

ELECTROCHEMICALLY DEPOSITED CADMIUM
ELECTRODE FOR SEALED Ni-Cd CELLS

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INTRODUCTION

Electrochemical impregnation processes for cadmium electrodes have undergone considerable development at Eagle-Picher under contract to the U.S.A.F. (ref 1). Previous work has focussed on thin high rate electrodes for vented, aircraft starting type batteries. A review of the history of cadmium electrochemical processes led to some feeling that an improved aerospace quality electrode might be manufactured using these processes. Electrochemically loaded cadmium electrodes are reported to have reduced cadmium migration over cycle life (ref. 2), more stable capacities than conventional electrodes (ref. 3) and possess an increased surface area that might provide good utilization and recombination ability.

Two similar processes for electrodeposition of cadmium in sintered plates have been known for some time and development has taken place at the USAF and Bell Laboratories. Production equipment for the USAF process has been installed at Eagle-Picher and could be utilized to produce high quality electrodes for sealed nickel cadmium cells. Our experience with electrochemical impregnation has indicated benefits in terms of lowered production costs and more importantly improved process control.

To evaluate the potential for improved flight quality cadmium electrodes, we instituted an investigation into the known work on electrochemical cadmium deposition processes. Subsequently, we set up a beaker impregnation system in the laboratory to investigate the practical limits of loading and the effect of various process parameters utilizing the USAF process (ref. 3). Reasonably high loadings of cadmium were obtained and the process appeared amenable to tight control and the production of uniform consistent electrodes. At this point, we constructed a pilot impregnation facility designed to further investigate either of the two known electrodeposition processes. Pilot system is a scaled down version of production USAF process equipment that we felt would allow real testing that would be applicable to full scale production. Both the inert anode (ref. 2) and consumable anode (ref. 3) processes were investigated. Results of this evaluation and an analysis of associated problems will be presented.

PROCESS DESCRIPTION

INERT ANODE

The inert anode process developed by Bell Laboratories (ref. 2) utilized platinum as the anode material and covered a broad range of parameters. Cadmium nitrate concentrations of 1.5

molar to saturation were investigated. Workable solution pH was identified as 1.4 to 4.3. Current densities of 0.25 to 1.0 amps/in² loaded electrodes to 2.25 g/cm³ void in 30 to 60 minutes. Emphasis was placed on temperatures greater than 85°C and to prevent variation in pH an alkali nitrite buffer was used namely sodium nitrite. The respective electrode reactions are shown in figure 3.

CONSUMABLE ANODE

This process developed for the USAF (ref. 3) differs from the other process mainly in the use of an metallic cadmium anode that is consumed in the process. Work was done at temperatures near the boiling point of the solution and at pH of 3.0 to 5.0. Cadmium concentrations of 1.5 to 3.0 molar were utilized. Current densities of 1.2 to 1.6 amps/in² loaded electrodes to 2.33g/cm³ void in times of 8 to 20 minutes. pH control was maintained by the addition of dilute nitric acid. Electrode reactions are presented in figure 4.

High Current Density With Current Reversal

Improvement in the USAF process was developed by Pickett and Puglisi (ref. 4), and consisted primarily of periodic current reversals during the impregnation. Forward to reverse time ratio was 8 to 1 and loadings of 2.50g/cm³ void were obtained. It appeared that the current reversal technique was also beneficial to the problem of film buildup on the cadmium anodes.

Low Current Density With Current Reversal

Development of the consumable anode process by Fritz et al. (ref. 5) indicated that the process could be better controlled and loadings improved if operated at lower current densities (approximately 0.2 amps/in²) and utilizing current reversal techniques. Lower current densities required longer impregnation times, however, uniform loadings were reported and a forward to reverse time ratio of 8 to 1 at a frequency of 1 c.p.m. effectively inhibited film buildup on the cadmium anodes.

LABORATORY INVESTIGATIONS

The USAF process was evaluated at a beaker level in controlled laboratory environment. Two cadmium anodes 2 in. by 6 in. by 0.75 in. thick were spaced 1.5 in. apart.

Sintered plaque coupons were held in place by teflon forms, and the entire assembly was operated in a 2 liter beaker with heat and agitation supplied. Impregnation parameters are listed in figure 7. Sintered nickel plaques 1.75 in. by 4.5 in. by 0.30 were utilized and electrode potentials were monitored with a saturated calomel electrode. Temperatures of 75°C and boiling were employed to verify the importance of high temperature.

