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WATER-STORAGE-TUBE SYSTEMS

FINAL REPORT (24 December 1981)

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Grant No. AED De-FG02-80R510241

United States Department of Energy

Midwest Appropriate Technology

Small Grants Program

Submitted by:

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12-24-81

Date

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MASTER

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OBJECTIVES

The objectives of this grant were to survey, design, fabricate phototype, and mechanically and thermally test the following passive solar thermal collection/storage/distribution systems:

- I. Static Water Storage Systems
 - A. Fiberglass tube
 - 1. Clear
 - 2. Opaque
 - B. Metal tube with plastic liners
- II. Thermo-siphoning tubes.

APPROACH

Our approach centered around two people: The Principal Investigator, and Fuller Moore, technical solar consultant. Based on Mr. Moore's experience as a practicing architect (specializing in passive solar applications) and a Professor of Architecture at Miami University, areas of interest to this grant were identified for further study. Mr. Moore then investigated the research literature (in particular, technical papers from the proceedings of past passive solar conferences) in order to analyze the results of previous work by other investigators.

We would then brainstorm ideas drawn from his experience as an architect and myself as a chemical engineer, fiberglass products

manufacturer, and boat builder. From these brainstorming sessions would emerge a concept.

Typically, we would then fabricate a prototype for the purposes of proving the concept. In most cases, because the basic thermal principles involved are not new, proof-of-concept testing was more a matter of mechanical and structural considerations rather than a thermal analysis. Once this phase was complete, we then would conduct extensive thermal testing using two identical passive solar test rooms in order to permit a side-by-side comparison under identical conditions of a control passive solar system against the experimental configuration. This thermal testing is to be monitored using thermal and isolation sensors and a data monitoring microcomputer.

APPROACH AND PROGRESS

While a detailed chronological laboratory log has been kept of the progress of these investigations, it is felt that, for the purposes of this report, it best to describe the results using a project-by-project format.

Vertical Fiberglass Water Tube

12" and 18" diameter clear fiberglass water storage tubes have been available commercially (Kalwall Corporation) for a number of years, and has been widely utilized as a low-cost method of storing solar heat in passive buildings. The technical consultant,

Mr. Moore, has experienced considerable problems with these commercially available units due to leakages caused by manufacturing defects and/or installation damage in several building projects from his architectural practice. We have attempted to produce a competitively priced product with an improved bonding on the vertical seam, and an end cap that is more resistant to mechanical damage and leaking.

Using five ounce by 36" wide clear acrylic sheet with ultra-violet inhibitor ("Lascolite" as manufactured by Lasco Industries, Covington, Kentucky) we have produced 8' x 11.37" diameter tubes using a specially developed bonding process. After a series of tests involving small samples of the Lascolite material bonded using a variety of techniques, we concluded that the most reliable fabrication consisted of sanding the two surfaces to be bonded, using a bodied polyester adhesive (based on Cargill, No. 8245 resin, Cabosil thickener, MEK peroxide with an accelerator to improve curing time). It was found the curing time could be reduced to one hour if a heated clamp was used (surface temperature 100°F to 110°F). Extended curing time beyond this did not improve performance.

A special clamping jig was fabricated in order to allow clamping an entire tube of 8' length with even, heated pressure. Several modifications of this apparatus were required to achieve the desired results; the final jig is shown in Fig. 1.

Fig. 1: Heated Gluing Jig for
Fiberglass Water Tubes

Fig. 2: Fiberglass Water Tube End Caps

In order to develop an improved bottom cap, a variety of configurations and adhesives were tested. The most successful, in terms of performance and fabrication ease is shown in Figs. 2 and 3. The caps are 12" in diameter by 1" tall and are formed using a female mold and three layers of polyester fiberglass matt applied with a "chopper gun." The previously assembled tubes are mechanically abraded on the ends, and positioned vertically in the end cap. The gap between the flange of the end cap and the tube is filled with a mixture of polyester resin and Cabosil thickener. After extensive testing, we conclude that this is a reliable method of producing tubes that are potentially maintenance free.

