DOE /NASA CONTRACTOR REPORT

DOE/NASA CR-150592

PROTOTYPE SOLAR HEATING AND HOT WATER SYSTEMS QUARTERLY REPORT

Prepared by

Solafern, Ltd.
P. O. Box M
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Under Contract NAS8-32246 with

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

For the Department of Energy

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Solar Energy

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This work was done under the technical management of Mr. Valmore Fogle, George C. Marshall Space Flight Center, Alabama.

16. ABSTRACT

This report contains one quarterly status report from Solarfern, Ltd., reflecting work progress from October 7, 1976 through January 28, 1977. Solarfern, under NASA/MSFC Contract NAS8-32246, is developing two prototype solar heating and hot water systems consisting of the following subsystems: collector, storage, control, and transport.

These two systems are being installed at Lansing, Michigan, and Tunkhannock, Pennsylvania.

Cost information has been removed.

17. KEY WORDS

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TABLE OF CONTENTS

PART I SUMMARY

This first quarterly report summarizes the progress made in the preliminary design phase of the project. To date no contract changes have been requested, but the status of the certification to be done by Underwriter's Laboratory, of the Proposed Instrumentation Plan and of the Operational Site Definition are given in Part II - Contract.

The Development and Verification Plan Schedule is given in Part III. The schedule of future deliverables as the Final System Specification is subject to the date when the government designates the operational sites.

A description of the Technical Performance is given in Part IV. The system has been defined and major hardware approaches selected. A two-pass air-heating collector was selected based on efficiency, ease of installation and development status. An Energy Transport Module,ETM, has been designed to compactly contain all the mechanical and electrical control components. The interfaces with the ETM are simplified, easing installation.

The next important step is to build the hardware needed for verification testing, including solar panels and an ETM. The solar panels will be tested on an instrumented test stand by Fern Engineering, and the ETM will be evaluated at the UL Laboratories in similar way that conventional HVAC subsystems are evaluated.

A list of Document and Drawing Submittals are provided at the end of the report.

PART II CONTRACT

CHANGES: No contract changes have been requested.

As a result of the preliminary design studies the solar system configuration was changed from what was proposed. These changes are:

1) The solar collector configuration was changed from a single-pass to a two-pass flow arrangement whereby the circulated air picks up heat from both sides of the absorber. The rationale for the change is that the two-pass is more efficient, eases installation and the development status is the same as the single-pass collector.

2) The system configuration was changed to centralize all mechanical components and controls into a single package, named the Energy Transport Module (ETM). By centralizing mechanical and electrical functions in the ETM, installation will be simplified. System certification is also simplified as the complete ETM can be shipped to an independent testing laboratory.

PROPOSED INSTRUMENTATION PLAN: A Proposed Instrumentation Plan, Fern Engineering Proposal F-312, was submitted to NASA with pricing on 1-24-76. The plan is based on the tentative site at Tunkhana, Pa. The approved P.I.P. is expected by 3-10-77.

CERTIFICATION: The Underwriters Laboratory was given initial funding to familiarize themselves with the system and to prepare a Certification Plan. Meetings were held with U.L. personnel on 12-27-76 and 1-24-77 (PDR).

CERTIFICATION, continued:

The scope of the U.L. effort was discussed jointly with NASA and U.L. representatives at the PDR. As a result of the joint PDR meeting U.L. will concentrate on the safety aspects, covering those requirements specified in the "Interim Performance Criteria", as well as those requirements that will ensure compliance with National Codes and Standards. It is anticipated that UL will test, in its own laboratory, an ETM module, containing the mechanical and electrical control components. UL will provide a document that describes the system, describes the test and evaluation they have done and which indicates safety criteria for application of the equipment.

OPERATIONAL SITE DEFINITION: Definition of the operational sites was scheduled for the PDR, however, the government has not as yet defined them. Delay in site definition will delay the final system specification. In order to assist NASA in site definition, several alternative methods of system retro-fit were presented to NASA at the PDR.

PART III SCHEDULE

The Development Plan Schedule is given in Table III-1.

The Design Data required for Government Furnished Site Data Acquisition Subsystem was furnished in the form of a Proposed Instrumentation Plan (PIP) per document SHC1006. This document was made available to Fern at the contract negotiations, and conformance to it required definition of the system and of the operational site. Preliminary site information was obtained from NASA on December 17 and then was used to develop the PIP.

The Preliminary Design Review and Quarterly Design Review were rescheduled at the convenience of the government per TD-04 (AH-00190).