LABORATORY RESULTS

Low temperature testing at various current density levels yielded uniform but low loadings in the range of 1.5 to 2.0 g/cm³ void. Increasing temperature to near boiling dramatically improved the results at all current densities. Plaque thickness increase was also lessened at high temperature. Monitoring of plaque potential through the impregnation indicated support for the work of Fritz et al. (ref. 6) in that excursions more negative than -0.650 volts vs. S.C.E. were accompanied by and significant electrode thickening and the formation of dark grey deposits on the electrode surface. Later runs in the laboratory set up employed variable current densities in an attempt to maintain plaque potential below -0.650 volts vs. S.C.E. for the maximum amount of time. Laboratory impregnation results listed in table 1 show the achievement of acceptable loadings at high temperature and a variety of low current densities. Improvement in loading is indicated with the variable current density technique.

PILOT FACILITY

DESCRIPTION

Pilot facility consists of a 40 liter impregnation tanks with 3 ft² working electrode capability. A batch tank holding 150 liters of bulk solution is maintained by intermittent addition of water and dilute nitric acid controlled by a process pH meter and level sensors. Impregnation and batch tanks as well as flow rate and counterelectrode spacing were designed to duplicate the parameters of the production equipment. Time, current density, and voltage are microprocessor controlled and adaptable to a wide range of impregnation regimes. Impregnation racks are fitted with balancing resistances for uniform current density. Plaque to anode spacing is maintained by teflon forms. A schematic of the pilot facility is shown in figure 9.

INERT ANODE: PILOT STUDIES

Impregnation Conditions

Cadmium nitrate concentration maintained at 2.0 molar. Sodium nitrite was used to maintain a pH range of 2.5 to 3.5. Temperature was held near the solution boiling point or approximately 98°C. Current densities of 0.07 to 0.20 amps/in² were investigated on a variety of plaque types. Anodes were 100 μ in. thick platinum plated on an expanded titanium grid.

Results

Inert anode impregnation results are presented in table 2. In general we verified the reported loadings for this process and extended that capability into lower current density regimes. Interesting results were obtained with oxidized plaque vs. unoxidized plaque that seem to verify the claims of Beauchamp et al. (ref 7).

CONSUMABLE ANODE: PILOT STUDIES

Impregnation Conditions

Pilot impregnations for this process utilized 1.0 in. thick cadmium anodes. Cadmium concentration was again held at 2.0 molar. Dilute nitric acid was used to maintain pH between 2.6 and 3.0. Current reversal techniques were used throughout in association with current densities of 0.10 to 0.20 amps/in². Laboratory results led us to perform all tests at the solution boiling point. Again, both oxidized and unoxidized plaque manufactured by both the dry sinter and slurry processes were tested.

Results

Results are tabulated in table 3. Loadings after plaque formation are comparable to the low current density, current reversal work of Fritz et al. (ref. 6). Later runs in the investigation where all parameters were held constant demonstrated very uniform plaque loadings.

DISCUSSION

Laboratory results proved to be reasonably accurate in the scale up to the pilot facility. Our results from pilot impregnations indicate that low current densities of 0.10 to 0.25 amps/in² are the most reliable regimes for impregnation on either of the two processes studied. Plaque potential monitoring vs. S.C.E. proved to be a reliable determination of effective loading limits under various regimes. Anode

passivation with the consumable anode process is still a problem making multiple impregnations under the same conditions difficult. Work with forward/reverse current ratios and cycle frequency has demonstrated improvement on the anode film buildup, and planned future investigations show promise of solving the problem. The inert anode process may have a problem of eventual buildup of sodium in the solution affecting loading results. To date this problem has not surfaced, but investigations are continuing.

SUMMARY

This program has shown that acceptable cadmium loading levels are achievable by either of the electrochemical processes tested. The added process controls incorporated in the pilot facility show promise of enabling production equipment to achieve higher loadings. Low current density regimes with reversal will be used to characterize production capabilities and analyze the long term anode passivation problem. Inert anode investigations will continue on the pilot facility to identify the scope of the projected sodium buildup problem.

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Table 1
Laboratory Impregnations

PLAQUE #	AMPS in ²	°C	IMPREG. TIME	AH INPUT	g/cm ³ VOID	THICKNESS CHANGE
CD-5	.09	76°	145	1.17	1.69	0
CD-6	.09	75°	135	.90	1.61	1
CD-7	.10	76°	125	1.12	1.61	2
CD-9	.10	75°	115	1.03	1.70	1
CD-10	.11	76°	100	.98	1.58	5
CD-11	.11	76°	77	.76	1.52	1
CD-12	.12	75°	140	1.50	1.69	1
CD-13	.12	75°	140	1.50	1.85	1
CD-14	.2	76°	55	.98	1.47	1
CD-15	.15	76°	155	2.08	2.10	1
CD-16	.20	76°	67	1.20	1.58	3
CD-17	.16	77°	148	2.15	2.22	3
CD-18	.17	76°	106	1.66	2.04	1.5
CD-20	.19	75°	75	1.26	1.66	1
CD-22	.20	76°	42	.75	1.28	2
CD-25	.16	77°	130	1.89	1.85	1
CD-26	.155	76°	180	2.54	1.91	1½
T-1	.16	97°	165	3.25	2.21	1
T-3	.16	97°	190	3.77	2.18	0
T-6	.16	97°	220	4.76	2.15	2
T-12	.31	90°	125	5.2	2.40	1
T-16	.25	95°	135	4.59	2.51	1
T-18	.29	95°	110	4.22	2.50	1
T-9	varied	97°	340	9.40	3.08	1
T-11	varied	90°	180	6.07	3.34	4
T-20	varied	95°	120	4.46	2.60	1
T-22	varied	95°	130	4.75	2.55	1
T-25	varied	96°	120	4.59	2.62	2

