DOE/ET/29345--75

DE-AC02-78ET29345-37

DEVELOPMENT OF ZINC-BROMINE BATTERIES

FOR UTILITY ENERGY STORAGE

MONTHLY PROGRESS REPORT

August 1981

R.A. PUTT

GOULD INC.

GOULD LABORATORIES ENERGY RESEARCH

40 GOULD CENTER

ROLLING MEADOWS

ILLINOIS 60008

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MASTER

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PREPARED FOR

THE U.S. DEPARTMENT OF ENERGY

UNDER CONTRACT NO. DE-AC02-78ET29345

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EXB

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Technical Progress Report
August 28, 1981
Page Two

MASTER

SUMMARY

TASK 5 - COMPONENT DEVELOPMENT AND ACCEPTANCE

The accelerated stress testing of the bipolar plate material and the cycle testing of 3 Wh cells proceeds uneventfully; over 350 cycles have accrued in the latter test, with steady energy efficiencies in the low 70's. These remain as the only two unachieved milestones of this task.

TASK 6 - HARDWARE DESIGN AND CONSTRUCTION

Construction of the two submodules for external testing proceeds on schedule. The first is to be delivered to Sandia mid-September, the second to SRI early November.

TASK 7 - TESTING

Testing of the module continues on a one cycle per day basis with average energy efficiencies of 55-60%. Thirty-two cycles have accrued to date with no down time or unavailability due to maintenance or repairs.

TASK 5 - COMPONENT DEVELOPMENT AND ACCEPTANCE

5A ELECTRODE: CYCLE TESTING

MILESTONE 2 - 1500 CYCLES ON ELECTRODE (3 Wh TEST CELLS)

The cycle testing described below is in accordance with the Electrode Test Guidelines - Revision 1, August 1980. In addition, the loading has been increased to 200 mAh/cm² (current density: 30 mA/cm²), and a dendrite inhibitor, ZDS-11, has been added to the electrolyte.

Cells 131-134 continue to cycle steadily with a minimal amount of maintenance involving an occasional pH adjustment (only twice so far in the life of the cells), or bromine addition.

A total of 360 cycles has been accumulated for cells 131-133 and 350 cycles for cell 134. The energy efficiencies are still in the 70's (see Figures 1A - 1D) with no noticeable signs of deterioration as shown by linear regression analysis (see Table 1). A slight negative slope was reported last month for the performance of cells 131 and 133, but the trend was not noticeable this month. This month, cell 134 shows a slight upward trend in energy efficiency, but we believe this trend is not very significant and will probably disappear as additional data are gathered.

5B ELECTRODE: CHEMICAL STABILITY

MILESTONE 3 - PERFORM ACCELERATED TESTING

(Based on Test Guidelines of September, 1980, Rev. 1)

Cell stacks 1-5 of the constant temperature/variable current portion of the experiment were disassembled after 8 months of testing. Each electrode was tested by subjecting it to a pressure of 42 psi. There were no failures.

The constant current/variable temperature portion of the experiment has been interrupted due to a power supply and two oil baths failing. The testing will resume upon replacement of these parts.

TASK 6

MILESTONE 10A - BUILD AND DELIVER SUBMODULE TO SANDIA (DOE)

Preparations are underway for a submodule to be sent to Sandia Labs for independent testing. This submodule will have a nominal rating of 0.8 kW due to limitations in the testing equipment at Sandia.

Submodule construction and delivery will be completed before the anticipated delivery date of September 14, 1981.

Materials are being gathered and initial work has begun on the submodule. The following is a summary of the cell components and their present status.

- Electrodes/Frames: The electrodes have been bonded to the frames using the hot air gun. The positive substrate and negative grids have also been added.
- Separators: The previous batch of separators prepared for cell assembly has been rejected. The coating used to minimize shunt currents failed to penetrate fully into the separator pores leaving shunt current paths available. A new batch of separators has been punched and cleaned and will be coated shortly. New material will be used for the coating.
- Threaded Rods, End Electrodes, End Plates, Backing Plates, and Springs: All are ready for cell assembly.

The flow system for storing and delivering electrolyte to the cell has been designed. All of the material is on hand with the exception of the electrolyte reservoirs. Special rotational molds are under construction to produce totally enclosed seamless tanks that will bond directly to the plumbing system. These new tanks will improve safety by reducing the chances for electrolyte leakage.

