

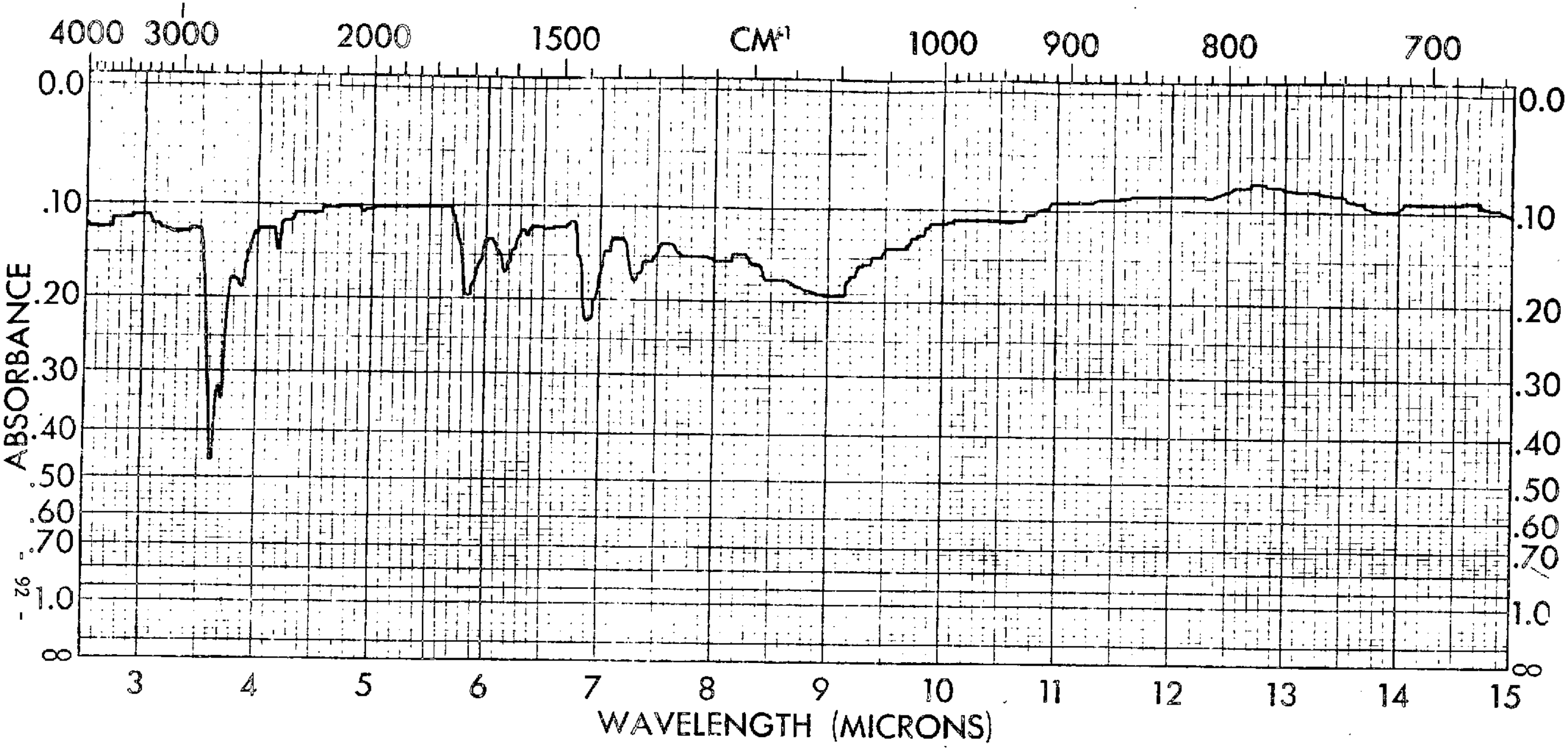
REMARKS The absorptions at 3.2, 6.25 microns are due to N-H stretching and bending vibrations, respectively. The absorptions at 3.6, 6.9 microns are due to C-H stretching and bending vibrations respectively.

SPECTRUM NO. 1
SAMPLE

FIGURE 22

PART NO.137-1280

THE PERKIN-ELMER CORPORATION, NORWALK, CONN.



SPECTRUM NO. 1321

SAMPLE BWL# 944591
Trichloro Ethylene
2505 Pellon

99-923

ORIGIN Eagle Picher Industries, Inc. Joplin, Mo. Couples Plant

PURITY

PHASE liquid

THICKNESS film

LEGEND

1.

2.

DATE liquid

OPERATOR J. Douglas

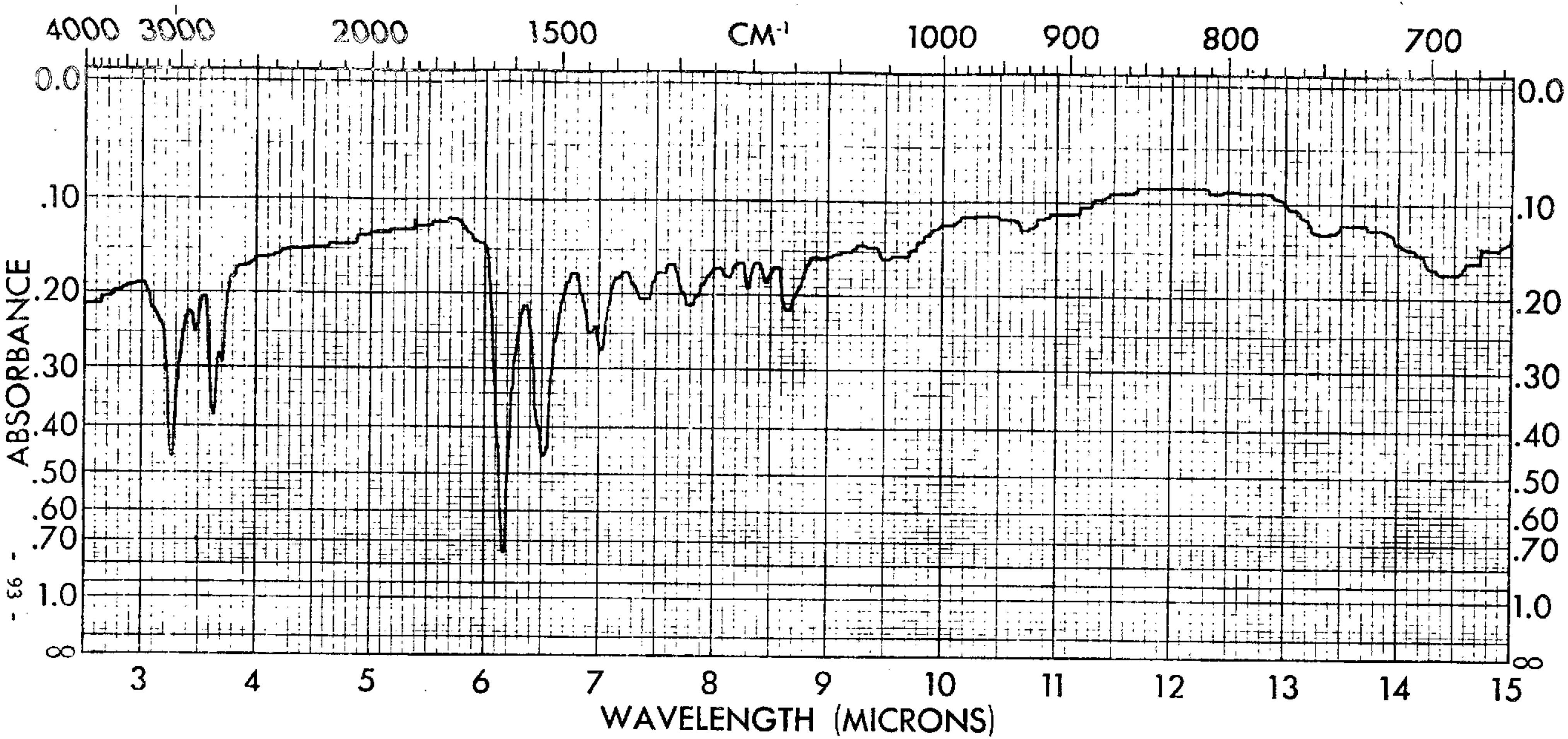
REMARKS The absorptions at 3.6, 6.9, 7.3 microns are due to C-H stretching and bending vibrations. The absorption at 5.8 is due to the C-O group. The absorption at 6.2 is indicative of C-C bending vibrations.

SPECTRUM NO. 2
SAMPLE

FIGURE 23

PART NO.137-1280 PE®

THE PERKIN-ELMER CORPORATION, NORWALK, CONN.



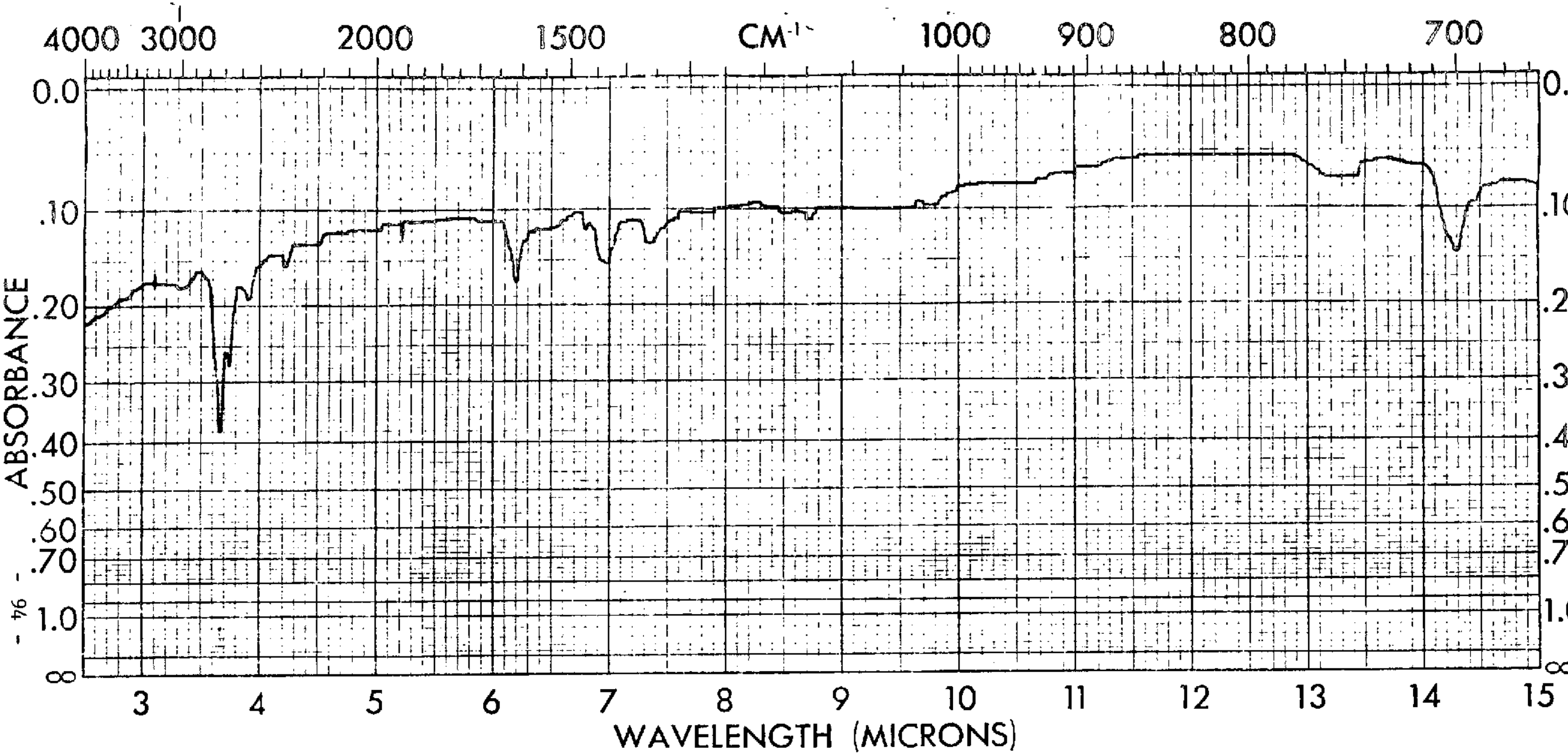
SPECTRUM NO. 1323	ORIGIN Eagle Picher Industries, Inc. Couples' Plant Joplin, Mo.	LEGEND	REMARKS The absorptions at 3.25, 6.2, 6.5 are due to N-H stretching and bending vibrations. The absorptions at 3.6, 6.9, and 7.0 are due to C-H stretching and bending vibrations.
SAMPLE BW2A 944593 Methanol Spunbound Nylon		1.	
	PURITY	2.	
	PHASE liquid	DATE 4-11-72	
99-973	THICKNESS film	OPERATOR J. Douglas	

SPECTRUM NO. 3
SAMPLE

PART NO.137-1280 PE®

FIGURE 24

THE PERKIN-ELMER CORPORATION, NORWALK, CONN.



SPECTRUM NO. 1324

SAMPLE BWLA 944594
Trichloro Ethylene
Spunbound Nylon

99-923

ORIGIN Eagle Picher
Industries, Inc.
Couples Plant
Joplin, Mo.

PURITY

PHASE liquid

THICKNESS film

LEGEND

1.

2.

DATE 4-11-72

OPERATOR J. Douglas

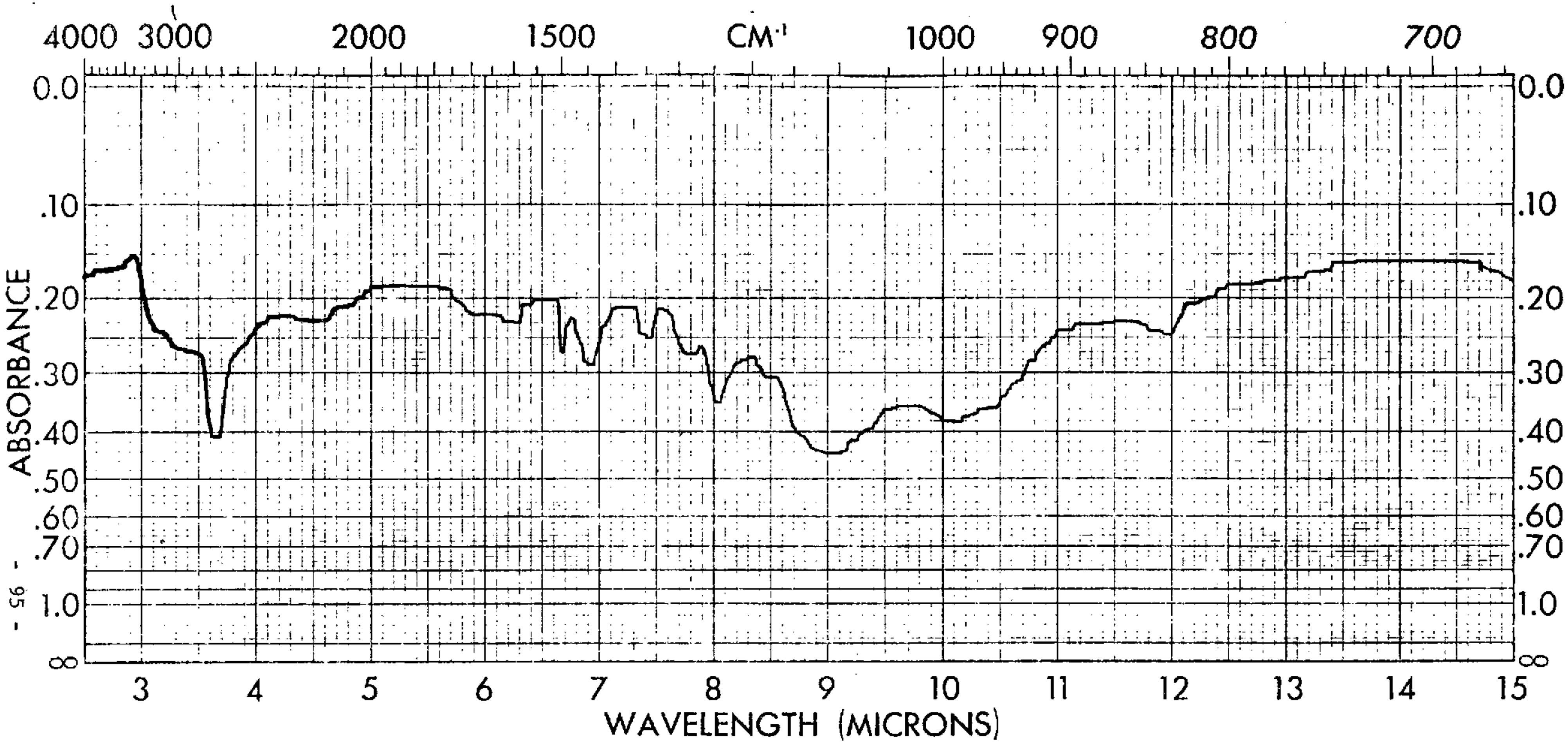
REMARKS The absorptions at 3.6, 7.0 microns are due to C-H stretching vibrations. The absorption at 6.2 is indicative of C-C vibrations.

SPECTRUM NO. 4
SAMPLE

FIGURE 25

PART NO.137-1280

THE PERKIN-ELMER CORPORATION, NORWALK, CONN.



SPECTRUM NO. 1322	ORIGIN Eagle Picher Industries, Inc. Couples Plant Joplin, Mo	LEGEND	REMARKS The absorption at 3.6, 6.7, 6.8 microns are due to C-H stretching and bending vibrations.
SAMPLE BWL# 944592 Methanol Polypropylene		1.	
	PURITY	2.	
	PHASE liquid	DATE 4-11-72	
99-923	THICKNESS film	OPERATOR J. Douglas	

SPECTRUM NO. 5
SAMPLE

PART NO. 137-1280

FIGURE 26

THE PERKIN-ELMER CORPORATION, NORWALK, CONN.

interpretation (Lyonel is identified in the Figure as Spunbound Nylon). Based upon the interpretations reported, to derive meaningful results (specific identification of extractable organic constituents) from this test method, a very skilled operator (infrared spectrometry) familiar with the probable types of organic constituents would be required.

10. Inorganic Analysis (Emission Spectrometry)

Samples of Pellon 2505 ML, Lyonel and Microweb were ashed and the ignition residues weighed. Percentage metallics, assumed to be the residues, were as follows:

Sample	Residue Weight %
Pellon 2505 ML	0.53
Lyonel	0.02
Microweb	0.11

All values are well beneath the target maximum of one per cent. It is seen that Pellon 2505 ML contains the greatest metallic content. Table No. XIV exhibits spectrographic analysis of Pellon 2505 ML ash and raw materials of all three separators. The samples of Microweb and Lyonel yielded insufficient quantity of ash for analysis. Pellon 2505 ML is confirmed as having a relatively high zinc content. It is not clear what effect this might have on cell performance, but this determination agrees with data presented in the Fifth Quarterly Report.

TABLE NUMBER XIV

SPECTROGRAPHIC ANALYSIS RESULTS

SAMPLE	%B	%P	%Mn	%Sb	%Pb	%Sn	%Mg	%Si	%Fe	%Al	%Cu	%Ag	%Zn	%Ti	%Ca
PELLON 2505 ML	.0005	ND	.0001	ND	ND	ND	.002	.01	.002	.002	.0005	.001	0.2	0.2	.01
LYONEL	.005	ND	ND	ND	.002	ND	.002	.01	.004	.001	.002	.001	ND	ND	.02
MICROWEB	.0005	0.2	ND	ND	.001	ND	.002	.01	.004	.002	.001	.001	ND	ND	.02
PELLON 2505 ML IGNITION RESIDUE	.004	.05	.001	.01	.0005	.0005	.01	0.1	.01	.01	.004	.001	3-5	1-3	.02

E. Conclusions

1. Scanning electron microscopy as a separator material test method appears to have limited value. The process is time consuming (equipment not locally available) and expensive ($50/photomicrograph). In addition, tests performed did not produce significant results which might be used to characterize various separator materials.
2. Infrared spectrometry also appears to have limited value as a separator material test method. Interpretation of the resulting infrared absorption bands would require a very skilled operator knowledgeable in the specific application to evolve meaningful separator characterization data. Different absorption bands for the same separator material were induced by the use of different solvents in the preceding extractions. This divergence reduces confidence in the results of this test method.
3. Classical wet chemical analyses and emission spectrometry are effective in determining the inorganic impurity levels associated with various separator materials. This is particularly demonstrated with the Zn impurity level associated with Pellon 2505 ML. However, as the two methods complement each other with respect to demonstrating detected impurity levels, both would not appear necessary. Emission spectrometry is more convenient and is the recommended test method.
4. The results of the electrical resistivity test were inconsistent. Considerably different voltages were observed for different samples of the same separator material and

sometimes a stable voltage could not be obtained. Little confidence could be attached to the results of this test method.

5. The remaining test methods evaluated in this study appeared to have merit. In summary, the following test methods could be recommended for use in the determination of suitability or quality control measures for separator materials.

    a. Unit weight determination
    b. Thickness variation
    c. Tensile strength
    d. Wetting agent determination
    e. Wettability (Wicking Rate)
    f. Electrolyte retention and absorbency
    g. Extractable organic content
    h. Inorganic analysis (emission spectrometry)

VIII. CARBONATE CONTAMINATION STUDY

A. Introduction

The previous studies were concerned with the major cell components (positive and negative electrodes, and separator materials). Beginning with this section, the process variable program will be concerned with the investigation of process variables associated with the complete cell.

The following section is devoted to the investigation of the major sources of carbonate contamination in sealed nickel-cadmium cells and possible means of elimination or reduction.

B. Background

It is generally accepted that the presence of carbonate in hermetically sealed nickel-cadmium cells exhibits a deleterious effect upon the cell electrical performance. The specific effects of carbonate contamination on the typical charge and discharge characteristics of nickel-cadmium cells has been the subject of study by a number of investigators. One of these investigations (Effect of Carbonate on the Performance of Sealed Nickel-Cadmium Cells, Power Sources 3 (6)) demonstrated a general carbonate concentration dependent degradation in most of the parameters used in cell performance evaluation. The observed degradations included 1) lower discharge voltages, 2) higher charge voltages, 3) shorter cycle life, 4) decreased charge acceptance and 5) higher cell pressure on overcharge. The exact mechanism by which carbonate brings about the observed deleterious effects is, however, still in dispute.

Previous investigations conducted at Eagle-Picher have generally collaborated most of the above observations. A procedure devised to reduce the apparent level of carbonate in the cell electrolyte resulted in a small improvement in the electrical capacity and a significant improvement in the oxygen recombination characteristic (lower pressure on overcharge). Basically the procedure consists of flooding the cell with fresh electrolyte, subjecting to a discharge/charge cycle, and then centrifuging to remove the excess electrolyte. The procedure is performed three (3) to five (5) times until the measured carbonate (in the extracted electrolyte) is reduced below 1% of the sample electrolyte weight.

C. Carbonate Source Determination

1. Procedure: To determine the major source or sources of carbonate contamination, two 6 amp hour sizes stainless steel cell cases were fixtured in order to accommodate the internal cell components (positive plates, negative plates, and separator material) individually or in combination. To determine if one or more of these components were a source of contamination, the plan was to first introduce the positive electrodes alone, electrically cycle to simulated cell conditions (starved electrolyte quantities), extract a small electrolyte sample, and determine the increase in carbonate level. The next step would be to add the negative electrodes and repeat the process to determine if this component or the combination of the two components (positive and negative electrodes) induced increased carbonate levels. In the final step, separator material

would be added (in effect forming a complete cell), and the above process and evaluation again repeated.

The analytical procedure used in determining the carbonate level in the extracted electrolyte was the "double end point" titration method described by Fleischer (9).

2. Results: The first test utilizing a group of positive electrodes resulted in an indication of 18.9% carbonate. This high value caused concern over performing these experiments on the bench exposed to the CO_2 in the atmosphere. A glove box (See Figure 27) was fabricated in which a CO_2 free nitrogen atmosphere could be maintained for performing future experiments.

   Two (2) more tests were run on the same lot of positive electrodes within the protective glove box. This resulted in indications of 11.0 and 10.1% carbonate. The significant reduction demonstrated this test must be performed in a protective atmosphere. Test results also indicated that there was still a very high level carbonate contamination associated with the electrodes, and they may be the major source of contamination. It was elected to concentrated the investigation in this area.

D. Electrode Experiments

1. Experiment Number One

To measure the amount of carbonate contained within the electrodes, a commercially available CO_2 analysis laboratory apparatus was utilized. The electrode sample, ground into a powder, is placed in a hot acidic solution

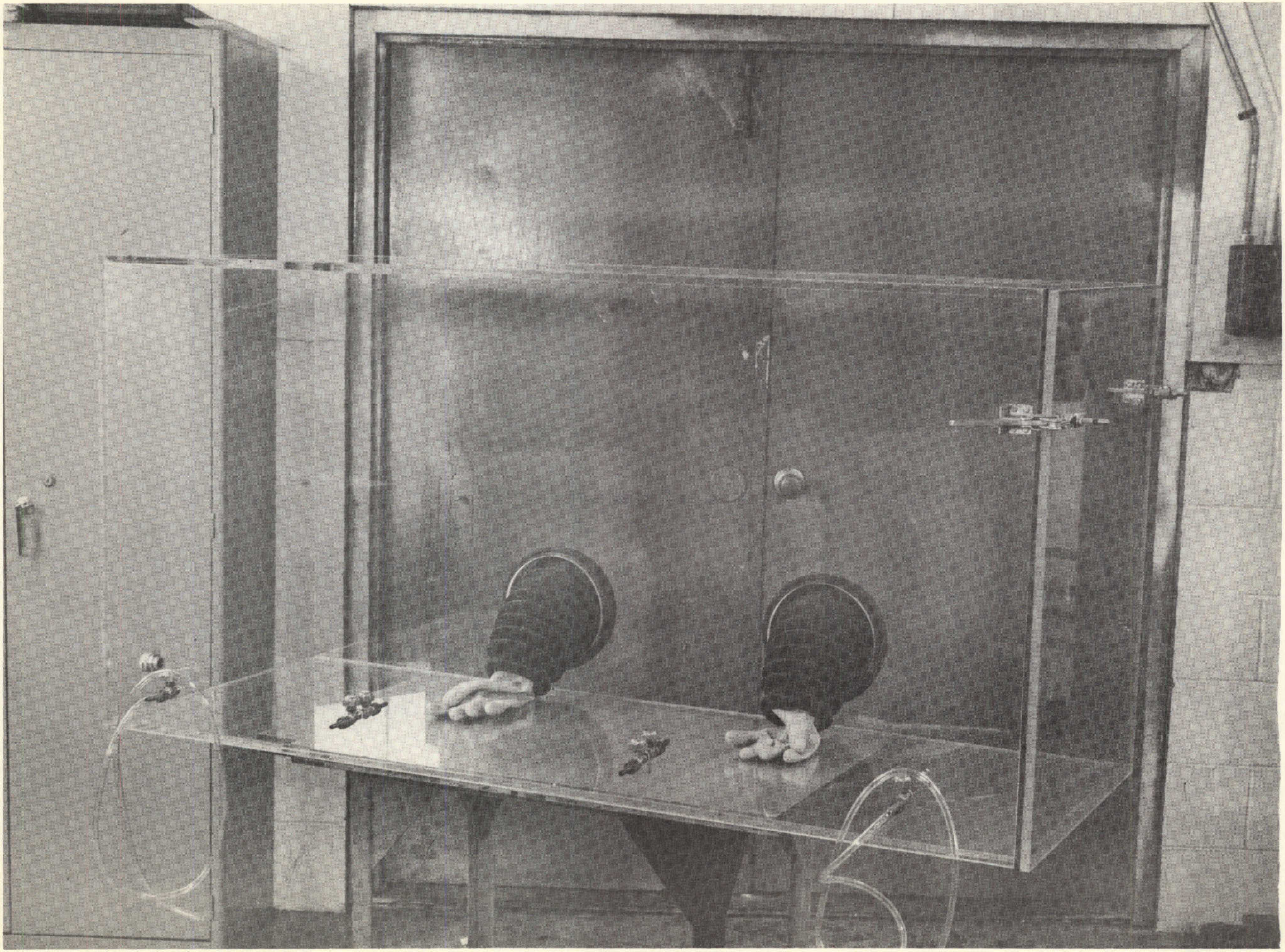


FIGURE 27 NITROGEN ATMOSPHERE GLOVE BOX

in which any carbonate present would be rapidly converted into CO_2 which evolves from the solutions as a gas. The gas is then trapped, measured and the value obtained converted back to carbonate and expressed as a percent of the electrode weight.

