DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150694

PROTOTYPE SOLAR HEATING AND COMBINED HEATING AND COOLING SYSTEMS (QUARTERLY REPORT NO. 6)

Prepared by

General Electric Company
Space Division
Post Office Box 8661
Philadelphia, Pennsylvania 19101

Under Contract NAS8-32092 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 accomplished under the technical management of Mr. William L. Moore, George C. Marshall Space Flight Center, Alabama.

16. ABSTRACT

The General Electric Company is developing eight prototype solar heating and combined heating and cooling systems. This effort includes development, manufacture, test, installation, maintenance, problem resolution, and performance evaluation.

All cost data have been removed from this report.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

INTRODUCTION

The Quarterly Status Report (Data Requirements Item No. 500-10) provides a summary of the cost, schedule and technical progress of the program. Since it includes and extends the information included in the Monthly Status Reports (Data Requirements Item No. 500-11) it also meets the contract requirement of a monthly status report. It is supplemented by the financial status report (Data Requirements Item No. 500-27) submitted under separate cover.

The report format is:

Part I - Summary

Part II - Cost

Part III - Schedules

Part IV - Technical Performance

The report is integrated with the program management systems being used on the program, so, where possible, multiple use of program data such as schedules or financial status reports has been accomplished.

A separate attachment that contains no Proprietary Data will be provided for general distribution.

PART I

SUMMARY

1.1 COST

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1.2 SCHEDULE

The working program schedule is posted on the walls of the Program Control Room and is used to monitor program status at daily "standup" meetings. Reviews with GE management are held in the Control Room to take advantage of the detail schedule data base. A summary schedule is shown in Figure 1-1 and 1-2.

Definition of the Operational Test Sites is a continuing schedule problem. Prototype design reviews have been rescheduled and rescoped to adapt to the number and dates of the identified sites. A First Article Reviews (FAR) were the Spokane and Normal Operational Test Sites. Installation of the Normal Ill., single family heating system was 60% complete at the end of the period. The TES tank was shipped to Spokane.

Work continued on the resolution of collector coating problems and independent verification tests have been scheduled for the first quarter of 1978.

The collector shrouds are the schedule limiting items for test site hardware.

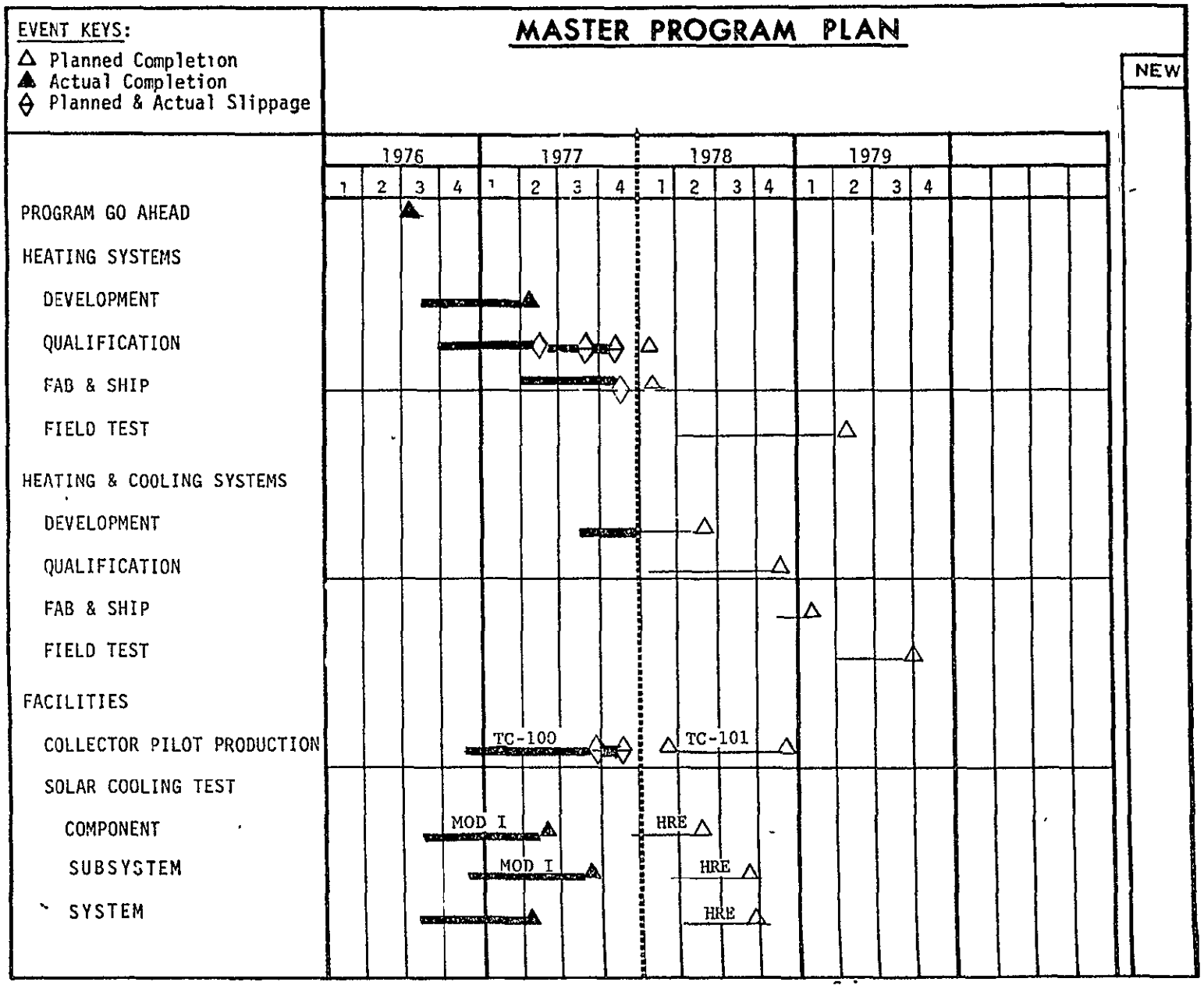

Figure 1-1. Master Program Plan

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1.3 TECHNICAL PERFORMANCE

1.3.1 PROGRAM MANAGEMENT

Program direction continued per plan. Highlights of the period were the First Article Reviews for the two test sites.

1.3.2 DEVELOPMENT

There was no significant activity in the analysis and integration sub task.

A concentrated effort was made in support of the development of the collector vacuum shroud coating process at the vendor. Shrouds with improved performance were received at the end of the period and placed on test at VFSC.

Design and analysis of the SEDHP subsystem continued.

A delta Preliminary Design Review was held early in the period. In attendance were representatives from the Air Conditioning Products Division. Subsequent discussion reviews and additional analysis resulted in the conclusion that R-22 was a better working fluid for the heat pump than R-114 and this change was communicated to NASA at a December meeting. A magnetic drive will be used to provide a hermetic system and an overrunning clutch will separate the electric motor drive from the solar drive.

1.3.3 DELIVERABLES

Hardware for the Normal, Illinois, site was shipped during the period following the FAR. By the end of the period, remaining items to be shipped included the collector glass shrouds, a qualified integrator to replace the temporary unit at the site and instrumentation items.

The TES tank was shipped to the Spokane site and other hardware is being accumulated for shipment next period. The tank was shipped because it has to be mounted on the foundation prior to completion of the small building being built to house the tank. All other hardwares are on order; same items were received this period.

Hardware for the Milwaukee site is on order. Delivery of the TES tank is being delayed until it is needed at the site.

1.3.4 OPERATIONAL TEST

A contractor was selected to install equipment at the Normal site. Construction was initiated and was about 60% complete at the end of the period.