It is our practice to water test every tube prior to shipment. This tube and a similar smaller-diameter tube are shown in Fig. 4 on the right.

One set of ten of these tubes have been produced for a local building contractor and installed successfully in one of his houses. (This house was one of the U.S. HUD Passive Solar Demonstration houses, designed by Fuller Moore and Ann Klein, located in Richmond, Indiana.) During open house tours of this installation, public response to the aesthetic features of the tube was very positive. The water in the tube was treated with one-half cup of Clorox per tube (to prevent algae formation), but no coloring dye. It is felt that while leaving the water clear reduces the storage efficiency of the tube somewhat, the illumination benefits of having

Fig. 3: Detail of End Cap

Fig. 4: Two TANKWALL Units and
Two Fiberglass Water Tubes

Fig. 5: Molds for Round and Oval End Caps

the light transmitted into the house, as well as the visual beauty of the product, offset this minor reduction in performance. (A number of investigators have reported, at passive solar conferences, that the reduction in thermal performance is small if the water is left clear.)

Because the primary costs of the tubes involve labor associated with the various fabrication processes, we are now investigating a different shaped tube (elliptical) in order to provide a greater surface collection area without a corresponding increase in the thickness of the tube. A 12" by 24" ellipse can be formed by using a 60" wide sheet of fiberglass (the widest that is commercially available). Fig. 5 shows the elliptical mold being developed as well as the round mold used for 12" diameter tubes.

Fuller Moore, technical consultant, has invented two devices that are relevant to these tubes. Of the first, "SUNBEAMS" allows the utilization of these tubes horizontally in conjunction with clearstory windows, or skylights. After discussing Mr. Moore's invention, we fitted a tube with two sealed end caps and a fill hole. We then filled the tube in a horizontal position with water, supporting the 8' length at 2' long center with 2" wide fabric straps. This proved unsuccessful and ultimately caused the failure of the tube, due to the localized distortion of the tube out of its round configuration. It was observed, however, that this failure seemed to result from the distortion of the shape rather

than the inherent weight of the water or the strength of the fiberglass tube. This tube was then temporarily patched and retested using support at the end caps only. Not only did the tube withstand its own weight in this configuration, it appeared to be strong enough to support additional weight provided that could be distributed uniformly without distorting the shape of the tube. This discovery is seen as significant because it offers the potential of positioning the tube at high heights above floor using vertical support (cables or columns) at 8' on center spacing. It is felt that this approach warrants further investigation (See Figs. 6 and 7).

Mr. Moore's other invention "SUNLOUVERS" is a "louver" that could be placed in the center of a clear fiberglass tube (see Fig. 8) that would accomplish a number of thermal storage functions. Basically, the louver is a flat sheet (width of tube x length of tube in size) that is silver on one side and black on the other. Depending on the orientation of the louver within the water tube relative to the sun, solar heat could be transmitted through the water tube, absorbed by the black side of the louver and thereby stored in the tube, or reflected by the silver surface of the louver and reflected back out.

1. Vertical Tubes: The louver could be fixed (probably) or made adjustable (possibly) to allow early morning sun to be transmitted, afternoon sun to be absorbed in the

Fig. 6: Structural Span Capability of 8' x 12"Ø Water-filled Fiberglass Tube with End Caps

Fig. 7a: Support Alternatives for SUNBEAM Horizontal Fiberglass Water Storage Tubes

Fig. 7b: Alternative mounting for SUNBEAMS

Fig. 8: SUNLOUVER Being Inserted in Fiberglass Tubes.

in the tube (See Fig. 9) , and summer heat to be reflected.

