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NON-GASSING NICKEL-CADMIUM BATTERY ELECTRODES AND CELLS

Report No: 712-122-4

Final Report
15 June 1971 to 15 June 1972

Prepared by E. Luksha and D.J. Gordy
Approved by C.J. Menard

15 July 1972

Jet Propulsion Laboratory
Contract No. 953184

Gould Inc., Gould Laboratories
Energy Technology
1110 Highway 110
Mendota Heights, Minnesota 55118

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GLOSSARY

Q_3	State-of-charge of an electrode at the third cycle
Q_{20}	State-of-charge of an electrode at the 20th cycle
E_j	Effect of variable j
j	Column position
i	Row position in experimental design
N	Number of tests performed
Y	Test value recorded
C	Multiplier value in the design
$A/in.^2$	Current density amperes per inch square
$g/in.^3$	Electrode active material loading, grams per inch cube
AA*	Chromatographic peak area x attenuation
V_{O_2}	Rate of oxygen evolution, cc/min
V_{H_2}	Rate of hydrogen evolution, cc/min
i_{O_2}	Current consumed for oxygen evolution, amps
i_{H_2}	Current consumed for hydrogen evolution, amps
i	Total current, amps
E	Cell voltage, volts
N	In Appendices, not detectable
N.C.	In Appendices, detectable, but not calculatable

I. SUMMARY

There are various special applications for very long-lived, a decade or more, sealed nickel-cadmium batteries. The gassing which normally occurs in such cells limits their lives severely and in many cases is the sole cause of failure. An approach toward dramatically increasing their lives is to incorporate electrodes in these batteries that exhibit little or no gassing with controlled charge input.

This requires: 1) the ratio of positive to negative active material be changed to make cells negative limited, and 2) use materials that possess the highest possible over-potentials for the hydrogen evolution reaction so that the onset of hydrogen gassing would result in a large voltage step to be used to cut off the charge.

This report describes work conducted at Gould Inc. towards this end. The concept of a negative limited nongassing nickel-cadmium battery was demonstrated by constructing and testing practical size experimental cells of approximately 25 Ah capacity. These batteries operated in a gas-free manner and had measured energy densities of 10-11 Wh/lb. Thirty cells were constructed for extensive testing. Some small cells were tested for over 200 cycles at 100% depth. For example, a small cell with an electrodeposited cadmium active mass on a silver screen still had 55% of its theoretical capacity (initial efficiency was 85%). A full factorial experimental design was used for the test program. Extensive testing of the gassing properties of nickel electrodes showed that the minimum positive/negative active material ratio was 1.7:1. This value had to be increased to 3:1 to account for other nocuous variables encountered in constructing real cells. There was no evidence of deterioration of gassing properties with cycling of the nickel electrodes. The charge temperature was observed to be the most critical variable governing nickel electrode gassing. This variable was shown to be age dependent. On an overall average basis nickel electrodes gassed at a 5% lower state-of-charge when the charge temperature was increased from 0° to 50°C, on the third cycle. They gassed at a 29% lower state-of-charge on the 20th cycle under the same conditions. Thus, the charge temperature variable was shown to be age dependent. Electrodes with high $Ni(OH)_2$ loadings were observed to gas at lower states-of-charge than those with lower loadings. A nickel electrode with a loading of about 20 g/in.^{3} $Ni(OH)_2$ was the optimum one because of its gassing properties, energy density, and physical properties. However, for use in the above mentioned practical size cells a higher loading had to be used because of design considerations.

Four types of cadmium electrodes were tested in this work: An electrodeposited cadmium active mass on a cadmium or silver substrate, a porous sintered silver substrate based electrode, and a Teflon bonded pressed cadmium electrode. The electrodeposited cadmium mass on a silver screen was found to be the best all-around electrode from a performance point of view and from the point of view of manufacturing them in a size required for a 25 Ah size battery.

The cadmium electrodes performed ideally, they did not gas until fully charged and exhibited large potential steps when fully charged. However, they had one fault: they exhibited degradation with cycling. The magnitude of this 'fading' was 0.1 - 0.2% per cycle for the best cells. The magnitude of the 'fading' is dependent on numerous test parameters and not confined to the above value. In the testing of real cells it was found that the nongassing behavior is not adversely affected by extended cycling. The gradually fading negative electrode increases the active material ratio so that there is less tendency to gas.

A safe cut-off voltage to ensure that no H_2 will be produced was 1.75V in the temperature range of 0° to 50°C.

The capacity of the negative electrode has to be low, 0.10 Ah/in.^{2}, to achieve the proper active material ratio in the cells. The low loadings also show less gassing.

The threshold voltage of H_2 gassing is 1.78 to 1.79 volts in the range of 0° to 50°C. This voltage exhibited a very small temperature dependence.

The depth-of-discharge shows no effect on gassing. Although the DOD does affect fading, the effect is less than in conventional cells.

The efficiency (Ah out/Ah in) is almost independent of charge rate. The efficiency is very slightly decreased by an increased charge rate.

The optimum charge rate of the negative limited cells is independent of temperature in the range of 0° to 50° if the cut-off voltage is $\leq$1.75V.

The plates are generally operable over the test range of 0° to 50°C. Cycle data is not available at the high temperature.

With the correct ratio of active materials, no gassing is observed, even in flooded cells. The Ah input/Ah output efficiency is 100%, and no cumulative pressure increase.

The electrodeposited negative electrode with a silver grid was mechanically stronger than commercial negative electrodes. The silver grid should provide better thermal conductivity; no data are available.

The cells will accept charge rates of 2C and higher without gas evolution. Conventional cells will gas under these conditions.

As far as manufacturing of the cells is concerned, the materials should be obtainable in the same quality in the future. No exotic equipment was required. Any quantity may be produced in a single 'lot'. The uniformity of the cells should be as good or better than conventional cells. The same control methods may be used. The controllability of the processes is equivalent to the current state of art or better. It is a function of inspection, materials purity, etc. If carbonates or nitrates have been present, they have shown no short-term effect on gassing. If sufficient carbonates were present to reduce the capacity of the cadmium electrode, the effect would probably be more apparent in the new cells since conventional positive limited cells have an excess of cadmium. No nitrogen compounds were found. No unusual separator materials were used.

II. INTRODUCTION

There is presently a need for very reliable and very long lived, about one decade, secondary batteries for applications such as in deep probe space vehicles, medical implantations, various cordless appliances, and other special uses. Sealed nickel-cadmium batteries are uniquely suited for such applications, mainly because of their long lives. However, the gassing that normally occurs in these cells, limits their reliability for very long life. The gassing problem becomes particularly severe during latter stages of the cell life. Aging effects on both electrodes can result in a set of circumstances that sealed cells can rupture due to hydrogen generation on charge. In many cases, gas evolution is the sole cause of life limitation of nickel-cadmium cells. As a result, an approach toward increasing the life of nickel-cadmium cells toward the decade or so required, is to construct cells designed with little or no gassing. The Jet Propulsion Laboratories have suggested an approach leading to the development of a 'nongassing' nickel-cadmium battery. Their approach involves essentially three changes in the design of conventional nickel-cadmium batteries. These are:

1. Change the ratio of positive to negative active material in the cells so that the cells become negative limited
2. Use a grid material for the cadmium electrode that has a high overpotential for the hydrogen evolution reaction so that the onset of hydrogen gassing would be signaled by a relatively large voltage step
3. Incorporation of a miniature electronic charge control device that will be used externally to each cell to end the charge using the voltage step as a signal

Gould Inc., Energy Technology Laboratories, under subcontract to JPL is involved in the design, development, and testing of a 'nongassing' battery in accordance with parts 1 and 2 above.

To reach these goals, cadmium electrodes with the highest possible overpotential for the hydrogen evolution reaction are being developed. The configurations of cadmium electrodes tested by Gould were:

- An electrodeposited cadmium active mass on an expanded cadmium metal screen
- A cadmium active mass deposited in a porous silver substrate of precisely controlled porosity and pore size
- An electrodeposited cadmium active mass on an expanded silver screen
- A pressed cadmium electrode prepared from electrolytic $Cd(OH)_2$ admixed with Teflon powder

These various electrodes were tested to determine the optimum configuration for minimum gassing as a function of temperature, charge and discharge rates, and loading.

III. EXPERIMENTAL

A. Cadmium Electrode Preparation

1. Electrodeposited Cadmium on Cadmium Screen

Electrodes were prepared using a laboratory version of a proprietary production process whereby a cadmium active mass was deposited on a cadmium 5 Cd 7-5/0 expanded metal (Exmet Corp) screen. In the past, electrodes of this type have been prepared with total coulombic efficiencies ranging from 20 to 95% for a 0.1A/in.[2] discharge. The efficiency depends solely on the process conditions. For this work, electrodes were prepared with efficiencies in the 50% range, a rather low value compared with commercial electrodes. The process is not limited to producing electrodes of the overall efficiencies described in this work. Since it was not the object of the work to prepare highly efficient electrodes the efficiencies of these electrodes were based on their formation output rather than weight gain.

2. Electrodeposited Cadmium on Silver Screen

Electrodes were prepared as above except that the cadmium active mass was deposited on a silver expanded metal screen designated 5 Ag 7-4/0 (Exmet Corp). These electrodes had somewhat superior mechanical properties than those with cadmium screens.

3. Teflon Bonded Pressed Cadmium Electrodes

Pressed cadmium electrodes were prepared by first plating cadmium metal onto a nickel foil, scraping it off, washing and drying it, and finally grinding it in a motorized mortar and pestle for 30 minutes. The resulting powder was blended with 15% by weight Teflon powder in a Twin-Shell blender. This mixture was pressed onto a cadmium screen at 6 tons/in.[2]

4. Porous Silver Substrate Cadmium Electrodes

Porous silver substrates for nongassing cadmium electrodes were also prepared employing a fugitive pore-former technique. The experimental work involved pore-former preparation, silver powder preparation, blending the two powders, die compacting the powder blend, removing the pore-former, and sintering the 'green' plaque. The following steps describe the various steps in the plaque preparative procedure.

Pore Former – Ammonium carbonate was shown to be[3] a very convenient pore-former material. It was prepared by:

- Fisher purified grade powder was placed in a pan in a dry room (RH 3-5%) overnight to allow loss of any excess moisture.
- The powder was then placed in a porcelain ball mill and ground for 15 to 20 minutes utilizing 13/16 in. diameter Burundum grinding media.

- After grinding, the powder was placed in a stack of standard sieves and placed on a Ro-Tap sieve shaker for 15 minutes. The -37μ fraction was separated and placed aside, and the remaining fractions were labeled and saved for future use and/or grinding.

  When a sufficient fraction of -37μ powder was obtained, it was placed in a three-inch micromesh sieve stack (44μ, 30μ, 20μ, 10μ) and placed on a Ro-Tap shaker for 15 minutes. The $-30+20\mu$ fraction was used in this work. All operations on the pore-formers (grinding, sieving, and storage) were performed in a dry room (RH 3-5%).

Silver Powder – Handy and Harmon Sil powder 120 was used in this work. It was processed by first placing a sample in a vacuum oven overnight at 80°C. After removal from the oven, the powder was placed in the dry room to cool. When cool, the powder was placed in the above-mentioned micromesh sieves and processed on the Ro-Tap for 15 minutes. The $-20+10\mu$ fraction was stored in the dry room for future use and the remaining fractions discarded.

Powder Blending – To prepare a blend for a 75% porous structure, for example, the silver and $(NH_4)_2CO_3$ were weighed out on a Mettler P162 balance in sufficient quantities to give a blend of $Ag:(NH_4)_2CO_3$ ratio of 3:1 by weight. The normal working weight was 200 grams. This was used to aid in handling and to avoid changes in composition due to storage. The powders were then mixed and placed in a 37μ sieve and brushed through with a bristle paintbrush. This procedure was followed to minimize lumping of the pore-former. Following the brushing process, the blend was placed in a Patterson-Kelley twin-shell dry blender and allowed to mix for 30 minutes. After mixing, the material was again brushed through a sieve and then stored in the dry room. The above operation was carried out in the dry room.

Powder Compaction – The blend was then loaded into a die, which already contained an expanded metal screen, by brushing through a 37μ sieve. All excess material was struck off, and the powder was compacted.

Pore-Former Removal – After compaction, the 'green' sintered specimen was removed from the mold and the $(NH_4)_2CO_3$ pore-former was removed by heating the specimen in a vacuum oven.

Green Plaque Sintering – The 'green' plaques were then removed from the decomposition oven and immediately placed into a vacuum furnace where they were sintered at a pressure of less than 50μ. Helium was used as a back-fill and cooling media.

B. Nickel Electrode Preparation

Inco 287 powder was used for the preparation of positive electrode gassing study portion of this program. The powder was first dried in a vacuum oven for one hour at 210°C. After removal from the oven, the powder was placed in a dry room to cool. When cool, the powder was placed in a set of standard sieves and processed on a Ro-Tap shaker for 15 minutes. The 1.04 g/cc (Scott

Densiometer, the -37μ fraction) fraction was stored in a dry room for use in this work. A portion of the powder was sprinkled into a mold containing a 20-mesh wire-woven nickel screen. The powder was removed from the mold and sintered in a vacuum furnace for 10 minutes at 1675°F. The plaques thusly prepared were first cut into about 2.7 square inch sizes, coined and then current collector tabs were welded on. The plaques prepared had a mean porosity of 72.8 $\pm$ 1.7% and a mean thickness of 25.4 $\pm$ 0.5 mils ($\bar{X}$ $\pm$ standard deviation).

One-hundred and fifty of such plaques were impregnated using one of Gould's private processes, 50 each at three different loading levels. The actual loading levels turned out to be 8.03 $\pm$ 0.33, 21.47 $\pm$ 0.66, and 31.63 $\pm$ 0.98 g/in.^{3} $Ni(OH)_2$ It was noted that the electrodes are of good quality as far as uniformity of active material loading is concerned.

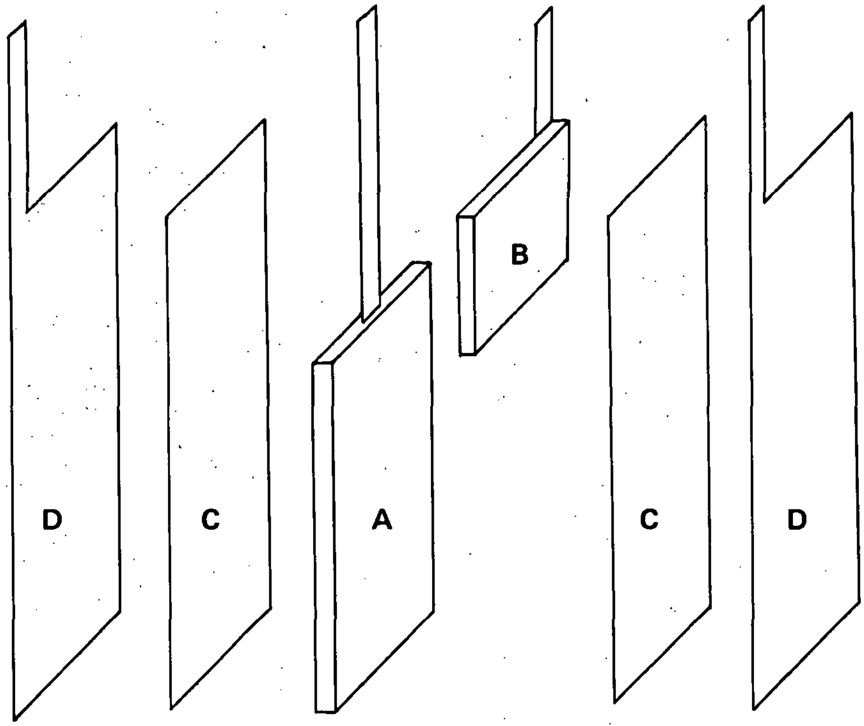
C. Cycle Testing and Cell Gassing Rate Measurement

Considerable care was exercised in measuring the gassing characteristics as a function of charge input because very minute quantities of gasses can be evolved at the early stages of the charging process. The nickel electrode where O_2 is evolved in small quantities during charge well before full charge is reached is notorious for such behavior. The same may perhaps be true for the cadmium electrodes. In addition, the simultaneous measurement of several gasses, hydrogen and oxygen, in addition to nitrogenaceous gases arising from processing impurities, was provided for.

Electrochemical tests for cadmium and nickel electrodes in the program were in the trielectrode configuration shown in Figure III-1. For testing nickel electrodes and referring to Figure III-1, A was a nickel test electrode, and D a cadmium counter electrode. The separator, C, consisted of one wrap of pellon on top of which was one wrap of visking. These encased the counter electrodes. This was to assure that the maximum amount of gas be evolved from the study electrode on charge and not combine with the counter electrode. The reference electrode, B, was a partially charged Cd/ $Cd(OH)_2$ electrode.

For the testing of cadmium electrodes, A and D were reversed; A was the cadmium test electrode and D the nickel counter electrode.

The electrode sandwiches were bound with insulating tape and placed in silver-zinc hardware (approximately 8 Ah) with a measured excess of 30% KOH electrolyte. The hardware, which was gas tight, permitted accurate measurement of gas evolution rates, with the following modifications. The anode and cathode contact posts were tapped with a 1/16 in. female pipe thread so that a previous nickel plated (with an electroless nickel deposition process) brass Poly-Flo 1/16 NPT x 1/8 tube fittings could be connected to the cell case. Thus, the contact post served also as gas inlet and outlet when 1/8 in. nylon tubing was connected to them. The reference electrode was brought out through the opening normally used as a vent and then potted closed with epoxy cement. The arrangement is shown schematically in Figure III-2. Use was made of two manifold systems, which are not shown in the schematic, which permitted introduction of a helium or argon carrier gas to



FOR NICKEL ELECTRODE TESTS

A. Nickel Test Electrode

B. $Cd/Cd(OH)_2$ or Hg/HgO Reference Electrode

C. *Separator:* 1 wrap pellon, 1 wrap visking around cadmium electrodes D

D. Cadmium counter electrodes

FOR CADMIUM ELECTRODE TESTS

A. Cadmium Test Electrode

B. $Cd/Cd(OH)_2$ or Hg/HgO Reference Electrode

C. *Separator:* 1 wrap pellon, 1 wrap visking around nickel counter electrodes D

D Nickel counter electrodes

FIGURE III-1. TRI-ELECTRODE TEST CONFIGURATION

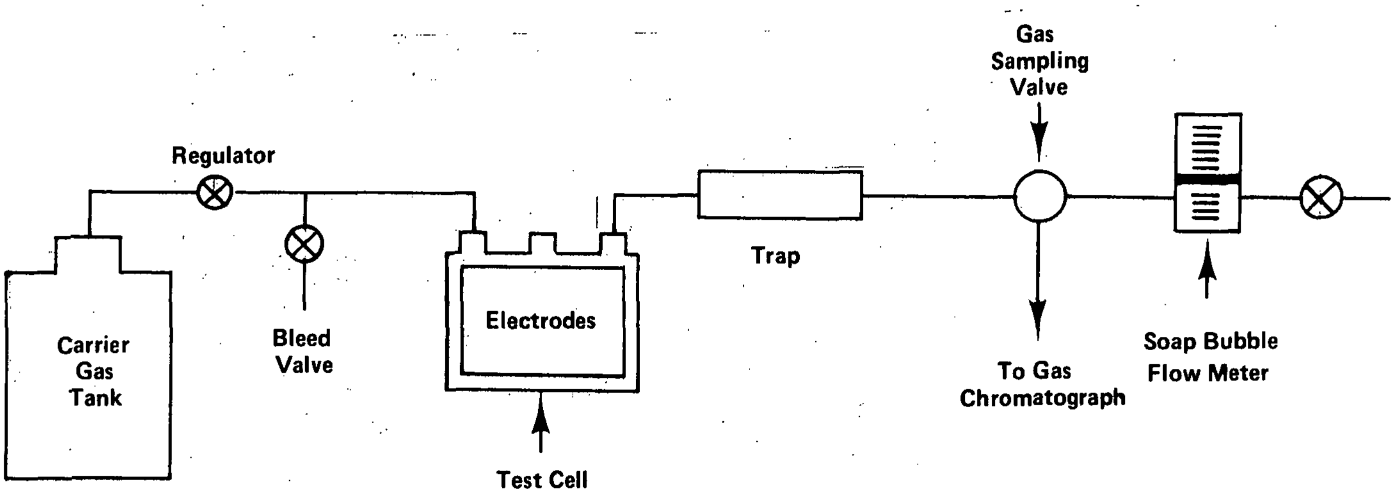


FIGURE III-2. SCHEMATIC FOR PRECISE DETERMINATION OF GAS COMPOSITION AND EVOLUTION RATES any of nine different cells. Another manifold system with three-way valves, permitted either venting the exhaust of the cell or routing it to the gas analysis system at any desired point in time during the charge or discharge of a particular cell.

The minute quantities of gas generated, if any, were therefore diluted and removed from the cell by the carrier gas stream. The carrier gas and any products were passed into a Beckman GC-2A gas chromatograph equipped with a differential thermal conductivity detector. The chromatographic measurements were made after the cell was operated for long enough times to eliminate biases due to concentration gradients in the exhaust system tubing. The gas chromatograph was calibrated daily by introducing the pure gases of interest.

A calibration of the above described apparatus in which hydrogen and oxygen were generated on polished 5-mil nickel sheets showed that quantities of hydrogen and oxygen corresponding to a total current of 0.3 mA could be determined. Also, a time lag of less than five minutes for oxygen and less than one minute for hydrogen was evident after a current of 1 mA/in.^{2} was turned on, assuming that all this current was consumed for the generation of the two gases. This was accounted for in the execution of the cell test program.

Retention times, peak heights, and areas were made on a Beckman millivolt recorder fitted with a disc integrator. The chromatographic column contained molecular sieve 5A as the adsorbant and was operated isothermally at 70°C. The composition of the exhaust gases and the total exhaust gas flow rates measured with a soap bubble flowmeter supplied all the necessary requirements to determine the gas evolution rates.

The voltage time data for the charge and discharge of the cells was collected using an automatic data acquisition system.

D. Experimental Design For Electrode Testing

1. Cadmium Electrode Test Program

Cadmium electrodes of 1.55 x 1.65 in. dimensions were prepared at each of the three loading levels, 0.30, 0.20, and 0.10 Ah/in.^{2} $Cd(OH)_2$. The hydrogen evolution rates as a function of charge input at two levels of charge temperature, 0° and 50°C were determined at the three levels of charge rate, 0.29, 0.17, and 0.06 A/in.^{2} These experiments were investigated using the experimental design shown in Table III-1.

2. Nickel Electrode Test Program

The preparation and some properties of nickel electrodes have been described in a previous section. The oxygen evolution rates were determined as a function of charge input at two levels of charge temperature, three levels of loading, and three levels of charge current density. These three variables each were investigated using the factorial experimental design shown in Table III-2.

TABLE III-1. EXPERIMENTAL DESIGN FOR STUDY OF CADMIUM ELECTRODE GASSING IN NEGATIVE LIMITED CELLS

Experimental Parameters and Limits for Cell Gassing Study

		LEVELS		
		+	0	–
X_1	Charge Temperature, °C	50°		0°
X_2	Charge Current Density, A/in.^{2}	0.29	0.17	0.06
X_3	Cadmium Electrode Loading, Ah/in.^{2}	0.30	0.20	0.10

Experimental Design for Study of Cadmium Electrode Gassing

EXP NO.	X_1	X_2	X_3	EXP NO.	X_1	X_2	X_3
1	+	+	+	10	–	0	0
2	–	+	+	11	+	–	0
3	+	0	+	12	–	–	0
4	–	0	+	13	+	+	–
5	+	–	+	14	–	+	–
6	–	–	+	15	+	0	–
7	+	+	0	16	–	0	–
8	–	+	0	17	+	–	–
9	+	0	0	18	–	–	–

TABLE III-2. EXPERIMENTAL DESIGN FOR STUDY OF NICKEL ELECTRODE GASSING IN NEGATIVE LIMITED CELLS

Experimental Parameters and Limits for Nickel Electrode Gassing Study

		LEVELS		
		+	0	–
X_1	Charge Temperature, °C	50°		0°
X_2	Charge Current Density, A/in.^{2}	0.27	0.18	0.09
X_3	Nickel Electrode Loading, g/in.^{3}	3.18	21.5	8.0

Experimental Design for Study of Nickel Electrode Gassing

EXP NO.	X_1	X_2	X_3	EXP NO.	X_1	X_2	X_3
1	+	+	+	10	–	0	0
2	–	+	+	11	+	–	0
3	+	0	+	12	–	–	0
4	–	0	+	13	+	+	–
5	+	–	+	14	–	+	–
6	–	–	+	15	+	0	–
7	+	+	0	16	–	0	–
8	–	+	0	17	+	–	–
9	+	0	0	18	–	–	–

3. Factorial Experiments

The principles and practices of statistical procedures have been fully described[1,2]. In such procedures the effects of several factors are studied at two or more levels. For the case at hand, three variables are studied at two or three levels. Each cell will contain a different combination of the n factors at different levels. In general, the procedure is as follows. Having chosen the various factors and factor levels, combinations are incorporated into a design containing the required number of cells to fulfill the experimental requirements. A parameter, characteristic of the system, is measured for each cell in the system. An effect is then calculated for each member. Each effect is a measure of the deviation of the parameter value from the set average, taking into account the specific factor-level combination contributing to the deviation; i.e., one calculates the effect due to changing a factor from a low level to a high level, averaged over the levels of the remaining factors. With a knowledge of the experimental error associated with each measurement for each member of the set, the significance of each calculated factor or factor combination effect can be estimated by means of the statistical t-test. Statistical experiments have been used in work of this type and have proven to be extremely useful. Their usefulness stems from the following advantages over conventional 'one-variable-at-a-time' designs:

- Maximum efficiency in collection of data especially when there are interactions between variables
- Interactions between variables (as is probably the case in this study) will be determined when they exist and thereby misleading conclusions will be avoided

4. Calculation of Effects and Interactions

The average effect of each variable is, as mentioned earlier, determined by averaging over the levels of the remaining factors. The equation for such a calculation is:

$$E_j = \frac{1}{2} \cdot \frac{1}{N/3} \sum_{i=1}^{N} (Y_i)(C_{ij})$$

where:

N is the number of tests performed
i is the row position of the design
j is the column position of the variable of the design
Y is the test value recorded
C is the multiplier value in the design

These are given in Table III-3.

TABLE III-3. MULTIPLIERS FOR CALCULATION OF EFFECTS AND INTERACTIONS

Exp No.	Linear X_1	Linear X_2	Linear X_3	Quadratic X_2	Quadratic X_3
1	+1	+1	+1	+1	+1
2	−1	+1	+1	+1	+1
3	+1	0	+1	−2	+1
4	−1	0	+1	−2	+1
5	+1	−1	+1	+1	+1
6	−1	−1	+1	+1	+1
7	+1	+1	0	+1	−2
8	−1	+1	0	+1	−2
9	+1	0	0	−2	−2
10	−1	0	0	−2	−2
11	+1	−1	0	+1	−2
12	−1	−1	0	+1	−2
13	+1	+1	−1	+1	+1
14	−1	+1	−1	+1	+1
15	+1	0	−1	−2	+1
16	−1	0	−1	−2	+1
17	+1	−1	−1	+1	+1
18	−1	−1	−1	+1	+1

The average effects of variable interactions is determined similarly from the following relation:

$$E_{jj_1} = \frac{1}{2} \cdot \frac{1}{N/3} \sum_{i=1}^{N} (Y_i)(C_{ij}C_{ij_1})$$

where as before j is the column position of one variable and j_1 is the column position of the other variable.

IV. RESULTS AND DISCUSSION

A. Nickel Electrode Gassing

1. Nickel Electrode Characterization

In order to meet the program goals of producing nongassing cells one must have available design data on the gassing characteristics of the nickel electrode so that oxygen evolution on charge can be minimized or eliminated. There is little information available regarding the gas-free capacities of practical cells or of nickel electrodes in practical configurations as a function of their loading, and charge rate, and temperature. The question that had to be answered was, since the cell is negative limited, what is the excess capacity required in the positive electrode to minimize oxygen evolution on charge and yet maintain a practical cell? This would have to apply at the worst possible operating conditions.