The Verification Plan is in accordance with the Verification Matrix for Doc. "Interim Performance Criteria for Solar Heating and Combined Heating & Cooling Systems and Dwellings" January 1, 1975. The Verification Plan was divided into phases, and in the Development Phase covered by this quarterly report the methods were limited to Similarity and Analysis. The status of all Verification Items is given in Table III-2. The Document and Drawing Nos. referred to therein are identified in Section IV-D "Data Submittals".

TABLE III-1

DEVELOPMENT SCHEDULE

	Contract 1st System	Actual	Contract 2nd System
Authority-to-Proceed	0		0
Design Data Required for Government Furnished Site Data Acquisition Subsystem (SDAS)	12/23/76	1/24/77	12/23/76
Preliminary Design Review	1/1/77	1/24/77	1/1/77
Quarterly Review	1/1/77	1/24/77	1/1/77
Prototype Design Review	5/5/77		5/5/77
Instrumentation Required for SDAS	5/19/77		7/1/77
Quarterly Review	5/5/77		5/5/77
SDAS Required	7/7/77		8/18/77
First Article Review	7/7/77		9/1/77
Quarterly Review	7/7/77		
Quarterly Review			9/1/77
Delivery of Prototype Systems	7/21/77		9/15/77
Installation Review	9/1/77		
Operational Test Review	3/9/78		
Completion of Contract Requirements	4/1/78		

TABLE II-2

	Development Phase								Compliance	
	Method		Document Numbers		Drawing Numbers		Acceptance Status			
1. FUNCTION										
1.1 System Performance	1,2			1004			C			
1.1.1 Heating Design Temps.	1,2			1007			C			
1.1.3 Relative Humidity & water Vapor Pressure	N/A									
1.1.4 Solar Contribution	1,2		1004	1007			C			
1.1.5 Operational Impairment	1,2		1001	2001		198-7	C			
1.2 DHW System/Subsystem Performance	1,2			1007		198-7	C			
1.2.1 Water Design Temp.	1,2			1007			C			
1.2.2 Storage Design Capacity	1,2			2002		198-7	C			
1.2.3 Solar Contribution	1,2		1004	1007			C			
1.2.4 Operational Impairment	1,2					198-7	C			
1.3 Collector Performance	1,2			1007			C			
1.3.1 Collector Efficiency	1,2			1007		198-22	C			
1.4 Thermal Storage Performance	1,2			1004			C			
1.4.1 Storage Capacity & Rate	1,2			2002		198-7	C			
1.5 Habitability of Occupied Spaces	1,2					198-7	C			
1.5.1 Heat or Humidity Transfer Effects	1,2					198-7	C			
1.6 Energy Transport Efficiency	1,2			2002			C			
1.6.1 Thermal Losses & Elec. Power	1,2		1007	2002			C			
1.7 Control	1,2		1001	1003		198-19	C			
1.7.1 Installation & Maintenance	1,2					198-19	C			
1.7.2 Manual Adjustment	1,2					198-19	C			
1.7.3 Inhabited Space Temp.	1,2					198-19	C			
1.7.4 Hot Water Temp.	1,2					198-19	C			
1.8 Auxiliary Energy	RETROFIT									
1.8.1 Design Loads	RETROFIT									
2. MECHANICAL										
2.1 System Design Conditions	1,2			2002		198-10	C			
2.1.1 Equipment Capabilities	1,2			2002		198-10	C			
2.1.2 Noise or Erosion-corrosion	1,2			2002		198-10	C			
2.1.3 Operating Conditions	1,2			2002	198-10	198-7				
2.1.4 Fluid Flow in Collectors	([illegible]	[illegible]	DATA	[illegible])				I		
2.1.5 Entrapped Air	1,2					198-7	C			
2.1.6 Thermal Expansion of Fluids	1,2					198-7	C			
2.1.7 Pressure Drops	1,2			2002						
2.1.8 Condensate Removal	N/A									
2.2 Mechanical Stresses	1,2									
2.2.1 Vibration Stress Levels	1,2	(SITE	DATA	REQ)				I		
2.2.2 Vibration from Moving Parts	1,2							I		
2.2.3 Water Hammer	1,2					198-7	C			
2.2.4 Vacuum Relief Protection	1,2					198-7	C			
2.2.5 Thermal Changes	1,2				198-1[illegible]	198-7	C			
2.2.6 Flexible Joints	1,2				198-8	198-7	C			

SCHEDULE ASSUMES ENGINEERING DATA AVAILABLE WHEN REQUIRED

ORIGINAL PAGE IS OF POOR QUALITY

TABLE 17-2 Cont.

