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Development of Bushings and Bearings for Use in Hot-Brine Pumps

QUARTERLY TECHNICAL PROGRESS REPORT NO. 6

SOLAR TURBINES INTERNATIONAL

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PERIOD: MARCH 1 to JUNE 1, 1981

Prepared for

**BROOKHAVEN NATIONAL LABORATORY
Upton, New York 11973**

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MGW

FOREWORD

This quarterly technical progress report covers work performed under Contract No. ENL 490656-S over the period March 1, 1981 to June 1, 1981. This contract with Solar Turbines International, An Operating Group of International Harvester, San Diego, California is sponsored by Brookhaven National Laboratory under Department of Energy prime Contract No. EY-76-C-02-0016.

Brookhaven's authorized liaison representative is Dr. D. Van Rooyen. There was a change in Solar's Principal Investigator on this program during this period due to the resignation of Mr. David P. Huey. Mr. George Hosang, Solar's Tribologist, has been assigned as Mr. Huey's replacement. Mr. Kirby V. Pool, Coop Engineer, will be in charge of day-to-day program activities. Mr. A. R. Stetson, Manager of Materials Technology at Solar, continues as Program Technical Director.

Solar's internal report number is SR81-R-4842-17.

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SYNOPSIS

- Phase I, Problem Definition is complete. Phase II, 100-hour Screening Tests, is 80 percent completed with promising results.
- Significant testing procedure modifications have been made and are presented.

Key Words: Geothermal, brine, pump, bearing, bushing, lubrication, journal bearing, wear.

1

INTRODUCTION

The exploitation of geothermal resources in the United States and other nations often requires that naturally heated subterranean brines be pumped to the surface from depths of up to 6000 feet underground while minimizing heat losses and maintaining sufficient fluid pressure to prevent boiling. At the East Mesa geothermal resource in California's Imperial Valley the liquid brine can be produced at the wellhead at approximately 365°F and 250 psia in quantities sufficient to extract energy which can be converted to hundreds of megawatts of electrical power. To accomplish this requires the use of downhole brine pumps capable of months of uninterrupted operation to steadily supply the unflashed, uncooled brine to the power conversion plants.

Current brine pump technology is lagging behind other aspects of geothermal energy exploitation technology. Significant problems with bearings used for lineshaft pumps in the geothermal wells have hampered the development of a highly reliable brine pump.

The objective of this research program is to determine the nature of the problems associated with commonly reported premature failures of downhole line shaft pump bearings, especially those tested in the Imperial Valley. Using the information gathered a series of bearing endurance tests will be performed on a variety of candidate bearing materials. These tests will be accomplished using test rigs specially developed to simulate actual geothermal field conditions and to isolate specific bearing wear problems. The program has been divided into tasks as follows:

Phase I Problem Definition, Material Selection, Bearing Design and Rig Construction

Task 1 Field and Literature Review and Analysis

Task 2 Design and Construction of Bearing Test Rigs

Task 3 Review of Phase I progress

Phase II Short Term Material Screening

Task 1 Establish Test Conditions and Initial Tests

Task 2 Test Output and Analysis

Task 3 Review of Phase II Progress

Phase III Bearing Redesign, Material Modification, and Long Term Bearing

2

EXPERIMENTAL PROGRAM

2.1 PHASE II - 100 HOUR RIG TESTS

The main effort during this reporting period was to generate test data, while at the same time, fine tuning the two test rigs and the testing procedure to guarantee reliable, trouble-free operation. One of the modifications which was necessary was the lowering of the temperature and pressure of the brine solution from 365°F and 190 psig (conditions closely simulating East Mesa Geothermal Brine) to 200°F and 8 psig, respectively (see Section 2.2). Also essential was the replacement of the existing packing material by a packing material which performed more reliably under these adverse test conditions (see Table 3). A slight modification of the pneumatic load application rod was necessary to ensure a constant loading of the test bearing. Finally, a method of in-test wear measurement was devised which allows for a running account of wear and makes possible early discontinuation of a test if excessive wear is encountered.

Seven (7) Phase II 100 Hour Screening Tests were completed during this reporting period. The total number of Phase II tests to date is nine. The results are presented and discussed in Section 2.3. The plans for future testing for Phase III are outlined in Section 2.4.