Table 2
Pilot System Impregnations-Inert Anode

PLAQUE #	PLAQUE DESCRIPTION	AH INPUT	ORIGINAL PLAQUE WEIGHT	g PICKUP Cd(OH) ₂	g/cm ² VOID	THICK. CHANGE	IMPRGN. TIME	AVG. CURRENT DENSITY	FORM. g PICKUP	FORM. g/cm ² VOID	Loss IN g.
1-7242	oxidized dry sinter 34 mil 84% porosity 132 in ²	137	127	126	2.13	-0.6	82 min.	.20	---	---	---
1-7243	"	137	128	121	2.03	-0.3	82 min.	.20	---	---	---
1-7244	"	137	127	124	2.08	-0.2	82 min.	.20	---	---	---
1-7245	"	137	126	112	1.89	0	82 min.	.20	---	---	---
2-7642	oxidized dry sinter 34 mil 84% porosity 160 in ²	161	154	156	2.13	-0.1	120 min.	.19	---	---	---
2-8044	"	161	156	167	2.27	+0.2	120 min.	.19	---	---	---
3-4130	"	186	156	170	2.38	0.1	140 min.	.15	136	1.90	20
3-4131	"	186	153	180	2.51	0.2	140 min.	.15	145	2.02	19.4
4-4131	"	196	154	183	2.64	0.4	130 min.	.175	146	2.03	20.6
4-4132	"	196	154	184	2.56	0.8	130 min.	.175	153	2.14	19.0
5-4137	unoxidized dry sinter 34 mil 86% porosity 160 in ²	207	141	212	3.01	1.0	156 min.	.16	173	2.46	22.5
5-4138	"	207	142	211	2.79	2.1	150 min.	.16	174	2.31	17.5
6-4146	"	252	141	234	2.97	2.9	195 min.	.15	203	2.58	13.2
6-4147	"	252	142	222	2.82	2.7	195 min.	.15	193	2.45	13.1
7-6029	unoxidized dry sinter 25 mil 84% porosity 160 in ²	150	111	126	1.91	5.1	140 min.	.14	86	1.60	31.7
7-6030	"	150	112	112	1.85	2.5	140 min.	.14	90	1.61	19.6
8-041	"	150	112	120	2.15	1.0	160 min.	.11	97	1.81	19.2
8-042	"	150	113	111	1.91	1.8	160 min.	.11	90	1.68	18.9
9-042	oxidized dry sinter 25 mil 84% porosity 160 in ²	188	113	146	2.49	0	240 min.	.09	118	2.01	19.2
9-043	"	188	114	134	2.72	0	240 min.	.09	108	2.20	19.4
10-3129	"	219	112	148	2.76	0.2	345 min.	.07	121	2.25	18.2
10-3130	"	219	112	143	2.66	0	345 min.	.07	117	2.18	18.2
11-4129	"	232	113	174	3.11	0.5	300 min.	.09	134	2.40	23.0
11-5130	"	232	113	153	2.85	-1.1	300 min.	.09	124	2.31	23.4