These tanks will be delivered shortly, and the electrolyte flow system will be completed shortly thereafter.

TASK 6

MILESTONE 10B - BUILD AND DELIVER SUBMODULE TO SRI

Preparations are underway for a second submodule to be sent to SRI for independent testing. This submodule will have a nominal capacity of 1 kW (8 kWh). Delivery is expected during October 1981 on a date yet to be confirmed.

Materials are being gathered for the submodule construction. The following is a summary of the cell components and their present status.

- Electrodes: Parts are on order with a confirmed delivery date of September 1, 1981. They will then be cleaned, heat treated and bonded to the frames.
- Frames, Positive Substrates, Grids, Threaded Rods, End Electrodes, End Plates, Backing Plates, and Springs: All parts are on hand, ready for cell assembly.
- Separators: The punching and cleaning of the parts are complete. The coating will be applied in a batch with those parts being prepared for the cell to be delivered to Sandia.
- Electrolyte Flow System: All material is on hand except the electrolyte reservoirs. These will be rotationally molded with those prepared for the cell to be delivered to Sandia. The flow system will be assembled shortly thereafter.

TASK 7 - TESTING

MILESTONE 10 - PERFORM PARAMETRIC TESTING ON 10 kW MODULE

Cycling of the 10 kW module continues on a one cycle per day basis. The module has accrued over 32 cycles (Figure 2) with a 100% operational availability factor (Table 2). There are three sets of data (Table 3) that can be evaluated from the cycle testing.

The first set (I) of data was used to establish a baseline. It is based on a loading of 500 Ah (125A - 4 hour). Since there are 5 parallel strings of submodules, the 500 Ah module loading is equivalent to a submodule loading of 100 Ah (25A - 4 hour). Therefore, the module baseline efficiencies can be compared to previous submodule cycling at a 100 Ah (25A - 4 hour) loading. The average voltaic, coulombic, and energy efficiencies for a 1 kW submodule were $75.67\% \pm 0.90$, $75.85\% \pm 1.62$, and $57.38\% \pm 1.80$ respectively (May, 1981 monthly report figure 2; the standard deviations were recomputed on a 95% confidence limit). Upon performing a t-test (95% confidence limit) between data set I and the comparison submodule, a significant effect is present in the coulombic efficiencies. This significance is misleading, though, because the comparison submodule was cycled at a higher temperature than the module. This would have an effect on the coulombic efficiency. Therefore, the efficiencies of the comparison submodule and the baseline data of the module can be considered to be similar. This is an important fact because any problems present at the submodule stage have not been magnified by the scale up.

The second set (II) of data is based on a loading of 600 Ah (150A - 4 hour). Ten gallons of polybromide had also been added due to a high bromine concentration (17 g/l) at the end of charge. Upon performing a t-test (95% confidence limit) between data sets I and II there was a significant effect on both the voltaic and coulombic efficiencies. The voltaic efficiency in data set II shows an $\sim 10\%$ decrease as compared to data set I. This is partially due to the increased amount of polybromide in the system. There is an increase in internal resistance with more polybromide entering the submodules. With cycle 18, the polybromide flow was decreased. Cycles since then have shown an $\sim 4\%$ increase in voltaic efficiency (Figure 2). The significant increase in coulombic efficiency ($\sim 4\%$) can be attributed to a decrease in aqueous phase bromine concentration (~ 7 g/l end of charge on the positive side).

Cycles 21 and 22 had a considerable decrease ($\sim 7\%$) in coulombic efficiency. This was due to excessive (~ 20 gal.) electrolyte crossover from the positive to the negative sides. For this reason, it was thought that by causing an electrolyte crossover from the negative to the positive sides, there would be an increase in coulombic efficiency. Test data set III (Table 2) shows the average efficiencies with electrolyte crossover from the negative to the positive sides. A t-test (95% confidence limit) on data sets II and III showed no significant effect in the coulombic efficiency. There was, however, a significant effect in the voltaic efficiency. This, however, could have been a result of the polybromide flow rate being decreased. Therefore, the electrolyte crossover from the negative to the positive sides showed no effect.

In conclusion, what we have thus far learned is:

- The module's performance is comparable to a submodule.
- Electrolyte crossover from the negative to the positive side has no effect, but the reverse causes a significant decrease in coulombic efficiency.