Electrodes impregnated to three different loading levels, 8.03 ± 0.33, 21.47 ± 0.66, and 31.63 ± 0.98 g/in.^{3} $Ni(OH)_2$ were characterized. The positive electrodes were assembled into cells in a positive limited configuration as previously described, and their gassing characteristics as a function of charge rate, temperature, and $Ni(OH)_2$ loading, at two stages, the third and twentieth cycle, in their lives was determined. These tests were performed employing a full factorial experimental design which is shown in Table III-2. The charge temperature and the nickel electrode loadings were realistic levels of the variables. The charge rate was an experimental expedient which permited logging considerable cycle data in a short time, and yet provided useful design information for rapid orbits, 1-1/2 hours for example. An analysis of the gassing data obtained at the two extreme temperatures, 0° and 50°C, showed that gassing characteristics were defined well enough at the experimental conditions chosen that obtaining additional data would serve no good purpose. Typical examples of good quality, complete gas evolution data is given in Figures IV-1 and IV-2. This data is for heavily loaded electrodes, 31.6 g/in.^{3} $Ni(OH)_2$, charged at the high current density 0.3 A/in.^{2} at the high and low temperature, respectively. The ordinate axis in these curves is the logarithm of O_2 volume generated. The very bottom of the axis is linear and zero is shown to account for the state-of-charge at which no oxygen evolution was detected. Rather abrupt changes from the gassing to the nongassing mode of operation are evident in these two figures. The dotted lines in these two figures represent the theoretical values of oxygen evolution for the current density in question. The oxygen evolution rate is seen to approach this value asymptotically. Perhaps a view offering a little better perspective is offered in Figures IV-3 and IV-4 in which essentially the same data is plotted but this time the ordinate axis is the percentage of the input charge current that is utilized for oxygen generation. This value was calculated from the total gas flow rates and the measured oxygen concentration in the gas stream. The abscissa is the fraction of charge returned that was removed during the previous cycle. The intersection of these curves with the line X = 10% was arbitrarily chosen as the 'onset' of significant oxygen evolution, and of course is in reality the fraction of charge returned at which 10% of the current goes to oxygen evolution. From Figures IV-3 and IV-4 and 15 other sets of similar data, which are given in tabular form in Appendix A, Table IV-1 was constructed giving gassing data for both the third and twentieth

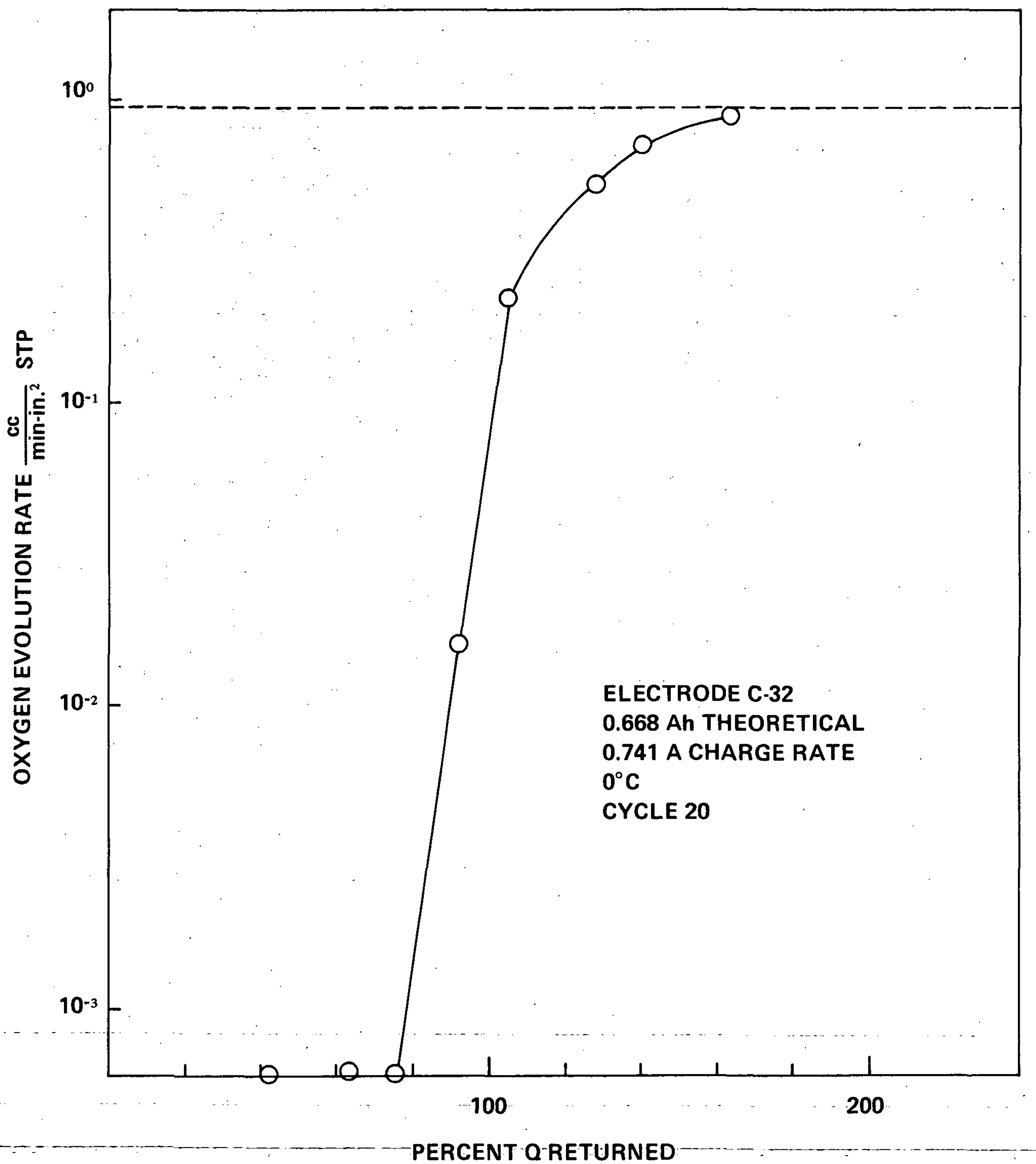


FIGURE IV-1. OXYGEN EVOLUTION ON CHARGE OF A HEAVILY LOADED NICKEL ELECTRODE

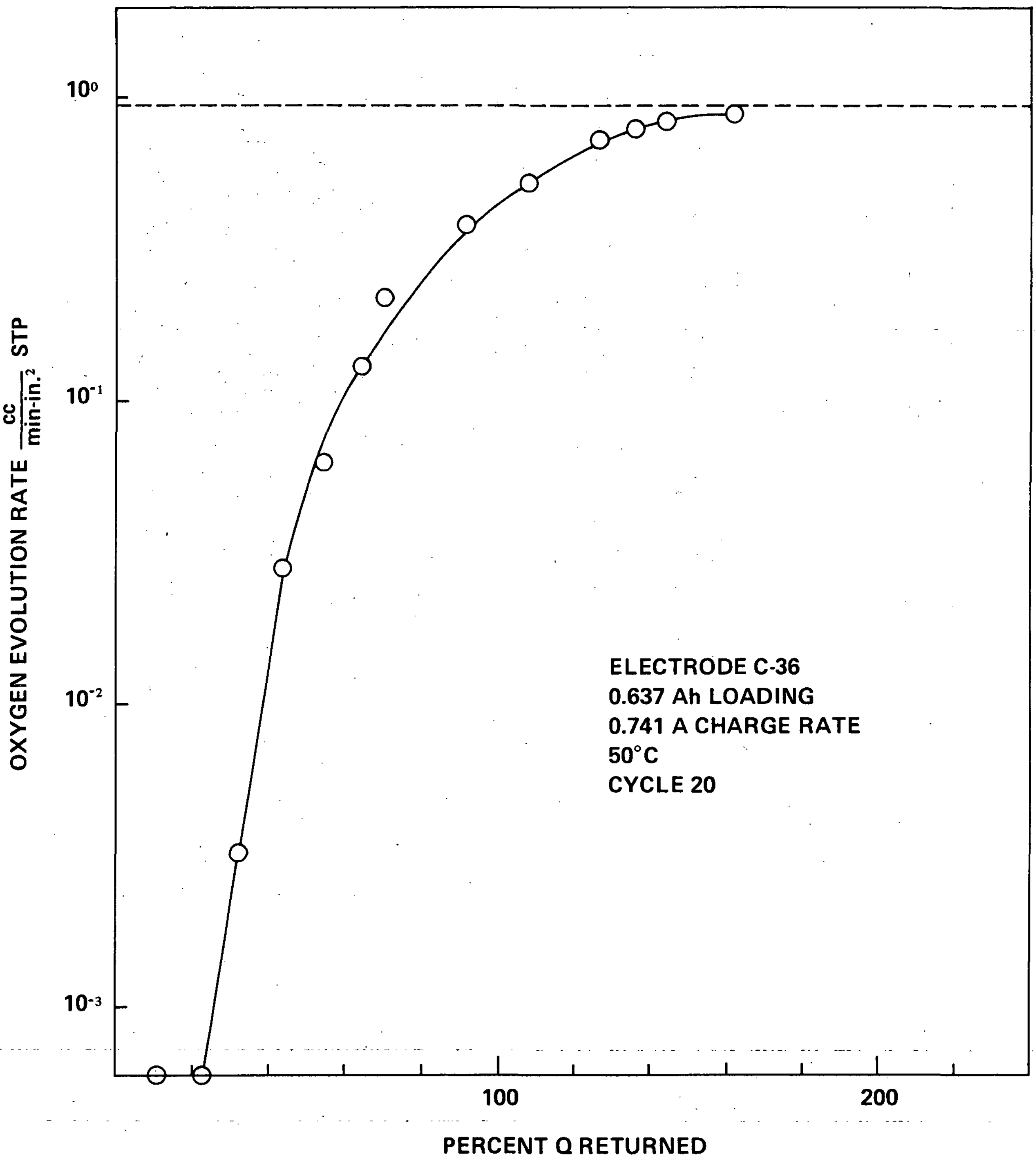


FIGURE IV-2. OXYGEN EVOLUTION ON CHARGE OF A HEAVILY LOADED NICKEL ELECTRODE

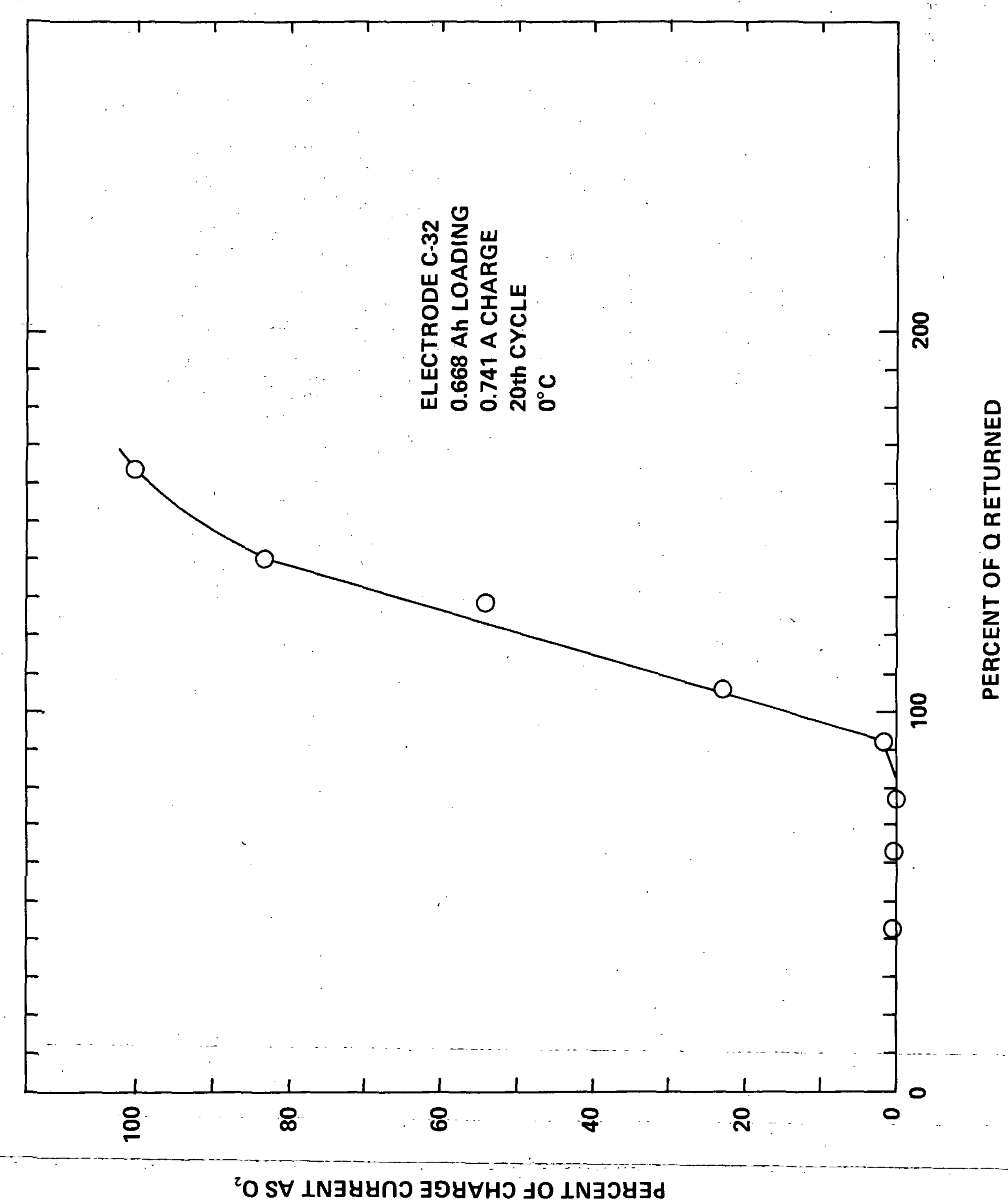


FIGURE IV-3. OXYGEN EVOLUTION ON CHARGE OF A HEAVILY LOADED NICKEL ELECTRODE

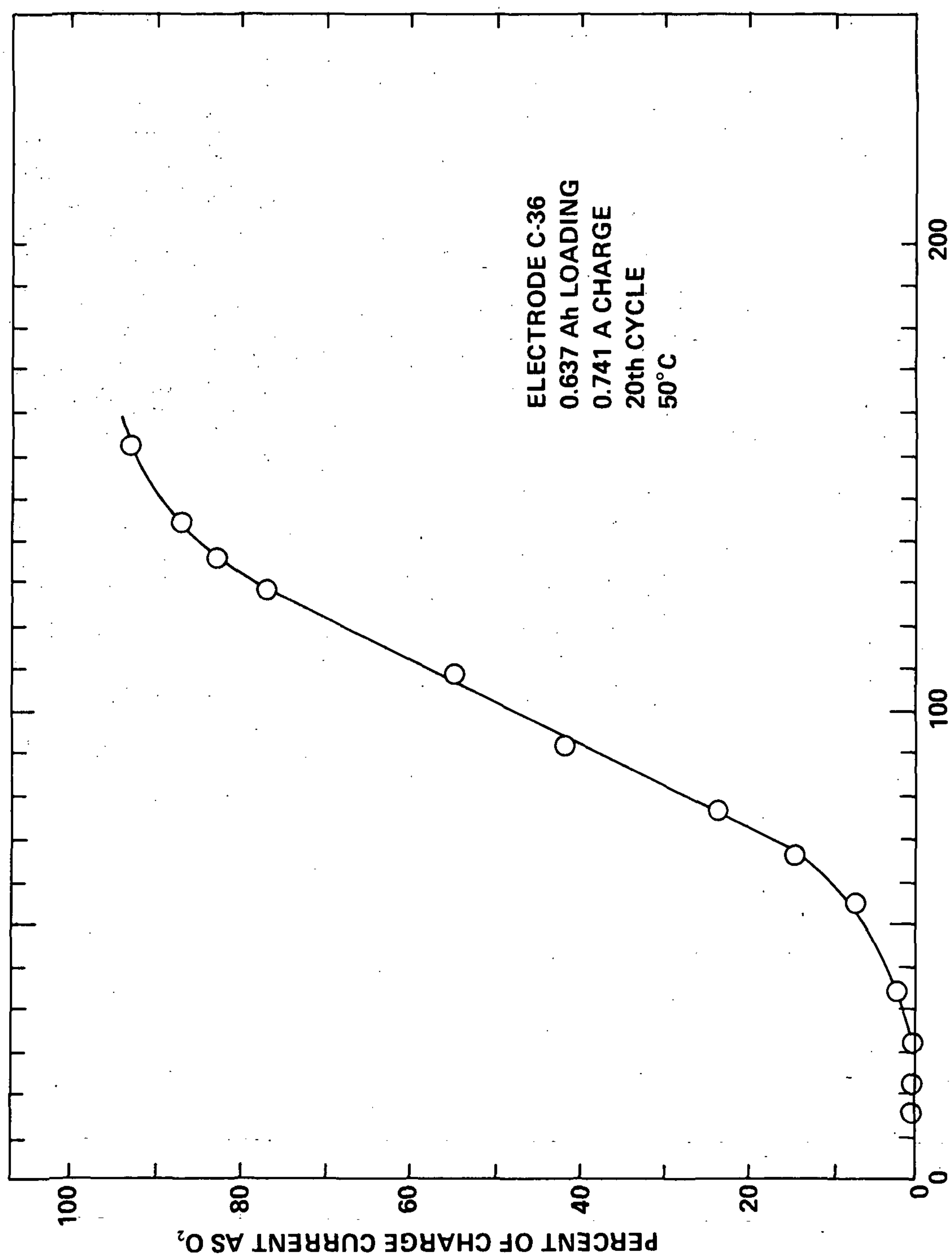


FIGURE IV-4. OXYGEN EVOLUTION ON CHARGE OF A HEAVILY LOADED NICKEL ELECTRODE

cycles. The values in Table IV-1 were used to calculate the average effect of each variable. This was determined by averaging over the levels of the remaining factors, as described earlier. The results of such computations are given in Table IV-2 for the third and twentieth cycles.

TABLE IV–1. ONSET OF OXYGEN EVOLUTION AT THIRD AND TWENTIETH CYCLE

EXP NO.	X_1	X_2	X_3	% Q_3	% Q_{20}
1	+	+	+	60	60
2	–	+	+	60	100
3	+	0	+	95	80
4	–	0	+	80	120
5	+	–	+	60	60
6	–	–	+	65	120
7	+	+	0	65	65*
8	–	+	0	90	90
9	+	0	0	100	100
10	–	0	0	90	120
11	+	–	0	130	70
12	–	–	0	90	130
13	+	+	–	75	70
14	–	+	–	120	120
15	+	0	–	75	75
16	–	0	–	100	100
17	+	–	–	60	70
18	–	–	–	85	100

*Data lost, estimated value

TABLE IV-2. EFFECTS OF VARIABLES AND INTERACTIONS ON THE 'ONSET' OF O_2 EVOLUTIONS

VARIABLES (LINEAR)	MAGNITUDE OF EFFECT ON % Q_3	% Q_{20}
Charge Temperature	– 5.0	–29.2
Charge Current	– 1.7	– 3.8
Loading $Ni(OH)_2$	– 7.9	0.4
Charge Temperature – Current	– 6.7	1.9
Charge Temperature – Loading	8.8	– 2.9
Charge Current – Loading	– 4.6	– 4.3
VARIABLES (QUADRATIC)		
Charge Current	–10.0	–14.3
Loading $Ni(OH)_2$	–16.3	– 6.3

The meaning of the signs of the effects of the variables in Table IV-2 is as follows:

- A positive sign means an increase in the effect as the level of the variable is changed from the minus to the plus value. In the case at hand, oxygen is evolved at a high state-of-charge.
- A negative sign means a decrease in the effect as the level of the variable is changed from the minus to the plus value. In this particular case, oxygen is evolved at a lower state-of-charge.

Thus it is seen from Table IV-2 that although all the variables have some degree of relevance as far as gassing of the nickel electrode on charge is concerned the most important is the charge temperature. Oxygen evolution is observed at a 29.2% lower state-of-charge at 50°C at the 20th cycle, than 0°C, on an average basis.

All the linear effects and interactions given in Table IV-2 are seen to be small in comparison with the magnitude of the temperature effect. Actually, the experimental error is in the 5-10% range so that of all the linear effects, only temperature is significant. It is when one looks at the quadratic effects, that the expected effects of charge current and $Ni(OH)_2$ loading manifest themselves with strong negative effects, indicating gassing at lower states-of-charge from the higher charge currents and the higher loadings. It is worthwhile to note the change in the effects caused by electrode cycling. It appears that the only effect that is altered by the cycling regime used in this study is the charge temperature. The effects of the other variables are changed to a lesser extent, some even in a favorable direction. The average of all the test conditions, the average values of the data in Table III-2, are for % Q_3 = 83.3 and % Q_{20} = 91.6. As a result, the aging if any, apparently improved the gassing properties of the electrodes, at least to a limited extent.

A different view of the data is offered in Figure IV-5 which shows the charge input at which the onset of gassing is observed as a function of loading at the three charge rates and the two temperatures studied. Here the data is given in a more natural form and one has a better feel for the experimental variation in the test data. Here also, it is apparent that there is a sizable effect of temperature, a smaller effect of loading.

2. Positive/Negative Capacity Ratio

The primary objective of the positive electrode test program was to define an acceptable positive/negative active material ratio for the new negative limited cells, to assure minimum gassing operation on charge. On one hand, one wants to operate at the lowest state-of-charge of the positive electrode to eliminate gassing on charge and on the other hand, a low positive/negative ratio to achieve an attractive energy density. The data already discussed provide the necessary basis to choose a positive/negative active material ratio to assure minimum gassing, if one considers only the charge rate, charge temperature, and electrode loading of the nickel electrode. The worst conditions for gassing encountered were as mentioned earlier; the high charge rates, high temperature, and high loadings. It was decided to design around the toughest test variable which was found to be the charge temperature. The median loaded electrode, 20.5 g/in.^{3} $Ni(OH)_2$ loading was the most suitable from a consideration of their energy density, gassing, and physical properties. The lighter loaded electrode had somewhat better gassing properties but were too low in output. The test data for the suggested median loaded nickel electrodes at high and low temperatures are given in Figures IV-6 and IV-7, respectively, for the 0.247 A charge rate. It is apparent that these electrodes gas significantly at about 60% Q returned, so that the minimum positive/negative active material ratio would be 1.7:1. However, this should be considered as only a first estimate; testing in cells corresponding closer to reality may reveal variables that must be considered in addition to the temperature, charge rate, and loading considerations made here.

B. Cadmium Electrode Gassing

Cadmium electrodes, the preparation of which was described earlier were tested in realistic, small negative limited cells using a previously described test installation . The testing involved the determination of the H_2 and O_2 evolution rates from both electrodes in such cells as a function of charge rate, discharge rate, discharge temperature, and cadmium electrode loading.

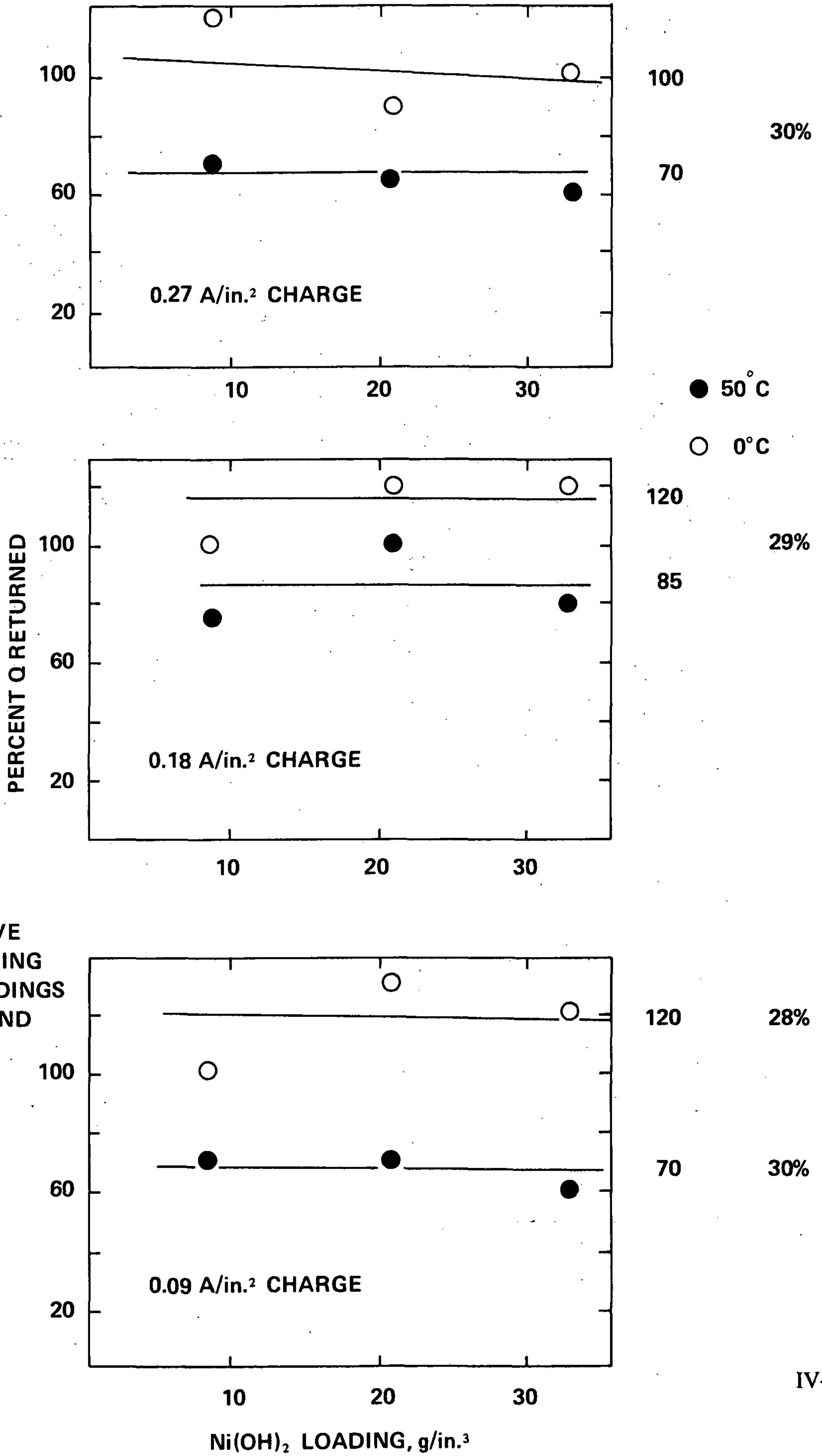


FIGURE IV-5. POSITIVE ELECTRODE GASSING AT VARIOUS LOADINGS CHARGE RATES AND TEMPERATURES

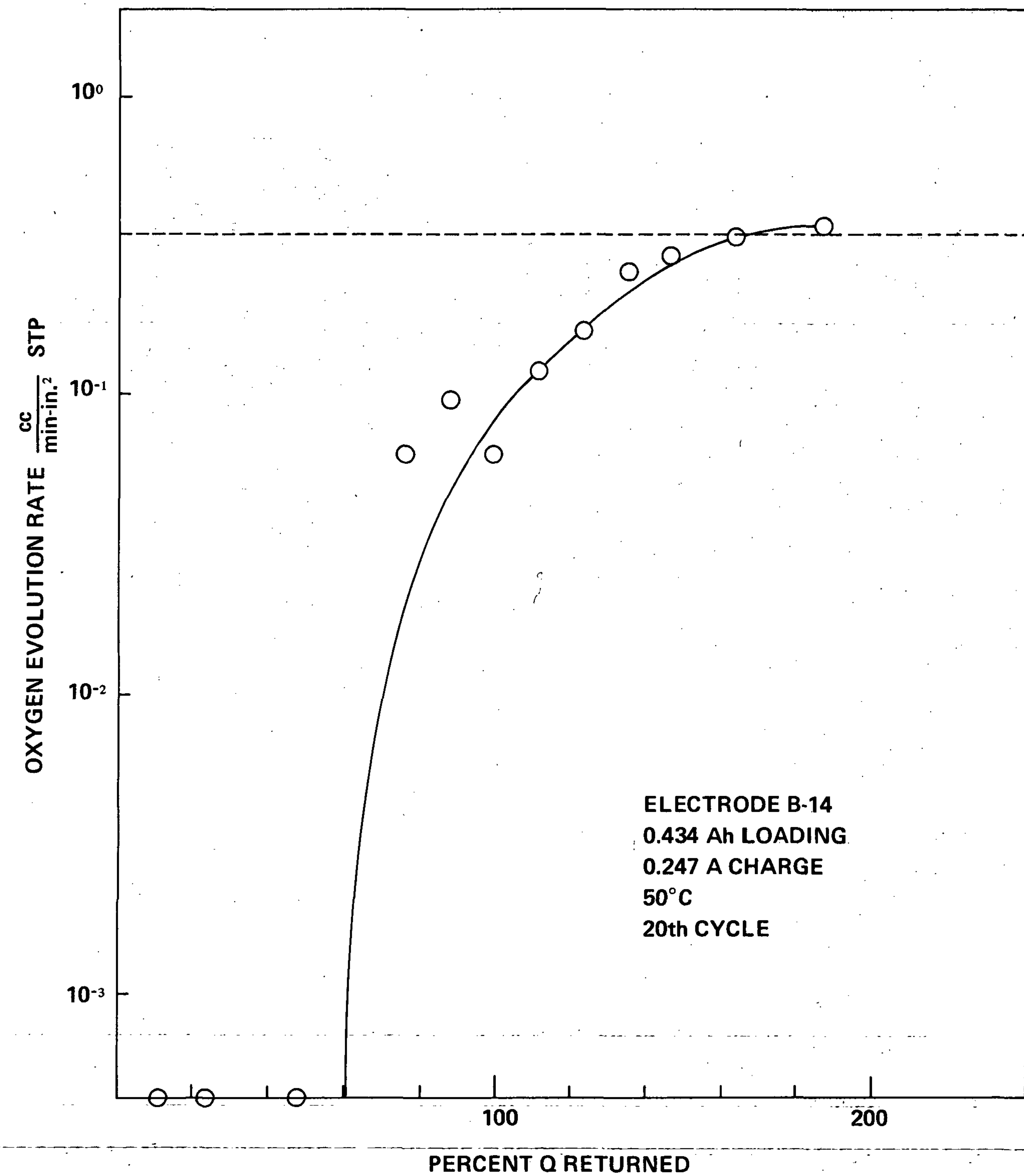


FIGURE IV-6. OXYGEN EVOLUTION ON CHARGE OF A MODERATELY LOADED NICKEL ELECTRODE AT THE WORST TEST VARIABLE, i.e., High Temperature

