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DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150545

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PROTOTYPE SOLAR DOMESTIC HOT WATER SYSTEMS
(A Collation of Quarterly Reports)

Prepared from documents furnished by

Solar Engineering and Manufacturing Company
1054 N. E. 43rd Street
Ft. Lauderdale, Florida 33441

under Contract NAS8-32248 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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Solar Energy

DISCLAIMER

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16. ABSTRACT

This report is a collection of quarterly reports from Solar Engineering and Manufacturing Company (SEMCO) covering the period from November 1976 through September 1977. SEMCO, under NASA/MSFC Contract NAS8-32248, is developming two prototype solar domestic hot water systems consisting of the following subsystems: collector, storage, control, transport, and auxiliary energy.

These two systems are being installed at sites in Loxahatchee, Florida (OTS-27), and Macon, Georgia (OTS-28).

Cost information has been removed from these reports.

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INTRODUCTION

This document is a collation of quarterly reports from Solar Engineering and Manufacturing Co. (SEMCO) covering the period November 1976 through September 1977. The quarterly reports have been retyped and formatted by NASA/MSFC. Cost information was also removed from this report.

SEMCO, under NASA/MSFC Contract NAS8-32248, is developing two prototype solar domestic hot water systems consisting of the following subsystems: collector, storage, control, transport, auxiliary energy.

This report describes the progress of the development program during this period. It is separated into three reporting periods:

A. November and December 1976
B. January, February, and March 1977
C. April through September 1977

A.

MONTHLY REPORT

DECEMBER 1976

and

FIRST QUARTERLY REVIEW 1/11/77

Part I - Summary

The thrust of the effort under this contract to date has been on the double wall heat exchanger for the Storage Subsystem. Preliminary testing has shown that the 1/2" copper tube coiled around the tank is not an efficient heat exchanging system. Data refinement, charts and graphs will follow. Various telephone conversations with other companies working in the double wall heat exchanger field, lead this contractor to the preliminary conclusion that the Roll-Bond plate as manufactured by Olin Brass will be the best currently available heat exchanging hardware for the contract double wall heat exchanger. Our future R&D will follow this course.

Part II - Contract

Work is proceeding as described in the original contract. No "Changes" are required or requested at this point in time.

Part III - Schedules

Work on the contract is proceeding on schedule. The Development Plan (SHC-3018) in paragraph 1.15 Storage Subsystems outlines the procedure for development work on double wall heat exchangers. The first stage of the test procedure using 1/2" soft copper tubing has been completed. Further tests to verify the initial data will be conducted. The second stage of the test procedure using Roll-Bond is scheduled for the latter part of January and February 1977. Completion of this work will lead to the Preliminary Design Review scheduled for 3/30/77 as set down in the Development Plan time schedule (Paragraph 2.0).

Part IV - Technical Performance Test Stand Construction

Construction of the double wall heat exchanger using 1/2" soft copper tube coiled around the hot water storage tank has been completed and preliminary tests have been conducted. The construction of the test hardware was done as follows:

1. Starting with a standard 40 Gallon glass lined electric hot water heater (RHMGLS Standard) the upper pan, outer case, insulation, electric elements and drain plug were removed. The tank studs for the electric elements were closed with two 1 1/4" gal. pipe plugs. The stripped tank size is 54" high x 14" dia.

2. The upper pan was replaced and the tank placed on its side like a large spool. The 1/2" soft copper tube was slipped over one end and worked into tight fitting coils 2" center to center as shown in pictures 1, 2 and 3. Nineteen (19) coils covering a distance of thirty eight (38") inches were used. The bottom coil was turned up with a sweat elbow and a vertical copper input pipe attached. Each coil was spot soldered to the vertical pipe to hold the coils in the 2" center to center position. The top coil was turned up with a sweat elbow and a vertical copper input pipe attached as pictured.

3. The tank and coils were returned to the vertical position and the upper pan removed. A circular base of 1 1/2" polyurethane insulation 28" inches in diameter was fabricated. The 14" tank was placed in the center of this insulating bottom leaving 7" for the wall insulation to overlap. See pictures 4 and 5.