Cycling of the module will continue on a one cycle per day basis until the system controller has been completed and installed.

/ss

attachments

FIGURE 1A

+	VOLTAIC	COULOMBIC	ENERGY	+
+	(%)	(%)	(%)	+
+	90.11	84.33	76.04	+
+	STD DEV 1.75	5.11	4.47	+
+	NUMBER OF CYCLES TO DATE= 72 X 5			+
+	TODAY'S DATE IS 8/20/1981			+

EFFICIENCY VS. CYCLE NO. (131 3.2WH TEST CELL)

V : VOLTAIC EFFICIENCY
C : COULOMBIC EFFICIENCY
E : ENERGY EFFICIENCY

FIGURE 1B

+	VOLTAIC	COULOMBIC	ENERGY	+
+	(%)	(%)	(%)	+
+	88.36	80.90	71.58	+
+	STD DEV 2.03	4.73	4.39	+
+	NUMBER OF CYCLES TO DATE= 72 x5			+
+	TODAY'S DATE IS 8/20/1981			+

EFFICIENCY VS. CYCLE NO. (#132 3.2WH TEST CELL)

V : VOLTAIC EFFICIENCY
 C : COULOMBIC EFFICIENCY
 E : ENERGY EFFICIENCY

FIGURE 1C

+	VOLTRIC	COULOMBIC	ENERGY	+
+	(%)	(%)	(%)	+
+	90.17	82.71	74.64	+
+	STD DEV 1.74	4.41	3.99	+
+	NUMBER OF CYCLES TO DATE= 72 x5			+
+	TODAY'S DATE IS 8/20/1981			+

EFFICIENCY VS. CYCLE NO. (133 3.2WH TEST CELL)

V : VOLTRIC EFFICIENCY
C : COULOMBIC EFFICIENCY
E : ENERGY EFFICIENCY

FIGURE 1D

+	VOLTAIC	COULOMBIC	ENERGY	+
+	(%)	(%)	(%)	+
+	91.39	84.21	77.03	+
+	STD DEV 1.83	4.21	4.07	+
+	NUMBER OF CYCLES TO DATE= 70 x5			+
+	TODAY'S DATE IS 8/20/1981			+

EFFICIENCY VS. CYCLE NO. (#134 3.2WH TEST CELL)

V : VOLTAIC EFFICIENCY
 C : COULOMBIC EFFICIENCY
 E : ENERGY EFFICIENCY

TABLE 1

ELECTRODE TEST CELL EFFICIENCY (3 Wh CELLS)

LINEAR REGRESSION - ENERGY EFFICIENCY*

	Regression Coefficient	Intercept	F-Value for Regression Coefficient
Cell 131 Cycles 10-360	6.05×10^{-4}	75.6	.01
Cell 132 Cycles 10-360	2.55×10^{-3}	70.4	.15
Cell 133 Cycles 10-360	-3.90×10^{-3}	75.2	.40
Cell 134 Cycles 10-350	1.52×10^{-2}	74.1	5.30**

* Every 10th cycle was included in the analysis.

** Significant at the 95% confidence level: $F_{0.05}(1,33) = 4.14$.

FIGURE 2

10KW MODULE

TABLE 2

RELIABILITY ANALYSIS REPORT
TODAYS DATE: 08/20/81

MODULE NUMBERA1
STARTING DATE07/07/81

TOTAL ELAPSED TIME. 1,056.00
TOTAL OPERATING HOURS 228.39
TOTAL RUNS IN 32
TOTAL CYCLES IN 32
MODULE SERVICE FACTOR 21.63%
MODULE UTILITY AVAILABILITY FACTOR.100.00%
MODULE OPERATIONAL AVAILABILITY FACTOR. .100.00%
MODULE ACTIVITY RATE. 21.63%
MODULE IDLE RATE. 78.37%
FORCED OUTAGE RATE. 0.00%
CYCLE ACHIEVEMENT RATE.100.00%
TOTAL DOWNTIME FOR MAINTENANCE. 7.10
TOTAL DOWNTIME FOR REPAIR 0.00
TOTAL DOWNTIME FOR REPAIR AND MAINT . . . 7.10
RESERVE SERVICE HOURS827.61
TOTAL FORCED OUTAGE EVENTS. 0
TOTAL MAINTENANCE EVENTS. 71

