

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONTRACT NAS-5-9226

TECHNICAL STATUS REPORT NO. 12
(May 25 through August 26, 1966)

"PROCUREMENT AND DEVELOPMENT PROGRAM
FOR NICKEL-CADMIUM CELLS TO
SPECIFICATION S-615-P-2"

I. SUMMARY: The cover problems have been solved and superior covers are being made. More pressure transducers were received and recording equipment was modified so that 48 can be used at one time. The High Reliability operations were re-located and operators were trained and certified for all production operations. Results of eight "screening" tests (overcharge at -5°C) are given which were done after several types of conditioning procedures. Correlation was sought between pressure and voltage on -5°C overcharge, and voltage during cell "reversal" with overcharge behavior. Efforts were made to predict behavior during 120 hour overcharge by voltage, pressure and pressure decay at an early stage of the overcharge. Carbonate content of cell electrolyte was reduced. A delivery schedule for Item 2 cells is included.

II. DESIGN AND EQUIPMENT:

A. Cover. Further problems were encountered with the multiple glass-ceramic-metal seal principally caused by unsatisfactory metallized ceramic parts and migration of the braze metal. These have been solved by a change of the braze metal and special electroplating of the metallized coating of the ceramic part. Considerable experimental work, not assigned to this contract, was done before the solution of these problems was achieved. We believe that we now have a cover seal which is definitely superior to any other used for sealed cells. We have proved this out in the 2 inch diameter stainless steel cover by making 30 covers in the past few days with a yield of approximately 90% this change, to the use of gold rather than silver in brazing the ceramic element to the positive cup terminal and the stainless steel cover, will occur with cell No. 231. Another minor change will be made which is expected to take place at approximately cell No. 290. This involves the use of a cover whose diameter is 0.01 inch greater to be used with the thin wall (0.025 inch) cell cases.

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PORTABLE POWER

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- B. Test Equipment. We have constructed a switching device so that pressure and voltage data for two sets of 24 cells can be taken on our 24 point recorders. Additional pressure transducers were received. We now have 55 transducers for use on this project.
- C. Re-location of Operations. The move of the High Reliability operations was made during the period May 26 to June 1. The testing is being continued with the same personnel at the Battery R & D Laboratory in Elmsford and the production equipment was moved to the plant at Cold Spring, N. Y. where it is located in a separate room of 2,000 square feet apart from the other battery operations. Four workers have been secured and trained, three for Production and one for Quality Control. At least one operator has been certified by Mr. George LeFloch, the DCASR representative for each of the 16 operations according to our training program and NASA specification NPC-200-31. This was completed between July 6 and July 15. A Quality Control supervisor, Mr. Frank Crozier, was assigned to the High Reliability facilities on June 13.

III. ITEM 1 CELLS (PROTOTYPE EVALUATION):

Tests are being continued on cells 130 through 135 which have the "filler tube-gage adapter" integral with the cell cover together with the cells of Item 2. The other cells, which were subject to leakage at the adapter to transducer connection, were tested for several weeks with Item 2 cells and then the tests were discontinued due to the leakage problem and the uncertainty of cell pressure readings. We expect that we can get more than enough cells to satisfy the contract requirements for Item 1 cells. Some of them will be "conditioned" cells from those with adapters not integral with the cover, probably at least 10 of the 15 (approximately) available. Then there will be cells from the group Nos. 130 through 135 which have adapters integral with the cover. In the remainder we propose that cells from the Item 2 group which do not satisfy some minor requirement of the Acceptance Tests be used. This would be done after mutual agreement with DRTE and NASA-Goddard engineers.

IV. ITEM 2 CELLS (PROTOTYPE INSTALLATION):

More cells were assembled so that we now have 31 cells (Nos. 200 through 230). The remaining 41 cells which exist as plate-separator assemblies have not been completed due to the cover problems mentioned in section IIA. Plates for 25 more cells have completed "open cell" tests. These plates (80 each positive and negative) constituted a test for effect of the special treatment during open cell test which was described in section B of the "Summary of the Design Review Meeting of April 12" which was submitted with Report No. 11.

Of the 31 cells which have been assembled 24 are being subjected to tests described in Section V. The remaining 7 cells were damaged as follows:

- Cell 204. The adapter broke away from the cover during the 8/1 to 8/5 overcharge.
- Cell 205. The cell "bulged" on the overcharge test of 6/13 to 6/17. There was no record of excessive pressure.
- Cell 222. This cell "bulged" due to excessive pressure on the initial charge. The cell was cut open, examined and no defects were noted. We believe it was "reverse" connected during charge.
- Cell 225. The adapter broke from the cover on 6/14/66/
- Cell 226. The adapter broke at the start of the filling operation in early June.
- Cell 229 and 230. These cells "bulged" while on overcharge of 6/13 to 6/17. There was no record of excessive pressure on these cells and cell 205. The cause was probably a leak at the connection to the transducer so that the true pressure was not recorded.