Bid requests, with a due date of December 30, 1977, were issued for construction at the Spokane site. The TES tank was shipped to the site because it had to be put in position

before its building could be completed. A contractor was hired to put the tank in position and this was accomplished by the end of the period.

Design activity for the Milwaukee site was placed on hold because site preparation was delayed. The county of Milwaukee decided to proceed with the project late in the period and design activity was resumed.

PART II

COST

This section has been deleted

PART III

SCHEDULES

Summary program schedules are shown in Figures 3-1, 3-2, and 3-3. These schedule data are extracted from the detailed program working schedules posted in the Control Room at Valley Forge.

Figure 3-1 is the summary key events schedule. Significant scheduled customer events included delta Preliminary Design Review on the cooling subsystem (10/4/77), First Article Reviews for the residential heating (10/4/77) and commercial heating (12/7/77) and a Quarterly Program Review (10/5/77).

The key activity in the solar collector task was the continuing effort to produce satisfactory coatings on the vacuum. A team worked at the vendor's plant to identify and control the significant process parameters. The delay in production of this item has made it the limiting hardware item for the Normal, Illinois Operational Test Site and potentially limiting item for the Spokane site. The development of the TC-101 solar collector proceeded on schedule.

Scheduled events this period for the cooling subsystem development task were delayed and replanned due to additional configuration studies and changed design selections. In particular the selection of R-22 as a heat pump working fluid affected the schedule and a replan for the near term events is being produced. Design of certain accessories, such as the feed pump, proceeded per plan.

Hardware items for the Operational Test Site at Normal were shipped to the site and installation is proceeding. At the end of the report period the electrical work was underway and most of the plumbing is complete. Missing items include the TC-100 vacuum shrouds, the SDAS, and a flow meter*. An Installation Acceptance Review is scheduled for March.

Figure 3-2 is the schedule for the WBS elements. The activity associated with the heating and cooling systems has been rescheduled.

Figure 3-3 shows the data deliveries. During this period all scheduled software deliveries were completed except the new Technology Report which is in preparation.

Hardware items for the Spokane site were received this period and the TES tank was shipped on 12/20/77 to be installed on the footings so the tank shelter could be completed. A First Article Review was held on 12/7/77. Shipment of other items will occur after selection of the installation contractor and completion of building modifications.

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* Note that an engineering model solar integrator is being used until a qualified unit is available.