	UNITS DEVELOPMENT PHASE								O.A.	
	Method		Document Numbers		Drawing Numbers		Milestone Schedule			
2. MECHANICAL cont'd										
2.3 Leakage Prevention	1,2									
2.3.1 Pressure Test: Nonpotable Fluids	N/A									
2.3.2 Pressure Test: Potable Water	AC	CEPTANCE		TESTS						
2.3.3 Air Transport Systems	AF	TER	SITE	DEF.						
2.4 Collector Adjustments	1,2					198-77	C			
2.4.1 Orientation and Tilt	1,2					198-77	C			
2.4.2 Mutual Shadowing	RE	Q	SITE	DEF						
2.5 Subsystem Isolation	1,2					198-[illegible]				
2.5.1 Shutdown in Multifamily Housing	N/A									
2.6 Heat Transfer Fluid Quality	1,2					198-7	C			
2.6.1 Liquid Quality	1,2					198-7	C			
2.6.2 Air Quality	1,2					198-18	C			
2.6.3 Fluid Treatment	1,2					198-7	C			
2.6.4 Freezing Protection	1,2				198-1	198-7	C			
2.7 Piping Supports		REQ	SITE	DEF						
2.7.1 Applicable Plumbing Standards		[illegible]	[illegible]	[illegible]						
2.8 Excessive Pressure and Temp.	1,2					198-7	C			
2.8.1 Relief Valves and Vents	1,2					198-7	C			
3. STRUCTURAL										
3.1 Structural Design Basis	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		C			
3.1.1 Applicable Standards	REQ	SITE	DATA			198-7	I			
3.1.2 Service Loads	AS	STATED								
3.2 Failure Loads and Load Capacity	1,2		3001	[illegible]						
3.2.1 Ultimate Load Combinations	1,2		[illegible]							
3.2.2 Ice Loads	1,2						I			
3.2.3 Vehicular Loads	SITE	DATA	REQ							
3.2.4 Load Capacity	CONVENTIONAL ELEMENTS									
3.3 Damage Control	1,2			3003			C			
3.3.1 Resistance to Damage	CONVENTIONAL ELEMENTS									
3.3.2 Glazing Design	1,2			3003	[illegible]	198-15	C			
3.4 Cyclic Loads	CONVENTIONAL ELEMENTS									
3.4.1 Deflection Limitations	CONVENTIONAL ELEMENTS									
3.5 Cutting of Structural Elements		SITE	DATA	REQ						
3.5.1 Design Provisions		[illegible]	[illegible]	[illegible]						
3.6 Creep and Residual Deflection		[illegible]								
3.6.1 Deflection Limitations		[illegible]	[illegible]	[illegible]						
3.7 Hail Resistance		[illegible]	[illegible]	[illegible]						
3.7.1 Hail Size and Loading		[illegible]	[illegible]	[illegible]						
3.8 Constraint Loads		[illegible]	[illegible]							
3.8.1 Foundation Settlement: Contraction and Expansion		[illegible]	[illegible]							
3.9 Ponding Conditions		[illegible]								
3.9.1 Design Provisions		[illegible]								

SCHEDULE ASSUMES ENGINEERING DATA AVAILABLE WHEN REQUIRED

TABLE 39-2 (CONT.)