2.1.1 Materials

Bearing Materials

Material selection for this program was made with the properties of surface hardness (to resist scoring by sand particles) and corrosion resistance (to resist the harsh environment) as the main criteria. Also being sought were materials with known good frictional and wear properties. Some of the more promising materials are also some of the more expensive (approaching an order of magnitude more costly than the standard SAE 660 bronze).

This cost, however, is more than made up for if the life of the operating rig can be increased from the present 6-week life, to just twice that, or 12 weeks. The following example illustrates the point.

660 Bronze - 6 week life

Change 50 bronze bearings @ \$20 each	=	\$ 1,000
Replace 250 ft of shaft @ \$11/ft	=	\$ 2,750
Labor to install	=	<u>\$30,000</u>
Total		\$33,750

Cost equivalent to \$5,625 per week

Alternate Bearing Material - 12 week life

Change 50 bearings @ \$200 each	=	\$10,000
Replace 250 ft of coated shaft @ \$15/ft	=	\$ 3,750
Labor to install	=	<u>\$30,000</u>
Total		\$43,750

Cost equivalent to \$3,646 per week

- Total Savings of \$1,979 per week

Details of the bearing materials currently being tested are included in Table 1.

Shaft Materials

A single shaft material, 416 stainless steel at a hardness of Rc 19-22, was used in all Phase II screening test experiments. In selected experiments, however, two coatings, plasma-sprayed Tribaloy® 700 and a Ni-Cr-B-Si alloy were applied to the shaft to assess the influence of journal surface hardness on bearing and shaft wear in general, and to assess the performance of these two coatings in particular. Details of the shaft material and coatings are provided in Table 2. Figures 1 and 2 show the interface between the coating and substrate for the Tribaloy® and Ni-Cr-B-Si coatings, respectively.

2.2 PHASE II - SCREENING TESTS- PROCEDURE

At the beginning of this program it was hoped that all testing could be carried out in an environment closely simulating the actual operating environment of East Mesa Geothermal lineshaft pumps. Unfortunately, while it was possible to complete two 100-hour screening tests in these conditions ($T = 365^{\circ}\text{F}$ and $P = 200$ psig), it was not practical to continue in this manner. Due to excessive and unpredictable leakage which occurred at the shaft packings in the bearing housing, it was necessary to provide full time monitoring, two shifts per day, to keep the rigs running. This exceeded the manpower and funds available for this activity. It was decided that the temperature and pressure should be lowered to some manageable value (i.e., $T = 200^{\circ}\text{F}$, $\Delta P = 8$ psig). This change can be justified by noting that changing the temperature and pressure of the system only effects the viscosity of

Bearing Materials

***Measured values**

Table 2

Shaft Materials

Shaft Material	416SS	Tribaloy® T-700 Coating on 416SS	Ni-Cr-B-Si Coating on 416 SS
Source	Castle Metals San Diego, CA	Flame Spray, Inc. San Diego, CA	Solar
Composition	Nominal 0.15 C (max) 1.25 Mn (max) 1.00 Si (max) 12-14 Cr 0.15 S (min) Fe (balance)	Ni - 50% Mo - 32% Si - 3% Cr - 15%	Ni - 86% Cr - 9.5% Si - 2.5% B - 1.5% Al - 0.5%
Hardness	R _C 19-22* (15N - 70.5)	Vickers - 470* (R _C -47)	Vickers 440 with particles up to Vickers 920* (R _C 44.5 to 67.5) Sonadur - RC68*
Surface Finish	16 μ in. or better	16 μ in. or better	16 μ in. or better
Spray Parameters	Not applicable	<ul style="list-style-type: none"> - Flame sprayed 8-10 mils thick - Porosity: <8% - Plasma arc voltage: 70V - Plasma arc current: 500A - Argon hydrogen plasma gas - Argon carrier gas - Air cooling - Target nozzle distance: 4.5 in. nom - Target velocity: 60-120 sfm - Bond coat: nickel base 	<ul style="list-style-type: none"> - Flame sprayed 8-10 mils thick - Porosity: ~5% - Plasma arc voltage: 50V - Plasma arc current: 400A - Argon hydrogen plasma gas - Argon carrier gas - Air cooling - Substrate Temp: 250°F - Target nozzle distance: 4 in. nom - Target velocity: 50 sfm - Base coat: 89.5 Ni - 5.5 Al - 5 Mo
*Measured values

Figure 1.

Tribaloy T-700 Coating
on 416 SS Substrate

Magnification: 100X

Figure 2.

