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DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150575

PROTOTYPE SOLAR HEATING AND HOT WATER SYSTEM
(A Collection of Quarterly Reports)

Prepared by

Wormser Scientific Corporation
88 Foxwood Road
Stanford, CT 06903

Under Contract NAS8-32250 with

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

For the U. S. Department of Energy

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U.S. Department of Energy



Solar Energy



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15. SUPPLEMENTARY NOTES This work was done under the technical management of Mr. Valmore Fogle, George C. Marshall Space Flight Center, Alabama.					
16. ABSTRACT This report contains three quarterly reports that cover the progress made in the development of a solar heating and hot water system. These quarterly reports discuss the development work and improvements to components and subsystems. The system uses the pyramidal optics solar concentrator for heating, and consists of the following subsystems: collector, control, transport, and site data acquisition. The system is installed at Columbia, South Carolina. Cost information has been removed.					
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TABLE OF CONTENTS

	<u>Page</u>
Quarterly Report #1	1
Quarterly Report #2	13
Quarterly Report #3	19

Quarterly Report #1 (Period 10/7/76 - 1/13/77)
and Monthly Report #3
WSC-107 Contract NAS8-32250
Additional Development of Pyramidal Optics Concentrator Solar
Heating and Hot Water System

Contents:	Part I	-	Summary
	Part II	-	Contract
	Part III	-	Schedules/Appendices

PART I - SUMMARY:

Development work has been initiated on all the components and subsystems of the pyramidal optics concentrator solar heating system which require improvement for better technical performance, manufacturability and greater cost effectiveness. The status of the development effort is briefly summarized below and in the other documents which are being submitted herewith in advance of the Preliminary Design Review (PDR) scheduled for January 27, 1977.

The operation of the prototype pyramidal optics installation at Rehoboth, Delaware described in Reference 2.2.1 is being monitored through analysis of recorded data and verbal reports from the builder/developer who is occupying the house. The solar system and the auxiliary heat pump system have been performing very well during a period of exceptionally cold weather in the months of October to December, 1976. Only twelve hours of back-up electrical resistance heat has been recorded during October by the recording electrical demand meters analyzed monthly by the local electrical company. Records for November and December have not yet been analyzed though similar results are expected. As a result of operating experience with the Delaware pyramidal optics house further improvements are being incorporated in the

method of piping to obtain uniform flow in the collector array of the first four unit townhouse now nearing completion in Columbia, S.C. This piping technique will also be retrofitted in the Delaware house and incorporated in this project.

The final assembly of the four unit townhouse solar system at Yacht Cove, Columbia, S.C. is being monitored carefully to note any technical problem areas which might bear correction or improvement.

Mr. Wormser of Wormser Scientific Corporation (WSC) met Mr. Ralph Murphy of MSFC and Messrs. Keith Belser and Joseph Schulhofer of the Yacht Cove organization on 12/14/76 at Columbia to consider a site selection for the project. (A separate report on the visit was prepared and is appended hereto.) An updated site plan of Section IIB of the Yacht Cove development dated 6/26/76 has since been received. The preferred site selections are four unit condominiums of the 2-5-5-2 type, in particular building 38 or building 39 on Leeward Road, which is a street on high open ground with six buildings. Building 33 near the tennis courts would be a third alternative. A simple modification in the condominium design pulling back the center section by 9' has been prepared and submitted to Yacht Cove and MSFC.

PART II - CONTRACT

The Preliminary Design Review (PDR) was postponed to January 27 at the request of the government technical personnel. It is intended to compress the subsequent schedule in order to complete construction in accordance with the original schedule prior to start of the '77-'78 heating season.

There are no contractual problems at the present time.

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PART IV - TECHNICAL PERFORMANCE:

1. Reflective Surfaces

Work is under way on combining reflective mylar films with impregnated water resistant corrugated board substrates. Sample laminations have been ordered and will be evaluated for optical quality, durability and ease of installation. This should constitute a light weight, easy to install, low cost reflective material.