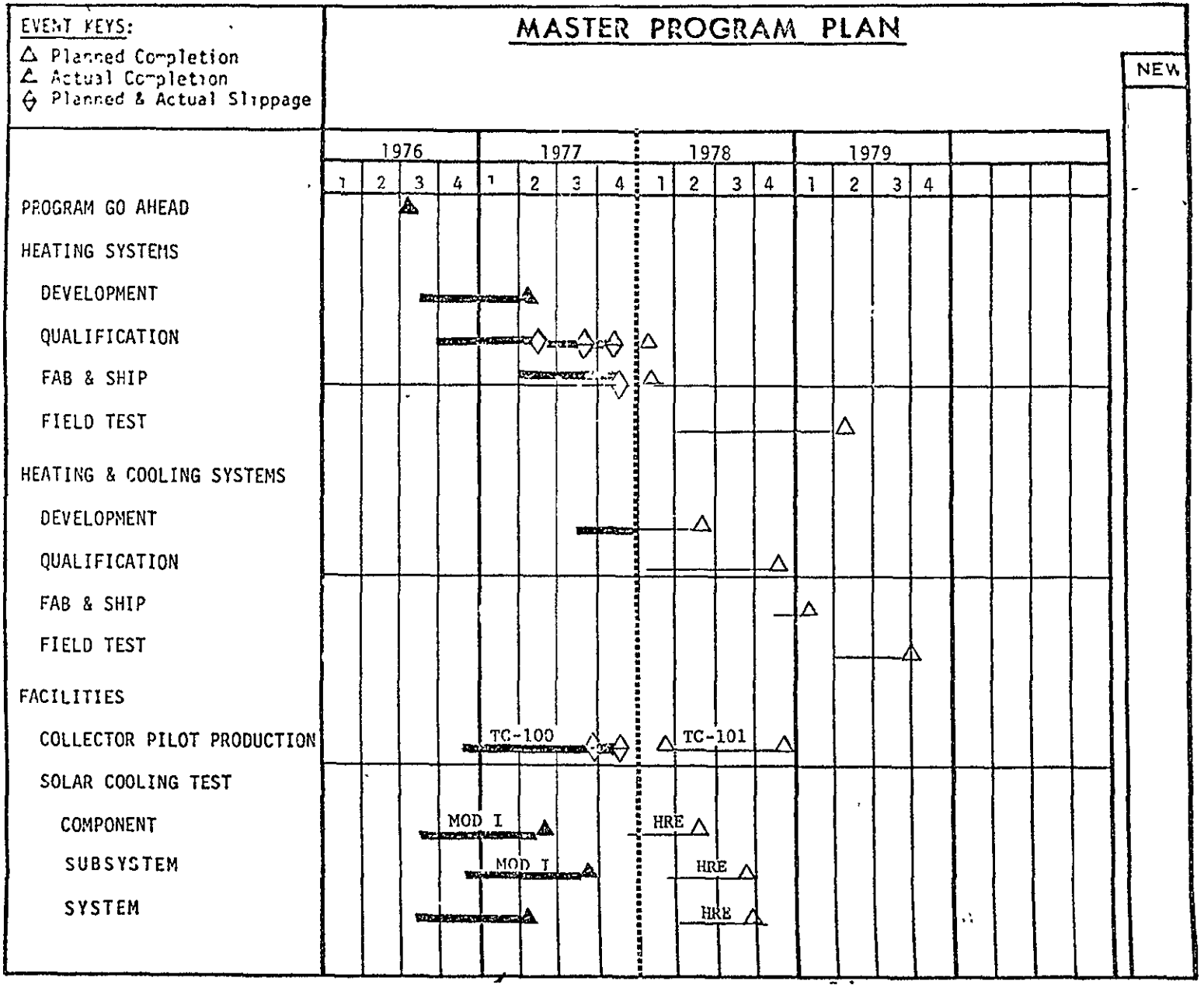

Figure 3-1. Master Program Plan

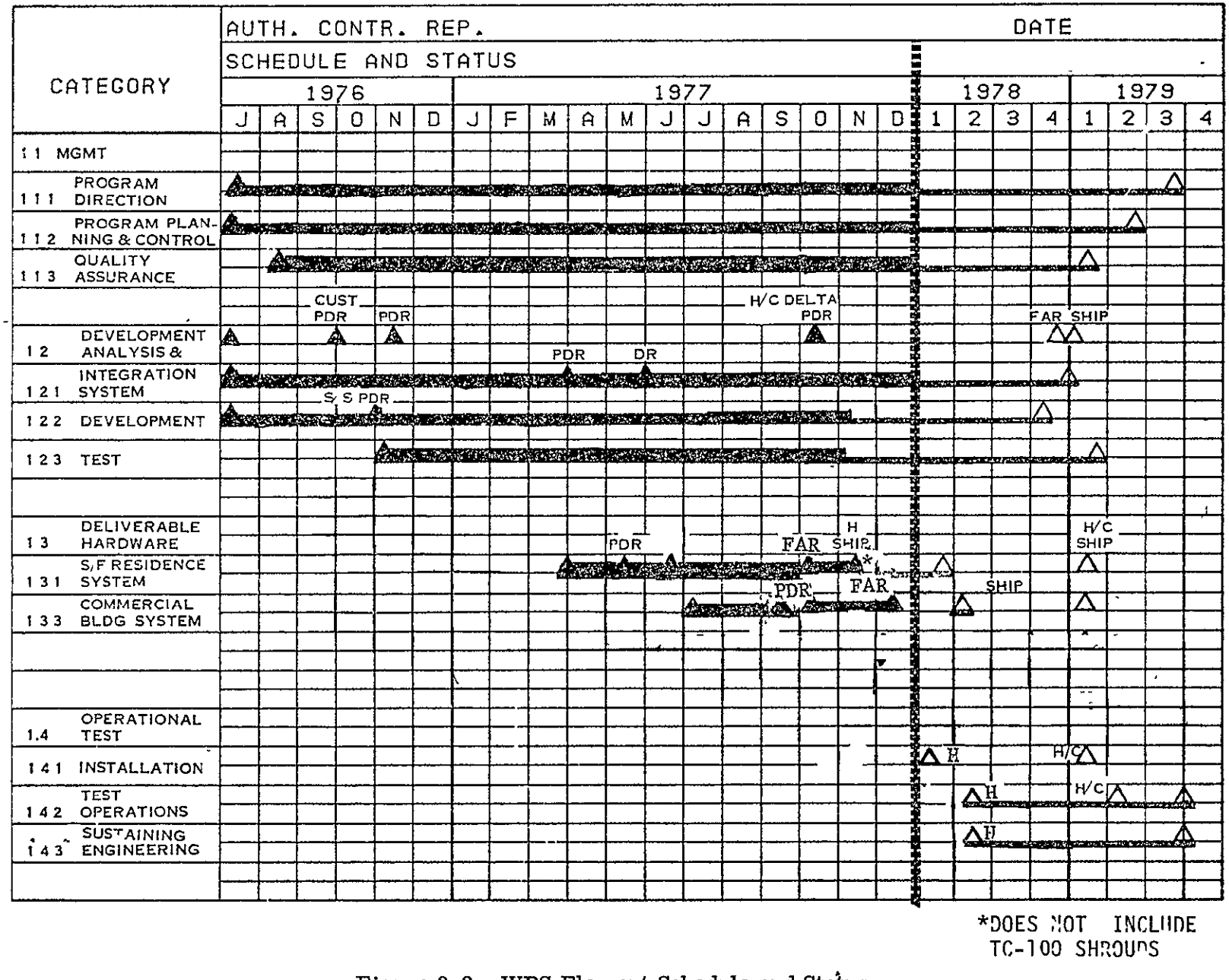

Figure 3-2. WBS Element Schedule and Status

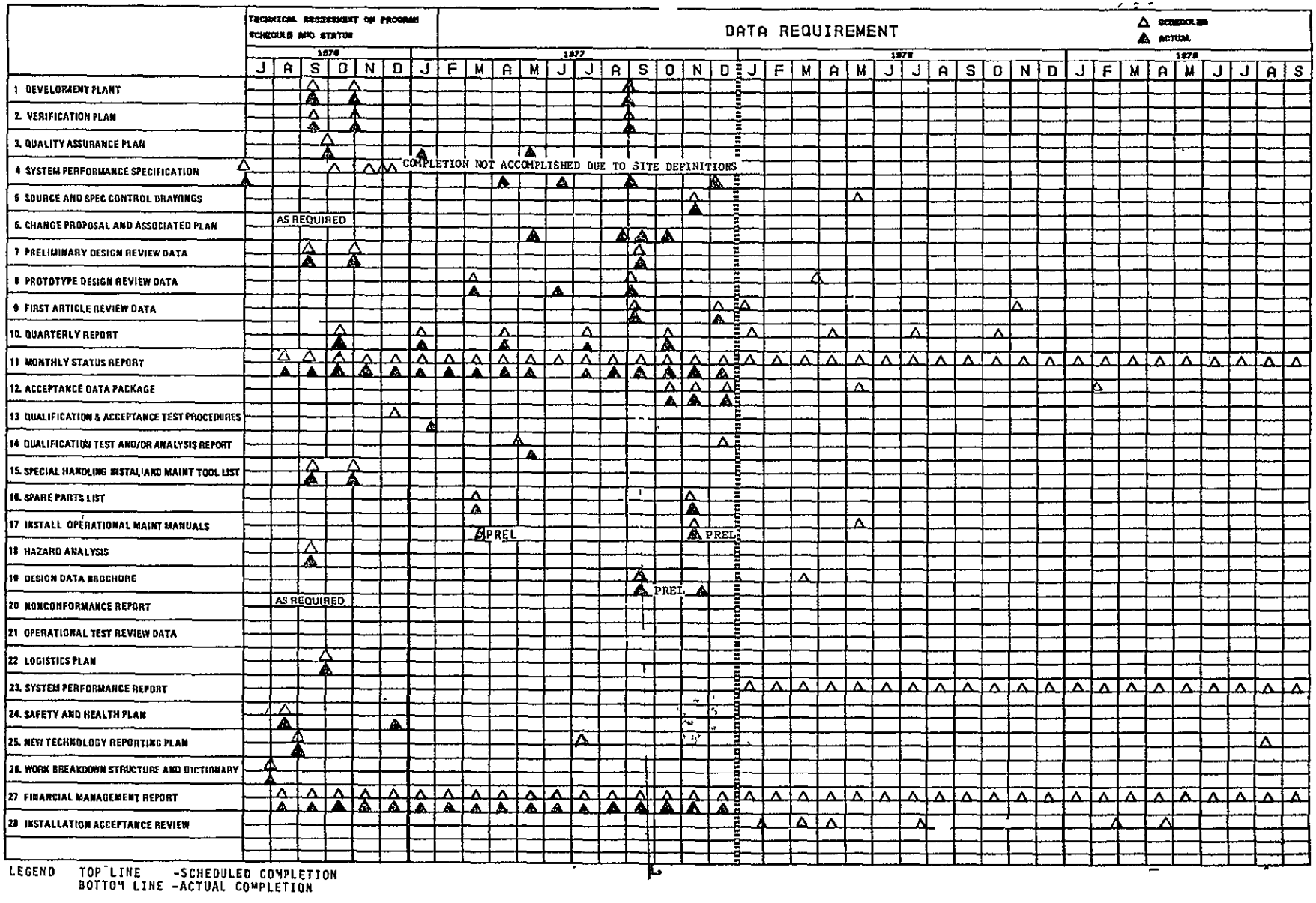

Figure 3-3. Data Requirements Status

The Milwaukee site was inactive most of this period due to a building modification cost problem. Near the end of the period the owner decided to proceed and installation design activities were resumed. A revised installation schedule is being prepared.

PART IV

TECHNICAL PERFORMANCE

4.1 PROGRAM DIRECTION (WBS 1.1.1)

During this period program operation continued in the manner established during the initial quarters. The program team chart, shown in Figure 4-1, has been updated to reflect changes since the last quarterly report and shows the following changes:

1. J. Zimmerman deleted. The system analysis activity is essentially complete and this position was eliminated.
2. J. Hatman replacing R. Bingmann in the Solar Collector position. Mr. Bingmann is leaving the General Electric Company and his responsibilities will be assumed by Mr. Hatman.
3. R. Berg as "All Others" Engineer. This position is no longer a full time assignment and Mr. Kahn has been reassigned to another program.
4. L. Gray added to Manufacturing Engineering box because he fills this role for the cooling subsystem.
5. G. Podolsky replaced E. Sheehan in the Subcontracts box.
6. A. Cheddar has replaced W. Davis as Quality Assurance representative. Mr. David is assigned to the solar collector facility and is available to the program as required.
7. R. Casagrande is designated in the Projects and Field Operations box to reflect his activities in coordinating the test sites installation and operation.
8. Corporate Program Advisory Board has been modified to reflect corporate reassignments. Mr. Fink has been appointed Group Executive and his participation in the Board has not been established. Mr. Dawson has moved to an operating organization and his continued participation on the Board has not been established. Mr. Farnham's new position is reflected in the figure.