A probable mechanism for carbonate build-up in electrodes is the conversion of residual KOH not removed by washing after the formation process. It is believed the following reactions occur.

$$2OH + CO_2 \longrightarrow CO_3 + H_2O$$

To investigate this probable mechanism, three (3) lots of positive and negative electrodes were acquired which reflected three levels of washing.

Group 1	Contained development electrodes which received a minimum fixed washing period of six (6) hours.
Group 2	Electrodes were washed until they passed pH paper neutrality test which typically requires 8 - 10 hours.
Group 3	Electrodes were washed until they passed the new phenalphthalein neutrality test described in a previous section of this report. Washing 20-24 hours is normally required to obtain a neutral indication with this sensitive indicator.

Samples of these materials were subjected to the CO_2 analysis discussed above with the following results:

	CO_3%	
Group	Positive	Negative
1	1.88	1.50
2	1.46	1.37
3	1.17	2.64

In the case of the positive tests there appeared to be a reduction of carbonate level associated with increased washing time; however, this trend did not hold for the negative tests. The values obtained do agree with the results obtained in the previous simulated cell tests. The 2% level measured in the electrodes could result in a 10% level in the electrolyte. The electrolyte level in the starved state is approximately 1/5 of the weight of the electrodes; assuming complete solubility, the level of carbonate measured in the electrolyte sample would be approximately five times greater than that measured in the electrodes.

2. Experiment Number Two

At the suggestion of the NASA/GSFC Technical Monitor, a second mechanism was considered. It is possible the carbonate build-up occurs at an earlier point in the manufacturing process, for example, during the polarization cycle in NaOH. It is also possible the carbonate assumes a form which is not readily soluble in water and not removed by the final washing procedure.

To investigate this possible mechanism, the scaled-down production equipment described in a preceding section of this report was modified. All process tanks were modified in order to be sealed and accept a CO_2 free nitrogen atmosphere. A group of positive electrodes were then processed through impregnation, polarization and formation with out exposure to normal atmosphere except after the final wash period. Samples of these material subjected to a CO_2 analysis resulted in the following:

Sample	CO_3%
1	0.81
2	1.61
3	1.32

With the exception of Sample 1, the carbonate levels were not significantly reduced.

3. Experiment Number Three

At this point, the original assumption of conversion of residual caustic (NaOH or KOH) as the predominent source of contamination was questioned. A positive and negative electrode which had been subjected to the new phenolphthalein wash procedure were ground into a fine powder and exposed to the atmosphere for a period of one week to induce carbonate contamination. A CO_2 analysis resulted in the following:

Electrode	CO_3%
Positive	3.26
Negative	3.22

Samples of these powders were then subjected to an atomic absorption analysis for specific potassium and sodium ion contents with the following results:

SAMPLE	PPM K	PPM Na	% BY WEIGHT
Positive	3690	Trace	0.37
Negative	137	Trace	0.01

It is obvious the conversion of residual caustic can not account for the levels of carbonate detected. Assuming the carbonate existed as potassium carbonate (K_2CO_3), it would require 13.5 times the percent potassium ion measured to result in the 3.26% carbonate detected in the positive electrode. The discrepancy is much greater in the negative electrode case.

This evidence indicates the major source of contamination may be conversion of the actual electrode active material which could occur by the following reactions:

$$Ni(OH)_2 + CO_2 \longrightarrow NiCO_3 + H_2O$$

$$Cd(OH)_2 + CO_2 \longrightarrow CdCO_3 + H_2O$$

It is also possible these reactions may occur whenever the electrodes are exposed to the atmosphere.

4. Experiment Number Four

In an attempt to measure the rate of contamination (if it occurs) when electrodes are exposed to the atmosphere, a positive and negative electrode were selected from group which exhibited an initially very low value of carbonate. The electrodes were cut in half and the two halves of each subjected to two storage modes. One storage mode consisted of a 30 day stand in a desiccator chamber; the other mode consisted of a 30 day stand exposed to the atmosphere. The following CO_2 analysis results were recorded:

	CO_3% Positive	CO_3% Negative
Initial	0.83	0.14
Desiccator Storage	0.81	0.67
Atmosphere Storage	1.28	0.74

Carbonate levels do increase with exposure although the absence of moisture in the atmosphere appeared to retard the increase in the positive electrode. The increases were not as great as might be expected from the length of exposure although there are probably factors not considered. The electrodes selected with their very low initial carbonate levels may have already demonstrated a resistance to carbonate build-up.

E. Carbonate Prevention and Elimination Experiments

1. Experiment Number One

Assuming electrodes may have a carbonate level in excess of 2% by weight just prior to cell fabrication, a remedial procedure which would effect a reduction or elimination at this point would be of considerable value. Two (2) positive electrodes were subjected to a dilute H_2SO_4 acid treatment in order to eliminate carbonate by the following reaction:

$$2K_2CO_3 + H_2SO_4 \longrightarrow K_2SO_4 + 2KHCO_3$$

$$2KHCO_3 + H_2SO_4 \longrightarrow K_2SO_4 + 2H_2O + 2CO_2$$

This reaction is the basis of operation of the CO_2 analysis apparatus referenced above.

The CO_2 analysis of these electrode samples produced the following:

Sample	CO_3%
1	2.05
2	2.22

No apparent reduction occurred, however, as a result of vacations, approximately one (1) week (samples were sealed in polyethylene bags during this period) was inadvertently allowed to elapse between performance of the acid treatment and the subsequent CO_2 analysis. This treatment would probably not enjoy general acceptance as the result of the unknown effects and possibility of not removing all traces of the acid by the subsequent washing.

2. Experiment Number Two

In the final section of this report, a study is described in which electrodes are processed to produce various parameters to be investigated on a cell level. These parameters include possible carbonate reduction procedures such as additional formation cycle to effect superior electrode cleaning, and vacuum drying of electrodes after the final wash. In addition, all electrode groups incorporate the latest carbonate control procedures imposed upon the manufacturing process. These controls include maintaining electrodes under de-ionized water during process stand times (prevent CO_2 pick-up), use of the new phenolphthalein washing procedure, and heat sealing of all electrodes in polyethylene bags for both shipment and storage immediately after completion of the final drying procedure. The availability of these electrode groups presented an opportunity to evaluate the imposition of a preventative carbonate treatment.

The following electrode groups were subjected to a CO_2 analysis with the following results (for a more complete definition of the electrode groups, see last section of this report).

		CO_3%	
Group	Parameter	Positive	Negative
II	One Formation Cycle	1.43	1.77
III	Ten Formation Cycles	1.43	1.40
IV	Vacuum Dried	1.57	1.95

The results would indicate with increased control and careful handling the carbonate levels for both positive and negative electrodes may be maintained below a 2% by weight level but further reduction does not seem possible. No significant reduction could be attributed to additional formation cycles or vacuum drying of finished electrodes.

F. Conclusions

1. Cell electrodes appear to be the major source of carbonate contamination of the cell electrolyte.
2. The most probable mechanism of carbonate build-up in the electrodes is conversion of the actual electrode active material. This process may occur whenever the electrodes are exposed to the atmosphere.
3. Careful handling of electrode materials with respect to minimizing exposure to the atmosphere throughout processing, shipment and storage appears to be the most practical means of carbonate control. These controls should include the following:
    a. Maintaining electrode materials under de-ionized water during any process stand time prior to final drying.
    b. Washing electrodes during the final wash to pass the sensitive phenolphthalein test.
    c. Immediate heat sealing of electrode materials in polyethylene bags for both storage and shipment after the final drying procedure.
    d. Storing electrode and electrode assemblies in inert atmosphere chambers during cell assembly stand times.

    Use of the above controls permit maintaining electrode carbonate contamination at or below a 2% (of electrode weight) level, however, further reduction does not appear feasible.

IX. AUXILIARY ASSEMBLY AND PROCESS STUDY

A. Introduction

The following section has been inserted at this point to present work performed in three areas which are termed auxiliary in the sense they are not directly related to the nickel-cadmium manufacturing process. The three areas are concerned with ceramic-to-metal seal assemblies, the electrolyte activation process, and cell gauge and valve assembly. Effort was directed toward these three areas as a result of a previous record of difficulties.

B. Ceramic-to-Metal Seal Assemblies

Numerous difficulties or possible difficulties have been reported concerning the ceramic-to-metal seals used in sealed nickel-cadmium cells. These include leaking assemblies, poor appearance, and inability to determine reliability of seals for extended five-to-ten years life applications. Many of these difficulties are believed to be related to non-uniformity of the product. To address this problem, the subject program directed effort into two (2) areas.

The first effort involved the preparation of a comprehensive procurement specification which controls the manufacturing process from beginning to end. The specification is the culmination of a thorough review of the pertinent literature to assess the critical process variables and apply the necessary controls. In addition, what were believed to be the better provisions of existing ceramic-to-metal seals specification were also incorporated.

The specification is intended to impose upon the manufacturers the minimum requirements to assure a standard level of acceptable uniformity.

The main provisions of this specification may be outlined by sections as follows:

1. Materials Inspection

   This section imposes upon the vendor the responsibility of assuring the identification and quality of the raw materials which are used in the fabrication of the end product. It includes the necessity of an evaluation of both physical properties and the chemical composition of materials. In addition, it requires the establishment of a documentation program in which the records of tests, evaluations, inspections, and material certifications are maintained.

2. Materials Cleaning and Handling

   This section imposes upon the vendor the responsibility of establishing adequate materials cleaning procedures. Conformance to military standards is specified. Also the minimum requirements to be used in the handling and storage of cleaned parts are stated.

3. Preproduction Materials Qualification

   The responsibility of a preliminary evaluation of the vendors over all manufacturing capability before the start of actual production is imposed by this section. In addition, a portion of the inspection procedures to be utilized in the evaluation of the final cover assembly is described therein.

4. Cover Assembly Processing

Performance requirements, manufacturing inspection requirements, and general workmanship requirements are defined by this section. This section also reflects the introduction of specifications and standards to control manufacturing processes.

5. Cover Assembly Inspection Requirements

The minimum inspection requirements to be utilized in the evaluation and acceptance of a cover assembly lot are described in this section. The introduction of specifications and standards to control inspection procedures and acceptance criterion is reflected therein.

6. Quality Assurance Provisions

Inspection responsibilities and document submittal procedures are defined by this section. In addition, the responsibility for the establishment and operation of a quality assurance program is imposed upon the vendor. The provisions of the program must include the establishment and maintenance of controls over the manufacturing processes, the establishment and maintenance of adequate record keeping procedures, evaluation and control of subcontractors, suitable methods and facilities for processing materials, and the establishment and maintenance of adequate calibration procedures.

7. Packaging

This section defines the minimum packaging requirements to assure the integrity of the cover assembly upon receipt by the Buyer.

This specification titled "Quality Assurance Specification for the Manufacture of Ceramic-to-Metal Seals" (EP-MS-122) was published in the Appendix of the Third Quarterly Report(3) and is presently used by Eagle-Picher Industries for procurement of ceramic-to-metal seals.

The second effort involved the re-design of an existing 20 ampere-hour rated ceramic-to-metal seal presently procured from Ceramaseal, Inc., New Lebanon Center, New York. The following re-designed features were proposed in cognizance with the subject vendor's engineering staff:

1. Replace 96.0% ceramic body with 99.5% body (higher purity body more resistant to titanium diffusion).
2. Reduce tolerances of mating surfaces (braze areas) to provide more uniform braze flow characteristics.
3. Increase seal geometry length to provide wider, stronger braze joints.
4. Modify jigs and heat sinks to provide more uniform temperature distribution across assembly during brazing operation.
5. Replace alloy 42 in assembly metal parts with alloy 52. This alloy reportedly does not require undesirable copper plating to effect braze wettability.

These design changes are reflected on the new seal procurement drawing, Figure 28. Seals for evaluation have been procured utilizing this drawing and the procurement specification discussed

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

NOTES:

1. REQUIREMENTS AND QUALITY ASSURANCE PROVISIONS SHALL BE IN ACCORDANCE WITH EP-MS-122.
2. METALLIZING PROCESS SHALL BE "ACTIVE METAL TYPE" USING 99.0% PURE TITANIUM POWDER.
3. THE BRAZING ALLOY SHALL BE SILVER BASE MATERIAL PER MIL-B-1509A.
4. THE AREA INDICATED BY DOTTED LINES SHALL BE HOT-DIP SOLDER FINISHED (60-40 SOLDER) PER MIL-F-14072 FINISH NO. M221. FLUX SHALL NOT BE ALLOWED TO ENTER THE INTERNAL CAVITY OF THE CERAMIC. AFTER COMPLETION OF THE FINISH OPERATION, POSTS SHALL BE WASHED WITH RUNNING HOT WATER (40°C) AND SCRUBBED THOROUGHLY DURING THIS WASH FOR A MINIMUM OF 30 SECONDS USING A NYLON BRUSH OR TEST TUBE BRUSH.
    - 4a. TERMINAL AREA SHALL BE DIPPED IN A SOLUTION OF 5% AMMONIUM HYDROXIDE AND POSTS IMMERSED FOR A MINIMUM OF 10 SECONDS.
    - 4b. RINSE WITH WATER
    - 4c. RINSE IN ACETONE.
    - 4d. PLACE UNDER A MINIMUM VACUUM OF 25 INCHES Hg.

    ANALYTICAL CHECK FOR FLUX TRACES - A STANDARD FLUORIDE CHLORIDE TEST (SILVER NITRATE) SHALL BE CONDUCTED AS FOLLOWS:

    - a. POUR 40 CC OF BOILING DISTILLED WATER OVER THE TERMINAL AREAS AND COLLECT WATER IN A BEAKER.
    - b. CONDUCT A STANDARD FLUORIDE-CLORIDE TEST ON THIS COLLECTED WATER.
    - c. IF THE ANALYTICAL CHECK IS NEGATIVE (SHOWING AN ABSENCE OF FLUORIDE-CHLORIDE TRACES), THE CELL CAN GO TO THE NEXT PRODUCTION STEP.
    - d. IF THE ANALYTICAL CHECK IS POSITIVE (SHOWING PRESENCE OF FLUORIDE-CLORIDE TRACES), REPEAT STEPS 4 THROUGH 4d.

    SOLDER MAY FLOW OUT ON UPPER BRAZE CUP (FIND NO. 2).
5. FOUR HOLE TERMINAL PLATE SHALL BE BRAZED TO TERMINAL POST WITH SILVER COPPER ALLOY WITH 14.5% INDIUM.

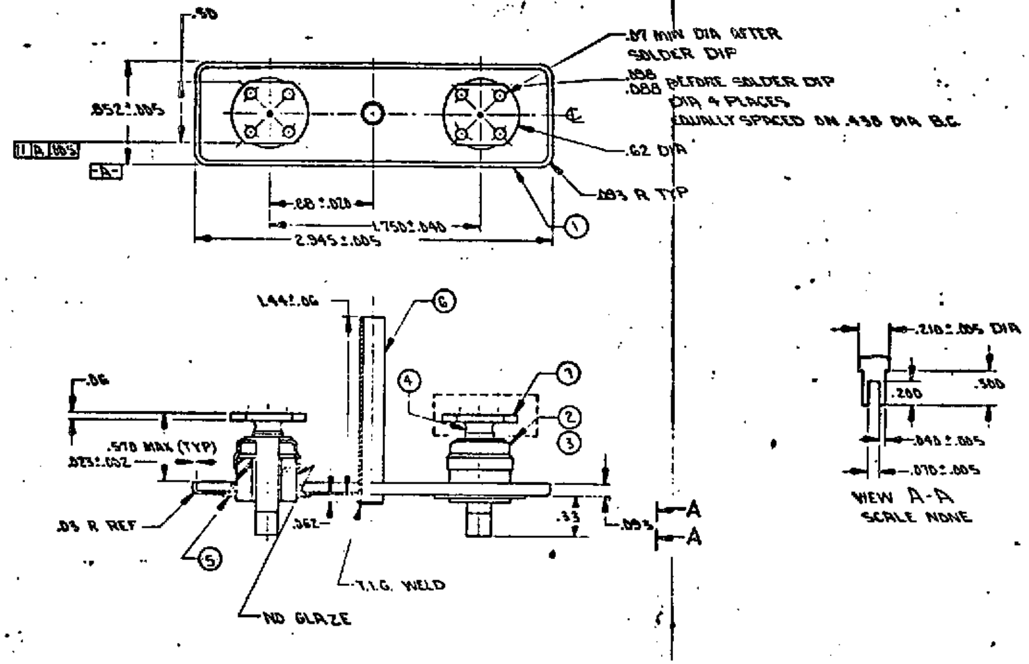


FIGURE 28

FIND NO.	QTY REQD.	CODE IDENT.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	SPEC	MATERIAL OR NOTE	EP NO.
7	2			TERMINAL PLATE		OFHC COPPER	
6	1			TUBE	MIL-T-8504A	S. S. 304 except Para. 3.2.2	
5	2			STRESS RELIEF COLLAR		52 ALLOY	
4	2			TERMINAL		270 NICKEL	
3	2			TERMINAL SLEEVE		99.5% ALUMINA	
2	2			UPPER BRAZE CUP		52 ALLOY	
1	1			COVER	QQ-S-766, Cond. A	304L S. S.	

PARTS LIST

HSN-17
HSN-21
NEXT ASSY | USED ON
APPLICATION

MATERIAL:

CONTRACT NO.
DATE
PREPARED 21 SEP 71
CHECKED
ENGINEER Harold Owens 71

EAGLE PICHER INDUSTRIES, INC
COUPLES DEPARTMENT
JOPLIN, MISSOURI

COVER ASSEMBLY

SIZE D | CODE IDENT NO. 81855 | 09-04-013 - 1
SCALE 2/1 | SHEET 1 OF 1

above. As of this writing, however, insufficient data has been gathered to comment upon the increased uniformity characteristics.

C. Electrolyte Activation Process

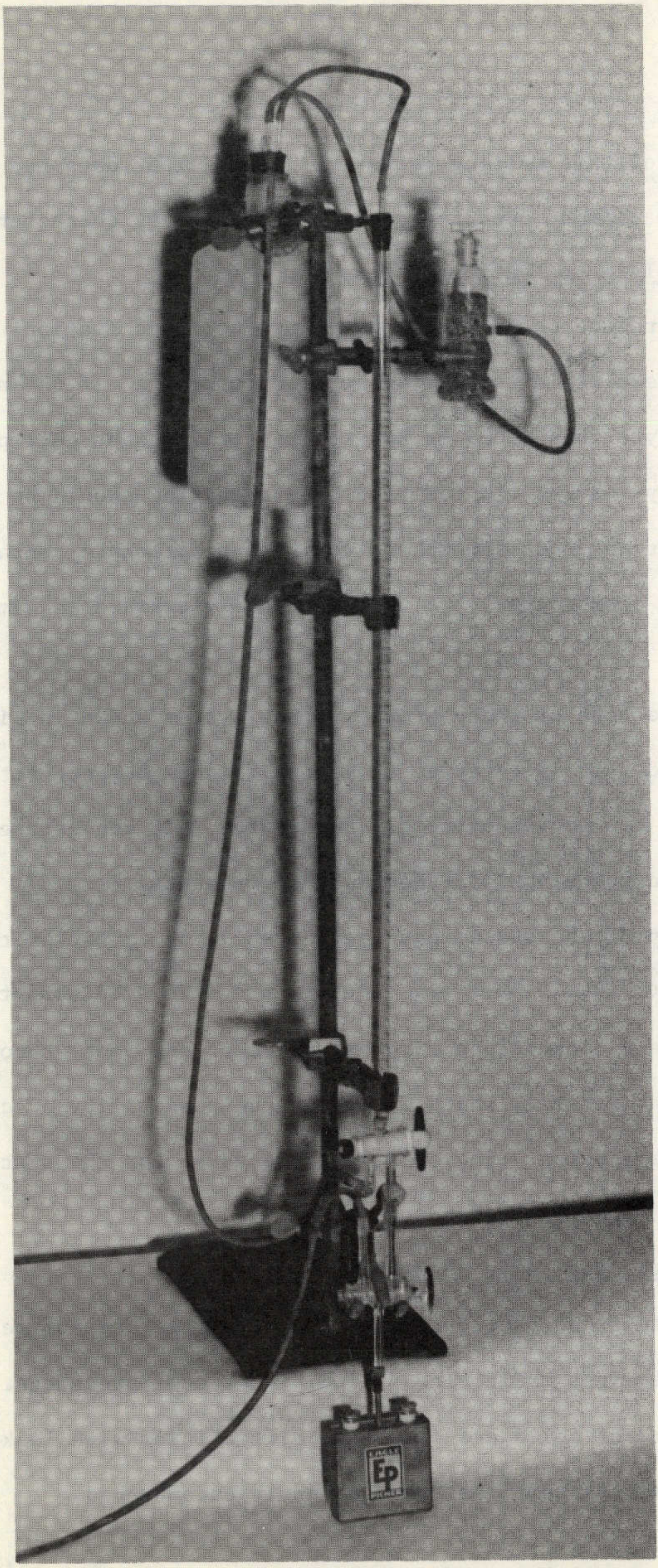
The introduction of electrolyte into cell (activation) typically results in two (2) areas of difficulty. If the amount of electrolyte introduced is not accurate, divergent cell performance may result. In addition, the operation should be performed under an inert atmosphere to prevent carbonate contamination of the electrolyte, but this is usually awkward and impractical.

To solve both of these problems, the system shown in Figure 29 was designed. It is referred to as the "Vacuum Burette Activation System" and has proven extremely successful. It consists entirely of inexpensive off-the-shelf components.

Accuracy of the system has been established at better than ±0.05%, which should meet any requirements. In addition, the system forms a closed loop with exception of one vent through a CO_2 absorbent material which precludes the possibility of carbonate contamination. The operating procedure for the system is included in Appendix B of this report.

D. Cell Gauge and Valve Assembly

Acceptance test procedures for sealed nickel-cadmium cells typically requires monitoring of individual cell pressures. When large numbers of cells are involved, difficulties with leaking gauge and valve assemblies are frequently encountered.



VACUUM BURETTE ACTIVATION SYSTEM

FIGURE 29

For this discussion, a gauge and valve assembly consist of a compound gauge with a suitable range, a valve for the introduction and control of the cell atmosphere, and a tube fitting assembly for attachment to the cell. These components are married together with a tee by means of thread-to-thread connections.

In the past, it has been observed when a large number of gauge and valve assemblies are fabricated and leak checked (helium leak, 10^{-5} cc/sec maximum allowable) up to 25% of the units leak and require re-work. In addition, up to 5% of the assemblies will leak later during acceptance testing (particularly after temperature changes) resulting in the loss of the cell. There is also the concern that small leaks which occur later may not be detected, resulting in an unknown change in a cell's "state-of-charge".

It was further observed the leaks which have been detected occurred at one or more of the three (3) thread-to-thread connections associated with the assemblies. These connections were sealed with a Teflon tape pipe thread sealant.

To remedy this problem, available commercial catalogs were reviewed in an attempt to devise an alternate assembly which would eliminate thread-to-thread connections. However, it did not appear anything was available which would meet the requirements as well as the present system.

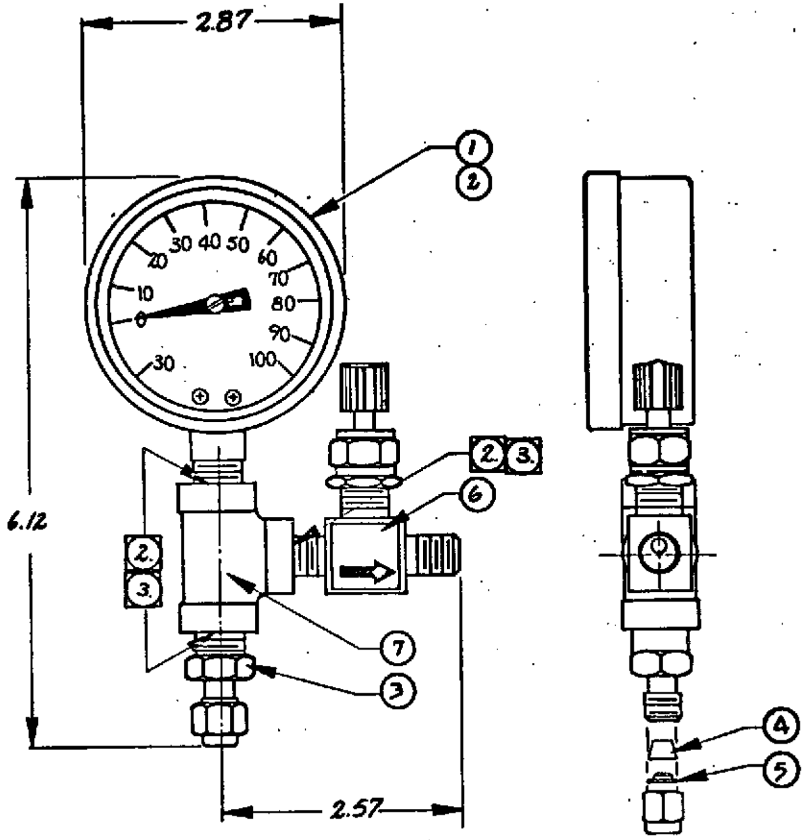
It was then determined to attempt to find a sealant superior to teflon tape for the existing assembly. Several were investigated, but most either effected a permanent bond in the process of sealing or were not stable in the presence of caustic. One sealent appears promising however.

A "Loctite" sealant Grade AVV has been tested with considerable success. Less than 5% of the assemblies sealed with this material leaked during the initial leak test and no leaks have been detected later during acceptance tests. The material is reported stable in the presence of caustic within the temperature range typically seen in acceptance testing of nickel-cadmium cells (150°F max).

Figure 30 presents a gauge and valve assembly with instructions for the application of subject sealant.

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	(1) REVISED PER E.O. 27613	24 OCT 72	

FIGURE 30



NOTES:

1. MALE AND FEMALE THREAD MATING CONNECTIONS SHALL BE CLEANED OF ALL FOREIGN MATERIAL.

2. APPLY "LOCQUIC" PRIMER GRADE T, P/N 47-55 WITH SMALL SYRINGE TO FIRST THREE (3) THREADS OF MALE THREAD CONNECTION. IMMEDIATELY ASSEMBLE WITH RESPECTIVE FEMALE CONNECTION, HAND TIGHT, TO ASSURE PRIMER IS APPLIED TO BOTH MATING SURFACES. IMMEDIATELY DISASSEMBLE AND ALLOW PRIMER TO DRY 10 MINUTES MINIMUM.

3. APPLY "LOCTITE" SEALANT GRADE AVV, P/N 86-41 TO APPROXIMATELY FIRST THREAD OF MALE THREAD CONNECTION. ASSEMBLE WITH RESPECTIVE FEMALE CONNECTION HAND TIGHT. IF HAND TIGHT POSITION FOR GAGE OR VALVE ASSEMBLE DOES NOT CORRESPOND TO SHOWN ALIGNMENT, A WRENCH SHALL BE USED TO COMPLETE PORTION OF REVOLUTION TO BRING INTO PROPER POSITION. THE LOWER "SWAGELOK" COMPONENT SHALL BE LIGHTLY TIGHTENED WITH A WRENCH.