* * MAINTENANCE EVENTS DISTRIBUTION * *

ITEM	EVENTS	% OF EVENT	VOLUME
PH MEASUREMENT	19	26.76%	
FLON ADJ	1	1.41%	
BR ADDITIONS	0	0.00%	BR ADDED: 0ML
HBR ADDITIONS	8	11.27%	HBP ADDED: 3550ML
E-LYTE ADDED	1	1.41%	E-LYTE ADDED: 20GAL
BR CONC. POS	21	29.58%	
BR CONC. NEG	21	29.58%	

TABLE 3

★	Number of Observations	Voltaic	Efficiencies (%)		Energy
				Coulombic	
I	8	75.86±0.96	79.38±1.36		60.25±0.99
II	9	65.44±1.59	83.67±1.28		54.89±1.46
III	7	67.86±0.83	83.00±1.92		56.43±1.67
(95% Confidence Limits)					

* I Loading 500 Ah (125A - 4 hour)

II Loading 600 Ah (150A - 4 hour); added 10 gal. polybromide.

III Loading 600 Ah (150A - 4 hour); added 20 gal. electrolyte, crossover
from negative to positive sides.

APPENDIX

ASSESSMENT OF ALTERNATIVE POSITIVE ELECTRODE SUBSTRATES

An investigation into alternatives to the carbon felt positive substrate was initiated this month.

In the zinc-bromine battery, carbon felt exhibits favorable electrochemical properties due to its large surface area, however, its structural properties cause some undesirable effects, i.e., it tends to entrap large quantities of polybromide, it inhibits the flow of electrolyte through it requiring higher pumping power, and it sloughs off carbon fibers that occasionally clog flow channels. For these reasons alternatives were investigated.

EXPERIMENT

The two substrates investigated this month were a ribbed carbon plate and a ruthenized titanium mesh/carbon plate composite (See Figure A1). The ruthenized Ti mesh was bonded to the carbon plate with a conductive adhesive at different orientations with respect to the flow. All substrates were cycled in a 3.2 Wh cell at a flowrate of 0.6-0.7 ml/s. After approximately 2-3 hours of charging, the bromine concentration in the positive reservoir was determined. E/I measurements were taken and then plotted. (See Figures A2 - A4.)

In making the composite electrodes (B, C and D₁), the adhesive was usually applied to the whole area of contact, masking the area underneath the mesh and reducing the carbon plate's activity. An electrode comparable to D₁ was constructed (D₂), but the adhesive was applied sparingly leaving approximately 90% of the electrode area underneath the mesh exposed.

From the E/I curves presented, the D₂ electrode appears to exhibit the best electrochemical properties (lowest overpotential). The ribbed carbon (A) also performs well (Figure 1), but the bromine concentration was 12g/l, whereas D₂'s performance was achieved at a bromine concentration of 7g/l.

The initial data is promising and it appears that a replacement for the carbon felt will be found. Other alternative positive substrates are being obtained and will be assessed when they become available.

ALTERNATIVE POSITIVE ELECTRODES

A. RIBBED CARBON PLATE

C. RUTH. MESH/ CARBON PLATE
COMPOSITE (lattice perpen-
dicular to flow) B. RUTHENIZED TITANIUM
MESH/ CARBON PLATE COMPOSITE
(lattice parallel to flow) D₁. like C, but electrode
turned 180°.
D₂. like D₁, but adhesive
only at corners of mesh

FIGURE A2

E/I CURVE FOR
ELECTRODES (A) AND (C)

FIGURE A3

E/I CURVE OF ELECTRODE (B)

FIGURE A4

E/I CURVE FOR
ELECTRODES (D_1) AND (D_2)

PROJECT STATUS REPORT

September 25, 1981
Report No. 37
Report Period: August 1981

Contract Title and Number:

Zinc-Bromine Batteries for Utility Energy Storage
DE-AC02-78ET29345

Contractor Name:

Gould Laboratories Energy Research
40 Gould Center
Rolling Meadows, Illinois 60008

Contract Period: 1 September 1978 - 31 October 1981

1. Task 5 - Component Development and Acceptance

The accelerated stress testing of the bipolar plate material and the cycle testing of 3Wh cells proceeds uneventfully; over 350 cycles have accrued in the later test, with steady energy efficiencies in the low 70's. These remain as the only two unachieved milestones of this task.