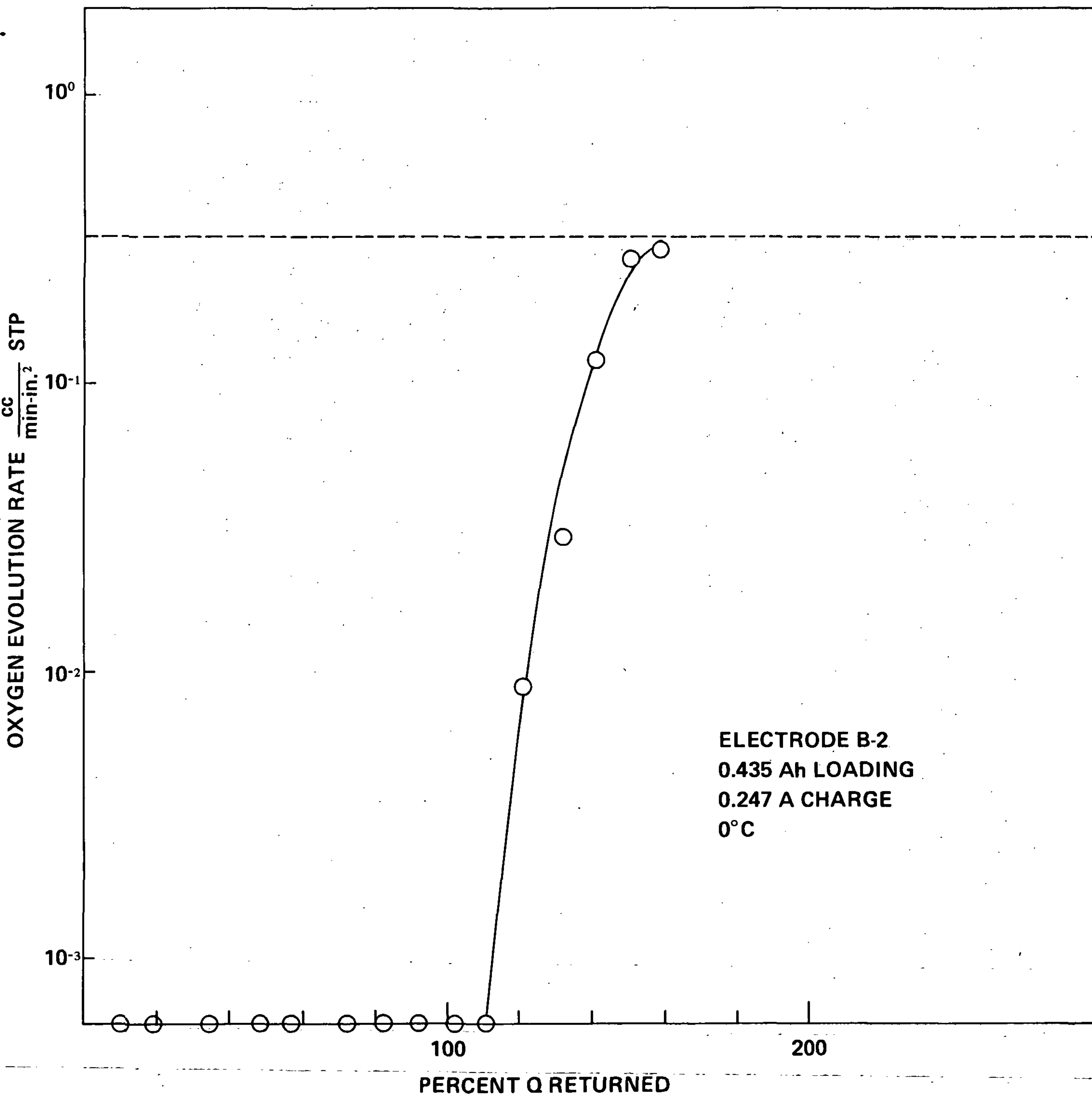


FIGURE IV-7. OXYGEN EVOLUTION ON CHARGE OF A MODERATELY LOADED NICKEL ELECTRODE AT LOW TEMPERATURE

1. Electrodeposited Cadmium Electrodes on Cadmium Screen

The gassing characteristics were determined for both the cadmium and nickel electrodes in negative limited cells constructed with electrodeposited cadmium active mass on a cadmium screen in accordance with the experimental design shown in Table III-1. These cells were constructed with two nickel electrodes of 20 $g/in.^3$ loading. Representative gassing data obtained at the 151 mA charge rate at 0° and 50°C charge temperature are shown in Figures IV-8 and IV-9. These are semilog plots except at the break at zero current to allow representation of no detected gassing. In both figures hydrogen appeared abruptly when the electrode reached full charge. The evolution of hydrogen was accompanied by a potential step. In Figure IV-8 it is noted that no oxygen was detected, while in Figure IV-9 oxygen was evolved before end-of-charge. This was due to the very high efficiencies of this type of cadmium electrode at the high charge temperature. The states-of-charge, Q, at which hydrogen and oxygen were first detected at the third and twentieth cycle are shown in Table IV-3. The cycle data was obtained at the high temperature only. Several noteworthy features are evident. There is an increase in the gas-free capacity of the cadmium electrode with increasing charge temperature. The cadmium electrodes tested in this portion of the program had abnormally high efficiencies at the high temperature, some as high as 150%. It was previously shown that the oxygen gassing occurred at lower states-of-charge on nickel electrodes charged at higher temperatures. The combination of higher gas-free capacity on the cadmium electrode and lower gas-free capacity on the positive electrode makes the high temperature, high charge rate, and gas-free operating condition a tortuous condition, since the actual positive/negative ratio is at the lowest level.

Also, there were indications of negative electrode performance degradation by the change in the gas-free capacity of the cadmium from the third to the twentieth cycle. There is a considerable uncertainty in the magnitude of 'fading' to be expected. The best estimates of the effects at the operating conditions described above are given in Table IV-4.

Very large quadratic effects were apparent indicating that the median levels of charge and loading are preferred to minimize performance degradation for this particular configuration of negative electrodes.

Also of interest in Table IV-4 are the states-of-charge at which oxygen is first detected in the negative limited cells. Since cells were constructed with at least a P/N ratio of about 2:1 the detection of oxygen at the rather low states was somewhat of a surprise based on the nickel electrode gassing study described earlier. However, the test conditions were different for the two cases. First, the trielectrode configuration in cadmium electrode gassing was positive/negative/positive and was negative/positive/negative for nickel electrode tests. The latter arrangement is more realistic since it approximates a practical configuration as far as the nickel electrode is concerned, and therefore, the gassing data obtained in the nickel electrode gassing portion of the program is more reliable. Also, the charge currents are different in the two cases. In addition the use of cadmium screens posed additional problems of causing increased internal cell resistance at the contacts and perhaps influencing gassing data.

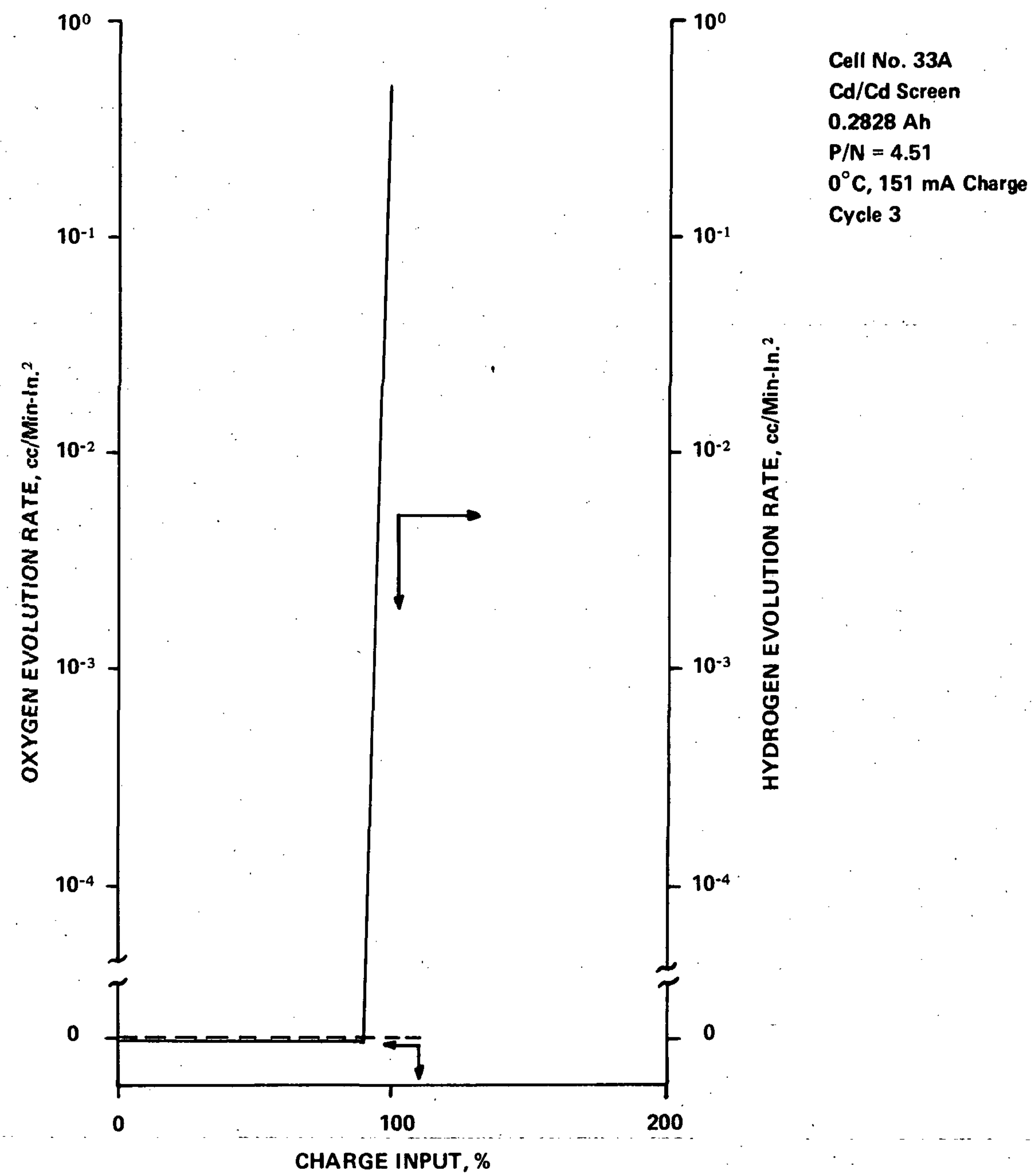


FIGURE IV-8. HYDROGEN & OXYGEN EVOLUTION RATES IN NEGATIVE LIMITED CELLS WITH ELECTRODEPOSITED CADMIUM ON CADMIUM SCREEN

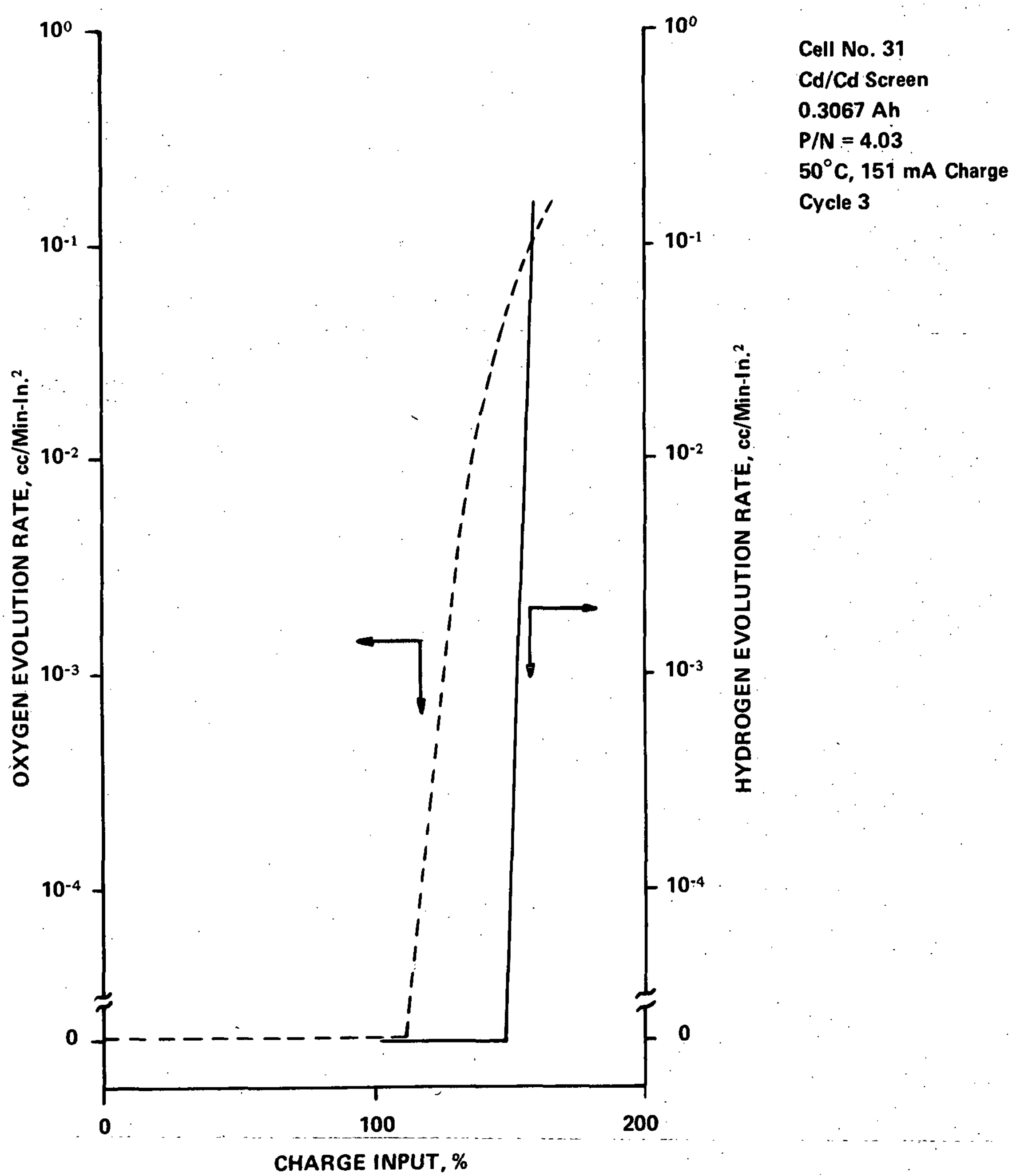


FIGURE IV-9. HYDROGEN & OXYGEN EVOLUTION RATES IN NEGATIVE LIMITED CELLS WITH ELECTRODEPOSITED CADMIUM ON CADMIUM SCREEN

TABLE IV-3. SUMMARY OF RESULTS

State-of-Charge, Q, of each Electrode When Gassing Was First Detected in Negative Limited Cells

Cd on Cd Screen

Q_3 = 3rd Cycle

Q_{20} = 20th Cycle

				H_2 Evolution		O_2 Evolution	
Exp No.	X_1	X_2	X_3	% Q_3	% Q_{20}	% Q_3	% Q_{20}
1	+	+	+	126	93	12	30
2	–	+	+	25		30	
3	+	0	+	100	110	32	28
4	–	0	+	75		40	
5	+	–	+	140	94	22	16
6	–	–	+	94		50	
7	+	+	0	150	104	17	29
8	–	+	0	42		15	
9	+	0	0	112	110	22	16
10	–	0	0	88		21	
11	+	–	0	116	118	23	24
12	–	–	0	95		43	
13	+	+	–	150	100	12	17
14	–	+	–	93		20	
15	+	0	–	125	100	26	19
16	–	0	–	96		22	
17	+	–	–	148	41	27	(?)
18	–	–	–	94		23+(?)	

? Oxygen not generated

TABLE IV-4. EFFECTS OF CHARGE CURRENT AND LOADING ON CADMIUM ELECTRODE 'FADING'

Variables (Linear)	Efficiency Loss (20 Cycles)
Charge Current	7
Loading	17
Charge Current – Loading	−10
Variables (Quadratic)	
Charge Current	−39
Loading	−22
Charge Current – Loading	−50

The effects and interactions of the variables are given in Table IV-5. The most important variable as far as hydrogen evolution is concerned, is the charge temperature, with gassing at higher states-of-charge at the higher temperatures. The other variables, charge, rate, loading, and interactions have far less important effects.

TABLE IV-5. EFFECTS OF VARIABLES AND INTERACTIONS ON GASSING NEGATIVE LIMITED CELLS – Cd ON Cd SCREEN

Variables (Linear)	H_2 Evolution, % Q_3
Charge Temperature	39
Charge Current	− 8
Loading $Cd(OH)_2$	−12
Charge Temp – Current	16
Charge Temp – Loading	3
Charge Current – Loading	− 9
Variables (Quadratic)	
Charge Current	7
Loading $Cd(OH)_2$	5

2. Electrodeposited Cadmium Electrodes on Silver Screen

A set of data similar to the one described above for the electrodeposited cadmium active mass on a cadmium screen was obtained for electrodes prepared in a manner that was identical except that they contained a silver screen rather than a cadmium screen. Representative gassing data obtained for these particular cells at 151 mA charge at 0° to 50° C are shown in Figures IV-10 and IV-11. Once again these are semilog plots except at the break at the origin to allow for representation of no gassing. A summary of all the test data, the state-of-charge at which gassing was first detected on the positive and negative electrodes is given in Table IV-6. The cadmium electrode prepared with the silver screens have lower gas-free capacities than their cadmium screen counterparts. The overall average for the cadmium screen electrodes was % Q_3 = 104 and the overall average for silver screen set was 85%. Also of importance was the state-of-charge at which oxygen was evolved on the nickel electrodes on an overall average, gassed at 25% state-of-charge for cells prepared with cadmium screened electrodes and at 33% state-of-charge in cells prepared with cadmium electrodes containing silver screens. The difference is perhaps due to the lower cell operating potentials due to the improved current collection as a result of the use of the silver screen. Both sets of data obtained on nickel electrode gassing in this portion of the program using the unsymetrical P/N/P trielectrode configuration are indicative of gassing at lower states-of-charge of the N/P/N configuration.

The effects of the variables and their interaction on hydrogen gassing in the cells is given in Table IV-7. Once again the charge temperature is seen to be an important factor governing cell efficiency, however to a lesser extent than observed for the cells containing the cadmium screens. As far as the other variables are concerned in view of the experimental uncertainty evident by comparing the results in Tables IV-3 and IV-7, it is not possible to unambiguously sort out the effects of the other variables.

The use of an electrodeposited cadmium active mass on a silver screen is a promising electrode for use in the proposed nongassing cell.

3. Porous Silver Substrate Cadmium Electrodes

The preparation of cadmium electrodes from sintered silver substrates has been described in Section A.3. Initial data in negative limited cells using such electrodes showed that silver sinter based electrodes possessed initial efficiencies far lower than required in the range of 30-40% of weight gain rather than the 70% range. Aside from this particular difficulty, they performed as the other varieties of cadmium electrodes in negative limited cells. In view of the rather unsatisfactory results for such structures it was decided not to devote more time on this particular type of electrode, because of the development work that would be required. However, the authors still regard silver sintered structures as promising and worthy of attention if future efforts are to be made in the area of nongassing cells.

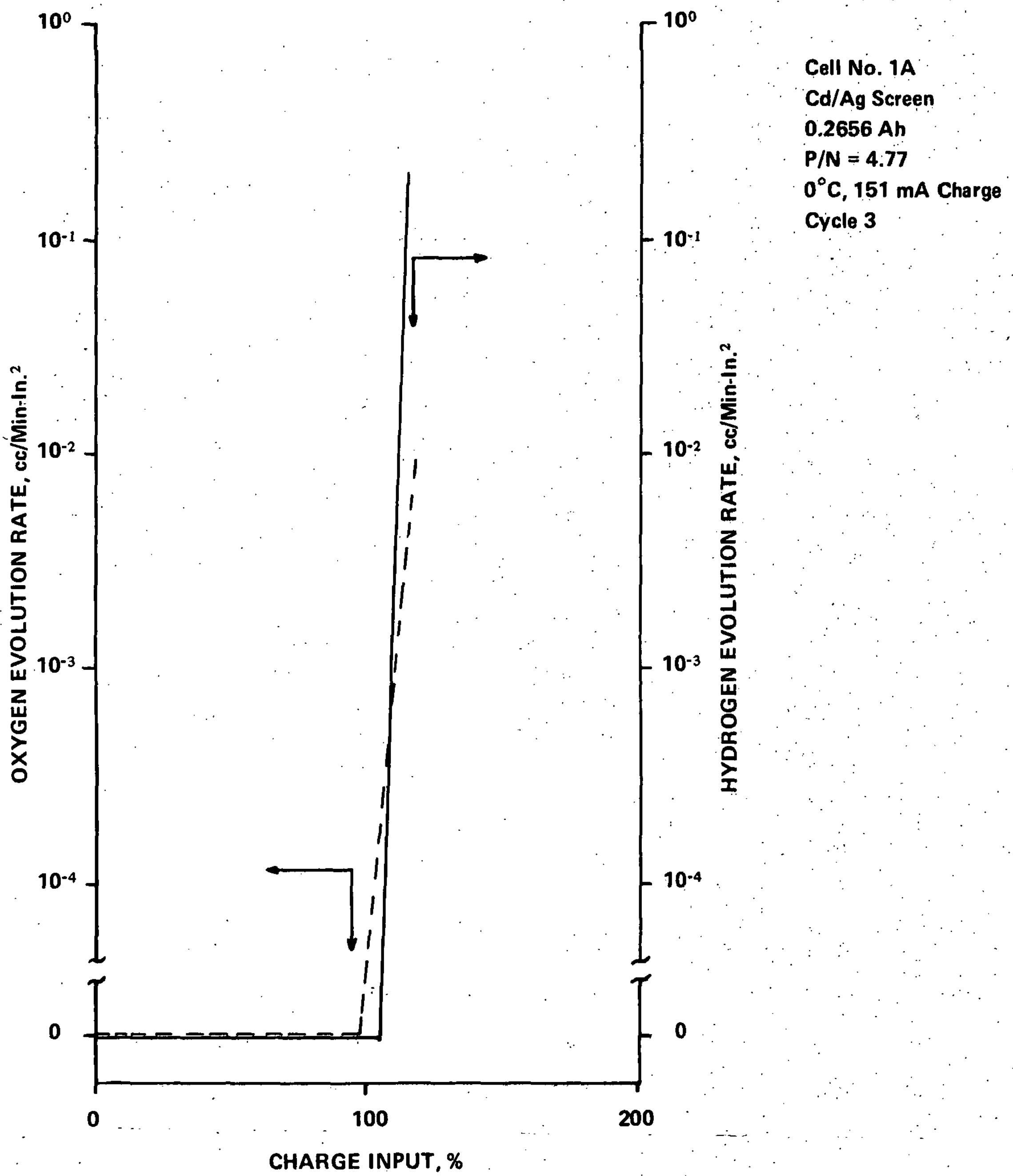


FIGURE IV-10. HYDROGEN & OXYGEN EVOLUTION RATES IN NEGATIVE LIMITED CELLS WITH ELECTRODEPOSITED CADMIUM ON SILVER SCREEN

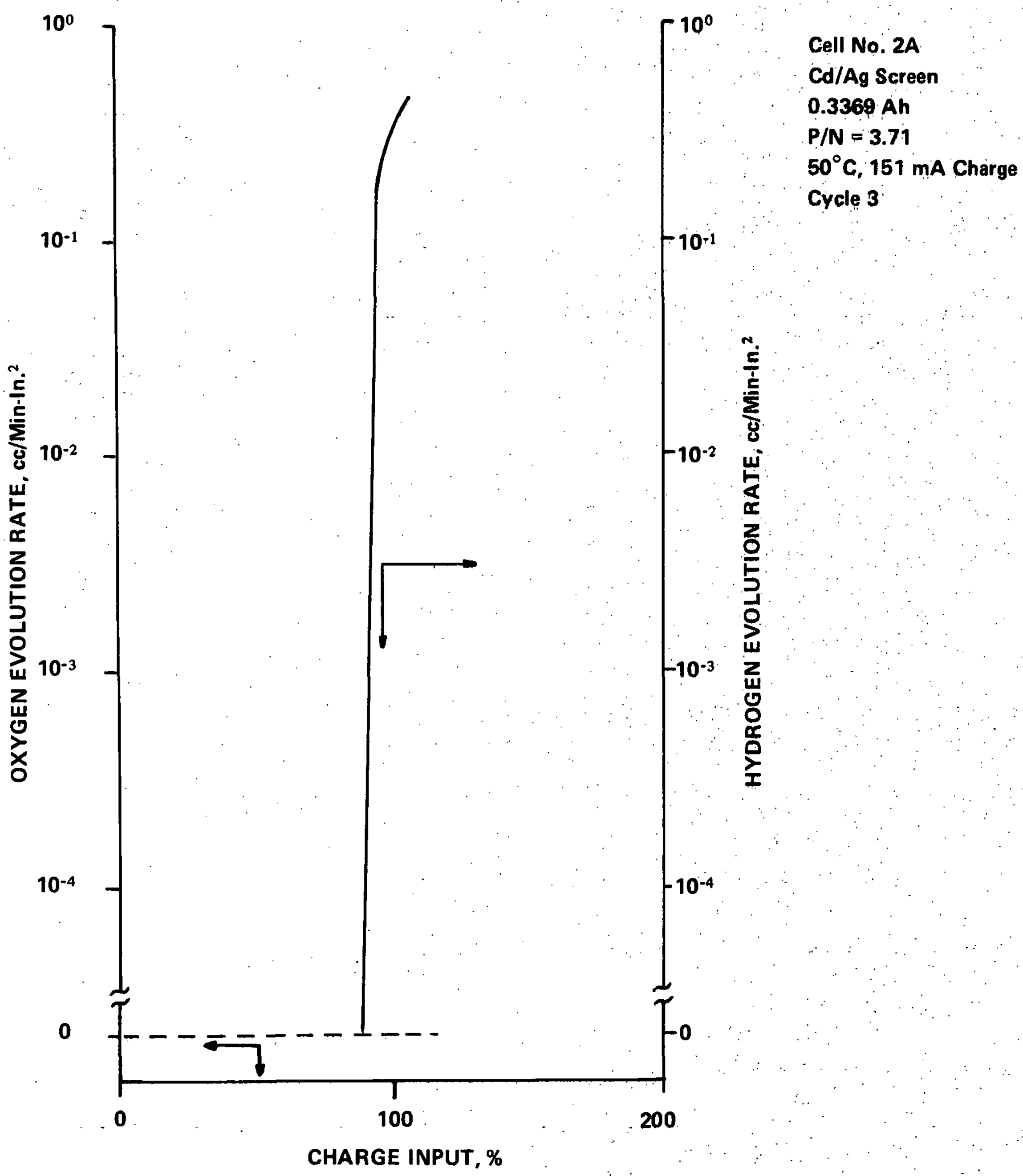


FIGURE IV-11. HYDROGEN & OXYGEN EVOLUTION RATES IN NEGATIVE LIMITED CELLS WITH ELECTRODEPOSITED CADMIUM ON SILVER SCREEN

TABLE IV-6. SUMMARY OF RESULTS

State-Of-Charge, Q, At Which Gassing Was First Detected In
Negative Limited Cells
Cd on Ag Screen
Q_3 = 3rd Cycle
Q_{20} = 20th Cycle

Exp No.	X_1	X_2	X_3	H_2 Evolution % Q_3	O_2 Evolution % Q_3
1	+	+	+	81	22
3	–	+	+	65	39
4	+	0	+	96	55
6	–	0	+	75*	39*
7	+	–	+	65	38
9	–	–	+	70	40
10	+	+	0	83	23
12	–	+	0	61	27
13	+	0	0	85	43+
15	–	0	0	50	22
16	+	–	0	93	37
18	–	–	0	72	31
19	+	+	–	96	27
21	–	+	–	75	16
22	+	0	–	160	48
24	–	0	–	102	26+
25	+	–	–	90	37+
27	–	–	–	105	21
				Avg = 85	Avg = 33

*Data lost – estimated values

TABLE IV-7. EFFECTS OF VARIABLES AND INTERACTIONS ON GAS EVOLUTION IN NEGATIVE LIMITED CELLS – Cd/Ag SCREEN

Variables (Linear)	H_2 Evolution, % Q_3
Charge Temperature	15
Charge Current	– 3
Loading $Cd(OH)_2$	–15
Charge Temp – Current	5
Charge Temp – Loading	– 3
Charge Current – Loading	– 2
Variables (Quadratic)	
Charge Current	–15
Loading $Cd(OH)_2$	16

4. Teflon Bonded Pressed Cadmium Electrodes

The initial performance and properties of these electrodes offered no apparent advantages over the electrodeposited types described in IV.B.1 and IV.B.2 and were therefore not tested further.