2. Horizontal Tubes: The "louver" could be fixed in the tube, and the tube made to be pivoted, creating a "venetian blind" to transmit solar heat and light directly to the space, absorb the solar heat completely within the tube for storage, or reflect the light on to the ceiling for indirect daylighting illumination of the room, (See Fig. 10) . Because of the relatively low cost of such a device, and because it has applications for winter heating, summer cooling, and natural daylighting, it is felt that this strategy also warrants further investigation.

We have been awarded additional funding under the same grant program to allow investigation of these two strategies as well as other projects.

Metal Tubes With Liners

Hollow tubes to contain water for purposes of storing passive solar heat must perform two tasks: (1) they must structurally contain the pressure of the water; and (2) they must be water tight. The round shape of a vertical tube resting on a flat surface provides an ideal structural geometry because the circular shape is the shape that the container naturally wants to assume because of

Fig. 9: SUNLOUVERS in Vertical Water Tubes

Fig. 10: SUNLOUVER in Horizontal Watertubes (SUNBEAMS)

End cap for SUNBEAMS

internal hydrostatic pressure. We have investigated metal tubes with plastic liners on the assumption that it might be cost effective to consider a container that meets the structural requirements, and a separate container that provides water proofing. (A number of other researchers were pursuing this path: Harold Hay has developed the "Skytherm" roof pond system which utilizes a plastic bag supported on a metal roof structure, and Wayne Nichols has developed a flat, hollow "Trombe" wall that is made water proof using a plastic liner.)

In an attempt to utilize a tube configuration that would be compatible with standard carpentry construction practices, a 7" diameter tube was selected in order that three such tubes could be positioned between wall studs 24" on center. This still provided approximately 6" average water thickness that has been proposed as an optimum amount of thermal mass for such passive solar systems (Balcomb, 1980). This configuration also allowed the room side surface of the water tubes to be covered with a conventional wall finished material in order to hide the potentially objectionable appearance of the metal tubes, as well as to eliminate problems of dust collection on the many recesses of the surfaces. The final design configuration is illustrated in Figs. 11 and 12. We have constructed a full-scale mockup of this and feel that it is compatible with existing carpentry construction practices.

Subsequent discussions with other researchers (at the Amherst

Fig. 11: Isometric, TUBEWALL

Interior, TUBEWALL installation

Fig. 12: TUBEWALL Operation

Prototype TUBEWALL Tube with Liner and Tension Bands

Passive Solar Conference) have indicated that they have experienced problems with heat transfer from the water storage tubes to the room when the transfer mode was limited to natural thermosiphoning air convection. According to these individuals, the effect of the loss of radiation from the tube surface to the occupants of the room is significant. We are concerned about this possibility and will carefully evaluate it during the thermal testing prior to the final report.

Initially we experienced considerable difficulty in obtaining 8' long by 7" diameter snap-lock seam tubing (similar to that used for stove pipe). The maximum length of such units commercially available is 5' (this dimension is limited by standard roll forming equipment). For initial test purposes, however, we utilized 2' and 5' sections of standard 7" stove pipe in conjunction with 24" circumference seamless polyethylene tubing. This material was seamed initially at the bottom using a heat seal process. We have found through mechanical testing that 26 gauge sheet metal pipe with snap-lock seams does not develop sufficient strength to withstand the pressure of an 8' water head. However, increasing the wall thickness to 22 gauge has produced a unit strong enough to withstand 10' water pressure head in our testing. As a safety precaution, we have developed a set of bands to be placed around the tubes (fabricated from standard metal strapping material such as used for packaging). We have fabricated some tubes with no

locking seam by a roll forming 26 gauge metal and restraining the tube with bands at 1' 2" on center. While this worked on our tests, the stiffness of even 36 gauge material requires that the sheet metal be preformed to curved configuration, which requires special 8' long roll forming equipment (which is very expensive).

We have located a source of 7" diameter of 28 gauge galvanized metal downspout material. Structural tests of this tube with a plastic liner have been successful. However, costs of such tubes are comparatively high, and prevents this combination from being the low-cost strategy originally envisioned.

