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PROTOTYPE SOLAR HEATING AND COOLING SYSTEMS (Monthly Progress Reports)

Prepared from documents furnished by

AiResearch Manufacturing Company of California
Division of the Garret Corporation
2525 West 190th Street
Torrance, California 90509

Under Contract NAS8-32091 with

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

April 1979

For the U. S. Department of Energy

U.S. Department of Energy

Solar Energy

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Twenty-Fourth Monthly Status Report
Data Requirement No. 500-11

SOLAR HEATING AND COOLING SYSTEMS DESIGN AND DEVELOPMENT

Contract NAS8-32091

76-13110(24)

January 10, 1979

Prepared for

George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama 35812

AIRESEARCH MANUFACTURING COMPANY
OF CALIFORNIA

INTRODUCTION

This is the twenty-fourth monthly status report prepared by AiResearch Manufacturing Company of California under Contract NAS8-32091 for the National Aeronautics and Space Administration Marshall Space Flight Center (MSFC). The report summarizes activities from November 1 to December 31, 1978.

For simplicity in reporting, activities are reported by subject matter rather than by WBS item number.

MEETINGS, REVIEWS AND MAJOR ACTIVITIES

NASA-AiResearch program review meetings were held at Torrance, California on November 15 and December 11, 1978. (Personnel attending the meetings are listed in Appendix B of this report.) During the December meeting, the turbo-compressor development problems were reviewed in detail.

A meeting was held at the City Engineer's Office, City of Las Vegas on November 16 to discuss NASA plans to proceed with the conventional heating and cooling system, and completing the solar system work as far as possible without the heat pump delivery.

Job Meeting No. 39 was held at Houston, Texas, on December 7 to review program status. System control sensors were delivered during this meeting for installation by the field contractor. Minor SDAS changes were made (see Site Activities).

Meetings scheduled for January include:

- A status review meeting at Houston on January 4, 1979.
- A NASA-AiResearch program review meeting on January 9 and 10.
- A system inspection and checkout visit will be made to the Houston site on January 22, if the installation is complete.

SITE ACTIVITIES

Status of Sites

1. Lawrenceburg, Tenn. (OTS-13)

   a. No status change; awaiting delivery of the heat pump.

   b. Plumbing has been hard plumbed except for lengths adjacent to the heat pump to facilitate final alignment on installation.

2. Allaire State Park, N.J. (OTS-11)

   a. Two 500-gallon water storage tanks were delivered November 20, 1978.

   b. Negotiations have been carried on with one contractor, Central of New Jersey, with a resultant lower cost figure based on some contractor suggested spec changes. The specific spec changes have not been discussed with AiResearch to date, however, as all preliminaries have been handled by Mr. Robert DeGennaro of the New Jersey Bureau of Parks.

3. Harrisonburg, Va. (OTS-14)

   a. The solar collector field is complete.

   b. The system is plumbed, except for the heat pump, which is scheduled for delivery in March.

4. Novato, Ca. (OTS-12)

   a. A bid package was released to seven contractors on November 15, 1978.

   b. An 800-gallon water storage tank was ordered on November 15, 1978.

   c. Revisions to the bid package were sent to four bidders, all of whom are mechanical contractors. Apparently, the two general contractors have dropped out.

   d. The new response date for written bids is postmark 1-12-79.

   e. Twenty-four solar collector panels have been delivered to site with the remaining six being held at Dunham-Bush, Harrisonburg.

5. Redmond, Ore. (OTS-17)

   a. AiResearch-reviewed Bonneville Power Administration Redmond Substation SHAC plans received on November 29. The marked up drawings were returned to BPA on December 5.

   b. BPA is in process of revising plans and specs in preparation for bid release.

   c. PIP is being developed by AiResearch.

6. Cleveland, Tenn. (OTS-16)

The SHAC building at this site is no longer available.

7. Houston, Texas (OTS-18)

a. A decision was made to ship the 75-ton heat pump (less the turbo-compressor) to the site on November 7. It arrived on the 10th.

b. Dunham-Bush was notified to exchange wattmeters with the university.

c. The heat pump electrical enclosure was sent to Houston on December 1 for installation on the heat pump by the field contractor (because of labor union problems).

d. Sensor Nos. S1, S2, S4 and S5 were hand delivered to the University of Houston during the SHAC December meeting.

e. Minor SDAS changes were made, such as deletion of the room supply air relative humidity sensor (R602), and the relocation of the WI00 and WI01 flowmeters from the supply to the return lines.

f. Isolation valves and balancing valves for all pumps in the system had not been specified by the designer. Those valves were added on during piping installation.

g. AiResearch has prepared a system checkout guideline and provided this guideline to NASA (December 7, 1978).

h. AiResearch will inspect the system installation and start the pump in the heat pump package upon the completion of installation.

i. The piping installation and system checkout, such as preparation, testing, filling and balancing, will be completed in January.

j. IBM will hook up their monitoring system after checkout of the SDAS instrumentation.

k. System startup is scheduled to be complete in February, at which time NASA will make the final inspection and acceptance visit.

l. The operation and maintenance (O&M) manual has been started.

8. Las Vegas, Nev. (OTS-19)

a. Work-around procedures were discussed and agreed upon at the Las Vegas November 16 meeting to maintain continuity of construction in view of the delay in delivery of the heat pump.

b. A survey of the Stewart-Mojave site revealed that the floor slab has been poured and the tilt-up walls are fixtured in place. The roof has been papered and will be poured in January. Roof truss installation has been completed.

c. Solar collectors have been delivered to the site.

d. The tilt-up wall fixtures have been removed. The partitions have been framed in and are ready to be sheet-rocked in January.

e. Wiring and plumbing are underway; this work has not been extended into the heat pump area.

f. JBA has not had any discussions as yet at the site regarding work-around procedures.

g. Tiberti has not yet responded with the requested cost impact on the work-around. Mr. Leo F. Borns will advise AiResearch upon receipt of this information.

Sites and Site Equipment Status Charts

Site status Chart I has been updated to reflect latest anticipated delivery and test dates, and is included as Appendix A of this report.

Status of Preliminary and Approved Instrumentation Plans (PIP-AIP)

Site	Revision	Remarks
Allaire Park, N.J.	B	Letter 89312-10837-045, dated 9-28-78, submitted to NASA with suggested revisions to AIP's for these three SHAC sites. No reply has been received from NASA as yet.
Lawrenceburg, Tenn.	A	
Harrisonburg, Va.	-	
Novato, Ca.	-	The final PIP was issued October 30, 1978
Cleveland, Tenn.	-	The SHAC building at this site is no longer available.
Redmond, Ore.	-	Initial PIP is being generated; completion is anticipated in January.
Houston, Tx.	-	Final PIP was submitted October 19, 1978.
Las Vegas, Nv.	E	Final PIP was submitted November 17, 1978. Errata pages and a new Figure I were submitted on December 1, 1978.

PROGRAM DOCUMENTATION

a. Twenty-Third Monthly Status Report 76-13110(23), dated November 10, 1978 (DR500-11).

b. Quarterly Contractor Financial Management Report (DR500-27).

Other publications were submitted during November/December to the parties listed as tabulated below:

Submittal Date	To	Subject
11-7-78	F. Rushing (Lawrenceburg, Tenn.)	Collector Loop Check Valve Location (Mark-up Drawing C473037)
11-13-78	E. Samfield (Univ. of Houston)	Review of Barber-Colman Control Drawing and Heat Pump Electrical Dwg. H-TEX-E)
11-17-78	E. Samfield	Review of MEP Drawings MEP-1, P3
11-17-78	J. Clark (NASA)	Las Vegas, Nev., Final PIP
11-30-78	R. Joeckel (JBA) L. F. Borns	Las Vegas, Nev., Final PIP Errata
12-15-78	E. Samfield, J. Clark	Heat Pump Internal Electrical Connections

SYSTEM DEVELOPMENT

The activities reported below involve heat pump component design, fabrication and testing, and heat pump package development.

Component Design, Fabrication and Test (at AiResearch)

1. Turbomachines

(a) 75-Ton Unit

A 75-ton unit was instrumented internally with 15 pressure taps and 18 thermocouples to provide data related to pressure and temperature distribution in the motor and bearing cooling circuits. Runout probes were also installed to measure shaft excursion during operation. The 25-ton test system at AiResearch was modified to allow testing of the 75-ton unit.

A test plan was created to establish a logical evaluation of the bearing problem. Various design modifications were evaluated for feasibility. It was decided that the baseline configuration would be the last configuration tested at Dunham-Bush.

During the assembly of the unit, flow and pressure distribution tests were conducted statically at various stages of the buildup to determine where restrictions exist within the cooling circuits. These tests, as well as the dynamic tests that followed, were conducted with air and liquid freon. Dynamic tests were then conducted at speeds up to 18,000 rpm. This data showed that the flow splits and magnitudes were as predicted analytically. The cavity pressures were lower than predicted.

The turbomachine was installed in the system and a freon charge of 300 lb was applied. On the first start, a speed of only 8000 to 10,000 rpm could be obtained with full current command and a command speed of 16,000 rpm. The unit was operated for approximately three minutes and was shut off. Repeated attempts to restart caused the over-voltage protection circuit in the controller to fail. Repairs were made and the starting current available from the controller was varied to determine its effect.

A successful start and a run of 25 minutes at 16,000 rpm was made. The current during the first 15 minutes of the run was at a maximum value of 110 amps. (Previous tests at this speed at Dunham-Bush resulted in current levels of 80 to 90 amps.) After 15 minutes, the current decreased to approximately 90 amps, indicating a substantial change in torque. At approximately 24 minutes, the current increased to 110 amps, the speed reduced to 8000 rpm and the system was shut off. No restart was possible.

The unit was removed from the system and the torque was 185 in.lb (original torque 43 in. lb). Upon disassembly, the thrust bearing was found to have failed. It was burnt on the outboard portion of the bearing. No indication of failure, other than the increase in current and decrease in speed, was apparent during the test. Debris and an oily substance was found throughout the unit. The debris was a combination of copper and iron and the oily substance was of a silicon and mineral oil.

Test data from the run showed that the pressure differentials across the bearings was very low on the compressor end of the unit (0.25 psi) with 0.75 psi across the turbine-end journal bearing. The chamber pressure was very near the supply pressure indicating that the outlets are restricting. These exhaust ports were enlarged and another one was added for the next test. The failure was attributed to lack of pressure across the bearing. System cleaning is being done and the unit being rebuilt for the next test.

In addition to the added and enlarged drains, the lines are being replumbed so that there is no possibility of accumulating liquid within the machine. This was definitely the case during the initial portion of the test and the data correlates with the last test run at Dunham-Bush.

Additional analysis is being conducted to evaluate the possibility of gas cooling the journal and thrust bearings.

(b) 25-Ton Unit

The 25-ton unit has been cleaned and reassembled. It will be shipped to Dunham-Bush in early January for installation in the system which is still undergoing cleaning. The system is scheduled for test after January 18.

(c) 3-Ton Unit

A 3 ton compressor will be built with minimum instrumentation (chamber pressure and runout probe) and shipped to Dunham-Bush for testing late in January.

2. Motor Controller

Activities for this component were confined to system tests of the 75-ton heat pump.

