DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150830

PROTOTYPE SOLAR HEATING AND COOLING SYSTEMS (Monthly Progress Reports)

Prepared from Documents furnished by

AiResearch Manufacturing Company of California
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

For the U. S. Department of Energy

U.S. Department of Energy

Solar Energy

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This work was done under the technical management of Mr. James W. Clark, George C. Marshall Space Flight Center, Alabama

16. ABSTRACT

This report is a collection of monthly status reports from the AiResearch Manufacturing Company, who is developing eight prototype solar heating and cooling systems under NASA Contract NAS8-32091. This effort calls for the development, manufacture, test, system installation, maintenance, problem resolution, and performance evaluation The systems are 3-, 25-, and 75-ton size units.

Cost information has been removed from these reports.

17 KEY WORDS	18 DISTRIBUTION STATEMENT UC-59c Unclassified-Unlimited William A. Brooksbank, Jr. WILLIAM A. BROOKSBANK, JR. Mgr, Solar Heating and Cooling Project Office

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Twentieth Monthly Status Report
Data Requirement No. 500-11

SOLAR HEATING AND COOLING SYSTEMS DESIGN AND DEVELOPMENT

Contract NAS8-32091

76-13110(20)

August 10, 1978

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 twentieth monthly status report prepared by AiResearch Manufacturing Company of California under Contract NAS8-32091 for the National Aeronautics and Space Adminstration Marshall Space Flight Center (MSFC). The report summarizes activities from July 1 to July 31, 1978.

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

MEETINGS, REVIEWS AND MAJOR ACTIVITIES

Activities during June were as follows

- A meeting was held in Albuquerque, N.M., with Bridgers and Paxton, consulting engineers for the Novato, Ca., SHAC site on July 7, 1978. Bridgers and Paxton were informed of changes in site concepts since the site was reactivated. Mssrs. Benson, Yee and Walker of AiResearch provided latest site equipment information.

- A quarterly review meeting was held at AiResearch on July 11, 1978 to assess program progress. Program acceleration methods were reviewed in detail with Mr. James Clark of NASA/MSFC. Mssrs. P. Benson, R. Nelson, R. Susag and H. Yee of AiResearch attended.

- A contractor/owner interface meeting was held at Portland, Ore., on July 12, 1978 with the Bonneville Power Authority (BPA) to discuss details on the contemplated Redmond SHAC site. Mssrs. J. Clark and R. Gunner of NASA/MSFC and Benson, Yee and Walker of AiResearch attended this meeting and the meeting at Novato the following day. AiResearch is to provide a system schematic, and ISPI and an updated drawing of the 25-ton unit to BPA personnel. The meeting amounted to a design concept presentation by BPA with a critique by AiResearch rather than the usual preliminary design review.

- A contractor/owner interface meeting was held July 13, 1978 at Oakland, Ca. regarding the Novato site. Site-related cost estimates were made and means of consolidating NAVY and NASA funding explored to cover house modifications.

- A contractor/owner interface meeting (Houston Job Meeting No. 20) was held at Houston on July 20, 1978, with Mssrs. Clark and Gunner of NASA and Mr. Benson of AiResearch attending. Cost of repairing the storage tank damaged in transit to Houston in June were directed to AiResearch.

Meetings scheduled for the month of August include.

- An overall program status and site status meeting at Dunham-Bush, Inc. on August 2 and 3, 1978.

- A contractor/owner interface meeting at Lawrenceburg, Tenn., on August 17, 1978.

- A contractor/owner interface meeting at Redmond, Ore., on August 23, 1978.

Site and Site Equipment Status Charts

Site status Charts 1 through 5 were updated to coincide with latest test and delivery activities as of July 31. The charts are included as Appendix A of this report.

Status of Instrumentation System Planning Information (ISPI)

Site	Revision	Remarks
Allaire Park, N.J.	B	Delta Approved Instrumention Plan (ΔAIP) received 7-17-78 via NASA TD No. 18. Exceptions will be listed and resubmitted to NASA this month.
Lawrenceburg, Tn.	A	ΔAIP received 7-17-78 via NASA TD No. 17. Collector loop new to use ethylene-glycol/water instead of glycerol/water. Exceptions to ΔAIP are imminent.
Harrisonburg, Va.	--	Geo. Mizell of IBM/Huntsville requested changes or original ISPI per telecon on 7-28-78.
Novato, Ca.	--	Preliminary site information received; PIP to be started this month.
St. Louis, Mo.	--	No action; site no yet determined.
Redmond, Ore.	--	Preliminary site information received; heating and cooling schematic (with instrumentation) has been started.
Houston, Tx.	D	Minor wattmeter changes are being made per comments received from G. Mizell of IBM/Huntsville on July 28, 1978.
Las Vegas, Nv.	D	Extensive plumbing and instrumentation changes are being made to system schematic of ISPI per NASA and IBM comments received in July.

Program Documentation

a. Nineteenth Monthly Status Report 76-13110(18), dated July 10, 1978 (DR500-11).

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

Other publications were submitted during July to the parties listed as tabulated below.

Submittal Date	To	Subject
7-1-78	J. Clark (NASA/MSFC)	AiResearch agreement to use ethylene glycol, as directed by NASA, instead of glycerol

Submittal Date	To	Subject
7-1-78	J. Peters, Project Site Mgr., Houston, Tx., and G. Neff, President, TEI	Revision E to storage Tank Dwg. H-TX-M2-2.

SYSTEM DEVELOPMENT

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

Component Design, Fabrication and Test

1. Turbomachines

(a) 3-Ton Unit

Unit D-2 was bench tested prior to installation in the heat pump package (which had been transferred from Dunham-Bush to AiResearch). It exhibited no unusual characteristics. Upon installation, rubbing occurred and the unit would not start. It was concluded that a torque caused by turbine inlet duct loading was causing deformation. The duct was realigned and tests were continued in the cooling mode without incident for two days to check system operation. On the third day, rubbing occurred during start and the unit was removed for examination. Seal rubbing was apparent at both the turbine and compressor-end seals. Further investigation revealed that several of the journal bearing undersprings were soft and could cause rubbing due to instability. Two other units were checked (one that exhibited intermittent rubbing and one that had not). The unit which had rubbed had soft springs, the other did not. All undersprings were replaced with stiffer springs. As a secondary precaution, the Dunham-Bush heat pump was reworked to eliminate the possibility of duct misalignment.

Testing was then resume with the freon pump in operation. The pump failed and it was found that the wrong power was being applied (208V instead of 110V). Upon disassembly, it was found to be contaminated with carbon particles. The turbomachine was removed and the compressor also evidenced carbon deposits. The reversing valve was determined to be the problem and is being replaced with a steel unit using chrome plating as opposed to a carbon unit.

The system has been flushed clean with freon and is currently being reassembled.

Two additional units are available for shipment.

(b) 25-Ton Unit

Unit No. 1 is at Dunham-Bush. Unit No. 2 will be ready for shipment on September 1, 1978.

(c) 75-Ton Unit

Unit No. 1 is at Dunham-Bush. System testing is to begin the first week of August.

Unit No. 2 is complete and will be shipped to Dunham-Bush on August 4, 1978.

2. Motor Controller

(a) 3-Ton Controller

Tests are being conducted on the heat pump package at AiResearch.

(b) 25-Ton Controller

Controller No. 1 has been shipped to Dunham-Bush while Controller No. 2 is 60 percent complete.

(c) 75-Ton Controller

Controller No. 2 will be ready for shipment on August 15, 1978.

3. System Controller

Five controllers are completed and await shipment to Dunham-Bush when needed.

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 is being held in abeyance pending system test evaluation.

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

1. Components (at Dunham-Bush)

(a) 3-Ton Heat Pump

All components for four 3-ton units are in house except for one condenser and the turbocompressors, freon pumps and controllers listed in Chart 5 (Appendix A). Two additional reversing valves have been ordered to replace the ones with carbon spools.

(b) 25-Ton Heat Pump

All components are in house for one heat pump except for reversing valve and all for the second heat pump except the boiler/evaporator, reversing valve and the imminent Chart 5 components.

(c) 75-Ton Heat Pump

All components are in house except those noted in Chart 5.

2. Assembly of Units (at Dunham-Bush)

One 75-ton unit has been assembled and is currently piped into the test facility. Assembly is proceeding on the second 75-ton unit.

The first 25-ton heat pump has been removed from the test facility. It is complete except for the 4-way reversing valve which is past due.

One 3-ton heat pump has been completed. The second and third units are nearing completion and the fourth is about one-fourth assembled.

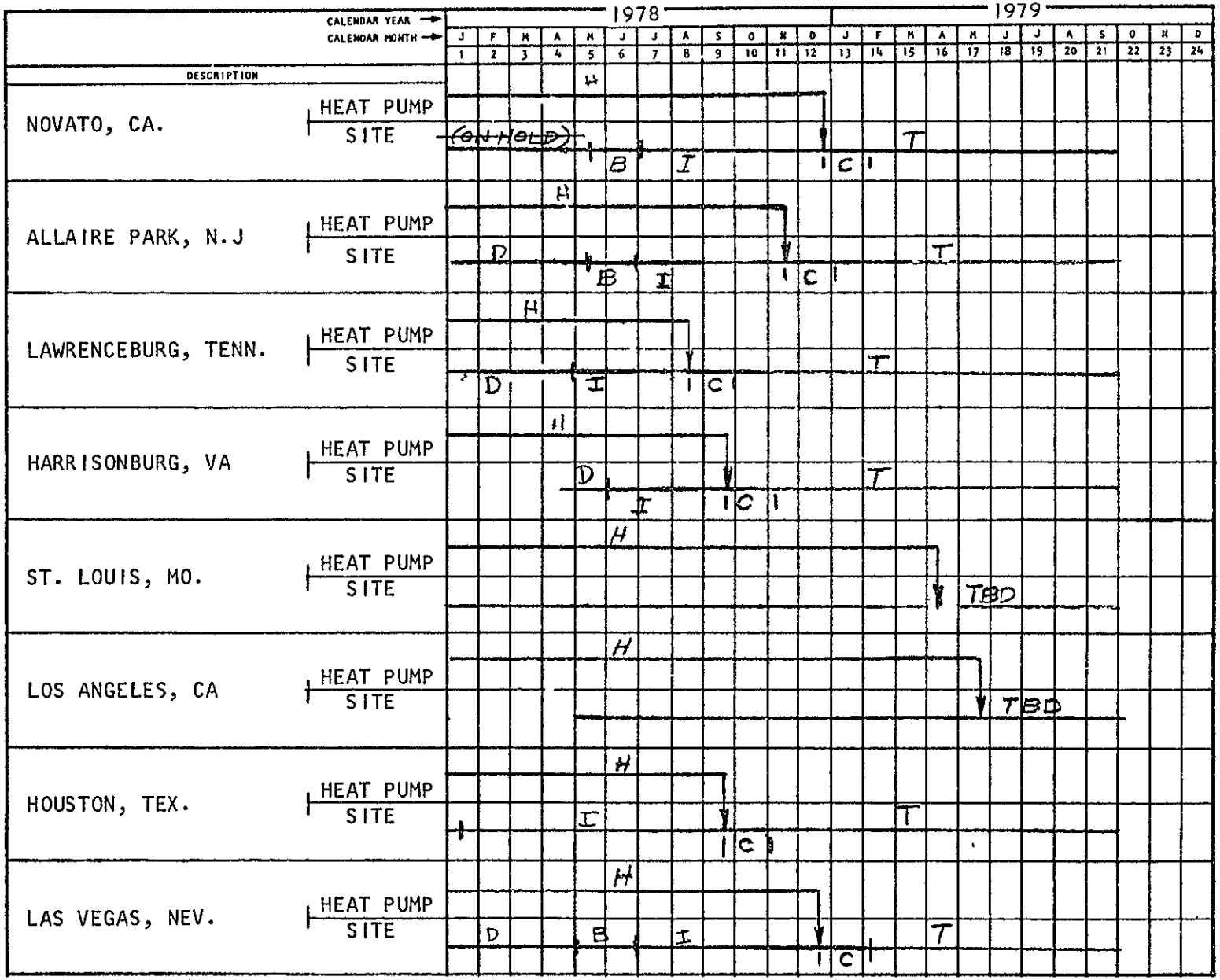
3. Tests of 3-Ton Heat Pump

The 3-ton heat pump was shipped to AiResearch the last week in June and all testing this month has been done in Torrance, Calif. All heat pump testing at AiResearch was concentrated on the turbomachine rubbing problems. Consequently heat pump testing is reviewed in Section I (a) of this report.

APPENDIX A

SITE STATUS CHARTS (ATTACHMENTS)

Chart	Title
1	Operational Test Site Status
2	Heat Pump Development and Test Schedule (Lawrenceburg, Tenn.)
2a	Heat Pump Development and Test Schedule (Harrisonburg, Va.)
2b	Heat Pump Development and Test Schedule (Allaire State Park, N.J.)
2c	Heat Pump Development and Test Schedule (Novato, Ca.)
2d	Heat Pump Development and Test Schedule (St. Louis, Mo.)
2e	Heat Pump Development and Test Schedule (Redmond, Ore.)
2f	Heat Pump Development and Test Schedule (Houston, Tx.)
2g	Heat Pump Development and Test Schedule (Las Vegas, Nev.)
3	Operational Test Site Subsystem Schedule (Allaire State Park, N.J.)
4	Operational Test Site Installation Schedule (Allaire State Park, N.J.)
3a	Operational Test Site Subsystem Schedule (Lawrenceburg, Tenn.)
4a	Operational Test Site Installation Schedule (Lawrenceburg, Tenn.)
3b	Operational Test Subsystem Schedule (Harrisonburg, Va.)
4b	Operational Test Site Installation Schedule (Harrisonburg, Va.)
3c	Operational Test Site Subsystem Schedule (Novato, Ca.)
4c	Operational Test Site Installation Schedule (Novato, Ca.)
3d	Operational Test Site Subsystem Schedule (St. Louis, Mo.)
4d	Operational Test Site Installation Schedule (St. Louis, Mo.)
3e	Operational Test Site Subsystem Schedule (Redmond, Ore.)
4e	Operational Test Site Installation Schedule (Redmond, Ore.)
3f	Operational Test Site Subsystem Schedule (Houston, Tx.)
4f	Operational Test Site Installation Schedule (Houston, Tx.)
3g	Operational Test Site Subsystem Schedule (Las Vegas, Nev.)
4g	Operational Test Site Installation Schedule (Las Vegas, Nev.)
5	Heat Pump Delivery Schedule (All sites)



H-Heat Pump Assembly, Test and Delivery to Site
D-System Installation Design
B-System Installation Bids
C-System Installation Checkout
T-System Test Operations
I-System Installation

SOLAR HEATING AND COOLING SYSTEMS OPERATIONAL TEST SITE STATUS

CHART 1
Date: 8-10-78

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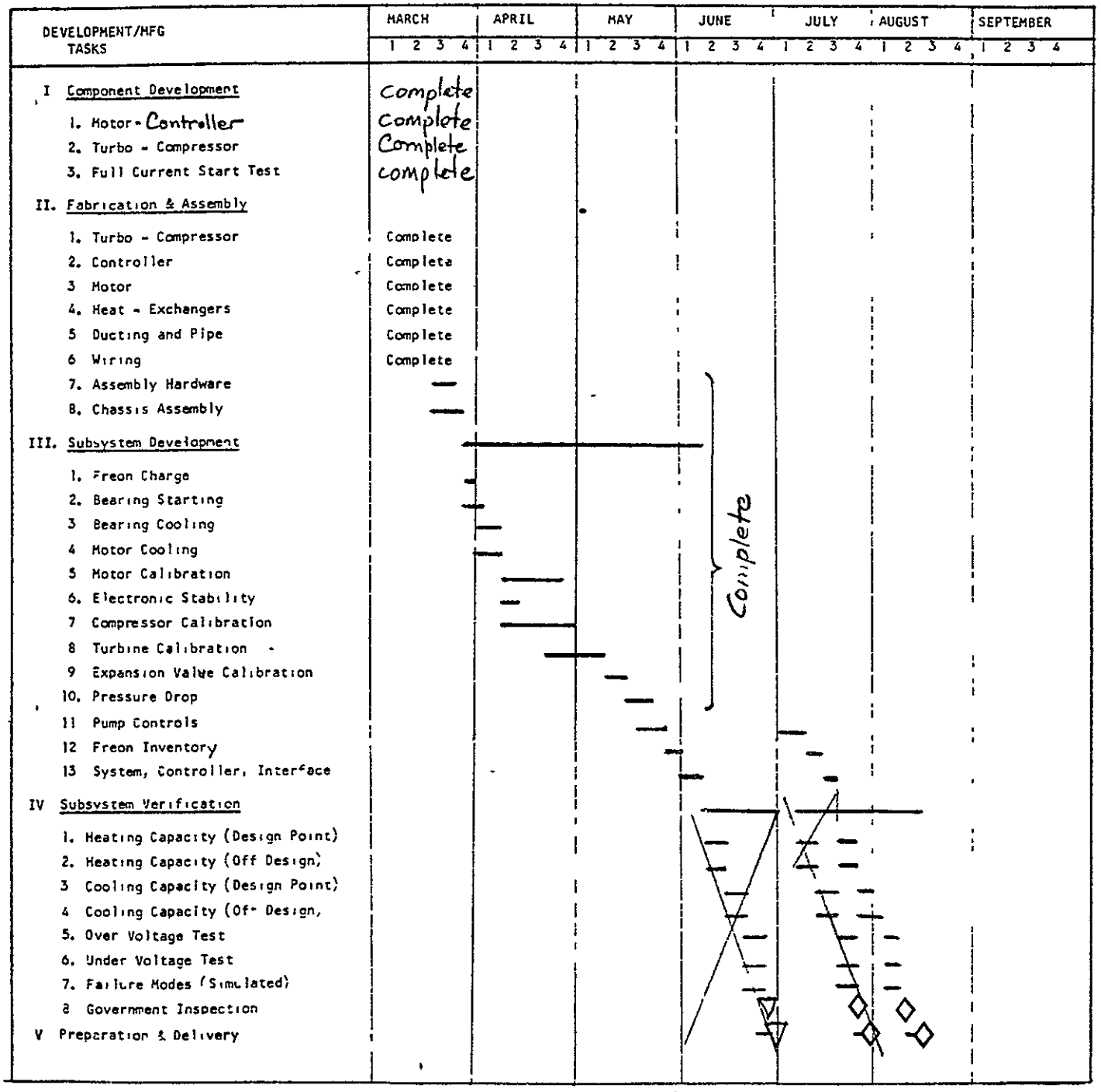
SOLAR HEATING AND COOLING SYSTEM
HEAT PUMP DEVELOPMENT AND TEST SCHEDULE
UNIT: 3-1 (LAWRENCEBURG)