5. Charge Voltage Characteristics

Figure IV-12 and IV-13 show actual voltage-time recorder traces near end-of-charge for negative limited cells using the cadmium electrodes with silver screens. The data shown is for 0° and 50°C for charge currents of 151, 452, and 753 mA. The test data for all other cells tested is given in the various Appendices.

The 'cut-off voltage' used in this work was determined by averaging the voltage at which H_2 was first detected for all the test cells. This value turned out to be around 1.80V. A value of 1.75 was selected to provide a small safety factor. This proved to be an adequate value since H_2 was never observed in good cells below this value.

The potential steps shown in Figures IV-12 and IV-13 are sharp enough and large enough to signal end-of-charge before hydrogen evolution. The signal is charge rate and temperature dependent.

C. Cycle Life of Negative Limited Nongassing Nickel-Cadmium Cells

Cycle test data has been accumulated on nongassing negative limited cells constructed with electrodeposited cadmium active mass on silver and cadmium screens in the trielectrode configuration used in the cadmium electrode gassing portion of the program. Figures IV-14 and IV-15 show the best

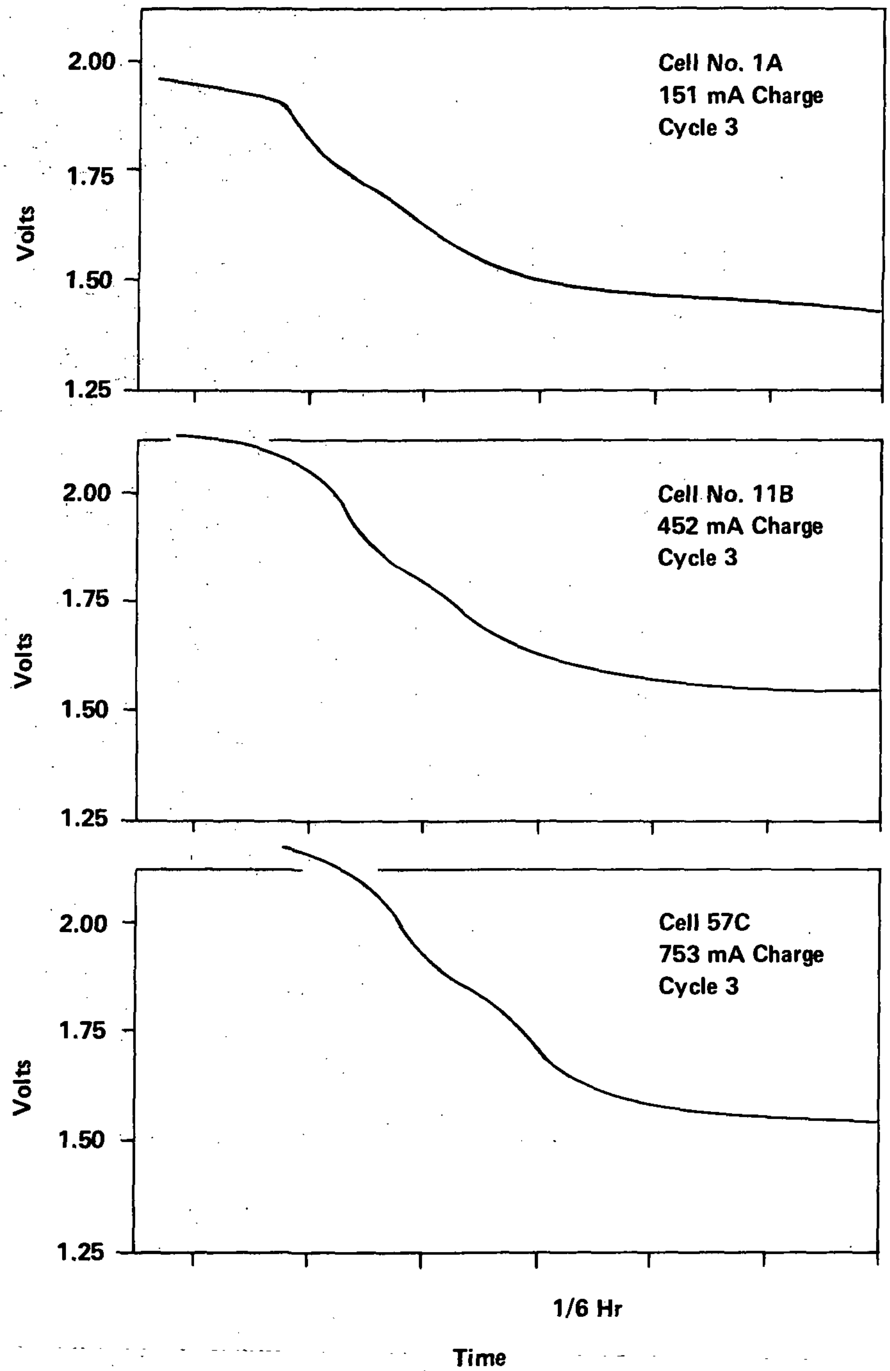


FIGURE IV-12. TYPICAL VOLTAGE TRACE NEAR END-OF-CHARGE FOR CELLS WITH Cd/Ag SCREEN ELECTRODES, 0°C

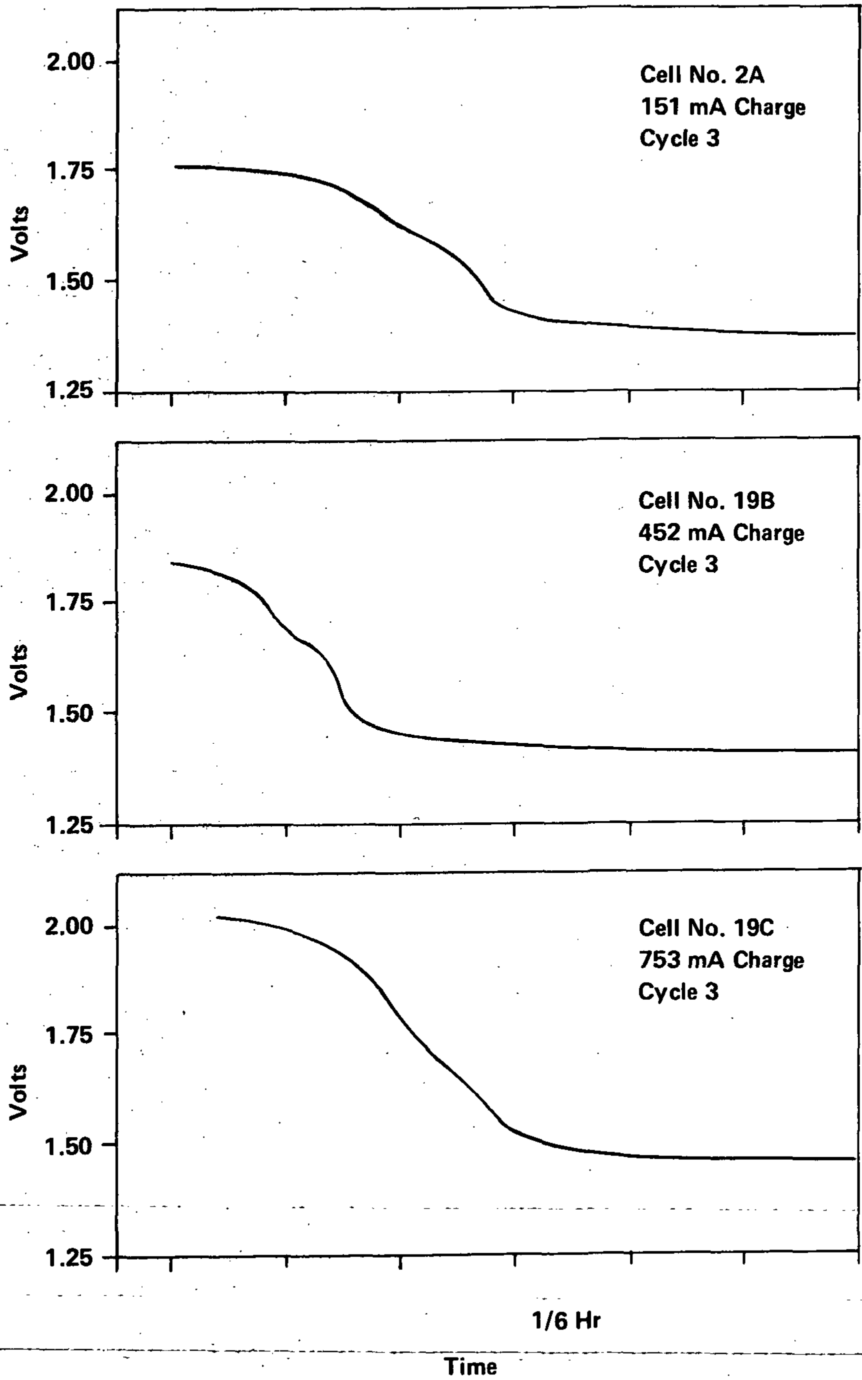


FIGURE IV-13. TYPICAL VOLTAGE TRACE NEAR END-OF-CHARGE FOR CELLS WITH Cd/Ag SCREEN ELECTRODES, 50°C

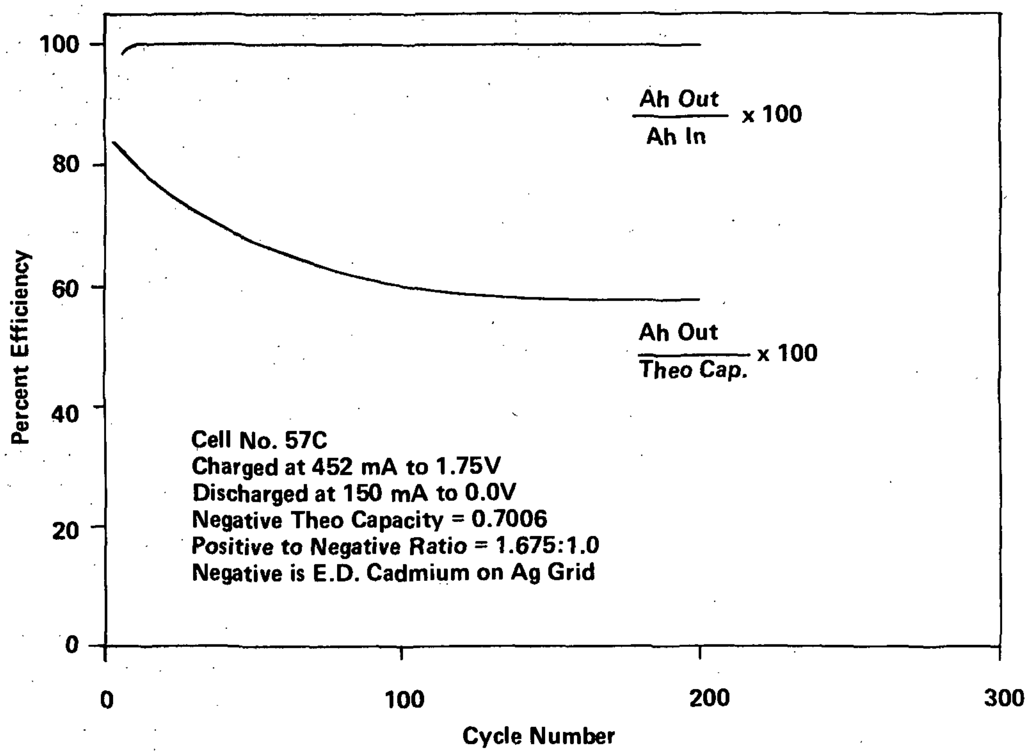


FIGURE IV-14. CYCLE DATA FOR SMALL NEGATIVE LIMITED NONGASSING NICKEL-CADMIUM CELL, 100% DEPTH OF DISCHARGE

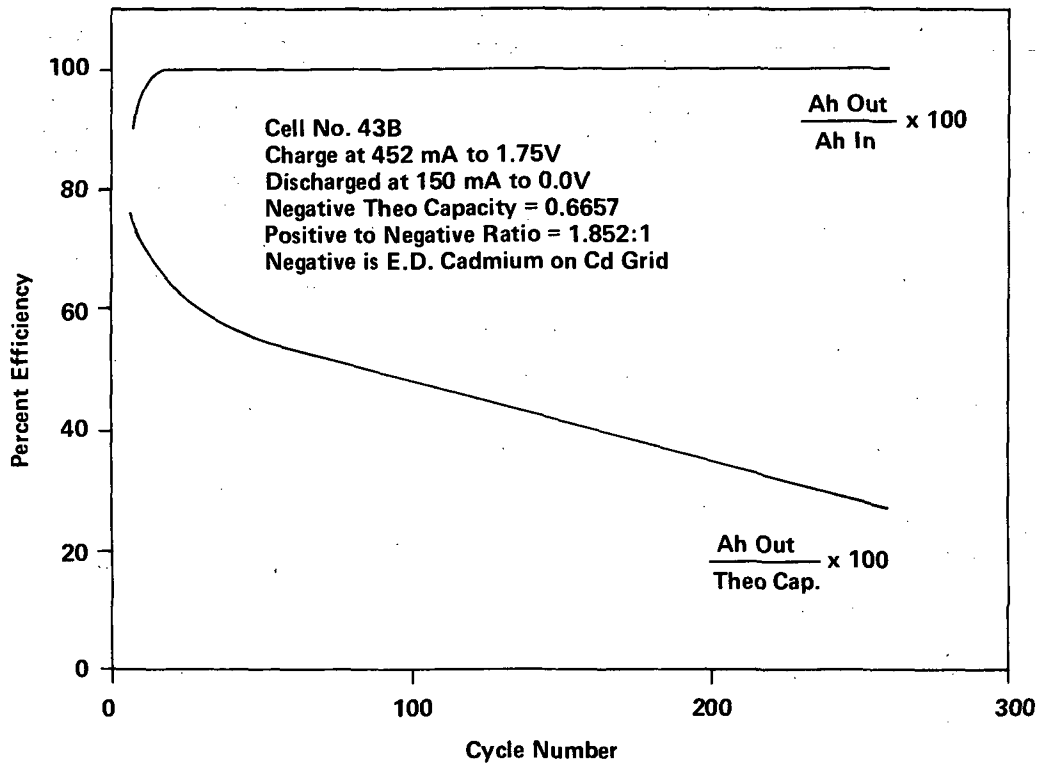


FIGURE IV-15. CYCLE DATA FOR SMALL NEGATIVE LIMITED NONGASSING NICKEL-CADMIUM CELL, 100% DEPTH OF DISCHARGE cycle data obtained at 100% depth-of-discharge. During early cycling, the input-output efficiency is less than 100% due perhaps to an improper P/N ratio. After some cycling due to aging one or both electrodes, the fading of the negative electrode being a very likely contributor, the proper P/N ratio is established for a nongassing cell. No gassing, based on cumulative volume changes in the cell, could be detected. The rate of degradation, due to fading of the negative electrode, is in the range of 0.2%/cycle, which is tolerable value for the nongassing cell in its present state of development. This value for the degradation rate is in good agreement with the values obtained in previous work[1] on conventional nickel-cadmium cells. The cell with the cadmium electrode containing the silver grid shows better life capabilities than the one with the cadmium grid.

D. Multiplate Nongassing Nickel-Cadmium Batteries

The work described in the previous sections indicated that cadmium electrodes employing an electrodeposited active mass on cadmium or silver screen were suitable for use in negative limited nickel-cadmium cells. This conclusion was based on extensive testing on idealized cells containing electrodes of approximately 2.5 $in.^2$ size. The concept of a negative limited, nongassing nickel cell, capable of operating over a wide range of test conditions and possessing reasonable life was demonstrated in the above mentioned small cells.

To select the better of the two cadmium electrodes and to further prove the concept, negative limited, nongassing practical batteries of about 25 Ah capacity were constructed and tested.

The batteries constructed with the cadmium screens (silver foil was used as tabs) contained 16 negative electrodes and 17 positive electrodes each of which was approximately 15.5 $in.^2$ in geometric area. Gassing measurements were made on such batteries on the third charge as described in Section III and no gas evolution was detected. Cumulative pressure changes were measured over an extended number of cycles. There was no cumulative pressure measure increase.

The all cadmium electrodes proved to be difficult to manufacture in the size required due to the poor mechanical properties, low conductivity, and high reactivity of the cadmium screens.

For reasons of this type it was decided to devote the effort to construct batteries with cadmium electrodes with silver screens. Such cells were constructed with 11 positive electrodes and 10 negative electrodes, had approximately 30 Ah theoretical capacity and also operated in a gas-free manner. They had a positive to negative ratio of 3:1 and an actual energy density of 10-11 Wh/lb.

Thirty cells with the nongassing cadmium electrodes containing the silver screen were constructed and their performance over a wide range of conditions will be evaluated.

V. CONCLUSIONS

The concept of a negative limited nongassing nickel-cadmium battery, capable of operation over a wide range of conditions was demonstrated by constructing and then testing practical batteries of approximately 25 Ah capacity. These cells operated in a gas-free manner. They had measured energy densities of 10-11 Wh/lb. Thirty batteries were constructed for extensive testing. Some small idealized cells were cycle tested over 200 cycles during which time no volume changes could be determined. Cells containing an electrodeposited cadmium active mass on a silver screen proved to be the best cadmium electrodes for use in negative limited batteries. This was due to the properties of the silver screen. The use of silver introduced no apparent life limitations; cycle life in excess of 200 cycles to 100% depth was demonstrated.

The above mentioned results were based on extensive testing of nickel electrodes as a function of loading, charge rate, and temperature, and four configurations of cadmium electrodes. For the nickel electrode gassing characteristics were determined as a function of charge input at the third and twentieth cycles for all the cells in order to establish the state-of-charge of the positive electrode at which they would possess acceptable gassing characteristics during charge. These data were then used to establish a minimum positive/negative ratio of 1.7:1. This value was based on charge rate, temperature, loading considerations only. This value was increased to 3:1 to account for other variables encountered in constructing practical cells.

In addition, an analysis of the above mentioned data indicates that:

- There was no overall deterioration of the gassing characteristics of the nickel electrode after the 20 cycles. Actually, the positive electrodes accepted charge better after 20 test cycles than earlier cycles. They actually gassed at higher states-of-charge at the end of 20 cycles. The effect of each variable changes with cycling, however.
- The effect of temperature was found to be the single most important variable. Gassing at lower states-of-charge was enhanced at the high charge temperature. This variable was also shown to be age-dependent. Its magnitude changed from -5.0 at cycle 3 to -29.2 at cycle 20.
- The $Ni(OH)_2$ loading was observed to have a large negative effect (-16.3) at the third cycle which indicates gassing at a lower state-of-charge. The magnitude of this effect decreased to -6.3% after 20 cycles.
- The charge current exhibited no significant linear effects but showed a sizable negative quadratic effect on the electrode gassing, -10.0% at cycle 3 and -14.3% at cycle 20. The gassing characteristics were worse at the higher charge currents.
- A nickel electrode with a loading in the range of 20 g/in.^{3} $Ni(OH)_2$ was selected as being most suitable for a nongassing cell from the point of view of their energy density, gassing, and physical properties.

Four configurations of cadmium electrodes were tested during the course of the work. These were an electrodeposited active mass on either a cadmium screen, a porous sintered silver substrate cadmium electrode, and a Teflon bonded pressed cadmium electrode. The two electrodeposited electrodes were the most promising and were thoroughly tested. They have excellent gassing characteristics in that they gas only at full charge. The gassing is also accompanied by a large potential step.

The charge temperature was observed to be the most important variable governing cadmium electrode efficiency. High charge temperatures promoted higher gas-free outputs.

VI. RECOMMENDATIONS FOR FUTURE WORK

The feasibility of nongassing nickel-cadmium negative limited batteries has been demonstrated in short-term tests with practical size (about 25 Ah) experimental batteries which performed in an entirely gas-free manner. Good life expectancy, somewhere in excess of 200 cycles, was also demonstrated in tests with small cells. Further testing of the 30 batteries constructed will show if there are any areas worthy of study. The work just completed indicates that the following problem areas require attention:

1. Capacity 'fading' is the primary difficulty with the system. This is most likely caused by microstructural changes in the cadmium electrode. There are a number of ways in which this problem can be attacked. Perhaps the most straightforward being through modification of the cadmium electrode design. By design changes, we mean, incorporation of discharge reserve, changes in the process variables to alter the electrode properties, and thereby minimize or eliminate this 'fading' for the useful life of the battery.

   Investigations into the exact morphological changes causing 'fading' and possible means of eliminating these changes are also suggested.

2. Improvement in the gassing properties of the nickel electrode beyond the limits found in this work, so that the energy density of the system can be improved is required. The use of additives to the electrode and electrolyte are promising approaches.

3. New substrates for both the nickel and cadmium electrodes. It was not possible to adequately evaluate new materials in this work. There are several materials that are worthy of consideration as electrode substrates. The use of these may perhaps reduce gassing, improve the life and energy density of the system.

4. Hardware development is also an area requiring work. New hardware that is essentially sealed, designed for high-rate applications, and ease of assembly with the nongassing electrodes is required.

5. Parametric studies on practical cells are necessary. Little is known about the best electrode configurations (thicknesses, etc.), types of separator, type and quantity of electrolyte, for use in the nongassing cells.

VII. REFERENCES

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APPENDIX A

GASSING DATA FOR CADMIUM ELECTRODES WITH CADMIUM GRIDS, CYCLE 3, 0°C

TABLE 1A. GASSING DATA ON CELL 33B,
0.2810 Ah THEO CAPACITY, 753 mA CHARGE RATE, 0°C
P/N = 3.253:1, Cd SCREEN, CYCLE 3

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	24.793	N	N	–	–	–	–	–	–	1.210
1.0	4.47	25.000	N	N	–	–	–	–	–	–	1.649
6.0	26.80	24.793	N	N	–	–	–	–	–	–	1.647
11.0	49.13	25.000	N	N	–	–	–	–	–	–	1.667
16.0	71.46	25.000	N	N	–	–	–	–	–	–	1.751
21.0	93.79	25.641	13.44	17.40	0.1705	0.0263	0.0434	0.0033	5.764	0.438	2.129
26.0	116.12	27.778	14.60	1410.00	0.2006	2.3089	0.0510	0.2936	6.773	38.991	2.250

TABLE 2A. GASSING DATA ON CELL 24C, CYCLE 3
0.4773 Ah THEO CAPACITY, 753 mA CHARGE RATE, 0°C
P/N = 2.6534:1, Cd SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	28.846	N	N	–	–	–	–	–	–	1.210
1.0	2.63	26.786	N	N	–	–	–	–	–	–	1.534
6.0	15.78	26.549	N	N	–	–	–	–	–	–	1.530
11.0	28.92	26.549	N	N	–	–	–	–	–	–	1.544
16.0	42.07	26.549	0.11	0.10	0.0014	0.0002	0.0004	N.C.	0.053	–	1.561
21.0	55.22	26.549	0.38	0.52	0.0050	0.0008	0.0013	0.0001	0.173	0.013	1.589
26.0	68.36	26.549	2.09	1.51	0.0275	0.0024	0.0070	0.0003	0.930	0.040	1.650
31.0	81.51	26.786	6.82	7.30	0.0904	0.0115	0.0230	0.0015	3.054	0.199	1.780
36.0	94.66	26.786	15.70	15.70	0.2081	0.0248	0.0529	0.0032	7.025	0.425	2.023
41.0	107.80	28.037	27.30	856.00	0.3787	1.4150	0.0964	0.1800	12.802	23.904	2.152

TABLE 3A. GASSING DATA ON CELL 46A, CYCLE 3
0.5641 Ah THEO CAPACITY, 753 mA CHARGE RATE, 0°C
P/N = 2.299:1, Cd SCREEN

Chg Time (min)	% Theo$_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	24.194	N	N	–	–	–	–	–	–	1.214
1.0	2.22	24.590	N	N	–	–	–	–	–	–	1.532
6.0	13.35	24.793	N	N	–	–	–	–	–	–	1.529
11.0	24.47	24.793	N	1.28	–	0.0019	–	0.0002	–	0.027	1.540
16.0	35.60	24.590	N	2.92	–	0.0042	–	0.0005	–	0.066	1.550
21.0	46.72	25.000	N	1.14	–	0.0017	–	0.0002	–	0.027	1.568
26.0	57.84	24.793	N	1.09	–	0.0016	–	0.0002	–	0.027	1.591
31.0	68.97	24.590	0.43	2.64	0.0052	0.0038	0.0013	0.0005	0.173	0.066	1.639
36.0	80.09	24.590	4.12	13.24	0.0501	0.0192	0.0127	0.0024	1.687	0.319	1.784
41.0	91.22	25.000	24.05	23.30	0.2974	0.0343	0.0756	0.0043	10.040	0.571	2.040
46.0	102.34	26.316	29.80	1014.00	0.3878	1.5725	0.0986	0.1966	13.094	26.109	2.168
51.0	113.46	27.778	50.10	2135.00	0.6883	3.949	0.1750	0.4369	23.240	58.021	2.214

TABLE 4A. GASSING DATA ON CELL 33C, CYCLE 3
0.2817 Ah THEO CAPACITY, 452 mA CHARGE RATE, 0°C
P/N = 3.245:1, Cd SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	25.641	N	N	–	–	–	–	–	–	1.183
1.0	2.67	25.641	N	N	–	–	–	–	–	–	1.494
6.0	16.05	25.641	N	N	–	–	–	–	–	–	1.476
11.0	29.42	25.641	N	N	–	–	–	–	–	–	1.482
16.0	42.79	25.641	N	N	–	–	–	–	–	–	1.492
21.0	56.16	25.641	N	N	–	–	–	–	–	–	1.507
26.0	69.53	25.641	N	N	–	–	–	–	–	–	1.536
31.0	82.90	25.641	N	N	–	–	–	–	–	–	1.639
36.0	96.27	25.641	1.98	1.51	0.0249	0.0023	0.0063	0.0003	1.394	0.066	1.879
41.0	109.64	26.316	7.88	268.50	0.1016	0.4124	0.0256	0.0519	5.664	11.482	2.027
46.0	123.02	26.786	10.26	1150.00	0.1346	1.7980	0.0339	0.2264	7.500	50.089	2.071

TABLE 5A. GASSING DATA ON CELL 24B, CYCLE 3
0.4794 Ah THEO CAPACITY, 452 mA CHARGE RATE, 0°C
P/N = 2.398:1, Cd SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	25.641	N	N	–	–	–	–	–	–	1.190
1.0	1.57	25.641	N	N	–	–	–	–	–	–	1.490
6.0	9.43	25.641	N	N	–	–	–	–	–	–	1.474
11.0	17.29	25.641	N	N	–	–	–	–	–	–	1.479
16.0	25.14	25.641	N	N	–	–	–	–	–	–	1.487
21.0	33.00	25.641	N	N	–	–	–	–	–	–	1.495
26.0	40.86	25.641	N	N	–	–	–	–	–	–	1.506
31.0	48.71	25.641	N	N	–	–	–	–	–	–	1.520
36.0	56.57	25.424	N	N	–	–	–	–	–	–	1.543
41.0	64.43	25.000	N	N	–	–	–	–	–	–	1.581
46.0	72.28	25.641	N	N	–	–	–	–	–	–	1.647
50.0	78.57	25.641	N	N	–	–	–	–	–	–	1.745
56.0	88.00	25.641	4.14	0.70	0.0519	0.0010	0.0130	0.0001	2.876	0.022	1.898
61.0	95.86	25.862	5.22	156.00	0.0660	0.2349	0.0166	0.0295	3.673	6.527	2.006
66.0	103.71	26.316	6.16	440.00	0.0792	0.6743	0.0199	0.0847	4.403	18.739	2.048

TABLE 6A. GASSING DATA ON CELL 43B, CYCLE 3
0.6657 Ah THEO CAPACITY, 452 mA CHARGE RATE, 0°C
P/N = 1.852:1, Cd SCREEN

Chg Time (min)	% Theo$_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	27.027	N	N	–	–	–	–	–	–	1.204
1.0	1.13	26.316	N	N	–	–	–	–	–	–	1.477
6.0	6.79	26.316	N	N	–	–	–	–	–	–	1.454
11.0	12.45	26.316	N	N	–	–	–	–	–	–	1.457
16.0	18.11	26.316	N	N	–	–	–	–	–	–	1.461
21.0	23.76	26.316	N	N	–	–	–	–	–	–	1.466
26.0	29.42	25.862	N	N	–	–	–	–	–	–	1.472
31.0	35.08	25.641	N	N	–	–	–	–	–	–	1.478
36.0	40.74	25.641	N	N	–	–	–	–	–	–	1.486
41.0	46.40	25.641	N	N	–	–	–	–	–	–	1.497
46.0	52.06	27.027	N	N	–	–	–	–	–	–	1.513
51.0	57.71	27.027	N	N	–	–	–	–	–	–	1.540
56.0	63.37	26.549	N	N	–	–	–	–	–	–	1.605
61.0	69.03	26.549	N	N	–	–	–	–	–	–	1.777
66.0	74.69	26.549	0.90	10.80	0.0118	0.0168	0.0030	0.0021	0.664	0.465	1.963
71.0	80.35	25.778	4.51	725.00	0.0616	1.1801	0.0156	0.1492	3.451	33.009	2.044
76.0	86.00	28.302	7.32	1132.00	0.1019	1.8773	0.0258	0.2373	5.708	52.500	2.076