V. TEST DATA:

- A. General. Although some tests were run on Item 1 cells the tests described here were done chiefly on Item 2 cells. Because of the difficulty, described in Reports 10 and 11, with the "120 hour overcharge" test at -5°C and the suggestion made by Mr. W. E. Threinen of DRTE we have concentrated on this test as a "screening" method. We have evaluated a number of conditioning treatments for the cells such as "reversal", overcharge and "reversal", repeated charge-discharge cycles, overcharge at $+25^{\circ}\text{C}$, discharge at a high rate, increase of amount of electrolyte and reduction of LiOH content of electrolyte. Eight overcharge tests were conducted for periods of 40 to 134 hours. The only treatment which shows promise is overcharge in a vented state followed by discharge and "reversal". These tests are still in progress and efforts are being made to predict the efficiency of the reversal from the voltage during reversal.

We have also attempted to correlate voltage with internal pressure during the -5°C overcharge test with negative results. Neither do pressure decay measurements on open circuit during early phases of the overcharge test prove useful in predicting behavior for the full 120 hours. Some success was had based on pressure after 40 hours of the test. We were able to reduce the K_2CO_3 content of the electrolyte to less than 3% by "electrolyte exchange".

- B. Outline of Overcharge Tests at -5°C .
1. Test of 6/13 through 6/17. On this test for 106 hours, 5 of 19 cells or 26% remained below 200 PSI.
 2. Test of 6/27 through 6/29. This test of 40 hours was performed following "open cell" reversal to -1.5 volt. Seven of the 21 cells or 33% remained below 200 PSI.

These results are the same as in the previous test, allowing for its shorter duration, so we consider the "open cell" reversal to be without benefit.

3. Test of 6/30 through 7/1. This 40 hour test was done after a discharge to 0.6 volts at 2C (20 amperes). Seven of 22 cells or 32% remained below 200 PSI, so this conditioning, also, is fruitless.
4. Test of 7/12(14) through 7/19 for 78 and 128 hours. Prior to this test all the cells were charged at +25°C for 89 hours. During this charge 11 of 22 or 50% remained below 200 PSI and pressures were approximately 2/3 the pressures shown at -5°C. Since only 6 of 24 or 25% survived this charge, we judge that +25°C overcharge is not productive. Included in this test were: 7 cycles of automatic charge-discharge at -5°C which was not advantageous as only 2 of 10 cells remained below 200 PSI at 35 hours overcharge; an "open cell" overcharge of 6AH after which only 1 of 5 cells was below 200 PSI; and an "open cell" overcharge of 12AH which gave 4 of 6 cells below 200 PSI after 128 hours overcharge. Only this last procedure shows promise.

Also before this test we increased the amount of electrolyte to 17 and 17½% from 16½% (% by weight of the plate-separator assembly weight) for four cells. Since these cells performed no better on this overcharge than they had done on the 6/30 through 7/1 test we conclude that there is nothing to be gained by increasing the amount of electrolyte.

5. Test of 7/19 through 7/20. Prior to this test, 18 cells were charged open for 12 and 18 ampere hours at 1 and 2 amperes. This treatment did not result in low pressures on this 40 hour overcharge.
6. Test of 7/24 through 7/29/66. This test of 120 hour duration for 18 cells was performed, following reversal for 1, 3 and 5 AH at 2 amperes. The reversal was done without an open cell overcharge. Of the six cells reversed for 1 AH only one stayed below 200 PSI. Of the six cells given 3 AH, two remained below 200 PSI and of the six given a 5 AH reversal, four stayed below 200 PSI. Apparently, a reversal of 5 AH gives better results than 1 or 3 AH.
7. Test of 8/1 and 8/2 through 8/5/66. Several pre-treatments were done for this 94 hour overcharge. Seven cells which had not been on test for more than two weeks (including Item I cells 130 through 135) received "open cell" overcharges for 12 AH followed by reversal of 5 AH and gave four cells which remained below 200 PSI during the overcharge. In another group of 5 cells which had been in the 7/24 through 7/29 test and had received the overcharge and reversal, only 1 of the 5 gave pressures below 200 PSI. In 6 cells the LiOH content of the electrolyte was reduced to 0.3 N or less by "flushing" the cell with 7.2 N KOH solution. None of these cells stayed below 200 PSI on this overcharge. This test, although apparently negative, will be respected when further cells are assembled.