4. CURE SEALANT BY PLACING ASSEMBLY IN OVEN (200°F) FOR 48 HOURS MINIMUM. DETERMINE ADEQUACY OF CURING PROCEDURE BY PROBING EXCESS SEALANT ON OUTSIDE OF THREAD-TO-THREAD CONNECTION, THIS MATERIAL SHOULD BE COMPLETELY HARD.

5. VALVE ASSEMBLY "MUST" BE INSTALLED WITH ARROW IN DIRECTION AS SHOWN.

FIND NO.	QTY REQD.	CODE IDENT.	PART OR IDENTIFYING NO:	NOMENCLATURE OR DESCRIPTION	SPEC	MATERIAL OR NOTE	EP NO.
7				TEE			15-37-010-0
6				VALVE ASSEMBLY			95-30-031-0
5				BACK FERRULE			95-77-092-2
4				FRONT FERRULE			95-77-092-1
3				SWAGE LOK			95-77-092-0
2				COMPOUND GAUGE	200 PSI		63-50-004-0
1				COMPOUND GAUGE	100 PSI		63-50-003-0

PARTS LIST

NEXT ASSY	USED ON
APPLICATION	

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

MATERIAL:

CONTRACT NO. ______

DATE		
PREPARED		5 June 72
CHECKED		9-June-72
ENGINEER		9 June 72

EAGLE PICHER INDUSTRIES, INC.
COUPLES DEPARTMENT
JOPLIN, MISSOURI

NI-CD SYSTEM GAUGE AND VALVE ASSEMBLY

SIZE C
CODE IDENT NO. 81855
005467
SCALE 1/1
SHEET

X. SIGNAL (AUXILIARY) ELECTRODE STUDY

A. Introduction

Oxygen sensing signal electrodes (also referred to as auxiliary or third electrodes) find application in nickel-cadmium cells as signalling devices for charge control systems. In the following phase of the process variable program, modifications of a basic signal electrode design are evaluated with respect to the oxygen sensing signal produced.

B. Background

The basic Eagle-Picher signal electrode design consists of a non-noble, sintered nickel electrode with a heat laminated teflon film on one side. The teflon film functions to prevent electrolyte flooding which would impede the desired oxygen reaction. The standard 10 cm^2 electrode is shown in Figure 31.

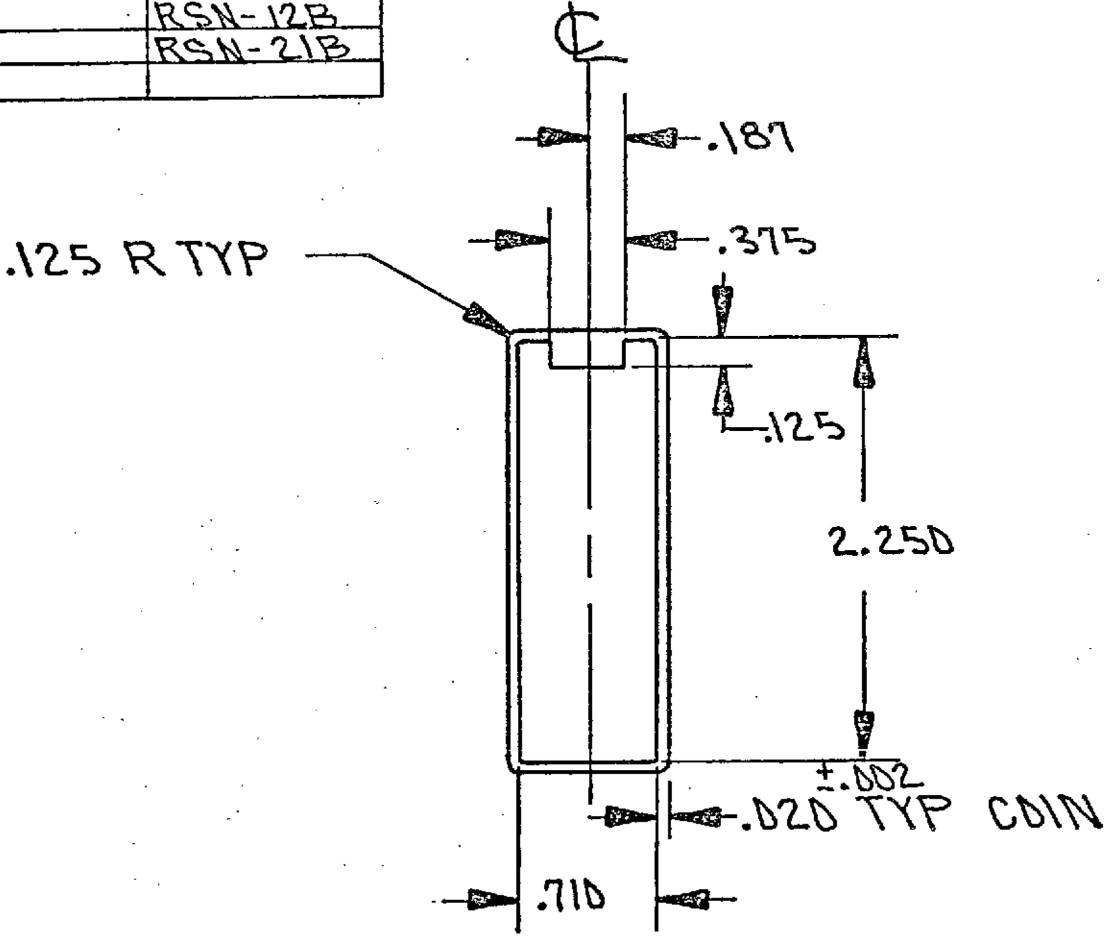
In cell assembly, the signal electrode receives two wraps of the cell separator material (typically Pellon 2505 ML) and is inserted along the narrow side of the prismatic cell case between the electrode stack and cell case wall. The teflon film side is toward the cell case. The signal electrode is then electrically connected to the cell case.

In cell operation, the oxygen evolved at the positive electrodes as the cell approaches full state of charge may be reduced at the surface of the signal electrode (very low rate) by the following reaction.

$$O_2 + 2\ H_2O \longrightarrow 4\ OH^-$$

APPLICATION	
NEXT ASSY	USED ON
23-05-028-0	RSN-110A
23-05-029-0	RSN-110B
	RSN-6C
	RSN-12B
	RSN-21B

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



NOTES:

1. THICKNESS PRIOR TO COIN IS .031.
2. THICKNESS AFTER COIN SHALL BE .010 - .015.

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES: FRACTIONS ±
ANGLES ±
3 PLACE DECIMALS ±.010
2 PLACE DECIMALS ±.03

CONTRACT NO.

DATE ________

PREPARED	BC CROWNOVER	11MAR71
CHECKED		
ENGINEER		3/12/71

FIGURE 31

EAGLE PICHER INDUSTRIES, INC.
COUPLES DEPARTMENT
JOPLIN, MISSOURI

AUXILIARY ELECTRODE PUNCH & COIN

SIZE	CODE IDENT NO.	DRAWING NO.
A	81855	005281

SCALE \ /\

SHEET

By connecting a load resitor, of suitable resistance, between the negative terminal and the cell case, a signal is developed which may be used to terminate or reduce the charge rate.

The primary problem which has been encountered in the use of this type of signal electrode has been hysteresis of signal voltage with cycling. After sensing oxygen, the signal developed typically does not return to its starting point when the oxygen is removed. The residual voltage is believed to result from some form of physical or chemical absorption of oxygen on the surface of the signal electrode.

The following section described an experimental effort to improve the hysteresis associated with the signal electrode. The effort consists of several modifications of the basic electrode design and the subsequent evaluation.

C. Experimental Procedure

A resealable test apparatus was designed which would accommodate four electrodes. For testing, the electrodes were arranged in the following order in a cell configuration: a negative electrode, a positive electrode, a second negative electrode, and a signal electrode. Tests were performed in a starved electrolyte condition and the three active electrodes maintained at approximately 50% state-of-charge. The resealable apparatus was connected by means of a three-way valve to an oxygen source and a vacuum pump.

To characterize the test system and establish a standard for comparison, the basic signal electrode design was subjected to a series of tests under varying load resistors. Figure 32 present the results of this effort.

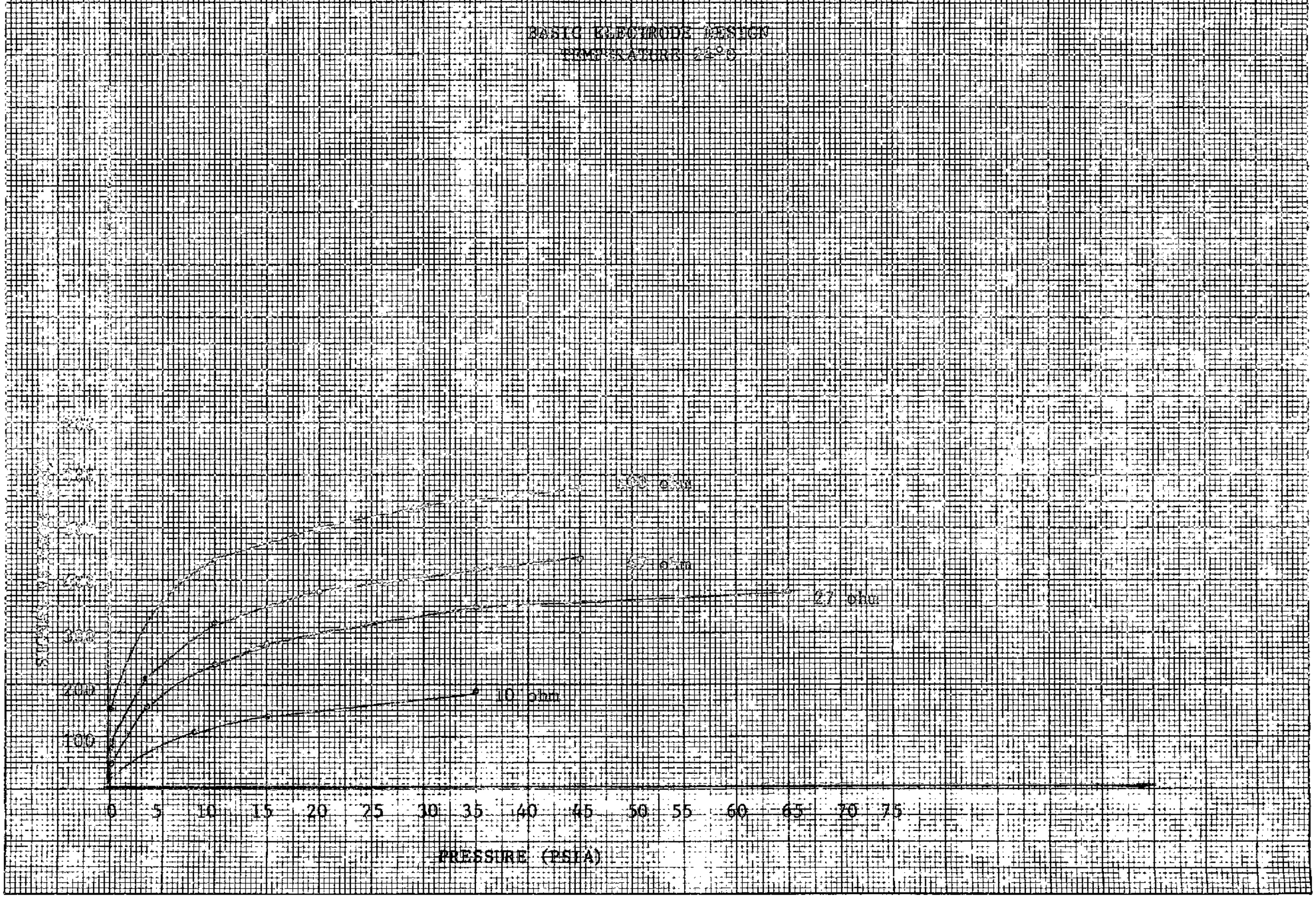


FIGURE 32

BASIC ELECTRODE DESIGN
TEMPERATURE 24°C

1. Design Modification One

The first design modification consisted of heat laminating teflon film to both sides of the electrode. Figure 33 presents the results of the evaluation of this design under varying load resistors. It is observed that the magnitude of the signal voltage has been depressed. Figure 34 presents the results of the second cycle under a 47 ohm load and the subsequent signal voltage decay. The residual voltage from the first cycle was approximately 200 MV (starting point of second cycle); however, as observed, the increase in residual introduced by the second cycle was considerably less (approximately 220 MV).

2. Design Modification Two

In this design the sintered nickel electrode is dipped in a teflon slurry to impregnate the electrode. The slurry consisted of DuPont "Teflon 30" (contains "Triton-X-100", a wetting agent) mixed with water in a ratio of 60/40 by weight. The electrode was oven dried (450°F) overnight to remove the water and wetting agent. Figure 35 presents the results of the evaluation of this design. It appears the signal voltage is depressed to such an extent this design would not be practical.

3. Design Modification Three

Instead of the heat lamination of a teflon film, in this design modification teflon is applied to one side of the electrode by aerosol spray. The electrode is again oven

FIGURE 33

DESIGN MODIFICATION ONE
TEMPERATURE 24°C

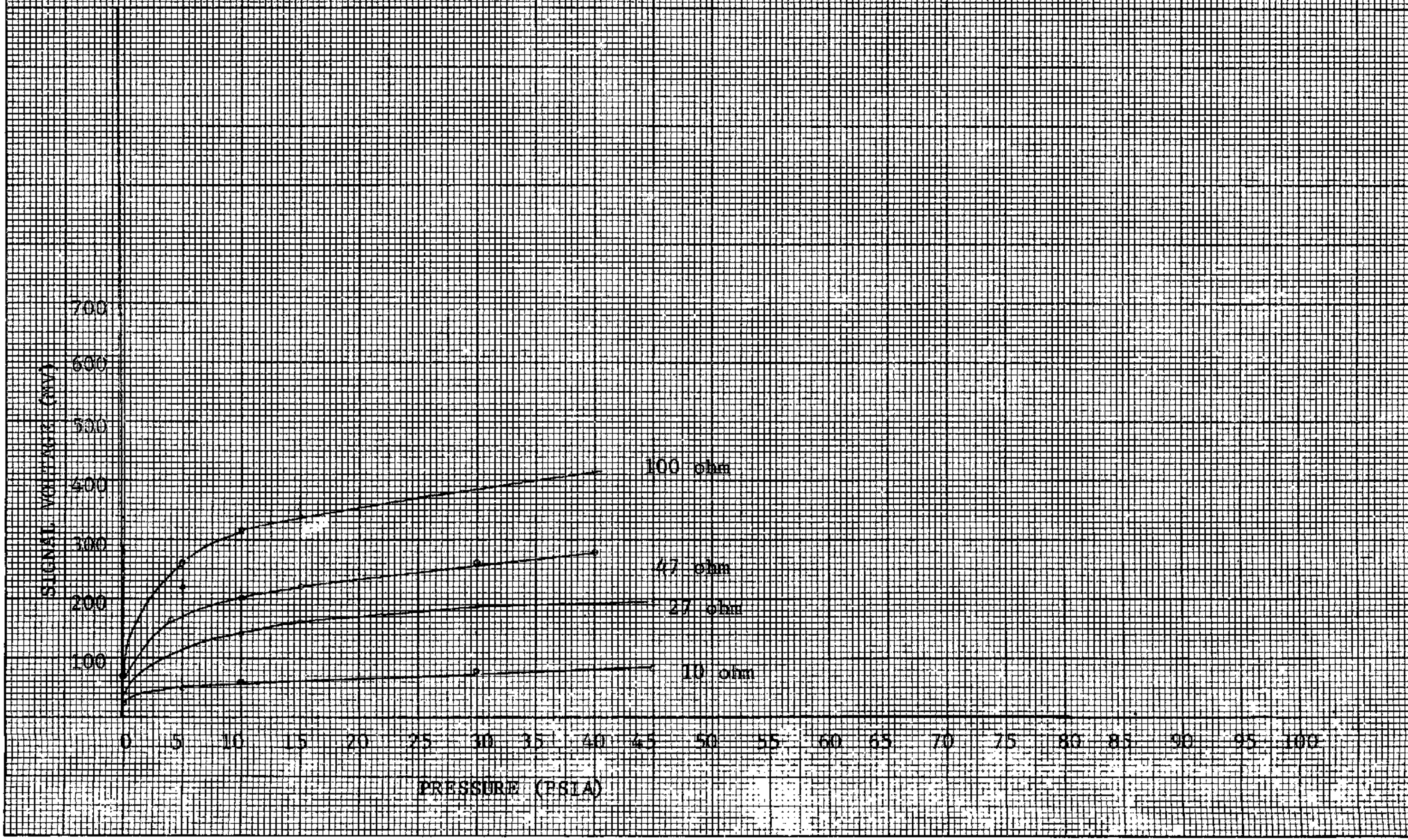


FIGURE 34

DESIGN MODIFICATION ONE
(SECOND CYCLE)
TEMPERATURE 24°C

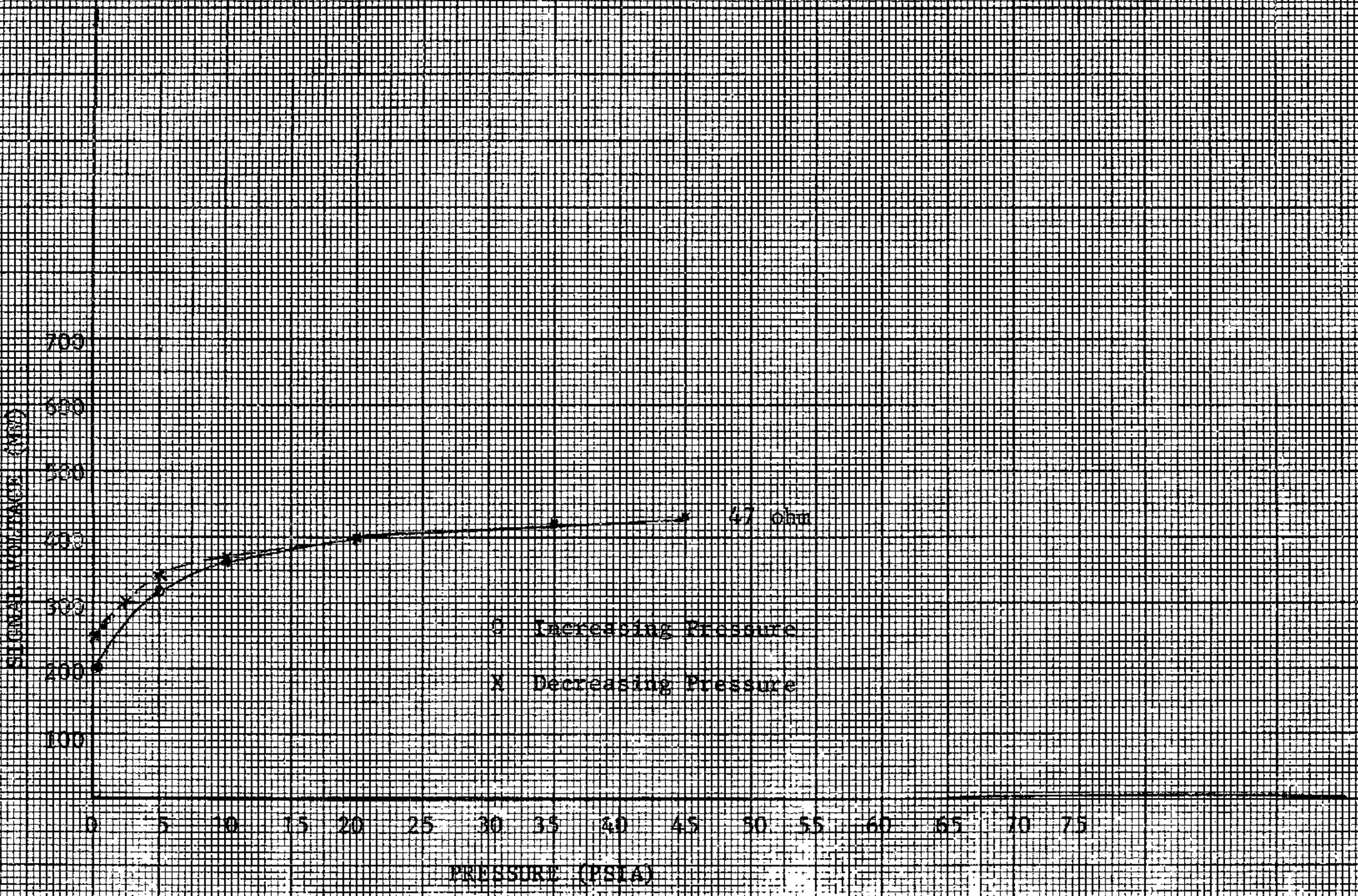
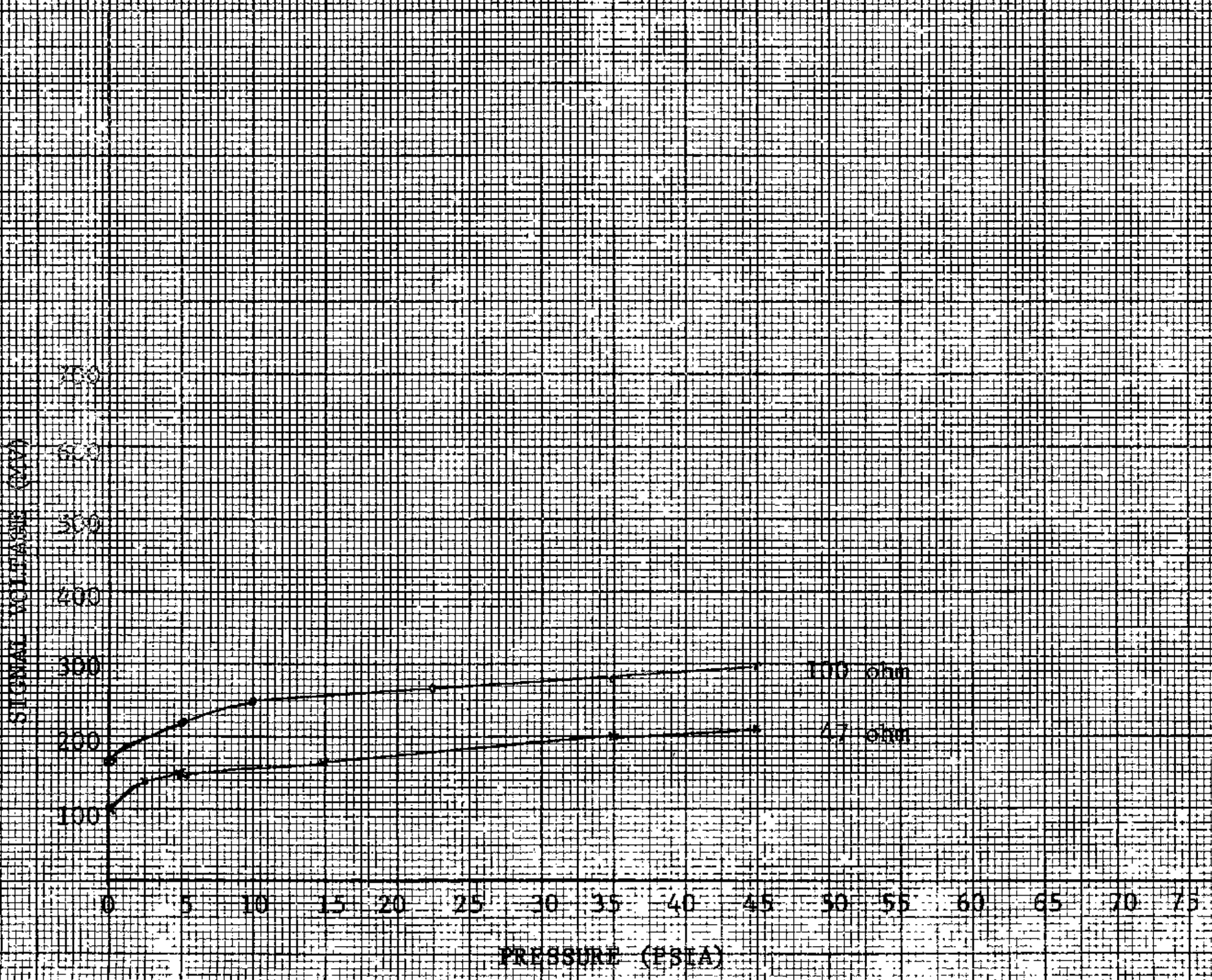


FIGURE 35

DESIGN MODIFICATION TWO
TEMPERATURE 24°C



dried (450°F) overnight to remove the spray solvents. Figure 36 presents the results of the evaluation of this design including first cycle voltage decay. It is observed that the signal voltage is again depressed (with respect to the basic design) and signal hysteresis occurred.

4. Design Modification Four

In this design the sintered nickel electrode was replaced with 7 mil sheet nickel cut to the same dimensions (10 cm^2 area). To increase the surface area, the electrode was etched in 0.1 N nitric acid for one minute. There was no teflonation process associated with this design.

Design evaluation results are presented in Figure 37. The magnitude of the signal voltage for this design appears too low to be useful.

D. Conclusions

The objective in this study to lessen the hysteresis (residual signal voltage increase with cycling) associated with signal electrode operation was not achieved. The various design modifications evaluated (generally consisting of different teflon de-wetting applications) reduced or depressed usable signal voltage (design modifications two and four), or where the signal produced indicated promise, signal hysteresis was still evident (design modifications one and three).