	10/4/76		DEVELOPMENT PHASE					1/24/77	QUALIFICATION	
	METHOD		DOCUMENT NUMBERS		DRAWING NUMBERS		MILESTONE STATUS			
4. SAFETY										
4.1 Plbg. & Elec. Installation	1,2	CODES	ON	FILE						
4.1.1 Plbg. Codes & Standards	1,2					198-7	C			
4.1.2 Elec. Codes & Standards	1,2					198-19	C			
4.2 Fail-safe Controls	1,2			5220		198-19	C			
4.2.1 System Failure Prevention	1,2			5001		198-19	C			
4.2.2 Auto. Pressure Relief Valve	1,2					198-7	C			
4.3 Fire Safety	1,2	CODES	ON	FILE			C			
4.3.1 Applicable Fire Standards	1,2				199-6	198-22	C			
4.3.2 Penetrations thru Fire-rated Assemblies		SITE	DATA	RQD						
4.4 Toxic & Flammable Fluids	N/A									
4.4.1 Provision of Catch Basin	N/A									
4.4.2 Detection of Toxic & Flammable Fluids	N/A									
4.5 Safety Under Emerg. Conditions	SITE	DATA	RQD							
4.5.1 Emergency Egress & Access	SITE	DATA	RQD							
4.5.2 Identification & Location of Controls	SITE	DATA	RQD							
4.6 Protection of Potable Water & Circulated Air	1,2				198-18	198-7				
4.6.1 Contamination by Materials	1,2					198-7	C			
4.6.2 Separation of Circulation Loops	N/A									
4.6.3 Backflow Prevention	1,2					198-7	C			
4.6.4 Growth of Fungi	1,2					198-7	C			
4.7 Excessive Surface Temps.	1,2		5001	5002			C			
5. DURABILITY / RELIABILITY										
5.1 Effects of External Environment	1,2		3002	5001			C			
5.1.1 Solar Degradation	1,2		3002	5001			C			
5.1.2 Soil Corrosion		SITE	DATA	RQD						
5.1.3 Airborne Pollutants	1,2					198-22	C			
5.1.4 Dirt Retention on Cover Plate Surface	1,2					198-22	C			
5.1.5 Abrasive Wear	1,2					198-22	C			
5.1.6 Fluttering by Wind	1,2					198-22	C			
5.2 Temp. & Pressure Resistance	1,2					198-22	C			
5.2.1 Thermal Degradation			3002				C			
5.2.2 Deterioration of Heat Transfer Fluids	N/A									
5.2.3 Thermal Cycling Stresses						198-22	C			
5.2.4 Leakage	N/A									
5.2.5 Deterioration of Gaskets & Sealants						198-22	C			

SCHEDULE ASSUMES ENGINEERING DATA AVAILABLE WHEN REQUIRED

TABLE III-2 Cont.

11/4/76 DEVELOPMENT PHASE 1/24/77

	METHOD		DOCUMENT NUMBERS		DRAWING NUMBERS			MILESTONE STATUS		
5. DURABILITY/RELIABILITY, continued:										
5.2.6 Transmission Losses due to Outgassing	1, 2		5003	1002				C		
5.3 Chem. Compatibility of Components	1, 2		2002	5003	198-7	198-22		C		
5.3.1 Matls/transfer Fluid Compatability	1, 2		2002	5003	198-7	198-22		C		
5.3.2 Corrosion of Dissimilar materials	1, 2			5003	198-7	198-22		C		
5.3.3 Corrosion by Leachable substances	1, 2			5003	198-7	198-22		C		
5.3.4 Effects of Decomposition Products	1, 2		2002	5003	198-7	198-22		C		
5.4 Components Involving Moving Parts	1, 2		2002			198-6		C		
5.4.1 Wear and Fatigue	1, 2		2002	/		198-6		C		
6 MAINTAINABILITY										
6.1 Accessibility for Maint. & Servicing					198-7	198-6				
6.1.1 Access for System Maintenance					198-7	198-6				
6.1.2 Access for System Monitoring					198-7	198-6				
6.1.3 Draining and Filling of Liquids					198-7					
6.1.4 Flushing of Liquid Subsystems					198-7					
6.1.5 Filters						198-18				
6.1.6 Potable Water Shutoff					198-7					
6.2 Installation, Operation and Maintenance Manual		SITE	DATA	8020						
6.2.1 Installation Instructions			"							
6.2.2 Maintenance and Operation Instructions			"							
6.2.3 Maintenance Plan			"							
6.2.4 REplacement Parts			"							
6.3 Repair and Service Personnel			"							
6.3.1 Maintenance of H and HC Systems			"							
6.3.2 Maintenance of DHW System			"							
7. FUNCTION										
7.1 Design										
7.1.1 Dwelling Design										
7.1.2 Mobile Home Design										
7.1.3 Site Design										
7.1.4 Passive Use of Solar Energy										
7.2 Adequate Space										
7.2.1 Collector Area										
7.2.2 Storage Area										
7.2.3 Utility Chases										
7.3 Functioning of Dwelling and Site										
7.3.1 Space Use										
7.3.2 Shading of Adjacent Structures										
7.3.3 Impact on Environment										
7.3.4 View										

SCHEDULE ASSUMES ENGINEERING DATA AVAILABLE WHEN REQUIRED

PART IV TECHNICAL PERFORMANCE

A. DESCRIPTION OF WORK

System Definition: Fifteen alternative approaches to the system configuration were studied, parametizing the number and location of the dampers, the number and location of the fans, the interface locations with the furnace (viz, upstream, downstream or parallel interfaces), the size and type of subsystems and operating modes. The system criteria are defined in Table IV-1.