8. Test of 8/10 through 8/16/66. This test was run for 134 hours on 21 cells, 8 of which had exhibited low pressure on one or two prior -5°C overcharge tests and 13 cells given reversal for 5 AH without a prior "open cell" overcharge. Of the 8 cells with earlier low pressure characteristics, 6 stayed within 200 PSI; of the cells subjected to reversal, only 2 of 13 showed low pressure. Apparently, reversal, without a preceding vented overcharge, is not helpful.
- C. Cell Voltage and Pressure on -5° Overcharge. Since voltage measurements are made much more easily than cell pressure measurements, it was hoped, and expected, that rather close correlation would be found between them. Previous work had indicated that low pressure would be associated with voltages of 1.52 to 1.55, with the voltage becoming lower with longer periods of overcharge. Unfortunately, this is not the case, at least for these cells. In the Appendix to this report, we have summarized, on pages A-1, A-2, and A-3, the results of the four latent overcharge tests.
- D. Pressure Characteristics in Early Stages of -5° Overcharge Test. We also examined the data with a view to determining whether some forecast could be made after shorter periods of charge, e.g., 20 or 40 hours, about behavior on the full 120 hour charge.
1. Pressure Decay. The pressure drop in one hour on open circuit was determined after the cells of the 8/1 through 8/5 tests had exceeded 200 PSI or after the end of the 94 hour test showed very good correlation - - those that exceeded 40% were the cells that remained below 200 PSI. In the following test, of 8/10 through 8/16, the charge was interrupted several times and the pressure decay rate determined, the "low pressure" and the "high pressure" cells did not show sharply different behavior. We feel that this method is not promising enough to warrant further work. The data are given on pages A-4 and A-5 of the Appendix.
 2. Pressure at Early Stages. We studied the results of four overcharges at -5°C which are given in summary form on pages A-6 and A-7 of the Appendix and find that the behavior can be predicted from the pressure at 40 hours charge. If 170 PSI is taken as the criterion, no "low pressure" cells would be rejected and 84% of the "high pressure" cells were above 170 PSI at 40 hours.
- E. Voltage During Reversal. The data on voltage during the "reversal" or "overdischarge" was reviewed and summaries are included in the Appendix as pages A-8, A-9 and A-10, for the three last overcharges. Three types of behavior took place: the voltage continued to rise (in a negative direction) slowly to -0.24 to -0.39 within the 5 ampere hours; the voltage became more negative at first and later became less negative (e.g. - 0.24 volts at $2\frac{1}{2}$ AH and -0.18 at 5 AH);

or the voltage became more negative than -0.40 volt before 5 ampere hours of reversal. Except for the third type, little correlation with overcharge characteristics was found.

In the first group where the voltage slowly became more negative, 9 cells showed "low" (less than 200 PSI) pressure on subsequent -5°C overcharge and 7 cells showed "high" pressure.

In the second group, where the voltage became more negative and later less negative on reversal 3 cells were "low" and 3 were "high" pressure in the next -5°C overcharge.

In the third group there were 9 cells which were more negative than -0.40 volt before 5 ampere hour on reversal and they all gave "high" pressure on -5°C overcharges.

- F. Amount of Electrolyte. A test is nearing completion in the Battery Research Laboratory in which the effect of electrolyte contents of 13 to 21% (based on the weight of the plate-separator assembly) on capacity at several rates of discharge and temperatures, overcharges for extended periods and charge retention is being studied. Our S-103 cells are being used, assembled with plates of the Isis type.
- G. Reduction of Carbonate in Cell Electrolyte. The electrolyte was conditioned several times during the course of cell tests. From the data, summarized on page A-11 of the Appendix, it appears that the potassium carbonate can be reduced to 3 percent by weight in three conditioning operations.

VI. MEETINGS:

Progress was reviewed with Mr. W. E. Threinen in weekly telephone calls and during a visit to Elmsford on August 21.

VII. SCHEDULE:

We have prepared a delivery schedule for Item 2 cells which appears on the next page. This is based on 90% yield in cell assembly; 50% yield for a "screening" test which consists of the 40 hours, -5°C overcharge test mentioned in Section V D2; and 80% yield for the Acceptance Test. With normal operations, both assembly and test, and little or no allowance for conflicts between tests or for unforeseen delays, we expect that the tests will be finished by November 17. We have made arrangements for overtime work on weekends which will move the completion date forward to November 10. There are technical people available for one extra day of test each week during the period September 15 to November 15. It is not likely that we can expect to extend this to a seven day week and move the date forward to November 3.

The data presented in section V D2 show that the screening test can be done in 40 hours instead of 120 hours as was stated in our last report.