FIGURE 36

DESIGN MODIFICATION THREE
TEMPERATURE 24°C

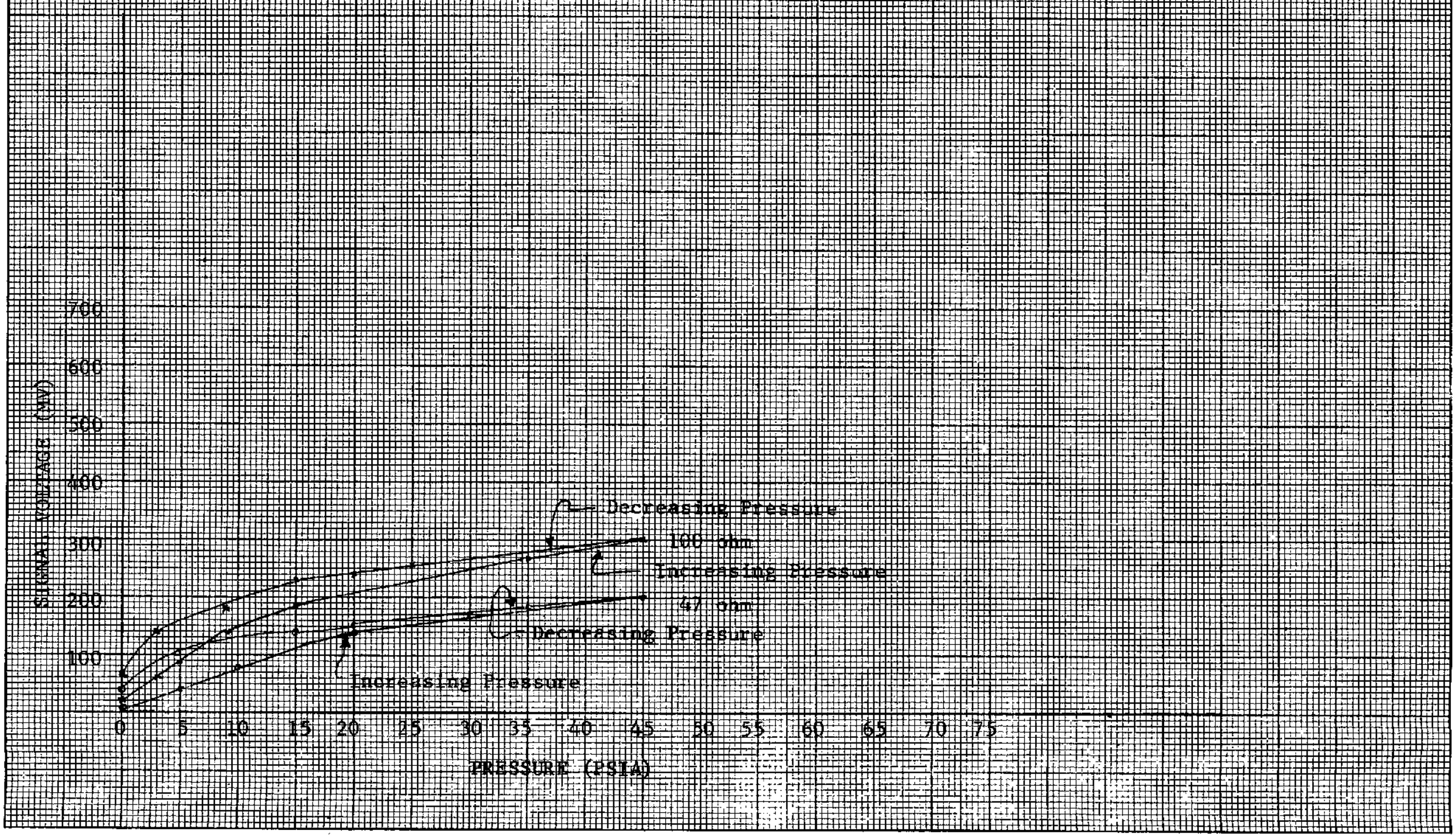
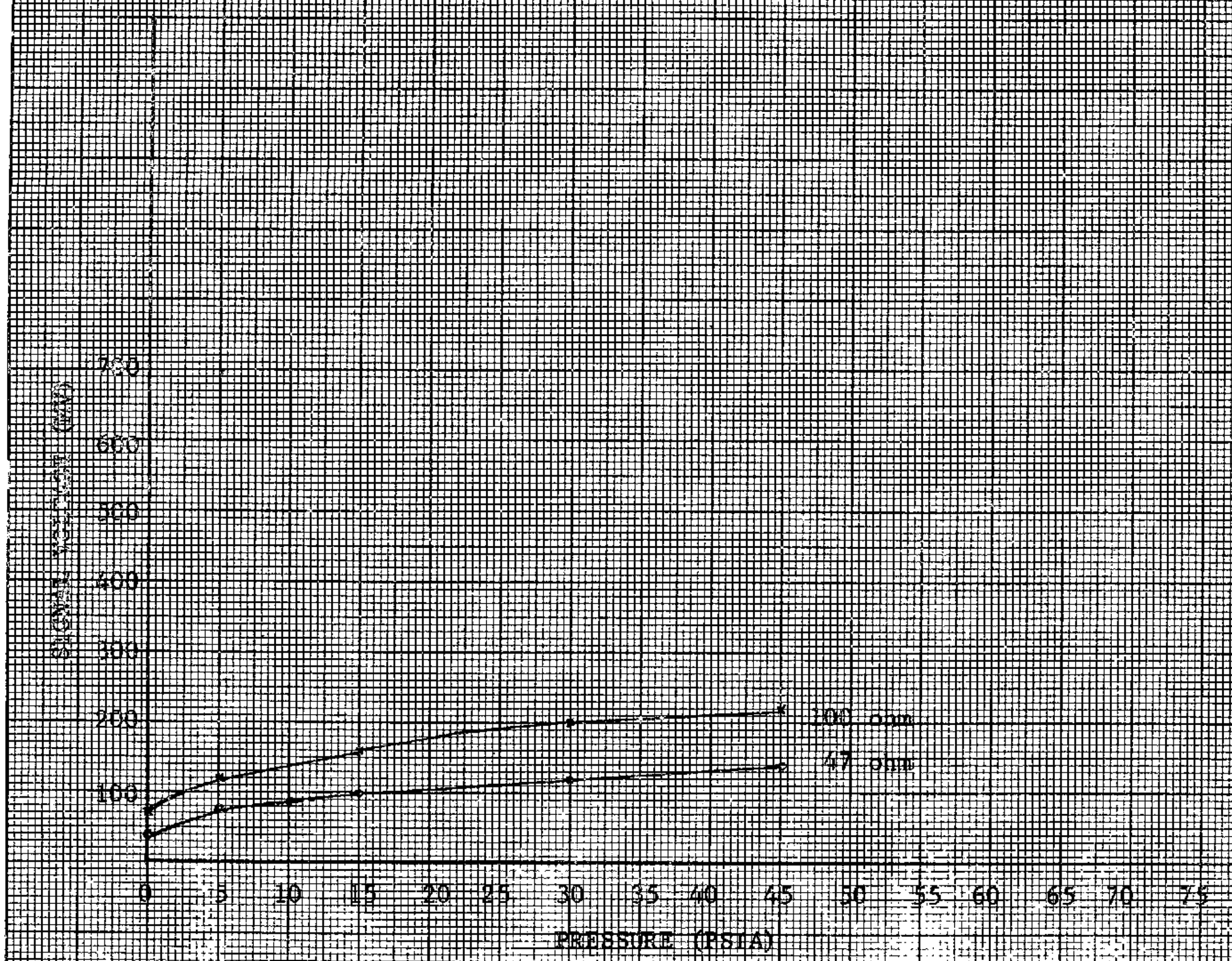


FIGURE 37

DESIGN MODIFICATION FOUR
TEMPERATURE 24°C



XI. PARAMETRIC CELL STUDY

A. Introduction

In the final phases of the Process Variable Study Program selected process variables associated with the sealed nickel-cadmium system were investigated at the actual cell level. Specifically, the process variables or parameters selected were associated with the cell electrodes. The effort was implemented by the careful processing and control of electrode groups to assure the incorporation of the desired parameter levels. These electrodes were fabricated into cells forming cell groups which were then characterized by a short sequence of acceptance type tests. The primary characterization will consist of cycle life tests conducted at The U. S. Naval Ammunition Depot (NAD), Crane, Indiana.

In addition, the parametric cells incorporate into their design a culmination of the results evolved from the previous sections of this report. Process variable study design improvements (optimization and increase control) were included from the initial sintered plaque process, through use of Pellon 2505 ML separator, to activation using the new vacuum burette activation system and including gauge and valve assembly which feature the new sealant described in the applicable section.

Specific information concerning the design levels utilized in the parametric cells will be presented later in this section.

B. Parametric Plan

The Eagle-Picher RSN-21 sealed, nickel-cadmium, aerospace cell was selected for use in this investigation (See Figure 38). The cell is nominally rated at 21 ampere hours at 24°C and contains 11 positive and 12 negative electrodes. For this program, the separator material was Pellon 2505 ML a 10 mil non-woven nylon material. The cover assembly was of a pinch tube design and was procured under the new comprehensive procurement specification (EP-MS-122).

Six (6) parameters of interest were selected; to investigate these, six (6) groups of four (4) cells each were processed. The parameter levels which are associated with the cell electrodes may be defined as follows:

1. Group I, Low Active Material Loading (Cell S/N 13-16)

   This group of cells is intended to investigate the effects of low electrode active material loading (impregnation level) in the sealed nickel-cadmium system. Targeted loading levels were 0.5-0.6 grams/in^2 for positive and 0.7-0.8 grams/in^2 for negative electrodes.

2. Group II, One Formation Cycle (Cell S/N 17-20)

   The purpose of this group of cells is to evaluate the effect of the elimination of additional formation cycles. After completion of an original low-rate formation cycle, electrodes typically receive three (3) additional higher rate charge/discharge cycles to enhance electrochemical cleaning, and improve voltage and oxygen recombination characteristics.

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	(1-3) REVISED PER ED. 25581	13 NOV 70	JSC

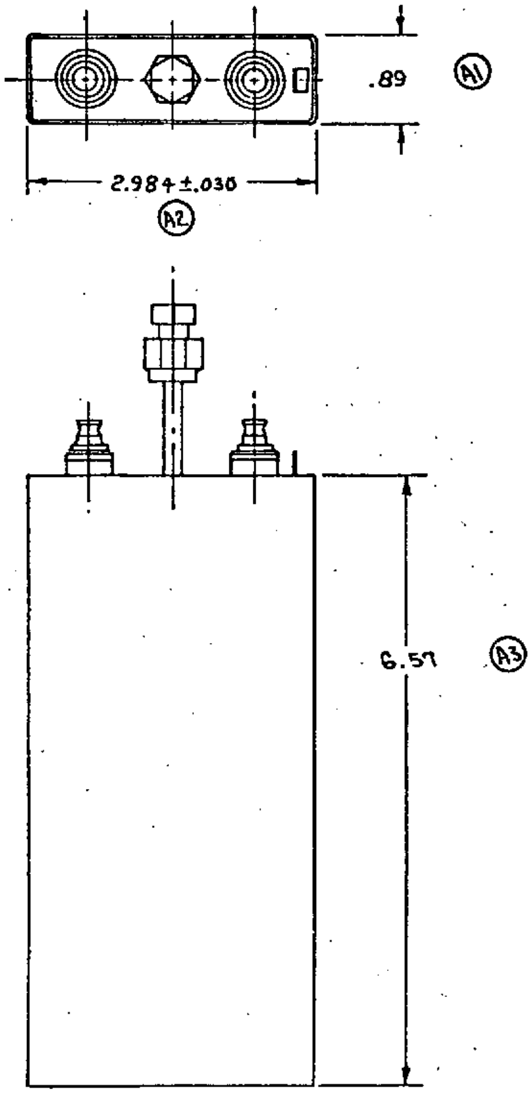


FIGURE 38

NOTES:

1. CELLS MAY BE LABELED BY ELECTROETCHING:

NICKEL-CADMIUM CELL
RSN-21B
EAGLE PICHER IND INC

FIND NO.	QTY REQD.	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	SPEC	MATERIAL OR NOTE	EP NO.

PARTS LIST

RSN-21
NEXT ASSY USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS DECIMALS ANGLES
±1/32 2PL ±.01 3PL ±.001 [illegible]

MATERIAL

CONTRACT NO

DATE
PREPARED JLA 24 SEP 70
CHECKED 25 SEP 70
ENGINEER HJB 25 SEP 70

EAGLE PICHER INDUSTRIES, INC.
COUPLES DEPARTMENT
JOPLIN, MISSOURI

CELL OUTLINE

C 81855 RSN-21B

SCALE 1/1 SHEET

Medium targeted loading levels were 0.7-0.8 grams/in^2 for positive and 0.9-1.0 grams/in^2 for negative electrodes.

3. Group III, Ten Formation Cycles (Cell S/N 21-24)

   To evaluate the effects of increasing the number of additional formation cycles, this group of cells included 10 additional formation cycles, in their processing. Medium targeted loading levels were 0.7-0.8 grams/in^2 for positive and 0.9-1.0 grams/in^2 for negative electrodes.

4. Group IV, Vacuum Dried Electrodes (Cell S/N 25-28)

   Immediately after completion of the final washing procedure, the electrodes of this group were vacuum dried. It is believed this technique might be used to prevent or retard carbonate contamination and this group is intended to evaluate the technique's effects upon cell performance. Moderate targeted loading levels were 0.7-0.8 grams/in^2 for positive and 0.9-1.0 grams/in^2 for negative electrodes.

5. Group V, High Active Material Loading (Cell S/N 29-32)

   This group of cells incorporated electrodes with high loading levels to evaluate the effects of pushing the capacity of sealed nickel-cadmium cells to higher levels. Targeted loading levels were 0.9-1.0 grams/in^2 for positive and 1.1-1.2 grams/in^2 for the negative electrodes.

6. Group VI, Formation Cycle Reversal (Cell S/N 33-36)

   During the three (3) additional formation cycles (standard production) the electrodes are normally discharged to a potential of 1.00 volts at which time the discharge is terminated.

In this final group of cells the discharge is continued past this point for a period of three (3) hours to evaluate the electrochemical cleaning effects resulting from a reverse gas evolution period. Medium targeted loading levels were 0.7-0.8 gram/in^2 positive and 0.9-1.0 grams/in^2 for the negative electrode.

Appendix C defines the process steps required in production of the subject electrode groups. In addition, this document defines a number of specific process levels (applicable to all electrode groups) whose values were selected based upon information evolved from previous work in this program.

Appendix D contains the manufacturing flow sheets which lists the pertinent build data associated with the parametric cells.

C. Activation and Conditioning

All parametric cell groups were activated (electrodes in the discharged state) with a volume of 1.350 sp. gr. KOH electrolyte equivalent to approximately 14.5% by weight of the respective core weights. The cells were then allowed to stand in a seal condition for a period of 24 hours.

All groups were then subjected to the following cycles.

1. Virgin Cycle

Temperature 75 ± 5°F

a. Charge c/10 rate (2.0 amps), 20 hours

b. Discharge C/2 rate (10.0 amps) to 1.0 volts per cell

c. Short one (1) ohm resistor for 16 hours minimum

d. Dead short one (1) hour minimum.

2. Precharge Introduction

After completion of the above sequence, the cells were again placed on charge at a C/10 rate and allowed to go into an overcharge condition. At this point, based upon the observed gauge pressure and the known free volume of each cell group, determined amounts of oxygen gas were removed from each cell to introduce a desired level of negative electrodes precharge.

An ampere hour equivalent of oxygen to 40% of the excess negative electrode capacity was removed to introduce this percent as precharged negative electrode capacity. The average excess negative electrode capacity for each parametric cell group was estimated based upon the known electrode loading factor and assuming 90% efficiency for positive and 60% efficiency for negative electrodes. Table XV summarizes the results of the activation and conditioning procedure.

D. Characterization Tests

Primary characterization of the parametric cell groups will be consummated by extensive cycle life tests conducted at the (NAD) Crane Test Facility. However, the cells were subjected to short sequence of acceptance type tests for preliminary characterization.

TABLE XV

PARAMETRIC CELL ACTIVATION

AND

CONDITION DATA

GROUP	NOMINAL CC's KOH INTRODUCED	NOMINAL CELL GROUP FREE VOLUME (CC)	OXYGEN REMOVED (CC)
I	59	98	1,880
II	66	91	1,530
III	62	100	860
IV	65	108	1,530
V	65	81	1,340
VI	62	105	1,580

Acceptance Test Sequence

1. Temperature 75 ± 5°F
   - a. Charge C/10 (2.0 amps) 20 hours.
   - b. Discharge C/2 (10.0 amps) to 1.00 volts.
   - c. Short one (1) ohm resistor 16 hours minimum.
   - d. Dead short one (1) hour minimum.

     NOTE: Steps c) and d) were performed at completion of each test.
2. Temperature 32 ± 5°F
   - a. Charge C/20 (1.0 amps) 48 hours.
   - b. Discharge C/2 (10.0 amps) to 1.00 volts.
3. Temperature 95 ± 5°F
   - a. Charge C/10 (2.0 amps) 20 hours.
   - b. Discharge C/2 (10.0 amps) to 1.00 volts.
4. Temperature 75 ± 5°F
   - a. Charge C/10 (2.0 amps) 20 hours.
   - b. Discharge C/2 (10.0 amps) to 1.00 volts.

After completion of the above sequence, selected cells from each parametric cell group were subjected to a precharge and then a flood electrode capacity measurement.

Precharge Measurement

1. Charge C/10 (2.0 amps) 20 hours.
2. Discharge C/2 (10.0 amps) to -1.00 volts.
3. Precharge amount measured from 0.00 volt to -1.00 volt.

Flooded Electrode Capacity Measurement

1. Flood cell with excess electrolyte.
2. Charge C/4 (5.0 amps) 20 hours.
3. Discharge C/2 (10.0 amps) to -1.00 volts.
4. Positive electrode capacity measured to 1.00 volts; negative electrode capacity measured from 0.00 volts to -1.00 volts.

Tables XVI through XIX present the results of preliminary characterization tests. Table XVI briefly re-summarizes the parametric cell program to facilitate review of the subsequent tables. Table XVII presents the summarized results of the acceptance test sequence. Table XVIII compares the charge efficiency factor for various parametric groups. And finally, Table XIX summarizes the results of the precharge and flooded electrode capacity measurements.

Appendix E contains the actual test data for various tests summarized in the following tables. As the results of test equipment failure, certain tests were repeated and both data records may be found in this appendix. In addition, the actual data records for the first 75°F acceptance test was misplaced after summarizing and will not be found in this appendix.

E. Results and Conclusions

1. The beneficial effects of additional formation cycles was substantiated by the low pressure and low charge voltage characteristics associated with parametric cell Group No. III. However, there appears to be some penalty in cell electrical capacity.

TABLE XVI

PARAMETRIC CELL PARAMETER LEVELS

Cell Size 20 Ampere Hour, Sample Size 24 Cells, 4 Cells/Parameter.

Group I	Low electrode loading, 0.5-0.6 grms./sq. in pos.; 0.7-0.8 grms./sq. in.neg.; three (3) formation cycles.
Group II	Moderate electrode loading, 0.7-0.8 grms./sq. in. pos.; 0.9-1.0 grms./sq. in. neg.; one (1) formation cycles.
Group III	Moderate electrode loading, ten (10) formation cycles.
Group IV	Moderate electrode loading, plaques vacuum dried during processing, three (3) formation cycles.
Group V	Heavy electrode loading, 0.9-1.0 grms./sq. in. pos.; 1.1-1.2 grms./sq. in. neg.; three (3) formation cycles.
Group VI	Moderate electrode loading, plaques over discharged during formation, three (3) formation cycles.

TABLE XVII

PARAMETRIC CELL PERFORMANCE DATA

GROUP	I	II	III	IV	V	VI
TEST TEMPERATURE 75°F						
PV	1.425	1.433	1.420	1.442	1.432	1.423
PP	10	30	10	100	35	55
AH	17.7	27.0	24.2	26.5	26.4	22.5
TEST TEMPERATURE 32°F						
PV	1.486	1.515	1.465	1.520	1.520	1.514
PP	30	80	9	90	55	55
AH	16.3	25.4	22.5	25.0	25.0	21.3
TEST TEMPERATURE 95°F						
PV	1.398	1.400	1.380	1.397	1.404	1.403
PP	85	100	55	100	60	70
AH	11.3	21.7	12.5	20.5	23.3	20.0
TEST TEMPERATURE 75°F						
PV	1.455	1.468	1.425	1.460	1.470	1.475
PP	35	55	-3	40	25	80
AH	17.5	27.2	22.8	27.0	27.3	22.8

PV	Peak Volts
PP	Peak Pressure (psig)
AH	Ampere Hour Capacity

TABLE XVIII

PARAMETRIC CELL CHARGE EFFICIENCY DATA

GROUP	I	II	III	IV	V	VI
75°F CAPACITY VERSES THEORECTICAL						
%	72	92	78	91	70	80
32°F CAPACITY VERSES 75°F CAPACITY						
%	92	94	93	94	94	95
95°F CAPACITY VERSES 75°F CAPACITY						
%	64	80	52	77	88	89

TABLE XIX

PARAMETRIC CELL PRECHARGE AND FLOODED ELECTRODE CAPACITY MEASUREMENT

PRECHARGE MEASUREMENT
(CHARGED NEGATIVE CAPACITY BEYOND POSITIVE CAPACITY)

S/N	16	19	22	26	32	35
Negative AH	23.7	30.0	25.7	32.7	29.5	26.0
Positive AH	16.5	28.0	20.9	28.7	26.7	23.4
Precharge AH	7.2	2.0	4.8	4.0	2.8	2.6

FLOODED ELECTRODE CAPACITY

Positive AH	22.2	29.8	28.0	29.7	31.9	26.3
Negative AH	45.8	48.3	41.7	50.0	43.9	42.5

2. Lightly loaded electrodes of parametric cell Group No. I also demonstrated relatively low pressures and low charge voltages, but the cells also exhibit poor electrical capacities. This cell group's high initial voltages during certain charges indicate they may contain insufficient quantities of electrolyte. A cell core made up of lightly loaded electrodes may require a higher percent of electrolyte than a normal design.
3. Parametric cell Group No. IV, containing vacuum dried electrodes, demonstrate very unusual pressure characteristics. The repeated occurrence of high cell pressures indicate vacuum drying affects the negative electrode recombination ability.
4. All cells in the parametric cell study have demonstrated unusually high pressures during the 35°C test. No explanation can be offered at this time for this occurrence.
5. Significant different electrical efficiencies between the different parametric groups were also observed. Efficiency appears to be inversely related to the number of formation cycles and is maximized by certain loading levels. For example, both lighter and heavier loaded cell groups are less efficient than medium-loaded groups.
6. Variation in precharge measurements were noted and the values recorded were typically lower than expected. The data probably reflects an inability of existing tests to measure the actual precharge available.

7. Observing the flooded electrode capacity data, it is noted the parametric cell groups which suffered lower capacity and charge efficiency (Groups I and III) benefited the most from excess electrolyte (increase in positive capacity). This may indicate, as suggested above, that small variation in design and processing require readjustment of electrolyte percents.

REFERENCES

(1) First Quarterly Report, Study of Process Variables Associated with Manufacturing Hermetically-Sealed Nickel-Cadmium Cells, prepared for NASA/GSFC, Contract Number NAS 5-21159, September, 1970; Eagle-Picher Industries, Inc., Joplin, Missouri.

(2) Second Quarterly Report, Ibid, December, 1970.

(3) Third Quarterly Report, Ibid, July, 1971.

(4) Fourth Quarterly Report, Ibid, September, 1971.

(5) Fifth Quarterly Report, Ibid, May, 1972.

(6) Barney, D. L.; Catotti, A. J.; and Pensabene, S. F. "Effect of Carbonate on the Performance of Sealed Nickel-Cadmium Cells", Power Sources 3, Great Britain, Oriel Press Limited, 1971.

(7) Interim Model Specification for High Reliability Nickel-Cadmium Spacecraft Cells, S-716-P-23, NASA/GSFC, April, 1969.

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(9) Fleischer, A., Determination of Carbonate in Potassium Hydroxide Electrolyte, U. S. Air Force Aero Propulsion Laboratory (Wright-Patterson Air Force Base, Ohio), Report Number 64AF11IT01, November, 1964.

APPENDIX A

FACTORIAL EXPERIMENTS

AND

REGRESSION ANALYSIS

APPENDIX A

FACTORIAL EXPERIMENTS AND REGRESSION ANALYSIS

With a particular manufacturing phase there is normally associated a number of process variables. An attempt to evaluate a process variable by changing its value results in the introduction of different possible combinations which require additional evaluation. The task of determining the effects of large numbers of process variables and their possible value combinations upon the results of a manufacturing process can obviously become quite formidable.

To avoid this difficulty, a statistical technique referred to as fractional, factorial design experiment was used. Briefly, this technique involves performing a limited number of experiments evaluating only a fraction of the possible variable combinations. However, the combinations evaluated contain pre-selected process variable values which permit determination of the main effects of each process variable. Throughout this program a process variable was evaluated at two (2) value levels.

To determine the main effects, the data resulting from the design experiments are subjected to a regression analysis. Actual mathematical implementation is by means of a computer program. The program evaluates the data resulting from the design experiments by mathematically (statistically) weighing each process variable's effect upon a particular manufacturing process result, for example, sintered plaque porosity. The program then calculates a numerical value which reflects the variable's significance with respect to the overall process.

Two interpretations may then be applied to the regression analysis results. The magnitude of the numerical value associated with a process variable defines its importance in the manufacturing process and renders information as to areas for increased process control to improve uniformity. In addition, the sign (positive or negative) of the numerical value indicates the change in a process variable value (increase or decrease) to effect an improvement in a manufacturing process result, for example, decrease sintering furnace temperature to increase sintered plaque porosity. In other words, the latter interpretation permits the optimization of the manufacturing process.

The enclosed figure visually presents the basic principles of the regression analysis technique for two and three variables. Additional discussion and specific application of the above statistical procedures may be found in the First through Fourth Quarterly Reports (1) (2) (3) (4) under the subject program.

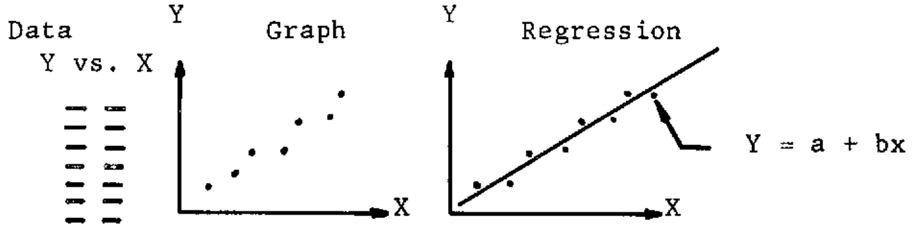
REGRESSION ANALYSIS, BASIC PRINCIPLES

PROBLEM

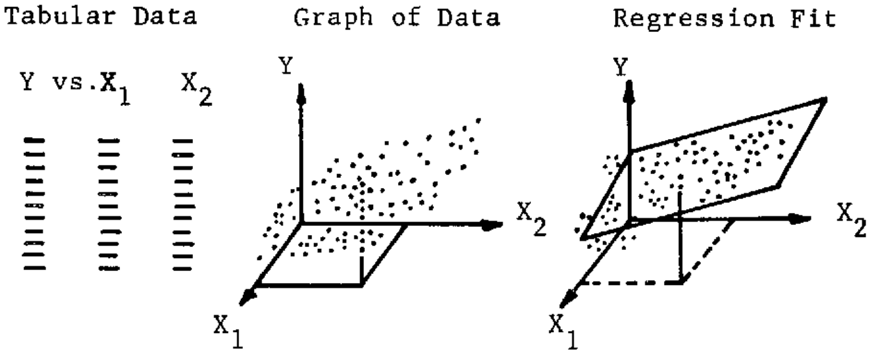
Y vs. X_1 X_2 X_3 . . . X_n

REGRESSION ANALYSIS

TWO VARIABLES



THREE VARIABLES



REGRESSION EQUATION

$$Y = a + b\ (X_1) + c\ (X_2) + d\ (X_3) + \ . \ . \ . \ + N\ (X_n)$$

Interpretation

Evaluation of coefficients b, c, d, . . . , N reveal main effects.

Prediction

Substitution of different variable values permit prediction for Y under levels and combinations of levels not tested.

APPENDIX B

VACUUM BURETTE ACTIVATION SYSTEM

OPERATING INSTRUCTIONS

1.0 SCOPE

The following document defines the "vacuum burette" cell electrolyte activation system. The information contained herein is primarily of an operating instruction nature.

2.0 EQUIPMENT

2.1 The necessary equipment and typical system setup is shown in the enclosed figure.

2.2 A burette size applicable to the volume of electrolyte to be introduced should be used. For example, if 16 ml's of electrolyte were the desired volume, a 25 ml rather than a 50 ml burette would be used.

3.0 PREPARATION

3.1 The system must be thoroughly clean. If the system does not appear to be clean, proceed to the washing procedure defined below.

3.2 Apply a light film of silicone stopcock grease to both stopcocks A and B.

3.3 Open valve on CO_2 absorption bulb (located in top plug) to the atmosphere.

3.4 Introduce a volume of electrolyte into the burette, as defined below, a few ml's greater than that estimated required. This operation is intended to "wet" the surface of the burette which is necessary to the proper formation of a "meniscus" and to remove any residual water remaining from a previous washing procedure. Drain this volume of electrolyte and discard.

4.0 ACTIVATION PROCEDURE

4.1 Stopcocks A and B are in the off position (handles in horizontal position).

4.2 Turn Stopcock A to burette fill position. As the electrolyte approaches the specified level on the burette scale, the flow rate shall be reduced in order that the bottom of the electrolyte meniscus may be precisely stopped on the correct scale position.

In order to reduce error, the eye must be level with the top of the liquid during the latter part of the above operation.

The burette shall be filled within ± 0.05 ml of the specified volume.