Task 6 - Hardware Design and Construction

Construction of the two submodules for external testing proceeds on schedule. The first is to be delivered to Sandia mid-September, the second to SRI early November.

Task 7 - Testing

Testing of the module continues on a one cycle per day basis with average energy efficiencies of 55-60%. Thirty-two cycles have accrued to date with no down time or unavailability due to maintenance or repairs.

5. Summary Assessment and Forecast:

Contract costs are in line with the current plan; no overruns are expected at this time.

Five copies of this report submitted to:

Mr. T. Costa
U. S. Department of Energy - Chicago Operations Office
Contracts Management Office
9800 South Cass Avenue
Argonne, Illinois

with accompanying forms in duplicate: Nos. 536, 535, 533, ERDA No. 426 and
Technical Progress Report for June 1981.

Single issue of the same documentation has been sent to:

William Webster, DOE, Washington, DC
William R. Frost, DOE, Argonne, Illinois
William C. Spindler, EPRI, Palo Alto, California
Gould Contract File

Technical Progress Report only sent to:

Albert Landgrebe, DOE, Washington, DC
James R. Birk, EPRI, Palo Alto, CA
Sam Perone, Purdue University, West Lafayette, IN
Stan Basin, Science Applications, Inc., Palo Alto, CA
Uziel Landau, CWRU, Cleveland, OH
J. R. Selman, IIT, Chicago, IL
Harry Balzan, Chattanooga, TN
John Appleby, EPRI, Palo Alto, CA
Robert Clark, Sandia Laboratories
Elton Cairns, LBL, Berkeley, CA

William J. Brown
Director, Contract Development

/ng

CONTRACT MANAGEMENT SUMMARY REPORT

11/78) TOTAL PROGRAM

1. Contract Identification Development of Zinc-Bromine Batteries for Utility Energy Storage	2. Reporting Period 8/1/81 through 8/31/81	3. Contract Number DE-AC02-78ET29345
4. Contractor (Name and Address) GOULD INC., GOULD LABORATORIES ENERGY RESEARCH 40 GOULD CENTER ROLLING MEADOWS, ILLINOIS 60008		5. Contract Start Date 9/1/78
		6. Contract Completion Date 10/31/81

7. Months	N	D	J	F	M	A	M	J	J	A	S	O					8. FY 81
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9. Cost Status														g. Cost Plan Date 10/79			
a.	-2500															h. Planned Costs Prior FYs 1,761,245	
																i. Actual Costs Prior FYs 1,872,383	
																j. Total Estimated Costs for Contract 2,567,215	
																k. Total Contract Value 2,567,215	
b. B&R Numbers	1500															l. Unfilled Orders Outstanding 12,600	
Accrued Costs	c. Planned	52	123	53	53	57	53	54	56	53	53	57	52	2,153	total		m. Estimate for Subsequent Reporting Period 53,000
	d. Actual	65	85	78	86	113	47	36	52	50	44						
	e. Variance	(13)	(38)	(125)	(33)	(56)	6	18	4	3	9						
	f. Cum. Variance	(206)	(168)	(193)	(226)	(282)	(276)	(258)	(254)	(251)	(242)						

10. Manpower Status (Direct Labor)														e. Manpower Plan Date 10/79			
a.	400															f. Planned Manpower Prior FYs 278.4	
																g. Actual Manpower Prior FYs 277.4	
																h. Total Estimated Manpower for Contract 417.2	
																i. Total Contract Manpower 417.2	
Manpower	b. Planned	290.3	301.2	312.4	323.9	334.8	346.0	357.5	368.4	379.6	393.2	404.1	417.2				
	c. Actual	287.2	297.5	308.1	318.6	331.1	342.0	350.1	359.9	370.0	378.3						
	d. Variance	3.1	3.7	4.3	5.3	3.7	4.0	7.4	8.5	9.6	14.9						

11. Major Milestone Status															
a.	Refer to Form 535 Attached														
b.															
c.															
d.															
e.															
f.															
g.															
h.															
i.															