The First Article Review for the HSP-2 system (Normal, Illinois site) and a delta Preliminary Design Review for the redirected cooling subsystem were held in conjunction with the Quarterly Program Review (10/4 and 10/5). Approvals to ship the Normal site hardware and to proceed with the cooling subsystem design and development were received. Subsequent analysis resulted in a change in the recommended working fluid for the heat pump section of the cooling subsystem and this was discussed in conjunction with the First Article Review for the HCOM-2 system (Spokane) held on 12/7/77. MSFC requested a technical presentation on the design concept in January 1978 at Huntsville, Alabama.

As agreed, at the above meetings the Spokane site moved ahead of the Milwaukee site because of delays in the modification of the building in Milwaukee. Design activity on the Milwaukee site was suspended pending resolution of the building modifications. No hardware is to be shipped to the site until the resolution is complete. This occurred near the end of the period

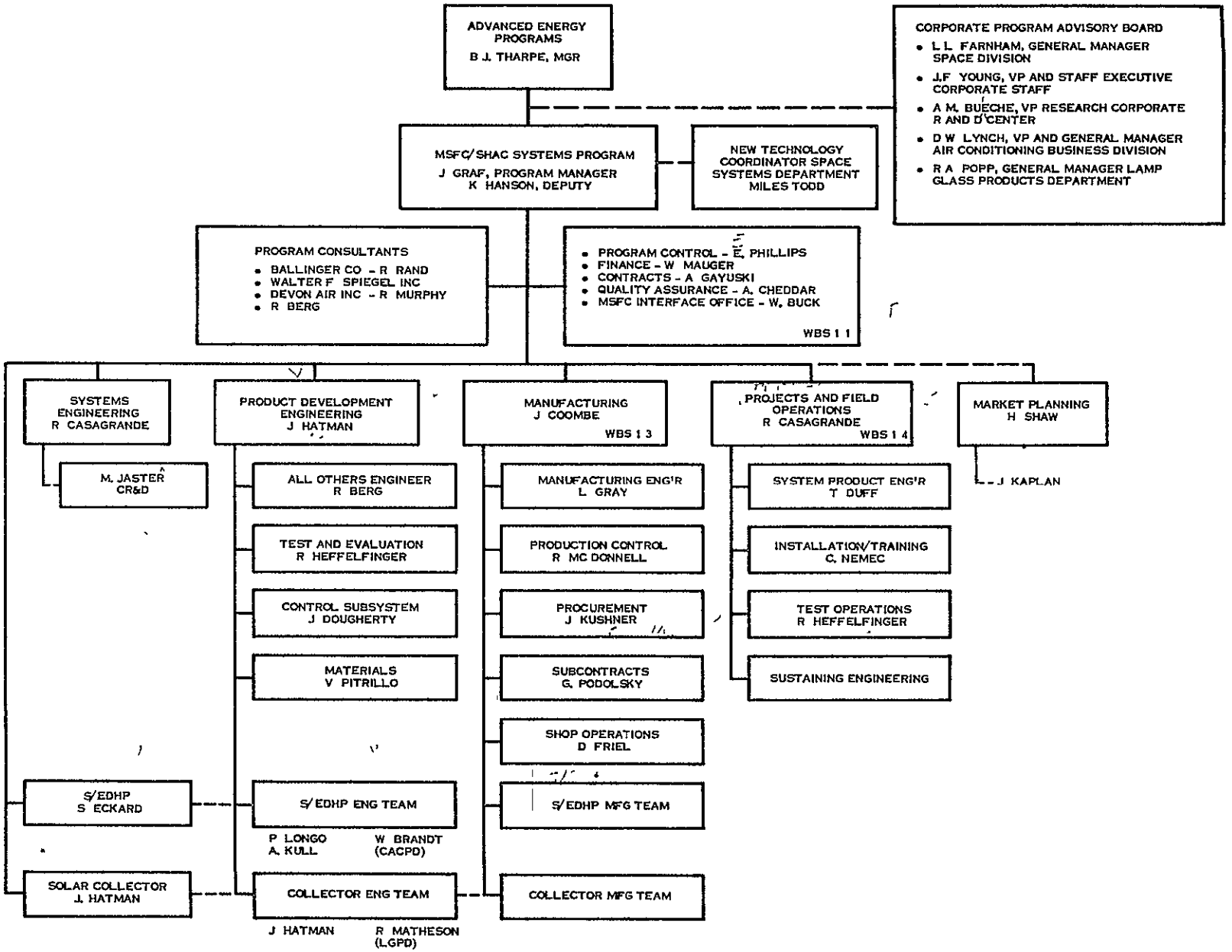

Figure 4-1. Program Organization

and design is proceeding. Hardware shipments will not be made until needed at the site as storage charges at the tank vendor make it cost effective to ship the equipment to Milwaukee for storage.

Selection of sites in the Philadelphia area was discussed at the December 1977 meeting and a number of criteria were discussed. These are open action items on the types of sites (private dwellings, etc.) that can be considered.

4.2 PROGRAM PLANNING AND CONTROL (WBS 1.1.2)

4.2.1 PROGRAM CONTROL

The basic program control tool being used on this program is the control room. It was used during this period to schedule key milestones and program activities and monitor their status. This control room represents the official program schedule against which GE's technical status and progress is monitored. The scheduled data required for the monthly, quarterly and management reports is extracted from the control room posting. The schedules in the control room include the overall program summary with detailed task schedules on the side walls. The individual task sections of the control room schedules are monitored and maintained by the responsible task leaders. Program status meetings are held frequently (3 to 5 times per week) to follow hardware items. Problems involving interactions are identified and resolved at these meetings by the assignment of action items which are posted and monitored in the control room.

In the budgets area, the program was monitored on the basis of the revised profile presented in the fifth quarterly report. Overall budget results are analyzed weekly and are available on a continuing basis for inspection by management.

4.2.2 DATA MANAGEMENT

The scheduled data submittals completed during this period were as follows:

Data Requirements No.	
-9	First Article Review Data Package (HCOM-2)
-10	Quarterly Report No. 5
-11	Monthly Status Report (2)
-26	Financial Management Report - Monthly (2)
-27	Quarterly Financial Report

As of this report, 13 RIDS are still outstanding from the FAR.

4.2.3 CHANGE CONTROL

The status of Change Proposals is given in Table 4-1.

Table 4-1. Change Proposal Status

Number	Title	Submittal Date	Approval Date	Notes
GE-JRF-001	Statement of Work	9/9/77	1/17/77	
GE-JRF-002	WBS and Dictionary	--	--	Cancelled. Customer initiated action.
GE-JRF-003	Ft. Meade Site Design and Installation	5/12/77		Site Cancelled 6/17/7 6/17/77
GE-JRF-004	Revision to Systems to be Delivered and Operational Test Sites	7/12/77		Part of CP007 Withdrawn
GE-JRF-005	Instrumentation Plan			Cancelled
GE-JRF-006	Normal, Ill. Design and Installation	7/15/77	8/8/77	
GE-JRF-007	Revision to Systems to be Delivered and Operational Test Sites	8/31/77	--	To be revised
GE-JRF-008	Milwaukee Design and Installation	10/31/77		
GE-JRF-009	Proto System Ship	Cancelled		Replaced with Letter
GE-JRF-010	Spokane Design and Installation			In Process
GE-JRF-011	Normal Installation Part II			In Process

The status of the Control Modifications is given in Table 4-2.