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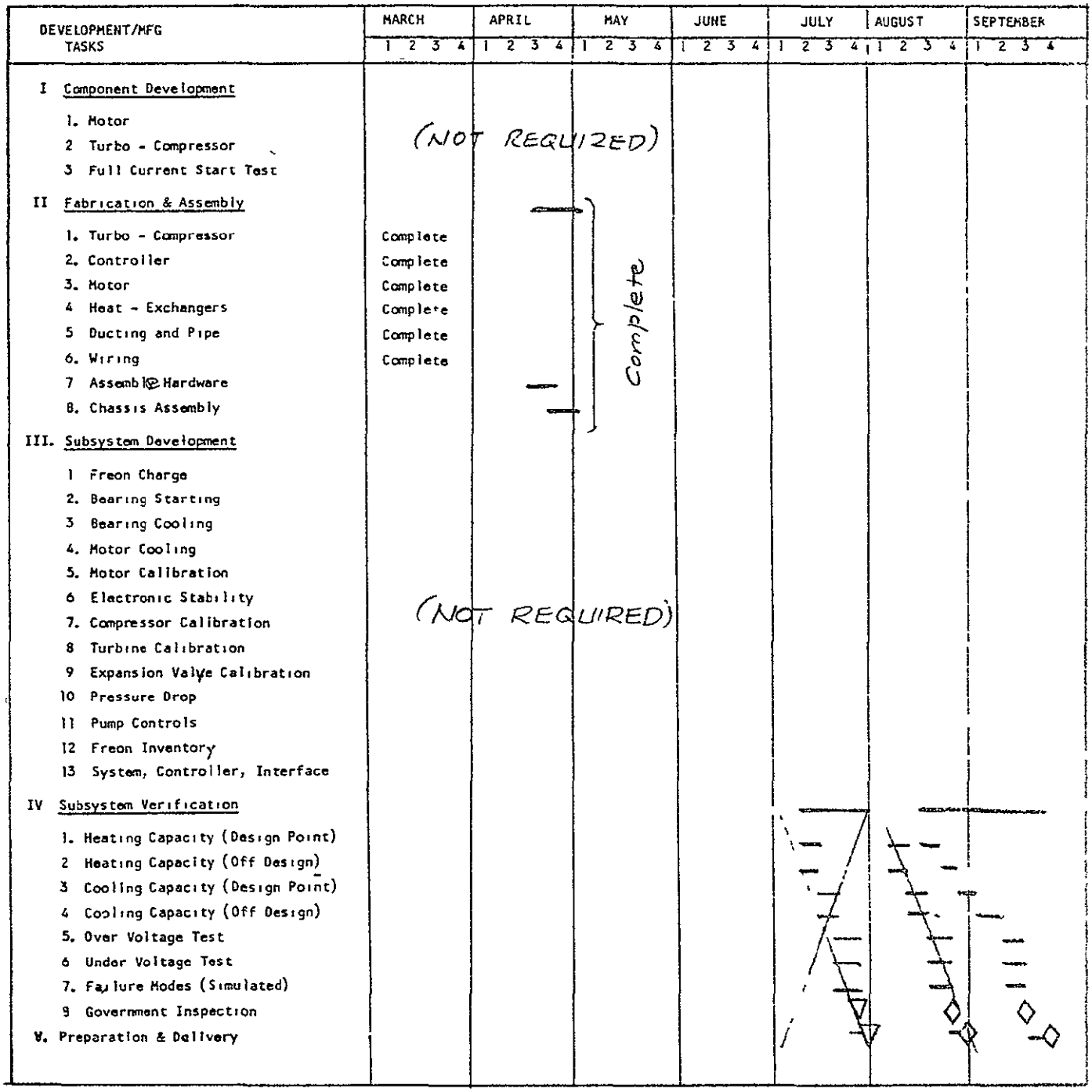
▽ Original milestone
◇ Rescheduled milestone

CHART 2
Date 8-9-76

-SOLAR HEATING AND COOLING SYSTEM
HEAT PUMP DEVELOPMENT AND TEST SCHEDULE
UNIT 3-2 (HARRISONBURG)

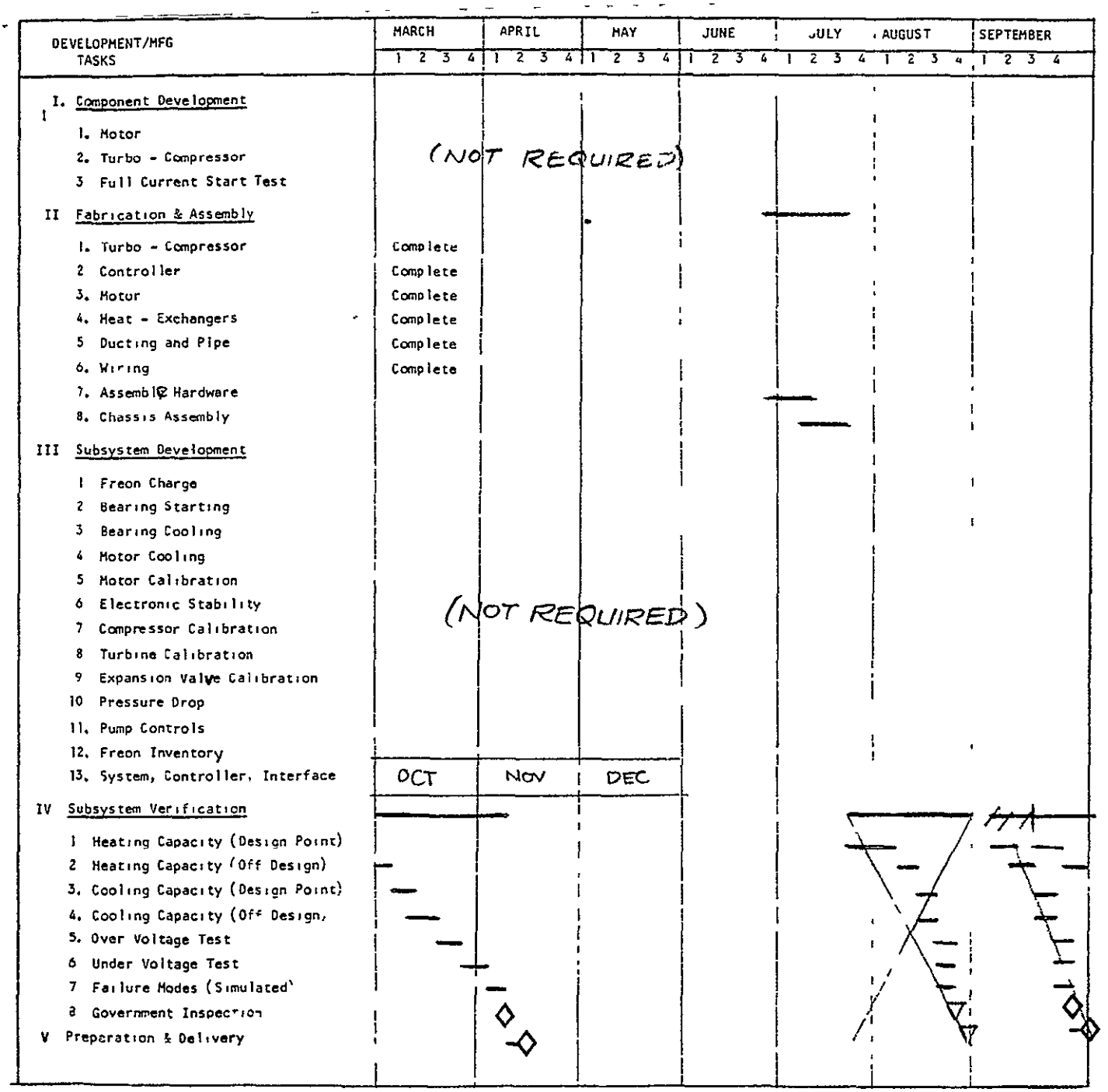


GARRETT AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

▽ Original milestone
◇ Rescheduled milestone

CHART 2a
Date 8-9-78

SOLAR HEATING AND COOLING SYSTEM
HEAT PUMP DEVELOPMENT AND TEST SCHEDULE
UNIT 3-3 (ALLAIRE)

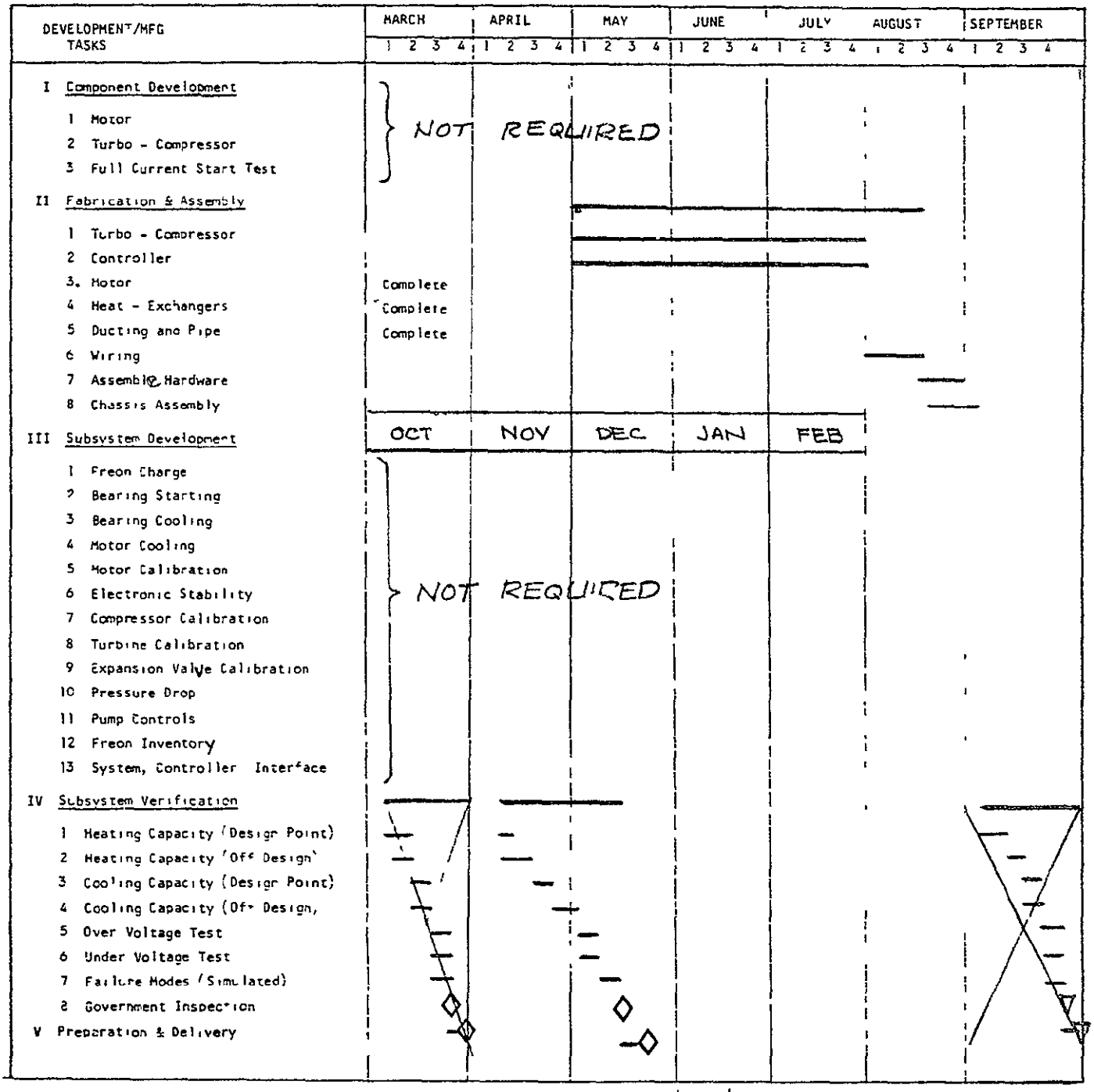


GARRETT AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

▽ Original milestone
◇ Rescheduled milestone

CHART 2b
Date 8-9-78

SOLAR HEATING AND COOLING SYSTEM
HEAT PUMP DEVELOPMENT AND TEST SCHEDULE
UNIT. 3-4 (NOVATO)



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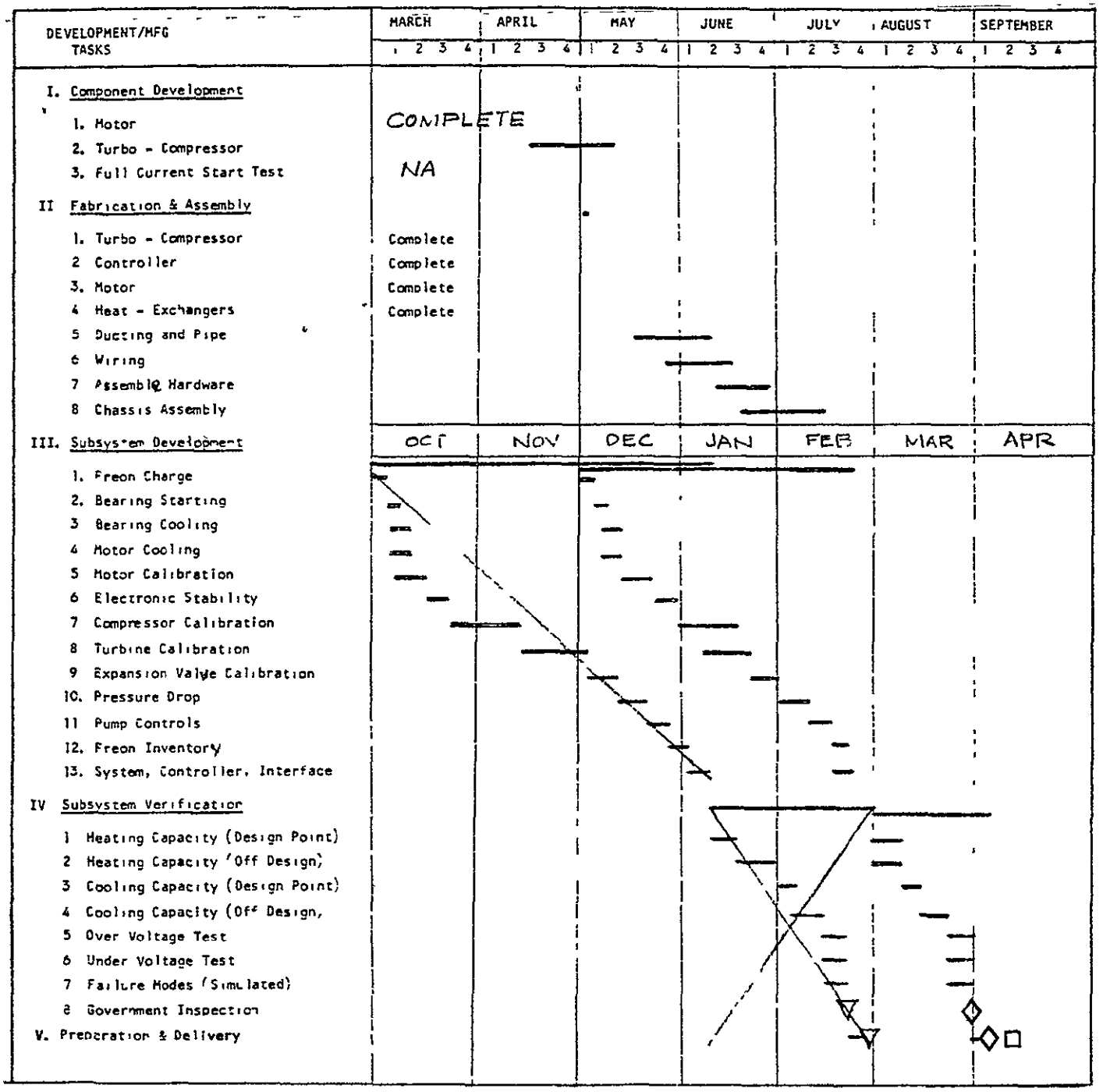
▽ Original milestone
◇ Rescheduled milestone

CHART 2C
Date: 8-9-78

SOLAR HEATING AND COOLING SYSTEM
HEAT PUMP DEVELOPMENT AND TEST SCHEDULE
UNIT: 25-1 (ST. LOUIS)



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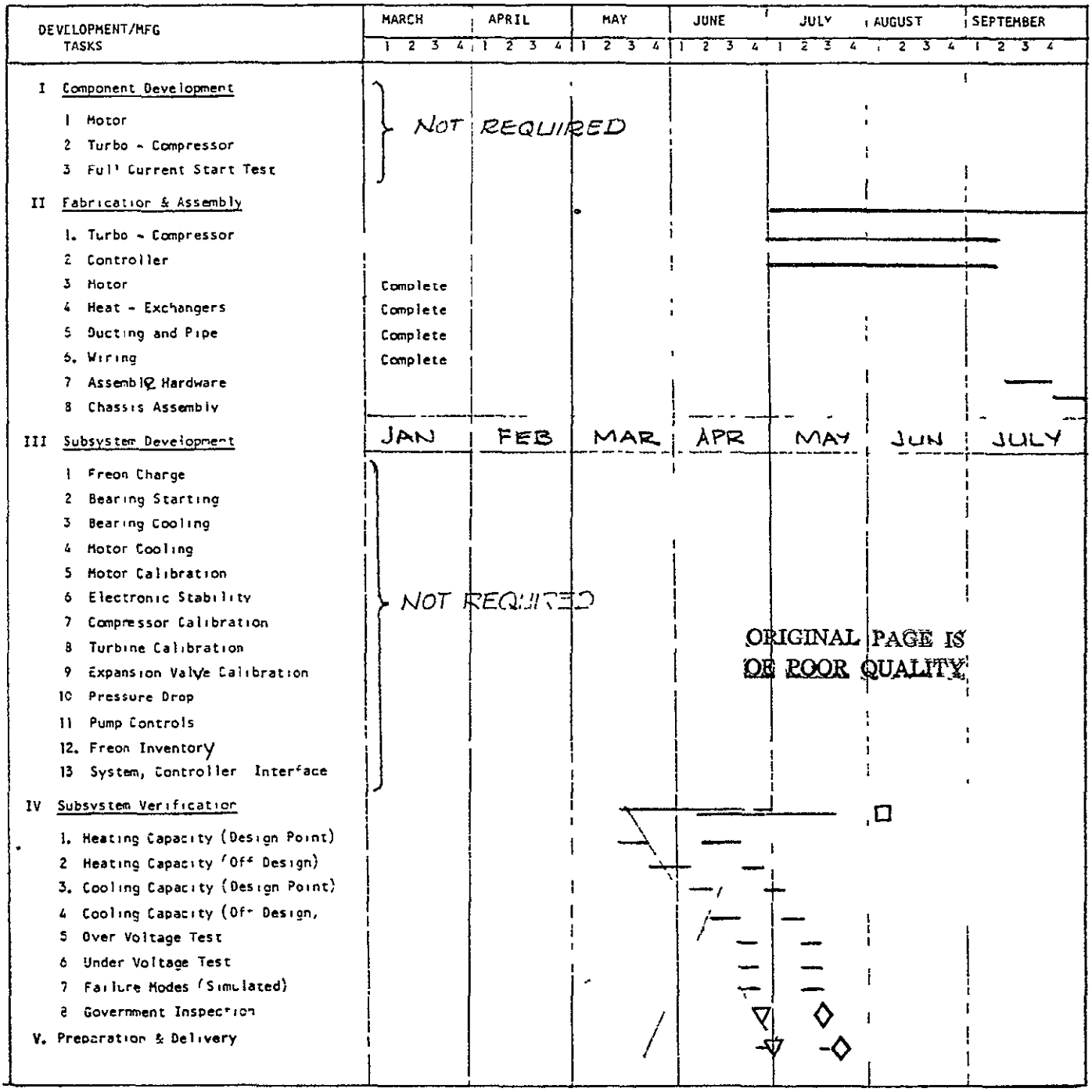
▽ Original milestone
◇ Rescheduled milestone
□ Delivery date may be affected by change of site