As a result of a suggestion from another researcher (again at the Amherst Conference) we are now recommending that the plastic liners not be sealed at the end, but instead, cut to twice the needed length, folded in the middle of the length before insertion into the tube. This results in no seam at the bottom of the tube and an elimination of this potential area of leakage.

Our general conclusions, as a result of our investigations of lined metal tubes, is that the strategy appears to be of questionable commercial application. The metal tube costs are higher than expected, it appears that polyethylene may not be the best material for the liner in spite of its low cost, because of potential

occurrences of pin holes in the material (other researchers have questioned the longevity of polyethylene when exposed continuously to water). While the technique provides for the use of standard carpentry construction, it does require 2 by 8 studs used, which increases the cost. We will continue our investigation of this area, but are not at present optimistic about the results.

Thermosiphoning Water Tube

Buckley (1976) has described a thermic diode thermosiphoning solar panel. In Buckley's design, water is heated in a thin solar collector facing the glazing, transported through a small opening to the back side of the panel which contains a larger volume of water for thermal storage. The two sides are separated by an insulation layer. The water is returned from the storage to the collector by an opening at the bottom of the tank. Back-siphoning at night is prevented through the use of an oil/water valve developed by Buckley. While Buckley reports satisfactory thermal performance of his unit, the present investigators feel that the system is complex to construct and is too expensive to be cost-effective.

Prior to this grant application, Fuller Moore proposed applying the same thermosiphoning principle to a tubular configuration in order to minimize structural and cost problems. The design and operation of this system is shown in Figs. 13 through 16.

Fig. 13: Plan, through one Thermosiphoning Water Tube

Fig. 14: Plan, Showing Thermosiphoning Water Tubes in Stud Wall

DAY

WATER THERMOSIPHONS
HEAT FROM COLLECTOR
TO STORAGE;
RADIATION AND CONVECTION
CONVECTION FROM STORAGE
TO ROOM.

NIGHT

FLAP VALVE STOPS REVERSE
WATER THERMOSIPHON AT
NIGHT.
RADIATION AND AIR
CONVECTION FROM STORAGE
TO ROOM CONTINUES

Fig. 15: Modes of Operation, Thermosiphoning Water Tubes

This grant proposed to construct, develop, and test these thermosiphoning tubes. A proof of concept experiment was conducted using a foam baffle insert in a 4" diameter water tube. The experiment confirmed that thermosiphoning did occur and the flap valve proposed by Moore was effective in allowing circulation to occur during the day and preventing reverse thermosiphoning at night.

Subsequently, Moore, in correspondence with the passive solar research group at the Los Alamos Scientific Laboratory, learned of some experiments being conducted there on the use of selective black surfaces on water wall passive solar systems. Selective surfaces have the unusual property of readily absorbing short-wave length solar radiation but inhibiting the emission of long-wave length radiation back to cold glass surfaces at night. While these materials have been available for several years, until recently their application has been limited to active solar collectors.

At Los Alamos, tests were conducted in identical test cells in order to compare the performance of selective surfaces for reducing heat loss with more conventional moveable night insulation. A test was conducted on two water wall systems: one system had flat black paint coating with double glazing and R-12 night insulation; the competing system had the same configuration with double glazing with selective surface coatings and no night insulation. The Los Alamos tests indicated that selective surface water walls without night insulation performed comparable to black water walls

with R-12 night insulation. (These results have subsequently been published; Hyde, 1980.)

Because selective surfaces are commercially available at considerably less cost than R-12 night insulation, and because they are maintenance free and have a long life expectancy, we felt that this would be an attractive alternative to the thermosiphoning configuration described above. We requested a pre-conference copy of Hyde's paper and carefully reviewed his findings. We then reviewed previous papers by other researchers regarding the use of selective surfaces on active solar collectors, and concluded that Hyde's results were reasonable in light of other experimental testing. At that point, we decided to delay further development of the thermosiphoning configuration and concentrate on selective surfaces as a means of reducing heat loss.