The resulting key ststem definition features are given in Table IV-2. The various operating modes are depicted in Figures IV-1 to IV-3. Because air-heating solar collectors are used, direct solar heating is possible. The signal from the first-stage of a two-stage room thermostat (T1) is used to activate Mode 1. A collector thermostat, (TC) inhibits Mode 1, unless the collector temperature has increased sufficiently (nominally 100°F) to close the collector thermostat circuit. All control functions are handled by Class 2 circuits. Relays located in the ETM regulate the action of the blowers, dampers and of the pump. Both the furnace fan and the solar collector operate in the direct heating mode. The temperature of the air delivered by the collector ranges from 90 to 140°F for Mode 1. Mode 2, Energy Storage is activated either by a signal from stage 2 of the room thermostat when the furnace burner is started, and/or by a signal from the differential thermostat having sensors attached to the absorber and to the storage tank(s). Simultaneous operation of the furnace burner and the solar collector delivering heated air is inhibited by the control; this avoids the possibility of overheating the house , as well as sending heated air to the collector. In Mode 2, air is circulated through the collector and over the finned heat exchanger in the ETM.

The pump in the ETM circulates water from the cooler regions of the storage tanks through the heat exchanger, thereby transporting solar energy to heated water storage. The air is returned to the collector for reheating when it exits from the heat exchanger. As the collector will be sized to be able to supply much more than the demand on a clear day, the operating mode will switch back and forth between direct solar heating and storage during a typical clear day. On cloudy days, a greater proportion of time will be spent in direct heating. The direct heating mode is the most efficient thermodynamically, as the temperature of the air entering the collector is lowest for this mode.

Mode 3 is heating by stored energy. This mode is activated by a signal from Stage 1 of the room thermostat, when the collector thermostat is open, e.g. cloudy periods and night. Mode 3 operation is inhibited by a storage thermostat which will preclude operation if the water temperature in the warmer regions of the storage tank is not sufficient for heating purposes (e.g. nominally greater than 90°F).

The storage sybsystem utilizes potable water. The storage subsystem is pressurized and connected to the DHW tank; a DHW draw causes a draw on the heated stored water, thereby reducing the energy required to heat the DHW to the set temperature. An expansion tank, provided with a diaphragm and precharge of air is used to limit system pressures between 50 and 80 psia while preventing any backflow.

A modular package, identified as The Energy Transport Module (ETM) has been designed to house the heat exchanger, all mechanical components and electrical controls. The ETM will be installed adjacent to the back-up warm-air furnace. Connects with the ETM are:

- o Two air duct connections with the back-up furnace.
- o Two air duct connections with the solar collector.
- o Class-Two circuit (24v) connections to the thermostats.
- o Furnace power run to ETM for parallel control of furnace fan.
- o Power to the ETM.
- o Two piping connections with the storage subsystem.

The air ducting, piping and storage are insulated.
The thermal resistance values are:

Air Ducting	R 13.5
Storage	R 30
Piping	R 3

Collectors: The collector alternatives studied are given in Table IV-3. Performance analyses have been carried out considering; a) the solar energy transmission and sbsorption of each cover, b) the radiated infra-red transmission and absorption of each cover, c) the convection losses between covers and on the exterior, d) the solar energy absorption efficiency of the absorber, e) the emissivity of the internal duct surfaces, f) the roughness of the internal duct surfaces, g) the amount of insulation, h) duct size, i) air velocity and j) air-flow distribution.

The two-pass collector design, whereby the air flows over the front of the absorber and returns in back of the absorber, was found to have superior thermal performance. The front-to-back two-pass collector simplifies installation as the inlet and outlet ducts are adjacent to each other on one end of the collector. The present baseline design approach is given in Table IV-4. The frame construction approach is still under study, comparing the cost of aluminum vs steel. A 20-year design lifetime is desired, and it is felt that hot-dipped galvanized and bonderized steel can provide the lifetime. Of concern is the future price of aluminum as projections indicate a 30% increase this year alone. A glass cover was selectedvis-s-vis a plastic cover to preclude any external fire hazard and to use the proven structural capacity and durability of glass.