12. Remarks															
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13. Signature of Contractor's Project Manager and Date <i>Ronald A. Pitt 9/25/81</i>	14. Signature of Government Technical Representative and Date
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CONTRACT MANAGEMENT SUMMARY REPORT

DOE Share

1. Contract Identification Development of Zinc-Bromine Batteries for Utility Energy Storage	2. Reporting Period 8/1/81 through 8/31/81	3. Contract Number DE-AC02-78ET29345
4. Contractor (Name and Address) GOULD INC, GOULD LABORATORIES ENERGY RESEARCH 40 GOULD CENTER ROLLING MEADOWS, ILLINOIS 60008	5. Contract Start Date 9/1/78	6. Contract Completion Date 10/31/81

7. Months	N	D	J	F	M	A	M	J	J	A	S	O				8. FY 81
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9. Cost Status															g. Cost Plan Date	
<p>Funding \$1,037,805</p> <p>\$1,016,553</p> <p>\$1,062,372</p> <p>807,450</p> <p>1,062,372</p> <p>Subtotal</p>															h. Planned Costs Prior FYs 673,000	
															i. Actual Costs Prior FYs 807,450	
															j. Total Estimated Costs for Contract	
															k. Total Contract Value 1,062,372	
l. Unfilled Orders Outstanding																
m. Estimate for Subsequent Reporting Period																
Accrued Costs																
c. Planned																
d. Actual																
e. Variance																
f. Cum. Variance																

10. Manpower Status (Direct Labor)															e. Manpower Plan Date	
															f. Planned Manpower Prior FYs	
															g. Actual Manpower Prior FYs	
															h. Total Estimated Manpower for Contract	
															i. Total Contract Manpower	
Manpower																
b. Planned																
c. Actual																
d. Variance																

11. Major Milestone Status														
a. Refer to Form 535 Attached														
b.														
c.														
d.														
e.														
f.														
g.														
h.														
i.														

12. Remarks														
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13. Signature of Contractor's Project Manager and Date Ronald Akut 8/15/81										14. Signature of Government Technical Representative and Date				
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CONTRACT MANAGEMENT SUMMARY REPORT

EPR1 Share

1. Contract Identification Development of Zinc-Bromine Batteries for Utility Energy Storage	2. Reporting Period <u>8/1/81</u> through <u>8/31/81</u>	3. Contract Number DE-AC02-78ET29345
4. Contractor (Name and Address) GOULD INC., GOULD LABORATORIES ENERGY RESEARCH 40 GOULD CENTER ROLLING MEADOWS, ILLINOIS 60008		5. Contract Start Date 9/1/78
		6. Contract Completion Date 10/31/81

7. Months	N	D	J	F	M	A	M	J	J	A	S	O				8. FY
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9. Cost Status															g. Cost Plan Date																																																									
<div style="display: flex; justify-content: space-between;"> <div style="width: 10%;">a.</div> <div style="width: 80%;"> </div> <div style="width: 10%;"> h. Planned Costs Prior FYs 470,000 i. Actual Costs Prior FYs 476,907 j. Total Estimated Costs for Contract k. Total Contract Value l. Unfilled Orders Outstanding </div> </div>																																																																								
<div style="display: flex; justify-content: space-between;"> <div style="width: 10%;">b. B&R Numbers</div> <div style="width: 80%;"> <div style="text-align: right; margin-bottom: 5px;">Subtotal</div> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td>c. Planned</td> <td>14</td><td>33</td><td>14</td><td>14</td><td>15</td><td>14</td><td>15</td><td>35</td><td>34</td><td>34</td><td>35</td><td>34</td><td>291</td> </tr> <tr> <td>d. Actual</td> <td>15</td><td>17</td><td>19</td><td>21</td><td>27</td><td>8</td><td>6</td><td>27</td><td>24</td><td>21</td><td></td><td></td><td></td> </tr> <tr> <td>e. Variance</td> <td>(1)</td><td>16</td><td>(5)</td><td>(7)</td><td>(12)</td><td>6</td><td>9</td><td>8</td><td>10</td><td>13</td><td></td><td></td><td></td> </tr> <tr> <td>f. Cum. Variance</td> <td>(19)</td><td>(3)</td><td>(8)</td><td>(15)</td><td>(27)</td><td>(21)</td><td>(12)</td><td>(4)</td><td>6</td><td>19</td><td></td><td></td><td></td> </tr> </table> </div> <div style="width: 10%;"> m. Estimate for Subsequent Reporting Period </div> </div>															c. Planned	14	33	14	14	15	14	15	35	34	34	35	34	291	d. Actual	15	17	19	21	27	8	6	27	24	21				e. Variance	(1)	16	(5)	(7)	(12)	6	9	8	10	13				f. Cum. Variance	(19)	(3)	(8)	(15)	(27)	(21)	(12)	(4)	6	19					
c. Planned	14	33	14	14	15	14	15	35	34	34	35	34	291																																																											
d. Actual	15	17	19	21	27	8	6	27	24	21																																																														
e. Variance	(1)	16	(5)	(7)	(12)	6	9	8	10	13																																																														
f. Cum. Variance	(19)	(3)	(8)	(15)	(27)	(21)	(12)	(4)	6	19																																																														