4.3 Turn Stopcock A to off position and then turn Stopcock B to cell vacuum position. Draw a minimum of -25 inches of vacuum on the cell.

4.4 Turn Stopcock A to burette drain position and then slowly turn Stopcock B to cell fill position. Set drain rate to require roughly 5-10 seconds to remove electrolyte from main body of burette.

4.5 As the level of electrolyte nears the bottom of the burette, the drain rate should be further reduced to require an additional 2-4 seconds for the electrolyte to pass through the capillary bore section of the stopcocks and interconnecting tubes. Allowing the electrolyte to be drawn through these confined areas too fast will cause "sputtering" of the electrolyte, leave small drops of the electrolyte in the capillary bores, and result in an error in activation.

4.6 As soon as the electrolyte has been completely drawn into the cell, turn Stopcock B fully open (vertical position of handle) for 2-3 seconds to neutralize the remaining vacuum in the cell with air drawn through the CO_2 absorption system. Then turn Stopcock A and B to the off position in preparation for the next activation cycle.

4.7 If the level of electrolyte is accidentally allowed to fill pass the desired burette scale point, the burette and stopcocks should be completely drained and procedure started again.

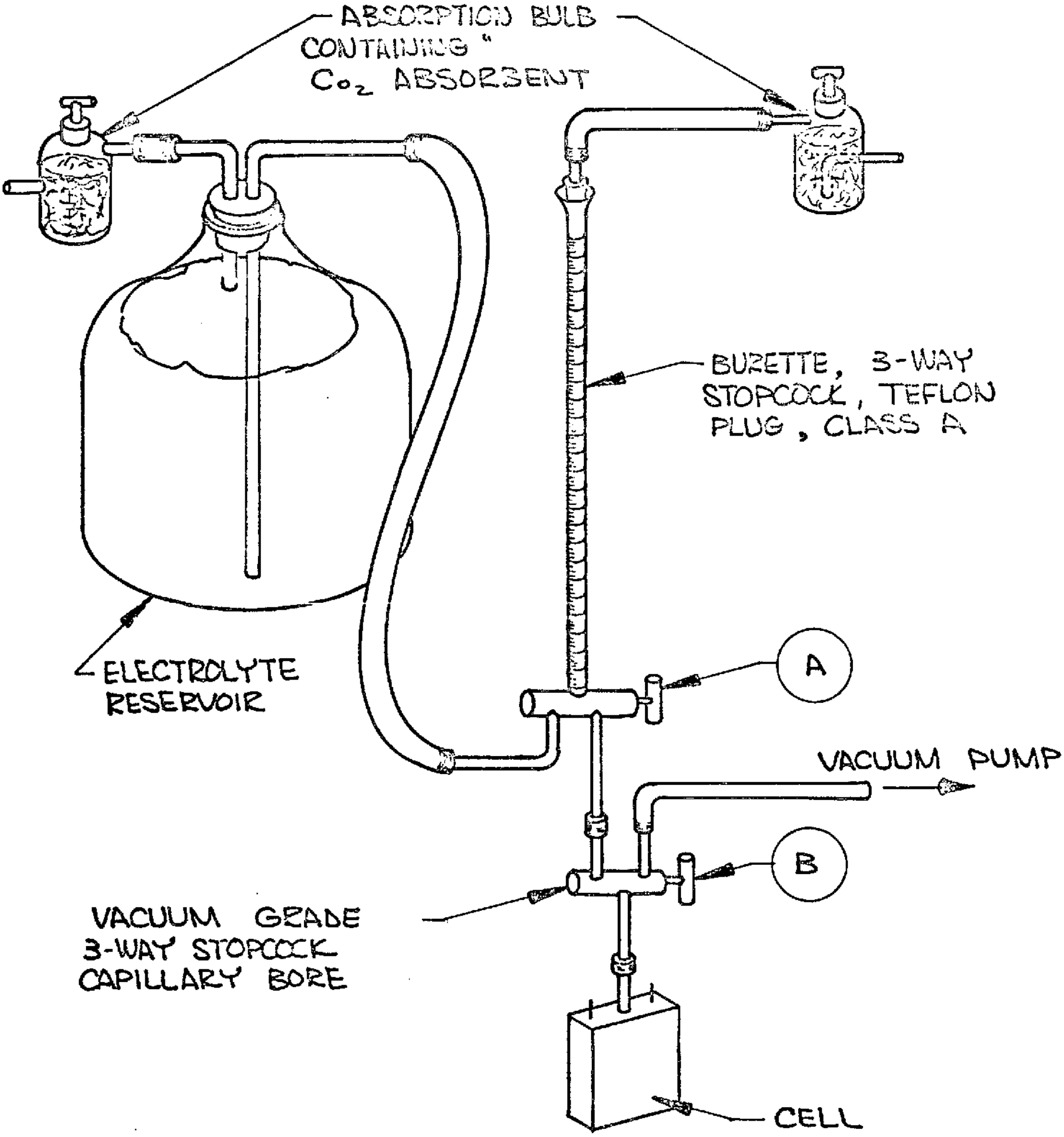
5.0 WASHING PROCEDURE

The strong caustic used in the above operation will attack the glass components of the above activation system. The system must be thoroughly washed after completion of the activation process.

5.1 Remove Stopcock A and B and wash in tap water. Flush the entire burette and stopcock systems twice with tap water. Flush the electrolyte reservoir and electrolyte feed tube assembly twice with tap water. Flush the vacuum tube assembly once with tap water.

Finally, flush all of the above items with the exception of the vacuum tube assembly once with deionized or distilled water.

5.2 Store the activation system with Stopcock A in the burette drain position and Stopcock B in the cell fill position to permit these items to drain. Close the valve on the CO_2 absorption bulb.



VACUUM BURETTE INDIVIDUAL CELL ELECTROLYTE ACTIVATION SYSTEM

APPENDIX C

PARAMETRIC CELL ELECTRODE PROCESSING REQUIREMENTS

SCOPE

The following document defines the impregnation/polarization/formation requirements for the fabrication of plaques for the "Parametric Cell Study" phase of the NASA "Process Variable Study" Program.

Briefly, the program plan consists of the fabrication of 20 RSN-21 cells divided into five (5) parametric cell groups (four (4) cells each) investigating five (5) independent parameters. It is intended the five (5) plaque groups incorporating the desired variables for this study will be obtained from a single tank of positive (116) and negative plaques (120).

The following requirements are inaddition to the standard manufacturing specifications which apply.

I. SINTERED PLAQUES

1) Size - RSN-21

2) Thickness - Positive 0.028 ± 0.003
   Target 0.027 ± 0.001

   Negative 0.028 ± 0.003
   Target 0.029 ± 0.001

3) Thickness Variation - ± 0.001 across entire plaque surface.

4) Strength - Positive 600 - 800 lbs.

   Negative 200 - 800 lbs.

5) Porosity - 85% or greater

6) Weight Tolerance - ± 2 grams about $\bar{X}$

II. IMPREGNATION CYCLE

	POSITIVE	NEGATIVE
1) Temperature	200° ± 10°F	135° ± 10°F
2) Specific Gravity	1.70 ± 0.05	1.80 ± 0.05

II. IMPREGNATION CYCLE (CONTINUED)

	POSITIVE	NEGATIVE
3) Free Acid	1.0 ± 0.1 g/1	0.5 ± 0.1 g/1
4) Time	One Hour	One Hour
5) Vacuum	No	No

III. POLARIZATION CYCLE

Standard Procedure

IV. FIRST FORMATION CYCLE

The first formation cycle after completion of the impregnation/polarization process shall consist of a 170% overcharge at a 16 hour rate. Throughout this work, the electrical capacity shall be based upon 90% of theoretical for positive and 60% of theoretical for negatives.

Additional formation requirements beyond this initial step will be defined in the applicable plaque group sections.

V. PLAQUE GROUP ONE (20 Positives and 16 Negatives)

1) Impregnation Cycle - Positive three (3) cycles - Negative four (4) cycles.

2) Formation - After completion of the first formation cycle defined above, the plaques shall be discharged to a potential of 1.0 volts at a C/3 rate. The plaques will then be subjected to three (3) charge (4 hours)/discharge cycles at a C/3 rate. The electrolyte shall be changed after the completion of the charge phase of each cycle.

   In this work, the plaques will always end the process in the discharged state.

3) Washing and Liquid Honing - The plaques shall be washed a minimum of 4 hours before being subjected to the liquid honing operation. After completion of this operation the plaques shall be returned immediately to the washing process and washed to pass the "Phenolphthalein Test".

4) Plaque Pressing - The plaques shall be pressed only to remove the bend. The shims used in this operation shall be 0.002" - 0.005" thicker than the nominal plaque thickness.

5) Drying - The plaques shall be air dried.

6) Storage and Shipping - Immediately after completion of the drying operation, a group of plaques shall be placed in a polyethylene bag (no cardboard or other materials inside of bag), as much air as possible removed, and the bag heat sealed.

For identification purposes, it is desirable that each of the plaque groups defined in this document be contained in individual bags; for example, the 20 positive plaques of Plaque Group One would be contained in a bag and the 16 negatives in another.

For shipping, the individual heat sealed polyethylene bags may be separated with cardboard sheets and shipped in any convenient configuration.

VI. PLAQUE GROUP TWO (16 Positives and 16 Negatives)

1) Impregnation Cycles - Positive four (4) cycles - Negative five (5) cycles.

2) Formation - After completion of the first formation cycle, the plaques shall be discharged to a potential of 1.0 volts at a C/3 rate. (No additional formation cycles).

3) Washing and Liquid Honing - See V,3).

4) Plaque Pressing - See V,4).

5) Drying - See V,5).

6) Storage and Shipping - See V,6).

VII. PLAQUE GROUP THREE (16 Positives and 16 Negatives)

1) Impregnation Cycles - See VI,1)

2) Formation - See V,2) except plaques shall receive ten (10) additional formation cycles rather than three (3).

3) Washing and Liquid Honing - See V,3).

4) Plaque Pressing - See V,4).

5) Drying - V,5).

6) Storage and Shipping - See V,6).

VIII. PLAQUE GROUP FOUR (30 Positives and 30 Negatives)

The single parameter of investigation for Group Four is hopefully plates containing minimum amounts of carbonate contamination. It is imperative this group of plaques be handled through the process in a fashion which will minimize their exposure to the atmosphere i.e., maintaining plaques under water, if necessary, to hold between processes.

1) Impregnation Cycles - See VI,1).

2) Formation - See V,2).

3) Washing and Liquid Honing - See V,3)

4) Plaque Pressing - See V,4).

5) Drying - The plaques shall be vacuum dried. If this is not feasible, the plaques, in the wet state, shall be immediately processed as defined in the Storage and Shipping Section and shipped to this facility for the vacuum drying operation.

6) Storage and Shipping - See V,6).

IX. PLAQUE GROUP FIVE (34 Positives and 42 Negatives)

1) Impregnation Cycles - Positive Six (6) cycles - Negatives - seven (7) cycles.
2) Formation - See V,2).
3) Washing and Liquid Honing - See V,3).
4) Plaque Pressing - See V,4).
5) Drying - See V,5).
6) Storage and Shipping - See V,6).

CHANGE

VIII. PLAQUE GROUP FOUR (30 Positive and 30 Negative)

to

PLAQUE GROUP FOUR (14 Positive and 14 Negative)

ADD

X. PLAQUE GROUP SIX (16 Positive and 16 Negative)

Same as Plaque Group Four except formation procedure. All discharges associated with the first and additional formation cycles shall be continued pass the 1.00 V potential point for three (3) hours, in reversal, at the C/3 rate.

APPENDIX D

PARAMETRIC CELL
MANUFACTURING FLOW SHEETS

RSN-21B MANUFACTURING FLOW SHEET

CELL S/N	POS.GRP. WT. (GMS)	NEG.GRP.WT. (GMS)	CORE WT. (GMS)	POS.GRP.THK (IN.)	NEG.GRP.THK (IN.)	CORE THK. (IN.)	CELL DRY WT. (GMS)	KOH WT. (GMS)	AFTER ACT.WT. (GMS)	AFTER COND.WT. (GMS)	FINISHED CELL WT. (GMS)
	Group I	11 Pos / 12 Neg Plates									
13	211	330	553	.264	.367	.827	742	80	822		
14	211	330	552	.266	.367	.800	743	80	823		
15	211	330	552	.266	.367	.812	740	78	818		
16	211	330	551	.265	.368	.800	739	80	819		
	Group II	11 pos / 12 Neg Plates									
17	251	352	613	.286	.375	.835	802	88	890		
18	251	352	614	.286	.374	.840	801	88	889		
19	251	352	614	.287	.375	.837	804	89	893		
20	251	352	614	.290	.375	.836	802	88	890		
	Group III	11 Pos / 12 Neg Plates									
21	252	322	584	.300	.357	.824	771	84	855		
22	252	322	583	.300	.352	.825	772	84	856		
23	252	322	583	.297	.355	.825	771	84	855		
24	252	322	584	.300	.353	.824	776	84	860		
	Group IV	11 Pos / 12 Neg Plates									
25	251	355	616	.295	.398	.842	805	88	893		
26	251	355	616	.293	.395	.849	802	88	890		
27	251	355	616	.294	.395	.840	804	89	893		
28	251	355	616	.290	.395	.550	804	88	892		

DATE OF CELL GROUP ACTIVATION 8-1-72 OPERATOR Allison

INSPECTION Lot 45, Mix 27

RSN-21B MANUFACTURING FLOW SHEET

CELL S/N	POS.GRP. WT. (GMS)	NEG.GRP.WT. (GMS)	CORE WT. (GMS)	POS.GRP.THK (IN.)	NEG.GRP.THK (IN.)	CORE THK. (IN.)	CELL DRY WT. (GMS)	KOH WT. (GMS)	AFTER ACT.WT. (GMS)	AFTER COND.WT. (GMS)	FINISHED CELL WT. (GMS)
	Group V	10 pos	/ 11 neg	plat							
29	254	328	590	.275	.342	.775	779	88	867		
30	254	328	590	.280	.345	.800	778	88	866		
31	254	328	592	.275	.344	.785	780	88	868		
32	254	328	592	.280	.340	.790	781	88	869		
	Group VI	10 pos	/ 11 Neg	plates							
33	231	333	570	.267	.375	.795	756	86	842		
34	231	333	573	.271	.373	.806	764	84	848		
35	231	333	572	.272	.375	.815	761	83	844		
36	231	333	573	.270	.370	.790	761	85	846		

DATE OF CELL GROUP ACTIVATION 8-1-72 OPERATOR

INSPECTION Lot 46, [illegible] 27

APPENDIX E

PARAMETRIC CELL TEST DATA

ITEM 1

FIRST 95°F CAPACITY TEST

RSN 20 DATA SHEET (CHARGE RECORD)

Chg. Rate 2.0 Amp. (Start @ 18:30

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE 95°F DATE 9-25-72

TEST DESCRIPTION ________

		5 MIN.			1 HOUR			2 HOURS			3 HOURS			4 HOURS		
	CELL S/N	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
1	13	1.367	-28	91	1.370	-28	93	1.375	-26	92	1.380	-10	92	1.384	+5	93
2	14	1.367	-26		1.372	-26		1.378	-26		1.381	-5		1.389	+6	
3	15	1.383	-28		1.380	-28		1.381	-28		1.386	-15		1.390	000	
4	16	1.393	-28		1.383	-28		1.380	-28		1.380	-20		1.384	-1	
5	17	1.344	000		1.352	000		1.360	000		1.363	000		1.368	+1	
6	18	1.329	+5		1.353	+5		1.361	+2		1.367	+2		1.372	+2	
7	19	1.323	+4		1.351	+4		1.363	+4		1.366	+1		1.374	+1	
8	20	1.334	000		1.354	000		1.368	-2		1.370	-2		1.375	-2	
9	21	1.294	-36	93	1.342	-30	92	1.356	-21	94	1.361	+1	94	1.368	+12	94
10	22	1.312	-27		1.347	-27		1.358	-20		1.365	0		1.371	+15	
11	23	1.327	-30		1.357	-30		1.366	-20		1.370	-10		1.375	+10	
12	24	1.342	-30		1.350	-30		1.356	-28		1.365	-12		1.368	+12	
13	25	1.343	+53		1.356	+53		1.361	+50		1.366	+50		1.369	+52	
14		2														
15	27	1.356	+30		1.363	+30		1.367	+1		1.372	+1		1.374		+11
16	28	1.349	+35		1.361	+35		1.365	+27		1.369	+26		1.373	~~+33~~	+27
17	29	1.344	+27	92	1.354	+27	92	1.359	+33	92	1.366	+30	92	1.372	+33	93
18	30	1.342	-20		1.354	-20		1.361	-18		1.368	-18		1.371	+10	
19	31	1.348	000		1.360	000		1.368	-10		1.372	-10		1.378	00	
20	32	1.326	+5		1.352	+5		1.362	-8		1.367	-10		1.373	00	
21	33	1.293	-1		1.352	-1		1.364	+8		1.375	0		1.379	+6	
22	34	1.293	000		1.353	000		1.367	+00		1.379	-5		1.381		
23	35	1.277	+10		1.344	+10		1.360	-5		1.389	-8		1.375		
24	36	1.315	-10		1.362	-10		1.372	+10		1.374	0		1.384		

OPERATOR ________ INSPECTION ________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN ~~8~~ 20 DATA SHEET (CHARGE RECORD)

Chrg. Rate 2.0 amp.

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE 95 °F DATE 9-25-72

TEST DESCRIPTION ________

CELL S/N	5 HOURS			6 HOURS Box 98°			7 HOURS Box 96°			Box 92° 8 HOURS			9 HOURS			
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	
13	1.387			1.391	25	93	1.390	34	94	1.389	36	94	1.388	42	90	
14	1.391			1.393	32		1.391	41		1.389	45		1.386	48		
15	1.394			1.397	18		1.398	30		1.396	35		1.394	42		
16	1.390			1.394	22		1.394	36		1.396	45		1.393	55		
17	1.372			1.379	8		1.382	15		1.384	20		1.387	27		
18	1.380			1.384	10		1.388	17		1.394	23		1.396	32		
19	1.378			1.385	8		1.390	14		1.394	18		1.397	25		
20	1.380			1.385	2		1.390	6		1.394	10		1.398	16		
21	1.372			1.376	40	93	1.376	50	93	1.374	55	94	1.372	59	94	
22	1.374			1.386	47		1.375	60		1.373	65		1.372	70		
23	1.380			1.384	30		1.384	42		1.383	46		1.380	53		
24	1.375			1.376	26		1.377	35		1.377	40		1.378	47		
25	1.374			1.380	66		1.383	80		1.387	88		1.389	100	*	
27	1.379			1.383	38		1.388	43		1.391	50		1.398	60		
28	1.377			1.381	40		1.386	49		1.388	55		1.391	65		
29	1.379			1.382	4	88	1.387	12	88	1.389	18	89	1.394	32	[illegible]	
30	1.378			1.382	9		1.387	18		1.391	25		1.393	32		
31	1.382			1.388	10		1.393	18		1.395	25		1.399	33		
32	1.377			1.383	18		1.388	28		1.392	35		1.392	45		
33	1.388			1.394	18		1.398	29		1.401	35		1.403	42		
34	1.389			1.396	18		1.400	40		1.400	45		1.401	50		
35	1.383			1.389	35		1.393	49		1.395	65		1.394	68		
36	1.389			1.395	35		1.400	35		1.402	40		.400	45		

OPERATOR ________ INSPECTION ________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN ~~X~~ 26 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. _________ PARA. _______ AMBIENT TEMPERATURE 95 ± 5°F DATE 9-26-72
TEST DESCRIPTION 20 Hour overcharge @ 2 AMP

CELL S/N	10 HOURS Box 98°			11 HOURS Box 94°			12 HOURS Box 96°			13 HOURS Box 96°			0830 14 HOURS		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.382	45	98	1.378	46	100	1.378	46	101	1.377	45	102	1.377	45	103
14	1.380	52		1.374	51		1.373	50		1.374	48		1.375	48	
15	1.388	50		1.384	53		1.382	54		1.380	54		1.379	52	
16	1.392	72		1.384	81		1.381	87		1.378	90		1.379	92	
17	1.388	40		1.389	50		1.390	60		1.390	70		1.389	77	
18	1.398	46		1.398	60		1.399	70		1.398	83		1.400	72	
19	1.397	38		1.401	38		1.400	55		1.402	67		1.403	73	
20	1.406	25		1.403	34		1.405	42		1.407	50		1.406	56	
21	1.367	65	93	1.367	64	95	1.365	63	98	1.369	62	98	1.370	61	~~103~~ 95
22	1.366	75		1.364	75		1.343	72		1.366	72		1.365	71	
23	1.378	60		1.373	60		1.373	63		1.373	60		1.376	60	
24	1.373	53		1.369	55		1.369	57		1.370	55		1.371	55	
		100+			100+			100+							
27	1.394	78		1.396	94		1.399	100+ *							
28	1.391	83		1.395	98		1.395	100+ *							
29	1.394	40	94	1.396	50	94	1.397	60	97	1.398	70	97	1.399	85	98
30	1.395	46		1.394	58		1.397	60		1.396	80		1.396	83	
31	1.398	46		1.399	60		1.400	77		1.399	82		1.400	88	
32	1.393	64		1.394	79		1.394	51		1.393	100+	*	1.344		
33	1.402	51		1.398	58		1.397	64		1.394	69		1.399	92	
34	1.397	60		1.393	65		1.392	73		1.389	79		1.389	79	
35	1.394	80		1.390	90		1.388	96		1.386	100+	*			
36	1.398	53		1.398	60		1.395	60		1.395	63		1.397	63	

OPERATOR ____________________ INSPECTION ____________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 20 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ______ PARA. ______ AMBIENT TEMPERATURE 95 ± 5 °F DATE 9/26/92

TEST DESCRIPTION Overcharge @ 2.0 amps

CELL S/N	0930 15 HOURS			16 HOURS			1130 17 HOURS			1230 18 HOURS			1330 19 HOURS		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.378	44	101	1.379	94		1.377	44	103	1.3[illegible]	44	104	1.379	44	104
14	1.377	45		1.374	44		1.376	44		1.373	43		1.374	42	
15	1.379	50		1.380	50		1.379	50		1.379	50		1.380	49	
16	1.377	92		1.375	92		1.375	92		1.374	91		1.372	90	
17	1.389	89		1.387	88		1.388	91		1.385	94		1.386	96	
18	1.399	100*													
19	1.402	79		1.401	81		1.401	93		1.399	85		1.400	87	
20	1.407	62		1.408	61		1.408	63		1.409	62		1.410	61	
21	1.372	62	94	1.370	62		1.371	61	94	1.368	61	95	1.371	60	95
22	1.367	72		1.367	71		1.365	71		1.366	71		1.368	70	
23	1.377	60		1.375	60		1.375	60		1.373	62		1.374	60	
24	1.372	55		1.374	57		1.373	56		1.373	56		1.371	55	
25															
26															
27															
28															
29	1.400	85	95	1.399	85		1.398	85	94	1.404	82	95	1.401	96	95
30	1.398	89		1.398	90		1.396	92		1.396	93		1.395	94	9
31	1.399	92		1.400	95		1.397	96		1.398	97		1.400	98	
32															
33	1.396	73		1.395	72		1.395	73		1.394	75		1.393	74	
34	1.390	79		1.390	83		1.390	84		1.390	85		1.387	84	
35															
36	1.396	60		1.397	59		1.397	57		1.397	54		1.399	53	

OPERATOR ______________________ INSPECTION ______________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ______ PARA. N/A AMBIENT TEMPERATURE 95 ± 5 DATE 9/26/72

TEST DESCRIPTION Charge @ 2 amps

CELL S/N	1430 20 HOURS			21 HOURS			22 HOURS			23 HOURS			24 HOURS		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.380	43													
14	1.374	41													
15	1.378	48													
16	1.372	89													
17	1.385	97													
✓ 18															
19	1.398	88													
20	1.410	60													
21	1.370	59													
22	1.368	70													
23	1.373	59													
24	1.372	55													
✓ 25															
✓ 26															
✓ 27															
✓ 28															
29	1.400	75													
30	1.394	95													
31	1.398	98													
✓ 32															
33	1.393	75													
34	1.368	84													
✓ 35															
36	1.399	50													

OPERATOR ______ INSPECTION ______

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN ~~3~~ 20 DATA SHEET (DISCHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. NA AMBIENT TEMPERATURE 95±5 DATE 9/26/72
TEST DESCRIPTION 10 amp discharge

1440

	CELL S/N		5 MIN.			15 MIN.			30 MIN.			45 MIN.			60 MIN.		
			VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
95	1	13	1.256	36	104	1.223	30	105	1188	24	106	1.146	19				
96	2	14	1.257	34		1.225	29		1192	20		1.151	17				
97	3	15	1.261	40		1.232	35		1201	29		1.174	21		1.099		
98	4	16	1.262	83		1.234	76		1204	69		1.178	63		1.115		
99	5	17	1.305	93		1.284	89		1265	83		1.249	76		1.238		
100	6	18	1.288	70		1.274	67		1257	64		1.248	60		1.236		
101	7	19	1.313	85		1.291	80		1271	75		1.260	69		1.251		
102	8	20	1.314	58		1.288	53		1272	50		1.261	45		1.253		
103	9	21	1.275	50	96	1.244	44	96	1215	36	96	1.191	29		1.104		
104	10	22	1.270	60		1.238	52		1212	42		1.188	37		1.110		
105	11	23	1.284	53		1.254	44		1226	34		1.203	26		1.168		
106	12	24	1.281	47		1.252	40		1222	30		1.202	26		1.171		
107	13	25	1.260	70		1.242	68		1221	67		1.204	65		1.161		
~~108~~		26															
109	15	27	1.278	74		1.262	76		1244	74		1.230	70		1.216		
110	16	28	1.269	78		1.253	77		1237	75		1.221	71		1.205		
111	17	29	1.304	70	96	1.282	67	97	1261	60	98	1.248	50		1.236		
112	18	30	1.304	90		1.281	84		1260	79		1.247	70		1.235		
113	19	31	1.307	93		1.284	87		1265	80		1.250	72		1.237		
114	20	32	1.265	48		1.249	45		1234	41		1.219	40		1.203		
115	21	33	1.299	70		1.274	61		1252	56		1.240	50		1.227		
116	22	34	1.290	80		1.266	71		1243	65		1.228	58		1.211		
117	23	35	1.258	39		1.243	38		1225	35		1.209	32		1.192		
118	24	36	1.295	45		1.268	40		1247	36		1.230	30		1.211		

OPERATOR ________________ INSPECTION ________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

RSN ~~3~~ 20 DATA SHEET (DISCHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE 95° DATE 9/27/72

TEST DESCRIPTION 95° Test Discharge

	CELL S/N	75 MIN. VOLTS	75 MIN. PRESS.	75 MIN. TEMP.	90 MIN. VOLTS	90 MIN. PRESS.	90 MIN. TEMP.	105 MIN. VOLTS	105 MIN. PRESS.	105 MIN. TEMP.	120 MIN. VOLTS	120 MIN. PRESS.	120 MIN. TEMP.	135 MIN. VOLTS	135 MIN. PRESS.	135 MIN. TEMP.
095	13	—			—			—								
096	14	—			—			—								
097	15	—			—			—								
098	16	—			—			—								
99	17	1.225			1.213			1.197								
100	18	1.220			1.204			1.179			0.990					
101	19	1.241			1.231			1.219			—					
102	20	1.245			1.237			1.228			1.216			1.000		
103	21	—			—			—			1.210					
104	22	—			—			—								
105	23	—			—			—								
106	24	—			—			—								
107	25	~~1.236~~			—			—								
108	26	—			—			—								
109	27	1.185			—			—								
110	28	1.180			—			—								
111	29	1.219			1.209			1.185								
112	30	1.221			1.207			1.189								
113	31	1.223			1.213			1.190								
114	32	1.177			—			—								
115	33	1.204			1.170			—								
116	34	1.176			—			—								
117	35	1.016			—			—								
118	36	1.187			—			—								