The calculated performance of several key alternatives is shown in Figure IV-4. Small gains are possible by refinements of the internal design of the ducts; these are currently being left as future product improvements. The alternative of using FEP instead of KALWALL is currently being pursued. The FEP has a low index of refraction, resulting in smaller reflection losses than for glass. The FEP has greater transparency to infra-red transmission, but the net performance benefit is significant. In addition, as the absorber temperature increases during a no-flow condition, the infra-red transmission increases, thereby reducing the no-flow temperature.

The use of selective surfaces was studied, and although they can improve performance at high temperatures, the no-flow temperature is markedly increased, aggravating material requirements for the collectors. As an indicator of the collector performance in comparison with other systems, the calculated results were superimposed on an available correlation of published manufacturers data in Figure IV-5. The comparison in Figure IV-5 indicates that the baseline collector has performance equal to high quality double-glazed collectors being manufactured, and collectors with significantly better performance are either focused or have loss suppression devices (selective coating, fire convection suppressors). As pointed out above, the no-flow temperature will increase as loss suppressors are added so that active control of the no-flow condition is required. As one of the project guidelines, however, the collectors must survive no-flow conditions resulting from loss-of power without degradation; hence, based on the current limit in no-flow temperature to 360°F at the absorber, the collector performance is at the upper edge of the current state-of-the-art.

System Performance: System performance calculations were carried out over a heating season for the tentative site location at Tunkhana, Pa. Four system alternatives were evaluated using the parameters shown in

Table IV-5. The results shown in Table IV-5 illustrate the effect of collector size, storage capacity and use of a reflector. A typical installation for this house would be two rows of panels running the full length of the house having a 300 ft^2 collector aperture, and would provide 40% of the space heating. The system performance will depend on site location, insulative quality of the house and of the system component. Based on the performance calculations, a preliminary system performance specification was developed and is given in Table IV-6.

Certification Plan: Two meetings were held with representatives of the Underwriter's Laboratory to devise a certification plan. At present, UL is developing a plan to meet the safety criteria of national codes and standards and at the HUD Interior Performance Doc. 1-1-75, UL has been provided with drawings, analysis and descriptions of the system. The certification plan is summarized in Table IV-7.

Retrofit Studies: System design must consider the diverse aspects of retrofit approaches. Alternative approaches are sketched in Figures IV-6 to IV-11. Actual retrofit installations will be dependent on house orientation, available lot space, location of chimneys and vents, roof pitch and gables, local building codes, and accessibility to the installed heating plant. The finalization of a system specification will depend at least on the features of the site noted above.

B. FORECAST OF ACTIVITIES TO COMPLETE TASKS

Prototype Design: Prototype design will continue, refining the design, performing engineering and cost analyses, developing specifications and preparing fabrication drawings.

Development/Verification Testing: Solar collector performance verification will be achieved via testing a nominal 100 ft^2 collector array instrumented in accordance with NBS/ASTM recommendations and tested in accordance with criteria being developed by ASHRAE and HUD. An Energy Transport Module, (ETM), mechanically and electrically complete will be fabricated, tested and sent to the Underwriter's Laboratories for safety verification.

Final System Specification: A final system specification will be developed upon selection of the operational test sites by the government.

Installation Drawings: Installation drawings will be developed when the Final System Specification is completed.

Prototype Hardware Fabrication: Release of drawings for fabrication will be done when all specifications are finalized and the prototype system is approved. Production studies will be made to select the approach providing the best advantages.

Installation Proposals: Proposals for installing the systems will be developed upon request of the government.

C. Identification of Major Problem Areas or Difficulties Encountered:

To date, the primary effort has been in preliminary design and selection of hardware approaches. Hence, problem solving is a continuing effort, but at the moment, no major problems or difficulties have as yet been encountered.

D. Data Submittals:

A list of document submittals is given in Table IV-8, Drawing submittals are given in Table IV-9.

KEY SYSTEM CRITERIA

- SAFETY & RELIABILITY
  - ABIDE BY NATIONAL CODES & STANDARDS
  - AVOID PREHEATING FURNACE AIR
  - AVOID SIMOULTANEOUS START UP OF ALL MOTORS
  - AVOID BACKFLOWS
  - USE CERTIFIED EQUIPMENT
  - USE TEMPERED GLASS
  - AVOID HAZARDOUS USE OF MATERIALS
  - DESIGN TO WITHSTAND NO-FLOW TEMPERATURES
  - AVOID POTENTIAL DUCT OBSTRUCTIONS IN BACK-UP OFF
  - LOCATE FANS IN COOLEST LOCATIONS
  - PROVIDE STORAGE TEMPERATURE LIMIT
  - PROVIDE PRESSURE RELIEF