Ni-Cr-B-Si Alloy
Coating on 416 SS
Substrate

Magnification: 100X

the lubricating fluid (brine). By changing the load accordingly, the bearing characteristic number (Sommerfeld No. S) and thus the minimum film thickness, position of minimum film thickness and maximum film pressure can be made a constant, for example, with the Sommerfeld number defined as

$$S = \left(\frac{r^2}{c} \right) \frac{\mu N}{P} \quad (\text{Ref. 1})$$

and

- r = radius of journal (in.)
- c = radial clearance (in.)
- μ = absolute viscosity (reyn)
- N = relative speed of journal and bearing (rpm)
- P = load per unit of projected area (psi)

We have:

Case 1: $T_1 = 365^\circ\text{F}, \mu = 2.6 \times 10^{-8} \text{ reyn (Ref. 2)}$

$S = 0.0010, W_1 = PA = 50 \text{ lb}_f$

Case 2: $T_2 = 200^\circ\text{F}, \mu_2 = 4.8 \times 10^{-8} \text{ reyn}$

$S = 0.0010, W_2 = ?$

Since all other variables are essentially constant over this range of temperature for the materials we are concerned with:

$$\frac{\mu_1}{W_1} = \frac{\mu_2}{W_2} \quad \text{or} \quad W_2 = \frac{\mu_2}{\mu_1} W_1$$
$$= \frac{4.8 \times 10^{-8} \text{ reyn}}{2.6 \times 10^{-8} \text{ reyn}} 50 \text{ lb}_f = 92.3 \text{ lb}_f$$

Theoretically, with the minimum film thickness and maximum film pressure constant, the wear should be similar. Our subsequent testing and lower temperature and pressure ($T = 200^\circ\text{F}$, $P = 8 \text{ psig}$ and $W = 95 \text{ lb}_f$) have borne this theory out.

As a consequence of our packing problems there have been numerous opportunities to test the different types of packing materials available (see Fig. 3). Knowing that a similar packing problem exists in the field, we have included our results in Table 3. Each type of packing tested was given a rating according to the following scale:

Excellent	- Very little leakage, little or no adjustment necessary
Good	- Little leakage, occasional adjustment necessary
Fair	- Controllable leakage if adjusted frequently
Poor	- Virtually uncontrollable leakage

In addition to the procedural modifications, there were also some slight improvements made to the rig itself. One such improvement was the remachining of the load application rod to prevent the inevitable scale build-up from interfering with its free motion. Another improvement was the addition of a device to measure the amount of total wear while the test is in progress. This allows the early discontinuation of a test if the wear is excessive, and thus prevents loss of significant test time.

Figure 3. Packing Materials (see Table 3 for details)

Table 3

Packing Materials

Material *	Designation	Rating	Comments
1) Grafoil ribbon tight wrap)	G6396	Good	Performs excellently at lower temperatures
2) Grafoil ribbon (loose wrap) (not shown in figure)	G6396	Poor	Completely inadequate with at high pressure (not tested at low pressure)
3) Graphite filament yarn	1625GF	Fair	Good in conjunction with Grafoil
4) Teflon braided yarn	C-1040	Poor	Leaked uncontrollably even at low pressure
5) TFF molded packing sets	CVH Size 1678	Good	If adjusted correctly, performs excellently at lower temperatures (not yet tested at high temperatures)
6) Jacketed "super-seal" plastic packing	Superseal 6J	Fair-Poor	Hardened after exposure to brine

*All packing material supplied by John Crane

2.3 PHASE II - SCREENING TESTS - RESULTS

2.3.1 Test Results

Test numbers 1 and 2 were carried out at the higher temperature and pressure. Test numbers 3 and 4 were run for approximately 5-6 hours at the high temperature and pressure and then completed at the lower temperature and pressure. Test numbers 5 through 9 were carried out at the lower temperature and pressure alone. These results are presented in Table 4. These results are also presented in graphic form in Figure 4.

Figure 5 shows a typical wear pattern in a test bearing (in this case the bearing is the alumina bearing from test 4-2A1). The spiral or angular wear pattern seems to be common to all tested bearings. It is believed to be caused by slight misalignments of the shaft with respect to the bearing. Figure 6 shows a typical wear track on a test shaft (this is the shaft from Test 3-1TB).