Schedule for Isis Cells - Item 2

AUG	SEP	OCT	NOV	DEC
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Lot	DAYS REQ'D-YIELD (CELLS)		PLATE CONDING	CELL ASSY 907.	PRELIM. TEST COND, SCREEN etc	EVALU; X-RAY, COND. ETC.	ACCEPTANCE TEST		* Completion of Test - DAY WEEKS		
	Cells	CELL Nos.					OVERCHARGE	END, X-RAY, PULSE Int. Shot, Leak	5	6	7
1	14	200-230	5 day	3 day	7	50%	12	90%	5	6	7
2	22	231-252	Before 8/66 -	8/30	> 8/29 (14)	9/13-9/28 (22)	9/13-9/28 (10)	9/29-10/4 WEEK END	(20) 10/5-10/12 (20)	10/12	10/16-10/30
	21	253-273	Before 8/66	- 9/13	9/16-9/26 (24)						
3	32	274-305	- 9/12	9/13-9/15 (3)	9/16-9/26 (24)	9/27-10/13 (22)	10/14-10/18 WEEK END	(20) 10/19-10/26 (20)	10/26	10/19	10/12
	33	231-301 (Re-run)	-	(Lot 4) 8/22-9/26 (15)	9/27-10/6 (24)	10/7-10/25 (22)	10/16-10/31 WEEK END	(20) 11/1-11/9 (20)	11/9	11/13	10/27
4	17	306-322	- 9/21	9/22-9/26 (15)	9/27-10/6 (24)	10/7-10/25 (22)	10/16-10/31 WEEK END	(20) 11/1-11/9 (20)	11/9	11/13	10/27
	24	231-318 (Re-run)	-	(Lot 4) 10/3-10/5 (24)	10/5-10/14 (12)	10/18-11/3 (12)	10/14-11/9 WEEK END	(20) 11/10-11/17 (20)	11/17	11/13	11/3
	26	323-348	- 9/30	10/3-10/5 (24)	10/6-10/17 (12)	10/18-11/3 (12)	10/14-11/9 WEEK END	(20) 11/10-11/17 (20)	11/17	11/13	11/3

* The column "5 day week" includes one week-end of work during 120 hour overcharge with 1 or 2 readings each day. Since there are 5 other week-ends during the period of test, including Preliminary Tests, the "6 day week" moves the completion date 5 days back and the 7 day week moves it 10 days back.

We propose that consideration be given to the following modifications in the test procedure so that the work can be completed within the scheduled time:

- A. Removal of the requirement for pressure readings during the charge-discharge cycles when the equipment is needed for "overcharge" or "screening" tests which are proceeding simultaneously. We find that the pressure during a normal charge of 12 to 13 hours is invariably very low, rarely more than 50 PSI.
- B. Increase of the 100 PSI pressure during the 120 hour overcharge at -5°C to 200 PSI. The data presented in the Appendix indicate that pressures often become constant or increase very slowly in the region of 130 to 180 PSI.
- C. Decrease of the time for the -5°C overcharge test from 120 hours to 40 hours. Section V D2 and Appendix pages A-6 and A-7 show that, in most cases, high pressure is evidenced within 40 hours of charge.



George A. Baumstark

Relationship between voltage and pressure during the 120 hour overcharge test at -5°C .

8/19/66

Examination of data from the overcharge tests run 7/12-7/19, 7/24-7/29, 8/1-8/5 and 8/10-8/16 shows no correlation between voltage and ability of cells to be overcharged with internal pressure remaining below 200 P.S.I.

The data from these tests have been summarized on the next three pages. The summary divides the cells into two sets: those that remained below 200 P.S.I. internal pressure and those that did not. For the former we give the pressure range and for the latter, the time at which the pressure exceeded 200 P.S.I. Voltages given are maximum, that at 20 hours and the final. The table below gives these, with range and average voltage for "Low" & "High" Pressure Cells.

Test	Maximum Voltage			Max. at circa 20 hrs			Final Voltage		
	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average
7/12-19 "Low P."	1.520	1.548	1.532	1.511	1.540	1.527	1.508	1.520	1.513
"High P."	1.512	1.636	1.542	1.512	1.608	1.535	—	—	—
7/24-29 "Low P."	1.505-1.700		1.583	1.498	1.698	1.568	1.498-1.626		1.563
"High P."	1.528	1.686	1.601	1.526	1.688	1.599	1.536	1.688	1.627
8/1-8/5 "Low P."	1.539	1.608	1.565	1.530	1.545	1.537	1.538	1.608	1.559
"High P."	1.525	1.625	1.551	1.528	1.551	1.536	1.530	1.625	1.549
8/10-8/16 "Low P."	1.535	1.603	1.568	1.526	1.574	1.551	1.528	1.602	1.558
"High P."	1.535	1.576	1.555	1.535	1.575	1.553	1.526	1.585	1.548