3. System Controller

Five controllers have been completed and checked out. Fabrication of the final three system controllers is now 95 percent completed.

4. R-11 Liquid Pump

(a) 3-Ton Unit

Three pump units were delivered in March. Testing is now at the subsystem level.

(b) 25-Ton Unit

One pump has been tested and shipped to Dunham-Bush. Assembly of the other two pumps was completed in September. Installation into the heat pump will occur coincidentally with the turbocompressor.

Heat Pump Design, Fabrication and Test (Dunham-Bush Activity)

(a) 75-Ton Heat Pump

The second 75-ton package is complete to the point of turbocompressor installation and is in place for test. System testing will be delayed until completion of the turbocompressor tests now underway in the AiResearch Torrance facility. It is expected that the outcome of these component tests will be incorporated prior to continuation of system testing.

(b) 25-Ton Heat Pump

The first 25-ton system has been reassembled after cleaning the heat exchangers. New suction valves have been ordered and are scheduled for January 12 delivery. The turbocompressor has been cleaned and system testing is expected to resume late in January.

(c) 3-Ton Heat Pump

One 3-ton package has been equipped with sight glasses and thermocouples to evaluate the liquid refrigerant slugging conditions noted in the last test series. An instrumented turbocompressor will be installed in this system to determine the machine reaction to liquid ingestion.

One electrical control panel is complete and three others are in process. New solenoid-operated suction valves have been ordered to reduce pressure loss in the heating mode. These valves are scheduled for January 15, delivery.

Size	Unit	Turbocompressor	Motor Control	Freon Pump	Heat Pump Complete	Start Test	Test Time, Weeks	Test Complete	Ship Date	Intended Site
3 Ton	#1	2-16	complete	complete	2-23	2-24	1	3-2	3-2	Harrisonburg, Va.
	#2	1-19	complete	complete	1-26	1-26	4	2-23	3-2	Lawrenceburg, Tenn.
	#3	2-23	2-23	2-23	3-2	3-3	4	4-2	4-6	Allaire Park, N.J.
	#4	3-9	3-9	3-9	4-2	4-3	8	5-29	6-4	Novato,Ca.
25 Ton	#1	1-12 (or) 3-9	complete --	complete --	1-19 (or) 3-16	1-19 (or) 3-19	11 (or) 11	4-6 (or) 6-4	4-3 (or) 6-11	Redmond, Oregon
	#2	5-2	5-2	5-2	6-1	6-5	5	7-10	7-17	Cleveland, Tenn.
75 Ton	#1	2-20	complete	received	shipped*	2-27**	7	4-17	5-1	Houston, Texas
	#2	3-30	complete	received	2-19***	4-24	11	7-3	7-10	Las Vegas, Nevada

HEAT PUMP DELIVERY SCHEDULE

*Heat pump less turbocompressor
**Using #2 H.P.
***#2 H.P. with #2 turbocompressor

Chart 5
Date: 1-10-79
76-13110(24)
APPENDIX A

ATTENDEES TO NOVEMBER-DECEMBER
SHAC COORDINATION MEETINGS

Program Review Meeting at Torrance, Ca. (November 15, 1978)

James Clark (NASA/MSFC)
Richard Nelson (AiResearch)
Paul Benson (AiResearch)
Robert Susag (AiResearch)
Hack Yee (AiResearch)
Shing Leung (AiResearch)

Site Work Procedure Meeting at City Engineer's Office, Las Vegas, Nevada (November 16, 1978)

James Clark (NASA/MSFC)
Robert Gunner (NASA/MSFC)
G. Johnson (City of LV)
D. Peterson (City of LV)
A. Steele (City of LV)
Leo Borns (Leo Borns AIA)
W. Folkerson (Tiberti Construction Co.)
R. Morgan (Southwest Air)
H. Yee (AiResearch)

Job Meeting No. 39 at LIH/CLC Developmental Arts Bldg. (December 7)

Ed Samfield (UH/FP & C)
Jack Peters (UH/FP & C)
James Clark (NASA/MSFC)
Robert Gunner (NASA/MSFC)
Gordon Neff (Timmerman Engr., Inc.)
Robert Ice (Timmerman Engr., Inc.)
Shing Leung (AiResearch)

Program Review Meeting at Torrance, Ca. (December 11, 1978)

James Clark (NASA/MSFC)
Claude Dorning (NASA/MSFC)
William Richardson (NASA/MSFC)
Richard Nelson (AiResearch)
Paul Benson (AiResearch)
Dick Lockwood (AiResearch)
Al Silver (AiResearch)
Robert Susag (AiResearch)
Shing Leung (AiResearch)

Pre-Bidder's Conference at Hamilton AFB, Novato, Ca. (December 12)

James Clark (NASA/MSFC)
C. Dorning (NASA/MSFC)
G. Gunner (NASA/MSFC)
W. Richardson (NASA/MSFC)
Cmdr. Kaufman (Hamilton AFB)
F. Page (PWC-SF)
F. Carleo (AiResearch)
H. Yee (AiResearch)
S. Knoles (Knoles and Co.)
K. Knoles (Knoles and Co.)
S. Krogstad (Malm Metal Products)
M. McKenna (Reliance Enterprises)

Twenty-Fifth Monthly Status Report
Data Requirement No. 500-11

SOLAR HEATING AND COOLING
SYSTEMS DESIGN AND DEVELOPMENT

Contract NAS8-32091

76-13110(25)

February 9, 1979

Prepared for

George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama 35812

AIRESEARCH MANUFACTURING COMPANY
OF CALIFORNIA

INTRODUCTION

This is the twenty-fifth monthly status report prepared by AiResearch Manufacturing Company of California under Contract NAS8-32091 for the National Aeronautics and Space Administration Marshall Space Flight Center (NASA/MSFC). The report summarizes activities from January 1 to January 31, 1979.

For simplicity in reporting, activities are reported by subject matter rather than by WBS item number.

PROGRAM SUMMARY

For the last three months, program activities have been directed primarily toward elimination of turbocompressor and system performance problems. Previous attempts at system testing at Dunham-Bush had resulted in turbocompressor bearing failure, mostly due to system contamination. However, the final series of system runs at Dunham-Bush in October and early November on the 75-ton machine showed that bearing cooling was also suspect. Because of the similarity of the cooling concepts on the three machines, it was decided to interrupt the system tests at Dunham-Bush and perform development tests on the turbocompressor at AiResearch. This decision was based upon the availability of sophisticated instrumentation at AiResearch, the ready access by all AiResearch engineering personnel to the hardware and test data, and the elimination of the machine turn-around time associated with supplying hardware to Dunham-Bush.

Because the 75-ton machine had been successfully operating for brief periods in the system at Dunham-Bush, it was decided to concentrate development efforts on that unit. The 75-ton unit necessary changes will then be incorporated in the 3 and 25-ton machines. A team of machinery, electronic, and vapor-cycle system engineers was designated to review the equipment configuration and test results, and to correlate them with available analyses. This team recommended that initial tests of the machine obtain a baseline of performance so that the effects of any later changes could be determined. To that end, the machine was fully instrumented and the available test rig was modified to allow operation with the 75-ton unit. Attempts to test the machine in the rig were unsuccessful in obtaining run times of the duration required to develop steady-state temperatures within the unit. The machine bearings failed, most probably due to liquid slugging of the compressor. Attempts were made to modify the test rig, as well as to operate the machine with Freon cooling in the motor and bearing circuits, but with the compressor and turbine operating in air. With this configuration, the test was highly successful in obtaining steady-state performance data in different cooling configurations. Analysis of this data is still in process. Similarly, machine testing in the rig had yet to occur (as of 1-31-79).

In mid-January, it was decided by the review team that the 3 and 25-ton machines were sufficiently developed to justify continuation of the system testing at Dunham-Bush. Although no design changes were made to the machines (their configuration was identical to that used in the previous system testing), the impact of liquid slugging upon machine performance in the 75-ton rig tests at AiResearch had resulted in the incorporation of machine drains on the 25-ton

system at Dunham-Bush (with plans for similar drains on the 3-ton system). The resumption of system tests was successful in that the 25-ton machine operated for over 17 hrs, during which sufficient running occurred to identify several system modifications that will be necessary. (The exact nature of these modifications is still being defined as the test data reduction continues.) The 25-ton tests were terminated due to (1) the nearly simultaneous need for modification (i.e., no further testing with the system in its present configuration would be meaningful) and (2), by the failure of the turbocompressor to start (required start torque exceeded the controller capability). On the 3-ton unit, a total of about 11 hr of operation in the system took place prior to the failure of one of the position sensors in the machine. (This sensor is required for machine startup.) Both turbocompressors were returned to AiResearch where they will be disassembled and inspected prior to the continuation of system tests at Dunham-Bush. Meanwhile, the systems themselves will be modified as defined by the test analysis.

In summary, testing at Dunham-Bush and AiResearch during the 3-month period has:

- obtained sufficient data to define necessary system modifications to the 3 and 25-ton systems at Dunham-Bush.
- obtained sufficient data on the 75-ton turbocompressor to create a baseline cooling circuit performance model

The unanticipated high increase in machine and system development during the prior six months plus the additional development program being performed at AiResearch Torrance required an in-depth reassessment of costs required to fulfill the requirement of the contract. A revised estimate to complete was submitted on January 19, 1979, and was followed by technical-financial discussions with NASA program representative at AiResearch on January 29, 30, and 31, 1979.

DEVELOPMENT

System Engineering

System engineering effort has been directed toward the following tasks during the last month:

1. Responsibility for the test rig for the 75-ton turbocompressor testing at AiResearch.
2. Direction of 3 and 25-ton heat pump tests at Dunham-Bush.
3. Program task projections for the estimate to complete.
4. Preparation for system start-up at Houston.
5. Evaluation of the proposition of possible deletion of the heat pump heating mode for the Redmond, Oregon site, for cost savings purposes.

Of the above, Items 1 and 2 are covered in detail in other sections of this report. Item 3 has been submitted to NASA.

The preparations for AiResearch participation at Houston are complete. All tools and special test equipment have been accumulated and are ready for transportation to Houston. Procedures for checkout have been demonstrated in the laboratory (system controller). Daily contact with Houston site personnel has been recently established. The expected date for initiation of startup effort is February 12, 1979.

A computer analysis of the Redmond, Oregon, site operation without benefit of heat pump heating (direct solar heating only) has been conducted. The analysis indicates the following yearly data:

	Direct Solar and Heat Pump Heating	Direct Solar Heating Only
Percent Solar Heating Contribution	45.8	32.2
Auxiliary Heating (KWH)	25.3×10^4	31.6×10^4
Heat Pump Power (KWH)	3.3×10^4	0
Collector Pump Power Allocated to Heating (KWH)	0.9×10^4	0.7×10^4
Total Power for Heating (KWH)	29.5×10^4	32.3×10^4
Power Saved by Heat Pumping (KWH)	2.8×10^4	

Redmond electrical costs are reported as follows:

500	KWH @ $0.031 per KWH
500-3000	KWH @ $0.015 per KWH
above 3000	KWH @ $0.009 per KWH

Net savings with heat pump $278 per year.