OPERATOR ______________________ INSPECTION ______________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

RSN 20 DATA SHEETS (END OF DISCHARGE RECORD)

TEST PROCEDURE NO. ______ PARA. ______ AMBIENT TEMPERATURE 95 ±5 DATE 9/26/72

TEST DESCRIPTION 95° Discharge @ 10 amps

CELL		1.2 HOURS			MINUTES TO 1.1 VOLTS			MINUTES TO 1.0 VOLTS			MIN. TO 0.5 VOLT	MIN. TO 0.0 VOLT	MIN. TO -0.5 VOLT	MIN. TO -1.0 VOLT	MIN. TO -1.5 VOLTS
	S/N	VOLTS	PRESS.	TEMP.	MIN.	PRESS.	TEMP.	MIN.	PRESS.	TEMP.					
95	13							56							
96	14							56							
97	15							69							
98	16							69							
99	17							120							
100	18							110							
101	19							128							
102	20							135							
103	21							66							
104	22							66							
105	23							69							
106	24							69							
107	25							68							
108	26														
109	27							85							
110	28							85							
111	29							118							
112	30							118							
113	31							119							
114	32							87							
115	33							100							
116	34							85							
117	35							76							
118	36							94							

OPERATOR ______ INSPECTION ______

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

ITEM 2

FIRST 32°F CAPACITY TEST

Start 1415 10/4/72

RSN 21 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ______ PARA. NA AMBIENT TEMPERATURE 32 ± 5 DATE 10/4/72

TEST DESCRIPTION 32° overcharge, 1 amp rate

CELL S/N	5 ~~HOURS~~ min			1 HOURS			2 HOURS			1720 3 HOURS			1820 4 HOURS		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.405	-29		1.405			1.408	-29		1.420	-29		1.412		
14	1.405	-29		1.402			1.404	-29		1.406	-29		1.408		
15	1.464	-29		1.449			1.444	-30		1.442	-30		1.440		
16	1.386	-30	30	1.397			1.399	-30		1.402	-30	33	1.404		
17	1.263	-16		1.320			1.343	-14		1.356	-14		1.366		
18	1.272	-16		1.327			1.350	-16		1.363	-16		1.373		
19	1.272	-17		1.328			1.350	-20		1.364	-20		1.373		
20	1.272	-28		1.328			1.350	-28		1.363	-28		1.373		
21	1.273	-28		1.330			1.354	-28		1.367	-28		1.377		
22	1.274	-28		1.332			1.356	-26		1.369	-26		1.378		
23	1.278	-28		1.336			1.360	-24		1.373	-24		1.383		
24	1.272	-29		1.330			1.354	-24		1.367	-24		1.376		
25	1.272	-4	29	1.330			1.350	-4		1.361	-4	32	1.371		
26															
27	1.277	-22		1.333			1.355	-24		1.367	-24		1.379		
28	1.274	-24		1.329			1.350	-22		1.363	-22		1.388		
29	1.323	-20		1.347			1.363			1.372	-20		1.380		
30	1.270	-20		1.326			1.349			1.362	-20		1.372		
31	1.275	-4		1.331			1.354			1.367	-4		1.377		
32	1.272	-6	30	1.327			1.350			1.363	-6	28	1.373		
33	1.277	-10		1.334			1.358			1.372	-10		1.382		
34	1.284	-12		1.341			1.363			1.377	-12		1.387		
35	1.277	-12		1.333			1.356			1.369	-12		1.378		
36	1.279	-12		1.338			1.361			1.373	-11		1.383		

OPERATOR ______________________ INSPECTION ______________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ____ PARA. ____ AMBIENT TEMPERATURE 32±5 DATE 10/4/72

TEST DESCRIPTION 32° overcharge

CELL S/N	1920 5 HOURS			2020 6 HOURS			2120 7 HOURS			2220 8 HOURS			2320 9 HOURS			
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	
13	1.414	/	/	1.415	/	/	1.415	/	/	1.416	/	/	1.417	/	/	
14	1.411			1.411			1.413			1.414			1.415			
15	1.438	/	/	1.434	/	/	1.432	/	/	1.429	/	/	1.427	/	/	
16	1.407			1.408			1.410			1.411			1.413			
17	1.374	/	/	1.379	/	/	1.384	/	/	1.388	/	/	1.391	/	/	
18	1.380			1.386			1.391			1.394			1.397			
19	1.381	/	/	1.386	/	/	1.390	/	/	1.394	/	/	1.397	/	/	
20	1.379			1.385			1.390			1.393			1.397			
21	1.384	/	/	1.389	/	/	1.393	/	/	1.397	/	/	1.396	/	/	
22	1.385			1.390			1.395			1.398			1.401			
23	1.390	/	/	1.394	/	/	1.399	/	/	1.403	/	/	1.405	/	/	
24	1.384			1.388			1.393			1.396			1.399			
25	1.378	/	/	1.383	/	/	1.387	/	/	1.391	/	/	1.394	/	/	
—26	—			←			—			→			—			
27	1.384	/	/	1.390	/	/	1.394	/	/	1.398	/	/	1.401	/	/	
28	1.380			1.386			1.390			1.394			1.397			
29	1.386	/	/	1.391	/	/	1.395	/	/	1.399	/	/	1.402	/	/	
30	1.379			1.384			1.389			1.393			1.397			
31	1.384	/	/	1.390	/	/	1.395	/	/	1.399	/	/	1.402	/	/	
32	1.380			1.386			1.390			1.394			1.397			
33	1.389	/	/	1.394	/	/	1.398	/	/	1.402	/	/	1.406	/	/	
34	1.394			1.399			1.403			1.407			1.411			
35	1.386	/	/	1.391	/	/	1.395	/	/	1.399	/	/	1.402	/	/	
36	1.390			1.394			1.398			1.402			1.405			

OPERATOR ____ INSPECTION ____

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE 32 ± 5° F DATE 10/5/72

TEST DESCRIPTION Low temperature overcharge

CELL S/N	0020 10 HOURS			0120 11 HOURS			0220 12 HOURS			0320 13 HOURS			0420 14 HOURS			
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	
13	1.419	/	/	1.420	/	/	1.422	/	/	1.424	/	/	1.427	/	/	
14	1.418			1.419			1.421			[illegible].423			1.425			
15	1.427	/	/	1.427	/	/	1.427	/	/	1.428	/	/	1.430	/	/	
16	1.415			1.417			1.419			1.420			1.423			
17	1.394	/	/	1.398	/	/	1.400	/	/	1.402	/	/	1.406	/	/	
18	1.400			1.404			1.407			1.409			1.412			
19	1.401	/	/	1.404	/	/	1.406	/	/	1.409	/	/	1.412	/	/	
20	1.400			1.403			1.405			1.409			1.411			
21	1.403	/	/	1.406	/	/	1.409	/	/	1.412	/	/	1.414	/	/	
22	1.404			1.407			1.410			1.412			1.414			
23	1.409	/	/	1.412	/	/	1.415	/	/	1.417	/	/	1.419	/	/	
24	1.403			1.406			1.408			1.410			1.413			
25	1.398	/	/	1.400	/	/	1.402	/	/	1.405	/	/	1.408	/	/	
26	~~1.40[illegible]~~															
27	1.404	/	/	1.407	/	/	1.410	/	/	1.412	/	/	1.415	/	/	
28	1.401			1.403			1.406			1.409			1.412			
29	1.405	/	/	1.407	/	/	1.410	/	/	1.413	/	/	1.415	/	/	
30	1.400			1.403			1.406			1.409			1.412			
31	1.406	/	/	1.409	/	/	1.412	/	/	1.414	/	/	1.417	/	/	
32	1.401			1.404			1.407			1.409			1.412			
33	1.410	/	/	1.413	/	/	1.416	/	/	1.420	/	/	1.423	/	/	
34	1.414			1.418			1.421			1.425			1.428			
35	1.406	/	/	1.409	/	/	1.413	/	/	1.415	/	/	1.419	/	/	
36	1.409			1.411			1.415			1.417			1.420			

OPERATOR ____________________ INSPECTION ____________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE 32 ± 5°F DATE 10/5/72

TEST DESCRIPTION Low temperature overcharge

CELL S/N	0520 15 HOURS			0620 16 HOURS			0720 17 HOURS			0820 18 HOURS			0920 19 HOURS		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.431	/	/	1.435	/	/	1.440	/	/	1.445	-24	/	1.452	/	/
14	1.428			1.431			1.435			1.438	-28		1.442		
15	1.433	/	/	1.435	/	/	1.439	/	/	1.441	-28	/	1.445	/	/
16	1.426			1.429			1.434			1.436	-29		1.440		
17	1.408	/	/	1.411	/	/	1.415	/	/	1.417	-12	/	1.419	/	/
18	1.415			1.418			1.422			1.424	-16		1.426		
19	1.415	/	/	1.418	/	/	1.421	/	/	1.424	-15	/	1.427	/	/
20	1.414			1.417			1.420			1.423	-20		1.426		
21	1.418	/	/	1.420	/	/	1.424	/	/	1.423	-28	/	1.424	/	/
22	1.418			1.421			1.424			1.425	-20		1.426		
23	1.423	/	/	1.425	/	/	1.428	/	/	1.429	-20	/	1.429	/	/
24	1.416			1.419			1.422			1.422	-18		1.424		
25	1.410	/	/	1.413	/	/	1.416	/	/	1.417	-6	/	1.418	/	/
26															
27	1.418	/	/	1.420	/	/	1.424	/	/	1.424	-20	/	1.426	/	/
28	1.415			1.417			1.420			1.421	-18		1.423		
29	1.417	/	/	1.420	/	/	1.423	/	/	1.427	-10	/	1.433	/	/
30	1.414			1.416			1.417			1.420	-10		1.424		
31	1.419	/	/	1.422	/	/	1.424	/	/	1.426	-8	/	1.429	/	/
32	1.415			1.417			1.418			1.421	-18		1.424		
33	1.426	/	/	1.429	/	/	1.432	/	/	1.436	-22	/	1.442	/	/
34	1.432			1.435			1.440			1.446	-6		1.457		
35	1.422	/	/	1.425	/	/	1.429	/	/	1.433	-4	/	1.442	/	/
36	1.424			1.426			1.430			1.433	-10		1.438		

OPERATOR ____________________ INSPECTION ____________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ____________ PARA. __________ AMBIENT TEMPERATURE 32° ± 5° DATE 10-5-72

TEST DESCRIPTION Low temperature Overcharge

CELL S/N	1020 20 HOURS VOLTS	PRESS.	TEMP.	1120 21 HOURS VOLTS	PRESS.	TEMP.	1220 22 HOURS VOLTS	PRESS.	TEMP.	1320 23 HOURS VOLTS	PRESS.	TEMP.	1420 24 HOURS VOLTS	PRESS.	TEMP.
13	1,461			1.470	-14		1.476			1.482			1.483	10	
14	1,448			1.455	-20		1.466			1.478			1.485	6	
15	1,450			1.458	-24		1.468			1.480			1.490	5	
16	1,446			1.454	-25	31	1.464			1.477			1.485	8	
17	1,422			1.424	-14		1.426			1.430			1.435	-12	
18	1,428			1.431	-15		1.434			1.439			1.446	-13	
19	1,430			1.433	-14		1.437			1.443			1.452	-14	
20	1,431			1.434	-20		1.439			1.446			1.456	-18	
21	1,427			1.429	-22		1.433			1.438			1.445	-20	
22	1,429			1.432	-16		1.436			1.442			1.452	-11	
23	1,432			1.434	-21		1.437			1.441			1.447	-19	
24	1,427			1.429	-18		1.432			1.437			1.443	-18	
25	1,420			1.422	-2	31	1.424			1.428			1.432	-2	
26															
27	1,429			1.432	-20		1.436			1.441			1.450	-16	
28	1,427			1.429	-2		1.433			1.438			1.448	- 8	
29	1,439			1.445	- 8		1.457			1.485			1.518	+ 16	
30	1,427			1.429	- 6		1.432			1.437			1.443	- 6	
31	1,433			1.435	- 6		1.438			1.443			1.450	- 4	
32	1,427			1.430	-16	28	1.433			1.438			1.444	-12	
33	1,451			1.460	-19		1.478			1.503			1.515	+ 7	
34	1,475			1.498	+ 2		1.512			1.513			1.507	37	
35	1,453			1.470	0		1.498			1.514			1.513	42	
36	1,445			1.451	- 8		1.463			1.482			1.503	3	

OPERATOR ______________________ INSPECTION ______________________

SPECIAL INSTRUCTIONS:
1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ______ PARA. ______ AMBIENT TEMPERATURE 32 ± 5 DATE 10-5-72

TEST DESCRIPTION 32° overcharge

CELL S/N	1520 25 HOURS			1620 26 HOURS			1720 27 HOURS			1820 28 HOURS			1920 29 HOURS		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.481			1.479			1.477	16		1.473	18		1.472		
14	1.485			1.483			1.479	20		1.475	21		1.473		
15	1.491			1.489			1.484	25		1.479	27		1.476		
16	1.486			1.484			1.481	36	37	1.475	40		1.472		
17	1.442			1.458			1.478	-8		1.499	0		1.504		
18	1.457			1.480			1.502	0		1.511	20		1.508		
19	1.465			1.489			1.509	6		1.515	16		1.512		
20	1.472			1.500			1.517	4		1.518	21		1.514		
21	1.455			1.467			1.468	-4		1.463	0		1.461		
22	1.461			1.469			1.466	+2		1.461	5		1.459		
23	1.454			1.467			1.472	-4		1.468	0		1.466		
24	1.452			1.467			1.473	-2	34	1.470	4		1.467		
25	1.438			1.451			1.464	0		1.485	4		1.507		
26															
27	1.462			1.486			1.506	0		1.518	17		1.520		
28	1.460			1.486			1.506	10		1.514	27		1.513		
29	1.525			1.526			1.518	35		1.507	40		1.500		
30	1.450			1.466			1.484	58		1.501	18		1.511		
31	1.459			1.476			1.494	0		1.509	18		1.508		
32	1.453			1.468			1.484	0	32	1.496	10		1.503		
33	1.512			1.504			1.498	31		1.491	39		1.489		
34	1.499			1.491			1.486	30		1.481	55		1.478		
35	1.503			1.493			1.487	58		1.480	75		1.476		
36	1.512			1.511			1.502	24		1.493	26		1.490		

OPERATOR ______ INSPECTION ______

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ______ PARA. ______ AMBIENT TEMPERATURE 32±5 DATE 10/5/72
TEST DESCRIPTION Low temperature overcharge

	2020 30 HOURS			2120 31 HOURS			2220 32 HOURS			2320 33 HOURS			0020 34 HOURS		
CELL S/N	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.473	20		1.471			1.475	20		1.473	20		1.470		
14	1.474	21		1.472			1.475	23		1.473	23		1.473		
15	1.476	28		1.474			1.476	29		1.475	28		1.475		
16	1.471	43		1.468	40		1.470	43	40	1.469	44		1.469		
17	1.502	30		1.497			1.497	39		1.494	44		1.493		
18	1.505	62		1.500			1.498	71		1.496	74		1.495		
19	1.510	56		1.505			1.502	67		1.500	75		1.499		
20	1.511	61		1.504			1.503	70		1.500	77		1.499		
21	1.459	2		1.456			1.465	4		1.458	5		1.461		
22	1.458	5		1.455			1.461	8		1.458	8		1.459		
23	1.464	4		1.462			1.466	5		1.463	6		1.464		
24	1.465	8		1.461	38		1.466	9	32	1.463	9		1.463		
25	1.517	11		1.518			1.531	11		1.529	11		1.532		
26															
27	1.516	68		1.508			1.506	84		1.499	90		1.495		
28	1.508	76		1.499			1.496	87		1.491	92		1.487		
29	1.496	58		1.487			1.485	55		1.486	52		1.483		
30	1.516	42		1.511			1.512	40		1.511	40		1.507		
31	1.520	48		1.514			1.511	60		1.506	62		1.500		
32	1.503	44		1.497	33		1.493	50	34	1.488	51		1.483		
33	1.489	30		1.487			1.487	30		1.487	30		1.486		
34	1.478	59		1.476			1.477	60		1.476	60		1.476		
35	1.475	69		1.474			1.474	75		1.474	81		1.474		
36	1.490	21		1.487			1.490	21		1.490	20		1.490		

OPERATOR ______ INSPECTION ______

SPECIAL INSTRUCTIONS:
1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ______ PARA. ______ AMBIENT TEMPERATURE 32 ±5 DATE 10/6/72

TEST DESCRIPTION Low temp Overcharge

CELL S/N	0120 35 HOURS VOLTS	PRESS.	TEMP.	0220 36 HOURS VOLTS	PRESS.	TEMP.	0320 37 HOURS VOLTS	PRESS.	TEMP.	0420 38 HOURS VOLTS	PRESS.	TEMP.	0520 39 HOURS VOLTS	PRESS.	TEMP.
13	1.474	/	/	1.474	/	/	1.474	/	/	1.475	/	/	1.476	/	/
14	1.474			1.474			1.474			1.475			1.475		
15	1.475	/	/	1.475	/	/	1.475	/	/	1.476	/	/	1.476	/	/
16	1.470			1.470			1.471			1.471			1.471		
17	1.493	/	/	1.493	/	/	1.493	/	/	1.493	/	/	1.493	/	/
18	1.495			1.495			1.495			1.495			1.495		
19	1.498	/	/	1.497	/	/	1.497	/	/	1.496	/	/	1.496	/	/
20	1.498			1.498			1.498			1.497			1.497		
21	1.456	/	/	1.458	/	/	1.457	/	/	1.459	/	/	1.458	/	/
22	1.458			1.457			1.457			1.458			1.459		
23	1.462	/	/	1.462	/	/	1.461	/	/	1.462	/	/	1.463	/	/
24	1.461			1.461			1.460			1.461			1.462		
25	1.530	/	/	1.531	/	/	1.531	/	/	1.533	/	/	1.535	/	/
26															
27	1.491	/	/	1.488	/	/	1.487	/	/	1.486	/	/	1.487	/	/
28	1.484			1.482			1.481			1.480			1.481		
29	1.485	/	/	1.483	/	/	1.483	/	/	1.482	/	/	1.482	/	/
30	1.507			1.504			1.501			1.498			1.495		
31	1.498	/	/	1.495	/	/	1.493	/	/	1.492	/	/	1.491	/	/
32	1.481			1.479			1.478			1.477			1.477		
33	1.486	/	/	1.487	/	/	1.487	/	/	1.487	/	/	1.487	/	/
34	1.476			1.477			1.477			1.477			1.477		
35	1.474	/	/	1.474	/	/	1.474	/	/	1.475	/	/	1.475	/	/
36	1.490			1.490			1.490			1.491			1.491		

OPERATOR ______ INSPECTION ______

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ____________ PARA. __________ AMBIENT TEMPERATURE ______________________ DATE 10/6/72

TEST DESCRIPTION ______________________________

CELL S/N	0620 40 HOURS VOLTS	40 HOURS PRESS.	40 HOURS TEMP.	0720 41 HOURS VOLTS	41 HOURS PRESS.	41 HOURS TEMP.	0820 42 HOURS VOLTS	42 HOURS PRESS.	42 HOURS TEMP.	0920 43 HOURS VOLTS	43 HOURS PRESS.	43 HOURS TEMP.	1020 44 HOURS VOLTS	44 HOURS PRESS.	44 HOURS TEMP.
13	1.474			1.474			1.473			1.473	20		1.474		
14	1.474			1.474			1.473			1.473	23		1.474		
15	1.476			1.475			1.475			1.474	26		1.475		
16	1.471			1.471			1.470			1.470	40		1.469		
17	1.492			1.493			1.492			1.490	39	42	1.490		
18	1.494			1.495			1.494			1.493	73		1.492		
19	1.995			1.495			1.494			1.493	92		1.492		
20	1.496			1.496			1.495			1.494	90		1.493		
21	1.455			1.456			1.459			1.454	5		1.461		
22	1.456			1.456			1.455			1.455	8		1.458		
23	1.460			1.460			1.459			1.459	7		1.463		
24	1.458			1.458			1.957			1.457	10	35	1.461		
25	1.531			1.531			1.527			1.523	8		1.531		
26															
27	1.484			1.483			1.482			1.482	97		1.485		
28	1.479			1.477			1.477			1.476	98		1.477		
29	1.482			1.482			1.482			1.482	44		1.490		
30	1.495			1.494			1.493			1.492	20		1.486		
31	1.490			1.489			1.489			1.489	44		1.485		
32	1.476			1.476			1.475			1.475	60	36	1.473		
33	1.487			1.487			1.487			1.487	25		1.485		
34	1.476			1.476			1.476			1.477	60		1.475		
35	1.474			1.474			1.474			1.474	78		1.473		
36	1.490			1.490			1.990			1.490	11		1.490		

OPERATOR ______________________________ INSPECTION ______________________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE 32 ± 5°F DATE 10/6/72

TEST DESCRIPTION Low temperature overcharge

CELL S/N	1120 45 HOURS			46 HOURS 1220			47 HOURS			48 HOURS					
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.475	17		1.472			1.477			1.478	18				
14	1.475	23		1.473			1.477			1.478	22				
15	1.476	25		1.474			1.477			1.478	25				
16	1.470	38		1.469			1.472			1.473	36				
17	1.490	39		1.488			1.492			1.492	36				
18	1.493	70		1.491			1.495			1.995	65				
19	1.492	92		1.490			1.493			1.494	90				
20	1.493	89		1.492			1.495			1.496	82				
21	1.460	6		1.455			1.463			1.463	6				
22	1.460	8		1.455			1.461			1.461	8				
23	1.464	7		1.460			1.465			1.466	7				
24	1.462	10		1.457			1.463			1.463	11				
25	1.531	8		1.522			1.532			1.533	6				
26															
27	1.487	92		1.483			1.488			1.489	90				
28	1.479	96		1.478			1.481			1.482	90				
29	1.476	52		1.479			1.479			1.482	50				
30	1.484	15		1.486			1.486			1.487	12				
31	1.483	43		1.484			1.485			1.487	40				
32	1.472	59		1.472			1.473			1.475	58				
33	1.485	22		1.485			1.486			1.487	21				
34	1.475	64		1.475			1.477			1.479	62				
35	1.473	82		1.472			1.474			1.476	90				
36	1.489	12		1.488			1.491			1.492	10				

OPERATOR ________________ INSPECTION ________________

<u>SPECIAL</u> <u>INSTRUCTIONS</u>:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (DISCHARGE RECORD)

Started 1424

TEST PROCEDURE NO. NA PARA. NA AMBIENT TEMPERATURE 32 ± 5 DATE 10-6-72

TEST DESCRIPTION Discharge @ 10Amps to 1.0volt.

		1429 5 MIN.			1439 15 MIN.			1454 30 MIN.			1509 45 MIN.			1524 60 MIN.		
	CELL S/N	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
92	13	1.251			1.211			1.199			1.188			1.166	+ 6	
93	14	1.264			1.222			1.210			1.202			1.186	+ 9	
94	15	1.259			1.214			1.202			1.193			1.177	+12	
95	16	1.254			1.205			1.193			1.183			1.165	+23	
96	17	1.319			1.271			1.241			1.238			1.235	+24	
97	18	1.323			1.275			1.247			1.244			1.242	+48	
98	19	1.322			1.275			1.246			1.243			1.240	+70	
99	20	1.322			1.274			1.245			1.242			1.239	+65	
100	21	1.289			1.252			1.239			1.236			1.232	- 6	
101	22	1.289			1.251			1.238			1.236			1.231	- 2	
102	23	1.295			1.258			1.244			1.242			1.238	- 4	
103	24	1.291			1.253			1.238			1.236			1.232	+ 1	
104	25	1.311			1.265			1.239			1.238			1.236	- 4	
	26															
	27	1.313			1.267			1.241			1.239			1.236	+70	
	28	1.301			1.255			1.230			1.228			1.225	+74	
	29	1.303			1.259			1.234			1.230			1.226	+32	
	30	1.304			1.262			1.239			1.236			1.235	000	
	31	1.309			1.266			1.242			1.239			1.236	+23	
	32	1.298			1.254			1.230			1.227			1.224	+38	
	33	1.296			1.249			1.233			1.231			1.226	+ 9	
	34	1.291			1.243			1.226			1.223			1.217	+48	
	36	1.287			1.240			1.221			1.219			1.212	+63	
	36	1.282			1.236			1.218			1.216			1.211	000	

OPERATOR ______________________ INSPECTION ______________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

RSN 3 DATA SHEET (DISCHARGE RECORD)

Started @ 1924

TEST PROCEDURE NO. NA PARA. NA AMBIENT TEMPERATURE 52°± 5 DATE 10-6-72
TEST DESCRIPTION Discharge @ 10 Amps to 1.0 v set.

CELL S/N	1539 75 MIN.			1554 90 MIN.			1609 105 MIN.			1624 120 MIN.			1639 135 MIN.		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
1 13	1.116	/	/	—	/	/		/	/		/	/		/	/
2 14	1.158			1.079											
3 15	1.151	/	/	1.072	/	/		/	/		/	/		/	/
4 16	1.134			1.064											
5 17	1.232	/	/	1.227	/	/	1.222	/	/	1.213	/	/	1,202	/	/
6 18	1.238			1.234			1.227			1.219			1,208		
7 19	1.236	/	/	1.232	/	/	1.224	/	/	1.215	/	/	1,203	/	/
8 20	1.235			1.230			1.222			1.213			1.199		
9 21	1.226	/	/	1.219	/	/	1.204	/	/	1.175	/	/		/	/
10 22	1.225			1.217			1.203			1.167					
11 23	1.232	/	/	1.224	/	/	1.213	/	/	1.189	/	/	1,104	/	/
12 24	1.226			1.218			1.208			1.191			1,129		
13 25	1.234	/	/	1.230	/	/	1.224	/	/	1.216	/	/	1,207	/	/
14 26															
15 27	1.232	/	/	1.226	/	/	1.218	/	/	1.209	/	/	1,191	/	/
16 28	1.220			1.214			1.206			1.195			1,175		
17 29	1.221	/	/	1.213	/	/	1.203	/	/	1.182	/	/	1,081	/	/
18 30	1.231			1.227			1.221			1.213			1,203		
19 31	1.232	/	/	1.226	/	/	1.219	/	/	1.209	/	/	1,190	/	/
20 32	1.220			1.214			1.207			1.196			1.176		
21 33	1.219	/	/	1.211	/	/	1.200	/	/	1.178	/	/	1,068	/	/
22 34	1.210			1.199			1.181			1.092					
23 35	1.208	/	/	1.194	/	/	1.173	/	/	1.097	/	/		/	/
24 36	1.203			1.194			1.178			1.141					

OPERATOR ______ INSPECTION ______

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

RSN 3 DATA SHEET (DISCHARGE RECORD)

TEST PROCEDURE NO. NA PARA. NA AMBIENT TEMPERATURE 32± 5 DATE 10-6-72

TEST DESCRIPTION

		1654 150 MIN.			165 MIN.			180 MIN.			195 MIN.			210 MIN.		
	CELL S/N	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
92	13															
93	14															
94	15															
95	16															
96	17	1.145														
97	18	1.138														
98	19	1.067														
99	20															
100	21															
101	22															
102	23															
103	24															
104	25	1.191			1.167											
105	26															
106	27	.868														
107	28															
108	29															
109	30	1.172			.859											
110	31															
111	32															
112	33															
113	34															
114	35															
115	36															

OPERATOR INSPECTION

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

RSN 3 DATA SHEETS (END OF DISCHARGE RECORD)

TEST PROCEDURE NO. NA PARA. NA AMBIENT TEMPERATURE 82° ± 5 DATE 10-6-72

TEST DESCRIPTION Discharge @ 10 Amps Started @ 1424

	CELL S/N	1.2 HOURS			MINUTES TO 1.1 VOLTS			MINUTES TO 1.0 VOLTS			MIN. TO 0.5 VOLT	MIN. TO 0.0 VOLT	MIN. TO -0.5 VOLT	MIN. TO -1.0 VOLT	MIN. TO -1.5 VOLTS
		VOLTS	PRESS.	TEMP.	MIN.	PRESS.	TEMP.	MIN.	PRESS.	TEMP.					
92	13							92							
93	14							101							
94	15							99							
95	16							96							
96	17							155							
97	18							158							
98	19							153							
99	20							147							
100	21							130							
101	22							128							
102	23							137							
103	24							138							
104	25							172							
105	26														
106	27							149							
107	28							148							
108	29							136							
109	30							164							
110	31							149							
111	32							149							
112	33							136							
113	34							122							
114	35							123							
115	36							128							

OPERATOR __________ INSPECTION __________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

ITEM 3

SECOND 75°F CAPACITY TEST

RSN 2T DATA SHEET (CHARGE RECORD)

Cells 1-Ω, then dead short before charge

TEST PROCEDURE NO. ______ PARA. ______ AMBIENT TEMPERATURE 75 ± 5 DATE 10-9-72
TEST DESCRIPTION Overcharge capacity (C/10 chg for 20 hrs.)