2. Glazing Detail and Supportive Structure

A neoprene zipper gasket is being evaluated to support and seal the $\frac{1}{2}$ " thickness plexiglass used in the solar window structure. Professor Willard Oberdick, Professor of Architecture and Director Architectural Research Laboratory at the University of Michigan has been consulted on this problem and is performing tests as described in the separate memorandum attached.

Studies have been performed by Stephen Weinstein, AIA of the Ehrenkrantz Architectural group to reduce the optical obscuration of the 4"x12" rafter beam structure presently used to support the optical window and the roof beam structure. A substitute structure using a 3"x6" rafter beam with a diagonal tubular support strut has been proposed and subjected to structural stress analysis. This will reduce window obscuration by nearly 50% and will reduce material cost and simplify window framing construction.

3. Absorber Plate and Absorber Plate Support

The initial tests of the prototype pyramidal optics system utilized four copper absorber plates 8'x3' each, copper oxide with horizontal flow patterns. Difficulties were encountered due to air blockages in the absorber plate assembly. The

difficulties were never completely explained but were thought to be associated with the horizontal flow pattern.

An assembly of nineteen 22'x48' black chrome selectively blackened copper rollbond absorber plates with vertical flow pattern were substituted. This cured the previous air blockage problems and very significantly improved the performance of the pyramidal optics assembly. It introduced additional plumbing assembly labor to assemble the nineteen collectors and also resulted in some unevenness in fluid flow distribution in the center units of the nineteen unit assembly. This problem has been previously noted in the literature* but has not been explained or solved. We are taking steps in the current HUD townhouses to introduce novel piping and valving to overcome this problem.

We are also investigating wider rollbond sections 34"x48" which would reduce the assembly to twelve units. We are also investigating similar tube in sheet type copper absorber plates now being made available by the Research Laboratory of Kennecott Copper.

4. Storage System

The Delaware prototype system and the HUD four unit townhouse utilize poured concrete storage tanks. This represents certain advantages in terms of the mass of the tank providing additional storage. It also permits on site fabrication at the same time and using the same techniques as are used on the foundation.

* Solar Energy Thermal Processes, Duffie & Beckman, John Wiley & Sons, 1974, New York, PP 261-264

Certain problems have arisen pertaining to water tightness requiring lining procedures. It is planned to investigate low pressure fiberglass tanks in lieu of concrete tanks which represent advantages in tightness, lightweight and compactness.

5. Component Assembly Methods

Once the development of improved components and subsystems is completed methods of assembling these into the building structure in a simplified way will be examined.

MEMORANDUM

December 21, 1976

From: Eric M. Wormser

To: Keith Belser, YC
Joseph Schulhofer, YC
John Kruse, YC
Carl Mezoff, WSC
John Bays, WSC
107 File

Valmore Vogel, MSFC
Ralph Murphy, MSFC

Subj: Meeting on Siting of Project 107 Contract (NAS-8-32250)
Four Townhouse Solar Heated Condominium
December 14, 1976

Ralph Murray, NASA, MSC
Keith Belser, Partner, Yacht Cove Associates
Eric M. Wormser, Wormser Scientific Corp.
Joseph Schulhofer, Comptroller, Yacht Cove Associates
(Part-time)

We inspected the Yacht Cove sight and progress on the HUD solar condominium (unit #24). They are presently awaiting the plexiglass in order to install it and to seal up the solar optical cavity.

The wooden mounting for the solar collectors is in place. The tank is installed and insulated. No other parts of the solar system are installed as yet. The appearance of the solar condominium is entirely in keeping with the model and the surrounding units, and Keith Belser expressed much satisfaction with the appearance. It appeared as though the cutback of the three-story section roof had not been carried out in accordance with plans. A sidewall maintaining the roof slope is now in place and has to be removed. I pointed this out to both Belser and Schulhofer and left the model which clearly shows the cutback (they assured me this would be taken care of).

The only significant comment Belser made about the construction so far was that the concrete tank took a lot of work and he would

prefer a fiberglass tank if feasible in the future.