CHART 2d
Date: 6-12-78

SOLAR HEATING AND COOLING SYSTEM
HEAT PUMP DEVELOPMENT AND TEST SCHEDULE
UNIT 25-2 (REDMOND, ORE)

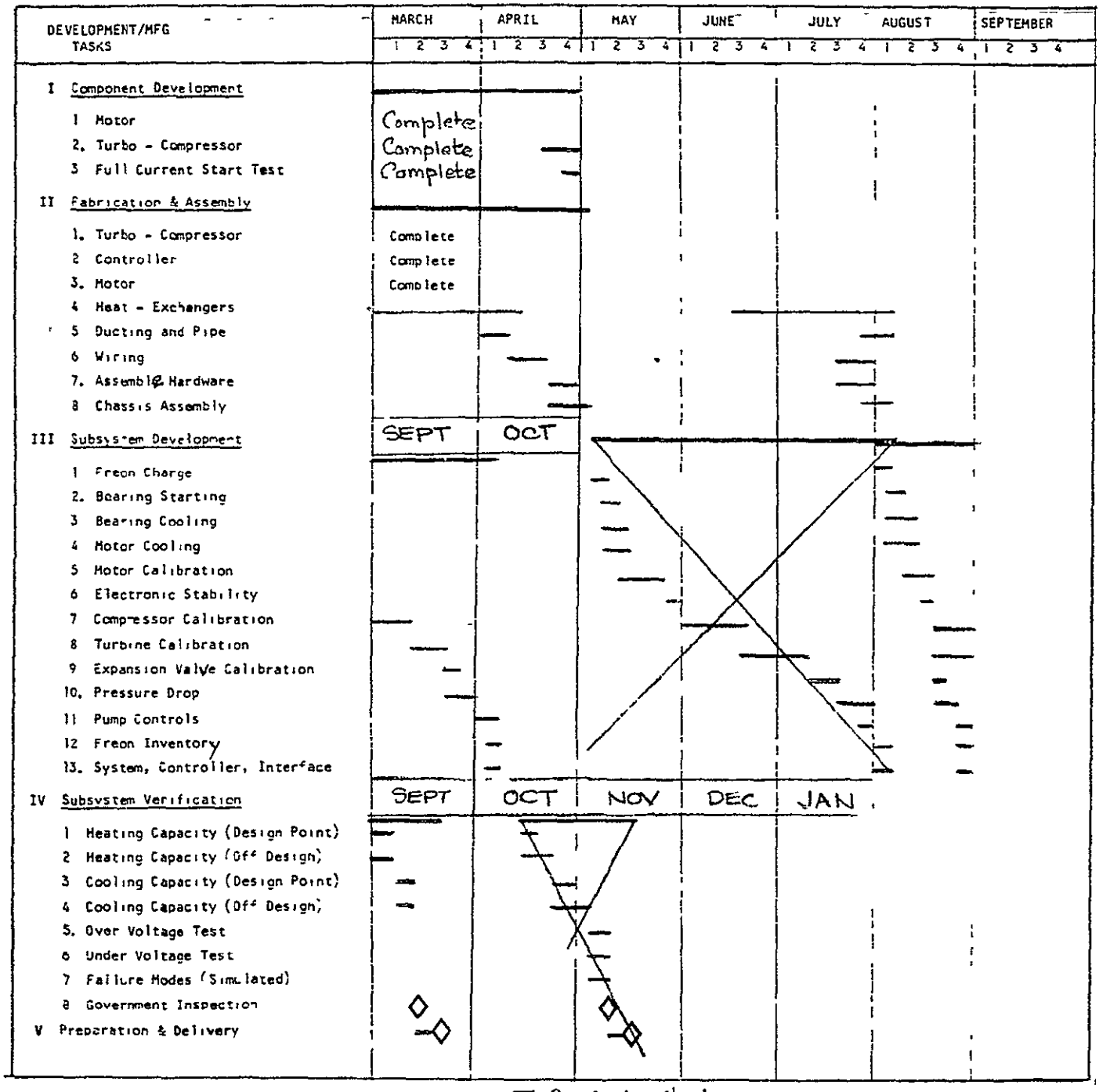


GARRETT AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

▽ Original milestone
◇ Rescheduled milestones
□ This scheduled may be expected one month should the St. Louis unit delivery be delayed by change of site.

CHART 2e
Date: 8-9-76

SOLAR HEATING AND COOLING SYSTEM
HEAT PUMP DEVELOPMENT AND TEST SCHEDULE
UNIT 75-1 (HOUSTON)



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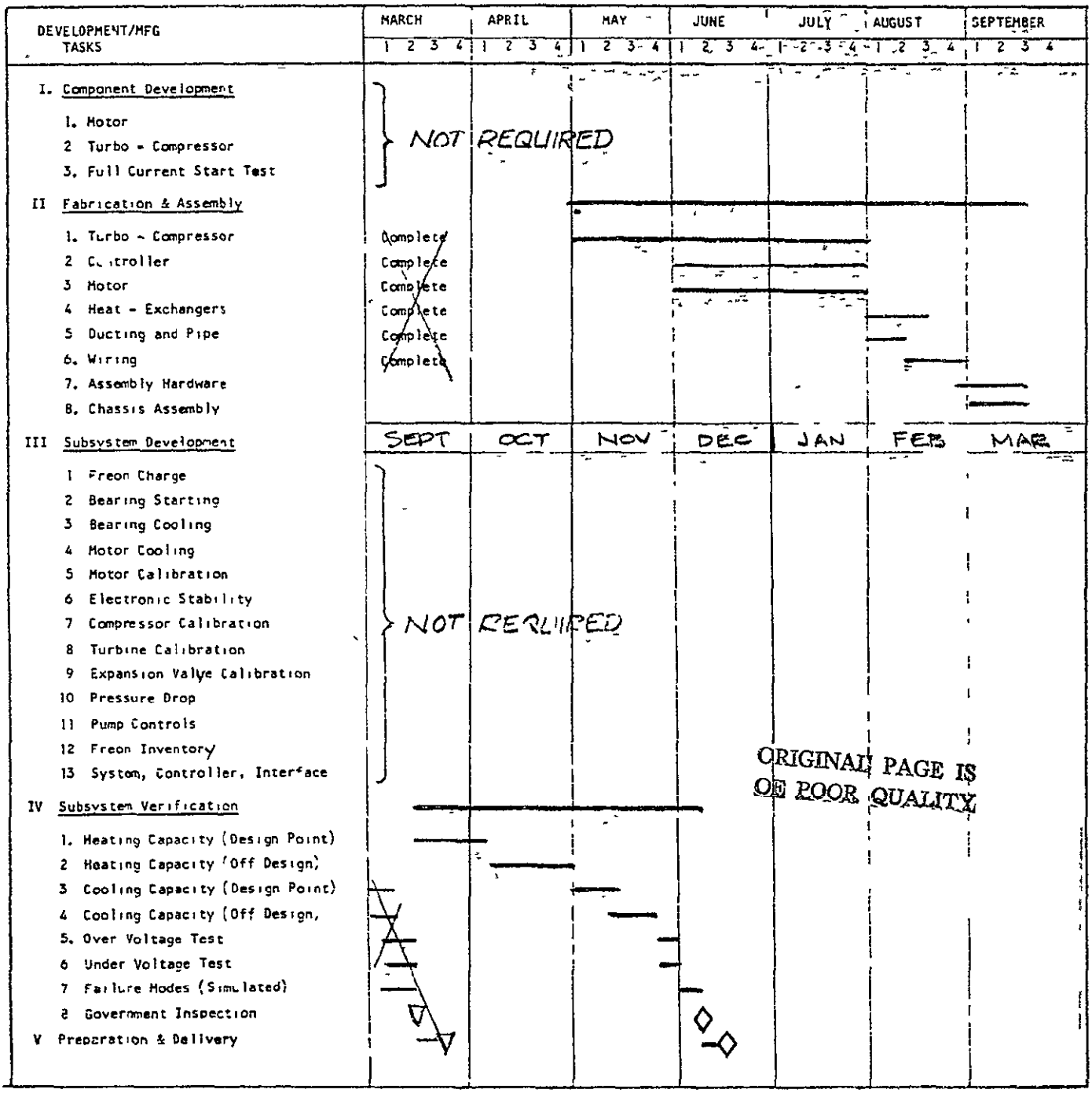
▽ Original milestone
◇ Rescheduled milestone

CHART 2B
Date: 8-9-78

SOLAR HEATING AND COOLING SYSTEM
HEAT PUMP DEVELOPMENT AND TEST SCHEDULE
UNIT 75-2 (LAS VEGAS)



▽ Original milestone
◇ Rescheduled milestone

GARRETT AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

CHART 29
Date: 8-9-78

SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE SUBSYSTEM SCHEDULE

SITE ALLAIRE STATE PARK, N.J

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SUBSYSTEM												
• Heat Pump (See Chart 1)									△	◇	◇	
• Collector S/S												
1. Develop Reqmts.	COMPLETE											
2. Delivery					△	◇						
• Storage S/S												
1. Develop Specs.	COMPLETE											
2. Procure												
3 Delivery						△		◇				
• Data S/S												
1 Develop ISPI	12/16/77 ←											
2. Review & Approve					###	△	◇ ΔAIP Received		◇			
3. Procure	(NASA)											
4. Delivery	(NASA)							◇		◇		
• System Controller S/S												
1. Manufacture	COMPLETE											
2. Ship to D/B						△		◇				
3 Delivery									△	◇	◇	
• DHW - Preheater												
1. Develop Specs	COMPLETE											
2. Procure												
3. Delivery						△			◇			
OTHER MAJOR COMPONENTS												
• Cooling Tower												
1. Develop Specs	COMPLETE											
2. Procure												
3. Delivery						△			◇			
• Auxiliary Heater												
1 Develop Specs	COMPLETE											
2 Procure												
3 Deliver						△			◇			

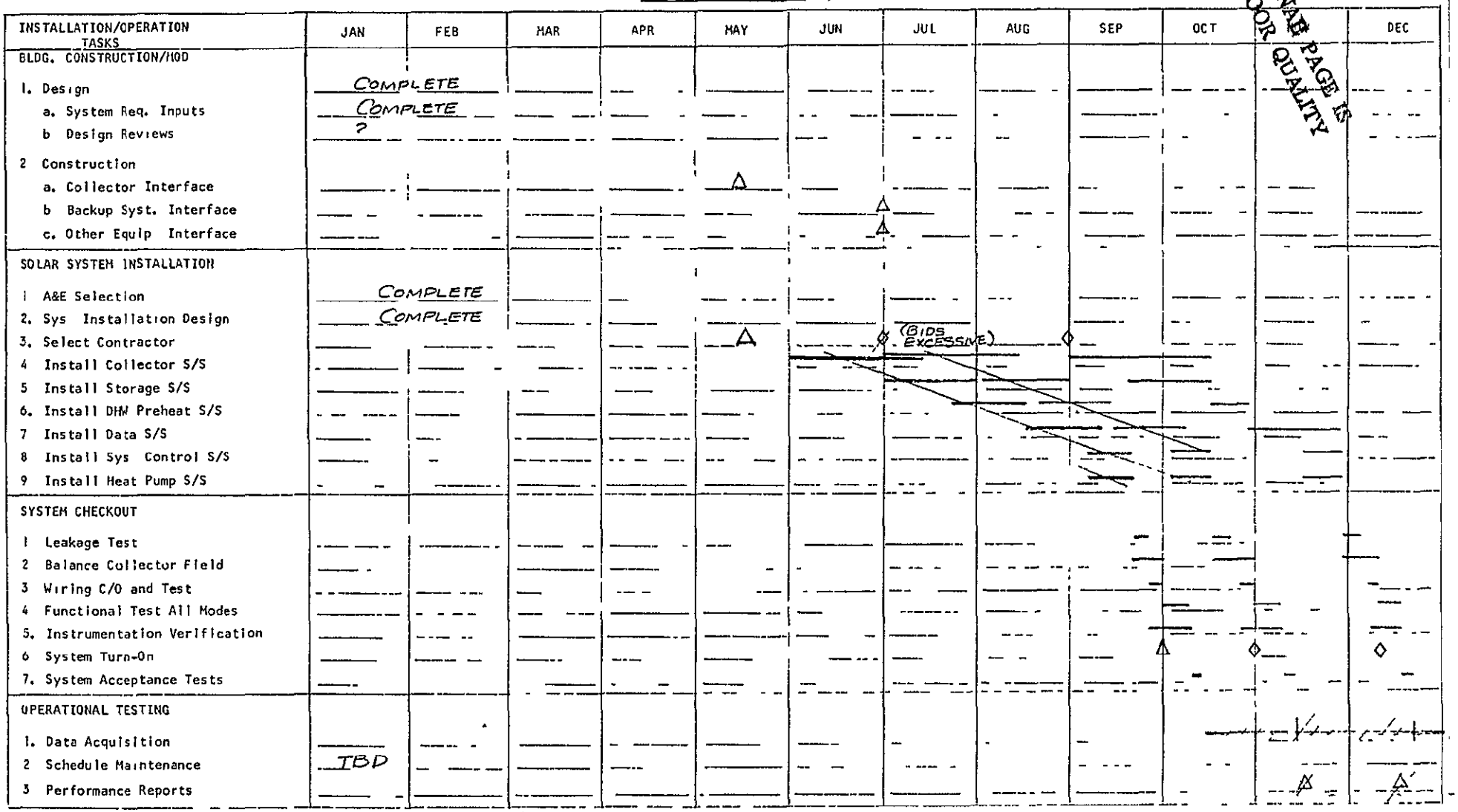
△ Original milestone ◇ Rescheduled milestone • General contractor procured item

GARRETT AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

Chart 3
Date 8-9-78

SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE INSTALLATION SCHEDULE

SITE ALLAIRE STATE PARK, N.J



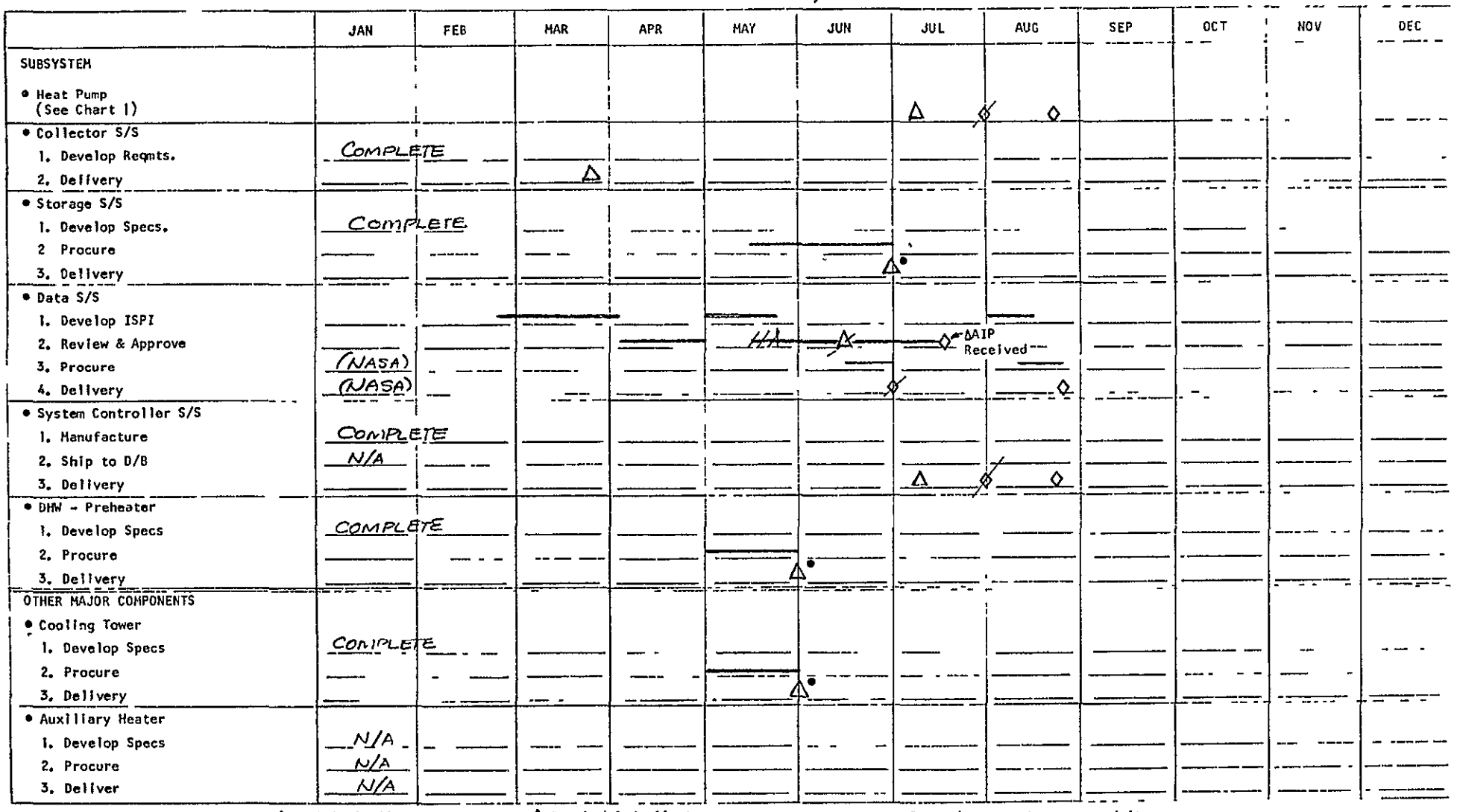
△ Original milestone ◇ Rescheduled milestone

AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

Chart 4
Date 8-9-76

SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE SUBSYSTEM SCHEDULE

SITE LAWRENCEBURG, TENN.



△ Original Milestone ◇ Rescheduled milestone • General contractor procured item

GARRETT AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

Chart 32
Date 8-9-79

SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE INSTALLATION SCHEDULE

SITE LAWRENCEBURG, TENN.