Development Tests, Component

1. Turbocompressors

a. 75-Ton Unit

During January, two attempts were made at running in the 25-ton test rig (which was modified to accomodate the 75-ton unit as shown in Figure 1). The first attempt had added drain lines to the center cavity of the unit to preclude the accumulation of liquid freon within the motor cavity. This test was unsuccessful and resulted in failure of the turbine end journal bearing. The

failure did not occur immediately, and several short (10 to 30 sec) runs were made. During removal of the unit from the system, a large quantity (4 lb) of liquid freon was found trapped in the turbine torus. This is assumed to have contributed to the bearing failure.

Drains were installed in both the compressor and turbine scrolls to eliminate the accumulation of liquid in the unit. The unit was reassembled and reinstalled in the system. The next series of tests again were short (25 runs with the longest run of 3 minutes). Heavy intermittent loading of the compressor, probably due to liquid slugging, was experienced. System changes were identified, and operational procedures were established to greatly reduce the liquid carryover into the compressor. While the system changes were being incorporated, the unit was removed and examined. The compressor journal bearing had failed but was still operable. Test data showed that this was similar to the failure at Dunham-Bush on an identical unit. A minor modification in the motor coolant distribution passages was identified and accomplished. This change provides a more positive coolant distribution to the thrust and compressor end journal bearing. The test system was modified to allow for simpler control and also for independent control of the cooling supply to the motor. A bench test was conducted using air at the turbine and compressor and freon motor cooling. (Refer to Figure 2.) The unit was operated for 40 minutes from 10,000 to 22,000 rpm without incident. The unit was reinstalled in the system for testing.

b. 25-Ton Unit

A unit was assembled and shipped to Dunham-Bush for testing. Refer to Development Tests, System section.

c. 3-Ton Unit

A unit was assembled with minimal instrumentation and shipped to Dunham-Bush for testing.

2. Motor Controllers

System checkout is currently in progress for the 75-ton unit. A new back emf integrator card was fabricated to command larger β (firing) angles in the 25 and 75-ton systems.

3. System Controller

A test fixture was built to permit checkout of installation wiring. This test fixture under manual control simulates interfacing drivers of the system controller (Blue Box). Pumps and valves in the system can be checked for proper wiring to the interface module (Black Box) via the simulated commands issued from the test fixture.

The system controller software is being modified to reflect changes necessary to interface and control the Houston installation. Primary software effort has been directed to handle the automatic heating and cooling mode. Additional effort will be expanded to restructure and integrate the latest changes into an universal controller program, i.e. - a single control program configurable via switches to control the 3-ton, 25-ton and 75-ton SHAC subsystems.

4. R-11 Liquid Pump

All pump activity is complete, pending results of the system tests.

Development Tests, System

1. Heat Pump Tests at Dunham-Bush

Testing was conducted on the 3-ton and 25-ton heat pump systems from the January 22 to February 2, 1979. In this test interval, the two systems accumulated the following run times:

3-Ton - 10.78 hr of which 2.47 hr was in the cooling mode with the Rankine cycle turbine assisting the electrical motor.

25-Ton - 16 hr 58 min of which 3 hr 47 min was in the cooling mode with the turbine assisting the motor.

a. 3-Ton System

The data taken during the above test runs is at present being reduced. The following general observations were noted during the 3-ton system testing:

1. Although one of the primary objectives of the test was the investigation of turbocompressor rotor-stator dynamic interference, none was detected.

2. The runout probes, set for 0.020 inch clearance using an output voltage technique, were lost immediately on the first start.

3. The evaporator control was unstable with approximately a 13-minute limit cycle. The temperature of the line to which the sensing bulb is strapped appears to lag the R-11 evaporator output temperature by approximately 6 minutes. (A thermal well to accept the evaporator sensing bulb is presently being installed in the system to eliminate this problem.)

4. The boiler thermal expansion valve was not controlling, due probably to the same reasons as the evaporator control, since the sensing bulb of this expansion valve was also strapped on externally. (This is also being placed in a thermal well.)

5. The R-11 pump requires at least 15°F subcooling to maintain a sufficient inlet head. This condition exists satisfactorily except for a period during one unstable portion of the evaporator system when the compressor was in surge.

6. Condenser drain-back is suspected during shutdown periods. The addition of a receiver may be necessary to resolve this problem.

b. 25-Ton System

The following general observations were noted during the 25-ton system test:

1. During the initial runs, a motor controller problem was detected. The controller exhibited the symptom of dwelling at a speed of 7000 to 8000 rpm during attempted starts. The problem was determined to be caused by a lack of sufficient stability margin between the characteristics of the circuit which control maximum current and a lead network in the current loop. The problem was eliminated temporarily by reducing the maximum controlled current to 90 amps (normally 100 amps, although it was 110 amps at the time the problem was detected). Excellent oscillograph traces of the problem were recorded. A minor circuit alteration will result, which will add sufficient margin to this operating condition.

2. The reversing valve would not operate. The valve was positioned manually.

3. The condenser appears to be draining into the evaporator, and possibly the boiler, during system shutdown. Ten to fifteen minutes elapsed before a subcooling condition appeared. This is expected to be the time required to refill the condenser (drain the evaporator). A receiver may be required to alleviate the problem.

4. The reversing valve ΔP is excessive, up to 1/3 of the compressor head. This valve has always been known to be marginal. (It is the largest size made in this type of valve.) Data supplied by the manufacturer indicates a much lower ΔP than the tests now indicate. Alternatives are presently being investigated.

5. The evaporator expansion valve sensing bulb is not responsive enough. A thermal well is being installed.

6. The R-11 pump appears to operate satisfactorily and is not as sensitive to system condition as for the 3-ton size.

7. The boiler expansion valve operates very satisfactorily. This sensing bulb is already in a thermal well.

8. Performance data for the various system components is presently being reduced and evaluated.

c. 75-Ton System

The system tests have been interrupted to permit component evaluation of the turbocompressor at AiResearch. (Refer to Development Tests, Component section.)

DELIVERY HARDWARE

Component Manufacturing

All turbocompressors have been assembled in kit form and are on hold pending results of latest bearing development tests and scroll drain-back modifications. The motor controllers are complete except for the incorporation of the latest printed wiring assembly (PWA) necessary to command larger β angles. Five system controllers are complete and the final three and 95 percent complete. All R-11 pumps are received (for the 75-ton unit) or completed and tested (for the smaller units).

System Manufacturing

All heat pump subsystems have been framed and plumbed and contain all components except for the turbocompressors and motor controllers.

Procurement of Site Related Hardware

The 800-gallon thermal storage tank for the Novato test site is the only site related hardware item presently in the procurement process. This unit is virtually complete and will be moved to the AiResearch plant at Torrance for storage.

OPERATIONAL TEST

Site Installation and Support

1. Lawrenceburg, Tenn. (OTS-13)

   a. No status change; awaiting delivery of the heat pump.

2. Allaire State Park, N.J. (OTS-11)

   a. The revised quote resulting from the fourth round of negotiations and discussions held with Central Jersey Heating & Cooling, Inc. by representatives of the State of New Jersey, NASA and Allaire State Park was finally received.

   b. The reduced quote in Item (a) reflects several major changes in the specs involving materials, design and task scope.

3. Harrisonburg, Va. (OTS-14)

   a. No status change; awaiting delivery of heat pump.

4. Novato, Ca (OTS-12)

   a. Two bid responses have been received for solar heat retrofit by this site from Reliance Enterprises of Santa Rosa, CA. and from Knoles & Company, San Rafael, Ca.

   b. Fabrication of 800-gal water storage tank has been completed and is being source inspected.

5. Redmond, Ore. (OTS-17)

   a. AiResearch is awaiting revised plans and specs from BPA (resulting from marked up drawings returned to BPA on 12-5-78) for review prior to bid release.

   b. A PIP has been generated by AiResearch but is being held with finalization pending review of revised plans forthcoming from BPA.

6. Cleveland, Tenn. (OTS-16)

   The SHAC building at this site is no longer available.

7. Houston, Texas (OTS-18)

   a. Solar system inspection, checkout, testing and balancing shall be rescheduled for February 12, 1979.

   b. Leakages were found from twelve (12) Daystar solar panels. Recommendations for replacing the leaking collectors have been sent to NASA on January 26, 1979.

   c. Installation of instrumentation by IBM is estimated to occur at the end of February.

   d. The final acceptance review by NASA is anticipated in March.

8. Las Vegas, Nev. (OTS-19)

   a. The contractor is continuing with wiring and plumbing and interior partitioning.

   b. No information regarding cost impact of the work-around has been received from Mr. Leo F. Borns as yet.

c. Mr. Ralph Joeckel has advised AiResearch that the flowmeters for the gas input to the Auxiliary Space Heater and the DHW Auxiliary Heater were incorrectly sized. These flowmeters have been resized for the proper equipment flow and mating pipe sizes called out on the site plans. The changes have been coordinated both with Joeckel and Mizell of IBM and have been reflected in the PIP revision dated January 31, 1979.

Site Equipment Status Chart

Site status Chart 1 has been updated to reflect latest anticipated delivery and test dates, and is included as Appendix A of this report.

Site SHAC Instrumentation PIP's

Site	Revision	Remarks
Allaire Park, N.J.	B	Letter 89312-10837-045, dated 9-28-78, submitted to NASA with suggested revisions to AIP's for these three SHAC sites. Received TD33 approving IP7933779, Rev. A, for Lawrenceburg SHAC on January 31, 1979.
Lawrenceburg, Tenn.	A	
Harrisonburg, Va.	-	
Novato, Ca.	-	The final PIP was issued October 30, 1978
Cleveland, Tenn.	-	Site cancelled.
Redmond, Ore.	-	Initial PIP is in work; completion is contingent on finalization of design by BPA.
Houston, Tx.	-	Final PIP was submitted October 19, 1978.
Las Vegas, Nv.	-	Final PIP was submitted November 17, 1978. Errata pages and a new Figure 1 were submitted on January 31, 1979.

PROGRAM DOCUMENTATION

The following documents were prepared in accordance with the requirements of Appendix A of the Statement of Work:

a. Twenty-Fourth Monthly Status Report 76-13110(24), dated January 10, 1979 (DR500-11).

b. Quarterly Contractor Financial Management Report (DR500-27).

Other publications were submitted during January to the parties tabulated below:

Submittal Date	To	Subject
1-26-79	J. Clark (NASA) F. Rushing (Lawrenceburg)	Lawrenceburg, Tenn. PIP
1-29-79	J. Clark (NASA) E. Samfield (Univ. of Houston)	Replacement of Leaking Solar Collectors
1-31-79	L. F. Borns	Las Vegas, Nev., Final PIP Errata

PROGRAM ACTIVITIES

NASA-AiResearch meetings were held on January 9 to 10 and January 29 to 31, 31, 1979. The first meeting was the monthly program review meeting, and was attended by Mssrs. W.F. Richardson and J.W. Clark of NASA and Mssrs. R.C. Nelson, P.A. Benson and J.D. McPherson of AiResearch.

The latter NASA-AiResearch meeting was a technical-financial meeting (1) to review a revised estimate to complete the program, submitted on January 19, (2) to review turbocompressor development difficulties and establish a mutually agreeable work plan to correct these problems, (3) to generate tradeoff cost data regarding sites and heat pump size.