- ECONOMIC
  - SIMPLIFY INSTALLATION
  - AVOID EXCESSIVE FAN & PUMP POWER
  - SELECT EFFICIENT FANS & MOTORS
  - SYSTEM EFFICIENCY AT LEAST STATE-OF-ART W/GROWTH
  - EASE OF MAINTENANCE

- MARKETING
  - AVAILABLE SUMMER '77
  - RETRO-FIT ADAPTABILITY
  - REDUCE PAY-OFF PERIOD

	DRAWN		
FERN ENGINEERING BUZZARDS BAY, MASSACHUSETTS U.S.A.	APP'D	KEY SYSTEM CRITERIA TABLE IV-1	
	DATE	DWG. NO.	REV.

WORKING FLUIDS

- AIR HEATED SOLAR COLLECTORS
- POTABLE WATER STORAGE

OPERATING MODES

- DIRECT SPACE HEATING BY SOLAR HEATED AIR
- STORAGE OF SOLAR ENERGY BY HEATING WATER
- SPACE HEATING BY STORED SOLAR ENERGY
- PREHEATED DHW DRAWN FROM STORAGE
- BACKUP FURNACE
- BACKUP WATER HEATER

FERN ENGINEERING BUZZARDS BAY, MASSACHUSETTS U.S.A.	DRAWN PL APP'D DATE 1-24-77	SYSTEM DEFINITION TABLE IV-2 DWG. NO.	REV.

COLLECTOR ALTERNATIVES STUDIED

- FLOW PATH
  - SINGLE PASS IN FRONT OF ABSORBER, 2 COVERS
  - SINGLE PASS REAR OF ABSORBER, 2 COVERS
  - DOUBLE PASS FRONT TO REAR, 2 COVERS
  - DOUBLE PASS REAR TO FRONT, 1 COVER
  - ROUGHNESS
  - EMISSIVITY OF DUCT WALLS
- OUTER COVER
  - KALWALL FRP
  - GLASS
- INNER COVER
  - KALWALL FRP
  - FEP FILM
- ABSORBER
  - 3M NEXTEL / 6 MIL AL
  - BLACK CHROME
  - BLACK COPPER
- INSULATION
  - FIBERGLASS
  - URETHANE
  - ISOCYANURATE
  - THICKNESS
- FRAME
  - EXTRUDED ALUMINUM
  - SHEET STEEL
  - WOOD
- SIZE
  - 34 x 78 GLASS VS 46 x 76 GLASS

FERN ENGINEERING BUZZARDS BAY, MASSACHUSETTS U.S.A.	DRAWN APP'D DATE	COLLECTOR ALTERNATIVES TABLE IV-3 DWG. NO.	REV.

SELECTED COLLECTOR APPROACH

- FLOW PATH
  - TWO PASS FRONT TO REAR
  - SMOOTH SURFACES
  - NO DUCT COATINGS

- OUTER COVER
  - LOW IRON TEMPERED GLASS

- INNER COVER
  - KALWALL FRP

- ABSORBER
  - 3M NEXTEL / 6 MIL AL.

- INSULATION
  - FIBERGLASS IN HOT ZONE
  - ISOCYANURATE ON PERIMETER

- FRAME
  - WELDED STEEL / BONDERIZE & PAINT MAIN FRAME
  - AL. EXTRUSION FOR GLASS COVER

SIZE
  - 46 X 96 GLASS

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FERN ENGINEERING BUZZARDS BAY, MASSACHUSETTS U.S.A.	DRAWN APP'D DATE	SELECTED COLLECTOR APPROACH TABLE IV-4 DWG. NO.	REV.

TABLE IV-6

SYSTEM PERFORMANCE SPECIFICATION

APPENDIX A

Specification No. ________
Page Date ________
Page ________ of ________

A SYSTEM IDENTIFICATION

This Appendix defines the performance and installation drawings for (Enter type of system), (Enter Contractor Name), System Model Number (Enter Model Number).

A-1 SYSTEM PERFORMANCE SHEETS

Site -

The system shall be installed in a residence in the city of Tunkhana, county of ________, state of Pennsylvania.

Heating Capacity *

The system will provide solar energy for 40 % of the average total heating load during the heating season based on an average total heating load of 8.4×10^6 BTU/Month and a peak heating load of 26550 BTU/hr.