INSTALLATION/OPERATION TASKS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BLDG. CONSTRUCTION/MOD												
1. Design	COMPLETE											
a. System Req. Inputs	COMPLETE											
b. Design Reviews	?											
2 Construction												
a. Collector Interface			△									
b. Backup Syst. Interface				△								
c. Other Equip. Interface				△								
SOLAR SYSTEM INSTALLATION												
1. A&E Selection	COMPLETE											
2 Sys Installation Design	COMPLETE											
3 Select Contractor	N/A											
4. Install Collector S/S						COMPLETE						
5. Install Storage S/S												
6. Install DHW Preheat S/S												
7. Install Data S/S												
8 Install Sys Control S/S												
9 Install Heat Pump S/S												
SYSTEM CHECKOUT												
1. Leakage Test												
2. Balance Collector Field												
3. Wiring C/O and Test												
4. Functional Test All Modes												
5 Instrumentation Verification												
6. System Turn-On								△	◇			
7 System Acceptance Tests												
OPERATIONAL TESTING												
1. Data Acquisition												
2 Schedule Maintenance	TBD											
3. Performance Reports										△	△ ◇	△ ◇

△ Original milestone ◇ Rescheduled milestone

GARRETT AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

Chart 4a
Date 8-9-78

SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE SUBSYSTEM SCHEDULE

SITE HARRISONBURG, VA

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SUBSYSTEM												
• Heat Pump (See Chart 1)								△	⊘ ◇			
• Collector S/S												
1. Develop Reqmts	COMPLETE											
2 Delivery				△								
• Storage S/S												
1. Develop Specs.	COMPLETE											
2. Procure												
3. Delivery						△	◇					
• Data S/S												
1 Develop ISPI												
2. Review & Approve							△		◇			
3. Procure	(NASA)											
4. Delivery	(NASA)							⊘	◇			
• System Controller S/S												
1. Manufacture	COMPLETE											
2. Ship to D/B						△						
3. Delivery						⊘ △			⊘ ◇			
• DHW - Preheater												
1 Develop Specs	COMPLETE						N/A					
2 Procure							N/A					
3. Delivery						△	N/A					
OTHER MAJOR COMPONENTS												
• Cooling Tower												
1. Develop Specs	COMPLETE											
2. Procure												
3 Delivery					△		◇					
• Auxiliary Heater												
1 Develop Specs	N/A											
2. Procure	N/A											
3 Deliver	N/A											

△ Original milestone ◇ Rescheduled milestone

CORRETT... APPLIED RESEARCH MFG. CO. OF CALIFORNIA

Chart 3b
Date 8-9-78

SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE INSTALLATION SCHEDULE

SITE HARRISONBURG, VA.

INSTALLATION/OPERATION TASKS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BLDG CONSTRUCTION/MOD												
1. Design	COMPLETE											
a. System Req. Inputs	COMPLETE											
b Design Reviews	?											
2. Construction												
a. Collector Interface				△								
b. Backup Syst Interface						△	◇					
c. Other Equip. Interface						△	◇					
SOLAR SYSTEM INSTALLATION												
1. A&E Selection	COMPLETE											
2. Sys. Installation Design	COMPLETE											
3. Select Contractor	N/A											
4. Install Collector S/S												
5. Install Storage S/S						N/A						
6. Install DHW Preheat S/S												
7. Install Data S/S												
8 Install Sys Control S/S												
9. Install Heat Pump S/S												
SYSTEM CHECKOUT												
1 Leakage Test												
2. Balance Collector Field												
3. Wiring C/O and Test												
4 Functional Test All Modes												
5 Instrumentation Verification												
6. System Turn-On									△	◇	◇	
7. System Acceptance Tests												
OPERATIONAL TESTING												
1. Data Acquisition	TBD											
2. Schedule Maintenance											△	△
3. Performance Reports												

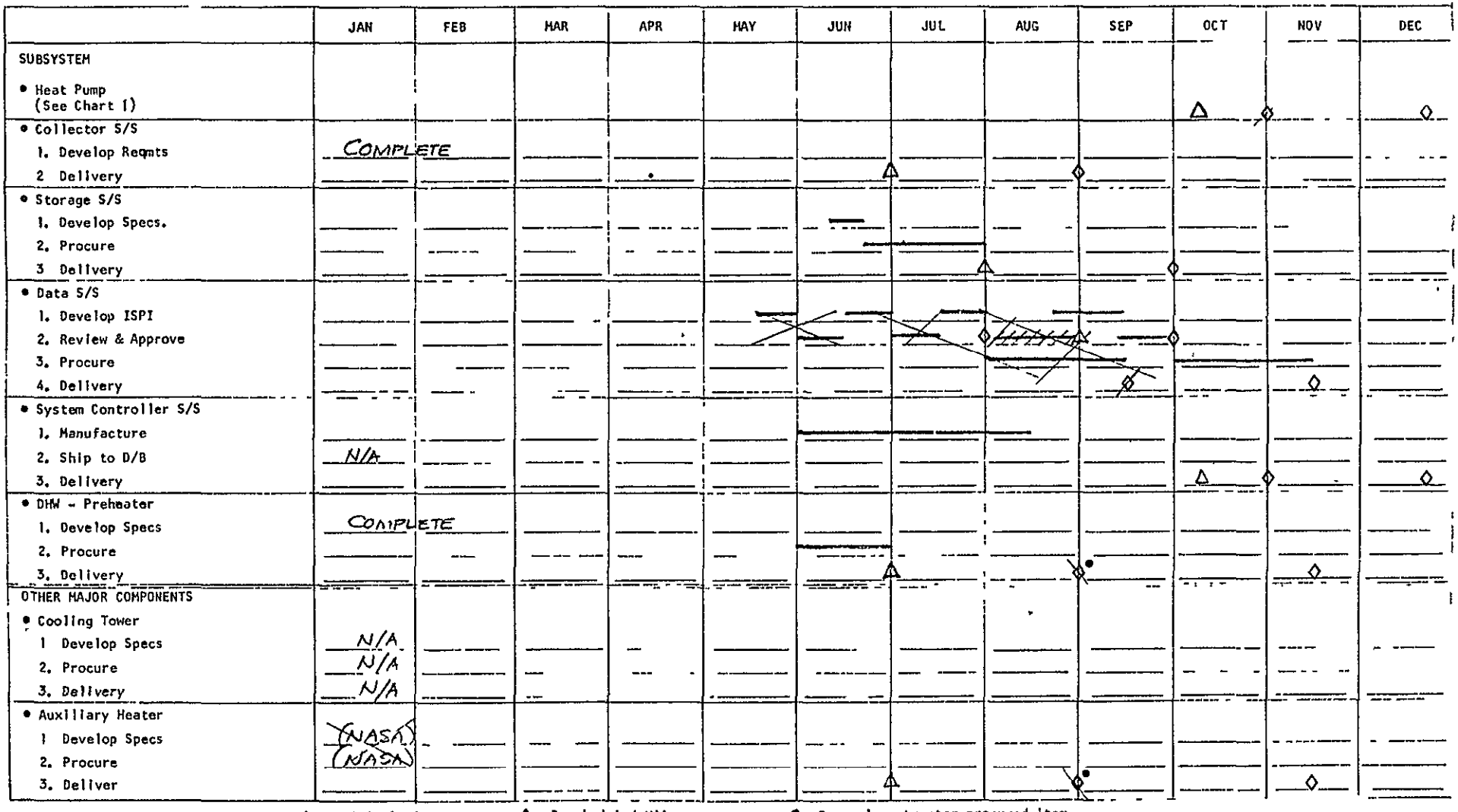
△ Original Milestone ◇ Rescheduled Milestone

GARRETT AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

Chart 46
Date 8-9-78

SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE SUBSYSTEM SCHEDULE

SITE NOVATO, CALIF.



△ Original Milestone ◇ Rescheduled Milestone • General contractor procured item

GARRETT AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

Chart 3C
Date 8-9-78

SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE INSTALLATION SCHEDULE

SITE Novato, Calif

INSTALLATION/OPERATION TASKS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BLDG. CONSTRUCTION/MOD												
1. Design	~~COMPLETE~~											
a System Req. Inputs	~~COMPLETE~~					△	◇		◇			
b. Design Reviews	(NASA)						◇			◇		
2. Construction												
a Collector Interface												
b. Backup Syst. Interface							△		◇		◇	
c. Other Equip. Interface								△	◇		◇	
SOLAR SYSTEM INSTALLATION												
1. A&E Selection					△	◇						
2. Sys. Installation Design							△		◇			
3. Select Contractor								△	◇			
4. Install Collector S/S												
5. Install Storage S/S												
6. Install DHW Preheat S/S												
7. Install Data S/S												
8. Install Sys Control S/S												
9. Install Heat Pump S/S												
SYSTEM CHECKOUT	1979 →											
1. Leakage Test												
2. Balance Collector Field												
3. Wiring C/O and Test												
4. Functional Test All Modes												
5 Instrumentation Verification												
6. System Turn-On	◇											
7. System Acceptance Tests												
OPERATIONAL TESTING												
1. Data Acquisition												
2 Schedule Maintenance	TBD											
3. Performance Reports		◇	◇	◇	ETC							1/22 → △

△ Original Milestone ◇ Rescheduled Milestone

AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

Chart 4C
Date 8-9-78

SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE SUBSYSTEM SCHEDULE

SITE St. Louis, Mo.

	1979 → JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC 1978 →
SUBSYSTEM												
• Heat Pump (See Chart 1)			Δ									
• Collector S/S												
1 Develop Reqmts							COMPLETE					
2 Delivery								Δ				
• Storage S/S												
1 Develop Specs.												
2. Procure												
3 Delivery										Δ		
• Data S/S												
1. Develop ISPI												
2. Review & Approve												
3. Procure							NASA					
4. Delivery							NASA					
• System Controller S/S												
1. Manufacture												
2. Ship to D/B	N/A											
3 Delivery			Δ									
• DHW - Preheater												
1 Develop Specs												
2 Procure												
3 Delivery								Δ				
OTHER MAJOR COMPONENTS												
• Cooling Tower												
1. Develop Specs							COMPLETE					
2. Procure												
3. Delivery								Δ				
• Auxiliary Heater												
1 Develop Specs	N/A											
2 Procure	N/A											
3. Deliver	N/A											

SCHEDULE SHOWN MAY BECOME OBSOLETE IF THIS SITE IS RELOCATED

Δ Original Milestone

AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

Chart 3d
Date 6-12-78

SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE INSTALLATION SCHEDULE

SITE St. Louis, Mo

1979 → 1978 →

INSTALLATION/OPERATION TASKS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BLDG CONSTRUCTION/MOD												
1. Design							COMPLETE					
a System Req Inputs							COMPLETE					
b. Design Reviews							(NASA)					
2. Construction												
a. Collector Interface								△				
b. Backup Syst Interface							N/A					
c Other Equip Interface							N/A					
SOLAR SYSTEM INSTALLATION												
1. A&E Selection							N/A					
2. Sys. Installation Design							COMPLETE					
3. Select Contractor												
4 Install Collector S/S												
5. Install Storage S/S												
6. Install DHW Preheat S/S							N/A					
7. Install Data S/S												
8 Install Sys Control S/S												
9. Install Heat Pump S/S												
SYSTEM CHECKOUT												
1. Leakage Test												
2. Balance Collector Field												
3. Wiring C/O and Test												
4. Functional Test All Modes												
5. Instrumentation Verification												
6. System Turn-On				△								
7. System Acceptance Tests												
OPERATIONAL TESTING												
1. Data Acquisition					→	→	→					
2. Schedule Maintenance	TBD											
3 Performance Reports					△	△						

SCHEDULE SHOWN MAY BECOME OBSOLETE IF THIS SITE IS RELOCATED

△ Original Milestone

ORIGINAL PAGE IS OF POOR QUALITY

A-25

AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

Chart 4d
Date 6-12-73

SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE SUBSYSTEM SCHEDULE

1979 SITE REDMOND, ORE.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SUBSYSTEM												
• Heat Pump (See Chart 1)					△							
• Collector S/S												
1. Develop Reqmts.	COMPLETE											
2. Delivery			△									
• Storage S/S												
1. Develop Specs.												
2. Procure												
3. Delivery			△									
• Data S/S												
1 Develop ISPI												
2. Review & Approve				△								
3. Procure												
4. Delivery					△							
• System Controller S/S												
1. Manufacture	COMPLETE											
2. Ship to D/B	N/A											
3. Delivery					△							
• DHW - Preheater												
1. Develop Specs	N/A											
2 Procure												
3. Delivery												
OTHER MAJOR COMPONENTS												
• Cooling Tower												
1. Develop Specs												
2. Procure												
3. Delivery			△									
• Auxiliary Heater												
1. Develop Specs	N/A											
2. Procure												
3. Deliver												

△ Original Milestone

GARRETT AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

Chart 3e
Date 8-10-79

SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE INSTALLATION SCHEDULE

SITE REDMOND, ORE

1979

INSTALLATION/OPERATION TASKS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BLDG. CONSTRUCTION/MOD												
1. Design												
a System Req. Inputs	BPA											
b Design Reviews	BPA											
2 Construction												
a. Collector Interface			△									
b. Backup Syst Interface			△									
c. Other Equip. Interface			△									
SOLAR SYSTEM INSTALLATION												
1 A&E Selection 12-1-78												
2. Sys. Installation Design 10-1-78												
3. Select Contractor 12-1-78												
4. Install Collector S/S												
5. Install Storage S/S												
6. Install DHW Preheat S/S												
7. Install Data S/S												
8. Install Sys. Control S/S												
9. Install Heat Pump S/S												
SYSTEM CHECKOUT												
1. Leakage Test												
2. Balance Collector Field												
3. Wiring C/O and Test												
4. Functional Test All Modes												
5 Instrumentation Verification												
6. System Turn-On						△						
7. System Acceptance Tests												
OPERATIONAL TESTING												
1. Data Acquisition							→	→	→	→	→	
2 Schedule Maintenance	TBD											
3. Performance Reports												

△ Original Milestone

AiResearch Manufacturing Company of California

Chart 4e
Date 8-10-79

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SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE SUBSYSTEM SCHEDULE

SITE HOUSTON, TEX.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SUBSYSTEM												
• Heat Pump (See Chart 1)									◇	◇	◇	
• Collector S/S												
1. Develop Reqmts.	COMPLETE											
2 Delivery						△ ◇						
• Storage S/S												
1. Develop Specs.	COMPLETE											
2. Procure												
3. Delivery						△						
• Data S/S												
1. Develop ISPI (11-15-77)												
2. Review & Approve												
3. Procure	(NASA)											
4. Delivery	(NASA)					◇						
• System Controller S/S												
1. Manufacture	COMPLETE											
2. Ship to D/B	N/A											
3. Delivery									◇	◇	◇	
• DHW - Preheater												
1 Develop Specs												
2 Procure												
3. Delivery								△				
OTHER MAJOR COMPONENTS												
• Cooling Tower												
1. Develop Specs	N/A											
2. Procure	N/A											
3. Delivery	N/A											
• Auxiliary Heater												
1. Develop Specs	N/A											
2. Procure	N/A											
3 Deliver	N/A											

△ Original milestone ◇ Rescheduled milestone

GARRETT AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

Chart 3 of
Date 8/10/78

SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE INSTALLATION SCHEDULE

SITE Houston, Tex

INSTALLATION/OPERATION TASKS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BLDG CONSTRUCTION/MOD												
1 Design	COMPLETE											
a. System Req. Inputs	COMPLETE											
b Design Reviews	(NASA)											
2. Construction												
a. Collector Interface						△	◇					
b. Backup Syst Interface	N/A											
c Other Equip. Interface	N/A											
SOLAR SYSTEM INSTALLATION												
1. A&E Selection	N/A											
2. Sys. Installation Design	COMPLETE □											
3. Select Contractor	COMPLETE											
4. Install Collector S/S												
5. Install Storage S/S												
6. Install DHW Preheat S/S												
7 Install Data S/S												
8 Install Sys Control S/S												
9. Install Heat Pump S/S												
SYSTEM CHECKOUT												
1. Leakage Test												
2 Balance Collector Field												
3. Wiring C/O and Test												
4. Functional Test All Modes												
5 Instrumentation Verification												
6. System Turn-On										△	◇	
7. System Acceptance Tests												
OPERATIONAL TESTING												
1. Data Acquisition												
2. Schedule Maintenance	TBD											
3. Performance Reports (MONTHLY)												△

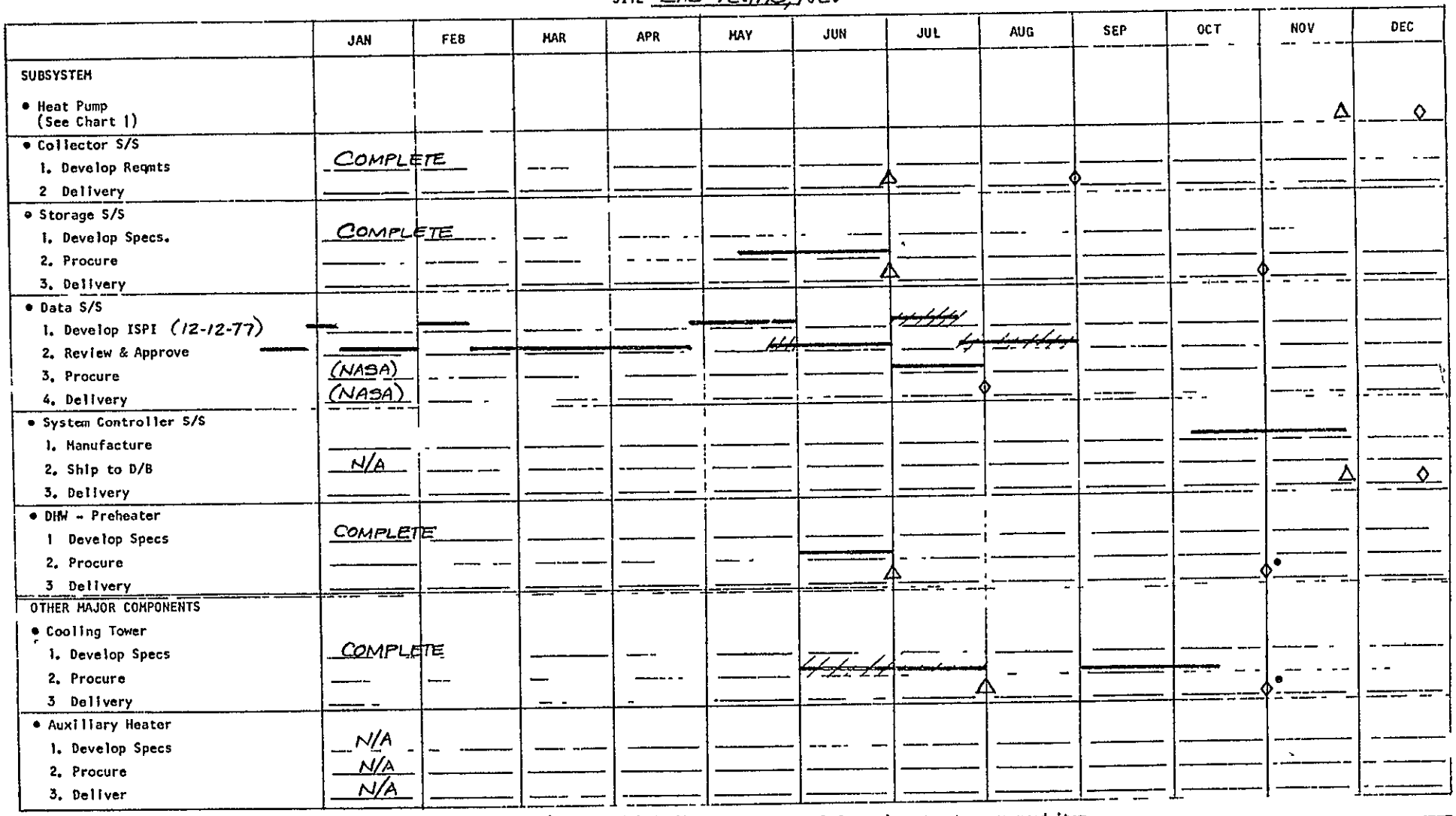
△ Original milestone ◇ Rescheduled milestone □ Except for instrumentation

AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

Chart 4
Date 8/10/78

SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE SUBSYSTEM SCHEDULE

SITE LAS VEGAS, NEV



△ Original Milestone ◇ Rescheduled Milestone • General contractor procured item

Chart 39
Date 8/10/78

SOLAR HEATING AND COOLING SUBSYSTEMS
OPERATIONAL TEST SITE INSTALLATION SCHEDULE

SITE LAS VEGAS, NEV.