This table has been deleted.

4.3 QUALITY ASSURANCE (WBS 1.1.3)

4.3.1 SIGNIFICANT QUALITY ASSURANCE ACTIVITIES

The major portion of the hardware for the normal, Illinois Single Family Heating System has been inspected, packed and shipped. Air Force Quality Control reviewed inspection records and packaging and approved the shipment.

FAR activities have been conducted for the acceptance of a Commercial Heating System to be installed at a YWCA in Spokane, Washington.

Shipment of hardware to the Spokane site has begun. DCAS Quality Control witnessed hydrostatic pressure testing at the supplier's plant and approved shipping papers for the Thermal Energy Storage and Expansion tanks.

A Q.A. representative has served continuously as a member of the Manufacturing team working with the supplier at his plant to determine the cause of degradation of the optical properties of coated glass tubes and to implement process changes and controls to eliminate this problem.

Inspection planning for purchased items and in-house fabricated items is in place and functioning. Quality inputs to Manufacturing Standing Instructions (MSI) are provided as these are generated.

PART V

TASK 1.2 - SYSTEM DEVELOPMENT

5.1 INTRODUCTION

The major program activity this period was site related in that designs were completed, hardware received, and shipped to two sites. Other significant activities included continued design activity on the S/EDHP which resulted in a change in the heat pump working fluid. Problem investigation of shroud coatings for the collector received emphasis and design of the TC-101 collector proceeded per plan.

5.2 ANALYSIS AND INTEGRATION (WBS 1.2.1)

No significant activity this period.

5.3 SYSTEM DEVELOPMENT (WBS 1.2.2)

5.3.1 HEATING SYSTEM (WBS 1.2.2.1)

5.3.1.1 Collectors (WBS 1.2.2.1.1)

5.3.1.1.1 Collectors Design and Performance Verification

The selection and evaluation of an anti-scratch coating has been completed. Production methods for application and curing of the coating have been developed and tested. No glass breakage has occurred since the anti-scratch coating has been adopted.

Coating equipment is operational and coating parameters have been established and are presently being fine tuned.

D. S. T. facility is presently saturated with HUD tests. The TC-100 is in line for test and scheduled for mid-February. Rework on the performance test loop at Valley Forge has been completed subsequent to fire damage. After awating sunshine in order to obtain performance data a few days of testing was accomplished at the end of the period. A mini-stagnation test fixture has been developed for evaluating individual shrouds based on stagnation temperature.

Shipping test on the evacuated collector packaging and tray and serpentine sub-assembly packaging have identified deficiencies. Packaging redesign is complete and retest has been rescheduled.

All glass fabricating equipment received to date is operational.

5.3.1.1.2 Collector Integration

Collector integration drawings are complete. The only other activity in this area includes drawing revisions as experience with manufacture of parts dictate:

5.3.1.1.3 Primary Loop

The only activity in the primary loop concerns revisions to the 300 collector heat dump system to be used at the Spokane site. Delivery of the heat dump system is scheduled for mid-January.

5.3.1.2 Through 5.3.1.6 Ancillary Components for Heating Systems

Procurement of hardware for Milwaukee and Spokane was completed.

5.3.1.7 System Components

Johnson Controls has been selected to fabricate the control units for Milwaukee and Spokane and will do the work in their Philadelphia facility. The units will include all system control logic (relays), terminal points for system sensors and motor starters and 24 Volt, Class Z power for all valves. Indicator lights are wired to pump and valve outputs and are integrated into a system diagram to illustrate system operation.

Solar integrators are currently in a retrofit state at Zia Associates to incorporate electrical and packaging changes. The flat glass window will be replaced by a dome. Noise immunity circuits have been added to correct a problem found in qualification testing. The units will be requalified before delivery to the field. Engineering units will be used at the field sites on a temporary basis until qualified units are available.

5.3.1.8 Electrical Subsystem

Drawings for the Milwaukee (132D6029) and Spokane (132D6030) HCOMM sites are complete.

5.3.1.9 System Integration (WBS 1.2.2.1.10)

The system integration activities were concentrated toward the detailed definition of the operational test sites. The results of these activities are included in Section 4.1 of this document.

5.3.2 HEATING AND COOLING SYSTEMS (WBS 1.2.2.2)

5.3.2.1 Collector Subsystem (TC-101) (WBS 1.2.2.2.1)

The TC-101 design is complete except for final assembly drawings. Preliminary test on the clamped fin appear successful and testing is continuing. Design and producibility studies of the two-foot fin are complete and performance verification test are in progress. The prototype cusp reflector is currently being tested.

5.3.2.2 Through 2.3.2.6 Ancillary Components for the Heating and Cooling System

Specifications have been written to satisfy new requirements for heating and cooling systems.

5.3.2.7 Controls - Heating and Cooling

No changes have been made during this reporting period to the heating and cooling single family or commercial design.

A specification for the analog temperature switch development has been completed. Requests for quotation will be released in the next month.

5.3.2.8 Electrical - Heating and Cooling

No activity in this task during this time period.

5.3.2.9 System Integration (WBS 1.2.2.2.10)

No significant activity this period.

5.3.2.10 Cooling Subsystems (WBS 1.2.2.2.11)

The following summarizes the activities during the reporting period of the cooling subsystems development effort. The cooling subsystems include 3-ton and 10-ton capacity split system solar/electric driven heat pumps and their associated equipment. The emphasis during this report period was on an analysis and design of the major heat pump and Rankine engine components. Model 1 expander test activities continued in the evaluation of low cost material applications and improved performance.

5.3.2.10.1 Subsystem Analysis

A key issue was the review of the heat pump fluid and recommendation for change. Fluid studies for the heat pump concentrated on R133a, R114 and R22. Of these fluids R133a showed the highest potential COP with R22 approximately 10% lower in potential COP. R114 has a 4% lower potential COP than does R133a. The R133a and R114 fluids are low density, low pressure, high specific volume refrigerants, while R22 is a high density, high pressure, low specific volume fluid. These low pressure type fluids (R133a and R114), when applied in a heat pump cycle, have higher theoretical performance than R22 but have limited low temperature heating capability relative to R22 (cutoff temperatures of $\approx 35^{\circ}F$ versus subzero). To achieve the theoretical performance for R133a, suction side hardware becomes large in size to minimize refrigerant pressure drop.

Hardware analysis indicated that in order to meet these low and controlled suction side refrigerant flow pressure drop requirements for the R133a and R114 heat pump cycles; control valves, heat exchangers, internal piping, interconnecting piping, etc., would have to be greatly oversized and specially circuited as compared to R22. The

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end result was a split system heat pump design which was physically larger, heavier, costlier, requiring special installation care (controlled physical separation of indoor and outdoor units). It was concluded that penalties associated with an R133a or R114 heat pump were larger than the small potential performance to be gained. Therefore, a program recommendation was made to use R22 as the heat pump working fluid. R22 designs are being prepared.

This table has been deleted

5.3.2.10.2 Expander Model 1

Performance evaluation of low cost materials for end plates and vanes was initiated during this report period and is continuing through the current period.

The following end plate materials are being evaluated in the Model 1 three-ton vertical expander.