~~Cooling Capacity~~

~~The system will provide solar energy for ______% of the average total cooling load during the cooling season, based on an average total cooling load of ______ BTU/Month and a peak cooling load of ________ BTU/hr.~~

Auxiliary Energy

The average rate of auxiliary energy used for heating shall be no greater than 4.35×10^6 BTU/Month of the total energy required for heating, including hot water. This shall be no greater than 60 % of the total energy required for heating. The average rate of ~~auxiliary energy used for cooling during the cooling season shall be no greater than ________ BTU/Month. This shall be no greater than ________% of the total energy required for cooling.~~

* Based on 6254DD, 6° F Design temp., 8 mos. heating season.

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TABLE IV-6, continued

SYSTEM PERFORMANCE SPECIFICATION

Specification No. ________
Page Date ________
Page ________ of ________

Hot Water

40 gallons of potable (or useable) hot water shall be delivered at no less than ________ gal/min at temperatures no less than 120 °F. Recovery time shall be no greater than 2.2 hours. The average hot water heating load will be 1.68×10^6 BTU/Month of which 60 % is provided by auxiliary energy.
(75 gal/day w/washer, 3 BR, 1-1/2 bath)

Operating Requirements

The maximum electrical energy required to drive the solar portion of the system at its rated capacity shall be no greater than .45 K.W. * The maximum electrical energy required to drive the complete system shall be no greater than 5 K.W. The average yearly electrical energy required to drive the system shall be no greater than 4400 K.W.H.* ~~Water requirements for cooling condensers and/or air humidification shall be no greater than ________ gal/hr.~~

* Includes operation of furnace fan to distribute air & KWH for water heater.

Physical Data - Table III

The following subsystems shall have:

	Design life no less than	Weight (filled) no greater than	Installation dimensions
Heating	20 years	200 lbs	ETM 25x30x48 in.
~~Cooling~~	________ years	________ lbs	________
Auxiliary Energy	20 years	2900 lbs	Furn. 30x30x48 in. Tank 2 x 5x5 ft.
Storage	20 years	3000 lbs	3 x 9 x 5 ft.
Potable Water (or useable)	20 years	465 lbs	2 x 2 x 5 ft. (2 Rows)
Collector	20 years	6 lbs/ft^2 .5 lbs/ft (w)	5' x 42' each
Energy Transport	20 years	4.1 lbs/ft(air)	N/A
Controls	20 years	25 each	N/A

(Other)

SYSTEM PERFORMANCE

SITE:

TUNKHANA, PA
1080 FT^2
HEAT LOSS 10 BTU/FT^2-DD

SYSTEM PARAMETERS:

60° TILT
SOUTH AZ.
10 MPH WINDS
$R_{DUCT} = 13.5$
$R_{STOR} = 30$

SYSTEM	COLLECTOR APERTURE	WATER STORAGE	AIR FLOW	REFL. ENH.
1	172 SQ.FT	2000 lbs	400 CFM	1
2	172	2000	400	VAR
3	344	2000	800	1
4	344	4000	800	1

RESULTS

SYSTEM	ANNUAL PERCENTAGE HEATING DEMAND	AVG. SYSTEM EFFICIENCY* (D, J, F)
1	28	.45
2	38	.69
3	45	.38
4	47	.40

*NO CREDIT FOR INSULATION LOSSES

	DRAWN	SYSTEM PERFORMANCE TABLE IV-5
FERN ENGINEERING BUZZARDS BAY, MASSACHUSETTS U.S.A.	APP'D	
	DATE	DWG. NO. REV.

CERTIFICATION PLAN

REQUIREMENT: CERTIFICATION THAT THE SYSTEM, SUBSYSTEM AND/OR COMPONENTS MEET NATIONAL STANDARDS AND CODES

STATUS: SYSTEM REVIEW WITH U.L. 12/27/76
PRELIMINARY UL REPORT & PLAN PDR

APPROACH:

- SELECT APPROPRIATE COMPONENTS APPROVED AND/OR CERTIFIED FOR INTENDED USE
- SUBMIT DWGS, ENGINEERING ANALYSIS TO UL FOR EVALUATION
- PROVIDE CONFIGURATION CONTROL DOCUMENTATION
- ADJUST DESIGN IF REQUIRED
- PROVIDE CERTIFICATION DOCUMENT WITH PROTOTYPE DELIVERY

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FERN ENGINEERING BUZZARDS BAY, MASSACHUSETTS U.S.A.	DRAWN APP'D DATE	CERTIFICATION PLAN TABLE IV-7	
		DWG. NO.	REV.