INSTALLATION/OPERATION TASKS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BLDG. CONSTRUCTION/MOD												
1. Design	COMPLETE											
a. System Req Inputs	COMPLETE											
b. Design Reviews	(NASA)											
2. Construction												
a. Collector Interface						△		◇				
b. Backup Syst. Interface	N/A											
c. Other Equip. Interface	N/A											
SOLAR SYSTEM INSTALLATION												
1. A&E Selection	COMPLETE											
2. Sys. Installation Design	COMPLETE											
3. Select Contractor	COMPLETE											
4 Install Collector S/S												
5. Install Storage S/S												
6. Install DHW Preheat S/S												
7. Install Data S/S												
8 Install Sys Control S/S												
9. Install Heat Pump S/S												
SYSTEM CHECKOUT	1979 →											
1. Leakage Test												
2. Balance Collector Field												
3. Wiring C/O and Test												
4. Functional Test All Modes												
5. Instrumentation Verification												
6. System Turn-On	◇											
7 System Acceptance Tests												
OPERATIONAL TESTING	1979 →											
1. Data Acquisition	////			→								
2 Schedule Maintenance	TBD											
3. Performance Reports		△	△	△ ETC								

△ Original milestone ◇ Rescheduled Milestone

AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

Chart 49
Date 8/10/78

Size	Unit	Turbocompressor	Motor Control	Freon Pump	Heat Pump Complete	Start Test	Test Time, Weeks	Test Complete	Ship Date	Intended Site
3 Ton	#1	Returned	Returned	Returned	Complete	7-13**	4	8-10	8-10	Lawrenceburg, TN
	#2	8-1	8-1	8-1	8-10	8-11	5	9-15	9-22	Harrisonburg, VA
	#3	8-11	8-11	8-11	8-31	9-15	8	11-10	11-17	Allaire Park, N.J.
	#4	8-15	8-15	8-15	9-15	11-10	4	12-15	12-22	Novato, CA
25 Ton	#1	Shipped	Shipped	Shipped	7-28	12-15*	11	3-30	4-7	St. Louis, MO
	#2	9-1	9-1	9-1	10-1	3-30	5	5-15	5-22	Redmond, OR
75 Ton	#1	Shipped	Shipped	Received	7-24	8-1	7	9-15	9-22	Houston, TX
	#2	8-4	8-15	Received	9-5	9-15	11	12-8	12-15	Las Vegas, NV

*Testing of the 25-ton system will start earlier if a break occurs in the 75-ton system testing.

**At AiResearch

Heat Pump Delivery Schedule

CHART 5
Date: 8-10-78

PART B

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

SOLAR HEATING AND COOLING SYSTEMS DESIGN AND DEVELOPMENT

Contract NAS8-32091

76-13110(21)

September 10, 1978

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-first 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 August 1 to August 31, 1978.

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

MEETINGS, REVIEWS AND MAJOR ACTIVITIES

Activities during August were as follows (personnel attending the meetings if not listed herein are tabulated in Appendix B of this report):

- An overall program review and site status meeting was held at Dunham-Bush, Harrisonburg, Va., on August 2 and 3 to discuss methods and costs for program acceleration. Mssrs. Paul Benson and John McPherson of AiResearch attended along with Charles Reichelderfer of Dunham-Bush and James Clark of NASA/MSFC.

- A contractor/owner interface meeting was held at Lawrenceburg, Tenn., on August 18. Pertinent details are summarized in the SITE ACTIVITIES section.

- A contractor/owner interface meeting was held at Portland, Ore. on August 23 to review equipment envelopes, location and method of installation for the Redmond, Oregon, site with Bonneville Power Authority (BPA) personnel.

- An overall program review meeting was held at Torrance, Calif., on August 24, 25 and 28 with NASA/MSFC representatives and system component engineers in attendance. A complete review of development and delivery problems was presented for each component by the cognizant engineer.

- A technical review meeting was held at Clear Lake City, Texas, on August 23 between Mr. Gordon Neff of Timmerman Engineering, Inc. and Robert Susag of AiResearch to resolve equipment interface details.

Meetings schedule for the month of September include·

- A contractor/owner interface meeting at Clear Lake City, Texas, on September 7 and 8, 1978.

- A contractor/owner interface meeting at Redmond, Ore., on September 12, 1978.

- A site review meeting in late September at Harrisonburg, Va.

SITE ACTIVITIES

Status of Sites

1. Lawrenceburg, Tenn. (OTS No. 13)

The site house has been surveyed. Solar collectors are in place and hoses are now being clamped to the panels. The storage tank and expansion tanks are plumbed

and await the heat pump. This site requires a pressure test and leak check procedure from AiResearch (which are in process). The IBM supplied SDAS and junction box are on hand. Four automatic air vents (to be used in the collector loop) have arrived. The site instrumentation program (Dwg. IP7933779) was received from IBM/Huntsville via James Clark on August 28, 1978.

2. Allaire Park, N.J. (OTS No. 11)

The two storage tanks for this site have been ordered by AiResearch. A and E bid packages were mailed August 21, 1978. The bid due date is September 7. Final resolution of AIP and PIP differences is being delayed pending IBM response to AiResearch list of questions given to Mr. Clark during August 28 program review meeting. The site instrumentation program (Dwg. IP7933777) was also received on August 28, 1978.

3. Harrisonburg, Va. (OTS No. 14)

The solar collector system is completed. A 550-gallon storage tank has been purchased locally and installed in the basement. Plumbing has been completed to the heat pump interface. Trunk ducts have been installed but branch ducts to the individual outlets are not yet complete. Comments have been received per telecon from IBM regarding differences between AIP and AiResearch ISPI submitted June 27, 1978. AiResearch questions for IBM were given to James Clark on August 28, 1978.

4. Novato, Ca. (OTS No. 12)

The preliminary bid package will be shipped early in September. The preliminary instrumentation plan (PIP) was transmitted to NASA on September 6, 1978. Determination of bid participants will occur throughout September, and contract award is anticipated by October 27, 178.

5. Redmond, Ore. (OTS No. 17)

The Bonneville Power Authority (BPA) meeting with AiResearch at Portland, Oregon, revealed that heat pump access to the site mechanical room was not possible without modifying the entry to this room. Alternate heat pump locations in the storage/lunch room, the vehicle storage room and a "doghouse" addition were discussed but all were rejected. BPA will finalize storage tank dimensions by mid-September, and will provide expansion tank details shortly. BPA will purchase its own storage tank and cooling tower. BPS sent a conceptual design package to AiResearch on August 14, 1978. AiResearch will review the design and advise BPA of any recommendations in September.

6. St. Louis, Mo. (OTS No. 16)

A Cleveland, Tennessee, site is now being evaluated in lieu of the St. Louis vocational center.

7. Houston, Tex. (OTS No. 18)

The technical review meeting at the site on August 23, 1978 was to resolve system interface details between the heat pump and adjacent components. An AIP, dated June 13, 1978, was received on August 28, 1978 which reflected Revision B ISPI values published March 6, 1978. Since that time, three revisions have been published. The

latest, Revision E, was published on August 31, 1978, to finalize power requirements.

8. Las Vegas

Building construction is still in progress at this site. A purchase order for the storage tank has not been received at this time. Revision E is to be submitted to NASA in early September reflecting finalized wattmeter requirements.

Site and Site Equipment Status Charts

Site status Chart 1 has been updated to reflect agreements made during the August program review meeting. Charts 2 through 5 have not been revised this month and thus, are not included in this report. Chart 1 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	Delta Approved Instrumentation Plan (ΔAIP) received 7-17-78. Final PIP to be submitted by September 22, 1978.
Lawrenceburg, Tn.	A	ΔAIP received 7-17-78. Final PIP to be submitted by September 22, 1978.
Harrisonburg, Va.	-	Geo. Mizell of IBM/Huntsville requested changes or original ISPI per telecon on 7-28-78; revised PIP to be issued by September 29, 1978.
Novato, Ca.	-	Preliminary PIP issued September 5, 1978.
St. Louis, Mo.	-	No action; site not yet determined.
Redmond, Ore.	-	Preliminary PIP to be issued by September 29, 1978.
Houston, Tx.	E	PIP submitted August 31, 1978, with finalized power requirements and corresponding wattmeters.
Las Vegas, Nv.	E	PIP submitted September 8, 1978 to agree with latest AIP (dated 7-26-78) except for updated power requirements.

PROGRAM DOCUMENTATION

a. Twentieth Monthly Status Report 76-13110(20), dated August 10, 1978 (DR500-11).

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

Other publications were submitted during July to the parties listed as tabulated below:

Submittal Date	To	Subject
8-9-78	W. Johnson (Tiberti Construction Co., Las Vegas)	Storage Tank Drawing H-TX-M2-2, Rev. F, for Las Vegas Installation Details
8-16-78	J. Clark (NASA/MSFC)	Conditional Approval Comments re NASA Technical Directives 17 and 18
8-17-78	T. Swanson (Mueller Assoc., Inc., Baltimore, Md.)	Transmittal of NASA SHC-3097 (June 1, 1978) Instrumentation Installation Guidelines
8-31-78	C.W. Downing (NASA/MSFC)	Revised Estimate of Contract Variance at Completion

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) 3-Ton Unit

After flush cleaning and reassembly of the heat pump system (after failure of the carbon reversing valve
Testing was then delayed by failure of a commutator sensor. After part replacement, the unit experienced mode "hitting" problems at high speed. Subsequent examination attributed the rotating assembly hitting to excessive sway space. The turbomachine unit was being rebuilt with stiffer bearing support spacers to reduce the sway space at month end.

(b) 25-Ton Unit

Testing of the 25-ton unit is at the subsystem level at Dunham-Bush. (Refer to the heat pump test section below).

(c) 75-Ton Unit

Testing of the 75-ton turbomachine is at the subsystem level at Dunham-Bush. (Refer to the heat pump test section below.)

2. Motor Controller

(a) 3-Ton Controller

Tests are being conducted on the heat pump package at AiResearch.

(b) 25-Ton Controller

Controller No. 1 is at Dunham-Bush awaiting completion of the dual heat pump test setup. The fabrication of Controller No. 2 is now complete and the testing of this controller has commenced.

(c) 75-Ton Controller

Controller No. 1 is being tested with the heat pump package at Dunham-Bush. The checkout of Controller No. 2 is awaiting availability of a motor.

3. System Controller

Five controllers have been completed and checked out. Fabrication of the final three system controllers has started.

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 is being held in abeyance pending system test evaluation.

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

1. Assembly of Units (at Dunham-Bush)

(a) 3-Ton Heat Pump

Two of the four 3-ton heat pumps have been revised to include changes similar to the 75-ton heat pump changes noted below. Revision is in process on the third heat pump and the fourth will be changed when it is returned from AiResearch.

(b) 25-Ton Heat Pump

The first 25-ton heat pump has been modified to incorporate changes similar to those made on the 75-ton unit. The second is approximately 50 percent assembled.

(c) 75-Ton Heat Pump

In accordance with the request from Mr. Jim Clark, all piping interfaces have been brought to the edge of the heat pump and equipped with flanges.

To facilitate the flow of R11 to the refrigerant pump, the liquid outlet from the condenser was changed from the side to the bottom. A vortex eliminator was placed in the outlet and a direct connection was made to the refrigerant pump. The first unit is again ready for operation as soon as the compressor is received from AiResearch.

The second 75-ton heat pump is about 75 percent completed.

2. Test Activities (at Dunham-Bush)

The 75-ton heat pump operated for two days. On the third day, the turbo-compressor speed would not stay at 12,000 rpm, and on each successive start, it stalled sooner until, on the fourth attempt, it would not start.

The compressor was disassembled and a badly burned thrust bearing was found. The grooves feeding refrigerant to the thrust bearing were too small. These grooves were milled out to 9 times the original area and the compressor was then reassembled with new thrust bearings. The same alteration was made on the second 75-ton machine.

Both machines were bench-tested to adjust the commutator position sensor. Turbocompressor No. 1 was to be installed in the heat pump, but it was out of balance, probably as a result of adjusting the sensors. The turbine wheel scraped on the housing and this turbocompressor was shipped back to AiResearch.

The sensors on turbocompressor No. 2 were adjusted and the turbocompressor seemed to operate satisfactorily. It was installed in the heat pump and the unit was charged with 800 pounds of R11. The turbocompressor was started and accelerated to 12,000 rpm. It ran for about one minute, and suddenly decelerated as if heavily loaded and the power was turned off. Power was reapplied for short periods several times, but the unit would not start. The turbocompressor was removed and shipped back to AiResearch.

Size	Unit	Turbocom-pressor	Motor Control	Freon Pump	Heat Pump Complete	Start Test	Test Time, Weeks	Test Complete	Ship Date	Intended Site
3 Ton	#1	8-15	at Air	at Air	9-26	9-27	1	10-6	10-6	Harrisonburg
	#2	at D-B	at D-B	at D-B	8-29	8-30	4	9-27	9-30	Lawrenceburg
	#3	9-23	9-23	9-23	10-5	10-6	4	11-3	11-7	Allaire Park, N.J.
	#4	10-15	10-15	9-8	11-5	11-6	8	1-20	1-24	Novato, CA
25 Ton	#1	Shipped	Shipped	Shipped	9-5	9-12*	11	12-5	12-8	Redmond, OR
	#2	10-15	10-15	10-15	12-4	12-5	5	1-23	1-26	Unknown
75 Ton	#1	Shipped	Shipped	Received	8-23	8-24	7	10-12	10-18	Houston, TX
	#2	9-15	9-15	Received	10-16	10-17	11	1-23	1-26	Las Vegas, NV

*Testing of the 25-ton system will start at completon of dual testing system.

**This unit at AiResearch until 9-4, at D-B 9-11, modified by 9-18

Heat Pump Delivery Schedule

ATTENDEES TO AUGUST
SHAC COORDINATION MEETINGS

Lawrenceburg, Tenn., Site Review Meeting (August 18, 1978)

Attendees:

Jim Clark (NASA/MSFC)
Bob Gunner (NASA/MSFC)
Floyd Rushing (Lawrenceburg)
Hack Yee (AiResearch)

Redmond, Ore., Site Review Meeting (August 23, 1978)

Attendees:

Bob Gunner (NASA/MSFC)
Hack Yee (AiResearch)
Jeffrey Johnson (BPA, Redmond, Ore.)
Jim Clark (NASA/MSFC)
Dave Hartmann (BPA System Engineer)
Gary Tyler (BPA/Architect)
Robert Bourn (BPA/Structural)
Motto Stanley (BPA/Electrical)
Jon Giard (BPA/Walla Walla Area Eng.)
Jose Aguilar (BPA/Mechanical)
Jack Elwood (BPA, BSCE RandD Coord.)
Marvin E. Nelson (BPA, BSCE, Mech. Eng.)

Program Review Meeting at Torrance, Calif. (August 24, 25 and 28)

(a) August 24, 1978

James Clark [1] (NASA/MSFC)
Claude Dorning (NASA/MSFC)
Bill Richardson (NASA/MSFC)
Dick Nelson [2] (AiResearch)
Paul Benson [2] (AiResearch)
Hack Yee [2] (AiResearch)
Roy Brown (AiResearch)
Carl Dolland (AiResearch)
Al Silver (AiResearch)
Frank Weigand (AiResearch)

(b) August 28, 1978 (new attendees)

Robert Susag (AiResearch)
Paul Hildebrand (AiResearch)

[1]Attended all three days
[2]Attended meetings on August 24 and 25

PART C

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

SOLAR HEATING AND COOLING SYSTEMS DESIGN AND DEVELOPMENT

Contract NAS8-32091

76-13110(22)

October 10, 1978

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-second monthly status report prepared by AiResearch Manufacturing Company of California under Contract NAS8-32091 for the National Aeronautics and Space Adminstration Marshall Space Flight Center (MSFC). The report summarizes activities from September 1 to September 30, 1978.

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

MEETINGS, REVIEWS AND MAJOR ACTIVITIES

Activities during September were as follows (personnel attending the meetings if not listed herein are tabulated in Appendix B of this report):

- A contractor/owner interface meeting was held at Clear Lake City, Texas on September 7 and 8, 1978 to clarify AiResearch/NASA/TEI site responsibilities and to review site equipment schedules.

- An owner/AiResearch interface meeting was held at Torrance, Calif., on September 12, 1978 to provide BPA and C.T. Main Co. with preliminary data concerning heat pump weight and size data, heat pump control operation, and storage tank data.

- A presentation* was made at the Third Annual SHAC R&D Contractors' Meeting, Washington, D.C. on September 27, 1978 by Robert Susag concerning the status and accomplishments of the subject SHAC system. Maurice Gunderson of AiResearch also attended.

- A design review meeting was held at Portland, Ore., on Sept. 27 to discuss installation details for the heat pump and storage tank. AiResearch released a preliminary schematic diagram, SDAS preliminary instrumentation list and heat pump wiring diagram of the meeting.

- An equipment status and site related discussion was held at Torrance, Calif., with NASA on September 28, 1978. Drafts of intended technical directives were received from Mr. Clark.

- A meeting was held at Houston, Texas, on September 28, 1978, to review switching and control details for the heat pump. A representative from Barber-Colman was there for indoctrination.