Table 3
Pilot System Impregnation-Consumable Anode

RUN #	PLAQUE DESCRIPTION	NET AH INPUT	ORIGINAL PLAQUE WEIGHT	g PICKUP Cd(OH) ₂	g/cm ³ VOID	THICK. CHANGE	IMPREG. TIME	AVG. CURRENT DENSITY	CYCLES PER MINUTE	-/+ TIME RATIO	FORM. g/cm ³ VOID	FORM. t	% LOSS
1-7129	unoxidized dry sinter-24 mil 85% porosity 160 in ²	165	113	158	2.94	- - -	180 min.	.16	2½	N/A	2.00	+0.2	31.6
2-8129	"	165	113	126	2.35	- - -	160 min.	.14	10	N/A	1.90	0.4	19.0
3-6133	"	162	114	117	2.17	- - -	210 min.	.09	3.5	N/A	1.82	-0.2	16.2
4-3129	"	187	113	140	2.62	- - -	225 min.	.13	3.75	3	2.14	0.4	17.1
5-4129	"	186	114	129	2.39	- - -	195 min.	.17	3.5	4	1.97	-0.1	17.8
6-129	unoxidized slurry-22 mil 163 in ² -86% porous	157	100	96	1.89	- - -	210 min.	.12	3.75	6	1.62	- -	14.6
7-0136	"	149	100	103	2.04	- - -	195 min.	.12	3.75	6	1.71	- -	15.5
8-A	"	159	100	98	2.24	0.1	270 min.	.10	3.5	4	1.86	-0.1	14.3
9-5129	oxidized slurry-22 mil 163 in ² -86% porosity	248	99	138	2.98	1.4	420 min.	.10	3.5	4	2.57	.25	15.9
10-7129	oxidized slurry-22 mil 163 in ² -86% porosity	211	99	148	3.20	2.0	255 min.	.14	3.5	4	2.74	0.7	18.9
15-8130	"	215	99	165	2.88	5.7	180 min.	.20	3.5	4	2.69	2.0	21.2
17-4133	"	169	100	138	2.71	3.0	205 min.	.14	3.5	4	2.36	0.1	17.4
19-5175	"	165	99	142	2.60	4.2	200 min.	.14	3.5	4	2.51	1.2	18.3
22-5229	"	168	99	143	2.50	5.7	200 min.	.142	3.5	4	2.43	2.1	19.6
23-5227	"	162	100	136	2.49	4.7	205 min.	.134	3.5	4	2.33	1.7	19.1
24-5225	"	162	99	148	2.44	6.5	210 min.	.131	3.5	4	2.40	1.3	20.9
28-5217	"	163	99	136	2.54	3.3	210 min.	.131	3.5	4	2.33	0.9	18.4
29-0275	"	163	100	133	2.49	3.5	210 min.	.131	3.5	4	2.31	0.7	18.0
31-0269	"	163	99	121	2.55	1.7	210 min.	.131	3.5	4	2.25	0.4	16.5
32-0271	"	166	99	118	2.38	2.4	210 min.	.134	3.5	4	2.12	0.3	15.3
33-0267	"	166	98	116	2.45	2.1	210 min.	.134	3.5	4	2.18	0.1	15.5

- Potential Application of Improved Cadmium Electrodes in Aerospace Nickel-Cadmium Cells.
 - Reduced Cadmium Migration.
 - High Surface Area to Provide Good Utilization and Recombination Ability.
 - Reduced Production Costs; Labor and Material.
 - Basic Processes Established by U.S.A.F. and Bell Laboratories.
 - Production Equipment and Vented Cell Technology in Place at E.P.I. - Colorado Springs under Air Force Contract No.
 - Improved Process Control and Plate Uniformity vs. Traditional Electrode Processes.
 - High Quality E.C. Cadmium Electrode to Match Proven E.C. Positive for Long Life, High D.O.D. Applications.
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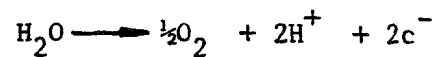
Figure 1. Electrochemically deposited cadmium electrodes.

- Baseline: E.P.I./U.S.A.F. Cadmium Electrochemical Impregnation Process for Vented Nickel-Cadmium Cells.
 - Laboratory Investigation of Practical Limitations of Loading and Process Parameters.
 - Pilot Facility Fabrication: Scaled Down Version of Production Equipment with Capability of Conversion to Either "EC" Process.
 - Inert Anode Evaluation on Pilot Facility.
 - Consumable Anode Evaluation on Pilot Facility.
 - Comparison of Results/Analysis of Problems.
 - Verification of Cadmium Electrode Producibility on Production Equipment.
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Figure 2. Electrochemical impregnation: process evaluation.

- Platinum Sheet Counter Electrodes.
- Temperature Greater than 85°C.
- 0.25 to 1.0 Amps/In².
- pH 1.4 to 4.3.
- Cadmium Concentricity - 1.5 to 3.0 M.
- Impregnation Times 30-60 Minutes.
- Buffered with Alkali Nitrite (NaNO₂).
- 1.5 In² Nickel Sinter Electrodes.
- Reported Loading of 2.2-2.3 g/cm³ Void.

ANODE REACTION



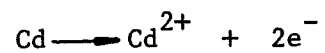
CATHODE REACTION

Reduction of NO₃⁻ with Subsequent Local pH Rise
and Precipitation of Cd(OH)₂.

Figure 3. Inert anode: process description.

- Cadmium Sheet Counter Electrodes.
- Temperature - 95° to 110°C.
- 1.2 to 1.6 Amps/In².
- pH - 3 to 5.
- Cadmium Concentration - 1.5 to 3M.
- Impregnation Times - 8 to 20 Minutes.
- pH Control with 0.1 M HNO₃.
- 13 In² Nickel Electrode - 70 to 90% Porous.
- Reported 2.33 g/cm³ Void Loading.