We submitted a suggested design of a modified 2-5-5-2 condominium to both Murphy and Belser with the center section pulled back 9' to avoid solar shadowing. Belser felt this could be built without any problems, since each townhouse is a self-contained unit. Belser also felt that this would not affect the cost of the unit in any significant way. Regarding approval by the Equitable Belser stated that Yacht Cove could obtain approval at a higher level without any difficulty..

We inspected possible sites for 2-5-5-2 units in Section IIA of the Yacht Cove Development scheduled for construction next Spring. One prospective unit is located a few hundred feet behind the tennis courts on a short road (scheduled for construction early spring) and another somewhat further back on high land on a clearing on a six unit street (scheduled for construction in late spring). The latter appeared to be the preferred site. (Mr. Schulhofer will send us a copy of the revised site plan.)

Mr. Murphy noted down the background of the development and will submit the site for approval by their site selection committee. He pointed out that essentially all the sites selected so far had been at government installations.

He showed us a typical site agreement which provided for the site owner to bear the cost of building modifications and site preparation. The existing contract between NASA and WSC provides for the installation of solar hardware i.e. collectors, reflectors, windows and their assembly. It does not provide for building modification or preparation of buildings nor for any

Page 3.

substantial amount of assistance by Yacht Cove in the solar system installation if this should be required. An estimate covering these items will be prepared by Mr. Schulhofer and forwarded to WSC. After this estimate is reviewed by WSC it will be submitted to NASA for their consideration in connection with the site selection negotiations.

Eric M. Wormser

Eric M. Wormser

EMW/lkt

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MEMORANDUM

January 5, 1977

From: Carl Mezoff

To: Eric M. Wormser
Willard Oberdick
S107 file

Subj: December 29th, 1976 Conference With W. Oberdick, Prof.
of Architecture, University of Michigan, Re S107
Window Gasket Detail

Willard Oberdick, Professor of Architecture and Director of the Architectural Research Laboratory at the University of Michigan is a recognized authority on sealants and gaskets. Prof. Oberdick and I had an informative conference on possible methods for sealing the glazing of the pyramidal optics window area.

We reviewed the existing sealing details for the 104 installation. Prof. Oberdick had some concern about whether expansion and contraction could be accommodated by the detail. We then discussed some alternative approaches using the two piece neoprene zipper gasket. These included:

- A. Gasket directly on wood support structure fastened with nail or screw fastener.
- B. Gasket locked into mating aluminum channel which, in turn, would be screwed to wood or steel support structure.

We made some preliminary tests on alternative "A" above. A mock-up was constructed using a 6" length of gasket and two pieces of $\frac{1}{2}$ " plywood to simulate glazing. The assembly was attached to a length of 2x10 with one 1 3/4" galvanized roofing nail with a 3/8" diameter head. The nail was driven through the floor of the zipper cavity into the wood below. This mock-up was placed in a precision testing machine and tested for glazing roll out and nail pull out. Pressure was gradually applied simulating uplift forces.

Test Results

Pressure was applied until a force of 180 lbs. on the nail was reached. At this time the nail began to tear through the gasket and pull out of the wood. No roll out of glazing was seen. (This was a continuous loading situation. A much higher instantaneous load could probably be survived.)

Aluminum Channel System

An alternative method for fastening the gasket to the building would use an aluminum channel designed to receive a toothed flange on the gasket. This aluminum channel could be attached to a steel joist as well as a wood member. This assembly would be more

sturdy but more costly.

Recommendations

If we decide to go ahead with this system, Prof. Oberdick recommends some further testing.

1. Parallel sample mock-ups, one heat aged to simulate long term aging in the sun.
2. If more than a few P.O. systems will be built, a full scale module 8'x16' should be constructed and tested for uplift and water tightness.

Rates

Prof. Oberdick is willing to become involved in the required testing and development. During the coming school term he will have sufficient time due to reduced commitments.

This sentence has been deleted. More comprehensive testing would require other arrangements.