Meetings scheduled for the month of October include:

- A go-forward discussion between the owner and Mueller Associates, Inc., at Allaire State Park, N.J., on October 3, 1978.

- An operational and maintenance presentation, to the Univ. of Houston Maintenance groups. This meeting will be scheduled to coincide with the next site interface meeting.

- A site review meeting at Harrisonburg, Va., in late October.

*A copy of the presentation, and reproductions of the associated viewgraphs, is attached to this report as APPENDIX C.

SITE ACTIVITIES

Status of Sites

1. Lawrenceburg, Tenn. (OTS No. 13)

- A SHAC-to-site interface wiring diagram (AiResearch Drawing H-TENN-EI) was hand delivered to Jim Clark at Houston on September 7, 1978. In addition, various specification and clean, test and fill procedures regarding this site have been transmitted to the site director this month. (Refer to PROGRAM DOCUMENTATION section.)

2. Allaire State Park, N.J. (OTS No. 11)

Site activities are "on hold" pending discussions in October between the site owner and Mueller Associates, Inc., regarding bid package changes to reduce the overall cost.

3. Harrisonburg, Va. (OTS No. 14)

Progress at this site remains essentially unchanged since last month. The solar collector system is complete and all the plumbing is done up to the heat pump connections. Only some small feeder air ducts and registers await final installation. SDAS instrumentation was received from IBM/Huntsville except for a current transformer and two probes. Installation will begin when heat pump is received.

4. Novato, Ca. (OTS No. 14)

The technical specifications and drawings were received from Bridgers and Paxton Consulting Engineers, Inc., the A and E firm for this site, on September 11, 1978. AiResearch is currently reviewing this package, along with Novato-PWC engineers and NASA personnel.

5. Redmond, Ore. (OTS No. 17)

Two BPA-Charles T. Main - AiResearch interface meetings were held. During the first, technical data was submitted to BPA concerning direct-heat heat exchanger and the cooling tower design points, water circuit flow data and insulation data. During the second meeting, a revised SHAC system schematic diagram and instrumentation list were released to the owner and NASA, along with Heat Pump Wiring Diagram H-ORE-E1, Heat Pump Assembly Drawing C473038 and various photos marked with coded interfaces. At this time, BPA informed AiResearch of their decision to provide a room addition for the heat pump and storage tank.

6. Cleveland, Tenn. (OTS No. 16)

A preliminary design data package was submitted to J.C. Thomasson and Associates, Nashville, Tenn., an A and E firm contracted by the Cleveland, Tenn., Utilities Co., the owner of the potential SHAC site.

7. Houston, Texas (OTS No. 18)

Contractor interface difficulties have hampered progress at this site compounded by instrumentation changes in the Site Data Acquisition System. As a result of the September 7-8 meeting at Clear Lake City, Texas, and subsequent related telecons, it appears that NASA considers AiResearch's provision of direct heat exchanger specific procurement information as improper acceptance by AiResearch of the design responsibility of this heat exchanger. Consequently, transfer of information between AiResearch and the University of Houston has been suspended, with all information transfer channels being routed through NASA. Final AiResearch comments on the Houston site AIP are being held pending written instructions from NASA on correct submittal procedures. The September 28 meeting at Timmerman Engineers, Inc., Houston was held to orient the local controls firm (Barber-Colman) of the heat pump mode selection automatic procedures.

8. Las Vegas, Nevada (OTS No. 19)

Direct-heat heat exchanger design point data was released to NASA for this site and the Houston site on September 14 and 15, 1978, in separate letters. Dissemination of this data to the proper site authorities is requested of NASA.

Sites and Site Equipment Status Charts

Site status Chart 1 has been updated to reflect agreements made during the August program review meeting. Charts 2 through 5 have not been revised this month and thus, are not included in this report. Chart 1 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.
Lawrenceburg, Tenn.	A	
Harrisonburg, Va.	-	
Novato, Ca.	-	Preliminary PIP issued September 5, 1978.
Cleveland, Tenn.	-	Preliminary data submitted for owner evaluation prior to interface meeting.
Redmond, Ore.	-	Preliminary system sketch, wiring diagram and list of instrumentation released to site owner and NASA.
Houston, Tx.	—	Final PIP revisions made; awaiting NASA writ directives on how to submit.
Las Vegas, Nv.	E	PIP submitted September 8, 1978 to agree witl latest AIP (dated 7-26-78) except for update power requirements.

PROGRAM DOCUMENTATION

a. Twenty-first Monthly Status Report 76-13110(21), dated September 10, 1978 (DR500-11).

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

Other publications were submitted during September to the parties listed as tabulated below:

Submittal Date	To	Subject
9-8-78	J. Clark (NASA/MSFC)	Nipple Lengths for Novato, Ca., and Houston, Tx., SDAS Temperature Probes
9-14-78	J. Clark	Direct Heat Exchanger Design Point (Houston Site)
9-15-78	J. Clark	Direct Heat Exchanger Design Point (Las Vegas Site)
9-15-78	Floyd Rushing (Lawrenceburg, Tenn.)	Hardware Specs and Data Submittal for Lawrenceburg, Tenn.
9-19-78	J. Clark	Direct Heat Exchanger and Cooling Tower Design Points - Redmond, Oregon SHAC Site
9-20-78	Floyd Rushing	Directions for Cleaning, Filling and Pressure Testing Various System Piping Loops for Lawrenceburg, Tenn. Site
9-22-78	Clyde Sercy (Nashville, Tenn.)	Preliminary Data for Proposed SHAC Site at Cleveland, Tenn.
9-28-78	J. Clark	3-Ton SHAC System Test Site AIP Revisions
9-28-78	George Mizell	Solar Collector and Heat Pump Drawings

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) 3-Ton Unit

System testing at AiResearch with the Dunham-Bush heat pump package was completed. The unit was operated in the motor-driven mode successfully but could not be operated in the turbine-driven mode with freon change levels up to and including 155 lbs. This was attributed to piping problems within the package. Changes had been initiated at Dunham-Bush to correct this. Other system changes at Dunham-Bush were not incorporated in this unit, so testing was ended and the heat pump package was returned to Dunham-Bush for rework. All subsequent testing will be at Dunham-Bush.

During the testing at AiResearch, it was concluded that duct alignment to the compressor is very critical. It is anticipated that flex ducting will be required within the package to eliminate distortion.

(b) 25-Ton Unit

No testing has been acomplished during the past month. One unit is at Dunham-Bush for system testing.

(c) 75-Ton Unit

One unit with increased thrust bearing cooling potential has been shipped to Dunham-Bush and is being installed in their system. Testing should begin the first week of October. The tests will determine the adequacy of the change and the changes required to the motor controller to allow for full-load testing.

2. Motor Controller

(a) 3-Ton Controller

Unit No. 1 is at Dunham-Bush for heat pump system tests. Units No. 2 and 3 are complete and are awaiting start of heat pump package testing. Unit No. 4 fabrication is complete but has not received its final static test.

(b) 25-Ton Controller

Controller No. 1 is at Dunham-Bush awaiting completion of the dual heat pump test setup. Controller No. 2 is completed and in its final static test. The phase delay rectifier has been completed. Tests of the inverter and commutation circuits are imminent.

(c) 75-Ton Controller

Controller No. 1 is being tested with the heat pump package at Dunham-Bush. The checkout of Controller No. 2 is awaiting availability of a motor.

3. System Controller

Five controllers have been completed and checked out. Fabrication of the final three system controllers is now 60 percent complete.

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 last month. Installation into the heat pump will be effected this month.

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

1. Assembly of Units (at Dunham-Bush)

(a) 3-Ton Heat Pump

Two of the four 3-ton heat pumps have been revised to include the latest development changes. Revision is in process on the third heat pump and the fourth will be changed when it is returned from AiResearch.

(b) 25-Ton Heat Pump

The first 25-ton heat pump has been modified to incorporate latest development changes. The second is approximately 60 percent assembled.

(c) 75-Ton Heat Pump

The first 75-ton unit is complete and presently in system testing with a modified turbocompressor.

The second 75-ton heat pump is about 75 percent complete and waiting receipt of the turbocompressor for the remaining plumbing.

2. Test Activities (at Dunham-Bush)

(a) 3-Ton Heat Pump

Systems testing with the latest plumbing changes has started with the major effort directed toward operation in the turbine-driven cooling mode. Testing will continue into October.

(b) 25-Ton Heat Pump

The 25-ton package is complete and installed in the test system. The system is on vacuum and testing will start the first week in October.

(c) 75-Ton Heat Pump

A turbocompressor with improved bearing cooling passages was installed in the test system. Motor-driven operation indicated that the controller current range is limited, which will require evaluation by AiResearch Engineering. Photographs of specific wave forms have been transmitted. Operation of the R-11 pump is now satisfactory due to the recent plumbing changes. The turbocompressor thrust bearing appears to be running warme than anticipated and a modification is in process on the second unit to provide added localized cooling flow.

Size	Unit	Turbocom-pressor	Motor Control	Freon Pump	Heat Pump Complete	Start Test	Test Time, Weeks	Test Complete	Ship Date	Intended Site
3 Ton	#1	complete	complete	complete	10-26	10-27	1	11-3	11-3	Harrisonburg
	#2	complete	complete	complete	complete	9-28	4	10-26	10-30	Lawrenceburg
	#3	complete	complete	complete	11-3	11-6	4	12-11	12-14	Allaire Park, N.J.
	#4	10-15	10-15	10-15	12-11	12-12	8	2-20	2-23	Novato, CA.
25 Ton	#1	complete	complete	complete	complete	9-27	11	12-20	12-22	Redmond, OR.
	#2	10-15	10-15	10-15	12-4	1-2	5	2-6	2-9	Cleveland, Tenn.
75 Ton	#1	complete	complete	Received	9-25	9-26	7	11-14	11-17	Houston, TX.
	#2	10-15	10-15	Received	11-14	11-15	11	2-14	2-16	Las Vegas, NV.

HEAT PUMP DELIVERY SCHEDULE

Chart 5
Date 10-3-78
76-13110(22)
APPENDIX A

ATTENDEES TO SEPTEMBER
SHAC COORDINATION MEETINGS

Design Review Meeting at Portland, Oregon (Sept. 27, 1978)

Attendees:

Jim Clark (NASA/MSFC)
Robert Gunner (NASA/MSFC)
George Forsman (BPA)
Del Ramey (BPA)
Stanley Mirecki (BPA)
Roger Sarkinen (BPA)
Jose Aguilar (BPA)
Jeff Johnson (BPA)
Jon Giard (BPA)
Marvin Nelson (BPA)
Harry Reeder (C.T. Main)*
Tom Ocheltree (C.T. Main)
Ray Loofburrow (C.T. Main)
Hal Bonslett (C.T. Main)
Dave Kelly (C.T. Main)
Hack Yee (AiResearch)

Equipment Status Meeting at Torrance, Calif. (Sept. 28, 1978)

Attendees:

Robert Gunner (NASA/MSFC)
Jim Clark (NASA/MSFC)
R. C. Nelson (AiResearch)
Paul Hildebrand (AiResearch)
Hack Yee (AiResearch)

Houston, Texas, SHAC Control Interface Meeting (Sept. 28, 1978)

Attendees:

Ed Samfield (Univ. of Houston)
Gordon Neff (Timmerman Engrg., Inc.)
Robert Ice (Timmerman Engrg., Inc.)
Paul Benson (AiResearch)
Shing Leung (AiResearch)
(and a controls engineer from Barber-Colman)

Contractor/Owner Interface Meeting at Torrance, Calif. (September 12, 1978)

Attendees:

Hal Bonslett (C.T. Main)
Jose Aguilar (BPA)
Paul Benson (AiResearch)
Robert Susag (AiResearch)
Hack Yee (AiResearch)

*A Portland, Oregon, A and E firm contracted by BPA for the Redmond site.

SOLAR POWERED RANKINE HEAT PUMP
A PROGRESS REPORT

by Robert W Susag and Paul A Benson

AiResearch Manufacturing Company of California
2525 W 190th Street, Torrance, California

OBJECTIVE

This paper presents a brief description of the solar-powered Rankine cycle heat pump and an outline of the latest six-month progress of the AiResearch Manufacturing Company of California, Solar Heating and Cooling Project, on NASA Contract Number NAS8-32091.

SUMMARY

During this period, subsystem level development was dominant, with problem solving both at the component and subsystem level providing the program emphasis The progress was highlighted by completion of the following milestones

1 Rankine cycle cooling achieved with 3-ton subsystem

2 75-ton subsystem (to be installed at the University of Houston) operated in electric cooling mode

Progress has been at a pace slower than desired, due to design changes found necessary in system development However, no problems of any appreciable technical magnitude have been confronted The program is technically healthy, and proceeding toward a successful conclusion

BACKGROUND

The AiResearch system features a solar powered vapor-cycle heat pump using R-11 as the working fluid The heat pump turbomachine consists of a turbine, a compressor and a permanent magnet motor mounted on the same shaft The rotor is supported on process fluid bearings, no lubricants other than the process fluid are required The motor is powered in the electrical mode from utility power through a solid-state converter generating variable high frequency, thus providing variable speed operation

Solar energy is collected using flat-plate copper collectors and the thermal energy is transported by a water-ethylene glycol fluid flowing in a closed loop The heat energy is exchanged through an intercooler to a water loop which transports the energy to an insulated storage tank Temperature in this tank can vary from 40°F to 210°F depending only on the differences in energy every collection and energy usage

The system is presently being constructed in three sizes, 3-ton cooling (80,000 Btu/hr heating), 25-ton cooling (800,000 Btu/hr heating) and 75-ton cooling (2,000,000 Btu/hr heating). The 25-ton system is best used as the descriptive baseline since this system alone utilizes all of the modes heating and cooling Differences in the operational modes of the 3-ton and the 75-ton are explained later

Heating Operation

In the heating mode, two methods of energy transport are utilized Direct heating is utilized whenever the storage tank temperature is sufficiently higher than the temperature required to passively conduct heat to the conventional hydronic thermal transport loop This loop carries the heat energy to the air handlers in the various zones of the building The heat transfer is accomplished through a direct heat exchanger between the storage tank output loop and the hydronic transport loop.

Whenever the temperature in the storage tank is insufficient to accomplishing the full heating requirements of the building in the direct heating mode, the system is automatically switched to heat pump operation In this mode, electrical energy is supplied to the motor on the turbocompressor shaft to cause heat energy to be actively elevated in temperature so that the heat energy may pass from the lower temperature in the storage tank to the higher temperature hydronic transport loop The electrical energy provided to the motor in this mode is controlled to a value just sufficient to accomplish the heat energy transmission required by the building As the temperature of the storage tank decreases,

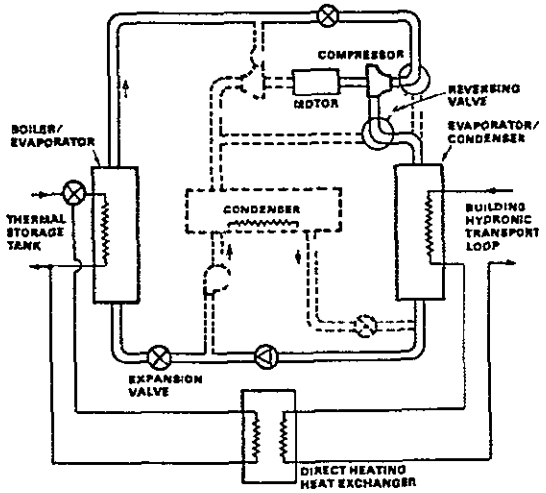


Figure 1. Heating Operation

3rd Annual Solar Heating and Cooling R&D Contractors' Meeting
September 1978

the heat pump becomes incapable of supplying all the heat required and a control signal is provided to activate a conventional water boiler which then supplies only the difference in the heat required and the heat available from the heat pump Should the storage tank water temperature approach the freezing point, the heat pump is automatically stopped, and all of the building heating requirements are supplied by the water boiler

In the heat pump mode of operation, the R-11 working fluid is evaporated at a low pressure in the subsystem input heat exchanger called the boiler/evaporator. Heat is extracted from the water in the thermal storage tank by the evaporation process, and the higher energy fluid is compressed by the compressor and condensed in the output heat exchanger named the evaporator/condenser The higher pressure condensing process provides a heat source at a sufficient temperature level for the building heat transport loop The liquid R-11 is conducted back to the expansion valve, thus closing the vapor cycle loop.

Cooling Operation

In the cooling mode of operation, the R-11 working fluid is used simultaneously in two operationally separate vapor cycle loops, although these loops are actually physically combined through the use of a common condenser. In the Rankine cycle drive loop, thermal energy is transported from the storage tank to the input heat exchanger (boiler) where it is used to vaporize the working fluid at high pressure (about 85 psia) The high pressure (high energy) vapor is expanded in the turbine to provide shaft power for the centrifugal compressor of the refrigeration loop The expanded vapor from the turbine is liquified in the common condensor, and pumped back to the expansion valve at the boiler inlet, thus closing the Rankine power loop In the refrigeration loop, the R-11 is vaporized in the output heat exchanger (evaporator) at a low pressure, thus providing cooling by lowering the temperature of the hydronic heat transport loop which supplies the various air handlers located in the building The low pressure vapor from the evaporator is compressed and combined with the turbine outflow before entering the condenser, where the vapor is condensed through energy extraction by a water tower transport loop. Liquid R-11 is returned to the evaporator through an expansion valve

Whenever sufficient energy is available in the storage tank (as depicted by the storage tank water temperature), the Rankine power loop is capable of supplying all of the shaft power required to drive the compressor, and the electric motor requires no power other than that required to initially start the turbocompressor The speed of the turbocompressor varies naturally dependent upon the operating conditions If the stored solar energy is insufficient to maintain a minimum compressor speed, electric power is automatically supplied to the motor to augment the turbine power. If no thermal energy is available to the turbine, the Rankine loop is functionally terminated and the entire requirements of the refrigeration loop are supplied by the electric motor drive subsystem.