NASA	AiResearch
J. W. Clark	P. A. Benson
C. W. Dorning	M. L. Hamilton
A. C. Krupnick	K. F. Jackson
J. Nelson	J. D. McPherson
W. F. Richardson	R. C. Nelson
	A. Silver
	G. H. Skinner

Job Meeting No. 43 was held at Houston, Texas, on January 11, 1979. Mr. Hack Yee of AiResearch attended. During this meeting, leakage of some of the Daystar solar panels was discussed. (Refer to Site Installation and Support section for remedial action.) Subcontractor pricing and status was discussed with seven companies. AiResearch action was confined to the solar panel problem and an estimate of the system checkout date.

No meetings are presently scheduled for February other than the Houston system checkout date.

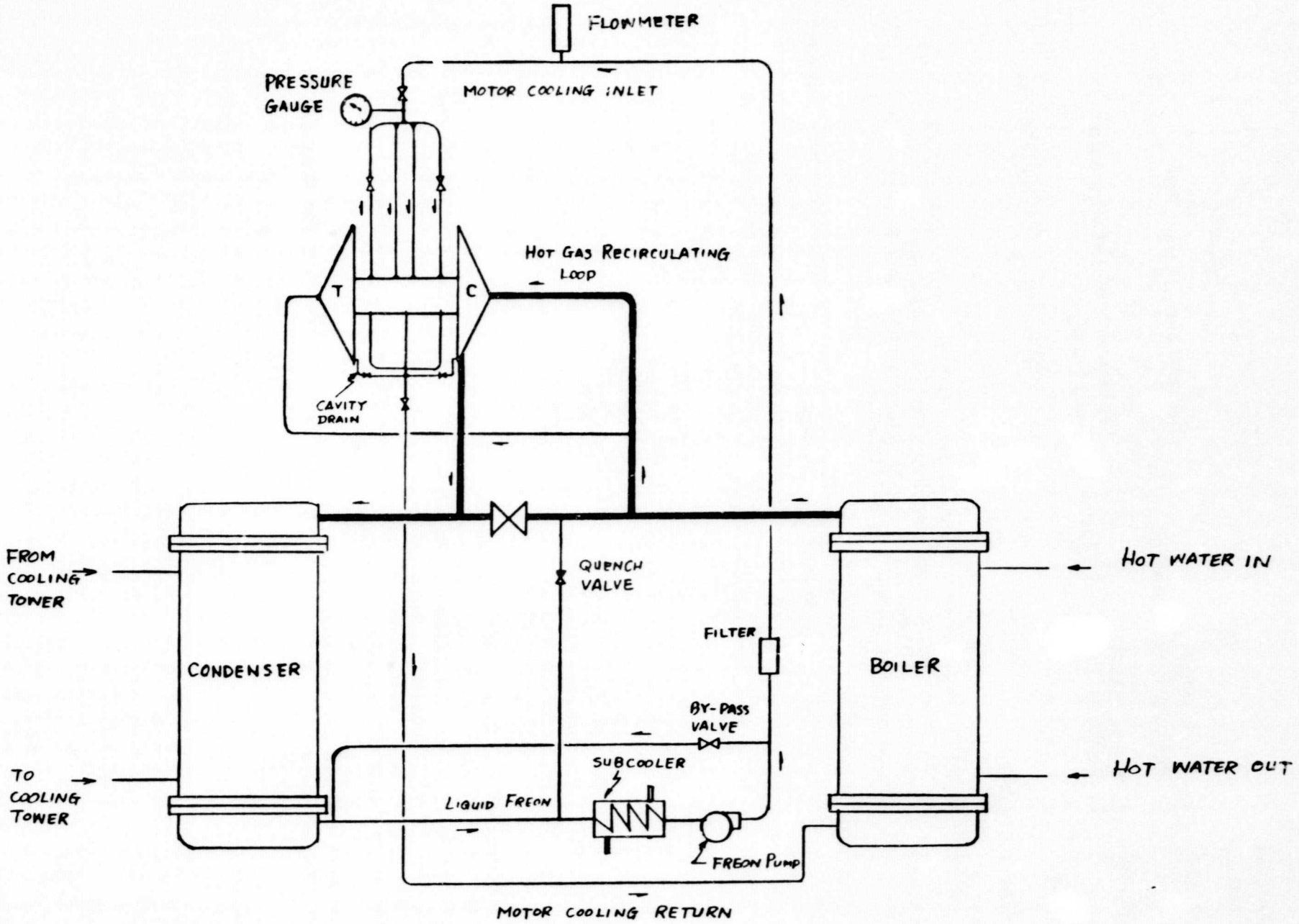
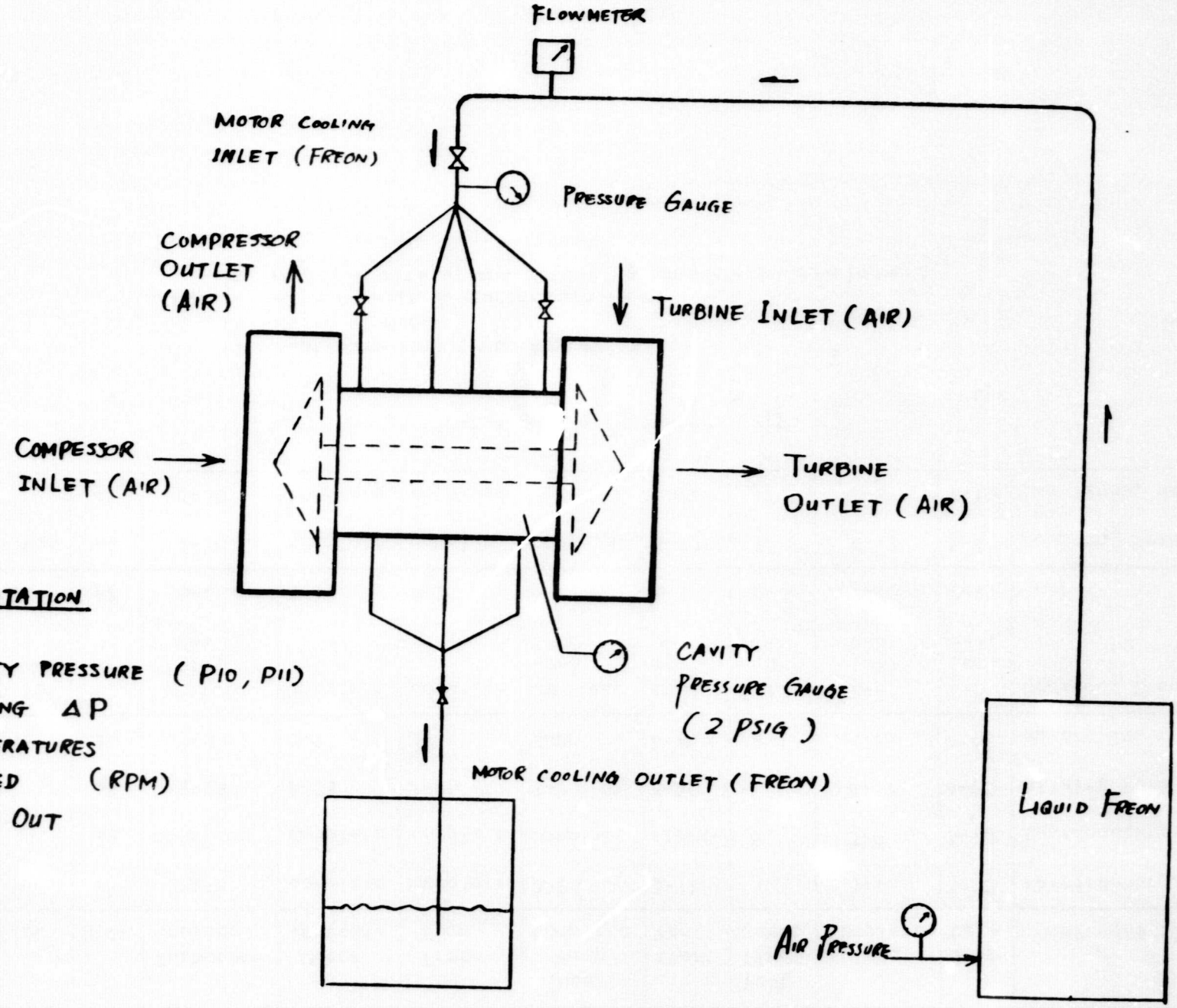


Figure 1. 75-Ton Turbomachine Test Schematic Diagram



INSTRUMENTATION

- 2 - CAVITY PRESSURE (P10, P11)
- 4 - BEARING ΔP
- 8 - TEMPERATURES
- 1 - SPEED (RPM)
- 1 - RUN OUT

Figure 2. 75-Ton Turbomachine Open System (Bench Test) Schematic Diagram

Size	Unit	Turbocompressor	Motor Control	Freon Pump	Heat Pump Complete	Start Test	Test Time, Weeks	Test Complete	Ship Date	Intended Site
3 Ton	#1	2-16	complete	complete	2-23	3-12	1	3-19	3-20	Harrisonburg, Va.
	#2	complete	complete	complete	complete	started	6	3-9	3-16	Lawrenceburg, Tenn.
	#3	2-23	2-23	2-23	3-2	3-20	4	4-17	4-23	Allaire Park, N.J.
	#4	3-9	3-9	3-9	4-2	4-18	8	6-13	6-18	Novato,Ca.
25 Ton	#1	complete (or) 3-9 (d)	complete --	complete --	complete (or) 3-16	started (or) 3-19	11 (or) 11	4-6 (or) 6-4	4-3 (or) 6-11	Redmond, Oregon
	#2	5-2	5-2	5-2	6-1	6-5	5	7-10	7-17	
75 Ton	#1	2-20	complete	received	shipped(a)	2-27(b)	7	4-17	5-1	Houston, Texas
	#2	3-30	complete	received	2-19 (c)	4-24	11	7-3	7-10	Las Vegas, Nevada

HEAT PUMP DELIVERY SCHEDULE

(a) Heat pump less turbocompressor
(b) Using #2 H.P.
(c) #2 H.P. with #2 turbocompressor
(d) Possible alterations resulting from 75-ton development

Chart 5
Date: 2-9-79
76-13110(25)
APPENDIX A

Twenty-Sixth Monthly Status Report
Data Requirement No. 500-11

SOLAR HEATING AND COOLING
SYSTEMS DESIGN AND DEVELOPMENT

Contract NAS8-32091

76-13110(26)

March 9, 1979

Prepared for

George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama 35812

AIRESEARCH MANUFACTURING COMPANY
OF CALIFORNIA

INTRODUCTION

This is the twenty-sixth monthly status report prepared by AiResearch Manufacturing Company of California under Contract NAS8-32091 for the National Aeronautics and Space Administration Marshall Space Flight Center (NASA/MSFC). The report summarizes activities from February 1 to March 1, 1979.

For simplicity in reporting, activities are reported by subject matter rather than by WBS item number.

PROGRAM SUMMARY

Analysis of test results of the 75-ton turbocompressor tested in January and early February with the turbine and compressor impellers operating in Freon was completed this month. Various system changes and turbocompressor modifications evolved as a result. These changes are reviewed in the Development Tests, Component section.

As a result of lengthy development testing of the turbocompressors and the associated costs, NASA decided to put all solar test sites, with the exception of the Houston and Las Vegas sites, on stop. Consequently, activity has been restricted to tests of the 75-ton turbocompressor and its subsystem.