TABLE 7A. GASSING DATA ON CELL 33A, CYCLE 3
0.2828 Ah THEO CAPACITY, 151 mA CHARGE RATE, 0°C
P/N = 3.070:1, Cd SCREEN

Chg Time (min)	% Theo$_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	24.390	N	N	–	–	–	–	–	–	1.198
1.0	0.89	25.210	N	N	–	–	–	–	–	–	1.439
6.0	5.34	25.862	N	N	–	–	–	–	–	–	1.417
11.0	9.79	25.862	N	N	–	–	–	–	–	–	1.414
16.0	14.24	25.862	N	N	–	–	–	–	–	–	1.414
21.0	18.69	25.862	N	N	–	–	–	–	–	–	1.415
26.0	23.14	25.862	N	N	–	–	–	–	–	–	1.417
31.0	27.59	25.641	N	N	–	–	–	–	–	–	1.419
36.0	32.04	25.424	N	N	–	–	–	–	–	–	1.422
41.0	36.49	25.424	N	N	–	–	–	–	–	–	1.426
46.0	40.94	25.424	N	N	–	–	–	–	–	–	1.429
51.0	45.39	25.424	N	N	–	–	–	–	–	–	1.434
56.0	49.83	25.641	N	N	–	–	–	–	–	–	1.439
61.0	54.28	25.862	N	N	–	–	–	–	–	–	1.446
66.0	58.73	25.641	N	N	–	–	–	–	–	–	1.453
71.0	63.18	25.641	N	N	–	–	–	–	–	–	1.461
76.0	67.63	25.641	N	N	–	–	–	–	–	–	1.473
81.0	72.08	25.862	N	N	–	–	–	–	–	–	1.488
86.0	76.53	25.862	N	N	–	–	–	–	–	–	1.515
91.0	80.98	25.210	N	N	–	–	–	–	–	–	1.565
96.0	85.43	25.210	N	N	–	–	–	–	–	–	1.690
101.0	89.88	25.000	N	N	–	–	–	–	–	–	1.817
106.0	94.33	25.210	N	67.10	–	0.0990	–	0.0125	–	8.278	1.928
111.0	98.78	25.424	N	219.78	–	0.3271	–	0.0413	–	27.351	1.948
116.0	103.23	25.641	N	514.23	–	0.7720	–	0.0975	–	64.570	1.959

TABLE 8A. GASSING DATA ON CELL 24A, CYCLE 3
0.4787 Ah THEO CAPACITY, 151 mA CHARGE RATE, 0°C
P/N = 2.625:1, Cd SCREEN

Chg Time (min)	% Theo$_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	27.778	N	N	–	–	–	–	–	–	1.180
1.0	0.53	27.523	N	N	–	–	–	–	–	–	1.441
6.0	3.15	27.273	N	N	–	–	–	–	–	–	1.418
11.0	5.78	27.273	N	N	–	–	–	–	–	–	1.414
16.0	8.41	27.273	N	N	–	–	–	–	–	–	1.413
21.0	11.04	27.027	N	N	–	–	–	–	–	–	1.413
26.0	13.67	26.786	N	N	–	–	–	–	–	–	1.414
31.0	16.30	27.027	N	N	–	–	–	–	–	–	1.415
36.0	18.93	27.027	N	N	–	–	–	–	–	–	1.417
46.0	24.18	27.027	N	N	–	–	–	–	–	–	1.420
51.0	26.81	27.027	N	N	–	–	–	–	–	–	1.422
56.0	29.44	27.027	N	N	–	–	–	–	–	–	1.423
61.0	32.07	27.027	N	N	–	–	–	–	–	–	1.426
66.0	34.70	27.027	N	N	–	–	–	–	–	–	1.427
76.0	39.96	27.027	N	N	–	–	–	–	–	–	1.432
81.0	42.58	27.027	N	N	–	–	–	–	–	–	1.434
86.0	45.21	26.786	N	N	–	–	–	–	–	–	1.437
91.0	47.84	26.786	N	N	–	–	–	–	–	–	1.440
96.0	50.47	26.549	N	N	–	–	–	–	–	–	1.443
101.0	53.10	26.549	N	N	–	–	–	–	–	–	1.446
106.0	55.73	26.549	N	N	–	–	–	–	–	–	1.449
111.0	58.36	26.316	N	N	–	–	–	–	–	–	1.453
121.0	63.61	26.316	N	N	–	–	–	–	–	–	1.462
126.0	66.24	26.316	N	N	–	–	–	–	–	–	1.467
131.0	68.87	25.862	N	N	–	–	–	–	–	–	1.473
136.0	71.50	25.862	N	N	–	–	–	–	–	–	1.479
141.0	74.13	26.087	N	N	–	–	–	–	–	–	1.487
151.0	79.39	26.087	N	N	–	–	–	–	–	–	1.508
156.0	82.01	26.087	N	N	–	–	–	–	–	–	1.522
161.0	84.64	26.087	N	N	–	–	–	–	–	–	1.546
166.0	87.27	26.316	N	N	–	–	–	–	–	–	1.588
171.0	89.90	26.316	N	N	–	–	–	–	–	–	1.656
176.0	92.53	26.316	N	N	–	–	–	–	–	–	1.715
181.0	95.16	26.316	N	0.20	–	0.0003	–	N.C.	–	–	1.781
186.0	97.79	26.316	N	8.94	–	0.0138	–	0.0017	–	1.126	1.905
191.0	100.41	26.316	N	91.20	–	0.1404	–	0.0177	–	11.722	1.939
196.0	103.04	26.316	0.40	130.50	0.0052	0.2008	0.0013	0.0253	0.861	16.755	1.950

TABLE 9A. GASSING DATA ON CELL 43A, CYCLE 3
0.6661 Ah THEO CAPACITY, 151 mA CHARGE RATE, 0°C
P/N = 1.901:1, Cd SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i}$ x 100	$\frac{i_{H_2}}{i}$ x 100	E (volts)
0.0	0.00	25.000	N	N	–	–	–	–	–	–	1.210
1.0	0.38	25.000	N	N	–	–	–	–	–	–	1.423
6.0	2.27	25.000	N	N	–	–	–	–	–	–	1.414
11.0	4.16	25.000	N	N	–	–	–	–	–	–	1.403
20.0	7.56	24.793	N	N	–	–	–	–	–	–	1.402
50.0	18.89	27.273	N	N	–	–	–	–	–	–	1.407
55.0	20.78	27.273	N	N	–	–	–	–	–	–	1.408
60.0	22.67	27.273	N	N	–	–	–	–	–	–	1.409
90.0	34.00	25.862	N	N	–	–	–	–	–	–	1.417
95.0	35.89	25.862	N	N	–	–	–	–	–	–	1.419
100.0	37.78	25.862	N	N	–	–	–	–	–	–	1.420
130.0	49.12	25.641	N	N	–	–	–	–	–	–	1.432
135.0	51.01	25.641	N	N	–	–	–	–	–	–	1.435
140.0	52.89	25.424	N	N	–	–	–	–	–	–	1.437
145.0	54.78	25.424	N	N	–	–	–	–	–	–	1.440
150.0	56.67	25.424	N	N	–	–	–	–	–	–	1.443
155.0	58.56	25.424	N	N	–	–	–	–	–	–	1.446
160.0	60.45	25.210	N	N	–	–	–	–	–	–	1.449
165.0	62.34	25.210	N	N	–	–	–	–	–	–	1.453
170.0	64.23	25.424	N	N	–	–	–	–	–	–	1.456
175.0	66.12	25.210	N	N	–	–	–	–	–	–	1.462
180.0	68.01	25.210	N	N	–	–	–	–	–	–	1.464
185.0	69.90	25.000	N	N	–	–	–	–	–	–	1.469
190.0	71.79	25.210	N	N	–	–	–	–	–	–	1.473
195.0	73.68	25.210	N	N	–	–	–	–	–	–	1.478
200.0	75.56	25.000	N	N	–	–	–	–	–	–	1.484
205.0	77.45	26.316	N	N	–	–	–	–	–	–	1.490
210.0	79.34	26.316	N	N	–	–	–	–	–	–	1.498
215.0	81.23	26.087	N	N	–	–	–	–	–	–	1.506
220.0	83.12	26.087	N	N	–	–	–	–	–	–	1.518
225.0	85.01	25.862	N	N	–	–	–	–	–	–	1.532
230.0	86.90	25.862	N	N	–	–	–	–	–	–	1.557
235.0	88.79	25.862	N	N	–	–	–	–	–	–	1.591
240.0	90.68	25.641	N	N	–	–	–	–	–	–	1.636
245.0	92.57	25.641	0.12	N	0.0015	–	0.0004	–	0.265	–	1.672
250.0	94.46	25.424	0.07	0.96	0.0009	0.0014	0.0002	0.0002	0.133	0.133	1.703
255.0	96.34	25.424	0.54	0.24	0.0068	0.0004	0.0017	N.C.	1.126	–	1.731
260.0	98.23	26.087	1.81	4.21	0.0235	0.0065	0.0060	0.0008	3.974	0.530	1.760
265.0	100.12	26.087	0.78	2.27	0.0101	0.0035	0.0026	0.0004	1.722	0.265	1.815
270.0	102.01	25.862	1.11	6.34	0.0143	0.0097	0.0036	0.0012	2.384	0.795	1.912
275.0	103.90	25.862	2.04	41.50	0.0262	0.0636	0.0067	0.0081	4.437	5.364	1.944
280.0	105.79	25.862	2.61	93.40	0.0336	0.1431	0.0086	0.0183	5.695	12.119	1.955
285.0	107.68	26.087	3.89	370.00	0.0504	0.5716	0.0129	0.0730	8.543	48.344	1.963

APPENDIX B

TABLE 1B. GASSING DATA FOR ELECTRODE No. 31
0.3067 Ah THEO CAPACITY, 151 mA CHARGE RATE, 50°C
CYCLE 3

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	29.412	N	N	–	–	–	–	–	–	
1.0	0.82	29.412	N	N	–	–	–	–	–	–	
6.0	4.92	29.412	N	N	–	–	–	–	–	–	
11.0	9.03	29.412	N	N	–	–	–	–	–	–	
16.0	13.13	29.412	N	N	–	–	–	–	–	–	
21.0	17.23	29.412	N	N	–	–	–	–	–	–	
26.0	21.33	29.126	N	N	–	–	–	–	–	–	
31.0	25.44	29.126	N	N	–	–	–	–	–	–	
41.0	36.64	29.126	N	N	–	–	–	–	–	–	
46.0	37.75	29.126	N	N	–	–	–	–	–	–	
51.0	41.85	29.126	N	N	–	–	–	–	–	–	
	Temperature = 24.0°C; Bar. P = 720.5 mm Hg										
56.0	45.95	28.846	N	N	–	–	–	–	–	–	
61.0	50.05	28.846	N	N	–	–	–	–	–	–	
66.0	54.16	28.846	N	N	–	–	–	–	–	–	
71.0	58.26	28.846	N	N	–	–	–	–	–	–	
76.0	62.36	28.846	N	N	–	–	–	–	–	–	
81.0	66.47	28.037	N	N	–	–	–	–	–	–	
86.0	70.57	27.523	N	N	–	–	–	–	–	–	
91.0	74.67	27.523	N	N	–	–	–	–	–	–	
96.0	78.77	27.273	N	N	–	–	–	–	–	–	
101.0	82.88	27.273	N	N	–	–	–	–	–	–	
106.0	86.98	27.273	N	N	–	–	–	–	–	–	
111.0	91.08	27.273	N	N	–	–	–	–	–	–	
116.0	95.19	27.273	N	N	–	–	–	–	–	–	
	Temperature = 24.2°C; Bar. P = 719.3 mm Hg										
121.0	92.29	27.273	N	N	–	–	–	–	–	–	
126.0	103.39	27.027	N	N	–	–	–	–	–	–	
131.0	107.49	26.786	N	N	–	–	–	–	–	–	
136.0	111.60	26.786	0.18	N	0.0023	–	0.0006	–	0.397	–	
141.0	115.70	26.549	1.39	N	0.0179	–	0.0045	–	2.980	–	
146.0	119.80	26.549	1.27	N	0.0164	–	0.0041	–	2.715	–	
151.0	123.91	26.549	1.53	N	0.0197	–	0.0049	–	3.245	–	
156.0	128.01	26.549	0.96	N	0.0124	–	0.0031	–	2.053	–	
161.0	132.11	26.549	2.15	N	0.0277	–	0.0069	–	4.570	–	
166.0	136.21	26.549	0.26	N	0.0034	–	0.0008	–	0.530	–	
171.0	140.32	26.316	0.92	N	0.0118	–	0.0029	–	1.921	–	
176.0	144.42	26.087	0.55	N	0.0070	–	0.0017	–	1.126	–	
181.0	148.52	26.087	2.80	N	0.0355	–	0.0089	–	5.894	–	
186.0	152.62	25.862	2.48	3.37	0.0311	0.0051	0.0078	0.0006	5.166	0.397	
191.0	156.73	25.862	4.40	81.60	0.0552	0.1229	0.0138	0.0155	9.139	10.265	
196.0	160.83	26.316	4.80	190.50	0.0613	0.2920	0.0153	0.0367	10.132	24.305	

TABLE 2B. GASSING DATA FOR ELECTRODE No. 22
0.4337 Ah THEO CAPACITY, 151 mA CHARGE RATE, 50°C
CYCLE 3

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	26.786	N	N	–	–	–	–	–	–	
1.0	0.58	26.786	N	N	–	–	–	–	–	–	
6.0	3.48	26.786	N	N	–	–	–	–	–	–	
16.0	9.28	26.786	N	N	–	–	–	–	–	–	
21.0	12.19	26.786	N	N	–	–	–	–	–	–	
26.0	15.09	26.786	N	N	–	–	–	–	–	–	
51.0	29.59	26.786	N	N	–	–	–	–	–	–	
56.0	32.50	26.786	N	N	–	–	–	–	–	–	
61.0	35.40	26.786	N	N	–	–	–	–	–	–	
71.0	41.20	26.549	N	N	–	–	–	–	–	–	
76.0	44.10	26.549	N	N	–	–	–	–	–	–	
81.0	47.00	26.549	N	N	–	–	–	–	–	–	
86.0	49.90	26.549	N	N	–	–	–	–	–	–	
91.0	52.81	26.549	N	N	–	–	–	–	–	–	
101.0	58.61	26.549	N	N	–	–	–	–	–	–	
111.0	64.41	26.549	N	N	–	–	–	–	–	–	
121.0	70.21	26.549	N	N	–	–	–	–	–	–	
126.0	73.12	26.316	N	N	–	–	–	–	–	–	
131.0	76.02	26.549	N	N	–	–	–	–	–	–	
136.0	78.92	26.549	N	N	–	–	–	–	–	–	
141.0	81.82	26.316	0.95	N	0.0121	–	0.0030	–	1.987	–	
146.0	84.72	26.549	2.73	N	0.0351	–	0.0087	–	5.762	–	
151.0	87.62	26.549	0.69	N	0.0089	–	0.0022	–	1.457	–	
156.0	90.52	26.549	0.30	N	0.0039	–	0.0010	–	0.662	–	
166.0	96.33	26.316	0.42	N	0.0054	–	0.0013	–	0.861	–	
171.0	99.23	26.316	0.64	N	0.0082	–	0.0020	–	1.325	–	
176.0	102.13	26.316	0.62	N	0.0079	–	0.0020	–	1.325	–	
181.0	105.03	26.316	1.41	N	0.0180	–	0.0045	–	2.980	–	
186.0	107.93	26.087	2.78	N	0.0351	–	0.0088	–	5.828	–	
191.0	110.83	26.087	0.83	N	0.0105	–	0.0026	–	1.722	–	
196.0	113.73	26.087	9.97	N	0.1260	–	0.0314	–	20.795	–	
201.0	116.64	25.862	1.98	N	0.0248	–	0.0062	–	4.106	–	
206.0	119.54	25.862	3.90	N	0.0489	–	0.0122	–	8.079	–	
211.0	122.44	25.862	4.12	22.05	0.0516	0.0329	0.0129	0.0041	8.543	2.715	
216.0	125.34	26.087	3.65	96.00	0.0461	0.1446	0.0115	0.0180	7.616	11.921	
221.0	128.24	26.087	4.35	168.00	0.0550	0.2530	0.0137	0.0315	9.073	20.861	
226.0	131.14	26.316	5.20	249.00	0.0663	0.3783	0.0165	0.0471	10.927	31.192	

TABLE 3B. GASSING DATA FOR ELECTRODE No. 46
0.5451 Ah THEO CAPACITY, 151 mA CHARGE RATE, 50°C
CYCLE 3

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	26.087	N	N	–	–	–	–	–	–	
1.0	0.46	26.087	N	N	–	–	–	–	–	–	
6.0	2.77	26.316	N	N	–	–	–	–	–	–	
15.0	6.93	26.317	N	N	–	–	–	–	–	–	
20.0	9.23	26.087	N	N	–	–	–	–	–	–	
50.0	23.08	26.087	N	N	–	–	–	–	–	–	
55.0	25.39	26.087	N	N	–	–	–	–	–	–	
60.0	27.70	26.087	N	N	–	–	–	–	–	–	
90.0	41.55	25.641	N	N	–	–	–	–	–	–	
95.0	43.86	25.641	N	N	–	–	–	–	–	–	
100.0	46.17	25.641	N	N	–	–	–	–	–	–	
130.0	60.02	25.424	0.23	N	0.0029	–	0.0007	–	0.464	–	
145.0	66.94	25.424	0.77	N	0.0097	–	0.0024	–	1.589	–	
150.0	69.25	25.424	2.88	N	0.0361	–	0.0092	–	6.093	–	
155.0	71.56	25.424	0.47	N	0.0059	–	0.0015	–	0.993	–	
170.0	78.49	25.210	2.18	N	0.0271	–	0.0069	–	4.570	–	
180.0	83.10	25.210	2.41	N	0.0300	–	0.0076	–	5.033	–	
185.0	85.41	25.210	2.94	N	0.0241	–	0.0061	–	4.040	–	
190.0	87.72	25.210	3.47	N	0.0431	–	0.0109	–	7.219	–	
195.0	90.03	25.000	2.10	N	0.0259	–	0.0066	–	4.371	–	
200.0	92.34	25.000	2.13	N	0.0263	–	0.0067	–	4.437	–	
210.0	96.95	25.000	3.50	N	0.0432	–	0.0109	–	7.219	–	
220.0	101.57	25.000	5.82	N	0.0718	–	0.0182	–	12.053	–	
230.0	106.19	25.000	5.99	N	0.0738	–	0.0187	–	12.384	–	
240.0	110.81	25.000	6.42	N	0.0792	–	0.0201	–	13.311	–	
245.0	113.11	25.000	7.18	N	0.0885	–	0.0224	–	14.834	–	
250.0	115.42	25.000	8.30	N	0.1023	–	0.0259	–	17.152	–	
255.0	117.73	25.000	7.54	N	0.0930	–	0.0236	–	15.629	–	
260.0	120.04	25.000	8.06	N	0.0994	–	0.0252	–	16.689	–	
265.0	122.35	25.000	9.04	N	0.1115	–	0.0283	–	18.742	–	
270.0	124.66	25.000	8.78	N	0.1082	–	0.0274	–	19.146	–	
275.0	126.96	25.000	10.88	N	0.1341	–	0.0340	–	22.517	–	
280.0	129.27	25.000	10.84	N	0.1336	–	0.0339	–	22.450	–	
285.0	131.58	25.000	13.14	N	0.1620	–	0.0411	–	27.219	–	
290.0	133.89	25.000	11.24	N	0.1386	–	0.0351	–	23.245	–	
295.0	136.20	25.000	12.68	N	0.1563	–	0.0396	–	26.225	–	
300.0	138.51	25.000	14.28	0.22	0.1761	0.0003	0.0446	N.C.	29.536	?	
305.0	140.82	25.000	14.60	1.15	0.1800	0.0017	0.0456	0.0002	30.199	0.132	
310.0	143.12	25.000	17.65	20.15	0.2176	0.0296	0.0552	0.0038	36.556	2.517	
315.0	145.43	24.793	13.80	31.20	0.1687	0.0455	0.0428	0.0058	28.344	3.841	

TABLE 4B. GASSING DATA FOR ELECTRODE No. 47
0.6184 Ah THEO CAPACITY, 452 mA CHARGE RATE, 50°C
CYCLE 3

Chg Time (min)	% Theo$_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	25.862	N	N	–	–	–	–	–	–	
1.0	1.22	26.087	N	N	–	–	–	–	–	–	
6.0	7.31	26.087	N	N	–	–	–	–	–	–	
1.0	13.40	25.862	N	N	–	–	–	–	–	–	
16.0	19.49	25.862	N	N	–	–	–	–	–	–	
21.0	25.58	25.641	N	N	–	–	–	–	–	–	
26.0	31.67	25.641	N	N	–	–	–	–	–	–	
31.0	37.76	25.641	N	N	–	–	–	–	–	–	
36.0	43.86	25.424	N	N	–	–	–	–	–	–	
41.0	49.95	25.424	N	N	–	–	–	–	–	–	
46.0	56.04	25.424	N	N	–	–	–	–	–	–	
51.0	62.13	25.424	N	N	–	–	–	–	–	–	
56.0	68.22	25.424	N	N	–	–	–	–	–	–	
61.0	74.31	25.424	0.27	N	0.0034	–	0.0009	–	0.199	–	
66.0	80.40	25.210	2.03	N	0.0257	–	0.0066	–	1.46	–	
71.0	86.49	25.210	1.46	N	0.0185	–	0.0048	–	1.06	–	
76.0	92.58	25.210	2.49	N	0.0315	–	0.0081	–	1.79	–	
81.0	98.67	25.210	4.47	N	0.0566	–	0.0146	–	3.23	–	
86.0	104.76	25.210	5.12	0.12	0.0648	0.0002	0.0167	N.C.	3.70	–	
91.0	110.86	25.210	5.37	N	0.0680	–	0.0175	–	3.87	–	
96.0	116.95	25.210	6.63	N	0.0839	–	0.0217	–	4.80	–	
101.0	123.04	25.210	13.72	0.31	0.1737	0.0005	0.0448	0.0001	9.91	0.02	
106.0	129.13	25.424	15.40	83.80	0.1966	0.1275	0.0508	0.0165	11.24	3.65	
111.0	135.22	25.424	17.85	196.00	0.2279	0.2981	0.0588	0.0385	13.01	8.52	
116.0	141.31	25.424	21.70	472.00	0.2818	0.7303	0.0728	0.0943	16.11	20.86	

TABLE 5B. GASSING DATA FOR ELECTRODE No. 28
0.4412 Ah THEO CAPACITY, 452 mA CHARGE RATE, 50°C
CYCLE 3

Chg Time (min)	% Theo$_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i}$ x 100	$\frac{i_{H_2}}{i}$ x 100	E (volts)
0.0	0.00	25.641	N	N	–	–	–	–	–	–	
1.0	1.71	25.000	N	N	–	–	–	–	–	–	
6.0	10.24	25.000	N	N	–	–	–	–	–	–	
11.0	18.78	25.000	N	N	–	–	–	–	–	–	
16.0	27.32	25.000	N	N	–	–	–	–	–	–	
21.0	35.86	25.000	N	N	–	–	–	–	–	–	
26.0	44.39	25.000	N	N	–	–	–	–	–	–	
31.0	52.93	25.000	N	N	–	–	–	–	–	–	
36.0	61.47	25.000	N	N	–	–	–	–	–	–	
41.0	70.01	25.000	N	N	–	–	–	–	–	–	
46.0	78.54	25.000	N	N	–	–	–	–	–	–	
51.0	87.08	25.000	0.54	N	0.0068	–	0.0018	–	0.398	–	
56.0	95.62	25.000	1.15	N	0.0145	–	0.0037	–	0.819	–	
61.0	104.16	25.000	2.40	N	0.0302	–	0.0078	–	1.726	–	
66.0	112.69	25.000	1.52	N	0.0191	–	0.0049	–	1.084	–	
71.0	121.23	25.000	8.20	0.92	0.1031	0.0014	0.0267	0.0002	5.907	0.044	
76.0	129.77	25.210	8.90	277.00	0.1129	0.4185	0.0292	0.0541	6.460	11.969	
81.0	138.30	25.862	12.35	664.00	0.1606	1.0292	0.0415	0.1313	9.181	29.447	

TABLE 6B. GASSING DATA FOR ELECTRODE No. 35B
0.2922 Ah THEO CAPACITY, 452 mA CHARGE RATE, 50°C
CYCLE 3

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	31.915	N	N	–	–	–	–	–	–	
1.0	2.58	31.915	N	N	–	–	–	–	–	–	
6.0	15.47	31.915	N	N	–	–	–	–	–	–	
11.0	28.36	31.915	N	N	–	–	–	–	–	–	
16.0	41.25	31.915	N	N	–	–	–	–	–	–	
21.0	54.14	31.915	N	N	–	–	–	–	–	–	
26.0	67.03	31.915	N	N	–	–	–	–	–	–	
31.0	76.92	31.915	N	N	–	–	–	–	–	–	
36.0	92.81	31.915	N	N	–	–	–	–	–	–	
41.0	105.70	31.915	N	N	–	–	–	–	–	–	
46.0	118.59	31.915	N	N	–	–	–	–	–	–	
51.0	131.49	31.915	0.52	0.70	0.0082	0.0010	0.0021	0.0001	0.465	0.022	
56.0	144.38	32.609	3.76	276.00	0.0607	0.5308	0.0154	0.0675	3.407	14.931	

TABLE 7B. GASSING DATA FOR ELECTRODE No. 29
0.3702 Ah THEO CAPACITY, 753 mA CHARGE RATE, 50°C
CYCLE 3

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	31.915	N	N	–	–	–	–	–	–	
1.0	3.39	31.915	N	N	–	–	–	–	–	–	
6.0	20.34	32.609	N	N	–	–	–	–	–	–	
11.0	37.29	32.609	N	N	–	–	–	–	–	–	
16.0	54.24	32.609	N	N	–	–	–	–	–	–	
21.0	71.19	32.609	0.83	N	0.0133	–	0.0034	–	0.452	–	
26.0	88.14	32.609	3.24	N	0.0519	–	0.0131	–	1.740	–	
31.0	105.0	32.609	11.04	N	0.1768	–	0.0447	–	5.936	–	
36.0	122.04	32.609	12.00	N	0.1922	–	0.0485	–	6.441	–	
41.0	138.99	32.967	29.35	N	0.4752	–	0.1200	–	15.936	–	
44.5	150.86	32.967	29.00	0.80	0.4696	0.0015	0.1186	0.0002	15.750	0.027	

TABLE 8B. GASSING DATA FOR ELECTRODE No. 40
0.2609 Ah THEO CAPACITY, 753 mA CHARGE RATE, 50°C
CYCLE 3

Chg Time (min)	% Theo$_F$ Input	Flushing (cc/min)	AA_{O_2}	AA_{H_2}	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	30.928	N	N	–	–	–	–	–	–	
1.0	4.81	30.928	N	N	–	–	–	–	–	–	
6.0	28.86	30.928	N	N	–	–	–	–	–	–	
11.0	52.91	30.928	N	N	–	–	–	–	–	–	
16.0	76.96	30.928	2.01	N	0.0306	–	0.0078	–	1.036	–	
21.0	101.02	31.250	5.10	N	0.0785	–	0.0199	–	2.643	–	
26.0	125.07	30.928	14.56	N	0.2218	–	0.0562	–	7.463	–	
31.0	149.12	31.579	45.25	0.26	0.7040	0.0005	0.1783	0.0001	23.679	0.013	
35.0	168.36	33.708	46.40	1078.00	0.7705	2.1330	0.1952	0.2701	25.923	35.870	

TABLE 9B. GASSING DATA FOR ELECTRODE No. 49
0.6113 Ah THEO CAPACITY, 753 mA CHARGE RATE, 50°C
CYCLE 3

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	AA_{O_2}	AA_{H_2}	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	30.303	–	–	–	–	–	–	–	–	
1.0	2.05	30.303	N	N	–	–	–	–	–	–	
6.0	12.32	30.612	N	N	–	–	–	–	–	–	
11.0	22.58	30.303	N	N	–	–	–	–	–	–	
16.0	32.85	30.303	N	N	–	–	–	–	–	–	
21.0	43.11	30.303	0.14	N	0.0021	–	0.0005	–	0.066	–	
26.0	53.38	30.303	0.18	N	0.0027	–	0.0007	–	0.093	–	
31.0	63.64	30.303	0.62	N	0.0092	–	0.0023	–	0.306	–	
36.0	73.91	30.303	1.43	N	0.0213	–	0.0054	–	0.717	–	
41.0	84.17	30.303	2.65	N	0.0395	–	0.0100	–	1.328	–	
46.0	94.44	30.303	6.09	N	0.0908	–	0.0230	–	3.055	–	
51.0	104.70	30.612	10.64	N	0.1602	–	0.0405	–	5.379	–	
56.0	114.97	30.612	34.55	N	0.5203	–	0.1316	–	17.477	–	
61.0	125.23	31.250	28.10	286.50	0.4320	0.5248	0.1093	0.0664	14.515	8.818	