ANODE REACTIONS



CATHODE REACTION

Reduction of NO₃⁻ with Subsequent Local pH rise and precipitation of Cd(OH)₂.

Figure 4. Consumable anode: process description.

- Cadmium Sheet Counter Electrode.
- Temperature - 101°C.
- pH - 3.5.
- Cadmium Concentration - 2.0M.
- Impregnation Time - 12 Minutes.
- 1.6 Amps/IN².
- Reported Loading of 2.26 - 2.49 g/cm³ Void.

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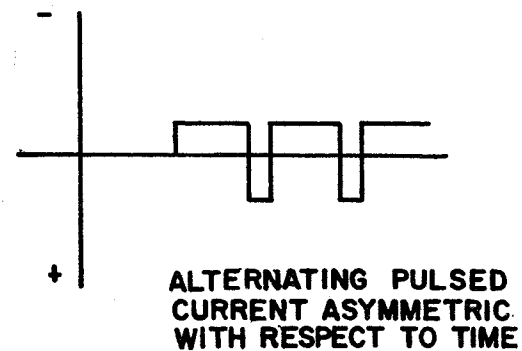
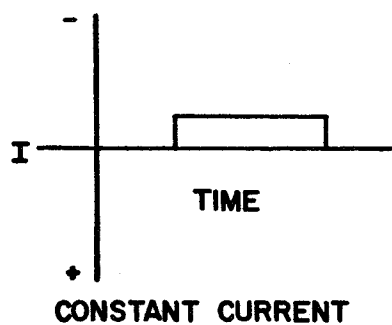


Figure 5. High current density impregnation using current reversal.

- Consumable Cadmium Anodes.
 - Temperature - 80 - 85°C.
 - pH 3.5 ± 0.1.
 - Cadmium Concentration - 2.0 M.
 - Use of Current Reversal Techniques Where By Plaque is Made Anodic 10-20% of the Time.
 - 0.2 Amps/In².
 - Impregnation Times of 3 Hours or More.
 - Reported Loadings of 0.9 g/IN² (~ 2.3 g/cm³ Void).
-

Figure 6. Low current density impregnations using current reversal.

- Consumable Cadmium Anodes 3/4" Thick, 2" Wide x 6" High, 1 1/2" Center to Center.
- Temperature - 75°C, Boiling (~ 95°C).
- pH - 2.5 to 3.5.
- Cadmium Concentration - 2.0 M.
- Calomel Reference Electrode Measuring Potential at Center of Plaque.
- Use of Current Reversal Techniques.
- 30 mil Thick Unoxidized Dry Sinter Nickel Electrodes 4 1/2" x 1 3/4".
- Impregnations Carried Out in a 2 Liter Glass Beaker.

PURPOSE

Investigate Impregnation Parameters, Find Realistic Loading Expectancy, Determine Where to Begin Pilot Project Studies.

Figure 7. Laboratory investigations.

- Batch Tank, Flow Rate, Impregnation Tank Sized to Reproduce Production System Parameters.
 - Automatic Continuous pH Control and Monitoring.
 - Automatic Solution Level Control.
 - Multiple Current, Voltage and Time Base Capability Provided by Microprocessor.
 - Impregnation Furnished with Balancing Resistance for Uniform Current Distribution.
 - 3 Ft² Electrode Capacity.
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Figure 8. Pilot system: description.