4. The copper coils were then wrapped with sheet aluminum. All joints were sealed with duct tape. The sheet extended several inches above the top coil. Fibreglass insulation was packed into this void forming an air tight envelope containing the copper coils. See pictures 4 and 5.

5. Two circulating systems were then installed as shown in picture 6. The tank circulating system consists of a Marsh Model 809, 200 GPH, magnetic drive, hot water circulating pump, a boiler thermometer (Range 40^{o} to $240^{o}F$) and an air release valve. This system also includes a tank bottom drain valve and 8" nipple shown in picture 2. This circulating system pumps the hot water from the top of the tank to the bottom of the tank through the tank boiler tube. This overcomes hot water stratification and gives an accurate reading of the temperature of the hot water in the tank.
The copper coil circulating system consists of a Marsh Model 809, 200 GPM, magnetic drive, hot water circulating pump and two boiler thermometers (Range 40^{o} to $240^{o}F$), connected to the hot and cold water lines of a 50 Gallon, 9,000 watt electric hot water heater. This circulating system pumps the $150^{o}F$ hot water from the supply tank. This gives the test system a constant supply of $140^{o}F \pm 5^{o}F$ hot water simulating the hot water supply of the Semco Solar DHW System.

6. The completed mechanical system was then wrapped with two layers of Fibreglas Insulation (3 1/2" - R-11) as shown in pictures 7 and 8. The top of the tank was also covered with 7" of Fibreglas Insulation as can be determined by comparing pictures 6 and 8 as to pipe length.

Test Stand Operation - Data

The testing facility was put into operation and the following data was collected.

Run #1   **Time**

Temp ^{o}F	2:00 p.m.		3:00 p.m.		4:00 p.m.		5:00 p.m.		6:00 p.m.		7:00 p.m.
tank	51		58		65		70		76		81
Hot in	146		141		143		140		139		146
Hot out	141		136		138		135		134		142
Room	51		52		54		54		54		55
tank Δt		7		7		5		6		5	
Average tank		55 1/2		61 1/2		67 1/2		73		78 1/2	
BTU Gain		2, 333		2, 333		1, 666		2, 000		1, 666	

Run #2   **Time**

Temp ^{o}F	12:00 p.m.		9:00 a.m.
tank	56		93
Hot in	147		150
Hot out	142		146
Room	43		40
tank Δt		4	
Average Tank		74 1/2	
BTU Gain/Hr		1, 370	

Run #3   **Time**

Temp ^{o}F	4:30 p.m.		7:30 p.m.
tank	91		100
Hot in	143		143
Hot out	140		141
Room	42		50
tank Δt		3	
Average Tank		95 1/2	
BTU Gain/Hr		1, 000	(40 x 8. 333 x 3)

Test Stand Operation - Conclusion

It is evident from the limited data presented above that the BTU transfer expected from this type of heat exchanger will not be adequate for the energy produced by a SEMCO - DHW - 2/120. For example, at solar noon on a clear day, insolation will be approximately 300 BTU/sq. ft. This factor times the 80 sq. ft. of collector in the contract DHW System times 50% efficiency will produce an optimum BTU gain of 12,000 BTU per solar noon hour.

The 14" dia. (40 gal.) test tank has an effective heat exchange area of (14" x 3.15 x 40") 1,758 sq. inches. The 24" dia. (120 gal.) contract tank has an effective heat exchange area of (24" x 3.14 x 40") 3,014 sq. inches. Comparing these areas, indicate a 72% increase when applying the test data to the contract tank. Using street water at 60°F and a maximum tank water at 140°F, the average tank temp. will be 100°F. Using 1,000 BTU (Run #3) heat gain times 1.72 (120 gal. tank) calculate out to a 1,720 BTU heat exchanger gain. This heat exchange system will be able to handle less than 15% of the energy generated by the collector Aray under optimum generating conditions. (1,720 - 12,000).

Additional Data will be collected to substantiate or disprove this preliminary conclusion.