APPENDIX C

GASSING DATA FOR CADMIUM ELECTRODES WITH CADMIUM SCREENS, CYCLE 20, 50°C

TABLE 1C. GASSING DATA ON CELL 31, CYCLE 20
0.3067 Ah THEO CAPACITY, 151 mA CHARGE RATE, 50°C
P/N = 4.027:1, Cd SCREEN

Chg Time (min)	% Theo$_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	28.037	N	N	–	–	–	–	–	–	
1.0	0.82	28.037	N	N	–	–	–	–	–	–	
6.0	4.92	27.523	N	N	–	–	–	–	–	–	
11.0	9.03	27.273	N	N	–	–	–	–	–	–	
16.0	13.13	27.273	N	N	–	–	–	–	–	–	
21.0	17.23	27.027	N	N	–	–	–	–	–	–	
26.0	21.33	27.027	N	N	–	–	–	–	–	–	
31.0	25.44	26.786	N	N	–	–	–	–	–	–	
36.0	29.54	26.549	N	N	–	–	–	–	–	–	
41.0	33.64	26.549	N	N	–	–	–	–	–	–	
46.0	37.75	26.316	N	N	–	–	–	–	–	–	
51.0	41.85	26.316	N	N	–	–	–	–	–	–	
56.0	45.95	26.316	N	13.70	–	0.0206	–	0.0026	–	1.722	
61.0	50.05	26.786	N	134.60	–	0.2065	–	0.0255	–	16.887	
66.0	54.16	26.786	N	228.00	–	0.3498	–	0.0432	–	28.609	

TABLE 2C. GASSING DATA ON CELL 22, CYCLE 20
0.4337 Ah THEO CAPACITY, 151 mA CHARGE RATE, 50°C
P/N = 2848:1, Cd SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	25.210	N	N	–	–	–	–	–	–	
1.0	0.58	25.210	N	N	–	–	–	–	–	–	
6.0	3.48	25.000	N	N	–	–	–	–	–	–	
11.0	6.38	24.793	N	N	–	–	–	–	–	–	
16.0	9.28	28.571	N	N	–	–	–	–	–	–	
21.0	12.19	26.549	N	N	–	–	–	–	–	–	
26.0	15.09	23.077	N	N	–	–	–	–	–	–	
51.0	29.59	27.273	N	N	–	–	–	–	–	–	
56.0	32.50	24.793	N	N	–	–	–	–	–	–	
61.0	35.40	24.793	N	N	–	–	–	–	–	–	
66.0	38.30	24.390	N	N	–	–	–	–	–	–	
71.0	41.20	25.641	N	N	–	–	–	–	–	–	
76.0	44.10	25.641	N	N	–	–	–	–	–	–	
81.0	47.00	25.424	N	N	–	–	–	–	–	–	
86.0	49.90	25.424	N	N	–	–	–	–	–	–	
91.0	52.81	25.424	N	N	–	–	–	–	–	–	
96.0	55.71	25.000	N	N	–	–	–	–	–	–	
101.0	58.61	25.000	N	N	–	–	–	–	–	–	
106.0	61.51	25.000	N	N	–	–	–	–	–	–	
111.0	64.41	25.000	N	N	–	–	–	–	–	–	
116.0	67.31	25.000	N	N	–	–	–	–	–	–	
121.0	70.21	26.087	0.52	N	0.0066	–	0.0016	–	1.060	–	
126.0	73.12	25.000	0.33	N	0.0040	–	0.0010	–	0.662	–	
131.0	76.02	25.210	1.13	N	0.0138	–	0.0034	–	2.252	–	
136.0	78.92	25.000	3.56	N	0.0432	–	0.0108	–	7.152	–	
141.0	81.82	25.000	3.27	N	0.0397	–	0.0099	–	6.556	–	
146.0	84.72	25.000	4.52	N	0.0548	–	0.0137	–	9.073	–	
151.0	87.62	25.000	6.24	N	0.0757	–	0.0189	–	12.517	–	
156.0	90.52	25.000	3.12	N	0.0378	–	0.0094	–	6.225	–	
161.0	93.42	25.000	3.34	N	0.0405	–	0.0101	–	6.689	–	
166.0	96.33	25.000	4.12	N	0.0500	–	0.0125	–	8.278	–	
171.0	99.23	25.424	5.82	0.41	0.0718	0.0006	0.0179	0.0001	11.854	0.066	
176.0	102.13	25.641	6.46	24.20	0.0803	0.0359	0.0200	0.0045	13.245	2.980	
181.0	105.03	25.862	9.52	97.80	0.1194	0.1462	0.0298	0.0182	19.735	12.053	
186.0	107.93	25.862	9.25	169.00	0.1160	0.2526	0.0289	0.0315	19.139	20.861	1.995
191.0	110.83	25.862	3.50	148.00	0.0439	0.2212	0.0109	0.0276	7.219	18.278	1.805
201.0	116.64	26.087	6.82	326.00	0.0863	0.4915	0.0215	0.0613	14.238	40.596	1.807
206.0	119.54	26.087	9.54	323.00	0.1207	0.4870	0.0301	0.0607	19.934	40.199	1.824

TABLE 3C. GASSING DATA ON CELL 46, CYCLE 20
0.5451 Ah THEO CAPACITY, 151 mA CHARGE RATE, 50°C
P/N = 2.266:1, Cd SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	27.273	N	N	–	–	–	–	–	–	0.508
1.0	0.46	27.273	N	N	–	–	–	–	–	–	1.365
6.0	2.77	27.778	N	N	–	–	–	–	–	–	1.345
15.0	6.93	26.316	N	N	–	–	–	–	–	–	1.345
20.0	9.23	26.087	N	N	–	–	–	–	–	–	1.345
50.0	23.08	26.087	N	N	–	–	–	–	–	–	1.347
55.0	25.39	25.862	N	N	–	–	–	–	–	–	1.362
60.0	27.70	25.862	N	N	–	–	–	–	–	–	1.364
90.0	41.55	25.210	6.59	0.52	0.0813	0.0008	0.0205	0.0001	13.576	0.066	1.367
95.0	43.86	25.210	2.55	N	0.0315	–	0.0079	–	5.232	–	1.378
100.0	46.17	25.000	3.56	0.67	0.0436	0.0010	0.0110	0.0001	7.285	0.066	1.383
115.0	53.09	25.000	3.33	0.44	0.0408	0.0006	0.0103	0.0001	6.821	0.066	1.389
120.0	55.40	25.000	6.39	0.43	0.0782	0.0006	0.0197	0.0001	13.046	0.066	1.391
125.0	57.71	25.000	6.02	0.41	0.0737	0.0006	0.0186	0.0001	12.318	0.066	1.394
130.0	60.02	25.000	3.65	0.10	0.0447	0.0001	0.0112	N.C.	7.417	–	1.395
135.0	62.33	25.000	8.77	0.22	0.1074	0.0003	0.0270	N.C.	17.881	–	1.397
140.0	64.64	25.000	18.30	N	0.2240	–	0.0465	–	37.351	–	1.400
145.0	66.94	27.523	16.12	N	0.2172	–	0.0547	–	36.225	–	1.403
150.0	69.25	27.523	19.30	N	0.2601	–	0.0655	–	43.377	–	1.407
155.0	71.56	27.273	14.85	0.42	0.1983	0.0007	0.0499	0.0001	33.046	0.066	1.410
170.0	78.49	27.273	15.10	0.41	0.2016	0.0007	0.0508	0.0001	33.642	0.066	1.421
180.0	83.10	27.273	14.40	N	0.1923	–	0.0484	–	32.053	–	1.445
185.0	85.41	27.273	16.45	N	0.2197	–	0.0553	–	36.623	–	1.495
190.0	87.72	27.273	13.55	N	0.1809	–	0.0456	–	30.199	–	1.543
195.0	90.03	27.273	19.90	1.46	0.2657	0.0023	0.0669	0.0003	44.305	0.199	1.629
200.0	92.34	27.273	21.00	0.30	0.2804	0.0005	0.0706	0.0001	46.755	0.066	1.682
205.0	94.65	27.273	18.80	0.79	0.2510	0.0013	0.0632	0.0002	41.854	0.132	1.706
210.0	96.95	27.273	23.25	21.80	0.3105	0.0347	0.0782	0.0044	51.788	2.914	1.721
215.0	99.26	27.273	21.10	4.65	0.2818	0.0074	0.0709	0.0009	46.954	0.596	1.732
220.0	101.57	27.273	23.30	11.45	0.3111	0.0182	0.0783	0.0023	51.854	1.523	1.743
230.0	106.19	27.273	22.65	25.85	0.3025	0.0411	0.0761	0.0052	50.397	3.444	1.759
240.0	110.81	27.273	28.75	26.10	0.3839	0.0415	0.0966	0.0052	63.974	3.444	1.773
245.0	113.11	27.027	20.75	32.15	0.2746	0.0507	0.0691	0.0064	45.762	4.238	1.781
250.0	115.42	27.027	25.50	58.80	0.3374	0.0927	0.0850	0.0117	56.291	7.748	1.790
255.0	117.73	27.027	29.30	70.00	0.3877	0.1104	0.0976	0.0139	64.636	9.205	1.794
265.0	122.35	27.273	28.10	118.20	0.3752	0.1881	0.0945	0.0237	62.583	15.695	1.805
270.0	124.66	27.273	25.90	78.20	0.3459	0.1244	0.0871	0.0157	57.682	10.397	1.811
290.0	133.89	27.273	28.65	151.50	0.3826	0.2411	0.0963	0.0303	63.775	20.066	1.823

TABLE 4C. GASSING DATA ON CELL 35B, CYCLE 20
0.2922 Ah THEO CAPACITY, 452 mA CHARGE RATE, 50°C
P/N = 4.227:1, Cd SCREEN

Chg Time (min)	% Theo$_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	27.273	N	N	–	–	–	–	–	–	
1.0	2.58	27.273	N	N	–	–	–	–	–	–	
6.0	15.47	26.786	N	N	–	–	–	–	–	–	
11.0	28.36	26.667	N	N	–	–	–	–	–	–	
16.0	41.25	26.549	N	N	–	–	–	–	–	–	
21.0	54.14	26.549	N	N	–	–	–	–	–	–	
26.0	67.03	26.549	N	N	–	–	–	–	–	–	
31.0	79.92	26.549	N	N	–	–	–	–	–	–	
36.0	92.81	26.549	4.97	N	0.0653	–	0.0166	–	3.673	–	
41.0	105.70	26.549	4.17	N	0.0548	–	0.0140	–	3.097	–	
46.0	118.59	26.549	7.27	1.19	0.0956	0.0019	0.0243	0.0002	5.376	0.044	
51.0	131.49	27.273	6.94	305.00	0.0937	0.4907	0.0239	0.0625	5.288	13.827	
56.0	144.38	29.412	21.72	2122.00	0.3163	3.6820	0.0805	0.5687	17.810	103.695	

TABLE 5C. GASSING DATA ON CELL 28, CYCLE 20
0.4412 Ah THEO CAPACITY, 452 mA CHARGE RATE, 50°C
P/N = 2.799:1.0, Cd SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	26.087	N	N	–	–	–	–	–	–	
1.0	1.71	26.087	N	N	–	–	–	–	–	–	
6.0	10.24	26.087	N	N	–	–	–	–	–	–	
11.0	18.78	26.087	N	N	–	–	–	–	–	–	
16.0	27.32	26.087	N	N	–	–	–	–	–	–	
21.0	35.86	26.087	N	N	–	–	–	–	–	–	
26.0	44.39	26.087	N	N	–	–	–	–	–	–	
31.0	52.93	25.641	N	N	–	–	–	–	–	–	
36.0	61.47	25.424	0.70	N	0.0088	–	0.0022	–	0.487	–	
41.0	70.01	25.424	2.07	N	0.0260	–	0.0066	–	1.460	–	
46.0	78.54	25.424	4.75	N	0.0597	–	0.0152	–	3.363	–	
51.0	87.08	25.000	6.77	N	0.0837	–	0.0213	–	4.712	–	
56.0	95.62	25.000	5.49	N	0.0678	–	0.0172	–	3.805	–	
61.0	104.16	25.000	12.24	N	0.1513	–	0.0384	–	8.496	–	
66.0	112.69	25.000	14.86	2.21	0.1836	0.0033	0.0467	0.0004	10.332	–	
71.0	121.23	25.000	24.50	110.50	0.3027	0.1627	0.0769	0.0207	17.013	–	
76.0	129.77	25.000	22.70	314.00	0.2805	0.4623	0.0713	0.0587	15.774	–	

TABLE 6C. GASSING DATA ON CELL 47, CYCLE 20
0.6184 Ah THEO CAPACITY, 452 mA CHARGE RATE, 50°C
P/N = 1.997:1.0, Cd SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	24.793	N	N	–	–	–	–	–	–	
1.0	1.22	24.793	N	N	–	–	–	–	–	–	1.381
6.0	7.31	24.590	N	N	–	–	–	–	–	–	1.384
11.0	13.40	24.590	N	N	–	–	–	–	–	–	1.390
16.0	19.49	24.390	N	N	–	–	–	–	–	–	1.395
21.0	25.58	24.194	N	N	–	–	–	–	–	–	1.400
26.0	31.67	24.194	N	N	–	–	–	–	–	–	1.404
31.0	37.76	24.590	N	N	–	–	–	–	–	–	1.408
36.0	43.86	24.590	N	N	–	–	–	–	–	–	1.414
41.0	49.95	24.590	N	N	–	–	–	–	–	–	1.418
46.0	56.04	24.590	0.93	N	0.0112	–	0.0028	–	0.619	–	1.424
51.0	62.13	25.862	3,25	N	0.0413	–	0.0104	–	2.301	–	1.429
56.0	68.22	25.862	4.39	N	0.0558	–	0.0141	–	3.119	–	1.433
61.0	74.31	25.862	7.90	N	0.1004	–	0.0254	–	5.619	–	1.438
66.0	80.40	25.862	5.62	N	0.0714	–	0.0181	–	4.004	–	1.443
71.0	86.49	25.862	13.00	N	0.1653	–	0.0418	–	9.248	–	1.450
76.0	92.58	25.641	8.56	N	0.1079	–	0.0273	–	6.040	–	1.461
81.0	98.67	25.424	9.08	N	0.1135	–	0.0287	–	6.350	–	1.476
86.0	104.76	25.424	14.18	N	0.1772	–	0.0448	–	9.912	–	1.520
91.0	110.86	25.424	32.95	N	0.4118	–	0.1041	–	23.031	–	1.765
96.0	116.95	25.424	21.40	13.52	0.2674	0.0201	0.0676	0.0025	14.956	0.553	1.810
101.0	123.04	25.424	26.10	84.00	0.3262	0.1251	0.0824	0.0158	18.230	3.496	1.841

TABLE 7C. GASSING DATA FOR CELL 40, CYCLE 20
0.2609 Ah THEO CAPACITY, 753 mA CHARGE RATE, 50°C
P/N = 4.734:1.0, Cd SCREEN

Chg Time (min)	% Theo$_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	25.210	N	N	–	–	–	–	–	–	
1.0	4.81	25.210	N	N	–	–	–	–	–	–	
6.0	28.86	24.793	N	N	–	–	–	–	–	–	
11.0	52.91	24.590	N	N	–	–	–	–	–	–	
16.0	76.96	24.590	N	N	–	–	–	–	–	–	
21.0	101.02	24.590	1.58	N	0.0190	–	0.0048	–	0.638	–	
26.0	125.07	27.778	12.58	1994.00	0.1713	3.2352	0.0432	0.4077	5.737	54.143	
31.0	149.12	30.000	27.82	3215.00	0.4091	5.6335	0.1031	0.7099	13.692	94.276	

TABLE 8C. GASSING DATA FOR CELL 29, CYCLE 20
0.3702 Ah THEO CAPACITY, 753 mA CHARGE RATE, 50°C
P/N = 3.336:1.0, Cd SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i}$ x 100	$\frac{i_{H_2}}{i}$ x 100	E (volts)
0.0	0.00	24.590	N	N	–	–	–	–	–	–	
1.0	3.39	24.590	N	N	–	–	–	–	–	–	
6.0	20.34	24.390	N	N	–	–	–	–	–	–	
11.0	37.29	24.194	N	N	–	–	–	–	–	–	
16.0	54.24	24.194	N	N	–	–	–	–	–	–	
21.0	71.19	24.194	N	N	–	–	–	–	–	–	
26.0	88.14	24.194	N	N	–	–	–	–	–	–	
31.0	105.09	23.810	0.44	N	0.0051	–	0.0013	–	0.173	–	
36.0	122.04	24.590	4.71	385.00	0.0568	0.5531	0.0143	0.0697	1.899	9.256	
41.0*	138.99	26.316	16.60	1896.00	0.2142	2.9152	0.0540	0.3675	7.171	48.805	

Additional peak noted; Retention time = 4.35 min, AA = 1.01 possibly N_2 (Not the result of a leak)

TABLE 9C. GASSING DATA FOR CELL 49, CYCLE 20
0.6113 Ah THEO CAPACITY, 753 mA CHARGE RATE, 50°C
P/N = 2.02:1, Cd SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	26.549	N	N	–	–	–	–	–	–	
1.0	2.05	26.549	N	N	–	–	–	–	–	–	
6.0	12.32	26.549	N	N	–	–	–	–	–	–	
11.0	22.58	26.549	N	N	–	–	–	–	–	–	
16.0	32.85	26.316	N	N	–	–	–	–	–	–	
21.0	43.11	26.316	N	N	–	–	–	–	–	–	
26.0	53.38	26.316	N	N	–	–	–	–	–	–	
31.0	63.64	26.316	0.06	N	0.0008	–	0.0002	–	0.027	–	
36.0	73.91	26.316	1.62	N	0.0209	–	0.0053	–	0.704	–	
41.0	84.17	26.316	4.36	0.89	0.0564	0.00014	0.0142	0.0002	1.886	0.027	
46.0	94.44	27.529	8.70	867.00	0.1176	1.3969	0.0297	0.1764	3.944	23.426	
51.0	104.70	29.703	18.45	2219.00	0.2692	3.8575	0.0680	0.4871	9.031	64.688	

APPENDIX D

CYCLE 19 DATA 'GAS MEASUREMENT CYCLE' FOR ALL CADMIUM ELECTRODES

TABLE 1D. CYCLE 19 DATA
AFTER DEEP DISCHARGE OF NEGATIVE

Cell No.	A.H. Input To 1.6V	Total A.H. Input	A.H. Out (Cell)	A.H. Out (Ref Neg)	E_{io} (Cell) 1.6V Cutoff	E_{io} (Ref Neg) 1.6V Cutoff	E_F (Cell)	E_F (Ref Neg)	ΔE_F (Ref Neg)-(Cell)
31	0.0138	0.0179	0.0620	0.1409	449.3	1021.0	20.2	45.94	25.7
22	0.0400	0.0436	0.0485	0.5551	121.3	1387.8	11.2	128.0	116.8
46	0.0947	0.1016	0.0978	0.8479	103.3	895.4	17.9	155.5	137.6
35B	Lost	Lost	0.1050	0.3224	–	–	35.9	110.3	74.4
28	Lost	Lost	0.1400	0.4654	–	–	31.7	105.5	73.8
47	Lost	Lost	0.2021	0.7158	–	–	32.7	115.8	83.1
40	0.2050	0.2221	0.2142	0.2142	104.5	104.5	82.1	82.1	0.0
29	0.2319	0.2538	0.2838	0.3532	122.4	152.3	76.7	95.4	18.7
49	0.2477	0.2770	0.2660	0.4827	107.4	194.9	43.5	79.0	35.5

APPENDIX E

GASSING CYCLE DATA FOR 'ALL' CADMIUM ELECTRODES

TABLE 1E. CYCLE DATA FOR CELL 31
0.3067 Ah THEO CAPACITY, Cd SCREEN
151 mA CHARGE RATE, 50°C
150 mA DISCHARGE RATE, 50°C

Cycle	A.H. Input 1.6V Cutoff	Total A.H. Input	A.H. Out	E_{io} Input 1.6V Cutoff	E_F
3	0.4513	0.4993	0.2781	61.6	90.7
4	0.2580	0.2699	Lost	–	–
5	Lost	Lost	0.2020	–	65.9
6	0.1933	0.2012	Lost	–	–
7	Lost	Lost	Lost	–	–
8	0.1429	0.1513	0.1357	95.0	44.3
9	0.1356	0.1432	0.1135	83.7	37.0
10	0.1141	0.1282	0.1070	93.8	34.9
11	0.1048	0.1143	0.0909	86.7	29.6
12	0.0903	0.0967	0.0914	101.2	29.8
13	0.0859	0.0935	0.0875	101.9	28.5
14	0.0805	0.0891	0.0766	95.2	25.0
15	0.0751	0.0803	0.0715	95.2	23.3
16	0.0666	0.0715	0.0695	104.4	22.7
17	0.0671	0.0717	0.0630	93.9	20.5
18	0.0614	0.0661	0.0080	13.1	2.6
19	–	–	–	–	–
20	0.1300	0.1706	0.1096	84.3	35.7

TABLE 2E. CYCLE DATA FOR CELL 46
0.5451 Ah THEO CAPACITY, Cd SCREEN
151 mA CHARGE RATE, 50°C
150 mA DISCHARGE RATE 50°C

Cycle	A.H. Input *1.6V Cutoff*	Total A.H. *Input*	*A.H. Out*	E_{io} Input *1.6V Cutoff*	E_F
3	0.7442	0.8081	0.5482	73.7	100.6
4	0.5176	0.5905	0.4099	79.2	75.2
5	0.3972	0.4329	0.3737	94.1	68.6
6	0.3566	0.4234	0.3080	86.4	56.5
7	0.2996	0.3377	0.2696	90.0	49.5
8	0.2624	0.2827	0.2541	96.8	46.6
9	0.2482	0.2775	0.1945	78.4	35.7
10	0.2024	0.2200	0.1831	90.5	33.6
11	0.1850	0.2017	0.1597	86.3	29.3
12	0.1610	0.1743	0.1690	105.0	31.0
13	0.1615	0.1730	0.1597	98.9	29.3
14	0.1530	0.1645	0.1378	90.1	25.3
15	0.1393	0.1505	0.1289	92.5	23.7
16	0.1256	0.1346	0.1291	102.8	23.7
17	0.1263	0.1329	0.1094	86.6	20.1
18	0.1136	0.1214	0.0951	83.7	17.5
19	–	–	–	–	–
20	0.5059	0.7462	0.4199	83.0	77.0

TABLE 3E. CYCLE DATA FOR CELL 22
0.4337 Ah THEO CAPACITY, Cd SCREEN
151 mA CHARGE RATE, 50°C
150 mA DISCHARGE RATE, 50°C

Cycle	A.H. Input 1.6V Cutoff	Total A.H. Input	A.H. Out	E_{io} Input 1.6V Cutoff	E_F
3	0.5078	0.5688	0.3173	62.5	73.2
4	0.2905	0.3081	0.2319	79.8	53.5
5	0.2318	0.2489	0.2113	91.2	48.7
6	0.2073	0.2261	0.1726	83.3	39.8
7	0.1754	0.1889	0.1483	84.6	34.2
8	0.1478	0.1630	0.1398	94.6	32.3
9	0.1393	0.1512	0.1002	71.9	23.1
10	0.1035	0.1141	0.0849	82.0	19.6
11	0.0879	0.0957	0.0686	78.0	15.8
12	0.0712	0.0825	0.0749	105.2	17.3
13	0.0707	0.0766	0.0695	98.3	16.0
14	0.0668	0.0724	0.0581	87.0	13.4
15	0.0585	0.0658	0.0530	90.6	12.2
16	0.0521	0.0556	0.0515	98.9	11.9
17	0.0531	0.0570	0.0442	83.2	10.2
18	0.0480	0.0519	0.0367	76.5	8.5
19	–	–	–	–	–
20	0.4244	0.5272	0.3170	60.1	73.1

TABLE 4E. CYCLE DATA FOR CELL 35B
0.2922 Ah THEO CAPACITY, Cd SCREEN
151 mA CHARGE RATE, 50°C
150 mA DISCHARGE RATE, 50°C

Cycle	A.H. Input 1.6V Cutoff	Total A.H. Input	A.H. Out	E_{io} Input 1.6V Cutoff	E_F
3	0.3575	0.4183	0.2531	70.8	86.6
4	0.2110	0.2242	0.2074	98.3	71.0
5	0.1963	0.2066	Lost	–	–
6	0.1802	0.1965	0.1709	94.8	58.5
7	0.1700	0.1773	0.2127	125.1	72.8
8	0.1612	0.1678	0.1870	116.0	64.0
9	0.1509	0.1547	0.1434	95.0	49.1
10	0.1465	0.1516	0.1391	95.0	47.6
11	0.1363	0.1477	0.1340	98.3	45.9
12	0.1319	0.1319	0.1289	97.7	44.1
13	0.1194	0.1216	0.1216	101.8	41.6
14	0.1216	0.1275	0.1184	97.4	40.5
15	0.1201	0.1297	0.1309	109.0	44.8
16	0.1084	0.1084	0.1065	98.3	36.5
17	0.1026	0.1106	Lost	–	–
18	Lost	Lost	Lost	–	–
19	–	–	–	–	–
20	0.3165	0.4146	0.2633	83.2	90.1

TABLE 5E. CYCLE DATA FOR CELL 29
0.3702 Ah THEO CAPACITY, Cd SCREEN
151 mA CHARGE RATE, 50°C
150 mA DISCHARGE RATE, 50°C

Cycle	E_F	A.H. Input 1.6V Cutoff	Total A.H. Input	A.H. Out	E_{io} Input 1.6V Cutoff	E_F
3	150.4	0.4845	0.5553	0.5054	104.3	136.5
4	129.5	0.4699	0.5028	0.4826	102.7	130.4
5	124.2	0.4650	0.4967	0.4733	101.8	127.9
6	118.3	0.4528	0.4845	0.4597	101.5	124.2
7	113.6	0.4345	0.4650	0.4437	102.1	119.9
8	106.4	0.4271	0.4613	0.4257	99.7	115.0
9	102.8	0.4223	0.4601	0.4152	98.3	112.2
10	100.4	0.4149	0.4406	0.4118	99.3	111.2
11	95.4	0.3979	0.4296	0.3987	100.2	107.7
12	93.9	0.3954	0.4308	0.3848	97.3	103.9
13	90.8	0.3673	0.4015	0.3673	100.0	99.2
14	86.7	0.3649	0.3942	0.3552	97.3	96.0
15	87.8	0.3527	0.3808	0.3600	102.1	97.2
16	91.3	0.3283	0.3564	0.3306	100.7	89.3
17	86.2	0.2929	0.3295	0.2776	94.8	75.0
18	82.6	0.2563	0.2844	0.2691	105.0	72.7
19	–	–	–	–	–	–
20	96.1	0.3612	0.5309	0.3661	101.4	98.9

TABLE 6E. CYCLE DATA FOR CELL 40
0.2609 Ah THEO CAPACITY, Cd SCREEN
151 mA CHARGE RATE, 50°C
150 mA DISCHARGE RATE, 50°C

Cycle	A.H. Input 1.6V Cutoff	Total A.H. Input	A.H. Out	E_{io} Input 1.6V Cutoff	E_F
3	0.3820	0.4430	0.3924	102.7	150.4
4	0.3307	0.3673	0.3379	102.2	129.5
5	0.3246	0.3564	0.3241	99.9	124.2
6	0.3136	0.3344	0.3085	98.4	118.3
7	0.2905	0.3136	0.2964	102.0	113.6
8	0.2856	0.3051	0.2776	97.2	106.4
9	0.2831	0.3063	0.2682	94.7	102.8
10	0.2636	0.2770	0.2618	99.3	100.4
11	0.2514	0.2704	0.2489	99.0	95.4
12	0.2538	0.2709	0.2451	96.6	93.9
13	0.2441	0.2612	0.2370	97.1	90.8
14	0.2319	0.2526	0.2263	97.6	86.7
15	0.2294	0.2526	0.2290	99.8	87.8
16	0.2124	0.2319	0.2383	112.2	91.3
17	0.2172	0.2380	0.2249	103.6	86.2
18	0.2063	0.2270	0.2159	104.7	82.6
19	—	—	—	—	—
20	0.2477	0.3966	0.2506	101.2	96.1

TABLE 7E. CYCLE DATA FOR CELL 47
0.6184 Ah THEO CAPACITY, Cd SCREEN
151 mA CHARGE RATE, 50°C
150 mA DISCHARGE RATE, 50°C

Cycle	A.H. Input 1.6V Cutoff	Total A.H. Input	A.H. Out	E_{io} Input 1.6V Cutoff	E_F
3	0.7326	0.8769	0.6413	87.5	103.7
4	0.5773	0.6051	0.5480	94.9	88.6
5	0.5231	0.5458	Lost	–	–
6	0.4461	0.4718	0.4271	95.7	69.1
7	0.4190	0.4373	0.4497	106.1	71.9
8	0.3846	0.3963	0.3948	102.7	63.8
9	0.3560	0.3700	0.3382	95.0	54.7
10	0.3311	0.3450	0.3219	97.2	52.1
11	0.3187	0.3253	0.3243	101.8	52.4
12	0.3018	0.3179	0.2959	98.1	47.9
13	0.2879	0.2960	0.2835	98.5	45.8
14	0.2842	0.2945	0.2723	95.8	44.0
15	0.2711	0.2798	0.2660	98.1	43.0
16	0.2418	0.2505	0.2409	99.6	39.0
17	0.2344	0.2462	Lost	–	–
18	Lost	Lost	Lost	–	–
19	–	–	–	–	–
20	0.6769	0.7743	0.5558	82.1	89.9