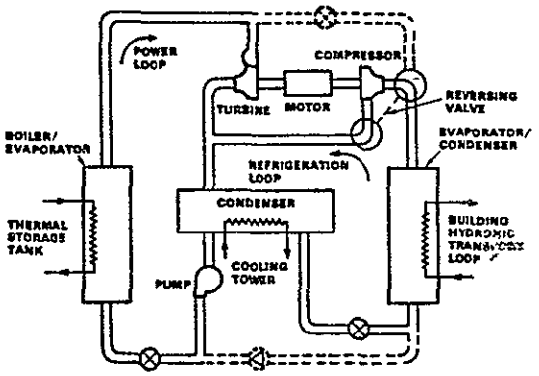


Figure 2. Cooling Operation

Minor variations in the preceeding description exist in the 3-ton and the 75-ton systems. The 3-ton (single family, one zone) system utilizes an output heat exchanger (evaporator/condenser) in which building air is cooled or heated directly, negating the requirement for a hydronic transport loop Design studies have indicated that a passive energy transfer from the storage tank directly to the unit output air is impractical, and consequently no direct heating mode exists in the 3-ton unit Conversely, the 75-ton system does not employ a heat pump heating mode due to the environmental nature of the two test sites selected for this system Both the Las Vegas and Houston areas do not require the heat pump heating mode since the heating requirements are most satisfactorily supplied by the direct heating mode

TECHNICAL ACCOMPLISHMENTS

During the past six months, significant progress has been made, both in the component and subsystem development areas. The following is a brief synopsis of the highlights of the development program

Turbocompressors

1. Compressor performances have been confirmed (3-ton and 25-ton)
2. The process fluid bearings have been optimized in all three sizes of machines
3. The motor/motor controller interface has been perfected to a high degree of confidence
4. A single-center rotating section was designed to replace the multiple piece rotating section to reduce (3-ton) unit rotor runout problems.
5. Maximum speeds have been reached without incident on all machines
6. Motor and bearing coolant circuits have been improved on all three sizes of machines

Freon Pumps

1. High efficiency freon pumps were developed and life tested satisfactorily in 3-ton and 25-ton sizes.

Motor Controllers

Motor controllers utilizing transistor commutating circuits (3-ton) and thyristor commutating circuits (25 and 75-ton) have been developed and are presently exhibiting excellent overall capability in subsystem development tests.

Reversing Valves

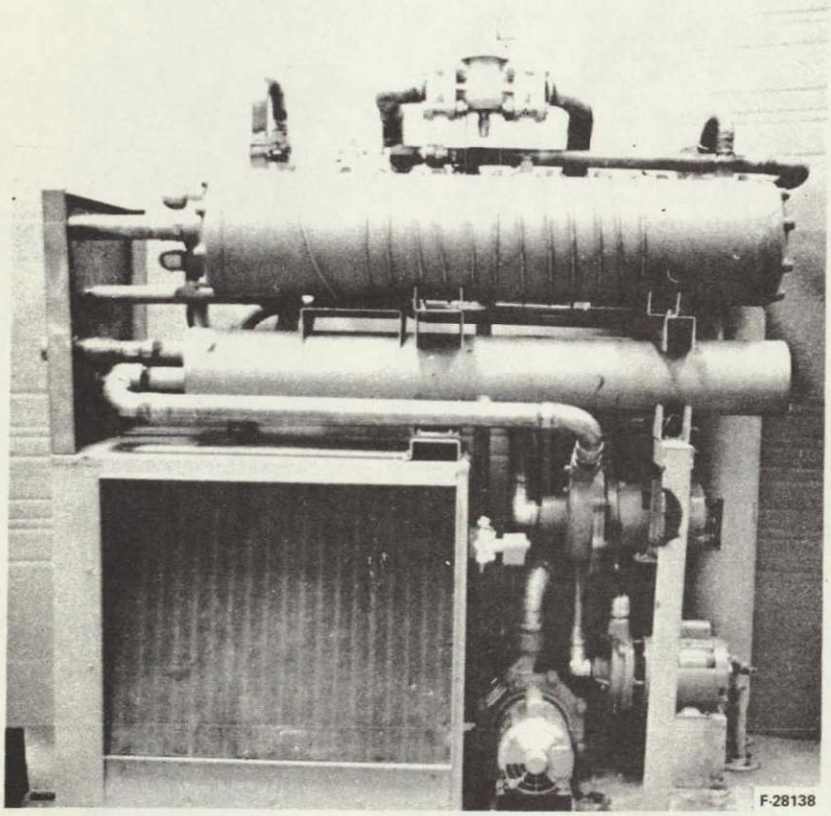
Reversing valves in 3-ton and 25-ton sizes are presently being tested at the subsystem level. Initial units using carbon pistons proved inadequate and have been replaced with units constructed with cast iron pistons in chrome-plated bore steel housings. These units have recently received minor changes in configuration, and are now expected to meet the subsystem requirements.

Subsystems

The subsystem development progress has reached the deliverable hardware testing phase. Presently, 3-ton heat pump units scheduled for delivery to the Lawrenceburg, Tennessee test site, and the Dunham-Bush test house are in final subsystem testing. A 25-ton heat pump unit, scheduled for the Redmond, Oregon test site and a 75-ton unit scheduled for the University of Houston test site are also in final subsystem testing. Delivery of these units is expected in the next several weeks.

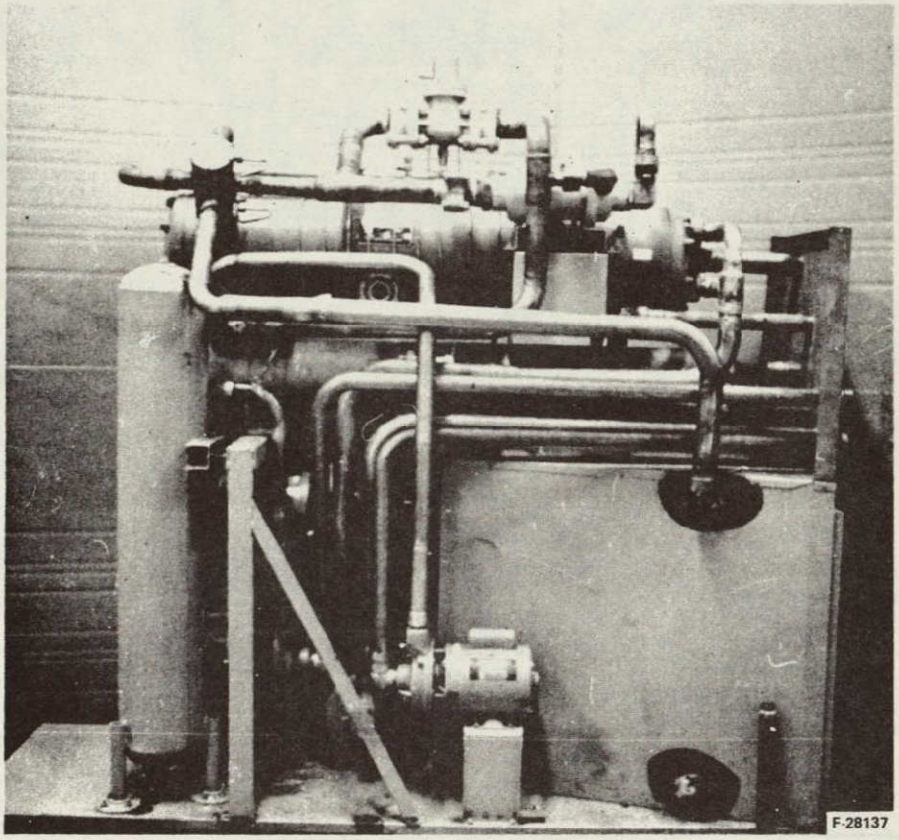
3-TON RANKINE CYCLE SOLAR HEAT PUMP FOR LAWRENCEBURG, TENNESSEE SITE

(SIDE VIEW SHOWING CONDENSER, INTERCHANGER, AND EVAPORATOR-CONDENSER)

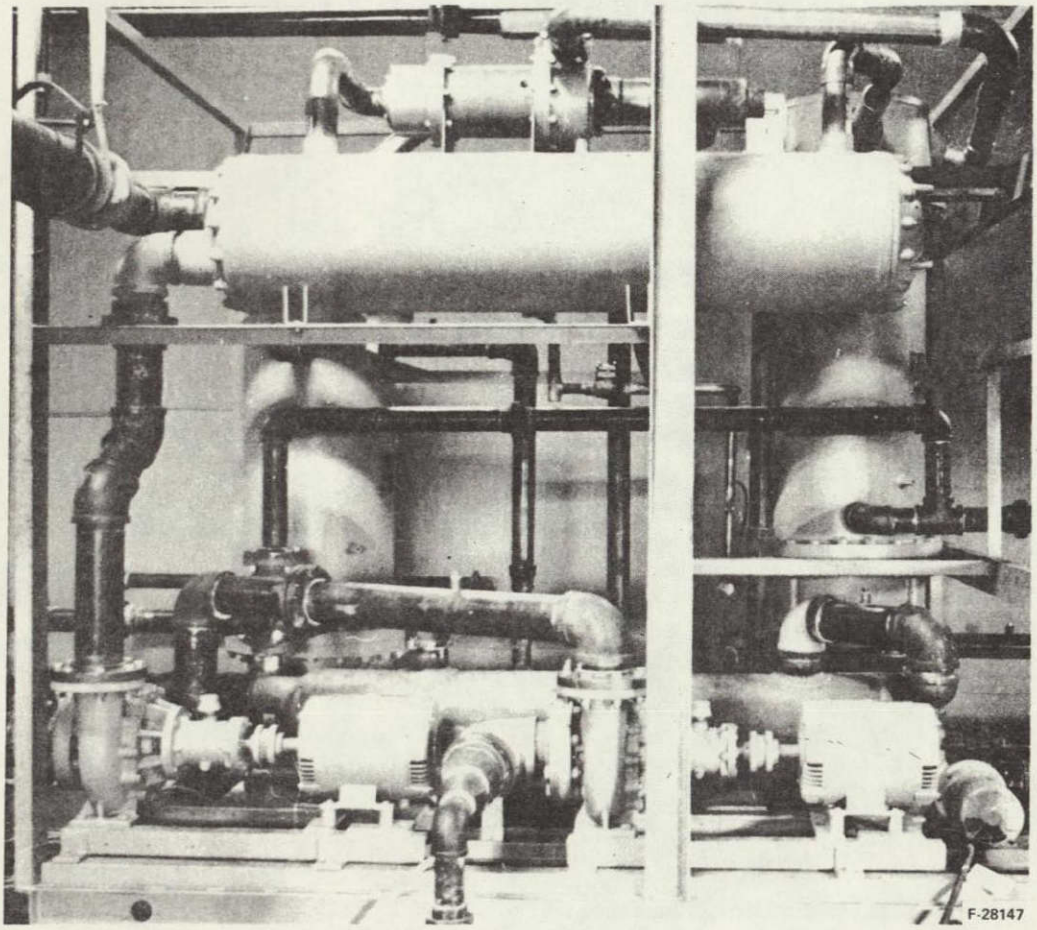


3-TON RANKINE CYCLE SOLAR HEAT PUMP FOR LAWRENCEBURG, TENNESSEE SITE

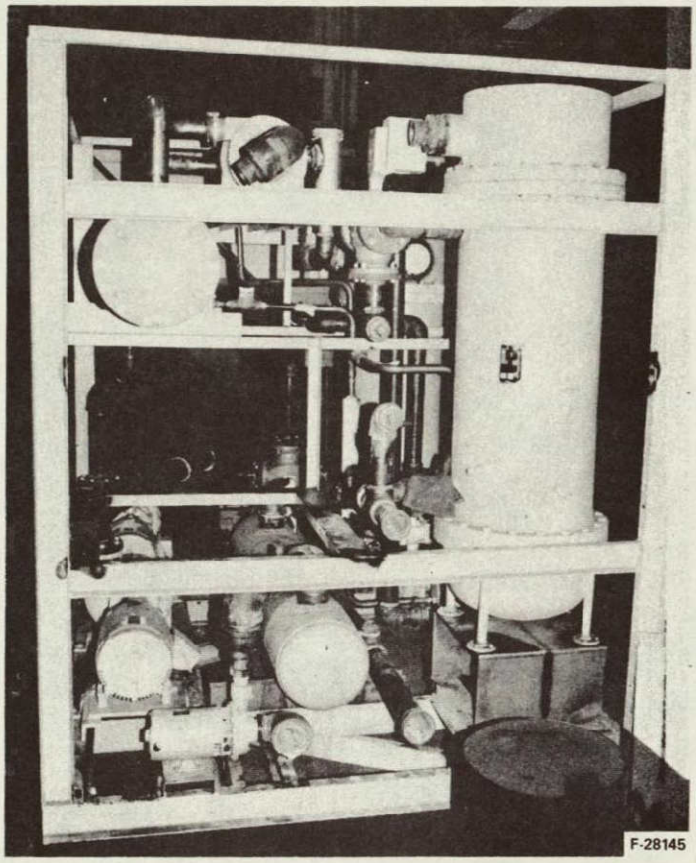
(BOILER-EVAPORATOR SIDE VIEW)



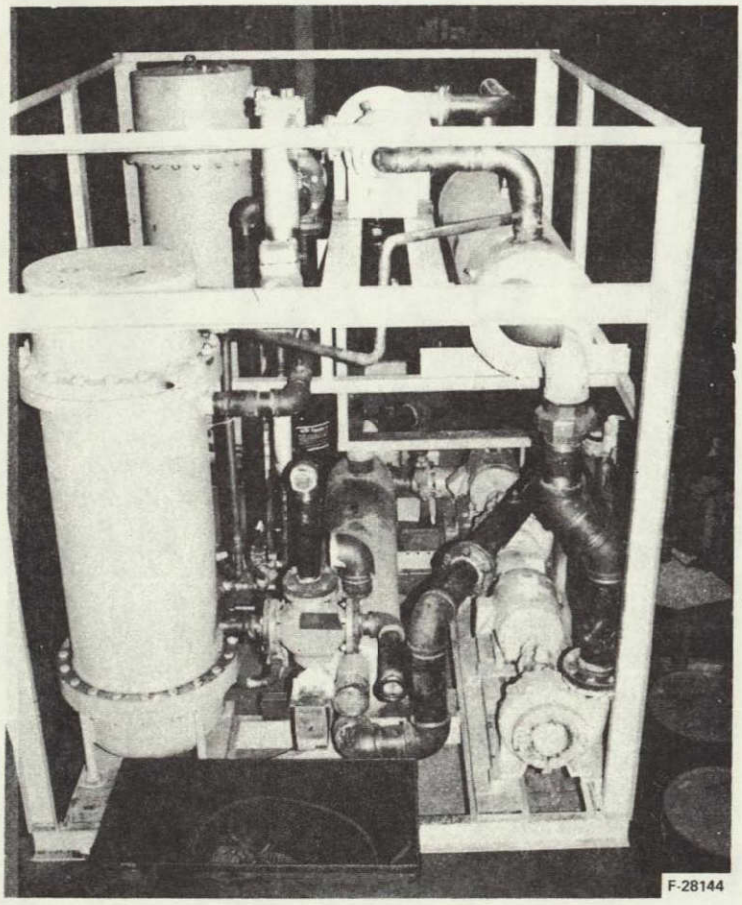
25-TON RANKINE CYCLE SOLAR HEAT PUMP FOR REDMOND, OREGON SITE
(SIDE VIEW)



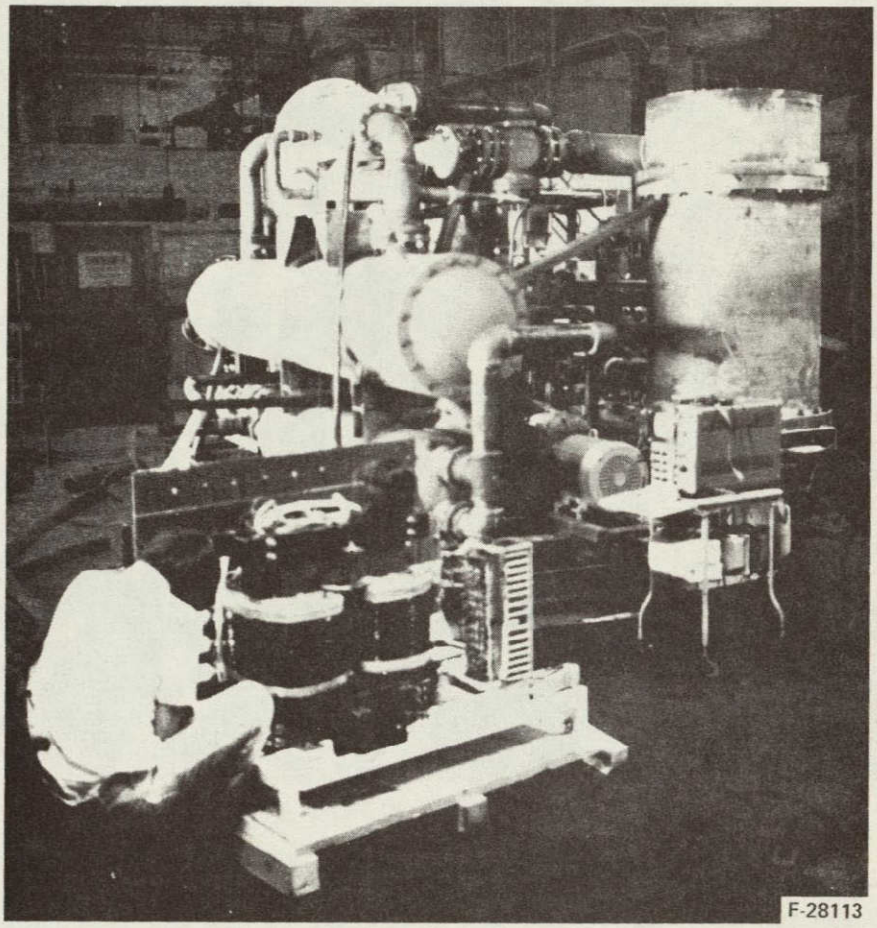
25-TON RANKINE CYCLE SOLAR HEAT PUMP FOR REDMOND, OREGON SITE
(CONDENSER-EVAPORATOR END VIEW)



25-TON RANKINE CYCLE SOLAR HEAT PUMP FOR REDMOND, OREGON SITE
(EVAPORATOR-BOILER END VIEW)