CELL S/N	1605 5 min ~~HOURS~~			1700 1 HOURS			1800 2 HOURS			1900 3 HOURS			2000 4 HOURS		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.374	-28		1.384	-28		1.390			1.395	-30		1.399		
14	1.377	-27		1.385	-26		1.389			1.394	-30		1.399		
15	1.404	-29		1.407	-27		1.406			1.405	-30		1.406		
16	1.375	-30		1.382	-30		1.386			1.390	-20		1.395		
17	1.273	-24		1.332	-25		1.354			1.366	-25		1.374		
18	1.292	-26		1.342	-26		1.360			1.371	-30		1.379		
19	1.262	-18		1.331	-27		1.359			1.372	-15		1.380		
20	1.279	-22		1.335	-22		1.358			1.371	-13		1.379		
21	1.276	-28		1.330	-28		1.358			1.373	-28		1.381		
22	1.274	-24		1.331	-29		1.359			1.373	-24		1.382		
23	1.290	-20		1.341	-20		1.365			1.378	-20		1.386		
24	1.302	-23		1.341	-23		1.361			1.373	-23		1.381		
25	1.355	-22		1.359	-22		1.366			1.371	-22		1.377		
26		—													
27	1.323	-20		1.354	-20		1.366			1.375	-15		1.382		
28	1.308	-20		1.348	-20		1.363			1.373	-15		1.380		
29	1.289	-19		1.328	-19		1.351			1.366	-20		1.375		
30	1.336	-28		1.347	-28		1.361			1.371	-28		1.379		
31	1.296	-12		1.337	-14		1.358			1.372	-10		1.382		
32	1.275	-16		1.330	-18		1.356			1.370	-15		1.379		
33	1.328	-28		1.356	-28		1.371			1.381	-30		1.389		
34	1.292	-14		1.348	-16		1.373			1.382	-15		1.393		
35	1.285	-12		1.338	-12		1.366			1.379	-10		1.387		
36	1.349	-10		1.363	-12		1.377			1.385	-10		1.392		

OPERATOR ______________________ INSPECTION ______________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 21 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ____________ PARA. __________ AMBIENT TEMPERATURE 75 ± 5 DATE 10/10/72

TEST DESCRIPTION Overcharge Capacity

	2100 5 HOURS			2200 6 HOURS			2300 7 HOURS			2400 8 HOURS			0100 9 HOURS		
CELL S/N	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1,403	-10		1,406	-10		1,411			1,415			1,421	8	
14	1,404	-10		1,407	-16		1,410			1,414			1,418	8	
15	1,408	-20		1,411	-20		1,414			1,417			1,421	5	
16	1,399	-20		1,403	-20	62	1,407			1,411			1,416	10	
17	1,379	-20		1,385	-20		1,389			1,393			1,397	2	
18	1,384	-25		1,390	-25		1,394			1,399			1,403	-6	
19	1,386	-20		1,391	-20		1,395			1,399			1,404	5	
20	1,385	-10		1,390	-10		1,394			1,399			1,404	-2	
21	1,388	-18		1,393	-18		1,397			1,401			1,404	2	
22	1,388	-10		1,394	-10		1,399			1,402			1,405	0	
23	1,393	-10		1,398	-10		1,402			1,406			1,408	4	
24	1,387	-10		1,393	-10		1,397			1,400			1,403	-3	
25	1,382	-15		1,387	-15	62	1,390			1,394			1,397	-2	
26															
27	1,387	-10		1,393	-10		1,397			1,401			1,406	-3	
28	1,386	-20		1,392	-20		1,396			1,401			1,404	3	
29	1,383	-15		1,389	-15		1,394			1,398			1,402	-4	
30	1,384	-20		1,389	-20		1,394			1,398			1,402	-16	
31	1,387	-10		1,393	-10	63	1,398			1,403			1,407	-10	
32	1,386	-10		1,391	-10		1,397			1,400			1,404	2	
33	1,395	-25		1,399	-25		1,404			1,408			1,412	-18	
34	1,399	0		1,405	0		1,410			1,414			1,418	7	
35	1,394	-5		1,399	-5		1,404			1,408			1,412	7	
36	1,397	-5		1,401	-5		1,406			1,409			1,413	3	

OPERATOR ______________________ INSPECTION ______________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 21 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE 75 ± 5 DATE 10/10/72

TEST DESCRIPTION C/10 overcharge Capacity

CELL S/N	0200 10 HOURS VOLTS	0200 10 HOURS PRESS.	0200 10 HOURS TEMP.	0300 11 HOURS VOLTS	0300 11 HOURS PRESS.	0300 11 HOURS TEMP.	0400 12 HOURS VOLTS	0400 12 HOURS PRESS.	0400 12 HOURS TEMP.	0500 13 HOURS VOLTS	0500 13 HOURS PRESS.	0500 13 HOURS TEMP.	0600 14 HOURS VOLTS	0600 14 HOURS PRESS.	0600 14 HOURS TEMP.
13	1.426/	/		1.432/	/		1.436/	18/		1.437/	/		1.435/	/	
14	1.422			1.425			1.428	16		1.430			1.431		
15	1.426/	/		1.431/	/		1.438/	12/		1.443/	/		1.444/	/	
16	1.421			1.424			1.430	20		1.435			1.438		
17	1.401/	/		1.404/	/		1.407/	7/	67	1.408/	/		1.411/	/	
18	1.407			1.410			1.412	2		1.414			1.416		
19	1.407/	/		1.411/	/		1.414/	10/		1.417/	/		1.428/	/	
20	1.407			1.411			1.414	3		1.418			1.422		
21	1.405/	/		1.406/	/		1.407/	0/		1.409/	/		1.410/	/	
22	1.406			1.407			1.408	8		1.409			1.410		
23	1.410/	/		1.411/	/		1.413/	-4/		1.414/	/		1.415/	/	
24	1.405			1.406			1.408	-2	65	1.409			1.412		
25	1.400/	/		1.412/	/		1.404/	-6/		1.407/	/		1.410/	/	
26															
27	1.408/	/		1.410/	/		1.413/	8/		1.416/	/		1.419/	/	
28	1.407			1.409			1.412	9		1.414			1.417		
29	1.405/	/		1.408/	/		1.411/	1/		1.414/	/		1.417/	/	
30	1.405			1.407			1.410	-10		1.413			1.415		
31	1.409/	/		1.412/	/		1.414/	-3/		1.418/	/		1.421/	/	
32	1.407			1.409			1.412	5	60	1.415			1.417		
33	1.415/	/		1.419/	/		1.422/	-12/		1.427/	/		1.433/	/	
34	1.422			1.426			1.429	11		1.435			1.442		
35	1.416/	/		1.419/	/		1.423/	13/		1.428/	/		1.436/	/	
36	1.415			1.418			1.422	4		1.425			1.430		

OPERATOR ____________________ INSPECTION ____________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 21 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE 75 ±5°F DATE 10/10/72

TEST DESCRIPTION c/10 overcharge capacity

CELL S/N	0700 ~~15~~ HOURS VOLTS	PRESS.	TEMP.	0800 ~~16~~ HOURS VOLTS	PRESS.	TEMP.	0900 ~~17~~ HOURS VOLTS	PRESS.	TEMP.	1000 ~~18~~ HOURS VOLTS	PRESS.	TEMP.	1100 19 HOURS VOLTS	PRESS.	TEMP.	
13	1.431	30		1.426			1.437			1.428	40		1.423	40		
14	1.428	27		1.424			1.433			1.423	38		1.418	40		
15	1.439	32		1.433			1.442			1.432	45		1.426	47		
16	1.434	45		1.428			1.437			1.427	62		1.420	63		
17	1.412	15		1.414			1.424			1.429	33		1.429	46		
18	1.419	11		1.422			1.435			1.446	40		1.447	68		
19	1.422	21		1.426			1.442			1.453	50		1.446	87		~~100~~ 94@1130
20	1.425	12		1.431			1.454			1.466	63		1.459	94		100 @1130
21	1.411	-3		1.411			1.416			1.415	3		1.413	3		
22	1.411	1		1.411			1.417			1.414	5		1.411	5		
23	1.417	-4		1.417			1.424			1.423	1		1.420	4		
24	1.413	-2		1.414			1.422			1.421	0		1.418	2		
25	1.413	-2		1.415			1.427			1.441	10		1.444	25		
26																
27	1.422	17		1.426			1.442			1.454	44		1.449	64		
28	1.420	18		1.423			1.438			1.451	45		1.446	65		
29	1.421	5		1.424			1.439			1.457	20		1.466	30		
30	1.418	-3		1.421			1.434			1.448	5		1.458	20		
31	1.423	8		1.427			1.441			1.452	15		1.459	30		
32	1.420	12		1.423			1.436			1.444	25		1.443	29		
33	1.443	1		1.457			1.465			1.450	45		1.441	50		
34	1.448	25		1.447			1.450			1.436	50		1.427	63		
35	1.447	91		1.451			1.453			1.438	83		1.430	88		
36	1.437	8		1.447			1.462			1.449	40		1.442	44		

OPERATOR ____________________ INSPECTION ____________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE 75 ± 5 DATE 10/10/72

TEST DESCRIPTION C/10 Overcharge capacity

CELL S/N	1200 20 HOURS			21 HOURS			22 HOURS			23 HOURS			24 HOURS		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.421	41													
14	1.415	40													
15	1.422	48													
16	1.414	64													
17	1.422	57													
18	1.438	82													
*19	1.373	91													
*20	1.382	96													
21	1.412	5													
22	1.408	8													
23	1.416	6													
24	1.415	5													
25	1.437	31													
26															
27	1.440	[illegible]													
28	1.437	94													
29	1.452	46													
30	1.447	23													
31	1.446	38													
32	1.433	48													
33	1.435	50													
34	1.423	65													
35	1.425	90													
36	1.439	42													

OPERATOR ________________ INSPECTION ________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (DISCHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE 75 DATE 10/10

TEST DESCRIPTION overcharge capacity

CELL S/N	1330 5 MIN.			1340 15 MIN.			1350 30 MIN.			1410 45 MIN.			1425 60 MIN.		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.249	12		1.232			1.224			1.212			1.189	4	
14	1.258	12		1.242			1.234			1.224			1.207	4	
15	1.257	18		1.237			1.229			1.219			1.202	8	
16	1.250	34		1.231			1.223			1.213			1.195	22	
17 15	1.289	49		1.263			1.256			1.252			1.247	39	
18 16	1.298	74		1.268			1.260			1.256			1.252	61	
19 17	1.293	75		1.266			1.259			1.255			1.250	62	
20 18	1.298	78		1.267			1.258			1.255			1.250	65	
21 19	1.287	-10		1.268			1.259			1.252			1.242	-20	
22 20	1.286	- 5		1.268			1.258			1.251			1.240	-14	
23 21	1.291	-10		1.271			1.263			1.256			1.247	-16	
24 22	1.286	-10		1.267			1.258			1.252			1.243	-18	
25 23	1.293	13		1.241			1.253			1.250			1.244	5	
26 ~~24~~															
27 25	1.297	52		1.265			1.256			1.253			1.247	40	
28 26	1.286	51		1.255			1.246			1.243			1.237	40	
29 27	1.292	25		1.262			1.252			1.248			1.241	16	
30 28	1.293	6		1.264			1.253			1.250			1.245	0	
31 29	1.296	18		1.267			1.258			1.253			1.248	12	
32 30	1.284	28		1.266			1.248			1.244			1.237	17	
33 31	1.284	22		1.253			1.247			1.242			1.235	13	
34 32	1.276	35		1.250			1.244			1.239			1.231	25	
35	1.274	57		1.245			1.239			1.234			1.226	45	
36	1.274	14		1.243			1.237			1.132			1.224	6	

OPERATOR ________________ INSPECTION ________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

RSN 3 DATA SHEET (DISCHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE 75 DATE 10/10/72

TEST DESCRIPTION Overcharge Capacity

CELL S/N	1440 75 MIN.			1455 90 MIN.			1510 105 MIN.			1525 120 MIN.			135 MIN.		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.149			1.068			—			~~1.253~~	0		—		
14	1.185			1.150			.993			~~1.250~~	-2		—		
15	1.180			1.147			.997			~~1.251~~	2		—		
16	1.173			1.135			—			~~1.247~~	15		—		
17	1.241			1.236			1.226			1.219	30		1.205		
18	1.246			1.242			1.229			1.226	49		1.213		
19	1.245			1.240			1.235			1.222	50		1.207		
20	1.245			1.239			1.233			1.222	52		1.207		
21	1.233			1.224			1.232			1.185	-22		—		
22	1.231			1.222			1.210			1.180	-18		—		
23	1.239			1.230			1.207			1.199	-20		1.118		
24	1.235			1.228			1.217			1.201	-20		1.164		
25	1.240			1.235			1.217			1.220	0		1.207		
26	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
27	1.242			1.237			1.229			1.219	32		1.204		
28	1.232			1.229			1.219			1.209	30		1.193		
29	1.235			1.230			1.222			1.210	10		1.188		
30	1.240			1.236			1.230			1.222	-8		1.210		
31	1.242			1.238			1.231			1.222	+7		1.207		
32	1.231			1.227			1.219			1.211	12		1.197		
33	1.229			1.222			1.202			1.197	8		1.154		
34	1.224			1.216			1.203			1.180	20		—		
35	1.219			1.210			1.197			1.172	38		—		
36	1.217			1.210			1.198			1.127	2		1.097		

OPERATOR ____________________ INSPECTION ____________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

RSN 3 DATA SHEET (DISCHARGE RECORD)

TEST PROCEDURE NO. ____________ PARA. __________ AMBIENT TEMPERATURE ______________________ DATE __________

TEST DESCRIPTION ____

	150 MIN.			165 MIN.			180 MIN.			195 MIN.			210 MIN.		
CELL S/N	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	~~1.193~~														
14	~~1.20~~														
15	—														
16	—														
17	1.193														
18	1.202														
19	1.194														
20	1.194														
21	—														
22	—														
23	—														
24	—														
25	1.197														
26	—														
27	1.185														
28	1.173														
29	1.141														
30	1.200														
31	1.192														
32	1.182														
33	—														
34	—														
35	—														
36	—														

OPERATOR ______________________________ INSPECTION ______________________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

RSN 3 DATA SHEETS (END OF DISCHARGE RECORD)

TEST PROCEDURE NO. ______ PARA. ______ AMBIENT TEMPERATURE ______ DATE 10/10/72

TEST DESCRIPTION overcharge capacity

CELL S/N	1.2 HOURS			MINUTES TO 1.1 VOLTS			MINUTES TO 1.0 VOLTS			MIN. TO 0.5 VOLT	MIN. TO 0.0 VOLT	MIN. TO -0.5 VOLT	MIN. TO -1.0 VOLT	MIN. TO -1.5 VOLTS
	VOLTS	PRESS.	TEMP.	MIN.	PRESS.	TEMP.	MIN.	PRESS.	TEMP.					
13							94							
14							104							
15							104							
16							103							
17							169							
18							166							
19							168							
20							168							
21							134							
22							133							
23							142							
24							149							
25							169							
26														
27							165							
28							165							
29							159							
30							169							
31							168							
32							168							
33							148							
34							134							
35							135							
36							140							

OPERATOR ______ INSPECTION ______

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

ITEM 4

SECOND 95°F CAPACITY TEST

RSN 20 DATA SHEET (CHARGE RECORD)

Started @ 1600

TEST PROCEDURE NO. ______ PARA. ______ AMBIENT TEMPERATURE 95 ±5 DATE 10-11-72

TEST DESCRIPTION Charge @ 2 Amps for 20 Hrs

	5 MIN.			1700 1 HOUR			2 HOURS			1900 3 HOURS			2000 4 HOURS		
CELL S/N	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.393	-28		1.387	-28		1.385			1.388	-15		1.393		
14	1.389	-28		1.384	-28		1.382			1.386	-15		1.393		
15	1.462	-28		1.418	-28		1.401			1.398	-20		1.399		
16	1.422	-30		1.397	-30		1.387			1.386	-20		1.390		
17	1.318	+1		1.349	0		1.356			1.361	0	90	1.369		
18	1.327	+8		1.357	7		1.363			1.367	0		1.376		
19	1.317	+20		1.350	18		1.359			1.366	-10		1.375		
20	1.321	+22		1.353	20		1.361			1.367	-10		1.375		
21	1.302	-22		1.342	-30		1.354			1.362	-20		1.367		
22	1.306	-26		1.345	-28		1.356			1.364	-20		1.368		
23	1.320	-24		1.354	-23		1.362			1.369	-20		1.373		
24	1.317	-24		1.349	-26		1.357			1.363	-20	90	1.369		
25	1.353	-24		1.353	-23		1.358			1.362	-20		1.367		
26															
27	1.326	+10		1.356	+9		1.363			1.368	5		1.373		
28	1.321	+10		1.352	+9		1.361			1.368	5		1.370		
29	1.314	-12		1.347	-12		1.357			1.363	-15		1.369		
30	1.334	-18		1.354	-18		1.360			1.366	-25	90	1.370		
31	1.324	-11		1.356	-12		1.364			1.370	-10		1.374		
32	1.313	-4		1.347	-10		1.358			1.365	-10		1.370		
33	1.340	-17		1.365	-18		1.371			1.376	-20		1.380		
34	1.300	+7		1.352	6		1.367			1.375	5		1.381		
35	1.305	+20		1.349	17		1.362			1.370	15		1.375		
36	1.364	-16		1.370	-15		1.373			1.377	10		1.381		

OPERATOR ______ INSPECTION ______

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE 95 ± 5°F DATE 10/12/72

TEST DESCRIPTION High Temp Overcharge

CELL S/N	2100 5 HOURS			2200 6 HOURS			2300 7 HOURS			2400 8 HOURS			0100 9 HOURS		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.393/	/		1.396/	15/		1.398/	/		1.398/	/		1.398/	38/	
14	1.393			1.396	20		1.398			1.398			1.397	47	
15	1.399/	/		1.401/	5/		1.403/	/		1.404/	/		1.404/	31/	
16	1.390			1.394	10		1.397			1.398			1.399	41	
17	1.369/	/		1.374/	5/		1.377/	/		1.380/	/		1.383/	27/	92
18	1.376			1.379	5		1.382			1.386			1.389	18	
19	1.375/	/		1.379/	10/		1.382/	/		1.386/	/		1.389/	28/	
20	1.375			1.379	10		1.383			1.386			1.389	21	
21	1.371/	/		1.374/	15/		1.377/	/		1.378/	/		1.378/	35/	
22	1.372			1.375	20		1.378			1.378			1.376	47	
23	1.378/	/		1.381/	15/		1.384/	/		1.385/	/		1.385/	34/	
24	1.372			1.376	10		1.379			1.380			1.381	36	
25	1.371/	/		1.375/	0/		1.378/	/		1.381/	/		1.383/	23/	92
26															
27	1.376/	/		1.380/	15/		1.383/	/		1.387/	/		1.390/	38/	
28	1.374			1.377	15		1.382			1.385			1.388	38	
29	1.373/	/		1.378/	0/		1.382/	/		1.385/	/		1.388/	14/	
30	1.374			1.379	-5		1.387							8	
31	1.379/	/		1.383/	-5/		1.387/	/		1.391/	/		1.394/	15/	
32	1.375			1.379	5		1.382			1.386			1.390	16	84
33	1.385/	/		1.388/	5/		1.392/	/		1.396/	/		1.399/	6/	
34	1.386			1.390	15		1.394			1.397			1.400	34	
35	1.380/	/		1.384/	20/		1.388/	/		1.392/	/		1.395/	39/	
36	1.385			1.388	3		1.392			1.396			1.398	16	

OPERATOR ______________________ INSPECTION ______________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. NA AMBIENT TEMPERATURE 95 ± 5°F DATE 10/12/72
TEST DESCRIPTION High Temperature Overcharge

	0200 10 HOURS			0300 11 HOURS			0400 12 HOURS			0500 13 HOURS			0600 14 HOURS		
CELL S/N	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.398			1.396			1.394	58		1.392			1.389		
14	1.396			1.394			1.390	72		1.387			1.385		
15	1.405			1.404			1.401	65		1.399			1.395		
16	1.399			1.399			1.398	79		1.395			1.392		
17	1.384			1.386			1.389	64	95	1.390			1.391		
18	1.391			1.394			1.397	50		1.399			1.400		
19	1.392			1.394			1.396	60		1.399			1.400		
20	1.393			1.395			1.398	44		1.401			1.403		
21	1.378			1.377			1.376	45		1.375			1.374		
22	1.377			1.376			1.373	62		1.372			1.371		
23	1.385			1.384			1.382	51		1.380			1.378		
24	1.381			1.381			1.379	50		1.378			1.376		
25	1.385			1.386			1.387	54	91	1.389			1.389		
26															
27	1.393			1.394			1.396	73		1.397			1.399		
28	1.391			1.392			1.394	73		1.395			1.396		
29	1.392			1.394			1.396	38		1.399			1.401		
30								27							
31	1.397			1.399			1.402	38		1.403			1.405		
32	1.392			1.395			1.397	39	84	1.399			1.399		
33	1.402			1.404			1.406	19		1.408			1.409		
34	1.402			1.404			1.404	52		1.404			1.403		
35	1.397			1.399			1.401	72		1.402			1.401		
36	1.400			1.402			1.404	22		1.404			1.404		

OPERATOR ________________ INSPECTION ________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 3 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ______ PARA. ______ AMBIENT TEMPERATURE 95 ± 5 DATE 10/12/72

TEST DESCRIPTION High Temperature Overcharge

CELL S/N	0700 15 HOURS VOLTS	PRESS.	TEMP.	0800 16 HOURS VOLTS	PRESS.	TEMP.	0900 17 HOURS VOLTS	PRESS.	TEMP.	1000 18 HOURS VOLTS	PRESS.	TEMP.	1100 19 HOURS VOLTS	PRESS.	TEMP.
13	1.387	62		1.385			1.384			1.383	62		1.382		
14	1.382	73		1.380			1.378			1.377	68		1.377		
15	1.391	76		1.388			1.385			1.384	77		1.383		
16	1.388	95		1.384			1.381			1.378	100	*	1.323		
17	1.390	88		1.388			1.386			1.383	105	*	1.333		
18	1.400	76		1.399			1.398			1.396	100	*	1.343		
19	1.401	85		1.401			1.400			1.399	100+	*	1.344		
20	1.406	60		1.407			1.408			1.408	88		1.408		
21	1.373	47		1.372			1.372			1.371	47		1.371		
22	1.369	62		1.368			1.367			1.367	62		1.366		
23	1.376	62		1.375			1.374			1.373	52		1.373		
24	1.374	55		1.372			1.371			1.370	54		1.369		
25	1.389	74		1.388			1.388			1.387	87		1.386		
26															
27	1.399	91		1.398			1.397			1.397	100+		1.344		
28	1.397	88		1.396			1.395			1.395	98		1.393		
29	1.403	52		1.404			1.404			1.404	50		1.403		
30	~~1.406~~	35					1.404			1.403	40		1.402		
31	1.408	51		1.406			1.405			1.404	59		1.402		
32	1.400	68		1.398			1.397			1.395	82		1.393		
33	1.412	24		1.409			1.407			1.404	37		1.400		
34	1.402	60		1.399			1.395			1.392	72		1.389		
35	1.400	89		1.397			1.395			1.392	100+		1.335		
36	1.404	24		1.403			1.401			1.399	29		1.397		

OPERATOR ______ INSPECTION ______

SPECIAL INSTRUCTIONS:
1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN ~~X~~ 20 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. ______ AMBIENT TEMPERATURE ______________ DATE ________

TEST DESCRIPTION ____

CELL S/N	20 HOURS			21 HOURS			22 HOURS			23 HOURS			24 HOURS		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.382	60													
14	1.377	66													
15	1.384	75													
16	1.315	63													
17	1.326	90													
18	1.335	88													
19	1.336	95													
20	1.408	95													
21	1.370	46													
22	1.366	60													
23	1.372	51													
24	1.368	55													
25	1.385	90													
26		—													
27	1.336	87													
28	1.393	99													
29	1.402	57													
30	1.399	41													
31	1.399	65													
32	1.390	90													
33	1.397	42													
34	1.388	76													
35	1.326	79													
36	1.397	30													

OPERATOR ____________________ INSPECTION ____________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN ~~3~~ 20 DATA SHEET (DISCHARGE RECORD)

Started @ 12:35

TEST PROCEDURE NO. ______ PARA. ______ AMBIENT TEMPERATURE 95 ± .5 °F DATE 10-12-72

TEST DESCRIPTION Discharge @ 100 AMPS to 1.00 VOLT/cell

CELL S/N	1240 5 MIN.			1250 15 MIN.			1305 30 MIN.			1320 45 MIN.			1335 60 MIN.		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.243	36		1.207			1.192			1.164			1.066		
14	1.247	43		1.210			1.195			1.168			1.058		
15	1.252	51		1.221			1.209			1.188			1.150		
16	1.238	47		1.211			1.199			1.179			1.130		
17	1.283	78		1.264			1.257			1.247			1.233		
18	1.290	77		1.269			1.266			1.257			1.247		
19	1.290	78		1.271			1.265			1.257			1.247		
20	1.301	83		1.274			1.268			1.261			1.253		
21	1.271	25		1.239			1.227			1.215			1.182		
22	1.265	37		1.234			1.222			1.205			1.177		
23	1.275	30		1.246			1.235			1.219			1.193		
24	1.273	31		1.244			1.232			1.217			1.193		
25	1.293	74		1.269			1.261			1.251			1.237		
26															
27	1.289	70		1.269			1.262			1.253			1.239		
28	1.290	85		1.267			1.257			1.247			1.234		
29	1.294	44		1.269			1.262			1.253			1.242		
30	1.289	30		1.265			1.258			1.249			1.239		
31	1.297	50		1.273			1.266			1.257			1.246		
32	1.285	74		1.262			1.255			1.246			1.234		
33	1.283	24		1.258			1.253			1.246			1.237		
34	1.280	57		1.256			1.249			1.240			1.227		
35	1.266	63		1.247			1.242			1.233			1.220		
36	1.277	15		1.251			1.244			1.235			1.224		

OPERATOR ______________________ INSPECTION ______________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

RSN 3 DATA SHEET (DISCHARGE RECORD)