Roll-Bond Heat Exchanger System
Olin Brass

Preliminary research on the Roll-Bond heat exchange hardware was begun by telephone conversation with the manufacturer, Olin Brass in Illinois. Mr. Ken Horn of Olin Brass (1-618-258-2702) stated that although they manufacture the hardware, there was no existing BTU transfer data on the product. The only "off the shelf" size is 17" x 50" - both sides inflated. Any other size or flat one side configuration would require a special set up charge of $650.00 with a lead time of 8 to 12 weeks. The maximum size of any special order would be 34" wide by any length up to 8 ft. Roll-Bond can be fabricated of either copper or aluminum, however aluminum has serious corrosion problems and is not recommended without the use of an anti-corrosive agent in the heat transfer fluid which Ken Horn says is very expensive. Mr. Horn then referred me to State Industries in Ashland, Tenn. and Grumman Energy Systems in Ronkonkoma, NY. He further indicated that State Industries had a special Roll-Bond exchanger made but because they had paid the set up charge it was available only through State Industries.

State Industries

State Industries was formerly known as State Stove and are one of the largest manufacturers of Electric Hot Water Heaters in the nation. They manufacture the Sears HWH among others. They have done some R&D on Solar tanks with double wall heat exchangers (Olin Brass-Roll Bond) but they have no BTU heat transfer data. Extended conversation with Mr. Denver Collins of State Ind. (1-800-251-8170 - Ex. 333) was very helpful in determining the existing state-of-the-art for the double wall heat exchangers. Their primary work has been with a 22" x 59" flat one side wrap-around Roll-Bond. A number of these tanks were manufactured for Grumman Energy Systems. This work developed the fact that a thermal mastic was necessary between the tank and Roll-Bond. Mr. Collins worked with General Adhesives of Tenn. and together they developed a thermal mastic that is graphite filled, high molecular weight, polybuteline caulk base cut with solvent for spreadability. Mr. Collins has expressed an interest in working with Semco on the R&D for the proposed contract double wall heat exchanger solar tanks.

Grumman Energy Systems

Grumman Energy Systems is a Division of Grumman Aerospace Corp. and is currently doing work on solar systems that include the double wall heat exchanger solar tank. Mr. Bert Swerdling (1-516-575-7261) stated that preliminary work developed a Roll-Bond BTU heat transfer valve of 30 to 40 BTU transfer/sq. ft./hour/^{o}F with a thermal mastic between the Roll-Bond and the tank. He further stated that Dean Products of NY, NY manufactures a steel flat plate heat exchanger that develops a heat transfer from steel exchanger to steel tank (water to water) 18-20 BTU/sq. ft./hour/^{o}F with no mastic. Missing in this data is the delta t range between the two liquids. Mr. Swerdling gave this information with the reservation that the figures were preliminary and needed further development. His final conclusion for his work was that a double wall heat exchanger tank would reduce the total efficience of the solar DHW system by 15% to 20% because of the increased collector operating temperature.

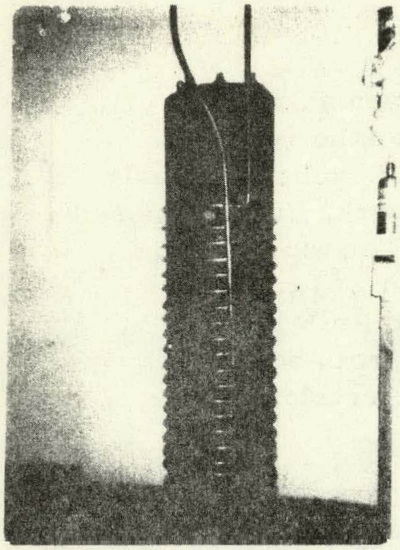
Conclusion

Again using the maximum solar insolation for the one hour at solar noon on a clear day of 300 BTU/sq.ft. times 50% collector efficiency times 80 sq. ft. of Collector times 85% system efficiency (300 x .5 x 80 x .85) a heat transfactor valve of 10,200 BTU is required for the Semco DHW 2/120 solar system.

The 30 to 40 BTU/sq. ft/hour/^{o}F Roll-Bond heat exchanger heat transfer valve indicates that a heat exchanger area of 9 sq. ft. is required for the proposed Semco DHW 2/120 solar system, i.e. (30 x 9 sq. ft. x 1 hour/40^{o}F = 10,800 BTU).