Overcharge at - 5°C. Voltage and Pressure					8/19/56 GAB				
Overcharge - 7/12(14) & 7/19-128 Hrs					Overcharge - 7/24-7/29 120 Hours				
Cell No	Voltage Max	Voltage $\frac{C_2}{20H}$	Final	Charge char. PSI-HRS.	Cell No	Voltage Max	Voltage $\frac{C_2}{20H}$	Final	Charge char. PSI-HRS.
217	1.540	1.540	1.518	167 - 128	200	1.607	1.604	1.582	76-100 ↓
218	1.548	1.530	1.514	188 - 128	202	1.700	1.698	1.559	141-154 ↓
219	1.530	1.527	1.520	138 - 128	209	1.612	1.554	1.573	110-142 ↓
220	1.522	1.528	1.508	150 - 128	213	1.531	1.515	1.512	98-117 ↑
223	1.535	1.528	1.520	186 - 128	215	1.505	1.498	1.505	124-143 ↓
224	1.520	1.511	1.514	162 - 128	218	1.565	1.562	1.565	159-183 ↑
					219	1.566	1.563	1.562	108-147 ↑
					220	1.578	1.578	1.578	100-140 ↑
					221	1.574	1.535	1.574	118-139 ↑
					223	1.578	1.578	1.568	118-136 ↑
					224	1.556	1.555	1.556	119-174 ↑
					228	1.628	1.571	1.626	89-110 ↓
200	1.524	1.524	-	200 at 35 Hrs	203	1.686	1.686	1.686	200 at 22 H.
201	1.533	1.526	-	200 at 78	204	1.536	1.534	1.536	200 at 26
202	1.512	1.512	-	200 at 17	206	1.626	1.626	1.626	200 at 24
203	1.516	1.516	-	200 at 19	207	1.688	1.688	1.688	200 at 25
204	1.520	1.516	-	200 at 35 ↑	208	1.636	1.636	-	200 at 31
206	1.528	1.528	-	200 at 35	210	1.603	1.602	-	200 at 31
207	1.608	1.608	1.584	NO DATA	211	1.558	1.558	-	210 at 28
208	1.532	1.532	-	200 at 35	212	1.560	1.560	-	200 at 42
209	1.636	1.542	-	NO DATA	214	1.608	1.608	1.608	200 at 24
210	1.51	-	-	200 at 19	216	1.528	1.526	-	200 at 31
211	1.530	1.530	-	200 at 35	217	1.562	1.550	-	200 at 42
212	1.528	1.528	-	200 at 35	227	1.618	1.618	1.618	200 at 21
213	1.538	1.538	-	200 at 32					
214	1.566	1.531	-	210 at 19					
215	1.522	1.518	-	200 at 32					
216	1.540	1.529	-	200 at 21					
221	1.539	1.554	1.539	200 at 38					
227	1.570	1.570	-	200 at 21					

Overcharge at -5°C. Voltage and Pressure

Overcharge of 8/10 to 8/16 + 8/5 - 94 Hrs

Cell No	Max. Voltage	Ca. 20 Hrs	Final	Overcharge PSI - Hrs
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203	1.608	1.541	1.608	93-121↑
130	1.548	1.535	1.548	111-183↑
131	1.539	1.533	1.538	44-49
134	1.548	1.530	1.548	67-82↑
135	1.552	1.545	1.552	70-78

201	1.552	1.551	1.547	200 at 52 Hrs
206	1.530	1.530	1.530	200 at 40+
207	1.625	1.528	1.625	200 at 52
208	1.540	1.539	1.540	200 at 52
210	1.538	1.531	1.530	200 at 52
211	1.502	1.55		200 at 18+
212	1.496	-		200 at 18+
214	1.528	-		200 at 18+
216	1.505	-		200 at 18+
217	1.518	-		200 at 18+
227	1.518	-		200 at 18+
132	1.536	1.533	1.536	200 at 40+
133	1.544	1.542	1.538	200 at 76

Rising 20-40
PSI/Hr. Taken out
at 18-4 Hrs

8/16/66 CAD

Overcharge of 8/10 to 8/16 134 Hours

Cell No	Max. Voltage	Ca. 20 H	Final	Overcharge PSI - Hours
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200	1.603	1.542	1.602	70-108↑
207	1.551	1.541	1.545	80-166↑
214	1.535	1.526	1.528	120-173↑
215	1.545	1.541	1.536	100-123↑
217	1.549	1.549	1.538	90-188↑
218	1.574	1.555	1.574	90-167↑
219	1.570	1.563	1.557	50-124↑
220	1.573	1.566	1.560	70-109↑
223	1.585	1.574	1.580	80-153↑

201	1.556	1.575	1.570	200 at 46 Hrs
206	1.551	1.551	1.548	200 at 29
208	1.535	1.535	1.529	200 at 37
210	1.557	1.557	1.546	200 at 34
211	1.538	1.538	1.526	200 at 28
212	1.547	1.547	1.535	200 at 36
216	1.547	1.538	1.535	200 at 41
224	1.576	1.571	1.570	200 at 87
227	1.549	1.547	1.548	200 at 28
228	1.588	1.572	1.585	200 at 63
132	1.557	1.551	1.546	200 at 33
133	1.562	1.556	1.539	200 at 51

↑ Signifies pressure rising at end of period; + means falling & steady

Pressure drop on 1 horn from circuit stand

8/16/66

Results of overcharge test of 8/10 & 8/16/66.