TEST OF 75 - TON RANKINE-CYCLE SOLAR HEAT PUMP FOR UNIVERSITY OF HOUSTON SITE



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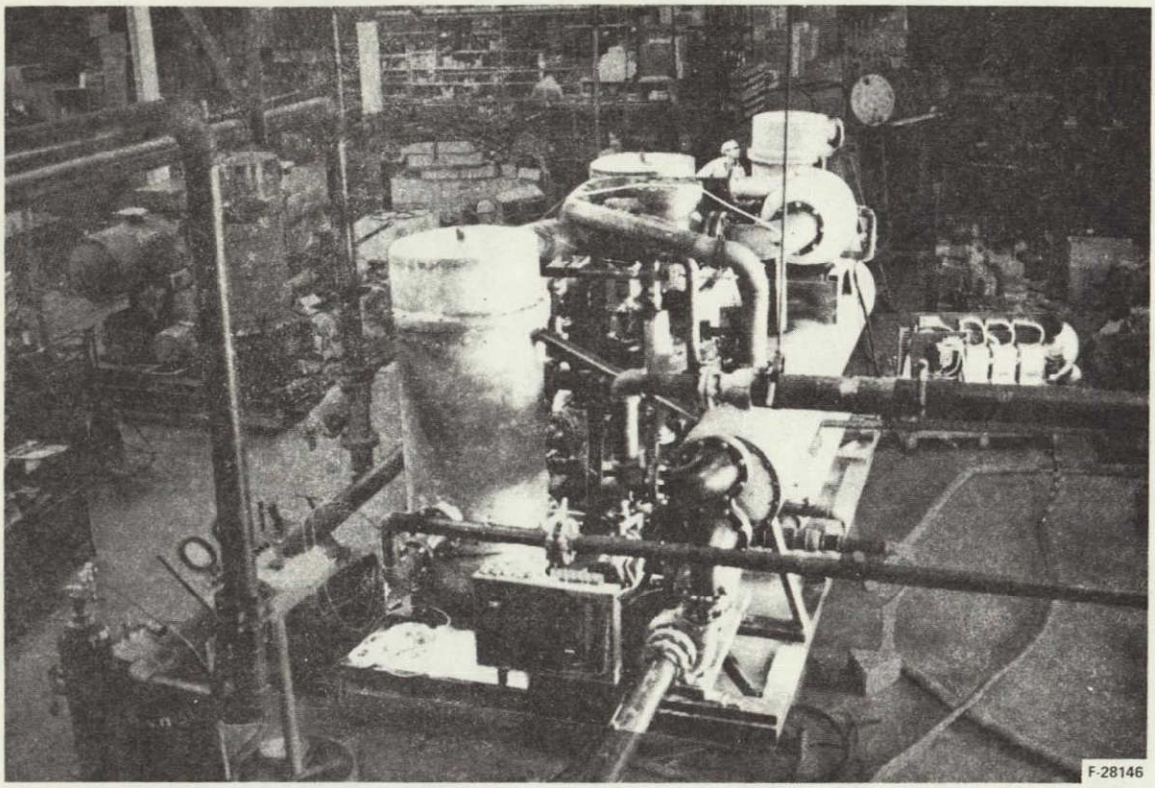
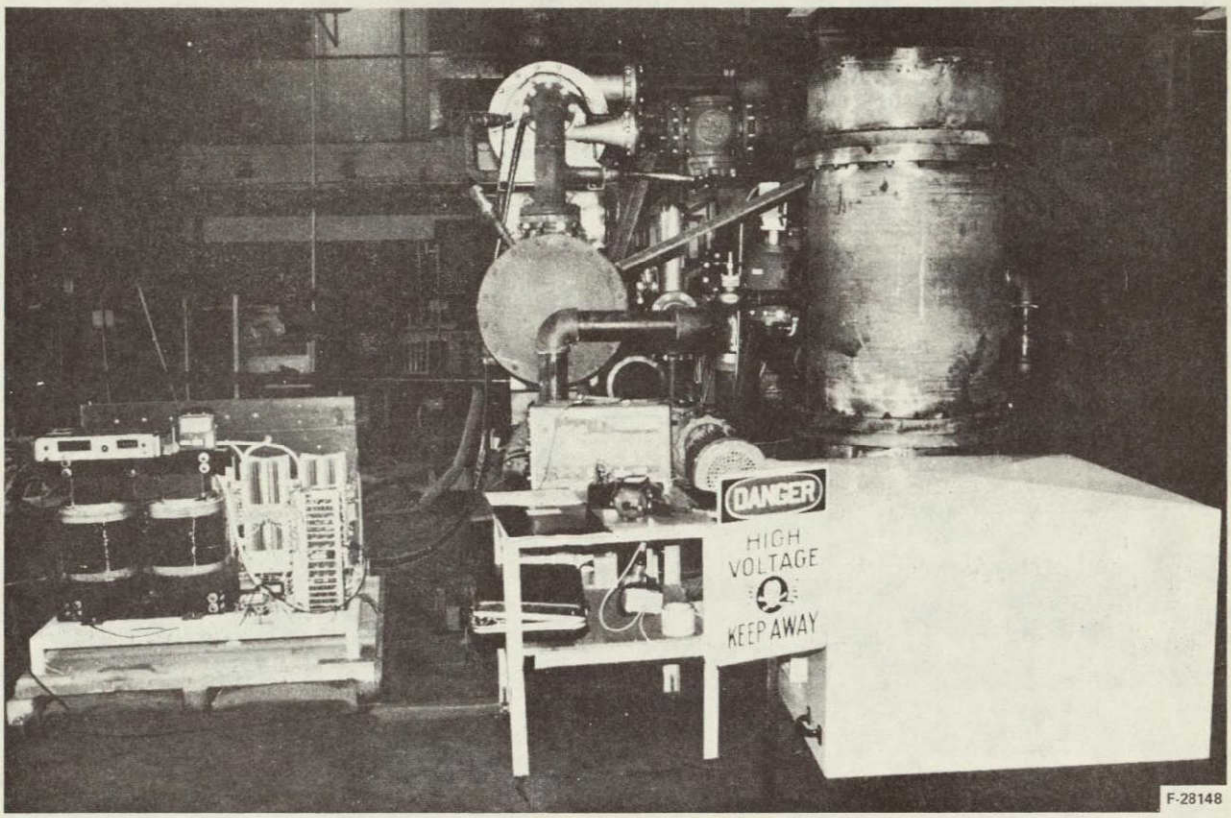
TEST OF 75-TON RANKINE CYCLE SOLAR HEAT PUMP FOR UNIVERSITY OF HOUSTON SITE

(EVAPORATOR END VIEW)



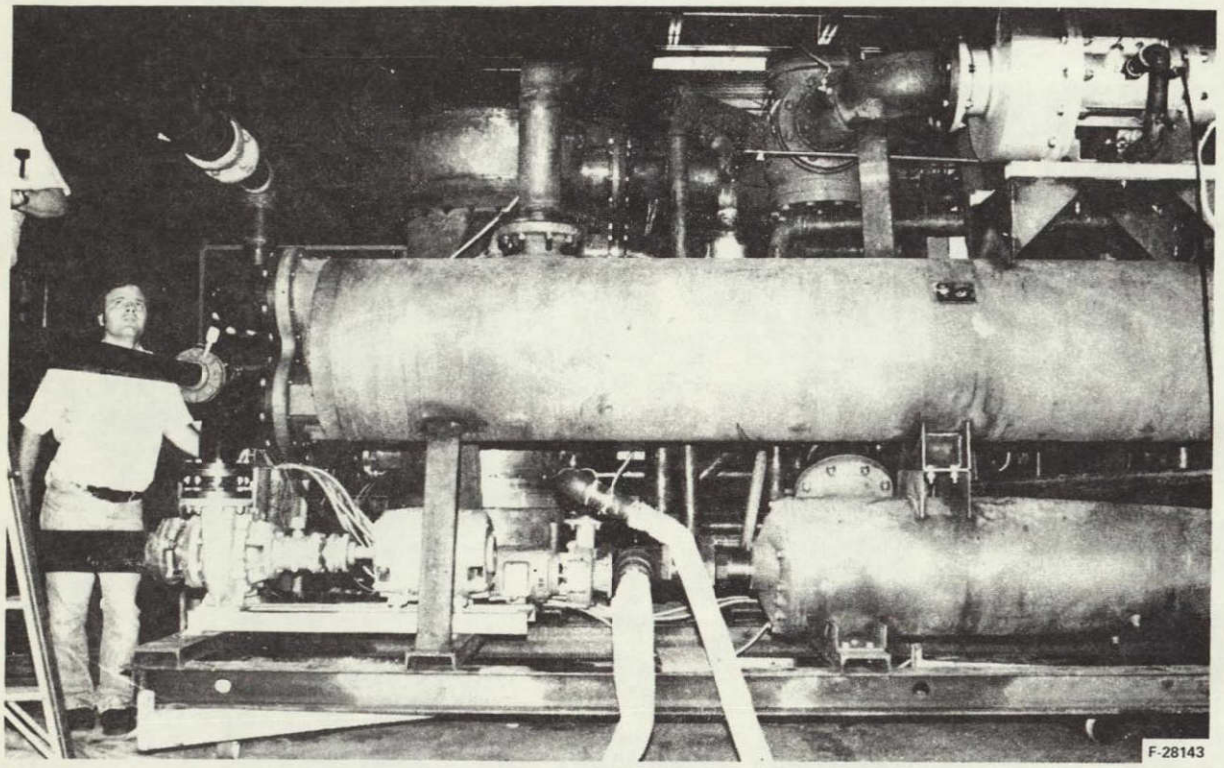
TEST OF 75-TON RANKINE CYCLE SOLAR HEAT PUMP FOR UNIVERSITY OF HOUSTON SITE

(BOILER END VIEW)



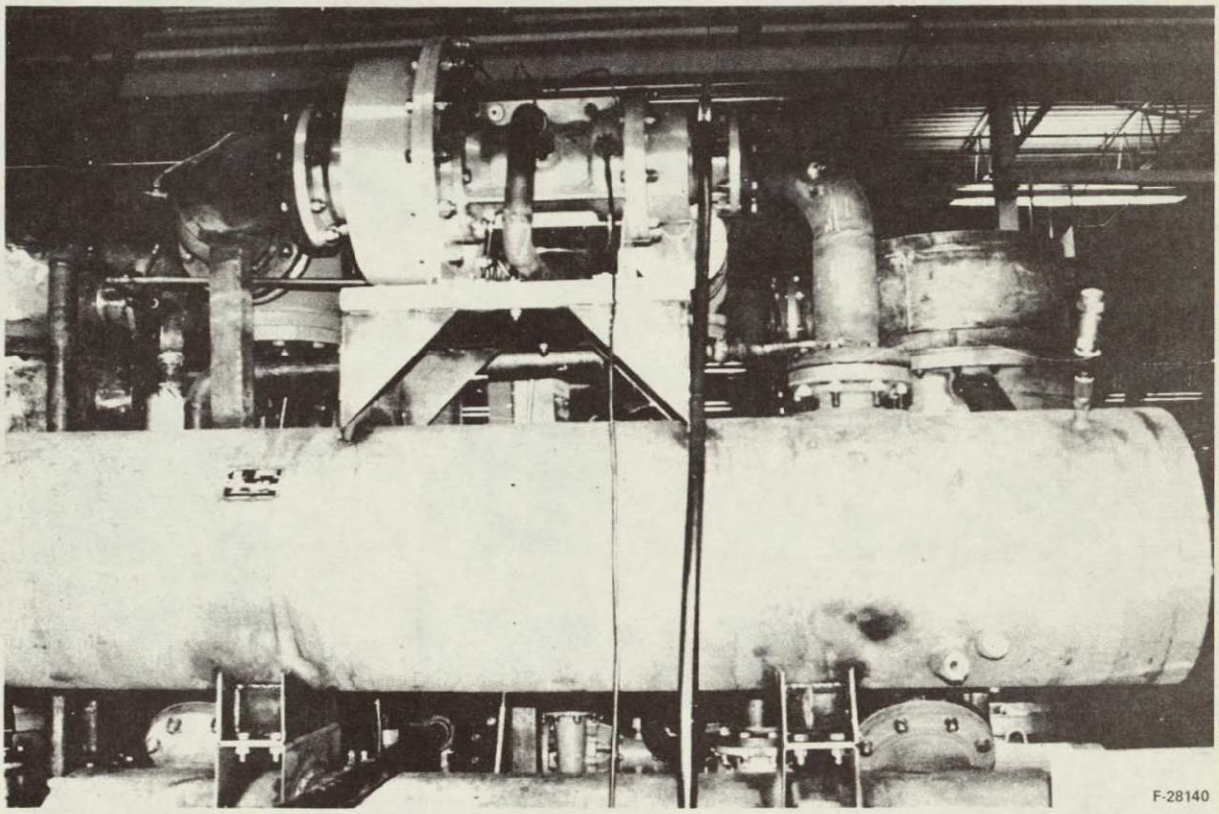
75-TON RANKINE CYCLE SOLAR HEAT PUMP FOR UNIVERSITY OF HOUSTON SITE

(CONDENSER SIDE VIEW)



75-TON RANKINE CYCLE SOLAR HEAT PUMP FOR UNIVERSITY OF HOUSTON SITE

(CONDENSER AND TURBOCOMPRESSOR)



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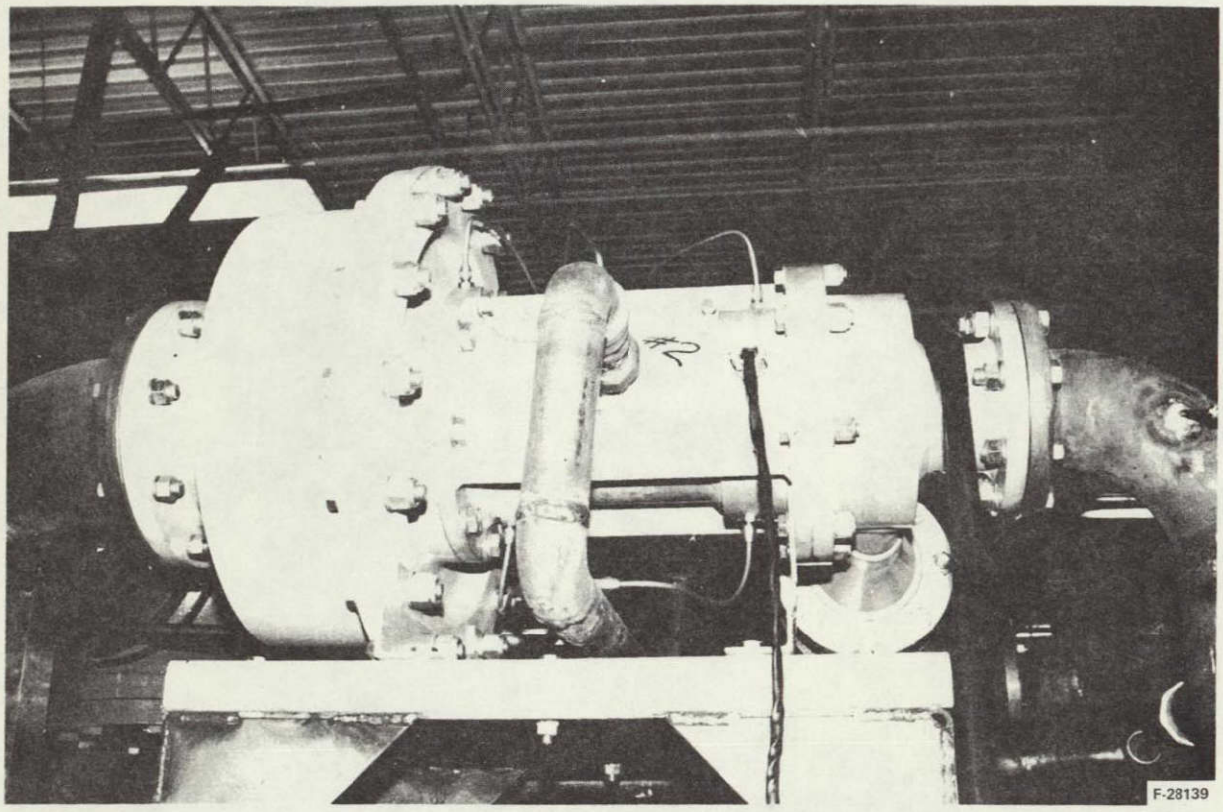
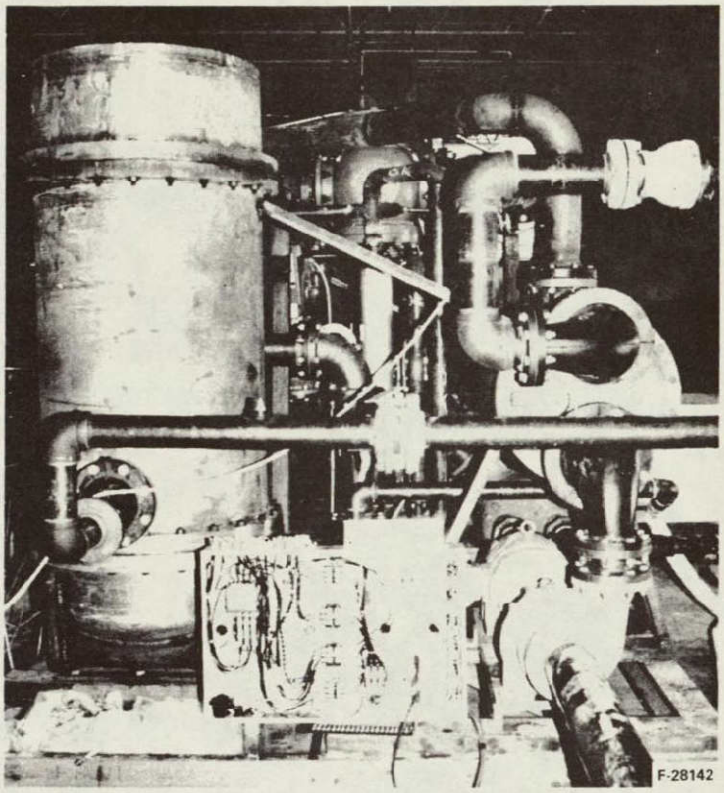
75-TON TURBOCOMPRESSOR



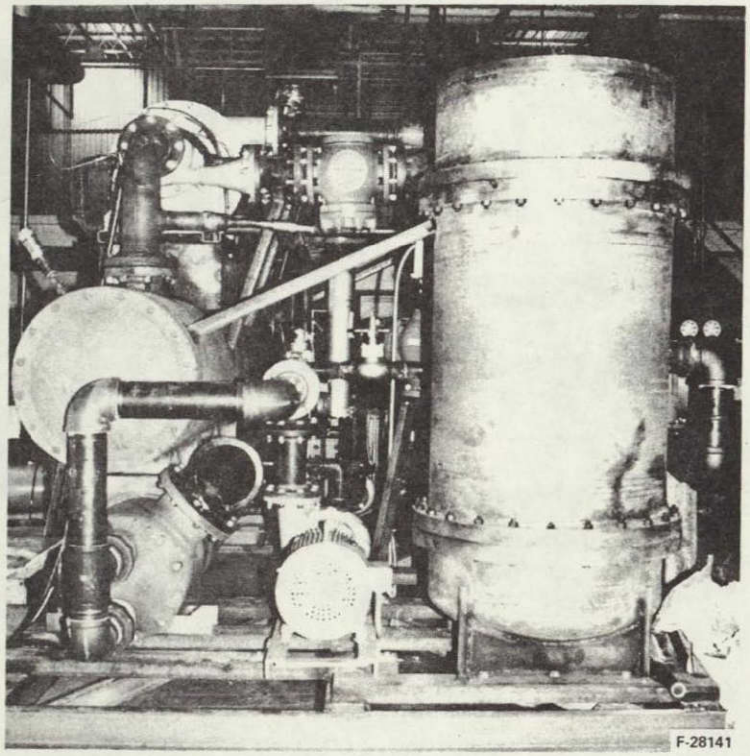
75-TON RANKINE CYCLE SOLAR HEAT PUMP FOR UNIVERSITY OF HOUSTON SITE

(EVAPORATOR END VIEW)



75-TON RANKINE CYCLE SOLAR HEAT PUMP FOR UNIVERSITY OF HOUSTON SITE

(BOILER END VIEW)



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