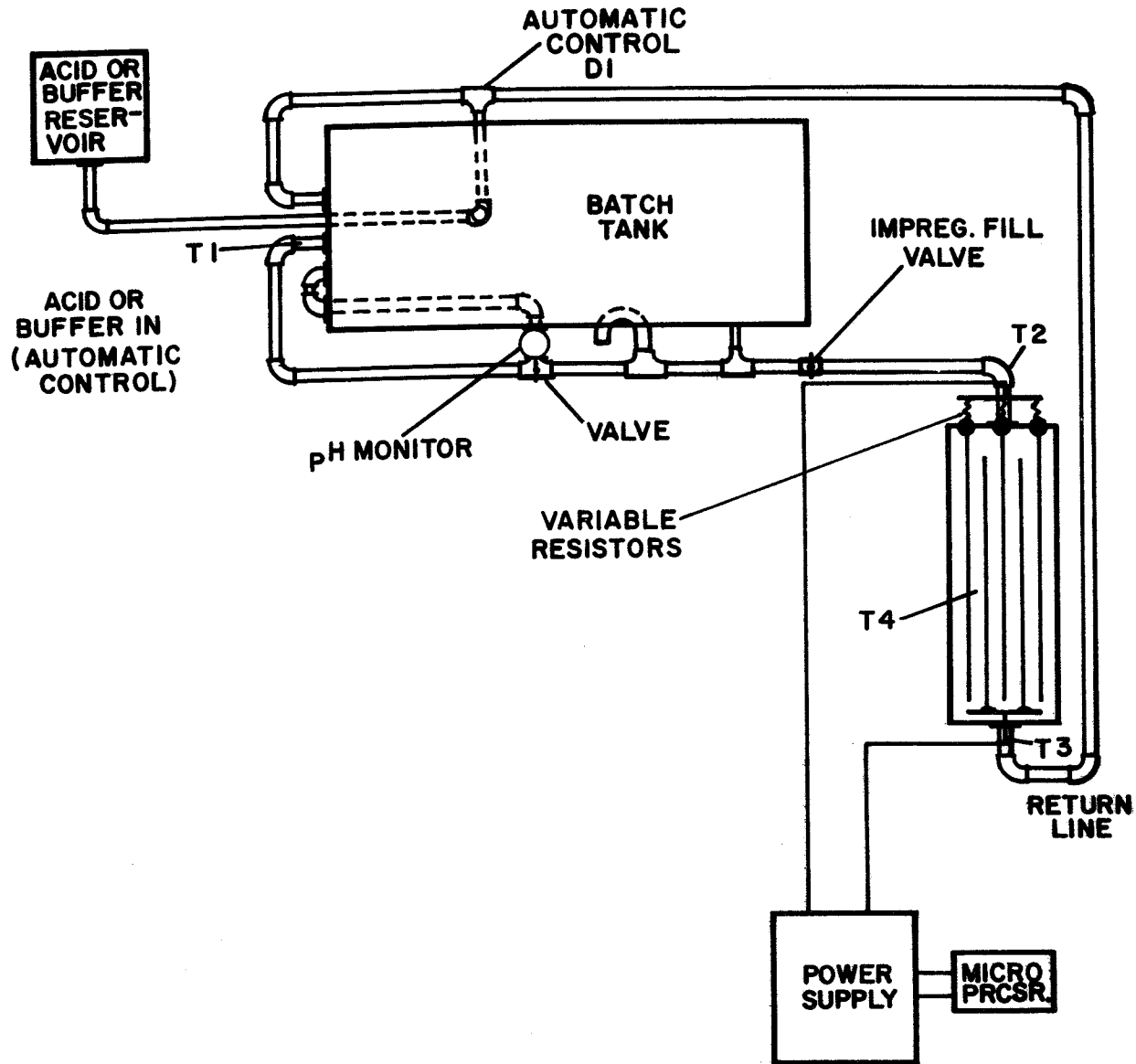


Figure 9. Pilot facility schematic.

- ° Platinized Titanium Anode - 100 Microinches Thick platinum - 14" x 24".
 - ° Cadmium Concentration - 2.0 M.
 - ° pH - 2.5 to 3.5.
 - ° Temperature - 95° to 98°C.
 - ° Low Current Densities - 0.07 to 0.20 Amps/In².
 - ° Dry Sinter Nickel Electrodes of Varying Thicknesses.
 - ° Oxidized and Unoxidized Electrodes.
 - ° NaNO₂ as a Buffer.
 - ° Retained Loadings Greater than 2.40 g/cm³ Void.
-

Figure 10. Pilot system impregnations-inert anode.

- ° Cadmium Sheet Anodes 14" x 24", 1" Thick
 - ° Cadmium Concentration - 2.0 M.
 - ° pH - 2.8 ± .02.
 - ° Temperature - 95 - 98°C.
 - ° Low Current Densities - 0.10 to 0.20 Amps/In².
 - ° Current Reversal Techniques Used.
 - ° Dry Sinter and Slurry Nickel Plaque - Varying Thicknesses.
 - ° 10% HNO₃ Added to Control pH.
 - ° Retained Loadings Greater than 2.70 g/cm³ Void.
-

Figure 11. Pilot system impregnations-Consumable anode.

- Either Electrochemical Cadmium Impregnation Process Appears Capable of Leading Plaque to Acceptable Levels for Aerospace Applications.
 - Additional Process Controls Incorporated in Pilot Facility Sould Enable Full Scale Production of Uniform Highly Loaded Electrodes.
 - Low Current Density With Reversal on the Consumable Anode Process Demonstrates the Best Loading and Improves the Anode Passivation Problem.
 - Evaluation of Anode Passivation and Sodium Buildup Problems Continuing.
 - Full Scale Electrode Production Tests Planned.
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Figure 12. Summary.