Cells that exceeded 192 PSI before 134 hrs				
Cell No	Voltage Drop - 2.			
	18/1hr	41/1hr	46-52	60-75
201	14	16	24	
206	No Data	4		
208	9	31	28	
210	11	28	30	
214	14	5	28	
212	11	30	32	
216	23	23	30	
224	22	25		25
227	6	1	11	
228	10	13	15	16
132	No Data	14	15	
133	23	29	34	

Cells that were below 192 PSI for 134 hrs				
Cell No	Voltage Drop 2.			Net P in 0.1hr
	18/1hr	41/1hr	134/1hr	
200	19	22	14	168
207	24	33	42	166
214	12	27	41	173
215	23	31	41	127
217	11	22	37	188
218	13	23	28	167
219	53	33	44	124
220	inadeq	27	42	109
223	26	26	32	153

Range 6-23 1-31
 Range 18%.

11-26 22-33
 27%.

If cells with $\geq 27\%$ more loss of p in one horn stand are considered "low pressure"
 9 of 9 actually "low pressure" will be chosen
 but also 6 of 12 "high pressure" will be erroneously sampled.

Recombination Rate from pressure decline on open circuit.

8/9/66

During and after the -5°C overcharge test of 8/1 & 8/5/66 the pressure was measured while on open circuit at -5°C .

at 18 hours at 66 hours

1) Cells which exceeded 200 psi before 94 hrs overcharge.

Cell No	No of Cells in Row	Initial P PSI	Decline in 1 hour	Initial P PSI	DECLINE IN PR. 1 HOUR PERCENT
201	52	188	24.4	58	13.7
206	40	50	4.0		
207	52	171	8.7	134	8.2
208	52	126	1.5		
210	52	156	28.8	57	14.0
211	18	55	14.5	70	17.1
212	18	66	21.2	85	28.2
214	18	43	9.3	58	13.7
216	18	50	12.0	65	21.5
217	18	70	25.0	81	30.8
227	18	54	1.0	78	7.6
132	40	48	18.7		
133	76	192	31.2		

2) Cells which did not exceed 200 psi during 94 hr overcharge

	MAX PSI	<u>at 94 hours</u>	
203	121	110	58.2
130	183	176	44.3
131	49	48	62.5
134	82	79	49.3
135	78	74	54.0

Drachy at -5°C. Pressure at early stage m. full 120 hours

1) Test of 7/12 (7/14) & 7/19

Cell No.	P (PSI) at 20	P (PSI) at 40	P (PSI) at 60	Final 120H
217	70 40	140	170	167
218	90 70	170		188
219	70 140	120 100	130	138
220	80 40	120 140	140	150
223	80 40	150	170	186
224	60 120	130	140	162
200	140	>200		at 235H
201	110	180		at 78H
202	>200	-		" 17H
203	>200	-		" 19H
204	120	170	Rising	out?
206	150	>200		" 35H
207	no data			
208	140	>200		" 35H
209	no data			at 78H
210	>200			" 19H
211	180	>200		" 35H
212	170	>200		" 35H
213	90 120	>200		" 32H
214	70 120			17H
215	100	>200		32H
216	70 140	>200		21H
221	120 120			38H
227	180	>200		21H

2) Test of 7/24 & 7/29

Cell No.	P (PSI) at 20	P (PSI) at 40	P (PSI) at 60	Final 120H
200	90	100	80	76-100H
202	110	150	140	141-154H
209	40	130	140	110-147H
213	50	100	100	98-117H
215	150	160	140	124-136H
218	120	160	170	157-163H
219	70	100	110	108-147H
220	50	100	110	100-146H
221	60	120	120	118-139H
223	100	120	120	118-136H
224	70	120	130	119-174H
228	100	90	90	59-110H
203	170	>200		out-22H
204	70	"		out-26H
206	90	"		out-24H
207	190	"		out-21H
208	80	"		out-31H
210	110	"		out-31H
211	120	"		out-28H
212	no data	180		out-42H
214	150	>200		out-24H
216	no data	"		out-31H
217	130	180		out-42H
227	190	>200		out-21H