10. Manpower Status (Direct Labor)																	e. Manpower Plan Date
a.																	f. Planned Manpower Prior FYs
b. Planned																	g. Actual Manpower Prior FYs
c. Actual																	h. Total Estimated Manpower for Contract
d. Variance																	i. Total Contract Manpower

11. Major Milestone Status		
a.	Refer to Form 535 Attached	
b.		
c.		
d.		
e.		
f.		
g.		
h.		
i.		

12. Remarks

13. Signature of Contractor's Project Manager and Date <i>Ronald O'Neil</i> 8/12/81	14. Signature of Government Technical Representative and Date
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MILESTONE SCHEDULE AND STATUS REPORT

Form EHS-35
(1-78)FORM EHS-35
(1-78)

1. Contract Identification Development of an 80KWH zinc bromine battery for utility energy storage		2. Reporting Period 8-1-81 through 8-31-81		3. Contract Number DE-AC02-78ET29345	
4. Contractor (name, address) Gould Inc., Gould Laboratories-Energy Research 40 Gould Center Rolling Meadows, Illinois 60008				5. Contract Start Date November 1, 1979	
				6. Contract Completion Date October 31, 1981	

Identification Number	8. Reporting Category (e.g., contract line item or work breakdown structure element)	9. Fiscal Years and Months														10. Percent Complete											
		1979		1980												1981											a) Planned
TASK	MILESTONE	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O		
5	COMPONENT DEVELOPMENT AND ACCEPTANCE																										
Lu 5A	ELECTRODE: CYCLE TESTING																										
	1. Establish test and evaluation guidelines																									100	100
	2. 1500 cycles on electrode																									95	92
5B	3. Report on results and assess acceptability																									0	0
	ELECTRODE: CHEMICAL STABILITY																										
	1. Develop mathematical model for accelerated test																									100	100
	2. Select conditions for testing																									100	100
5C	3. Perform accelerated test																									95	68
	4. Report on results and assess acceptability																									0	0
	ELECTRODE: ELECTRODE TREATMENT																										
	1. Select electrode treatment																									100	100

Remarks	
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12. Signature of Contractor's Project Manager and Date 9-25-81	13. Signature of Government Technical Representative and Date
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DE Form C-10-535
(1-78)

MILESTONE SCHEDULE AND STATUS REPORT

 FORM APPROVED
GSA NO. 48-010

1. Contract Identification Development of an 80kWh zinc bromine battery for utility energy storage		2. Reporting Period 8-1-81 through 8-31-81		3. Contract Number DE-AC02-78ET29345																							
4. Contractor Name and Address Gould Inc., Gould Laboratories-Energy Research 40 Gould Center Rolling Meadows, Illinois 60008		5. Contract Start Date November 1, 1979		6. Contract Completion Date October 31, 1981																							
7. Identification Number	8. Reporting Category (e.g., contract line item or work breakdown structure element)	9. Fiscal Years and Months														10. Percent Complete											
		1979		1980												1981											
TASK	MILESTONE	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	a) Planned	b) Actual
Attia 5D	ELECTROLYTE: ELECTROACTIVE SPECIES INVENTORY																										
	1. Characterize transport processes																								100	100	
	2. Specify design electrolyte volumes & concentrations																								100	100	
5E	ELECTROLYTE: DENDRITE INHIBITOR STABILITY																										
	1. Characterize loss mechanisms																								100	100	
	2. Specify means to maintain concentration																								100	100	
5F	SPACING RIBS																										
Heyland	1. Specify design																								100	100	
5G	CELL CASING																										
Heyland	1. Establish flow specifications																								100	100	
	2. Specify frame design																								100	100	