DEVELOPMENT

System Engineering

All work on the 3 and 25-ton systems and sites has been stopped by NASA direction. The reduced work load has allowed the reassignment of one of the systems engineers managing site activities.

The recent testing that occurred on the 25-ton system at Dunham-Bush resulted in data which has indicated a number of required changes in the 75-ton system. This testing, accomplished in January just before the work stoppage, was very timely and avoided considerable development delay.

The Houston site has progressed toward start-up using direct solar heating and the building conventional heating and cooling systems. Completion of the start-up, and beginning of data collection is expected to occur by March 23.

Development Tests, Component

As stated previously, all activities this month were confined to the 75-ton system components. Therefore, subheadings pertaining to the 25-ton and 3-ton components have been deleted in the following subsections.

1. Turbocompressor (75-ton Unit)

A minor modification of the motor coolant distributional passages was made to provide more positive coolant distribution to the thrust and compressor end journal bearings. The change is illustrated in Appendix B of this report. Testing of this configuration in the AiResearch system simulation rig was accomplished during January and February with satisfactory results. Figures 1a through 3b, included herein, are typical replots of oscillograph traces made during these runs. The runs demonstrated the mechanical integrity of the turbocompressor prior to qualitative performance runs at Dunham-Bush. Near month end, the turbocompressor was shipped to Dunham-Bush for system tests.

2. Motor Controller (75-ton Unit)

Controller No. 1 has been checked with no load at a motor speed of 20,000 rpm. All parameters looked good. This controller was then used to operate a loaded motor. At approximately 15,000 rpm and a load of 150 amps, the control signals became noisy. An investigation revealed that 50 Hz noise and 360 Hz noise was being coupled into the buffered back-emf waveforms. This problem was solved by enclosing the back-emf cable in a separate conduit. This reduced the noise from 50 mv to 1 mv.

This modification was also made to Controller No. 2. Controller No. 1 was shipped to Dunham-Bush for further development testing.

3. System Controller

The system controller software modification has been completed. The changes made were necessary to interface and control the Houston installation in the direct heat operation. Additional effort will be expended to restructure and integrate the latest changes into an universal controller program, i.e.-a single control program configurable via internal logic to control the 3, 25 and 75-ton SHAC system.

4. R-11 Liquid Pump

All pump activity is complete, pending results of the system tests.

Development Tests System

1. Heat Pump Tests at Dunham-Bush

All testing of the 3-ton and 25-ton systems was stopped on February 2, 1979. At that time, the tests were stopped to make improvements on the system (for the 3-ton unit) and on the motor controller (for the 25-ton unit). However, all work on these systems was stopped as requested by NASA. The systems were sealed, evacuated and charged with dry nitrogen. The system development testing performed during January had identified various changes to be incorporated, as shown in Appendix B, Pages B-1 and B-2.

No test activity occurred on the 75-ton system pending arrival of the turbocompressor from AiResearch. In the meantime, changes recommended by AiResearch were made to the system.

DELIVERY HARDWARE

Component Manufacturing

All component equipment has essentially completed the manufacturing phase. This category will no longer be reported.

System Manufacturing

All heat pump subsystems have been framed and plumbed and contain all components except for the turbocompressors and motor controllers.

As directed by NASA, all work has been stopped on the 3-ton and 25-ton heat pumps and the units have been evacuated, charged with dry nitrogen and sealed.

The following have been made on the 75-ton heat pump:

1. Wells for expansion valve sensing bulbs have been installed in the discharge pipe from the evaporator and from the boiler and also in the dome of the boiler.

2. A solenoid valve has been placed in the supply line to the evaporator ahead of the expansion valve.

3. A subcooler has been installed in the motor coolant line.

4. The heat pump has been filled with R11 (7200 lbs.) to remove any oil that might be left in the machine. Samples showed that previous washing was good. Two thousand pounds were lost by evaporation in the process. More will be lost when the remaining 5200 lbs. are distilled.

Procurement of Site Related Hardware

The 800-gallon thermal storage tank for the Novato test site is now completed and will be moved to the AiResearch plant at Torrange for storage.

Site Installation and Support

1. Lawrenceburg, Tenn. (OTS-13)

   (On stop)

2. Allaire State Park, N.J. (OTS-11)

   (On stop)

3. Harrisonburg, Va. (OTS-14)

   (On stop)

4. Novato, Ca. (OTS-12)

(On stop.) Reliance Enterprises and Knoles and Co., bidders on the solar retrofit of this site, were notified by NASA to discontinue all activities related to this site. Fabrication and inspection of the 800-gal water tank has been completed. The tank will be delivered to AiResearch for temporary storage pending final disposition of the site.

5. Redmond, Ore. (OTS-17)

   (On stop)

6. Cleveland, Tenn. (OTS-16)

This power utility site was cancelled as a candidate SHAC site on 11-15-78.

7. Houston, Texas (OTS-18)

   a. All piping in the mechanical room and the collector field was installed as per Timmerman Engineer's latest drawings.

   b. All electrical control and power circuits have been completed, except for the turbomachine and the motor controller.

   c. The instrumentation checklist has been completed. Copies of the checklist has been sent to NASA, IBM and the University.

   d. Startup of all water pumps in the heat pump package has been accomplished by putting jumper switches across relay contacts.

   e. All input/output commands of the system control interface unit (black box) were checked by a manual control simulator/breakout box.

   f. The system controller (blue box) has been checked for proper operation. Although control commands for the collector pump and the storage pump functioned satisfactorily, the heat source pump and hydronic pump control require some modification.

g. Since some additional plumbing work including support of the 1000-gallon expansion tank and isolation valves on collector return lines is being done, AiResearch will plan for an additional trip for the completion of flow balancing and final system startup. The expected date for the final solar heating system operation is mid-March, 1979.

8. Las Vegas, Nev. (OTS-19)

a. The roof of the building is expected to be completed in mid-March. Solar collectors will be installed as soon as the roof has been completed.

b. Instrumentation equipment and parts have been shipped to the site contractor. A final inventory checklist will be completed by the contractor. The new gas flowmeter for the domestic hot water heater will be delivered in April.

c. Due to the late delivery of the Rankine heat pump unit, the impact of the mechanical and electrical work will be discussed in the next site meeting, scheduled for March 12, 1979.

Site Equipment Status Chart

Site status Chart 1 has been updated to reflect latest anticipated delivery and test dates, and is included as Appendix A of this report.

Site SHAC Instrumentation PIP's

Site	Revision	Remarks
Allaire Park, N.J.	B	No further action; site on stop.
Lawrenceburg, Tenn.	A	No further action; site on stop.
Harrisonburg, Va.	-	No further action; site on stop.
Novato, Ca.	-	No further action; site on stop.
Cleveland, Tenn.	-	Site cancelled November 15, 1978.
Redmond, Ore.	-	No further action; site on stop.
Houston, Tex.	-	Final PIP was submitted October 19, 1978.
Las Vegas, Nev.	-	Final PIP was submitted November 17, 1978. Errata pages and a new Figure 1 were submitted on January 31, 1979.

PROGRAM DOCUMENTATION

The following documents were prepared in accordance with the requirements of Appendix A of the Statement of Work:

a. Twenty-Fifth Montly Status Report 76-13110(25), dated February 10, 1979 (DR500-11).

b. Quarterly Contractor Financial Management Report (DR500-27).

Other publications were submitted during February to the parties tabulated below:

Submittal Date	To	Subject
2-1-79	J. Clark (NASA) G. Mizell (IBM-Huntsville)	Transmittal of Latest Houston PIP and Site Mechanicl Dwgs. to IBM
2-23-79	J. Clark E. Samfield (Univ. of Houston)	Houston SHAC Site System Inspection, Checkout List and Startup Procedures

PROGRAM ACTIVITIES

A Houston site SHAC system inspection, checkout and initiation of startup was attended by Mssrs. P. Benson, S. Leung and C. Aikman of AiResearch from February 12 through February 21, 1979. Details of this meeting are covered in the OPERATIONAL TEST section of this report.

A program review meeting was held at Huntsville, Alabama on March 1, 1979, wherein Mssrs. G. McDonald and R. Nelson of AiResearch made a presentation to the NASA staff regarding the development and fabrication status of the three SHAC systems. A review of the 75-ton turbocompressor problems was made along with a contingency test plan to expedite the program. Material presented at this meeting is included in this report as Appendix B.

Meetings scheduled for March include:

- A NASA-AiResearch program review meeting at Torrance, Ca., on March 6-7, 1979
- A site review meeting at Las Vegas, Nev., on March 8
- A final Houston site system checkout meeting in mid-March when the system is ready

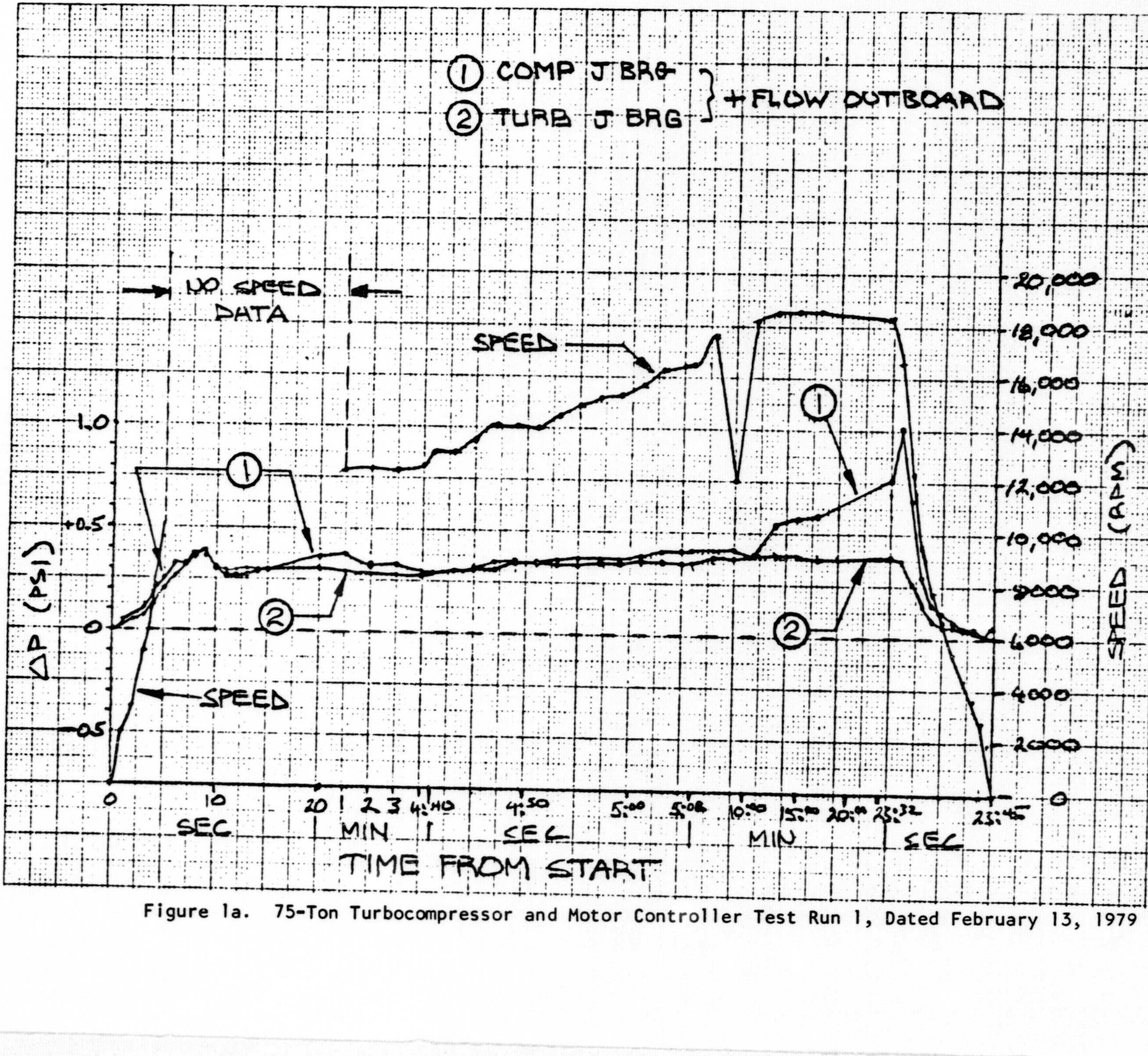


Figure 1a. 75-Ton Turbocompressor and Motor Controller Test Run 1, Dated February 13, 1979