3) Test of 5/1 (8p) & 8/5

Cell No	P(PSI) 20	at -- Hrs 40 60	Final 94 Hrs PSI
203	70	120	93-1218
130	100	160	111-1838
131	40	50	44-49
134	60	70	67-829
135	50	50	70-76
201	110	170	not 52H
206	50	190	" 740
207	60	80	" 52
208	50	160	" 52
210	50	140	" 52
211	↑	> 200	" 18+
212	all 50±	↓	" 18+
214	170	↓	" 18+
216	8 R. 20g	↓	" 18+
217	50 PSI	↓	" 18+
227	↓ PSI Hrs	↓	" 18+
132	120	190	" > 40
133	130	160	" 76

4) Test of 8/10 & 8/16/66

Cell No	P-PSI 22	at -- Hrs 39	Final 134 Hrs PSI
200	68	80	70-1089
207	78	130	80-1669
214	116	167	120-1739
215	122	126	100-1709
217	90	133	90-1589
218	60	117	90-1679
219	51	84	50-1249
220	50	99	70-1699
223	84	126	80-1529
201	78	164	not 46H
206	83	—	" 29
208	70	—	" 37
210	100	—	" 34
211	134	—	" 28
212	98	—	" 36
216	74	183	" 41
224	76	140	" 87
227	118	—	" 28
228	97	162	" 63
132	65	—	" 33
133	84	140	" 51

Overcharge test at -5°C 7/24-7/29

8/4/66

Following reversal without prior "open all" overcharge

Reversal after overcharge ① 12AH 8② 18AH at 1 ampere on 7/18, ③ 12AH & 18AH at 2 amps on 7/19, 20.

this was followed by charge at -5°C for 40 hours less, then all discharged at 2 amps & reversal 1, 3, 5AH at -5°C OVERCHARGE 7/24, 29

Cell No	TREATMENT BEFORE REVERSAL			REVERSAL			P RANGE - 120 KPS - MAX VOLTS
	Open - 0' chgs	0' chgs - -5°C	P	10 H at 7/22	1.0	2.0	
203	④	90 PSI at 12H		+1.012	-0.245		>200 PSI at 22H ④ 1.654
207	④	114 PSI - 12H		-0.218	-0.207		>200 PSI at 21H ④ 1.672
208	②	>200 at 16 1/2 H		-0.259	-0.264		>200 PSI at 31H 1.636
210	③	No P. data - 12H		-0.223	-0.227		>200 PSI at 31H 1.603
211	③	32 PSI at 12H		-0.234	-0.239		>200 PSI at 28H 1.558
213	③	No P. data - 12H		-0.341	-0.339		98-117↑ - 120H 1.531
200	②	90 PSI at 40H				2.8 3.0	76-100↓ - 120H 1.607
204	①	130 PSI at 32H				-0.084 -0.104	>200 PSI at 26H 1.536
206	②	>200 at 16 1/2 H				-0.088 -0.118	>200 PSI at 26H 1.536
206	②	>200 at 16 1/2 H				-0.096 -0.112	>200 PSI at 24H 1.626
214	①	>200 at 21H				-0.087 -0.113	>200 PSI at 24H ④ 1.608
227	②	No P. 39H				-1.352 -1.462	>200 PSI at 21H ④ 1.618
228	④	30 PSI - 12H				-0.096 -0.129	89-110↑ - 120H 1.628
202	②	>200 PSI at 32H		1.0	2.8	5.0	141-154↓ - 120H 1.594
209	①	>200 PSI at 13H		-0.253	-0.258	-0.096	110-142↓ - 120H 1.612
212	①	>200 at 32H		-0.244	-0.246	-0.190	>200 PSI at 42H 1.560
215	①	>200 at 32H		-0.244	-0.252	-0.330	124-163↓ - 120H 1.505
216	①	>200 at 21H		-0.254	-0.258	-0.323	>200 PSI at 31H 1.528
221	②	>200 at 21H		-0.256	-0.258	-0.273	118-139↑ - 120H 1.574
				-0.253	-0.257	-0.285	

④ These contain H_2 -- p. falls very slowly on open circuit & 3 more analyzed and found > 90% H_2