1. Ni-Resist with Cr_2O_3 Coating
2. Ductile Cast Iron (heat treated)
3. Nitronic 60
4. Ductile Cast Iron with Phosphate Coating
5. Gray Cast Iron with Cr_2O_3 Coating

To date all materials have been tested with the exception of the ductile cast iron/phosphated coated and gray cast iron with Cr_2O_3. Ni-Resist/Cr_2O_3 end plates have been used successfully since the beginning of this program, and continue to be the baseline design. The heat treated ductile cast iron end plates evidenced severe galling during 200 hours of continuous operation. The Nitronic 60 hardware evidenced the same galling as the ductile cast iron except that it occurred after only 6 hours of operation. Phosphate coated gray cast iron end plates have been fabricated and are scheduled for test during the next period.

The following vane materials were evaluated during this report period:

1. Vanasil 77
2. Vanasil 77/Ni-Tuff Coated
3. ACF-10Q Ti C Coated
4. D73-049
5. D2947

} Graphite Base Materials

All of the above vanes performed successfully with no measurable wear. The Vanasil/Nu-Tuff vanes appear most attractive due to their relatively low cost. The nitrided nitralloy stator exhibited no measurable wear when used with any of the above vane materials. Peak efficiency in the low 70% range was measured consistently during the current reporting period.

Dynamic and static rotary face seal test fixtures have been fabricated and assembled and are currently on test. The purpose of this series of tests is to measure leak rates and general seal performance.

5.3.2.10.3 Expander/Compressor Package

Figure 5-2 illustrates the three ton hermetically sealed Expander/Compressor assembly (static). This assembly will be positioned vertically in the solar electric driven heat pump package. The top portion houses the two-stage rotary vane expander. Construction is similar to Model 1 single-stage units where tie rods hold the entire unit together. Both rotors are free to move axially in a central shaft. This type of construction was selected to accommodate ease of assembly, differential thermal expansion and ease of fabrication.

The bearing system consists of two rolling element bearings with the bottom bearing serving as a radial and thrust bearing as indicated. Bearing and vane lubrication is provided via capillary tubes similar to Model 1.

Coupled to the output shaft of the expander is a magnetic drive/clutch arrangement. The magnetic drive provides hermeticity for both the Rankine loop and the heat pump loop. The outer magnet ring drives the inner magnet ring. Nested inside the inner magnet ring is an overrunning clutch assembly. This clutch automatically decouples the expander from the compressor when the electric motor is dirving the compressor. Bolted flanges are utilized on the first units to facilitate ease of internal adjustments and modifications.

5.3.2.10.4 Feed Pump

The hermetically sealed feed pump designs for both the three ton and ten ton sizes have been completed and the detail drawings are in process. A detailed layout of the three ton feed

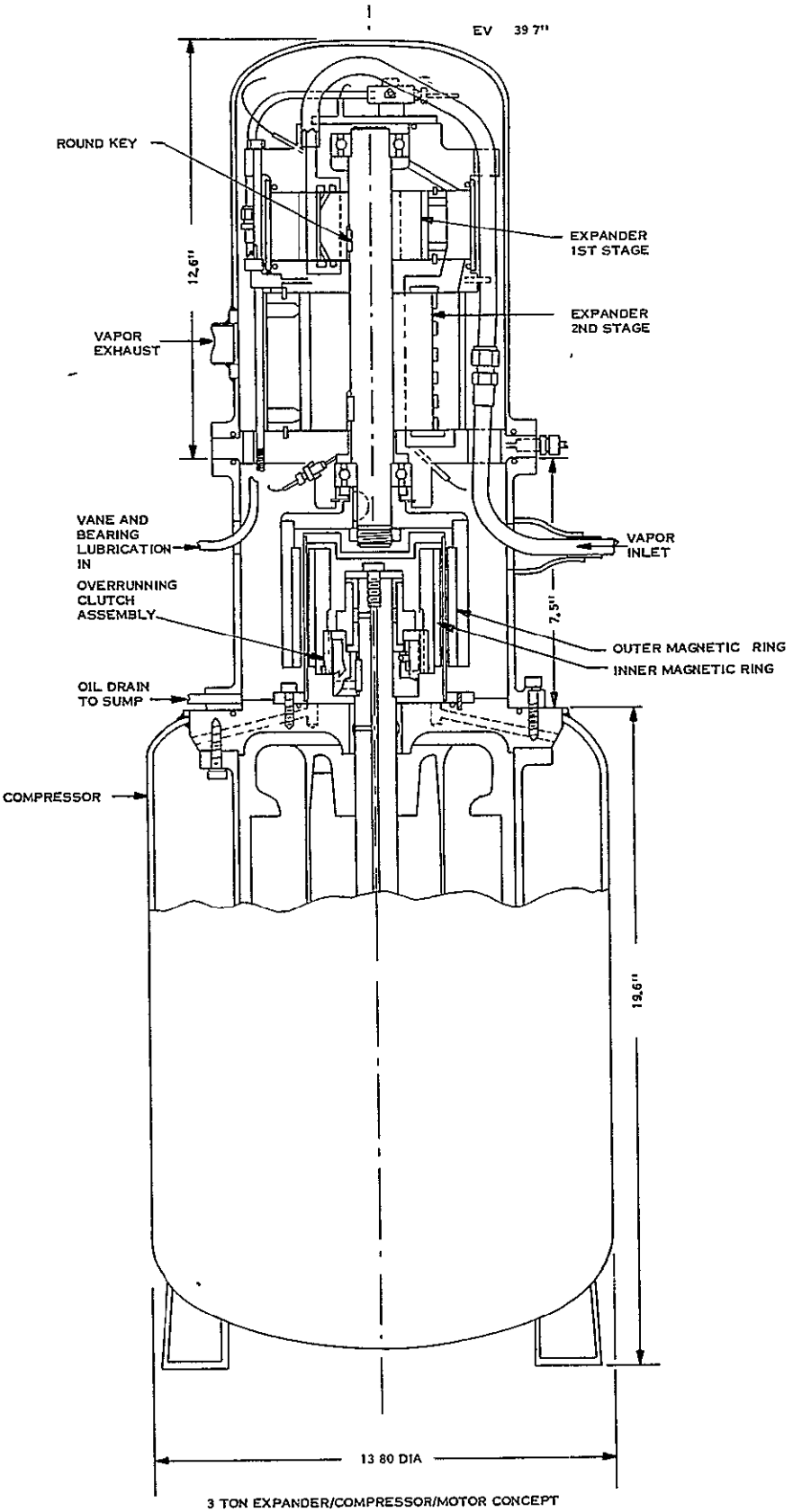

Figure 5-2. Three-Ton Expander/Compressor/Motor Concept

pump is shown in Figure 5-3. Pumping is accomplished in two stages. The first stage is a centrifugal while the second stage is a positive displacement gerotor type. Lubricant is supplied to the pump via the tube shown. Subsequently the lubricant is circulated through the bearings via the drag pump. Excess oil will emerge from the top of the pumping element and mix with the fluid in the sump. A conventional hermetic motor is utilized to drive the pump. Motor cooling is provided by channeling a small portion of the flow from the condenser directly past the motor as illustrated on the layout. A vapor condenser heat exchanger is provided exterior to the feed pump which will condense any vapor generated by the motor cooling system. A rotary shaft seal is provided, as shown, to prevent the working fluid from entering the bearing lubrication system. Internal and external relief valves are provided. Initially flanges are provided on the shells to facilitate easy access for internal adjustments.