TABLE 8E. CYCLE DATA FOR CELL 28
0.4412 Ah THEO CAPACITY, Cd SCREEN
151 mA CHARGE RATE, 50°C
150 mA DISCHARGE RATE, 50°C

Cycle	A.H. Input 1.6V Cutoff	Total A.H. Input	A.H. Out	E_{io} Input 1.6V Cutoff	E_F
3	0.5047	0.6102	0.9330	85.8	98.1
4	0.3729	0.3912	0.3545	95.1	80.4
5	0.3377	0.3538	Lost	–	–
6	0.3018	0.3165	0.2813	93.2	63.8
7	0.2733	0.2930	0.3148	115.2	71.4
8	0.2564	0.2711	0.2810	109.6	63.7
9	0.2418	0.2564	0.2331	96.4	52.8
10	0.2322	0.2440	0.2239	96.4	50.8
11	0.2220	0.2300	0.2164	97.5	49.1
12	0.2095	0.2220	0.2081	99.3	47.2
13	0.2015	0.2022	0.1972	97.9	44.7
14	0.2000	0.2066	0.1938	96.9	43.9
15	0.2000	0.2073	0.1979	99.0	44.9
16	0.1744	0.1846	0.1746	100.1	39.6
17	0.1729	0.1729	Lost	–	–
18	Lost	Lost	Lost	–	–
19	–	–	–	–	–
20	0.4667	0.5839	0.3856	82.6	87.4

TABLE 9E. CYCLE DATA FOR CELL 49
0.6113 Ah THEO CAPACITY, Cd SCREEN
151 mA CHARGE RATE, 50°C
150 mA DISCHARGE RATE, 50°C

Cycle	A.H. Input 1.6V Cutoff	Total A.H. Input	A.H. Out	E_{io} Input 1.6V Cutoff	E_F
3	0.6834	0.7603	0.6270	91.8	102.6
4	0.5809	0.6200	0.5626	96.9	92.0
5	0.5419	0.5809	0.5266	97.2	86.1
6	0.5004	0.5455	0.4904	98.0	80.2
7	0.4625	0.4955	0.4588	99.2	75.1
8	0.4394	0.4796	0.4279	97.4	70.0
9	0.4223	0.4601	0.4060	96.1	66.4
10	0.3954	0.4284	0.3902	98.7	63.8
11	0.3698	0.4064	0.3707	100.2	60.6
12	0.3698	0.3991	0.3579	96.8	58.6
13	0.3429	0.3796	0.3457	100.8	56.6
14	0.3344	0.3649	0.3255	97.3	53.3
15	0.3210	0.3503	0.3311	103.1	54.2
16	0.3039	0.3332	0.3092	101.7	50.6
17	0.2795	0.3185	0.2652	94.9	43.4
18	0.2477	0.2722	0.2633	106.3	43.1
19	—	—	—	—	—
20	0.4821	0.6566	0.4887	101.4	80.0

APPENDIX F

GASSING DATA FOR CADMIUM ELECTRODES WITH SILVER GRIDS, CYCLE 3, 0°C

TABLE 1F. GASSING DATA ON CELL 1A, CYCLE 3
0.2656 Ah THEO CAPACITY, 151 mA CHARGE RATE, 0°C
P/N = 3.199:1, Ag SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	24.390	N	N	–	–	–	–	–	–	0.531
1.0	0.95	26.087	N	N	–	–	–	–	–	–	1.448
6.0	5.69	26.087	N	N	–	–	–	–	–	–	1.429
11.0	10.42	25.641	N	N	–	–	–	–	–	–	1.427
21.0	19.90	25.424	N	N	–	–	–	–	–	–	1.429
26.1	24.73	25.424	N	N	–	–	–	–	–	–	1.431
31.0	29.37	25.424	N	N	–	–	–	–	–	–	1.433
36.0	34.11	25.862	N	N	–	–	–	–	–	–	1.436
41.0	38.85	25.862	N	N	–	–	–	–	–	–	1.439
46.0	43.59	25.862	N	N	–	–	–	–	–	–	1.442
51.0	48.32	25.862	N	N	–	–	–	–	–	–	1.445
56.0	53.06	25.862	N	N	–	–	–	–	–	–	1.449
61.0	57.80	25.862	N	N	–	–	–	–	–	–	1.452
66.0	62.54	25.862	N	N	–	–	–	–	–	–	1.457
71.0	67.28	25.862	N	N	–	–	–	–	–	–	1.463
76.0	72.01	25.862	N	N	–	–	–	–	–	–	1.469
81.0	76.75	25.641	N	N	–	–	–	–	–	–	1.479
86.0	81.49	25.641	N	N	–	–	–	–	–	–	1.491
91.0	86.23	25.641	N	N	–	–	–	–	–	–	1.511
96.0	90.96	25.641	N	N	–	–	–	–	–	–	1.546
101.0	95.70	25.641	N	N	–	–	–	–	–	–	1.611
106.0	100.44	25.641	0.37	N	0.0046	–	0.0011	–	0.728	–	1.713
111.0	105.18	25.641	0.39	0.13	0.0048	0.0002	0.0012	N.C.	0.795	–	1.799
116.0	109.91	25.862	1.40	13.33	0.0176	0.0197	0.0043	0.0024	2.848	1.589	1.927
121.0	114.65	26.087	1.03	137.60	0.0129	0.2052	0.0032	0.0253	2.119	16.755	1.952
126.0	119.39	26.316	2.22	313.50	0.0280	0.4717	0.0069	0.0582	4.570	38.543	1.965

TABLE 2F. GASSING DATA ON CELL 11A, CYCLE 3
0.5399 Ah THEO CAPACITY, 151 mA CHARGE RATE, 0°C
P/N = 2.298:1, Ag SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	27.523	N	N	–	–	–	–	–	–	0.601
1.0	0.47	26.316	N	N	–	–	–	–	–	–	1.430
6.0	2.80	26.087	N	N	–	–	–	–	–	–	1.415
11.0	5.13	26.087	N	N	–	–	–	–	–	–	1.412
20.0	9.32	25.862	N	N	–	–	–	–	–	–	1.413
50.0	23.31	25.210	N	N	–	–	–	–	–	–	1.425
55.0	25.64	27.778	N	N	–	–	–	–	–	–	1.427
60.0	27.97	27.778	N	N	–	–	–	–	–	–	1.430
90.0	41.95	26.316	N	N	–	–	–	–	–	–	1.447
95.0	44.28	25.862	N	N	–	–	–	–	–	–	1.451
100.0	46.61	26.087	N	N	–	–	–	–	–	–	1.456
105.0	48.94	25.862	N	N	–	–	–	–	–	–	1.461
110.0	51.27	25.641	N	N	–	–	–	–	–	–	1.468
115.0	53.61	25.000	N	N	–	–	–	–	–	–	1.476
120.0	55.94	25.424	N	N	–	–	–	–	–	–	1.486
125.0	58.27	25.424	N	N	–	–	–	–	–	–	1.500
130.0	60.60	25.641	N	N	–	–	–	–	–	–	1.519
135.0	62.93	25.641	N	N	–	–	–	–	–	–	1.547
140.0	65.26	25.424	N	N	–	–	–	–	–	–	1.583
145.0	67.59	25.424	N	N	–	–	–	–	–	–	1.624
150.0	69.92	25.424	N	N	–	–	–	–	–	–	1.656
155.0	72.25	25.424	0.24	N	0.0029	–	0.0007	–	0.464	–	1.678
160.0	74.58	25.424	0.22	N	0.0027	–	0.0007	–	0.464	–	1.698
165.0	76.91	25.424	0.17	N	0.0021	–	0.0005	–	0.331	–	1.735
170.0	79.24	25.424	0.82	0.26	0.0100	0.0004	0.0025	0.0001	1.656	0.066	1.805
175.0	81.57	25.862	0.35	30.60	0.0044	0.0453	0.0011	0.0056	0.728	3.709	1.897
180.0	83.90	25.862	1.31	243.00	0.0163	0.3599	0.0040	0.0445	2.649	29.470	1.915
185.0	86.24	25.862	1.33	321.49	0.0165	0.4762	0.0041	0.0588	2.715	38.940	1.921
190.0	88.57	26.087	1.67	350.00	0.0209	0.5229	0.0052	0.0646	3.444	42.782	1.925

TABLE 3F. GASSING DATA ON CELL 57A, CYCLE 3
0.7006 Ah THEO CAPACITY, 151 mA CHARGE RATE, 0°C
P/N = 1.723:1, Ag SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	26.549	N	N	–	–	–	–	–	–	1.181
1.0	0.36	26.549	N	N	–	–	–	–	–	–	1.434
6.0	2.16	26.316	N	N	–	–	–	–	–	–	1.412
11.0	3.95	26.087	N	N	–	–	–	–	–	–	1.409
20.0	7.18	25.424	N	N	–	–	–	–	–	–	1.409
50.0	17.96	25.210	N	N	–	–	–	–	–	–	1.417
55.0	19.76	25.641	N	N	–	–	–	–	–	–	1.418
60.0	21.55	25.641	N	N	–	–	–	–	–	–	1.420
90.0	32.33	25.424	N	N	–	–	–	–	–	–	1.429
95.0	34.13	25.210	N	N	–	–	–	–	–	–	1.431
100.0	35.92	25.424	N	N	–	–	–	–	–	–	1.433
130.0	46.70	26.087	N	N	–	–	–	–	–	–	1.447
135.0	48.49	26.087	N	N	–	–	–	–	–	–	1.450
140.0	50.29	26.087	N	N	–	–	–	–	–	–	1.453
170.0	61.07	25.862	N	N	–	–	–	–	–	–	1.483
175.0	62.86	25.862	N	N	–	–	–	–	–	–	1.492
180.0	64.66	26.087	N	N	–	–	–	–	–	–	1.506
185.0	66.45	25.862	N	N	–	–	–	–	–	–	1.537
190.0	68.25	25.862	0.06	N	0.0007	–	0.0002	–	0.132	–	1.606
195.0	70.05	25.862	1.01	0.39	0.0126	0.0006	0.0031	0.0001	2.053	0.066	1.694
200.0	71.84	25.862	2.21	0.30	0.0275	0.0004	0.0068	0.0001	4.503	0.066	1.761
205.0	73.64	25.862	1.56	2.81	0.0194	0.0042	0.0048	0.0005	3.179	0.331	1.904
210.0	75.44	25.862	1.07	99.80	0.0133	0.1480	0.0033	0.0183	2.185	12.119	1.934
215.0	77.23	25.862	1.28	153.50	0.0159	0.2276	0.0039	0.0282	2.582	18.676	1.949
220.0	79.03	26.087	1.51	194.50	0.0190	0.2910	0.0047	0.0360	3.113	23.841	1.960
230.0	82.62	26.087	L.H.T.	262.00	–	0.3919	–	0.0485	–	32.119	1.979

TABLE 4F. GASSING DATA ON CELL 10B, CYCLE 3
0.2638 Ah THEO CAPACITY, 452 mA CHARGE RATE, 0°C
P/N = 3.242:1, Ag SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	24.590	N	N	–	–	–	–	–	–	1.181
1.0	2.86	26.549	N	N	–	–	–	–	–	–	1.488
6.0	17.13	26.316	N	N	–	–	–	–	–	–	1.471
11.0	31.41	26.087	N	N	–	–	–	–	–	–	1.477
16.0	45.69	26.087	N	N	–	–	–	–	–	–	1.485
21.0	59.97	25.862	N	N	–	–	–	–	–	–	1.498
26.0	74.25	25.641	N	N	–	–	–	–	–	–	1.524
31.0	88.53	25.862	N	N	–	–	–	–	–	–	1.768
36.0	102.81	25.862	L.H.T.	100.40	–	0.1488	–	0.0184	–	4.071	2.012
41.0	117.08	26.549	L.H.T.	1373.72	–	2.0904	–	0.2585	–	57.190	2.060

TABLE 5F. GASSING DATA ON CELL 11B, CYCLE 3
0.5389 Ah THEO CAPACITY, 452 mA CHARGE RATE, 0°C
P/N = 2.278:1, Ag SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	25.641	N	N	–	–	–	–	–	–	1.152
1.0	1.40	25.641	N	N	–	–	–	–	–	–	1.556
6.0	8.39	25.641	N	N	–	–	–	–	–	–	1.547
11.0	15.38	25.424	N	N	–	–	–	–	–	–	1.554
16.0	22.37	25.641	N	N	–	–	–	–	–	–	1.563
21.0	29.36	25.210	N	N	–	–	–	–	–	–	1.574
26.0	36.35	25.641	N	N	–	–	–	–	–	–	1.589
31.0	43.34	25.641	N	N	–	–	–	–	–	–	1.614
36.0	50.32	25.641	0.36	0.21	0.0045	0.0003	0.0011	N.C.	0.243	–	1.665
41.0	57.00	25.641	1.60	0.53	0.0199	0.0008	0.0049	0.0001	1.084	0.022	1.751
46.0	64.30	25.641	4.69	2.33	0.0582	0.0034	0.0145	0.0004	3.208	0.089	1.839
51.0	71.29	25.424	5.41	2.58	0.0666	0.0038	0.0166	0.0005	3.673	0.111	2.003
56.0	78.28	25.641	11.32	362.00	0.1405	0.5353	0.0350	0.0666	7.743	14.735	2.092
61.0	85.27	26.087	12.00	857.00	0.1515	1.2892	0.0377	0.1604	8.341	35.487	2.130
66.0	92.26	26.549	18.35	1134.00	0.2358	1.7361	0.0587	0.2160	12.987	47.788	2.152

TABLE 6F. GASSING DATA ON CELL 1C, CYCLE 3
0.2676 Ah THEO CAPACITY, 753 mA CHARGE RATE, 0°C
P/N = 3.360:1, Ag SCREEN

Chg Time (min)	% Theo$_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	28.846	N	N	–	–	–	–	–	–	1.195
1.0	4.69	27.273	N	N	–	–	–	–	–	–	1.547
6.0	28.14	28.571	N	N	–	–	–	–	–	–	1.549
11.0	51.59	28.037	N	N	–	–	–	–	–	–	1.616
16.0	75.04	26.549	N	0.29	–	0.0004	–	0.0001	–	0.013	2.004
21.0	98.49	27.778	2.40	628.00	0.0326	1.0151	0.0082	0.1275	1.089	16.932	2.116
26.0	121.94	28.846	8.11	1498.70	0.1143	2.5157	0.0287	0.3159	3.811	41.952	2.154

TABLE 7F. GASSING DATA ON CELL 11C, CYCLE 3
0.5349 Ah THEO CAPACITY, 753 mA CHARGE RATE, 0°C
P/N = 2.247:1, Ag SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	25.210	N	N	N	N	N	N	N	N	1.187
1.0	2.35	25.210	N	N	–	–	–	–	–	–	1.520
6.0	14.08	25.000	N	N	–	–	–	–	–	–	1.515
11.0	25.81	26.316	N	N	–	–	–	–	–	–	1.530
16.0	37.54	30.000	N	N	–	–	–	–	–	–	1.555
21.0	49.27	21.277	N	N	–	–	–	–	–	–	1.678
26.0	61.00	28.571	1.13	0.14	0.0158	0.0002	0.0040	N.C.	0.531	–	1.923
31.0	72.73	29.126	6.70	470.00	0.0954	0.7971	0.0240	0.1001	3.187	13.294	2.055
36.0	84.46	29.412	11.60	1312.00	0.1667	2.2471	0.0419	0.2823	5.564	37.490	2.097

TABLE 8F. GASSING DATA ON CELL 57C, CYCLE 3
0.7006 Ah THEO CAPACITY, 753 mA CHARGE RATE, 0°C
P/N = 1.675:1, Ag SCREEN

Chg Time (min)	% Theo$_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	26.549	N	N	–	–	–	–	–	–	1.192
1.0	1.79	26.549	N	N	–	–	–	–	–	–	1.554
6.0	10.75	26.316	N	N	–	–	–	–	–	–	1.546
11.0	19.70	26.316	N	N	–	–	–	–	–	–	1.555
16.0	28.66	26.316	N	N	–	–	–	–	–	–	1.566
21.0	37.62	26.087	N	N	–	–	–	–	–	–	1.581
26.0	46.57	26.087	N	N	–	–	–	–	–	–	1.606
31.0	55.53	25.862	N	N	–	–	–	–	–	–	1.659
36.0	64.49	25.862	1.33	2.10	0.0169	0.0032	0.0043	0.0004	0.571	0.053	1.783
41.0	73.44	26.087	28.70	9.94	0.3677	0.0152	0.0929	0.0019	12.337	0.252	1.872
46.0	82.40	26.316	38.35	3.75	0.4957	0.0058	0.1252	0.0007	16.627	0.093	2.027
56.0	100.31	27.778	73.10	733.00	0.9973	1.1916	0.2519	0.1505	33.453	19.987	2.173

APPENDIX G

GASSING DATA FOR CADMIUM ELECTRODES WITH SILVER GRIDS, CYCLE 3, 50°C

TABLE 1G. GASSING DATA ON CELL 2A, CYCLE 3
0.3369 Ah THEO CAPACITY, 151 mA CHARGE RATE, 50°C
P/N = 3.820:1.00, Ag SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	25.000	N	N	–	–	–	–	–	–	0.195
1.0	0.75	25.000	N	N	–	–	–	–	–	–	1.108
6.0	4.48	25.000	N	N	–	–	–	–	–	–	1.340
11.0	8.22	25.000	N	N	–	–	–	–	–	–	1.366
16.0	11.95	24.793	N	N	–	–	–	–	–	–	1.372
21.0	15.69	25.000	N	N	–	–	–	–	–	–	1.373
26.0	19.42	25.000	N	N	–	–	–	–	–	–	1.372
31.0	23.16	25.000	N	N	–	–	–	–	–	–	1.371
36.0	26.89	24.793	N	N	–	–	–	–	–	–	1.370
41.0	30.63	24.793	N	N	–	–	–	–	–	–	1.370
46.0	34.36	25.000	N	N	–	–	–	–	–	–	1.370
51.0	38.10	25.000	N	N	–	–	–	–	–	–	1.371
56.0	41.83	24.793	N	N	–	–	–	–	–	–	1.371
61.0	45.57	26.549	N	N	–	–	–	–	–	–	1.371
66.0	49.30	26.316	N	N	–	–	–	–	–	–	1.372
71.0	53.04	25.641	N	N	–	–	–	–	–	–	1.374
76.0	56.77	25.424	N	N	–	–	–	–	–	–	1.376
81.0	60.51	25.424	N	N	–	–	–	–	–	–	1.378
86.0	64.24	25.000	N	N	–	–	–	–	–	–	1.381
91.0	67.98	25.210	N	N	–	–	–	–	–	–	1.385
96.0	71.71	25.210	N	N	–	–	–	–	–	–	1.390
101.0	75.45	24.793	N	N	–	–	–	–	–	–	1.397
106.0	79.18	25.000	N	N	–	–	–	–	–	–	1.408
111.0	82.92	25.000	N	N	–	–	–	–	–	–	1.430
116.0	86.65	25.000	N	N	–	–	–	–	–	–	1.557
121.0	90.39	25.000	N	0.18	–	0.0003	–	N.C.	–	–	1.629
126.0	94.12	24.793	N	76.00	–	0.1089	–	0.0136	–	9.00	1.714
131.0	97.86	25.000	N	393.50	–	0.5683	–	0.0708	–	46.80	1.746
136.0	101.59	25.424	N	512.12	–	0.7522	–	0.0937	–	62.03	1.758
141.0	105.33	25.424	N	602.58	–	0.8850	–	0.1103	–	73.04	1.766

TABLE 2G. GASSING DATA ON CELL 19A, CYCLE 3
0.5430 Ah THEO CAPACITY, 151 mA CHARGE RATE, 50°C
P/N = 2.349:1.0, Ag SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	24.390	N	N	–	–	–	–	–	–	0.580
1.0	0.46	25.210	N	N	–	–	–	–	–	–	1.325
6.0	2.78	25.641	N	N	–	–	–	–	–	–	1.386
11.0	5.10	25.424	N	N	–	–	–	–	–	–	1.380
20.0	9.27	25.424	N	N	–	–	–	–	–	–	1.368
50.0	23.17	26.316	N	N	–	–	–	–	–	–	1.363
55.0	25.49	26.087	N	N	–	–	–	–	–	–	1.363
60.0	27.81	26.087	N	N	–	–	–	–	–	–	1.363
90.0	41.71	25.862	N	N	–	–	–	–	–	–	1.368
95.0	44.03	25.862	N	N	–	–	–	–	–	–	1.368
100.0	46.35	25.862	N	N	–	–	–	–	–	–	1.369
105.0	48.66	25.862	N	N	–	–	–	–	–	–	1.370
110.0	50.98	25.862	N	N	–	–	–	–	–	–	1.371
115.0	53.30	25.862	N	N	–	–	–	–	–	–	1.373
120.0	55.62	25.424	N	N	–	–	–	–	–	–	1.373
125.0	57.93	25.424	N	N	–	–	–	–	–	–	1.375
130.0	60.25	25.424	N	N	–	–	–	–	–	–	1.376
135.0	62.57	25.000	N	N	–	–	–	–	–	–	1.377
140.0	64.89	25.210	N	N	–	–	–	–	–	–	1.379
145.0	67.20	25.000	N	N	–	–	–	–	–	–	1.380
155.0	71.84	28.571	N	N	–	–	–	–	–	–	1.383
160.0	74.16	25.210	N	N	–	–	–	–	–	–	1.385
165.0	76.47	25.210	N	N	–	–	–	–	–	–	1.388
170.0	78.79	25.210	N	N	–	–	–	–	–	–	1.390
175.0	81.11	25.210	N	N	–	–	–	–	–	–	1.393
180.0	83.43	25.000	0.44	N	0.0054	–	0.0013	–	0.861	–	1.396
185.0	85.74	25.000	0.16	N	0.0019	–	0.0005	–	0.331	–	1.400
190.0	88.06	24.590	0.15	N	0.0018	–	0.0005	–	0.331	–	1.404
195.0	90.38	24.590	0.10	N	0.0012	–	0.0003	–	0.199	–	1.409
200.0	92.69	25.210	0.28	0.11	0.0034	0.0002	0.0009	N.C.	0.596	–	1.415
205.0	95.01	25.210	2.13	0.60	0.0262	0.0009	0.0066	0.0001	4.371	0.066	1.424
210.0	97.33	25.000	0.87	0.10	0.0106	0.0001	0.0027	N.C.	1.788	–	1.440
215.0	99.65	25.000	0.38	0.06	0.0046	0.0001	0.0012	N.C.	0.795	–	1.496
220.0	101.96	24.590	3.60	0.50	0.0431	0.0007	0.0108	N.C.	7.152	–	1.563
225.0	104.28	24.390	0.53	0.31	0.0063	0.0004	0.0016	N.C.	1.060	–	1.595
230.0	106.60	24.390	0.83	1.43	0.0099	0.0020	0.0025	0.0003	1.656	0.199	1.617
235.0	108.92	24.390	1.28	14.92	0.0152	0.0211	0.0038	0.0027	2.516	1.788	1.649
240.0	111.23	24.793	8.66	56.40	0.1047	0.0812	0.0262	0.0101	17.351	6.689	1.692
245.0	113.55	25.000	5.18	291.50	0.0631	0.4233	0.0158	0.0527	10.464	34.901	1.712
250.0	115.87	25.000	2.96	205.50	0.0361	0.2984	0.0090	0.0372	5.960	24.636	1.723

TABLE 3G. GASSING DATA ON CELL 56A, CYCLE 3
0.7117 Ah THEO CAPACITY, 151 mA CHARGE RATE, 50°C
P/N = 1.810:1.0, Ag SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i}$ x 100	$\frac{i_{H_2}}{i}$ x 100	E (volts)
0.0	0.00	24.194	N	N	–	–	–	–	–	–	0.519
1.0	0.35	24.194	N	N	–	–	–	–	–	–	1.320
6.0	2.12	24.194	N	N	–	–	–	–	–	–	1.385
11.0	3.89	24.000	N	N	–	–	–	–	–	–	1.373
20.0	7.07	24.000	N	N	–	–	–	–	–	–	1.361
50.0	17.68	23.810	N	N	–	–	–	–	–	–	1.358
55.0	19.45	23.810	N	N	–	–	–	–	–	–	1.358
90.0	31.82	23.438	N	N	–	–	–	–	–	–	1.364
95.0	33.59	24.590	N	N	–	–	–	–	–	–	1.365
100.0	35.36	24.590	N	N	–	–	–	–	–	–	1.366
130.0	45.97	24.390	N	N	–	–	–	–	–	–	1.373
135.0	47.74	25.862	N	N	–	–	–	–	–	–	1.374
140.0	49.51	24.194	N	N	–	–	–	–	–	–	1.375
145.0	51.27	25.000	N	N	–	–	–	–	–	–	1.376
150.0	53.04	25.000	N	N	–	–	–	–	–	–	1.377
155.0	54.81	25.000	N	N	–	–	–	–	–	–	1.379
160.0	56.58	25.000	N	N	–	–	–	–	–	–	1.380
165.0	58.35	25.000	N	N	–	–	–	–	–	–	1.382
170.0	60.11	25.000	N	N	–	–	–	–	–	–	1.384
175.0	61.88	25.000	N	N	–	–	–	–	–	–	1.385
180.0	63.65	25.000	N	N	–	–	–	–	–	–	1.388
185.0	65.42	24.590	0.32	0.13	0.0038	0.0002	0.0010	N.C.	0.662	–	1.390
190.0	67.19	24.590	0.30	0.17	0.0036	0.0002	0.0009	N.C.	0.596	–	1.392
195.0	68.95	24.590	0.42	0.10	0.0050	0.0001	0.0013	N.C.	0.861	–	1.395
200.0	70.72	27.778	1.00	0.05	0.0135	0.0001	0.0034	N.C.	2.252	–	1.397
205.0	72.49	23.077	0.90	0.42	0.0101	0.0006	0.0025	0.0001	1.656	0.066	1.400
210.0	74.26	25.000	0.83	0.08	0.0101	0.0001	0.0025	N.C.	1.656	–	1.405
215.0	76.03	25.000	1.66	0.19	0.0202	0.0003	0.0050	N.C.	3.311	–	1.410
220.0	77.74	25.000	0.87	0.16	0.0106	0.0002	0.0026	N.C.	1.722	–	1.417
225.0	79.56	25.000	2.81	0.57	0.0342	0.0008	0.0085	0.0001	5.629	0.066	1.426
230.0*	81.33	25.000	6.83	2.07	0.0830	0.0030	0.0208	0.0004	13.775	0.265	1.441
235.0*	83.10	24.590	6.42	1.82	0.0769	0.0026	0.0192	0.0003	12.715	0.199	1.460
240.0	84.87	25.000	4.23	0.22	0.0514	0.0003	0.0129	N.C.	8.543	–	1.479
245.0	86.64	25.000	6.17	0.23	0.750	0.0003	0.0187	N.C.	12.384	–	1.505
250.0*	88.40	25.000	4.40	0.72	0.0535	0.0010	0.0134	0.0001	8.874	0.066	1.531
255.0*	90.17	25.000	15.92	0.61	0.1935	0.0009	0.0484	0.0001	32.053	0.066	1.562
250.0*	91.94	25.000	10.70	0.63	0.1301	0.0009	0.0325	0.0001	21.523	0.066	1.601
265.0	93.71	25.000	8.45	0.41	0.1027	0.0006	0.0257	0.0001	17.020	0.066	1.627
280.0	99.01	25.000	7.45	152.60	0.0906	0.2210	0.0226	0.0276	14.967	18.278	1.723
285.0	100.78	25.000	7.00	165.60	0.0851	0.2399	0.0213	0.0300	14.106	19.868	1.737
290.0	102.55	25.000	5.60	278.00	0.0681	0.4027	0.0170	0.0503	11.258	33.311	1.750
295.0	104.32	25.000	8.98	331.00	0.1092	0.4794	0.0273	0.0599	18.079	39.669	1.761

*Third peak noted

TABLE 4G. GASSING DATA ON CELL 2B, CYCLE 3
0.3348 Ah THEO CAPACITY, 452 mA CHARGE RATE, 50°C
P/N = 3.7775:1, Ag SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	26.549	N	N	–	–	–	–	–	–	0.454
1.0	2.25	26.549	N	N	–	–	–	–	–	–	1.384
6.0	13.50	27.273	N	N	–	–	–	–	–	–	1.426
11.0	24.75	26.786	N	N	–	–	–	–	–	–	1.428
16.0	36.00	26.786	N	N	–	–	–	–	–	–	1.427
21.0	47.25	26.786	N	N	–	–	–	–	–	–	1.429
26.0	58.50	26.786	N	N	–	–	–	–	–	–	1.432
31.0	69.75	26.786	N	N	–	–	–	–	–	–	1.435
36.0	81.00	26.786	N	N	–	–	–	–	–	–	1.441
41.0	92.25	27.027	N	N	–	–	–	–	–	–	1.447
46.0	103.50	27.027	N	N	–	–	–	–	–	–	1.454
51.0	114.76	27.273	N	N	–	–	–	–	–	–	1.464
56.0	126.01	27.778	N	N	–	–	–	–	–	–	1.482
61.0	137.26	29.126	N	N	–	–	–	–	–	–	1.527
66.0	148.51	25.424	N	N	–	–	–	–	–	–	1.588
71.0	159.76	25.424	N	0.08	–	0.0001	–	N.C.	–	–	1.660
76.0	171.01	26.316	N	95.60	–	0.1458	–	0.0182	–	4.027	1.768
81.0	182.26	28.037	2.23	932.00	0.0304	1.5140	0.0076	0.1893	1.681	41.881	1.817
86.0	193.51	28.846	7.46	1278.00	0.1046	2.1359	0.0262	0.2670	5.797	59.071	1.834