Overcharge at -5°C 8/1-5 and prior reversal following "open cell"
overcharge

8/4/66

Cell No	Prior Treatment	OPEN o'chge 12AH	Voltage on Reverse					-5° o'chge 8/1, 3 & 5	M4F Volts	
			A.H					P Range at Hrs.		
			0.2	1.4	2.6	4.1	4.4	5.0		
201	H1-p o'chge -5°c 7/18-20.	yes	+ .902		-.289		-.400	-1.597	7200-52H	1.550
203	High p. m o'chge -5°c 7/24-26			+ .884		-.207		-.212	93-1218-94H	1.608
204	"			+ .992		-.290		-.286	Broke adapter	
206	"			-.255		-.255		-.241	7200-40H	1.530
207	"			+ .209		-.187		-.176	7200-52H	1.625
208	"			+ .279		-.304		-.337	7200-52H	1.540
210	"			+ .212		-.255		-.270	7200-52H	1.530
130	-5°c o'chge approx 4/27		4.110		-.290		-.336	-.339	111-183A-94H.	1.548
131			+1.056		-.208		-.286	-.297	44-49 94H	1.539
132			-.189		-.244		-.203	-.181	7200-40H	1.536
133			-.419		-.1606		-.1622	-.1626	7200-76H	1.544
134			-.168		-.200		-.221	-.236	67-82-94H	1.548
135		✓	+ .986		-.210		-.247	-.280	70-78 94H	1.552

of the 7 cells which exceeded 200 PST on -5°C overcharge: 2 needed -1.5 volt on reversal
3 were less neg at 5 than at 2-4 AH
2 became more neg at 5 than at 2-4 AH

of the 5 cells which stayed below 200 PST on -5°C overcharge: all were more negative at 5 than at 2-4 AH.

Overcharge at -5°C 8/10-16 and prior reversal with no "open cell" 8/10, 16/66
overcharge

Cell No	Prior Treatment	Discharge +25 8/5, 9 2 amp AH	Reversal at +25°C 8/9/66 OPEN, 2 amp, 5AH r-t line above -0.4V AH	16 hr -0.4V AH	-5°C OVERCHARGE 8/10 to 8/16	MAX VOLT.
201	Reversal -5°C charge.	17.4	<u>1.0</u> <u>2.7</u> <u>4.0</u> <u>5.00</u> -1.95	2.6 (-1.5)	near 200 at 46H	(40) 1.575
206	with high pressures	18.8	+0.860 -0.360	3.3	>200 PSI at 29H	(29) 1.551
② 207		19.7	-0.247 -0.284 -0.322 -0.318	-	80-166 ↑ -134H	1.551
208		19.8	-0.282 -0.305 -0.338 -0.388	-	>200 at 37H	(37) 1.535
210		19.5	-0.272 -0.318 -0.348	4.9	>200 at 33.6	(34) 1.557
211		15.0	-0.255 -0.301 -0.332 -0.336		>200 at 28	(28) 1.538
212		15.0	-0.285 -0.362	3.5	>200 at 36.2	(36) 1.547
② 214		14.9	-0.222 -0.238 -0.270 -0.284		120-173 ↑	1.535
216		14.6	-0.278 ? +1.030	3.3	>200 at 41	(40) 1.538
217		11.2	+1.014 -0.237 -0.239 -0.248		90-188 ↑	1.549
② 227		14.6	-0.336 -0.337	3.7	>200 at 28.5	(28) 1.549
132		18.8	-0.277 -0.298 -0.286 -0.296		>200 at 32.7	(33) 1.551
133		15.1	-0.264 -0.378	3.3	>200 at 51H	(51) 1.562

② These cells showed Hz on overcharge 7/24-29 (evidenced by very slow p decay on open circuit, also analysis of gas). So did cell 203 which was OK on 8/1-5 overcharge.

- a) of 7 cells that became more negative on reversal all went over 200 PSI on -5°C charge
than -0.4V
- b) of 6 cells that continued to slowly become more negative but below -0.4V to full 5 AH reverse
3 stayed below 200 PSI and 3 exceeded 200 PSI on overcharge

8/23/66

Leaching of K_2CO_3 in electrolyte.
 PFR CE IT K_2CO_3

Cell
 No 5/6 6/13 6/17 6/20 7/20 7/1 8/1

200		C1.4	C		C1.1		
201		C2.6	C				
202		C2.6	C		C0.5		
203		C3.5	C		C1.6		
204	6.6	C2.8	C		C2.4		
205	6.6	C	C				
206		C	C3.6		C2.4		
207		C	C2.1		2.4		
208		C	C1.9		C1.9		
209		C	C2.5		1.5		
210			C6.2		C3.9		
211			C5.2		C3.0	C2.3	1.4
212			C		C6.9	C4.4	2.2
213			C6.3		C3.3		
214			C3.6		C1.9	C2.9	1.0
215			C5.2		C1.5		
216			C5.2		C3.2	C2.1	1.9
217			C5.2		2.6	C	3.0
218			C5.8				
219			C6.1				
220			C6.2		C		
221			C5.2		C5.4		
222							
223			C5.6				
224			C5.6	5.6			
225			C5.6	5.6			
227			C	5.4	C5.2	C2.8	2.1
228			C	5.6			
229			C	5.2			
230			C	5.8			

"C" Electrolyte conditioning with "low carbonate" electrolyte.

500.00 76838

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