5.3.2.10.5 Heat Exchangers

A vendor search was initiated for the vapor generator, regenerators and condensers. Preliminary designs for the vapor generators and regenerators have been received from Ametek and Dunham-Bush and are shown in Figures 5-4 and 5-5. These heat exchangers are of the tube and shell type and for packaging flexibility were designed for either horizontal or vertical operating orientation. Condenser specifications have been reviewed with Bohn, McQuay and Sunstrand. Trade-off studies continued between spine fin and plate fin overall performance.

5.3.2.10.6 Controls

The conceptual design was initiated for the motor controls and the analog temperature sensing and digital sequence controls. Motor control test circuits have been fabricated to prove feasibility of a limited range variable phase-angle ac induction motor control. This control has been developed primarily for Rankine engine feed pump modulation, although its use in the variation of system fan loads will also be investigated. The controller, featuring an optically coupled triac drive, has been tested on a GE, Weathertron 0.5 hp outdoor fan. Fan speeds were varied from 1120 rpm (no load) to 250 rpm. Further testing is required to check motor heating and stability. Preliminary design of analog temperature sensing circuits was started. The analog control will maintain superheat into the Rankine engine expander by sensing vapor generator temperature delta and varying pump flow. Analog sensing of outdoor ambient temperature and outdoor coil (heat pump) temperature will be elevated for control of defrost and outdoor fan speed. Digital sequence logic design is in the conceptual state. Two candidate approaches are hardwired logic and a Field Programmable Logic Array to handle the timing and decision logic of the S/E DHP.

5.3.2.10.7 Packaging

Trade-off studies continued on the three ton S/E DHP indoor and outdoor unit configurations. As preliminary component physical size and orientation requirements were defined, these inputs were incorporated into the packaging to firm up envelope dimensions. Serviceability requirements definition was initiated. A vendor search for high efficiency fan and blower systems was initiated. A decision was made to locate the I^2R supplementary heaters

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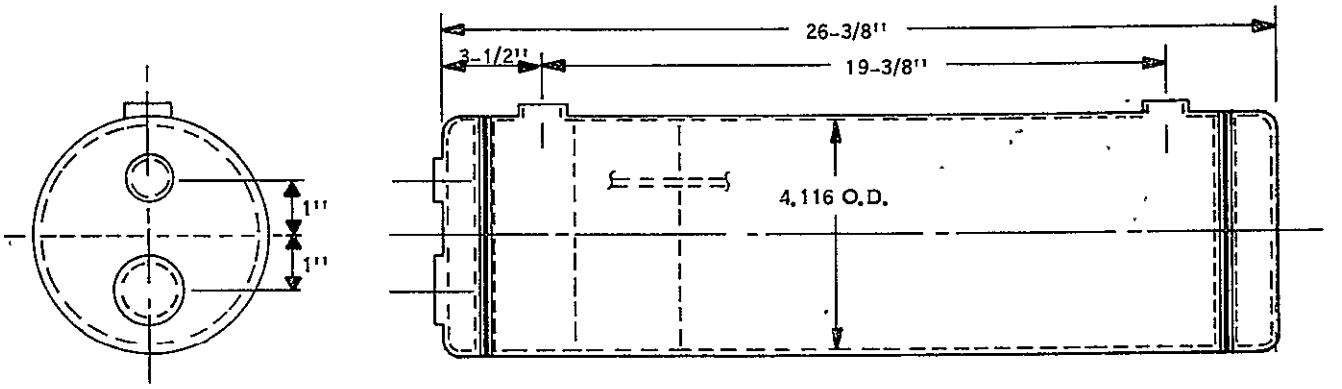

Figure 5-4. Three-Ton Vapor Generator Concept

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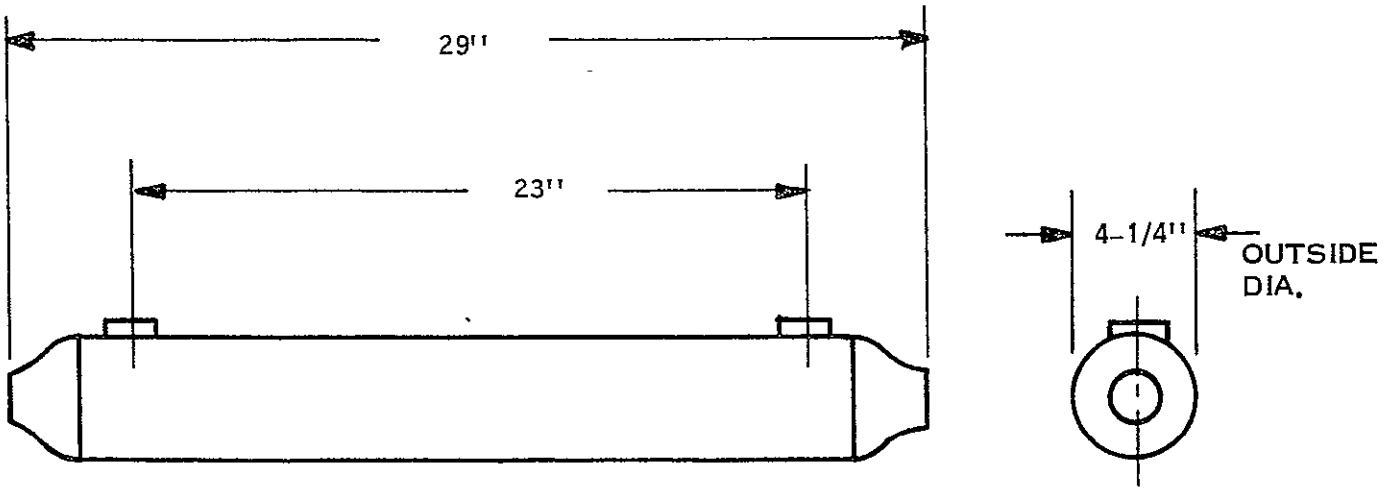

Figure 5-5. Three-Ton Regenerator Concept

downstream of the solar hydronic coil in the indoor air handler to allow the system flexibility, if desired, to operate I^2R and solar hydronic simultaneously.

5.4 TEST (WBS 1.2.3)

Testing proceeded at the component and subsystem level for the three ton heating and cooling configurations.

5.4.1 LOW TEMPERATURE RANKINE COMPONENT TEST LOOPS

Extensive testing of the three ton expander was conducted during this reporting period utilizing the operational "A"-Loop test facility. One of the test facility features that proved most useful this period is the "Unattended Operation Mode" which provides automatic shutdown of an expander test in the event of a test facility or expander anomoly. Overnight and weekend continuous operation of the three ton expander was successfully accomplished without incident.

The planning is completed for the test facility changes required to accommodate the new two stage expander and FC 88 working fluid. Changes to the test loops include higher range temperature controls for the 150 kW simulated solar fluid source, higher range temperature and pressure sensors, modified loop components e.g., liquid separators, vapor generators, condensers and feed pumps. New mounting fixtures, and inlet and discharge piping interfaces will be designed and build for the three ton and ten ton expanders.

5.4.2 COLLECTOR TESTING

The VF outdoor solar collector test facility is operational following repair of damages from a fire that destroyed the thermal insulation, power wiring, instruments wiring and the wood base structure that supports the tank and circulation pump. The failure investigation concluded that the fire started in the resistance heater circuit and subsequently ignited the insulation. Although only a small percentage of the insulation was burned, it all had to be removed in order to control the fire.

PART VI

TASK 1.3-DELIVERABLE HARDWARE

6.1 NORMAL

The deliverable hardware for Normal, Illinois has been delivered and received on site except the shrouds and solar integrator. There is a solar integrator available for systems start-up and it will be hand carried to the site by the middle of January. Delivery of the shrouds is dependent on the coating problem solutions which should be solved for shipment of glass in the next period.