The State Ind. Roll-Bond exchanger measures 22" x 59" or approximately 9 sq. ft. While this area appears to be a near perfect match for the requirements, this contractor feels that using two 22" x 58" Roll-Bond exchangers will give a safety factor commensorate with the R&D naute of the work. The proposed 120 gal. tank will be 24" in dia. and approximately 60" high. The top 1/3 (40 gal) will be electrically boosted when required while the bottom 2/3 will be solar heated with the exchanger. Again the 22" x 59" State and Roll-Bond exchanger is a near perfect match for the requirements. Two roll-bond units can be applied to the lower 2/3 of the 120 gal. tank where the electric booster will not interfere with the solar heat transfer system.

It is our proposed plan to purchase a 120 gal. double wall heat exchanger solar tank as described above from State Ind. and subject it to BTU heat transfer tests as were done with the 1/2" copper coil heat exchanger system. Assuming that the BTU transfer data substantiates the above predictions, this tank will be installed in the test system in Mr. Zimmerman's house in Boca Raton, Florida to further develop data on the tank as well as the complete Semco DHW 2/120 solar system.



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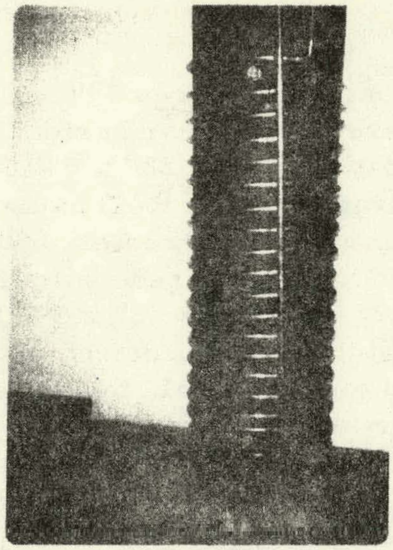

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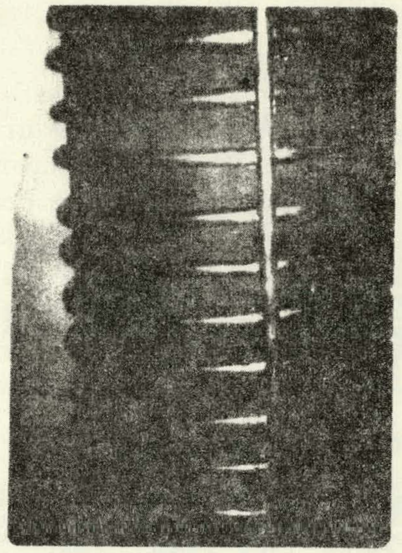

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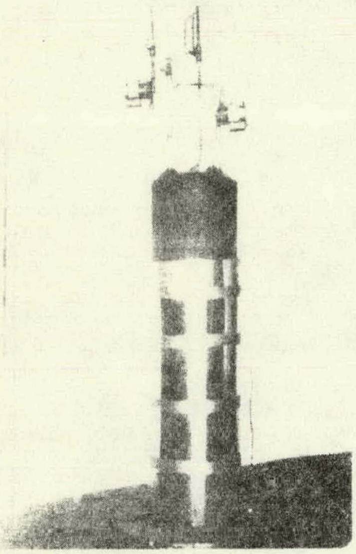

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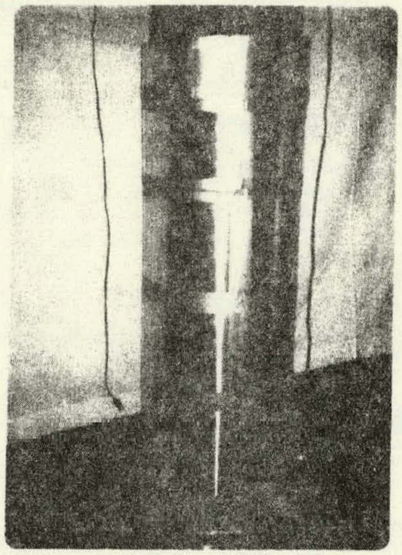