11. Remarks

12. Signature of Contractor's Project Manager and Date

9-25-81

13. Signature of Government Technical Representative and Date

MILESTONE SCHEDULE AND STATUS REPORT

Form DE-535
(1-78)FORM APPROVED
MAY 80 BY R. 01W

1. Contract Identification Development of an 80kWh zinc bromine battery for utility energy storage		2. Reporting Period 8-1-81 through 8-31-81		3. Contract Number DE-AC02-78ET29345																									
4. Contractor (Name, address) Gould Inc., Gould Laboratories-Energy Research 300 Gould Center Rolling Meadows, Illinois 60008		5. Contract Start Date November 1, 1979		6. Contract Completion Date October 31, 1981																									
7. Identification Number	8. Reporting Category (e.g., contract line item or work breakdown structure element)	9. Fiscal Years and Months												10. Percent Complete															
		1979		1980												1981													
TASK	MILESTONE	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	a) Planned	b) Actual		
5H Heyland	END PLATES																												
	1. Establish design																								100	100			
5I Heyland	PLUMBING																												
	1. Build flow system																								100	100			
	2. Perform flow and pressure drop study																								100	100			
	3. Prepare final design																								100	100			
Atia 5J	BROMINE STORAGE																												
	1. Design bromine storage system for 80kWh module																									100			

11. Remarks

12. Signature of Contractor's Project Manager and Date
9-25-81

13. Signature of Government Technical Representative and Date

MILESTONE SCHEDULE AND STATUS REPORT

1. Contract Identification Development of an 80KWh zinc bromine battery for utility energy storage															2. Reporting Period 8-1-81 through 8-31-81					3. Contract Number DE-AC02-78ET29345								
4. Contractor Name, Address Gould Inc., Gould Laboratories-Energy Research 50 Gould Center Rolling Meadows, Illinois 60008															5. Contract Start Date November 1, 1979					6. Contract Completion Date October 31, 1981								
7. Identification Number	8. Reporting Category (e.g., contract line item or work breakdown structure element)	9. Fiscal Years and Months																									10. Percent Complete	
		1979		1980												1981											a) Planned	b) Actual
TASK	MILESTONE	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O			
6 Heyland	HARDWARE DESIGN AND CONSTRUCTION																											
	1. Design #2 submodule																									100	100	
	2. Approval on design #2 submodule																									100	100	
	3. Build #2 submodule																									100	100	
	4. Design #3 submodule																									100	100	
	5. Approval on design #3 submodule																										100	100
	6. Build #3 submodule																										100	100
	7. Finalize module design																										100	100
	8. Approval on module design																										100	100
	9. Build 80KWh module Cell stacks																										100	100
	Electrolyte formulation																									100	100	
	Plumbing																									100	100	
	Final assembly																									100	100	
	Build and deliver #4 submodule to DOE/EPRI																									33	33	

11. Remarks	
12. Signature of Contractor/Project Manager and Date <i>[Signature]</i> 9-25-81	13. Signature of Government Technical Representative and Date

MILESTONE SCHEDULE AND STATUS REPORT

FORM APPROVED
JAN 80 24-610W

1. Contract Identification Development of an 80kWh zinc bromine battery for utility energy storage		2. Reporting Period 8-1-81 through 8-31-81		3. Contract Number DE-AC02-78ET29345																							
4. Contractor (name, address) Gould Inc., Gould Laboratories-Energy Research 40 Gould Center Rolling Meadows, Illinois 60008		5. Contract Start Date November 1, 1979		6. Contract Completion Date October 31, 1981																							
7. Identification Number TASK	8. Reporting Category (e.g., contract line item or work breakdown structure element) MILESTONE	9. Fiscal Years and Months																						10. Percent Complete			
		1979		1980												1981										a) Planned	b) Actual
		N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O		
7	TESTING																										
10	1. Identify losses in #1 submodule																									100	100
	2. Identify design improvements in #2 submodule																									100	100
	3. Identify design improvements for #3 submodule																									100	100
	4. Identify design improvements for module stacks																									100	100
	5. Establish parametric test program																									100	100
	6. Perform parametric testing on 8kWh submodule																										
	7. Establish cycle test guidelines																									100	100
	8. 200 cycles on submodule																									100	100
	9. Establish testing program for module																									100	100
	10. Perform parametric testing on module.																									75	75
8	Review Meetings																										
	Reports																										

11. Remarks	
12. Signature of Contractor's Project Manager and Date <i>[Signature]</i> 9-25-81	13. Signature of Government Technical Representative and Date