6.2 SPOKANE

Collector frames and mounting hardware for the Spokane site is available waiting shipping destination, which is held up until the General Electric site installation contractor is selected. Other items will be received in January. The storage tanks have been shipped to Spokane. The glass shrouds will be shipped in April, 1978.

6.3 MILWAUKEE

Milwaukee site material is being accumulated for shipment in May, 1978.

PART VII

TASK 1.4- OPERATIONAL TEST SITES

7.1 SITE IDENTIFICATION

The sites that have been investigated to date are listed in Table 7-1 and those that have been accepted are listed in Table 7-2. There have been no new site visits in this time period. As part of the program redirection, the size of the commercial operational test site has been reduced to one ten ton unit for each site. Also, the Los Angeles location has been changed to Philadelphia to HCCOM2.

A preliminary investigation was made of potential sites in the Philadelphia area for both residential and commercial application. The types of sites potentially available are listed in Table 7-3. Each of these potential site categories were evaluated using a rating scale of excellent, good, fair, and poor against the criteria listed in the table. The evaluation summary is listed in Table 7-4. This data has been given to the NASA-MSFC site manager.

7.2 SITE DESIGN

7.2.1 HSF-1 NORMAL, ILLINOIS

The site design work was completed at the beginning of this reporting period with the First Article Review being held on October 5, 1977. This site has progressed to the installation phase as described further in Section 7.3.

7.2.2 HCOM-1 MILWAUKEE, WISCONSIN

The site design work was started but put on hold pending progress of the site owner's A/E. The A/E had determined that the roof structure was inadequate to support the collectors in the manner designated by the County of Milwaukee Assistant Architect. Proposals were presented to the county for a support structure design that greatly exceeded the planned project budget.

Subsequently, the county has hired a second A/E firm to evaluate the roof capacity. They too have found the roof structure inadequate but have come up with a support structure design that can be made within a expanded budget. The county had given a go ahead to the second firm to continue with the site modification design on December 22, 1977. Design activities on the solar heating system have been resumed following the county's decision to continue with the project.

7.2.3 HCOM-2 SPOKANE, WASHINGTON

The start and completion of the design activities for the heating system and the site modification design have occured in this reporting period. The First Article Review was held on December 7, 1977 and a bid package was released December 9, 1977. The site modifications were reviewed and integrated into the solar heating system design. General Electric

Table 7-1. Sites Inspected by GE

Bldg. Type	General City	Site
HSF	Baltimore	7502 Youmg St., Ft. Meade, MD.
HCOM	Muscle Shoals	TVA Office at Muscle Shoals, AL.
HMF	Nashville	Airman's Quarters, AEDC, Tullahoma, TN.
HSF	Peoria	Chanute Air Force Base
HSF	Peoria	MHA, Champaign, ILL.
HSF	Peoria	ISU House, Normal, ILL.
HMF	Schenectady	MHA, Schenectady, NY
HMF	Schenectady	VA Hospital Staff Housing, Albany
HMF	Schenectady	Ely Park Housing, Binghamton, NY
HCMF	Chicago	Ft. Sheridan, ILL.
HCMF	Chicago	Great Lakes Naval Training Center
HCOM	Madison	Hill Farm State Office Bldg., Madison, WI.
HCOM	Milwaukee	Washington Park Senior Citizens Center
HCOM	Milwaukee	Washington Park Community Center
HCOM	Milwaukee	Dr. Martin Luther King Community Center
HCOM	Spokane	YWCA
HCOM	Spokane	East Washington State College
HCOM	Spokane	Community College
HCCOM	Los Angeles	West L. A. Municipal Bldg.
HCCOM	Los Angeles	Dept. of Water & Power #1
HCCOM	Los Angeles	Dept. of Water & Power #2
HCCOM	Los Angeles	Peck Park Rec. Bldg.
HCCOM	Los Angeles	Police Credit Union
HCSF	Dallas	President's Home, Univ. of Texas at Dallas
HCSF	Dallas	President's Home, N. Texas State, Denton, Texas
HCSF	Dallas	Grad Student Housing at SMU

Table 7-2. Operational Test Site Status

Type	Location	Date Accepted by GE	Comments
HSF	Ft. Meade, Md.	Jan. 19, 1977	
HSF	Normal, Illinois	Feb. 7, 1977	
HMF	Tullahoma, Tenn.	Feb. 7, 1977	Multi-family units dropped from program verbally on April 4 and documented in minutes of April 4 meeting
HCOM	Muscle Shoals, Alabama	Jan. 19, 1977	Converted to Heating and Cooling Site on 4/20/77*
HCOM	Milwaukee, Wisconsin	May 23, 1977	
HCOM	Open		
HCSF	Dallas, Texas		SMU House recommended by NASA on Aug. 15, 1977
HCSF	Open		
HCCOM	Muscle Shoals, Alabama	April 20, 1977	
HCCOM	Open		

*Design activity was on hold pending this decision.

Note: Great Lakes, Illinois was accepted as a HCMF site on Feb. 7, 1977. All multi-family sites have been dropped from the program.

Table 7-3. Potential Heating and Cooling OTS Sites

	Residential	Commercial
• Candidate Sites		
GE Townhouses	X	
GE-VF Building & Laboratories	X	X
Employee Residences	X	
Local Commercial Buildings	X	X
Local Public Buildings		
Libraries		X
Hospitals		X
Municipal Offices		X
Schools		X
Park Houses	X	
Military Family Quarters	X	
• Evaluation Criteria		
Validity of Data		
Accessibility for Installation and Maintenance		
Visibility		
Cost of Installation		
Landload Attitude		

Table 7-4. Evaluation of Cooling OTS Sites

Candidates	Validity of Data	Accessibility	Visibility	Cost of Installation	Landlord Attitude	Overall
GE Townhouses	F	E	E	P	P	P
GE VF Buildings & Laboratories	E	E	E	E	E	E
Employee Residences	E	G	F	F	E	G
Local Commercial Buildings	E	E	P	G	?	G+
Local Public Buildings						
Libraries	G	F	G	F	G	G
Hospitals	E	G	P	F	G	G
Municipal Offices	E	G	G	F	G	G
Schools	P	P	F	F	G	F
Park Houses	P	P	G	P	F	P
Military Quarters	E	G	F	G	G	G

Key: E = Excellent
G = Good
F = Fair
P = Poor

reservations the collector support structure design and these were documented in a letter to the A/E for the YWCA. The site construction phase has started and is described next in Section 4.3.

7.3 SITE CONSTRUCTION

7.3.1 HSF-1 NORMAL, ILLINOIS

A bidders briefing was held on October 4, 1977 to acquaint potential contractors with the requirements to acquaint them with the hardware installation approach. Only one of five contractors attended. Three bids were received on October 15, 1977 and the highest bid was triple the lowest bid. The low bidder attended the bidders briefing and also got the job.

Construction started on November 15, 1977. The construction had been delayed by bad weather and some equipment delivery delays. As of the end of this reporting period, most of the system has been installed. One of two rows of collectors have not been installed due to inclement weather. System installation should be completed in January, 1978.

7.3.2 HCOM-2 SPOKANE, WASHINGTON

A bidders briefing was held on December 19, 1977 and four contractors attended. The site modifications were already underway in preparation for the TES tank. The TES tank was installed at the site on December 30, 1977 by the construction firm doing the YWCA modifications. Construction bids for the solar heating system installation were obtained on December 30, 1977. The high and low bids differed by a factor of two.

The contractor selection and system installation will occur in the first quarter of 1978.

The TES tank was shipped to the site and placed on the concrete base at the end of the reporting period.

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