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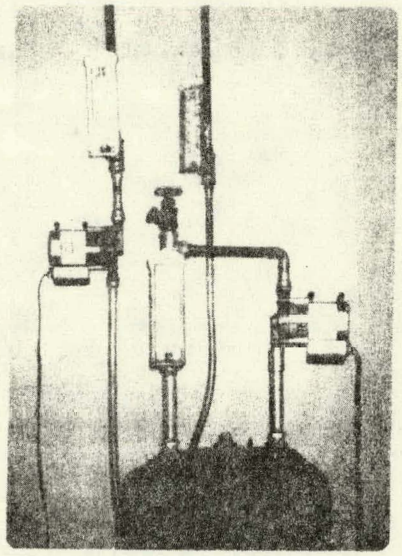

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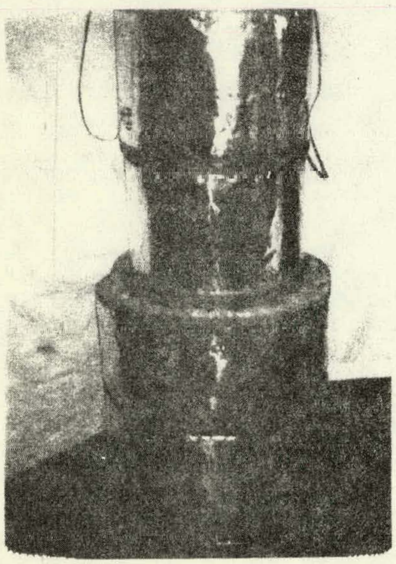

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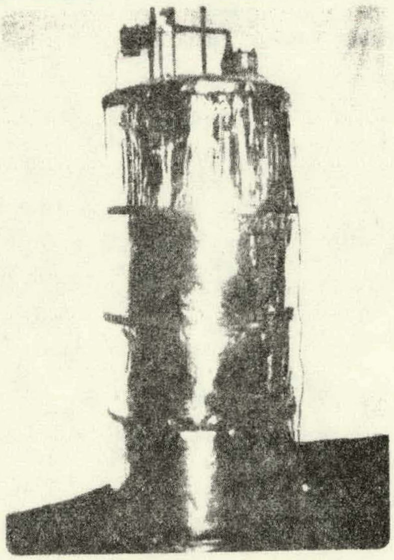

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B.

QUARTERLY REVIEW

JANUARY, FEBRUARY, AND MARCH 1977

Part I - Summary

The thrust of the Research and Development work in this Quarter has been to test and evaluate the storage subsystem and collector subsystem that is a part of the contract solar DHW system. The SEMCO Solar DHW system was an existing system and the R&D work has proven the need for additional development. These two subsystems have now been developed to a point where they can now be put in line in the complete DHW system for final analysis and review.

Part II - Contract

Deleted

Part III - Schedule

The contract work as listed in the Development Plan is approximately on schedule. Severe winter weather delayed January development work. Extra effort in February and March has brought the R&D work back on schedule. A work priority problem on the part of the Site Contractor has delayed the Preliminary Design Review one week. This delay will not effect the Prototype Design Review scheduled for April 28, 1977.

The NASA/Marshall Site Selection Manager, Mr. Bob Gunner, and the Site Contractor visited two possible installation sites in the South Palm Beach County area. They were the state owned houses at the Lantana Hospital and the state owned houses at the Fish and Wild Life Service Regional Station west of Boynton Beach. The latter location is the more desirable of the two because of the exposure anticipated by the demonstration DHW system. Thousands of people will see the solar collectors when they visit the nature trails and view the wild life in the Park.

Part IV - Technical

A 120 gallon solar storage tank was purchased from State Industries; Ashland, Tenn. The tank included a wrap-around Roll-Bond Copper Heat Exchanger with an area of 18 sq. ft. This wrap-around design provides the ERDA recommended "Double Wall" configuration.

Solar transport water to tank potable water heat exchange tests were performed with a specially constructed test stand. A simulated solar hot water supply at 140°F was pumped through the Roll-Bond heat exchanger at a flow rate of 1.5 GPH. This resulted in a 5,000 BTU/hr. heat exchange within a 90°F to 130°F range.

The flow rate of 1.5 GPM used in the test stand is at best marginal. Uneven hot water distribution through the Roll-Bond heat exchanger is suspected at this low flow rate which will appreciably reduce the efficiency of the exchanger.