Figures 7 through 10 show the wearing surfaces of some of the bearings tested. Note the difference in appearance between the bronze bearing, where the metal appears to be actually smearing across the wear surface and harder bearing surfaces, (the TiB_2 , Al_2O_3 and TC-30 to some extent) which appear to be cleanly ground.

Figures 11 through 15 show the wear on some of the tested shafts used. Figure 14 vividly shows the promise of the Tribaloy® T-700 coating.

2.3.2 Discussion of Results

An absolute requirement of bearing materials is minimum surface damage from sliding. Certain material combinations under a specific set of conditions give smooth or polished surfaces with low and constant friction. Other material couples under identical conditions give high surface damage with high variable friction. Our particular situation requires material combinations which not only produce minimum surface damage by sliding but which are also capable of passing suspended solid particles of 10 to 20 microns in size without appreciable problems. We therefore based our initial material selection on the surface hardness of the materials as well as their wear characteristics.

With the sintered silicon nitride and tungsten carbide bearing materials yet to be tested, the TC-30 material provided by Kyocera, Inc. seems to be the most promising new bearing material tested to date. This material performed excellently when run against the Tribaloy® 700 coated shaft.

Table 4
Test Results
(Sheet 1 of 2)

	Test No. 1-1BB	Test No. 2-2BB	Test No. 3-1TB	Test No. 4-2A1	Test No. 5-1TN
Duration (hr)	100	44.3	100.5	99.5	98.75
Dates	1/26 to 2/9/81	1/26 to 2/3/81	3/17 to 3/24/81	3/17 to 3/24/81	4/19 to 5/5/81
Conditions					
Materials					
Bearing	SAE 660 Bronze (83Cu-78Sn-7Pb-32Zn)		Ti-diboride coating on 6V-4Al Ti	99% pure alumina 95.7% theoretical density	TC-30 Cermet
Shaft (1.000 in. dia)	416 SS, annealed		416 SS, annealed	416 SS, annealed	416 SS, annealed
Brine Conditions		Same			
Salinity (NaCl, ppm)	33,000		33,000	33,000	33,000
Suspended solids (ppm)	None		None	None	None
Temperature (°F)	345-365		95 hr @200F	94.5 hr @200F	190°F
Pressure (psig)	185-200		95 hr @8 psig	94.5 hr @8 psig	8 psig
Side load (lb_f)	50-135		95 hr @92 lb	94.5 hr @92 lb	92 lb
Shaft speed (avg., rpm)	1675		1690	1720	1680
PV (psi-fpm)	8,100-22,000		15,000	15,300	15,000
Results					
Bearing Wear (100 hr)					
I.D. change (↔, in.)	+0.005	+ 0.045	+0.015	+0.019	Negligible
I.D. change (↑, in.)	0.000	0.002	0.000	0.001	Negligible
Wt change (gm, %)	-0.93 (-0.16%)	-15.85 (-28%)	-2.94 (1.5%)	-1.12 (0.5%)	-0.25 (0.000%)
Shaft Wear (100 hr)					
O.D. change	Negligible	Negligible	-0.02	-0.16	-0.020
Surface finish	Scored -360°	Scored -360°	Roughened, deep grooves	Shaft ground severely	Grooves
Brine					
pH	6.8 (start), 5.5 (end)	6.8 (start), 5.5 (end)	6.8 (start), 5.6 (end)	6.8 (start), 5.6 (end)	6.8 (start), 5.6 (end)
Dissolved O₂ (ppm)	<0.4 " <0.4 "	<0.4 " <0.4 "	<0.2 " <0.2 "	<0.2 " <0.2 "	<0.2 " <0.2 "
Comments	Insufficient wear, reason unknown. Variable side loads were caused by a leaky nitrogen regulator which has been replaced. Some variation is unavoidable due to normal fluctuations in brine pressure.	Test terminated due to motor controller burnout.	Coating was only 0.0005 in. thick. It was worn through.	Shaft was ground down severely.	Hairline crack in bearing, originating from diamond saw cut to control rotation

Table 4
Test Results
(Sheet 2 of 2)