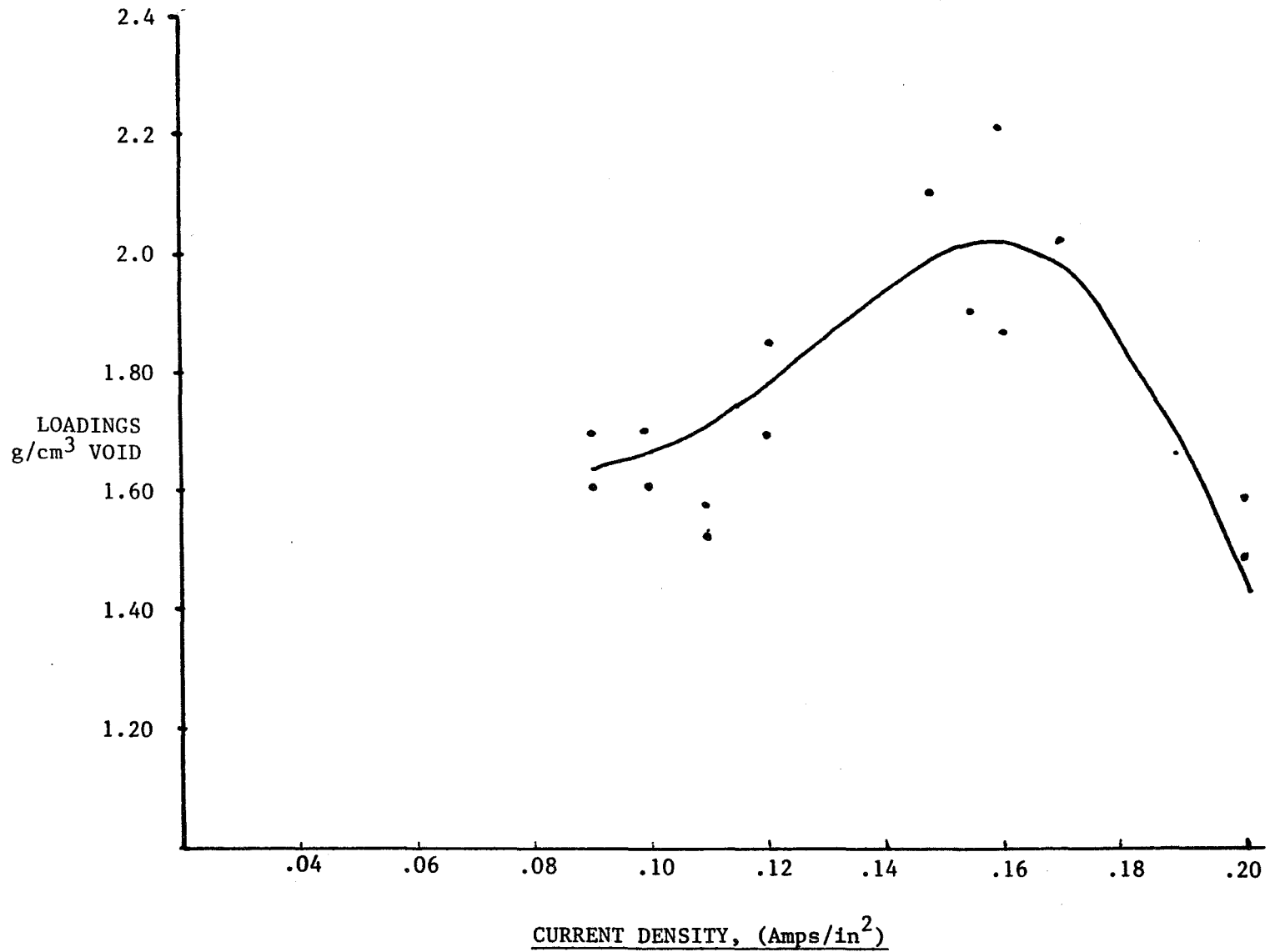


Figure 13. Plaque loading vs. current density, 75°C.