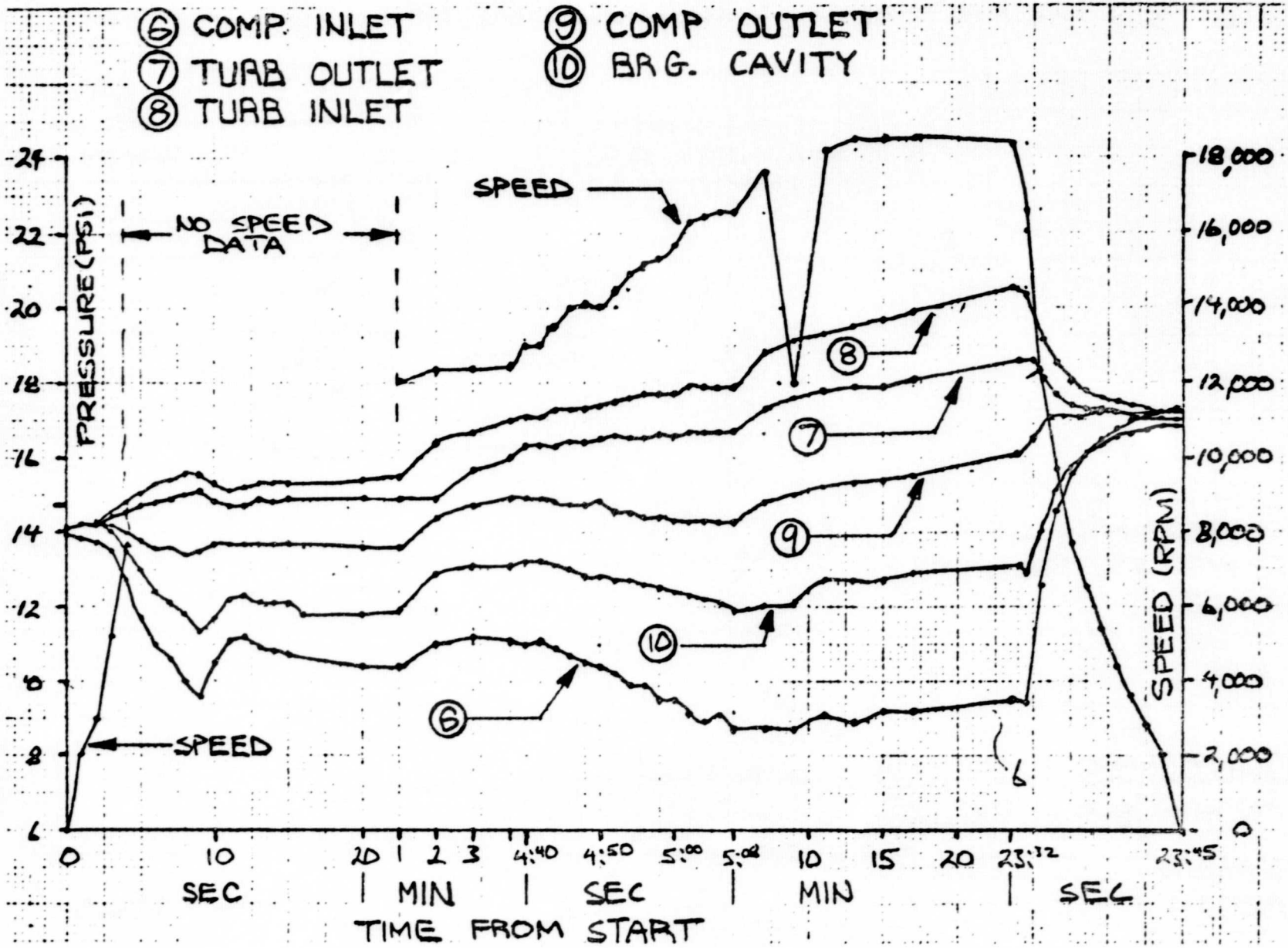


Figure 1b. 75-Ton Turbocompressor and Motor Controller Test Run, Dated February 13, 1979

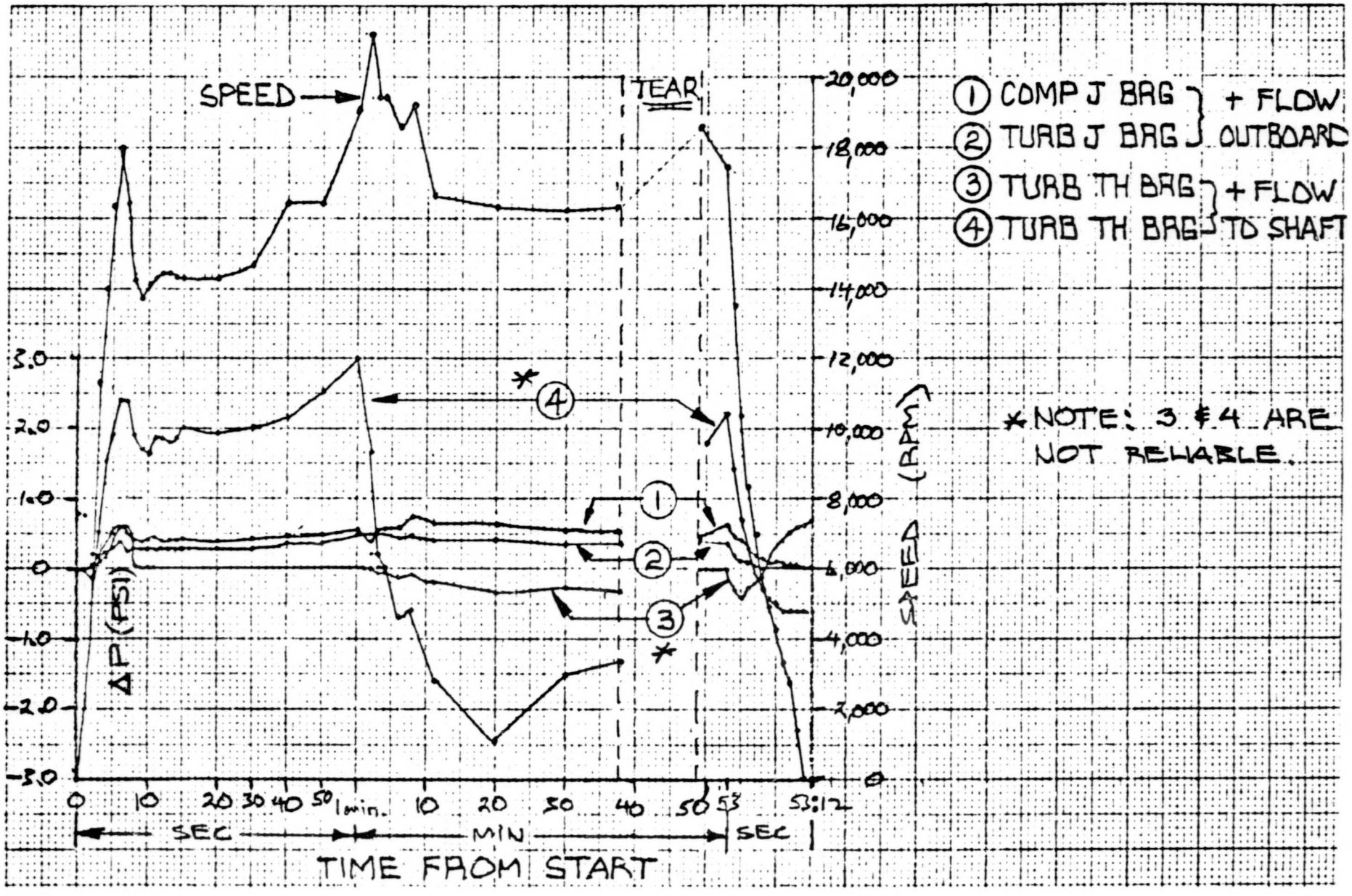


Figure 2a. 75-Ton Turbocompressor and Motor Controller Test Run 2, Dated February 15, 1979