Started @ 1235

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE 95 ± 5 °F DATE 10-12-72

TEST DESCRIPTION Discharge @ 10 amps to 1.0 volt/cell

CELL S/N	75 MIN.			~~15~~ 90 MIN.			~~30~~ 105 MIN.			~~45~~ 120 MIN.			~~60~~ 135 MIN.		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
1 13	—	16		—			—			—			—		
2 14	—	20		—			—			—			—		
3 15	1.000	29		—			—			—			—		
4 16	1.236	33		—			—			—			—		
5 17	1.221	60		1.207			1.189			—			—		
6 18	1.236	61		1.225			1.212			1.188			—		
7 19	1.236	63		1.225			1.212			1.186			—		
8 20	1.245	60		1.237			1.228			1.214			1.193		
9 21	—	7		—			—			—			—		
10 22	—	16		—			—			—			—		
11 23	—	11		—			—			—			—		
12 24	1.088	10		—			—			—			—		
13 25	1.224	48		1.212			1.196			1.123			—		
14 26	—	—		—			—			—			—		
15 27	1.227	57		1.214			1.195			.609			—		
16 28	1.222	61		1.211			1.195			1.152			—		
17 29	1.232	26		1.212			1.210			1.191			1.094		
18 30	1.230	10		1.221			1.211			1.196			1.154		
19 31	1.236	30		1.226			1.214			1.198			1.109		
20 32	1.223	48		1.213			1.199			1.178			1.021		
21 33	1.228	10		1.218			1.205			1.174			—		
22 34	1.213	38		1.197			1.139			—			—		
23 35	1.207	50		1.191			1.147			—			—		
24 36	1.212	5		1.199			1.176			.757			—		

OPERATOR ____________________ INSPECTION ____________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

RSN 3 DATA SHEETS (END OF DISCHARGE RECORD)

TEST PROCEDURE NO. ______ PARA. ______ AMBIENT TEMPERATURE 35°C (95°F) DATE 10/12/72

TEST DESCRIPTION High temperature Discharge

CELL S/N	1.2 HOURS			MINUTES TO 1.1 VOLTS			MINUTES TO 1.0 VOLTS			MIN. TO 0.5 VOLT	MIN. TO 0.0 VOLT	MIN. TO -0.5 VOLT	MIN. TO -1.0 VOLT	MIN. TO -1.5 VOLTS
	VOLTS	PRESS.	TEMP.	MIN.	PRESS.	TEMP.	MIN.	PRESS.	TEMP.					
1 13							65							
2 14							65							
3 15							75							
4 16							68							
5 17							114							
6 18							129							
7 19							129							
8 20							150							
9 21							73							
10 22							73							
11 23							74							
12 24							79							
13 25							125							
14 26							—							
15 27							120							
16 28							125							
17 29							140							
18 30							141							
19 31							140							
20 32							136							
21 33							129							
22 34							109							
23 35							112							
24 36							120							

OPERATOR ______ INSPECTION ______

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

ITEM 5

THIRD 75°F CAPACITY TEST

Cells dead short 48hr prior to chg

RSN 21 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. NA PARA. ______ AMBIENT TEMPERATURE 75° DATE 10/15/72

TEST DESCRIPTION Capacity test

CELL S/N	5 MIN. VOLTS	5 MIN. PRESS.	5 MIN. TEMP.	1 HOUR VOLTS	1 HOUR PRESS.	1 HOUR TEMP.	2 HOURS VOLTS	2 HOURS PRESS.	2 HOURS TEMP.	3 HOURS VOLTS	3 HOURS PRESS.	3 HOURS TEMP.	4 HOURS VOLTS	4 HOURS PRESS.	4 HOURS TEMP.
13	1.526	-27		1.458			1.436			1.426			1.421		
14	1.510	-27		1.451			1.432			1.422			1.417		
15	1.782	-29		1.549			1.487			1.458			1.441		
16	1.668	-30		1.504			1.458			1.434			1.420		
17	1.372	-23	77	1.372			1.375			1.379			1.381		
18	1.376	-25		1.377			1.381			1.384			1.387		
19	1.376	-19		1.377			1.381			1.384			1.388		
20	1.377	-22		1.378			1.381			1.384			1.388		
21	1.387	-30		1.384			1.382			1.384			1.388		
22	1.423	-26		1.410			1.398			1.392			1.393		
23	1.393	-29		1.390			1.389			1.390			1.393		
24	1.379	-30		1.380			1.382			1.383			1.387		
25	1.354	-26	77	1.376			1.377			1.379			1.382		
26															
27	1.380	-26		1.383			1.385			1.388			1.390		
28	1.406	-28		1.406			1.400			1.397			1.396		
29	1.371	-28		1.373			1.377			1.381			1.385		
30	1.378	-28		1.374			1.378			1.382			1.385		
31	1.376	-28		1.380			1.385			1.388			1.391		
32	1.380	-26	77	1.374			1.380			1.384			1.387		
33	1.383	-27		1.387			1.390			1.393			1.397		
34	1.413	0		1.417			1.416			1.415			1.413		
35	1.396	7		1.400			1.403			1.404			1.405		
36	1.394	-10		1.394			1.397			1.398			1.399		

OPERATOR ______________________ INSPECTION ______________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 21 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE ________ DATE ________

TEST DESCRIPTION ________

CELL S/N	5 HOURS			6 HOURS			7 HOURS			8 HOURS			9 HOURS		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.418			1.419	-22		1.419			1.422			1.426	-13	
14	1.415			1.416	-23		1.418			1.421			1.423	-13	
15	1.431			1.426	-26		1.425			1.425			1.428	-20	
16	1.415			1.413	-27	72	1.413			1.415			1.418	-20	
17	1.385			1.388	-23		1.390			1.393			1.397	-18	71
18	1.390			1.393	-25		1.396			1.398			1.401	-22	
19	1.391			1.393	-18		1.396			1.399			1.402	-15	
20	1.390			1.393	-22		1.396			1.399			1.410	-20	
21	1.391			1.395	-20		1.399			1.403			1.406	-6	
22	1.395			1.397	-19		1.401			1.404			1.408	-6	
23	1.397			1.401	-19		1.405			1.408			1.411	-9	
24	1.391			1.394	-20		1.399			1.402			1.405	-9	
25	1.385			1.388	-27	72	1.391			1.394			1.396	-22	72
26															
27	1.393			1.395	-25		1.398			1.400			1.403	-18	
28	1.396			1.397	-26		1.398			1.399			1.402	-20	
29	1.388			1.391	-28		1.394			1.397			1.400	-23	
30	1.389			1.393	-29		1.396			1.399			1.402	-25	
31	1.394			1.395	-22		1.401			1.404			1.407	-18	
32	1.390			1.394	-23	63	1.400			1.401			1.403	-19	63
33	1.400			1.404	-28		1.406			1.410			1.412	-25	
34	1.413			1.413	-10		1.414			1.416			1.417	-10	
35	1.406			1.406	2		1.407			1.409			1.411	2	
36	1.402			1.404	-7		1.407			1.410			1.414	-3	

OPERATOR ________ INSPECTION ________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 21 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE ________ DATE ________
TEST DESCRIPTION ________

CELL S/N	10 HOURS			11 HOURS			12 HOURS			13 HOURS			14 HOURS		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.432			1.440			1.451	4		1.457			1.455		
14	1.428			1.434			1.442	2		1.454			1.456		
15	1.432			1.437			1.447	-4		1.462			1.467		
16	1.422			1.427			1.434	-4		1.448			1.458		
17	1.400			1.404			1.409	-10	72	1.415			1.418		
18	1.405			1.408			1.412	-17		1.418			1.423		
19	1.405			1.408			1.412	-10		1.416			1.421		
20	1.404			1.407			1.410	-16		1.414			1.417		
21	1.409			1.411			1.413	-3		1.415			1.416		
22	1.411			1.413			1.415	-2		1.417			1.418		
23	1.414			1.416			1.419	-9		1.422			1.421		
24	1.409			1.411			1.414	-10		1.417			1.419		
25	1.399			1.403			1.406	-16	73	1.408			1.410		
~~26~~															
27	1.406			1.410			1.413	-10		1.418			1.423		
28	1.404			1.407			1.410	-14		1.413			1.417		
29	1.403			1.406			1.409	-18		1.413			1.417		
30	1.405			1.408			1.413	-19		1.417			1.421		
31	1.410			1.413			1.417	-13		1.421			1.425		
32	1.405			1.456			1.410	-12	64	1.411			1.406		
33	1.416			1.421			1.426	-22		1.434			1.442		
34	1.420			1.424			1.428	-08		1.434			1.440		
35	1.414			1.417			1.421	+1		1.426			1.430		
36	1.418			1.424			1.430	0		1.438			1.444		

OPERATOR ________ INSPECTION ________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 21 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ______ PARA. ______ AMBIENT TEMPERATURE 75 ± 5 DATE 10-16-72

TEST DESCRIPTION ______

CELL S/N	0900 15 HOURS			1000 16 HOURS			1100 17 HOURS			1200 18 HOURS			1300 19 HOURS		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.450		25	1.446			1.444			1.442	26		1.440		
14	1.451		24	1.444			1.440			1.438	30		1.436		
15	1.442		31	1.453			1.449			1.446	37		1.444		
16	1.458		36	1.451			1.444			1.441	53		1.437		
17	1.419		0	1.422			1.427			1.434	10		1.446		
18	1.427		-6	1.431			1.436			1.447	8		1.464		
19	1.426		0	1.430			1.435			1.448	9		1.470		
20	1.423		-12	1.431			1.441			1.460	3		1.480		
21	1.418		-8	1.420			1.421			1.422	- 9		1.422		
22	1.421		-4	1.423			1.424			1.425	- 5		1.423		
23	1.424		-11	1.425			1.427			1.427	- 8		1.425		
24	1.421		-11	1.423			1.426			1.427	- 10		1.426		
25	1.413		-5	1.418			1.425			1.439	+ 8		1.458		
26															
27	1.429		0	1.433			1.438			1.449	+ 9		1.465		
28	1.422		-8	1.428			1.434			1.443	+ 2		1.460		
29	1.423		-6	1.431			1.442			1.455	2		1.471		
30	1.428		-10	1.435			1.446			1.461	- 2		1.471		
31	1.432		-10	1.440			1.448			1.459	+ 4		1.474		
32	1.439		-10	1.432			1.469			1.445	+ 7		1.390		
33	1.460		-14	1.478			1.478			1.466	+ 33		1.458		
34	1.452		3	1.471			1.476			1.466	+ 72		1.457		
35	1.439		6	1.459			1.474			1.468	+ 84		1.458	*	
36	1.455		2	1.471			1.468			1.458	+ 25		1.452		

* Cell removed, P = 100#

OPERATOR ______ INSPECTION ______

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN 21 DATA SHEET (CHARGE RECORD)

TEST PROCEDURE NO. ________ PARA. ________ AMBIENT TEMPERATURE 75°F ± 5° DATE 10-16-72
TEST DESCRIPTION ________

1400

CELL S/N	20 HOURS			21 HOURS			22 HOURS			23 HOURS			24 HOURS		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.440	+26	74												
14	1.436	+30													
15	1.444	+35													
16	1.435	+53													
17	1.446	+39													
18	1.461	+53													
19	1.467	+29													
20	1.474	+63													
21	1.421	-4	76												
22	1.421	+0													
23	1.421	0													
24	1.423	-3													
25	1.458	+39													
~~26~~															
27	1.465	+43													
28	1.465	+38													
29	1.473	+27	86												
30	1.462	+15													
31	1.472	+26													
32	1.444	+32													
33	1.454	+36													
34	1.453	+90													
35	1.374	+90													
36	1.450	+26													

OPERATOR ________ INSPECTION ________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at three (3) hour intervals.

RSN ~~3~~ 20 DATA SHEET (DISCHARGE RECORD)

TEST PROCEDURE NO. ______ PARA. ______ AMBIENT TEMPERATURE 75±5 °F DATE 10-16-72

TEST DESCRIPTION ______

	5 MIN.			15 MIN.			30 MIN.			45 MIN.			60 MIN.		
CELL S/N	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.322			1.284	14		1.220			1.208			1.192	+5	
14	1.326			1.291	17		1.230			1.220			1.207	+5	
15	1.331			1.294	22		1.226			1.215			1.203	+9	
16	1.324			1.288	39		1.221			1.210			1.197	+25	
17	1.352			1.327	33		1.255			1.252			1.248	+24	
18	1.363			1.338	45		1.259			1.256			1.253	+36	
19	1.368			1.341	60		1.258			1.255			1.251	+44	
20	1.373			1.345	54		1.257			1.254			1.251	+41	
21	1.326			1.308	-16		1.256			1.248			1.241	-24	
22	1.327			1.308	-10		1.255			1.247			1.240	-20	
23	1.331			1.312	-10		1.260			1.252			1.245	-20	
24	1.330			1.309	-16		1.256			1.250			1.244	-22	
25	1.354			1.326	30		1.252			1.249			1.245	+19	
~~26~~															
27	1.363			1.335	35		1.256			1.253			1.249	+21	
28	1.354			1.325	29		1.245			1.242			1.238	+18	
29	1.354			1.326	19		1.253			1.249			1.244	+10	
30	1.349			1.321	17		1.250			1.246			1.243	-2	
31	1.358			1.330	17		1.258			1.254			1.250	+9	
32	1.347			1.320	25		1.247			1.243			1.238	+15	
33	1.354			1.324	23		1.245			1.241			1.235	+11	
34	1.349			1.318	75		1.239			1.234			1.229	+57	
35	1.327			1.299	85		1.234			1.229			1.223	+70	
36	1.342			1.301	14		1.234			1.227			1.224	+5	

OPERATOR ______ INSPECTION ______

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

RSN ~~X~~ 20 DATA SHEET (DISCHARGE RECORD)

TEST PROCEDURE NO. ____________ PARA. ________ AMBIENT TEMPERATURE 75 ± 5 °F DATE 10-16-72

TEST DESCRIPTION

CELL S/N	75 MIN.			90 MIN.			105 MIN.			120 MIN.			135 MIN.		
	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.	VOLTS	PRESS.	TEMP.
13	1.160			1.080			1—								
14	1.187			1.150			1—								
15	1.184			1.147			1—								
16	1.297			1.137			1—								
17	1.248			1.239			1.234			1.227			1.		
18	1.248			1.244			1.239			1.232			1.		
19	1.247			1.243			1.238			1.231			1.		
20	1.243			1.242			1.236			1.230			1.		
21	1.233			1.224			1.210			1.177			1.		
22	1.233			1.225			1.213			1.191			1.		
23	1.238			1.229			1.217			1.193			1.		
24	1.237			1.229			1.220			1.205			1.		
25	1.240			1.234			1.229			1.221			1.		
~~26~~															
27	1.244			1.239			1.233			1.225			1.		
28	1.233			1.228			1.222			1.214			1.		
29	1.239			1.234			1.227			1.220			1.		
30	1.239			1.234			1.228			1.222			1.		
31	1.246			1.241			1.234			1.228			1.		
32	1.234			1.229			1.223			1.216			1.		
33	1.230			1.224			1.216			1.202			1.		
34	1.222			1.214			1.204			1.183			1.		
35	1.216			1.207			1.195			1.166			1.		
36	1.218			1.210			1.198			1.177			1.		

OPERATOR ____________________ INSPECTION ____________________

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

RSN ~~9~~ 20 DATA SHEETS (END OF DISCHARGE RECORD)

TEST PROCEDURE NO. ______ PARA. ______ AMBIENT TEMPERATURE 75 ± 5 °F DATE 10-16-72

TEST DESCRIPTION ______

	CELL S/N	1.2 HOURS			MINUTES TO 1.1 VOLTS			MINUTES TO 1.0 VOLTS			MIN. TO 0.5 VOLT	MIN. TO 0.0 VOLT	MIN. TO -0.5 VOLT	MIN. TO -1.0 VOLT	MIN. TO -1.5 VOLTS
		VOLTS	PRESS.	TEMP.	MIN.	PRESS.	TEMP.	MIN.	PRESS.	TEMP.					
1	13							96							
2	14							106							
3	15							105							
4	16							104							
5	17							163							
6	18							165							
7	19							162							
8	20							161							
9	21							130							
10	22							134							
11	23							134							
12	24							141							
13	25							165							
~~14~~	~~26~~														
15	27							156							
16	28							156							
17	29							160							
18	30							167							
19	31							164							
20	32							163							
21	33							141							
22	34							134							
23	35							132							
24	36							139							

OPERATOR ______ INSPECTION ______

SPECIAL INSTRUCTIONS:

1. Record voltages as indicated.
2. Record temperatures & pressures at five (5) minutes and then at one (1) hour intervals.

ITEM 6

PRECHARGE MEASUREMENT

AND

ELECTRODE CAPACITY TEST

EAGLE-PICHER INDUSTRIES, INC.
Couples Plant - Joplin, Missouri

TYPE TEST: Precharge Determination
TEST SPECIMEN NO. 26
TEST PROCEDURE NO. N/A
DATE 9/12/72 • TIME ~~0930~~ 0940
TEST PARA. REF. NO. N/A
E. P. BAT. TYPE RSN-21 S. N.
AMBIENT TEMP. 75 °F ±5
BAT. NO.
BATT. TEMP. °F
TYPE PROGRAM: PROD. ☐ QUAL. ☐ R & D ☑
PREVIOUS TEST: Sealed capacity

/ Charge 6 amps for 5 hours

	TIME	VOLTS	AMPS	Pressure		
0925	~~[illegible]~~	1.16	0	-30		
	5 min	1.39	6			
10	1040	1:40		-30		
	1140	1.40		-30		
	1300	1.41		-24		
3h20	1420	1.43		-6		
5h20 m	~~14~~ 1500	1.44		6		
	0740	start	6	-10		
	0840					
		Discharge				
		~~[illegible]~~	-0-			
	C	1.48	0 ~~10 amps~~	63*		
	0845	Start	-10-			
	0850	1.30	~~69~~	67		
	1030	1.22+	10	44		
	1100	1.21		40		
	1115	1.20		38		
	1130	1.18		37		
	1.0v	2h52				
	.5v	2h59				
	.0v	3h 2				
	1150	-.22				
6	1200	.34				
	-1.0v	3h16				
	Pos	28.7				
	Neg	32.6				

TIME	VOLTS	AMPS			

	Voltmeter	Ammeter
TYPE	weston	weston
MODEL	931	931
S/N	7228	85231
CALIB. FACTOR	10 = .99	used 5.9 = 6
CALIB. DUE DATE	9/14/72	10-5-72
OPERATOR	GRA	
ENGINEER		
INSPECTOR		

EAGLE-PICHER INDUSTRIES, INC.

Couples Plant - Joplin, Missouri

TYPE TEST: Precharge measurement ~~Electrode Capacity~~

TEST SPECIMEN NO. ____

TEST PROCEDURE NO. AVO

TEST PARA. REF. NO. ____

AMBIENT TEMP. 75 °F

BATT. TEMP. ____ °F

DATE 10-30-72 TIME 1610

E. P. BAT. TYPE RSNi-21 S. N. ____

BAT. NO. ____

TYPE PROGRAM: PROD. ☐ QUAL. ☐ R & D ☐

PREVIOUS TEST: ____

Charge @ 2Amp to for 20 Hours

	16	19	22	32	35
TIME	VOLTS	AMPS			
ocv	1.27	1.26	1.27	1.27	1.27
1-min	1.36	1.36	1.36	1.32	1.34
30 min	1.38	1.35	1.36	1.34	1.36
0815	1.42	1.42	1.40	1.42	1.42+
P	51	40	14	47	13
1100	1.41+	1.44	1.41	1.41	1.42
P	51	84	10	39	10
1210	1.42	1.44	1.41	1.42	1.42
P	51	100+	8	38	15
1245	Discharge	@ 10 Amps			
OSV	1.35	1.36	1.35	1.35	1.35
1-min	1.28	1.32	1.31	1.31	1.29
1315 30 min	1.22	1.26	1.26	1.26	1.24
1345 60 min	.19	1.24	1.24	1.24	1.23
1415 90 "	1.11	1.24	1.21	1.23	1.21
120	-.18	1.23	1.09	1.22	1.18
150 min		1.23		1.17	
Time To 1	0-99 min	168 min	125 min	160 min	140 min
" To .05	112	167 min	127 min	161 min	143 min
" To 0	120	170 min	127 "	162 min	147 min
" To -.05	135	175 min	139	173 min	153 min
" To -1.00	142	180 min	150	177 min	156 min
" To -1.50	149 min	188 min	154 min	183 min	161 min
Pos	16.5	28.0	20.9	26.7	23.4
Neg	23.7	30.0	25.7	29.5	26.0

TIME	VOLTS	AMPS			

	Voltmeter	Ammeter
TYPE	weston	weston
MODEL	931	931
S/N	7228	85231
CALIB. FACTOR	1.0= .993	used
CALIB. DUE DATE	11/14/72	11/3/72
OPERATOR		
ENGINEER		
INSPECTOR		

TF-41 WHITAKER PTG 8387

EAGLE-PICHER INDUSTRIES, INC.
Couples Plant - Joplin, Missouri

TYPE TEST: Flooded Electrode capacity
TEST SPECIMEN NO. ____________

TEST PROCEDURE NO. ____________
TEST PARA. REF. NO. ____________
AMBIENT TEMP. ________ °F
BATT. TEMP. ________ °F

DATE 11-1-72 TIME 1615
E. P. BAT. TYPE RSN-21 S. N. Listed
________ BAT. NO. ________
TYPE PROGRAM: PROD. ☐ QUAL. ☐ R & D ☐
PREVIOUS TEST: ____________

Charge @ 5 AMPS 20 hours

TIME	VOLTS	AMPS				TIME	VOLTS	AMPS
Cell No	16	19	22	26	35	32		
5-min	1.36	1.36	1.36	1.38	1.36	1.35		
1 HOUR	1.38	1.37	1.38	1.38+	1.38	1.38		
2 HOUR	1.39	1.38	1.39	1.39+	1.39	1.38+		
3 HOURS	1.40	1.39	1.40	1.40	1.40	1.38+		
17-hours	1.48	1.48	1.47	1.42	1.42	1.49		
18 hours	1.48	1.47	1.46	1.42-	1.42	1.49		
19-hours	1.48	1.45	146	141	141	1.49		
20 hours	148	146	146	141	141	149		
122		Discharge @ 10 AMPS						
ocv	1.38	1.37	1.36	1.36	1.35	1.38		
1-min	1.31	1.31	1.30	1.31	1.30	1.32		
30 min	1.24	1.24	1.25	1.24	1.24	1.25		
1 hr.	1.24	1.24	1.24	1.24	1.24	1.24		
30 min	1.22	1.23	1.24	1.23	1.23	1.24		
2-hours	1.18	1.22	1.22	1.22	1.21	1.23		
30 min	-18	1.21	1.21	1.21	1.21	1.20		
3-hours	-.2	.58	.2	.47	-.17	1.18		
1.0	2hrs 13min	2:59	2:48	2:58	2:38	3:11		
.5	2hrs 15-min	3:03	2:53	3:00	2:43	3:12		
0	2:22	3:10	3:02	3:06	2:50	3:17		
-05	4:30		4:06	4:56	4:23	4:20		
-1.0	4:33	4:48	4:07	4:58	4:25	4:22		
-1.5	4:35	4:50	4:08	5:00	4:27	4:23		
Neg Capy	45.8	48.3	41.7	50 AH	42.5	43.9		
Pos Capy	22.2	29.8	28.0	29.7	26.3	31.9		

	Voltmeter	Ammeter
TYPE		
MODEL		
S/N		
CALIB. FACTOR		
CALIB. DUE DATE		
OPERATOR		
ENGINEER		
INSPECTOR		

TF-41 WHITAKER PTG 8387

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GODDARD SPACE FLIGHT CENTER                 MASTER LIST                                   PAGE  65
BUSINESS DATA BRANCH                      REPORT NO 1932
ADDRESS LABEL SYSTEM                         LIST   020
RUN DATE   FEB 11 1974
NASA                            1                                                                 1 CODE KT
NATIONAL AERO                   2                                                                 2
AND SPACE ADMIN                 3 MR ERNST M COHN CODE RPP        MR.SIMON MANSON,CODE ES         3 [illegible]
SCIENTIFIC AND TECHNICAL        4 NATIONAL AERO                   NATIONAL AERO & SPACE ADM.      4 NATIONAL AERO
INFORMATION CENTER, INPUT       5 AND SPACE ADMIN                 WASHINGTON,D.C.                 5 AND SPACE ADMIN
P.O. BOX 33                     6 WASHINGTON, D.C. 20546                                          6 WASHINGTON, D.C. 20546
COLLEGE PARK, MARYLAND 20740    7                                                                 7
0010                            8 0020                            0025                            8 0040

                                1 MR. JON RUBENZER, M.S. 244-2    MR.GERALD HALPERT CODE 711      1 MR. THOMAS HENNIGAN,
                                2 AMES RESEARCH CENTER CODE PBS   GODDARD SPACE FLIGHT CENTER     2 CODE 711
MR.R.D.GINTER                   3 NATIONAL AERO                   NATIONAL AERO                   3 GODDARD SPACE FLIGHT CENTER
CODE RE                         4 AND SPACE ADMINI                AND SPACE ADMIN                 4 NATIONAL AERO
NATIONAL AERO AND SPACE ADM     5 MOFFETT FIELD, CALIF. 94035     GREENBELT, MARYLAND 20771       5 AND SPACE ADMIN
WASHINGTON D.C.20546            6                                                                 6 GREENBELT, MARYLAND 20771
                                7                                                                 7
0041                            8 0060                            0070                            8 0080

                                1                                                                 1
                                2                                                                 2
MR.WILLIAM WEBSTER CODE 711     3 MR.FLOYD FORD CODE 711          MR.EUGENE STROUP CODE 757.1     3 VIRGINIA KENDALL CODE 251.2
NASA GODDARD SPACE FLIGHT CEN   4 NASA GODDARD SPACE FLIGHT CEN   NASA GODDARD SPACE FLIGHT CEN   4 NASA GODDARD SPACE FLIGHT CEN
GREENBELT MARYLAND 20771        5 GREENBELT MARYLAND 20771        GREENBELT MARYLAND 20771        5 GREENBELT MARYLAND 20771
                                6                                                                 6
                                7                                                                 7
0084                            8 0087                            0090                            8 0095

DR  LOUIS ROSENBLUM, MS 302-1   1 MR. HARVEY SCHWARTZ, MS 309-1   DR. J. STUART FORDYCE,          1 MR. CHAS B. GRAFF, S&E-ASTR-EP
LEWIS RESEARCH CENTER           2 LEWIS RESEARCH CENTER           MS 309-1                        2 GEO C. MARSHALL SPACE FL CEN
NATIONAL AERO                   3 NATIONAL AERO                   LEWIS RESEARCH CENTER           3 NATIONAL AERO
AND SPACE ADMIN                 4 AND SPACE ADMIN                 NATIONAL AERO                   4 AND SPACE ADMIN
2100 BROOKPARK ROAD             5 21000 BROOKPARK ROAD            AND SPACE ADMIN                 5 HUNTSVILLE, ALABAMA 35812
CLEVELAND, OHIO 44135           6 CLEVELAND, OHIO 44135           21000 BROOKPARK ROAD            6
                                7                                 CLEVELAND, OHIO 44135           7
0130                            8 0140                            0150                            8 0160

                                1                                                                 1
                                2                                                                 2
MR. DANIEL RUNKLE, MS 198-220   3 MR.SAM BOGNER MS 198-220        MR. AIJI UCHIYAMA, MS 198-220   3 DR. R. LUTWACK, MS 198-220
JET PROPULSION LABORATORY       4 JET PROPULSION LABORATORIES     JET PROPULSION LABORATORY       4 JET PROPULSION LABORATORY
4800 OAK GROVE DRIVE            5 4800 OAK GROVE DRIVE            4800 OAK GROVE DRIVE            5 4800 OAK GROVE DRIVE
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                                7                                                                 7
0180                            8 0185                            0190                            8 0200

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                                6                                                                 6
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0205                            8 0210                            0220                            8 0240

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                                2                                                                 2
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0245                            8 0255                            0260                            8 0270

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0280                            8 0290                            0300                            8 0310
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