TABLE 5G. GASSING DATA ON CELL 19B, CYCLE 3
0.5426 Ah THEO CAPACITY, 452 mA CHARGE RATE, 50°C
P/N = 2.327:1.0, Ag SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	27.027	N	N	–	–	–	–	–	–	0.612
1.0	1.39	24.390	N	N	–	–	–	–	–	–	1.430
6.0	8.33	25.000	N	N	–	–	–	–	–	–	1.414
11.0	15.27	24.793	N	N	–	–	–	–	–	–	1.407
16.0	22.21	25.000	N	N	–	–	–	–	–	–	1.407
21.0	29.16	25.210	N	N	–	–	–	–	–	–	1.407
26.0	36.10	25.000	N	N	–	–	–	–	–	–	1.410
31.0	43.04	26.316	N	N	–	–	–	–	–	–	1.413
36.0	49.98	25.210	N	N	–	–	–	–	–	–	1.419
41.0	56.92	25.000	N	N	–	–	–	–	–	–	1.427
46.0	63.87	25.862	N	N	–	–	–	–	–	–	1.441
51.0	70.81	25.862	N	N	–	–	–	–	–	–	1.473
56.0	77.75	25.641	N	N	–	–	–	–	–	–	1.649
61.0	84.69	25.862	N	68.20	–	0.1023	–	0.0128	–	2.832	1.779
66.0	91.63	26.786	N	951.86	–	1.4795	–	0.1852	–	40.974	1.827
71.0	98.57	27.523	N	1402.34	–	2.2396	–	0.2804	–	62.035	1.849

TABLE 6G. GASSING DATA ON CELL 56B, CYCLE 3
0.7158 Ah THEO CAPACITY, 452 mA CHARGE RATE, 50°C
P/N = 1.751:1.00, Ag SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	AA_{O_2}	AA_{H_2}	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i}$ x 100	$\frac{i_{H_2}}{i}$ x 100	E (volts)
0.0	0.00	23.256	N	N	–	–	–	–	–	–	0.548
1.0	1.05	23.810	N	N	–	–	–	–	–	–	1.420
6.0	6.31	25.862	N	N	–	–	–	–	–	–	1.413
11.0	11.58	25.641	N	N	–	–	–	–	–	–	1.403
16.0	16.84	25.424	N	N	–	–	–	–	–	–	1.400
21.0	22.10	25.000	N	N	–	–	–	–	–	–	1.400
26.0	27.36	24.793	N	N	–	–	–	–	–	–	1.400
31.0	32.63	24.590	N	N	–	–	–	–	–	–	1.401
36.0	37.89	25.000	N	N	–	–	–	–	–	–	1.402
41.0	43.15	24.793	N	N	–	–	–	–	–	–	1.404
46.0	48.41	24.793	N	N	–	–	–	–	–	–	1.405
51.0	53.67	25.000	N	N	–	–	–	–	–	–	1.407
56.0	58.94	24.793	N	N	–	–	–	–	–	–	1.410
61.0	64.20	25.000	N	N	–	–	–	–	–	–	1.414
66.0	69.46	24.793	N	N	–	–	–	–	–	–	1.418
71.0	74.72	25.000	N	N	–	–	–	–	–	–	1.423
76.0	79.99	25.000	N	N	–	–	–	–	–	–	1.431
81.0	85.25	24.793	N	N	–	–	–	–	–	–	1.444
86.0	90.51	25.000	N	N	–	–	–	–	–	–	1.471
91.0	95.77	24.793	0.23	0.14	0.0028	0.0002	0.0007	N.C.	0.155	–	1.555
96.0	101.03	24.793	0.57	1.69	0.0069	0.0024	0.0017	0.0003	0.376	0.066	1.623
101.0	106.30	24.793	1.05	1.81	0.0128	0.0026	0.0032	0.0003	0.708	0.066	1.686
106.0*	111.56	25.000	3.27	283.50	0.0401	0.4139	0.0101	0.0521	2.235	11.527	1.774
111.0*	116.82	25.424	7.72	652.00	0.0962	0.9680	0.0242	0.1220	5.354	26.991	1.809
116.0	122.08	25.862	6.12	882.00	0.0776	1.3321	0.0195	0.1678	4.314	37.124	1.836

TABLE 7G. GASSING DATA ON CELL 2C, CYCLE 3
0.3409 Ah THEO CAPACITY, 753 mA CHARGE RATE, 50°C
P/N = 3.643:1.0, Ag SCREEN

Chg Time (min)	% Theo$_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	25.641	N	N	–	–	–	–	–	–	0.428
1.0	3.68	26.549	N	N	–	–	–	–	–	–	1.452
6.0	22.09	27.273	N	N	–	–	–	–	–	–	1.457
11.0	40.50	26.549	N	N	–	–	–	–	–	–	1.455
16.0	58.90	26.549	N	N	–	–	–	–	–	–	1.464
21.0	77.31	26.549	N	N	–	–	–	–	–	–	1.574
26.0	95.72	27.273	1.10	71.90	0.0145	0.1131	0.0036	0.0141	0.478	1.873	1.888
31.0	114.12	30.612	11.03	3625.00	0.1635	6.4010	0.0407	0.7966	5.405	105.790	1.935
36.0	132.53	31.579	18.11	2825.00	0.2769	5.1460	0.0689	0.6404	9.150	85.046	1.954

TABLE 8G. GASSING DATA ON CELL 19C, CYCLE 3
0.5438 Ah THEO CAPACITY, 753 mA CHARGE RATE, 50°C
P/N = 2.330:1.0, Ag SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	28.037	N	N	–	–	–	–	–	–	0.621
1.0	2.31	26.549	N	N	–	–	–	–	–	–	1.483
6.0	13.85	26.549	N	N	–	–	–	–	–	–	1.462
11.0	25.39	26.316	N	N	–	–	–	–	–	–	1.465
16.0	36.93	26.087	N	N	–	–	–	–	–	–	1.470
21.0	48.46	25.862	N	N	–	–	–	–	–	–	1.478
26.0	60.00	26.087	N	N	–	–	–	–	–	–	1.495
31.0	71.54	26.087	0.32	N	0.0040	–	0.0010	–	0.133	–	1.556
36.0	83.08	26.087	17.54	0.54	0.2214	0.0008	0.0551	0.0001	7.317	0.013	1.694
41.0	94.62	26.549	41.65	14.00	0.5351	0.0214	0.1332	0.0027	17.689	0.359	1.848
46.0	106.16	27.273	49.50	865.00	0.6533	1.3604	0.1626	0.1693	21.594	20.483	1.958
56.0	129.24	28.846	50.40	3070.00	0.7036	5.1067	0.1751	0.6353	23.254	84.369	2.025

TABLE 9G. GASSING DATA ON CELL 56C, CYCLE 3
0.7117 Ah THEO CAPACITY, 753 mA CHARGE RATE, 50°C
P/N = 1.796:1.0, Ag SCREEN

Chg Time (min)	% $Theo_F$ Input	Flushing (cc/min)	$AA^*_{O_2}$	$AA^*_{H_2}$	V_{O_2} (cc/min)	V_{H_2} (cc/min)	i_{O_2} (A)	i_{H_2} (A)	$\frac{i_{O_2}}{i} \times 100$	$\frac{i_{H_2}}{i} \times 100$	E (volts)
0.0	0.00	23.438	N	N	–	–	–	–	–	–	0.787
1.0	1.76	23.438	N	N	–	–	–	–	–	–	1.606
6.0	10.58	23.256	N	N	–	–	–	–	–	–	1.605
11.0	19.40	23.077	N	N	–	–	–	–	–	–	1.626
16.0	28.21	23.077	N	N	–	–	–	–	–	–	1.638
21.0	37.03	30.000	0.12	N	0.0018	–	0.0004	–	0.053	–	1.644
26.0	45.85	23.810	0.27	N	0.0031	–	0.0008	–	0.106	–	1.653
31.0	54.66	23.622	0.31	N	0.0036	–	0.0009	–	0.120	–	1.657
36.0	63.48	23.256	0.40	N	0.0045	–	0.0011	–	0.146	–	1.669
41.0	72.30	23.077	0.62	N	0.0070	–	0.0017	–	0.226	–	1.712
46.0	81.12	22.901	1.57	0.09	0.0175	0.0001	0.0044	N.C.	0.584	–	1.887
51.0*	89.93	23.256	2.64	84.60	0.0299	0.1140	0.0075	0.0143	0.996	1.899	2.064
56.0	98.75	24.390	10.40	1224.00	0.1233	1.7297	0.0308	0.2162	4.090	28.712	2.134
61.0	107.57	25.641	L.H.T.	2610.00	–	3.8775	–	0.4847	–	–	2.160

*Additional Peak Noted

APPENDIX H
GASSING DATA FOR NICKEL ELECTRODES

TABLE 1H. GASSING DATA FOR ELECTRODE C-36

0.637 Ah Theo Capacity, 741 mA Charge Rate, 50°C

Cycle 3

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
34.90	0.078	0.020	2.70	36.09
58.16	0.292	0.075	10.12	60.14
63.98	0.412	0.106	14.31	66.16
75.61	0.651	0.167	22.54	78.19
87.24	1.334	0.342	46.15	90.21
106.63	2.125	0.545	73.55	110.27
116.33	2.312	0.593	80.03	120.03
135.71	2.499	0.641	86.51	140.34
155.10	2.582	0.662	89.34	160.39

Cycle 20

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
11.63	0	0	0	10.86
23.27	0	0	0	21.74
34.90	0.009	0.002	0.27	32.60
46.53	0.077	0.019	2.56	43.46
58.16	0.169	0.043	5.80	54.32
69.80	0.354	0.089	12.01	65.19
81.43	0.591	0.149	20.11	76.06
96.94	1.053	0.266	35.90	90.54
116.33	1.397	0.352	47.50	108.65
135.71	1.957	0.494	66.67	126.76
145.41	2.102	0.530	71.53	135.82
155.10	2.231	0.563	75.98	144.87
174.49	2.386	0.602	81.24	162.98

TABLE 2H. GASSING DATA FOR ELECTRODE B-22

0.440 Ah Theo Capacity, 741 mA Charge Rate, 50°C

Cycle 3

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
33.68	0.050	0.013	1.75	32.64
67.36	0.334	0.086	11.61	65.28
75.78	0.479	0.123	16.60	73.44
101.05	1.391	0.357	48.18	97.93
117.89	2.002	0.513	69.23	114.26
140.34	2.503	0.642	86.64	186.01
182.44	2.682	0.688	92.85	176.81

Cycle 20

Cell Shorted

TABLE 3H. GASSING DATA FOR ELECTRODE A-35

0.161 Ah Theo Capacity, 741 mA Charge Rate, 50°C

Cycle 3

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
23.01	0	0	0	24.86
46.02	0.082	0.021	2.83	49.73
69.04	0.270	0.069	9.31	74.60
115.06	1.466	0.376	50.74	124.33
161.09	2.215	0.568	76.65	174.06

Cycle 20

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
23.01	0	0	0	14.19
46.02	0	0	0	28.39
69.04	0	0	0	42.59
92.05	0.007	0.002	0.27	56.78
115.06	0.068	0.017	2.29	70.98
138.07	0.325	0.082	11.07	85.17
161.09	0.660	0.166	22.40	99.37
184.10	1.219	0.307	41.43	113.56
207.11	1.697	0.428	57.76	127.76
230.12	1.955	0.493	66.53	141.95
253.14	2.214	0.559	75.44	156.15

TABLE 4H. GASSING DATA FOR ELECTRODE C-35

0.634 Ah Theo Capacity, 414 mA Charge Rate, 50°C

Cycle 3

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
27.71	0	0	0	30.16
43.53	0	0	0	48.25
54.42	0.021	0.005	1.21	60.32
65.30	0.038	0.010	2.42	72.38
76.18	0.083	0.021	5.07	84.44
92.51	0.186	0.048	11.59	102.54
103.39	0.445	0.114	27.54	114.60
114.27	0.860	0.221	53.38	126.66
119.72	0.831	0.214	51.69	132.70
141.48	1.084	0.278	67.15	156.82
152.37	1.121	0.288	69.57	168.89

Cycle 20

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
10.88	0	0	0	12.92
21.77	0	0	0	25.85
32.65	0	0	0	38.76
43.53	0.020	0.005	1.21	51.68
54.42	0.042	0.011	2.66	64.61
65.30	0.088	0.022	5.31	77.53
76.18	0.163	0.041	9.90	90.45
87.07	0.293	0.074	17.87	103.38
97.95	0.501	0.126	30.44	116.29
108.83	0.787	0.199	48.07	129.21
119.72	0.989	0.250	60.39	142.14
130.66	1.157	0.292	70.53	155.06
141.48	1.299	0.328	79.23	167.97
152.37	1.330	0.336	81.16	180.90
163.25	1.353	0.341	82.37	193.82

TABLE 5H. GASSING DATA FOR ELECTRODE B-19

0.443 Ah Theo Capacity, 414 mA Charge Rate, 50°C

Cycle 3

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	i_{O_2}/i x 100	% Returned, Q
23.36	0	0	0	24.47
46.73	0	0	0	48.94
70.09	0	0	0	73.40
85.67	0.033	0.008	1.93	89.72
101.24	0.204	0.053	12.80	106.03
140.18	1.069	0.275	66.43	146.81
155.76	1.161	0.298	71.98	163.13
186.91	1.099	0.282	68.12	195.75

Cycle 20

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	i_{O_2}/i x 100	% Returned, Q
3.12	0	0	0	3.57
7.79	0	0	0	8.92
23.36	0	0	0	26.74
38.94	0	0	0	44.58
54.51	0.022	0.006	1.45	62.40
70.09	0.056	0.014	3.38	80.23
85.67	0.137	0.034	8.21	98.07
1.24	0.799	0.202	48.79	115.89
16.82	1.244	0.314	75.85	133.72
32.39	1.306	0.330	79.71	151.55
47.97	1.448	0.365	88.16	169.38
63.54	1.378	0.348	84.06	187.21
79.12	1.502	0.379	91.55	205.04
94.70	1.512	0.382	92.77	222.87

TABLE 6H. GASSING DATA FOR ELECTRODE A-8

0.176 Ah Theo Capacity, 414 mA Charge Rate, 50°C

Cycle 3

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
7.84	0	0	0	6.54
19.60	0.008	0.002	0.48	16.35
39.20	0.008	0.002	0.48	32.70
137.22	1.001	0.256	61.84	114.46
294.03	1.007	0.259	62.56	245.26
450.85	1.498	0.385	93.00	376.07

Cycle 20

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
7.84	0	0	0	4.52
19.60	0	0	0	11.31
39.20	0	0	0	22.62
58.81	0	0	0	33.94
78.41	0	0	0	45.25
98.01	0.026	0.007	1.69	56.56
117.61	0.140	0.035	8.45	67.87
137.22	0.173	0.044	10.63	79.18
156.82	0.296	0.075	18.12	90.49
176.42	0.467	0.118	28.50	101.80
196.02	0.752	0.190	45.89	113.11
215.63	0.857	0.216	52.17	124.43
254.83	1.013	0.256	61.84	147.05

TABLE 7H. GASSING DATA FOR ELECTRODE C-14

0.645 Ah Theo Capacity, 247 mA Charge Rate, 50°C

Cycle 3

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
19.15	0	0	0	33.66
28.72	0.020	0.005	2.02	50.48
38.29	0.085	0.022	8.91	67.29
47.87	0.171	0.044	17.81	84.13
51.06	0.195	0.050	20.24	89.74
57.44	0.255	0.065	26.32	100.95
63.82	0.327	0.084	34.01	112.16
70.21	0.392	0.100	40.49	123.39
76.59	0.472	0.121	48.99	134.61
82.97	0.532	0.136	55.06	145.82
95.74	0.641	0.164	66.40	168.26
108.50	0.707	0.181	73.28	190.69
114.88	0.720	0.185	74.90	201.90
121.27	0.806	0.206	83.40	213.30

Cycle 20

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
19.15	0	0	0	32.94
31.91	0.025	0.006	2.43	54.89
38.29	0.053	0.014	5.67	65.86
51.06	0.147	0.037	14.98	87.87
57.44	0.182	0.046	18.62	98.80
63.82	0.192	0.049	19.84	109.77
70.21	0.239	0.060	24.29	120.76
76.59	0.259	0.066	26.72	131.74
82.97	0.304	0.077	31.17	142.71
95.74	0.369	0.093	37.65	164.67
108.50	0.441	0.112	45.34	186.62
114.88	0.502	0.127	51.42	197.59
121.27	0.528	0.134	54.26	208.58

TABLE 8H. GASSING DATA FOR ELECTRODE Bi14

0.434 Ah Theo Capacity, 247 mA Charge Rate, 50°C

Cycle 3

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
9.49	0	0	0	20.91
18.97	0	0	0	41.79
37.98	0.012	0.003	1.22	83.58
52.17	0.055	0.014	5.67	114.93
61.66	0.108	0.028	11.34	135.84
80.63	0.209	0.054	21.86	177.63
90.11	0.333	0.085	34.41	198.52
99.60	0.482	0.123	49.80	219.42
109.08	0.792	0.203	82.19	240.31
118.57	0.639	0.164	66.40	261.22
132.80	0.711	0.182	73.68	292.56
151.77	0.893	0.229	92.71	334.36

Cycle 20

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
9.49	0	0	0	11.77
18.97	0	0	0	23.52
37.94	0	0	0	47.05
61.66	0.161	0.041	16.60	76.46
71.14	0.243	0.061	24.70	88.21
80.63	0.167	0.042	17.00	99.98
90.11	0.306	0.078	31.58	111.74
99.60	0.431	0.109	44.13	123.50
109.08	0.691	0.175	70.85	135.26
118.57	0.773	0.196	79.35	147.03
132.80	0.887	0.225	91.09	164.67
151.77	0.961	0.243	98.38	188.20

TABLE 9H. GASSING DATA FOR ELECTRODE A-4

0.165 Ah Theo Capacity, 247 mA Charge Rate, 50°C

Cycle 3

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	i_{O_2}/i x 100	% Returned, Q
4.99	0	0	0	4.71
12.47	0	0	0	11.76
37.42	0.017	0.004	1.62	35.28
62.37	0.107	0.027	10.93	58.81
87.32	0.339	0.087	35.22	82.33
124.75	0.666	0.171	69.23	117.62
174.65	0.586	0.150	60.73	164.67
336.82	0.830	0.213	86.24	317.57

Cycle 20

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	i_{O_2}/i x 100	% Returned, Q
4.99	0	0	0	3.47
12.47	0	0	0	8.68
37.42	0	0	0	26.05
62.37	0	0	0	43.42
87.32	0.069	0.018	7.29	60.79
112.27	0.123	0.031	12.55	78.16
137.22	0.103	0.026	10.53	95.53
174.65	0.372	0.094	38.06	121.59
361.77	0.906	0.230	93.12	251.87

TABLE 10H. GASSING DATA FOR ELECTRODE C-32

0.668 Ah Theo Capacity, 741 mA Charge Rate, 0°C

Cycle 3

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
33.28	0	0	0	42.03
49.92	0.068	0.017	2.29	63.04
61.01	0.658	0.165	22.27	77.04
72.10	1.380	0.347	46.83	91.05
83.20	1.851	0.465	62.75	105.06
101.68	2.297	0.578	78.00	128.40
110.93	2.395	0.602	81.24	140.08
129.42	2.502	0.629	84.89	163.43

Cycle 20

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
33.28	0	0	0	42.03
49.92	0	0	0	63.04
61.01	0	0	0	77.04
72.10	0.043	0.011	1.49	91.05
83.20	0.595	0.150	20.24	105.06
101.68	1.410	0.356	48.04	128.40
110.93	2.153	0.544	73.41	140.08
129.42	2.587	0.654	88.26	163.43

TABLE 11H. GASSING DATA FOR ELECTRODE B-32

0.450 Ah Theo Capacity, 741 mA Charge Rate, 0°C

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
		Cycle 3		
32.93	0	0	0	31.87
57.63	0	0	0	55.77
82.33	0.027	0.007	0.95	79.67
98.80	0.497	0.125	16.87	95.61
115.27	1.757	0.442	59.65	111.55
137.22	2.554	0.642	86.64	132.79
		Cycle 20		
32.93	0	0	0	31.87
57.63	0	0	0	55.77
82.33	0.170	0.043	5.80	79.67
98.80	0.431	0.109	14.71	95.61
115.27	1.751	0.443	59.78	111.55
137.22	2.837	0.717	97.76	134.79

TABLE 12H. GASSING DATA FOR ELECTRODE A-50

0.162 Ah Theo Capacity, 741 mA Charge Rate, 0°C

Cycle 3

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
22.87	0.003	0.001	0.14	34.40
45.74	0.003	0.001	0.14	62.80
68.61	0.004	0.001	0.14	94.19
114.35	2.397	0.603	81.38	156.99
182.96	2.907	0.731	98.65	251.18

Cycle 20

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
22.87	0	0	0	31.40
45.74	0	0	0	62.80
68.61	0.013	0.003	0.41	94.19
114.35	1.987	0.502	67.75	156.99
182.96	2.935	0.742	100.14	251.18

TABLE 13H. GASSING DATA FOR ELECTRODE C-31

0.658 Ah Theo Capacity, 414 mA Charge Rate, 0°C

Cycle 3

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
20.97	0	0	0	25.55
41.95	0	0	0	51.12
62.92	0.047	0.012	2.90	76.67
73.40	0.342	0.086	20.77	89.44
83.89	0.863	0.217	52.42	102.22
94.38	1.014	0.255	61.59	115.00
99.62	1.117	0.280	67.63	121.39
115.35	1.149	0.289	69.81	140.56
136.32	0.986	0.248	59.90	166.11

Cycle 20

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
36.70	0.006	0.001	0.24	44.23
41.95	0.004	0.001	0.24	50.56
62.92	0	0	0	75.83
73.40	0	0	0	88.46
83.89	0	0	0	101.10
94.38	0.083	0.021	5.07	113.74
99.62	0.163	0.041	9.90	120.06
110.11	0.638	0.161	38.89	132.70
115.35	1.054	0.266	64.25	139.01
136.32	1.441	0.363	87.68	164.28

TABLE 14H. GASSING DATA FOR ELECTRODE B-12

.0.442 Ah Theo Capacity, 414 mA Charge Rate, 0°C

Cycle 3

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
15.61	0	0	0	15.16
39.03	0	0	0	37.92
70.25	0	0	0	68.24
35.86	0.109	0.027	6.52	83.41
101.47	0.655	0.165	39.86	98.57
117.08	1.158	0.291	70.29	113.74
132.69	1.335	0.335	80.92	128.90
156.11	1.310	0.329	79.47	151.65
187.33	1.590	0.399	96.38	181.98

Cycle 20

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
15.61	0.008	0.002	0.48	17.34
39.03	0.006	0.001	0.24	43.35
70.25	0	0	0	78.02
85.86	0.010	0.003	0.73	95.35
101.47	0.107	0.027	6.52	112.69
117.08	0.489	0.123	29.71	130.02
132.69	1.312	0.331	79.95	147.36
156.11	1.477	0.372	89.86	173.37
187.33	1.694	0.427	103.14	208.04

TABLE 15H. GASSING DATA FOR ELECTRODE A-34

0.162 Ah Theo Capacity, 414 mA Charge Rate, 0°C

Cycle 3

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
8.52	0	0	0	12.11
21.30	0	0	0	30.27
63.89	0	0	0	90.79
127.78	1.460	0.367	88.65	181.58
149.07	1.581	0.397	95.89	211.84
212.96	1.564	0.393	94.93	302.63

Cycle 20

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
8.52	0.012	0.003	0.73	12.11
21.30	0.012	0.003	0.73	30.27
63.89	0.049	0.012	2.90	90.79
85.19	0.828	0.209	50.48	121.06
127.78	1.473	0.371	89.61	181.58
212.96	1.614	0.407	98.31	302.63

TABLE 16H. GASSING DATA FOR ELECTRODE C-26

0.663 Ah Theo capacity, 247 mA Charge Rate, 0°C

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
		Cycle 1		
15.52	0.010	0.003	1.22	
24.84	0.060	0.015	6.07	
43.46	0.380	0.095	38.46	
62.09	0.581	0.145	58.71	
74.51	0.687	0.171	69.23	
90.03	0.711	0.177	71.66	
105.56	0.841	0.209	84.62	
121.08	0.780	0.194	78.54	
130.39	0.824	0.205	83.00	
139.71	0.902	0.225	91.09	
149.02	0.775	0.193	78.14	
152.12	0.912	0.227	91.90	
		Cycle 3		
15.52	0.010	0.003	1.22	
24.84	0.060	0.015	6.07	
43.46	0.380	0.095	38.46	
62.09	0.581	0.145	58.71	
74.51	0.687	0.171	69.23	
90.03	0.711	0.177	71.66	
105.56	0.841	0.209	84.62	
121.08	0.780	0.194	78.54	
130.39	0.824	0.205	83.00	
139.71	0.902	0.225	91.09	
149.02	0.775	0.193	78.14	
152.12	0.912	0.227	91.90	
		Cycle 20		
15.52	0	0	0	24.21
40.36	0	0	0	62.96
49.67	0	0	0	77.49
55.88	0	0	0	87.17
62.09	0	0	0	96.86
68.30	0.009	0.002	0.81	106.55
74.51	0.067	0.017	6.88	116.24
80.72	0.172	0.043	17.41	125.92
86.93	0.336	0.085	34.41	135.61
93.14	0.495	0.125	50.61	145.30
99.35	0.652	0.164	66.40	154.99
111.76	0.814	0.205	83.00	174.35

TABLE 17H. GASSING DATA FOR ELECTRODE B-2

0.435 Ah Theo Capacity, 247 mA Charge Rate, 0°C

Cycle 1

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
9.46	0	0	0	
18.93	0	0	0	
33.12	0	0	0	
47.32	0	0	0	
61.51	0.013	0.003	1.22	
85.17	0.400	0.100	40.49	
104.10	0.651	0.162	65.59	
127.76	0.628	0.156	63.16	
141.95	0.760	0.189	76.52	
146.69	0.694	0.173	70.04	
170.35	0.759	0.189	76.52	

Cycle 3

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
9.46	0	0	0	9.62
18.93	0	0	0	19.24
33.12	0	0	0	33.66
47.32	0	0	0	48.09
56.78	0	0	0	57.71
70.98	0.010	0.003	1.22	72.14
80.44	0.034	0.009	3.64	81.76
89.90	0.342	0.086	34.82	91.37
99.37	0.618	0.156	63.16	101.00
108.83	0.752	0.190	76.92	110.61
132.49	0.743	0.188	76.11	134.66
156.15	0.836	0.211	85.43	158.70

Cycle 20

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
9.46	0	0	0	9.62
18.93	0	0	0	19.24
3312	0	0	0	33.66
47.32	0	0	0	48.09
56.78	0	0	0	57.71
70.98	0	0	0	72.14
80.44	0	0	0	81.76
89.90	0	0	0	91.37
99.37	0	0	0	101.00
108.83	0	0	0	110.61
118.30	0.023	0.006	2.43	120.24
127.76	0.078	0.020	8.10	129.85
137.22	0.312	0.079	31.98	139.46
146.69	0.682	0.172	69.64	149.09
156.15	0.772	0.195	78.95	158.70

TABLE 18H. GASSING DATA FOR ELECTRODE A-30

0.162 Ah Theo Capacity, 247 mA Charge Rate, 0°C

% Input	V_{O_2} (cc/min)	i_{O_2} (A)	$i_{O_2}/i \times 100$	% Returned, Q
		Cycle 1		
12.71	0	0	0	
38.12	0	0	0	
76.24	0	0	0	
114.35	0.289	0.072	29.15	
139.76	0.464	0.116	46.96	
152.47	0.589	0.147	59.51	
190.59	0.707	0.176	71.26	
266.82	0.787	0.196	79.35	
319.64	0.819	0.204	82.59	
		Cycle 3		
5.08	0	0	0	6.38
12.71	0	0	0	15.96
38.12	0	0	0	47.87
76.24	0.750	0.190	76.92	95.74
101.65	0.806	0.204	82.59	126.65
114.35	0.940	0.238	96.36	143.60
139.76	0.927	0.235	95.14	175.51
177.88	0.986	0.249	100.81	223.38
330.35	0.889	0.225	91.09	414.86
		Cycle 20		
5.08	0	0	0	6.38
12.71	0	0	0	15.96
38.12	0	0	0	47.87
76.23	0.043	0.011	4.45	95.73
101.65	0.773	0.195	78.95	127.65
114.35	0.856	0.216	87.45	143.60
139.76	0.979	0.247	100.00	175.51
177.88	0.973	0.246	99.60	223.38