	Test No. 6-2BB	Test No. 7-1A1	Test No. 8-2TN	Test No. 9-1SN	Test No. 10-2SN	Test No. 11-1TN
Duration (hr)	70.5	24.0	105.3	105.5	Test in progress.	Test in progress.
Dates	5/1 to 5/5/81	5/7 to 5/8/81	5/8 to 5/19/81	5/12 to 5/20/81	Started 5/26/81	Started 5/27/81
<u>Conditions</u>						
<u>Materials</u>						
Bearing	SAE 660 Bronze (83Cu-75Sn-7Pb-3Zn)	99% pure alumina 95.7% theoretical density T-700 coating on 416 SS	TC-30 Cermet T-700 coating on 416 SS	Silicon Nitrate (sintered) 416 SS, annealed	Silicon Nitrate (sintered) Ni-Cr-B coating on 416 SS	TC-30 Cermet Ni-Cr-B coating on 416 SS
Shaft (1.000 in. dia)	416 SS, annealed					
<u>Brine Conditions</u>						
Salinity (NaCl, ppm)	33,000	33,000	33,000	33,000	33,000	33,000
Suspended solids (ppm)	None	None	None	None	None	None
Temperature (°F)	190	190	190	190	190	190
Pressure (psig)	8	8	8	8.5	8	8
Side load (lbf)	92	92	92	92	92	92
Shaft speed (avg., rpm)	1700	1700	1700	1730	1730	1730
PV (psi-fpm)	15,200	15,200	15,200	15,400	15,400	15,400
<u>Results</u>						
<u>Bearing Wear (100 hr)</u>						
I.D. change (in.)	0.006	0.035	Negligible	0.003	Results N/A	Results N/A
I.D. change (in.)	Negligible	Negligible	Negligible	Negligible		
Wt change (gm, %)	-1.12 (-0.20%)	-2.4 (-1.0%)	-0.005 gm(0.000%)	-0.34 (0.2%)		
<u>Shaft Wear (100 hr)</u>						
O.D. change	<0.003	0.77 in.	-0.0005	<0.029		
Surface finish	Slight scored	Shaft ground severely	Shaft surface smooth.	Grooves		
<u>Brine</u>						
pH	6.8 (start), 3.6 (end)	6.8 (start), 5.6 (end)	6.8 (start), 5.6 (end)	6.8 (start), 5.6 (end)		
Dissolved O ₂ (ppm)	<0.2 " <0.2 "	<0.2 " <0.2 "	<0.2 " <0.2 "	<0.2 " <0.2 "		
<u>Comments</u>	Test discontinued after test shaft became unscrewed. (problem corrected)	Test discontinued due to excessive wear.

Figure 4. Graphic Representation of Bearing and Journal Wear for 100 Hour Phase II Screening Tests at 95 Lb Load and a Temperature and Pressure of 200°F and 8 psig, Respectively (unless otherwise noted)

Figure 5.

Wear Pattern on Alumina Bearing From Test #4-2A1

Magnification: 1.25X

Figure 6.

**Typical Wear Track on
416 SS Shaft. This
shaft was used in Test
#3-1TB**

Magnification: 1X

Figure 7.

**Bronze Bearing From Test
#2-2BB.**

Magnification: 8X

Figure 8.

**TiB₂ Coating Worn Through
During the 100 Hour Screen-
ing Test Against a 416 SS
Shaft**

Magnification: 8X

Figure 9.

Alumina Bearing From
Test #4-2A1

Magnification: 8X

Figure 10. ~

TC-30 Bearing From Test
#5-1TN. Shows very
little wear

Magnification: 8X

Figure 11.

416 SS Shaft Surface
After Test #2-2BB.

Magnification: 8X

Figure 12.

Cleanly Ground 416 SS
Shaft After Run Against
Alumina in Test #4-1A1

Magnification: 8X

Figure 13.

416 SS Shaft After Being
Run Against TC-30 in
Test #5-1TN

Magnification: 8X

Figure 14.

Tribaloy T-700 Coating
on 416 SS Shaft After
105 Hours Against TC-30
Bearing. Note the
excellent condition of
the surface.

Magnification: 8X

Figure 15.

416 SS Shaft Surface
After Being Run Against
Sintered Silicon Nitride
in Test #9-15N.

Magnification: 8X

One item which is still open for discussion is the importance of clearance on these bearing's performance. The standard field practice is to maintain a 5 to 8 mil diametral clearance but this choice seems to be based on tradition rather than anything else. It would seem that a large clearance will permit the dirt to pass through and will also permit a large flow of cooling lubricant. However, if the clearance becomes too large, the bearing becomes noisy and the minimum film thickness begins to decrease again. The optimum clearance should be just shy of the clearance for maximum film thickness to allow for increasing clearance due to wear. The field practice is probably dictated by ease of assembly of the bearing.