Carl Mezoff
CM/lkt

Quarterly Report #2
and Monthly Status Report #7
June 8, 1977
WSC-107 Contract NAS-8-32250
Additional Development of Pyramidal Optics
Concentrator Solar Heating and Hot Water System

Contents: Part I Summary
Part II Contract
Part III Schedules
Part IV Technical Performance
Appendix A-Prototype Design Review Summary

Part I - Summary

Development of components of the solar system is complete. The construction of the building to receive the system will commence immediately following receipt of an executed contract by Cambridge Development Associates from the government.

A prototype design review was held June 7-8, 1977 in Stamford, Connecticut the proceedings of which may be found as Appendix "A" to this report. Some small changes in scheduling of contract milestones have been made.

Part II - Contract

Prototype design review data were submitted and the review was held June 7-8, 1977 as required by contract. No contract changes have been approved since the last quarterly report.

Part III - Schedules

See Appendix "A" for schedule in Review summary.

Part IV - Technical Performance

The current technical status of the project was thoroughly discussed in the Prototype Review. Data submitted prior to and at the review document this status.

Appendix A

Memorandum of Summary of Prototype Design Review.

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MEMORANDUM

TO: Eric M. Wormser
John T. Bays
Val Fogle
Joe Schulhoffer
Jim Carter
107 File

FROM: Carl Mezoff

DATE: June 8, 1977.

SUBJECT: Summary of Prototype Design Review Held June 7-8, 1977, Stamford, Ct.
of 107-(NAS-8-32250) Pyramidal Optics Development

PARTICIPANT

AFFILIATION

Mr. Valmore Fogle
Mr. Larry Bradford
Mr. James Carter

NASA Marshall
NASA Marshall
Cambridge Development Associates

Mr. Eric Wormser
Mr. John Bays
Mr. Carl Mezoff

Wormser Scientific
Wormser Scientific
Wormser Scientific

AGENDA

Introduction of Participants	E.M. Wormser
Performance Improvement of Delaware Pyramidal Installation	E.M. W.
Development Program	C.R. Mezoff
- Components	
1. Reflective Surfaces	
A. Mylar Laminated to Galvanized Steel	J.T. Bays
B. Anodized (Kingston) Aluminum Sheet	J.T. B.
C. Stainless Steel	J.T. B.
D. Aluminized Mylar on Corregated Board	C.R. M.
2. Reflectice Panel Lifting Mechanism	C.R. M.
3. Dual Source Heat Pump	J.T. B.
A. Principle of Operation	
B. Performance Advantages	
C. Future Improvements	
4. Glazing Seal	C.R. M.
A. Nail-Down Model Development	
B. Proposed System	
C. Code Requirements	
5. Glazing Support Structure	C.R. M.
6. Absorber Plate Piping	C.R. M.
7. Storage System	C.R. M.
8. Controls	C.R. M.
Instrumentation For SDAS	C.R. M.
General Systems Drawings	C.R. M.
System Performance Specification	C.R. M.
Procurement Specification	C.R. M.
Special Tools	C.R. M.
Spare Parts	C.R. M.
Schedules	E.M. Wormser
Add-on of Single Family Residence	E.M. W.
Concluding Remarks	E.M. W.

Drawing Changes:

Mr. Carter asked for the following changes in the installation drawings:

- Sheet 4 - Eliminate cathedral ceiling, 4 x 12 decorative beams, 4' x 4' skylight at No. 2 living room. Bring ceiling down to 8' all over. This changes does not affect the solar system performance. Its only effect will be to slightly reduce thermal losses and slightly reduce the cost of building the unit (but not without a loss of attractiveness and saleability of the unit). Call for acoustic lining of the Master Bedroom pipe chase.
- Sheet 14 - Provide mechanical room plan and section.