This problem has been corrected with the installation of a Grundfos pump with an adjustable flow rate of 12 to 24 GPM. This pump has been installed in the "Test System". Additional heat transfer date will be recorded to prove to assumption that more than 5,000 BTU/Hr heat exchange can be generated with this "Double Wall" heat exchanger.

Attached is a schematic of the "Test System". Temperatures will be recorded for test runs of follows:

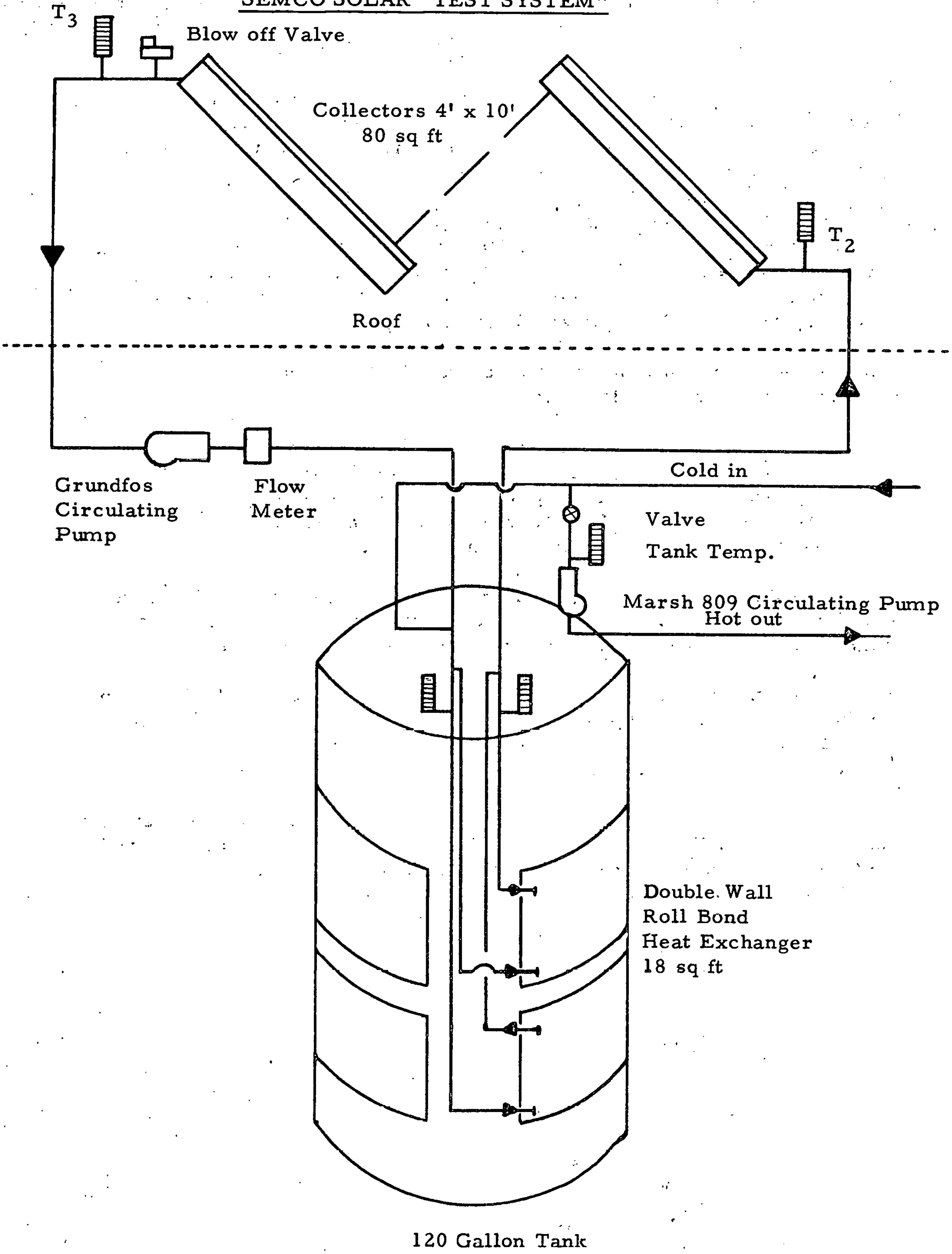
Tc-up	-	Transport fluid out of exchanger
Tc-in	-	Transport fluid into collector
Tc-out	-	Transport fluid out of collector
Tc-down	-	Transport fluid into exchanger
GPM	-	Transport fluid flowrate

A test run will require the cut off of the hot water to the house and a one hour tank water circulation by the tank circulating system to eliminate stratification and provide an accurate reading of the tank temperature.