New work in the future should be done to establish this optimum clearance and to make recommendations for further modifications to the journal-bearing system which will increase the bearing characteristic (Sommerfeld) number, thus increasing the minimum film thickness. Work will be done on establishing a reliable method of determining the friction drag between the bearing and shaft as a function of time.

2.3.3 Phase II - Test Plans

As of now the Phase II - 100 Screening Tests will proceed as outlined in the test matrix as shown in Table 5.

The material combinations were graded according to the following scale:

Excellent	- Negligible wear (<0.001 in.) in 100 hr for both bearing and shaft
Good	- Minor wear on either bearing or shaft, <10 mils total wear
Fair	- Less than 30 mils total wear
Poor	- More than 30 mils total wear

2.4 PHASE III - TEST PLANS

Based on the results from the Phase II screening tests, four material combinations will be selected for the 1000 hour Phase III tests. Each 1000 hour test will run at 200°F and 8 psig. TC-30 on Tribaloy® T-700 and bronze on 416SS have been tentatively selected for the first long-term test. The one or two best performing bearing combinations will be tested for 100 hours as above but with 10 μm SiO_2 added to the brine.

Table 5

Phase II - Test Matrix

Bearing/Shaft	416 SS	T-700 on 416SS	Ni-Cr-B on 416SS
Bronze baseline	Good	-	-
TiB ₂ coating on Ti6Al4V	Poor (coating too thin)	-	-
Alumina	Poor	Poor	-
TC-30	Fair	Excellent	Test in progress
Sintered silicon nitride	Fair	Next	Test in progress
Tungsten carbide	Bearing on order		

REFERENCES

1. Shigley, Joseph E., Mechanical Engineering Design, 3rd edition, see Chapter 10 for more detailed discussion.
2. Matthews, G.S. and Russell, D.G., Pressure Buildup and Flow Tests in Wells, Society of Petroleum Engineering Monograph, Vol. I, 1967. See Appendix G.

1. Contract Identification Development of Bushings and Bearings for Use in Hot Brine Pumps	2. Reporting Period 4/1/81 through 5/1/81	3. Contract Number BNL 490656-S
4. Contractor (Name and Address) Solar Turbines International 2200 Pacific Highway, P.O. Box 80966 San Diego, California 92138		5. Contract Start Date 11-15-79
		6. Contract Completion Date 11-14-81

7. Months	O	N	D	J	F	M	A	M	J	J	A	S	O	N		8. FY 81
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9. Cost Status															g. Cost Plan Date	
a. Thousands of Dollars																h. Planned Costs Prior FYs
																i. Actual Costs Prior FYs
																j. Total Estimated Costs for Contract 156.5
																k. Total Contract Value 156.5
																l. Unfilled Orders Outstanding 0.0
b. B&R Numbers																m. Estimate for Subsequent Reporting Period 2.5
	c. Planned	9.0	11.0	11.0	16.0	2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.0	
	d. Actual	6.0	2.9	4.1	5.0	6.0	3.7	3.7	2.7							
	e. Variance	3.0	8.1	6.9	11.0	(4.0)	(2.2)	(2.2)	(1.2)							
Accrued Costs	f. Cum. Variance	(5.0)	3.1	10.0	21.0	17.0	14.8	12.6	11.4							

10. Manpower Status (Direct Labor)															g. Manpower Plan Date	
a. Thousands of Manhours																h. Planned Manpower Prior FYs
																i. Actual Manpower Prior FYs
																j. Total Estimated Manpower for Contract 3.7
																k. Total Contract Manpower 3.7
Manpower	b. Planned	0.22	0.24	0.24	0.22	0.13	0.13	0.13	0.12	0.10	0.10	0.10	0.10	0.10	0.05	
	c. Actual	0.17	0.07	0.13	0.08	0.18	0.12	0.09	0.11							
	d. Variance	0.05	0.17	0.11	0.14	(0.05)	0.01	0.04	0.01							

11. Major Milestone Status														
a. Phase I Problem Def.														
b. Phase II 100-Hr Tests														
c. Phase III Long Term Tests														
d. Program Reviews														
e.														
f.														
g.														
h.														
i.														

12. Remarks EIA														
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13. Signature of Contractor's Project Manager and Date 6-19-81	14. Signature of Government Technical Representative and Date
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