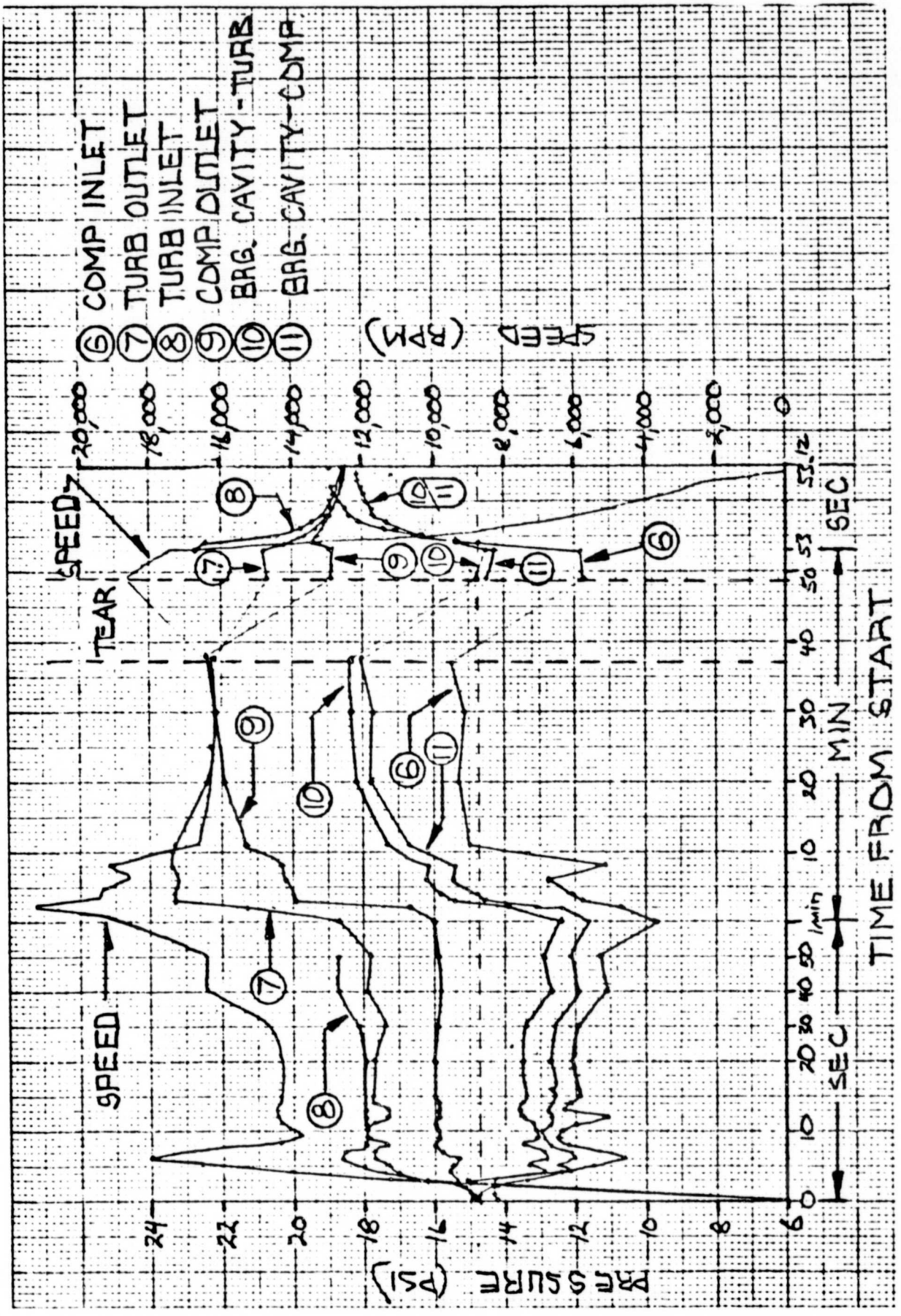


Figure 2b. 75-Ton Turbocompressor and Motor Controller Test Run 2, Dated February 15, 1979

76-13110(26)

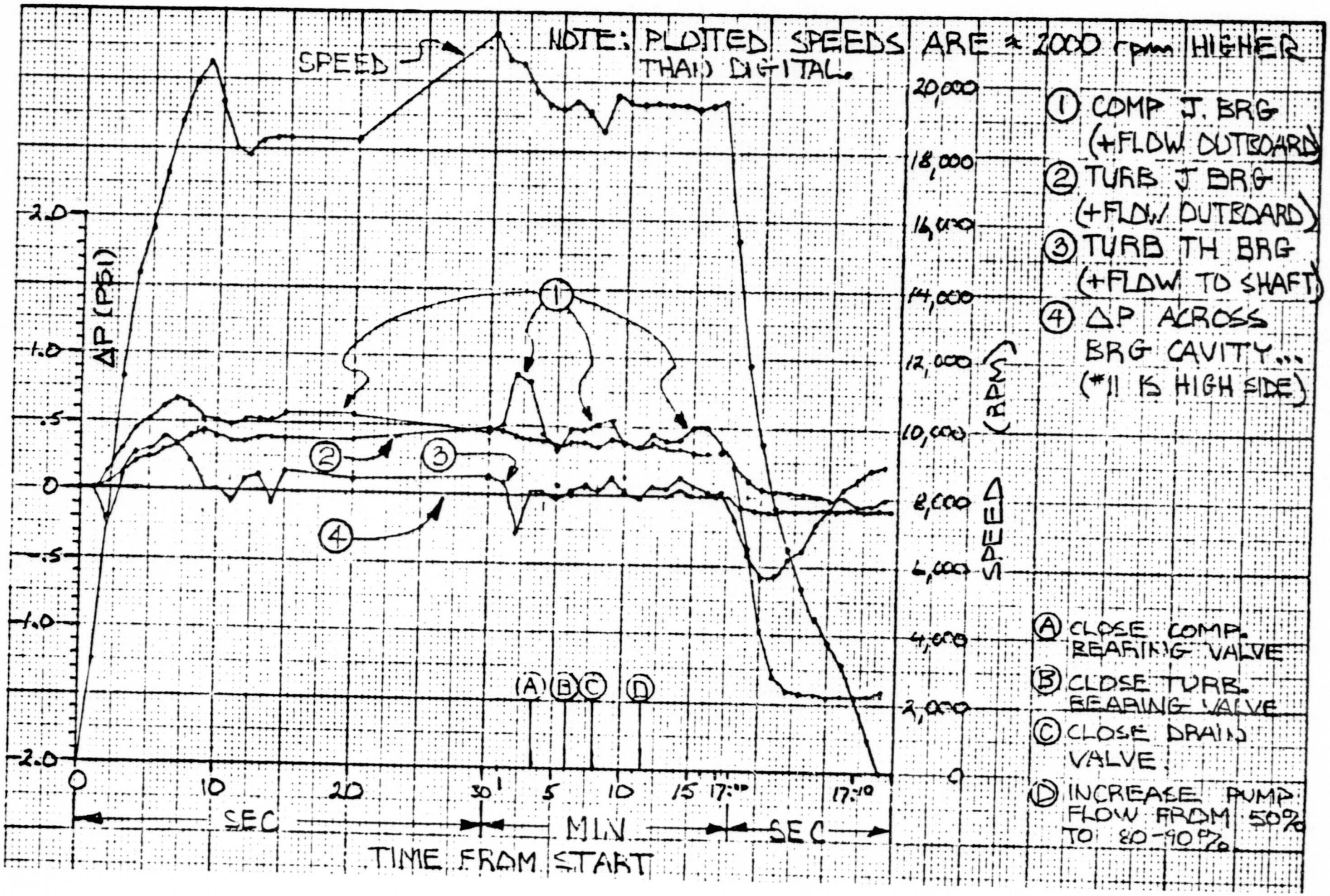


Figure 3a. 75-Ton Turbocompressor and Motor Controller Test Run 2, Dated February 19, 1979

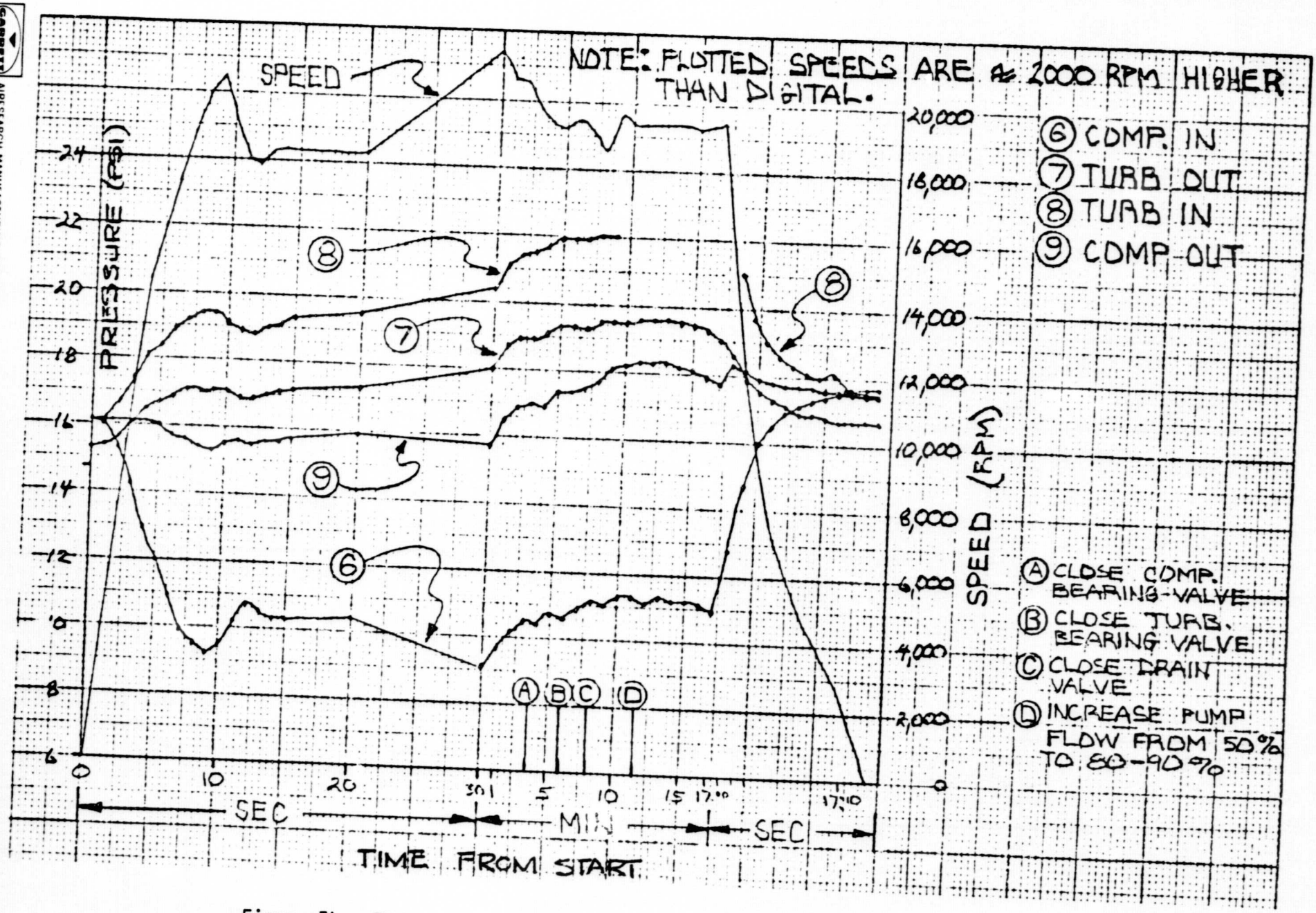


Figure 3b. 75-Ton Turbocompressor and Motor Controller Test Run 2, Dated February 19, 197

Size	Unit	Turbocompressor	Motor Control	Freon Pump	Heat Pump Complete	Start Test	Test Time, Weeks	Test Complete	Ship Date	Intended Site
3 Ton	#1	2-16	complete	complete	2-23	3-12	1	3-19	3-20	Harrisonburg, Va.
	#2	complete	complete	complete	complete	started	6	3-9	3-16	Lawrenceburg, Tenn.
	#3	2-23	2-23	2-23	3-2	3-20	4	4-17	4-23	Allaire Park, N.J.
	#4	3-9	3-9	3-9	4-2	4-18	8	6-13	6-18	Novato,Ca.
25 Ton	#1	complete (or) 3-9 (d)	complete --	complete --	complete (or) 3-16	started (or) 3-19	11 (or) 11	4-6 (or) 6-4	4-3 (or) 6-11	Redmond, Oregon
	#2	5-2	5-2	5-2	6-1	6-5	5	7-10	7-17	
75 Ton	#1	2-20	complete	received	shipped(a)	3-7 (b)	7	4-25	5-2	Houston, Texas
	#2	3-30	complete	received	2-19 (c)	5-2	11	7-19	7-26	Las Vegas, Nevada

HEAT PUMP DELIVERY SCHEDULE

(a) Heat pump less turbocompressor
(b) Using #2 H.P.
(c) #2 H.P. with #2 turbocompressor
(d) Possible alterations resulting from 75-ton development

Chart 5
Date: 3-9-79
76-13110(26)
APPENDIX A

APPENDIX B

The information herein was presented during the NASA-AiResearch SHAC Program Review Meeting at Huntsville, Alabama on March 1, 1979.