Drawing changes requested by NASA Marshall personnel:

- Sheet 4 & 14 - Indicate piping runs and provide mechanical room plan.
- Sheet 24 - Provide further details of collector and mounting arrangement.
- Sheet 15 - Indicate location of 3TAS (Tank temperature cross-over from direct solar to heat pump assist will be located close to or inside pipe return from collectors. Note in text of sequence of operations that "direct heating with solar heated water can be achieved at low tank temperatures, because solar heated water can pass directly from collectors to water-to-air coil without mixing in the storage tank."
- Sheet 19 - Modify SDAS instrumentation plan to reflect changes suggested by Val Fogle, Larry Bradford (NASA) and Mike Nash (IBM) whose comments will be received shortly.

General Systems
Performance Drawings - Amplify and provide more details.

DATA REQUESTS

Additional information or changes were requested by NASA Marshall on the following items:

- 1) A report of experimental and/or analytical determinations of the temperature of the absorber plate at stagnation conditions and the temperature of the aluminized mylar near the focus of the pyramid.

- 2) Analytical determination of temperature of wood absorber support behind absorber plate at stagnation temperature.
- 3) Provide a brief technical description, modes of operation and schematic of Dual Source Heat Pump showing coil arrangement.
- 4) Add a table of annual solar performance calculations to the system performance specification to explain system Appendix "A".
- 5) Add to the Physical Data Table III an entry describing the glazing system.
- 6) Consider the inclusion of a shorter "General Conditions" section for the procurement specification.
- 7) On Spare Parts List change lead time on fuses to "5 days."
- 8) Discuss with U.L. Labs how to solve the code restriction on plastic skylight maximum areas.
- 9) Provide two copies of corrected system specifications and 4 copies of drawings to NASA.
- 10) Provide test reports on the mylar-corregated board assembly, the lockstrip gasket assembly, and the flap lifting mechanism.
- 11) Provide illustrations in installation manual where appropriate.
- 12) Provide a more detailed training plan for sub-contractors and tradesmen on the job.
- 13) Submit an Itemized Form 633 for the Underwriter's Lab and University of Alabama Independent Agency Certification:Costs.
- 14) Submit a Form 633 for two year operational test period maintenance extension.
- 15) Provide satisfactory response to:

RID W2-hotspots
W3-drain-down
W4-heating directly from storage
W5-double wall heat exchanger
W6-heat pump cut off temp.
W7-heating directly from storage
W8-collector details

Questions:

1. Thermostat set points
2. Heat pump coil size
3. Storage cross-over temperature

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SCHEDULE

Although it is recognized that meeting some of the dates below depends on receiving approvals by certain agencies, it is hoped that all concerned will make their best effort to adhere to the schedule.

<u>EVENT</u>	<u>PERIOD</u>
Preparation of Building Modification Drawings	4-28-77 to 5-15-77
System Drawings sent to the Yacht Cove	6-5-77
Prototype Design Review	6-7-77 to 6-8-77
Building 38 Foundations	7-1-77 to 7-10-77
Delivery of Solar System	7-15-77 to 9-15-77
Building 38 Framing	7-11-77 to 8-7-77
Solar Window Installation	8-8-77 to 8-15-77
Receive Sensors	8-15-77
Mid-term Preliminary Installation Review at the site	8-17-77
Complete Construction	9-30-77
SDAS Installation	9-30-77
Final System Installation Review	10-5-77
Installation and Acceptance Review	10-19-77
Mid-term Operational Test Review	3-15-78
Final Operational Test Review	6-15-78

CM:klt

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Quarterly Report #3
and Monthly Status Report #9
October 19, 1977
WSC-S-107 Contract NAS8-32250
Additional Development of Pyramidal Optics
Concentrating Solar Heating and Hot Water System

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Contents:

Part I	Summary
Part II	Contract
Part III	Schedules
Part IV	Technical Performance
Appendix A	Preliminary Installation Review at the Site

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Part I: Summary

Cambridge Development Associates has received an executed contract from the government, permits and approvals from the local municipality, and approval from their lender, the Equitable Life. Construction of Building 38, in which the subject solar system will be installed, commenced 10/5/77.