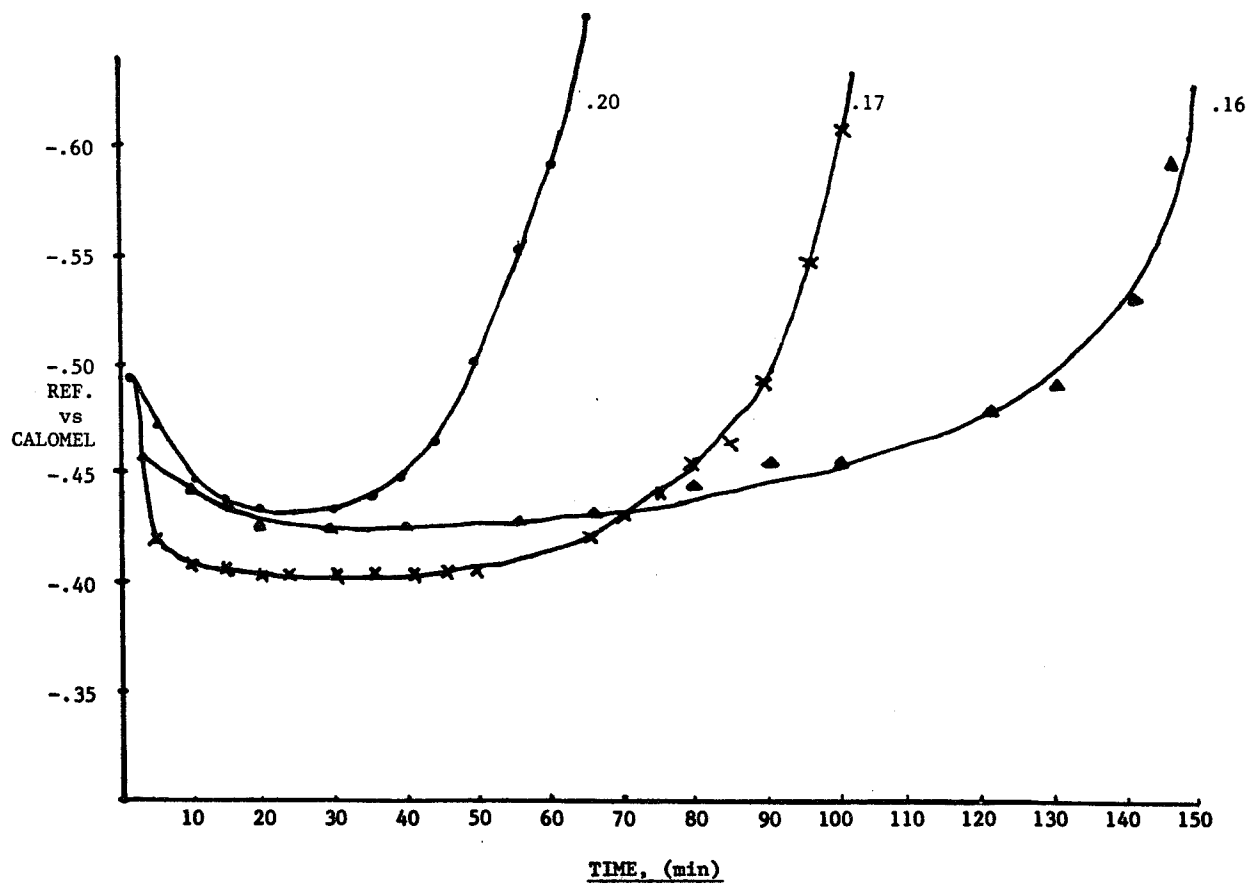


Figure 14. Reference V vs. time for varying current densities, 75°C.

- Q. Unidentified: I've got one question. On this test it seems to me that all your impregnations are done by the alcohol process?
- A. Edgar, Eagle Picher Company: That's true.
- Q. Unidentified: I'm curious why you didn't include the Bell process as well. Since by the way one of these you don't have in the Bell process is the problem of the build up in capacity during formation.
- A. Edgar, Eagle Picher Company: That's possibly true. The reason we ran the test on the Pickett process is we wanted to look at these electrodes essentially on a production type basis where we could involve a lot of them. And we are not set up at Colorado Springs to run the Bell process on this large of a scale.

COMMENT

Mallory, AT&T Bell Labs: I'll just take this opportunity to make a comment about the stress test and KOH concentration as it applies to the previous paper and this one. Burnhart and I reported some years ago that high KOH concentration has a substantial effect on growth rate. It increases the growth rate and it also increases the subceptibility to blister formation so during the stress test and lower KOH concentration is beneficial to the electrode if you want to put it that way. I also seem to recall that the cycle life of positives is reduced at higher concentrations. I'm not certain of that fact but I think it is.

Edgar, Eagle Picher Company: I guess maybe I didn't make it quite clear enough. The formation cycles were carried out 20% KOH but I believe the stress test cycles were carried out in 31%.

Ritterman, Comsat: You probably do form blister but at the higher concentration but primarily when the cell is reversed or when the positive electrode is reversed in this case.

- A. Edgar, Eagle Picher Company: That's right it's 31%.
- Q. Ritterman, Comsat: But you do avoid hydrogen gassing off of the positive electrode?
- A. Edgar, Eagle Picher Company: Yeah we do avoid that significantly. It isn't absolutely clear to me that's when blister formation takes place but it's been reported that it may.
- A. Ritterman, Comsat: It's not the only case but there is a higher tendency for blister formation when you do gas hydrogen.

- Q. Gaston, RCA-Astro: Paul, could you please explain, you mentioned in your conclusion one of the benefits higher charge temperatures. I tested nickel hydrogen with higher temperatures. My capacity was considerably lower. I don't know. Give me some details.
- A. Ritterman, Comsat: That's true. It will be lower as for the second viewgraph that I showed but now you can adjust long if you wanted to operate say 25 degrees instead of 20 or 10, or so you can adjust your concentration so that now you are allowed to operate at that temperature and the benefits of suppressing the oxygen getting the capacity you want with operating at the higher temperature.