At the start of the test run the above listed temperatures and GPM readings will be recorded together with time of day and cloud cover. At the end of the test period the tank temperature will again be recorded. This will provide additional data for the Prototype Design Review.

The SEMCO collector has been subjected to thermal performance tests by the Florida Solar Energy Center. Their data plus some design changes has led to the development of the Collector that will be recommended at the Prototype Design Review.

SEMCO SOLAR "TEST SYSTEM"



C.

QUARTERLY REPORT

APRIL THROUGH SEPTEMBER 1977

Part I - Summary

This quarterly report is a summary of the research and development work done by SEMCO under the subject NASA Contract. Two operational test site installations have been made. Site #1 is in the Loxahatchee Wildlife Refuge Area near Boynton Beach, Florida and is a direct feed solar DHW system. Site #2 is in Macon, Georgia and is a double wall heat exchanger solar DHW system. A site data acquisition system has been installed at each site. Energy transfer data is collected daily and transmitted by telephone line to a central computer located at NASA/ Marshall in Huntsville, Alabama. Both systems are on line and data is being accumulated daily.

Part II - Contract

Deleted

Part III - Schedule

All originally scheduled research, development and site installation work has been performed. Several minor system modifications remain to be done at each site under the original contract. The broken glass replacement will be done upon the receipt of the tempered glass now on order. Delivery of the glass is now scheduled for the month of November 1977.

Part IV - Technical

The research and development work done by SEMCO under the subject NASA Contract has provided the opportunity for SEMCO to measurably improve the component hardware and system design for the SEMCO solar water heater. Significant improvements have been made in the collector and contract subsystems. The installation of both a direct feed system and a double wall heat exchanger system have provided experience and site data to enable SEMCO to make informative decisions as our solar market expands into areas where freeze protection is required.

The R&D work with the double wall heat exchanger system has led SEMCO to the decision not to attempt to distribute this product in the commercial market. While this system can be designed to function adequately, the dollar cost per BTU generated does not serve the interest of future SEMCO customers. The standard direct fee system with drain down and fail safe provisions will be marketed in areas requiring freeze protection.

The specific reasons for this decision are as follows:

1. The cost of the double wall heat exchanger tank is approximately $400.00 more than a standard solar tank.

2. The transport fluid must be either water with an antifreeze solution or silicone oil. Water with antifreeze must be replaced in time. Silicone oil is very difficult to work with and costs more than $100.00 per system.

3. The double wall heat exchanger reduces the efficiency of the system thereby requiring an increase in collector area to maintain equivalent BTU output.

4. The drain down provisions on a direct feed system requires the addition of two solenoid and two check valves for an additional cost of less than $100.00.

The research and development work done by SEMCO under the subject NASA Contract has resulted in the following component and system improvements:

1. Increase the collector insulation from 1/2 inch to 1 inch urethane with a resultant increase in absorber plate temperature.

2. Replace the 1/8 inch DBS glass (double glazing) with tempered 1/8 inch DBS glass (double glazing) to withstand the increased collector temperatures under stagnation.

3. Inclusion in the system of the Hawthorne variable flow differential controller with an upper limit temperature control sensor and a freeze control sensor for direct feed systems in moderate climates.

4. Inclusion of a Grundfos 1/20 h.p. circulating pump to replace the Marsh 809 circulating pump. This change will eliminate the system breakdown from excess scale buildup around the pump impeller.

5. Increase the size of the transport fluid lines from 1/4 inch to 1/2 inch to increase the flow and BTU gain of the system.

6. Location of the circulating pump below the water level of the storage tank to prevent pump from running dry in case of pressure failure in the system.

7. Addition of a mixing valve to prevent supply hot water from being too hot. Mixing valve preset for 140°F hot water output.

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