A Preliminary Installation Review was held 10/11/77 at the site, a summary of which may be found a Appendix A to this report.

Part II: Contract

The Preliminary Installation Review at the site was held 10/11/77 as required by contract. Technical directives 07, 08, and 09 have been returned to the technical manager, signed in acknowledgement. No contract changes have been approved since the previous quarterly report.

Part III: Schedules

The following schedule is the latest update of the solar building 38 Build-out schedule:

<u>Event</u>	<u>Period</u>
Preliminary System Drawings Sent to Yacht Cove	6-5-77
Prototype Design Review	6-7-77 to 6-8-77
Final Approved Drawings and Specifications Sent to Yacht Cove	8-10-77
Complete Engineering, Grading, Roads or Grand (Rough) Off Site Utilities	9-26-77

<u>Event</u>	<u>Period</u>
Utilities (Underground)	9-21-77 to 10- 3-77
Receipt of Sensors from IBM	9-22-77
Preliminary Design Review	10-11-77
Plumbing Under Slab	9-30-77 to 10- 4-77
Building 38 Foundations	10- 5-77 to 10-10-77
Slab on Grade	10-10-77 to 10-13-77
Walls	10-13-77 to 10-20-77
Construct Storage Tank	10-17-77 to 10-28-77
Building 38 Framing	10-14-77 to 11- 3-77
Building 38 Siding and Exterior Trim	11- 6-77 to 11-16-77
Solar Window Installation	11-17-77 to 11-27-77
Install Absorber Plate	11-14-77 to 11-18-77
Rough Mechanical	11-14-77 to 11-18-77
Solar Plumbing and Heat Pumps	11-14-77 to 11-23-77
Solar Electrical	11-21-77 to 11-25-77
Install Reflectors	11-21-77 to 11-25-77
Drywall	11-19-77 to 11-28-77
Interior Trim and Ceramic Tile	11-29-77 to 12- 7-77
SDAS Installation	11-28-77
Final System Installation Review	11-30-77
Complete Construction: Finish Mechanical, Trim, Paint	12- 6-77 to 12-16-77
First Article Review	12-14-77

Part IV: Technical Performance

Final system drawings with suggested modifications of the prototype design review have been submitted to the government. The test report on the gasket assembly will be forwarded as soon as it is received from our sub-contractor, the University of Michigan. Technical performance evaluation will commence upon system completion. The SDAS sensors have been received at the site, and all items shipped arrived in good condition.

Appendix A: Preliminary Review at the Site Summary

<u>Participant</u>	<u>Affiliation</u>
Mr. Ralph Murphy	NASA Marshall
Mr. Valmore Fogle	NASA Marshall
Mr. John Kruse	Cambridge Development Group
Mr. Joe Schulhofer, Jr.	Cambridge Development Group
Mr. Eric Wormser	Wormser Scientific Corp.
Mr. John Bays	Wormser Scientific Corp.
Mr. Carl Mezoff	Wormser Scientific Corp.

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Mr. Murphy and Mr. Fogle were shown the building under construction. Foundations had been poured, and under slab plumbing was in place. The mechanical room of Building 24, the previous, similar solar installation, was inspected with special attention given to the quietness of the pump arrangement.

Following this, a discussion between the NASA representatives and Kruse, Schulhofer, Wormser, Bays, and Mezoff was held covering the following points:

- 1) A revised schedule was presented (See update in Part III of this report) indicating an expected completion date of 12-6-77.
- 2) Valuable suggestions for better sensor installation were provided by Messrs. Murphy and Fogle, to wit:
 - Shield of sensor wire should be grounded at J-box only.
 - Inside J-box, insulation of all wires and of shield should be carried to terminal.
 - The SDAS requires a twist lock receptical.
 - The telephone coupler will be within 3' of the SDAS and a hand set will be installed.
- 3) This paragraph has been deleted.
- 4) Mr. George Mizell of IBM will be informed when the SDAS box should be shipped. He has offered to come to the site prior to wiring the sensors to help the electrician with any questions.