3 TON HEAT PUMP DEVELOPMENT ACCOMPLISHMENTS

- DETERMINED THAT TXV THERMAL BULB WELLS ARE REQUIRED
- DETERMINED THAT EVAPORATOR SHUTOFF VALVE IS REQUIRED
- OPERATED BOILER AT FULL DESIGN HEAT LOAD
- OPERATED TURBINE AT DESIGN INLET PRESSURE
- DISCOVERED PROBABLE CAUSE OF COMPRESSOR MOTOR STATOR DYNAMIC INTERFERENCE (REVERSE FLOW THROUGH A SOLENOID VALVE)
- OPERATED SYSTEM IN HIGH POWER, HIGH TEMPERATURE HEATING MODE WITHOUT INCIDENT

TESTING WAS DISCONTINUED BECAUSE OF A FAILURE OF ONE OF THE POSITION SENSORS.

25 TON HEAT PUMP DEVELOPMENT ACCOMPLISHMENTS

- RESOLVED CONTROLLER PROBLEM WHICH HAD CAUSED STARTING DIFFICULTIES
- DETERMINED THAT TXV THERMAL BULB WELLS ARE REQUIRED
- DETERMINED THAT EVAPORATOR SHUTOFF VALVE IS REQUIRED
- OPERATED BOILER AT FULL DESIGN HEAT LOAD
- FOUND REVERSING VALVE ΔP EXCESSIVE
- DETERMINED THAT REFRIGERATION MANAGEMENT IS MORE DIFFICULT THAN 3 OR 75 TON SYSTEMS

TESTING WAS DISCONTINUED BECAUSE OF A SUSPECTED BEARING FAILURE CAUSING STARTING DIFFICULTIES--THIS WAS LATER FOUND TO BE A MOTOR-CONTROLLER PROBLEM.

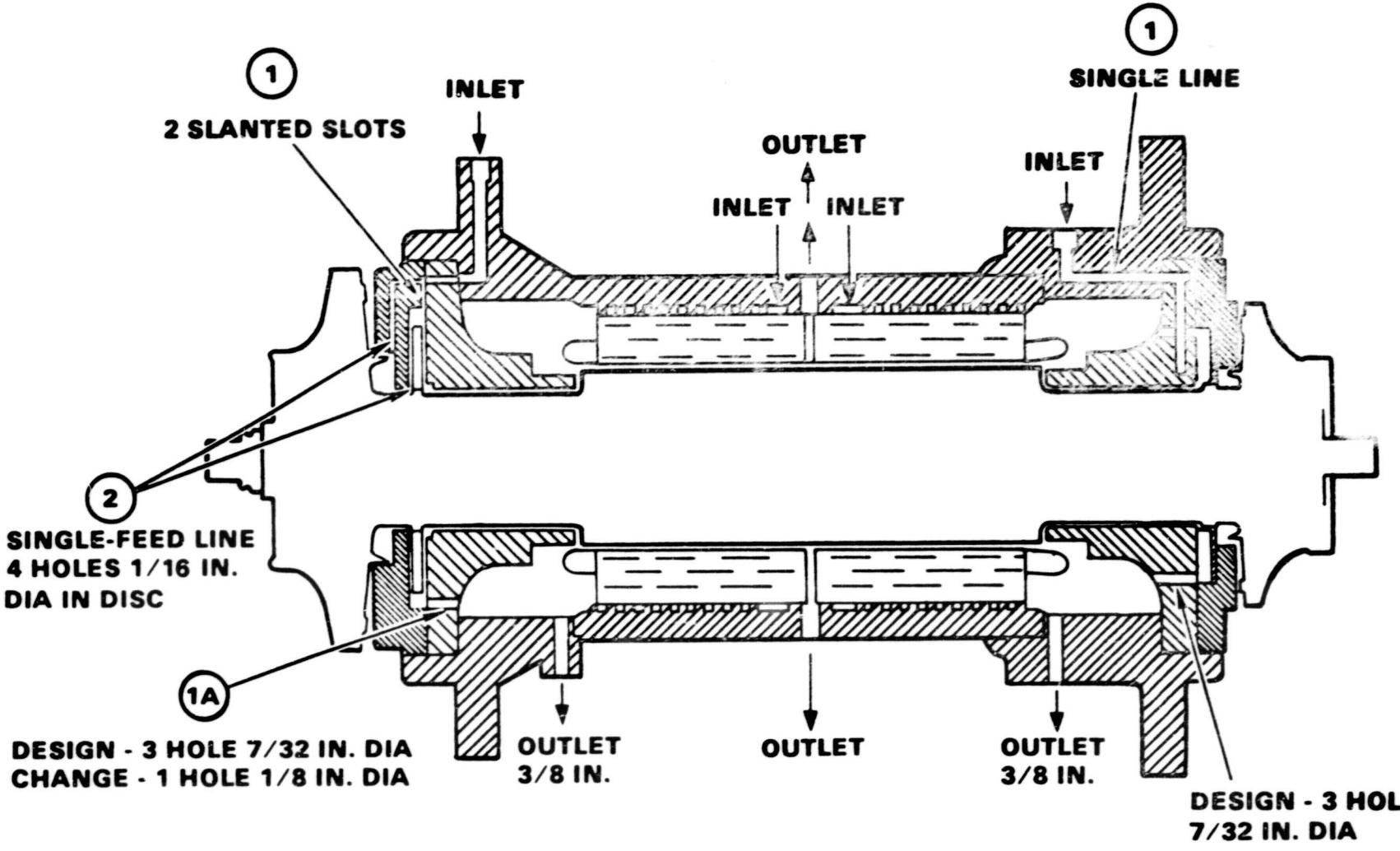
75 TON HEAT PUMP CONTINGENCY TEST PLAN

POSSIBLE DEVIANCE	ALTERNATIVE ACTIONS
1. MOTOR CONTROLLER MALFUNCTION	1. (A) INVESTIGATE FAILURE MODE USING NUMBER 2 UNIT AND SHIP CORRECTIVE HARDWARE (B) SHIP NUMBER 2 UNIT TO DUNHAM-BUSH IF PRIORITY DICTATES (C) SHIP NUMBER 2 UNIT AS SOON AS PRESENT TESTING AT AIRESEARCH IS COMPLETED
2. TURBOCOMPRESSOR FAILURE	2. (A) SHIP NUMBER 2 UNIT TO DUNHAM-BUSH IF PRIORITY DICTATES (B) SHIP NUMBER 2 UNIT AS SOON AS CONTROLLER TESTING IS COMPLETE
3. HEAT PUMP MODIFICATION OR MALFUNCTION	3. (A) WORK AROUND WITH SPARE SYSTEM HARDWARE, OR OTHER AVAILABLE EQUIPMENT AT DUNHAM-BUSH (B) FALL BACK TO 25 TON SYSTEM TO CONTINUE SYSTEM DEVELOPMENT

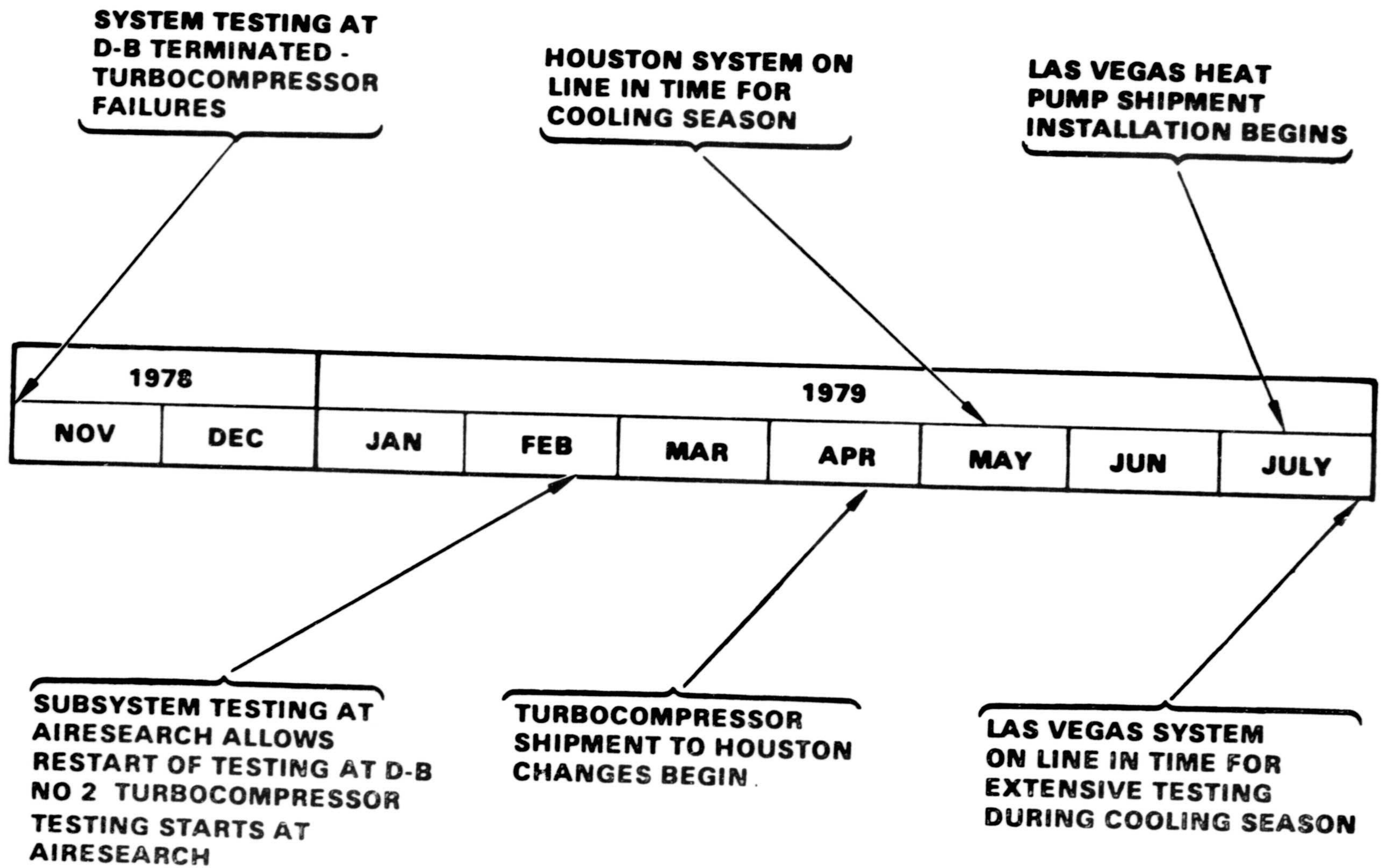
HEAT PUMP FABRICATION STATUS AT DUNHAM-BUSH

UNIT		REMARKS	% COMPLETE
3 TON	1	IN TEST STAND	95
	2		90
	3		90
	4		75
25 TON	1	IN TEST STAND	95
	2		85
75 TON	1	IN HOUSTON	90
	2	IN TEST STAND	90

75-TON TURBOCOMPRESSOR



75-TON TURBOCOMPRESSOR DEVELOPMENT SUMMARY



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