Most passive solar thermal storage walls that utilize water as the storage medium have one or more of the following disadvantages:

1. Require night insulation;

2. Excessive surface area that collects dust;
3. aesthetic appearance is objectionable;
4. Difficulty in preventing evaporation (fiberglas tubes);
5. difficulty in preventing air in contact with glazing from flowing around the water containers and mixing with room air; and
6. Requires some modification of standard wall framing construction practices.

May of these disadvantages are associated with the products that we have been developing described above.

Because of that, Mr. Moore suggested consideration of one of his inventions as an alternative. This invention "TANKWALL" is shown in Figs. 17 and 18 (early sketches by Moore). We have developed this product to the production stage and the configuration is essentially unchanged from that shown in these drawings, except that the internal stiffeners have been modified. The tankwall unit is a complete, easy-to-install water panel that fits between standard 2 by 6 studs, 24" on center (absolutely no modification from conventional framing practices is required). The use of a selective black surface eliminates night insulation (Hyde, 1980). This system is particularly attractive because it:

1. requires no change in conventional carpentry construction;
2. is installed in fifteen minutes by conventional carpentry skills;

Fig. 17: Isometric, TANKWALL Panel

selective black absorbs solar heat while reducing radiant losses (equal to R-12 night insulation)

anodized aluminum reflector on concrete slab adds approx. 45% heat

water stores heat

TANKWALL radiates heat directly to interior

WINTER

reflector converts to patio with carpet cover

overhang shades collector

SUMMER

Fig. 18: TANKWALL Modes of Operation

3. completely separates room air from contact with glazing;
4. room surface is leather texture and requires no further finishing and houses no recesses for dust collection;
5. eliminates evaporative loss from the water used for storage;
6. has horizontal baffles to prevent thermal stratification of water normally associated with vertical containers;
and
7. can be installed at less incremental cost than comparable field constructed passive systems.

Furthermore, the system seems particularly adaptable to mass production techniques, and, because it does not contribute to the structure of the house nor does it admit light, it is assumed that it would qualify for Federal Income Tax energy credits.

We have experienced only two problems in developing this product to the production stage. They are: (1) gelcoat problems in the area of sharp radius corners near the flange; and (2) developing sufficient strength to withstand the hydrostatic pressure of the water which caused splitting of the panel at the flange in early prototypes. Both of these problems have now been resolved.

We constructed the mold for the tankwall unit in two halves. That portion of the room side mold that would be exposed was

finished with a leather texture for a pleasing finished appearance. Once the molds were prepared, a gelcoat was sprayed in both molds, allowed to cure, and then three coats of chopper-gun fiberglass lay-up was applied. Before this lay-up could begin to cure, previously fabricated fiberglass stiffeners were positioned in the solar side of the mold using a polyester putty. Then both halves of the mold were clamped together and the lay-up allowed to cure as one solid piece. This effectively eliminated a possibility for water leakage.

After the parts were removed from the mold and trimmed, a 1" diameter hole was drilled in the top of the unit for the purpose of filling with water. In production, this hole will be capped with a plastic plug with a pinhole vent to allow for thermal expansion and contraction.

Mechanical testing of the first prototype resulted in two failures. First of all, the internal stiffening ribs separated from the flat portion of the panel, allowing it to bulge out excessively (4" to 6"). This occurred when the panel was approximately one-third full of water. We continued to fill the panel until it was about one-half full when the side seam at the flange split apart approximately 12" from the bottom of the panel. Subsequent structural analysis indicated that this location is the area of greatest potential failure due to hydrostatic stress.

After lay-up and positioning of the internal ribs, the two mold halves are clamped together prior to curing.

End of TANKWALL after stripping from molds, before trimming.

After repeating essentially the same failure twice, we began to investigate alternative methods of bonding the two halves together, and alternative designs for the stiffeners. The problem was finally resolved by designing the horizontal stiffener in such a way that it contacted both the front and back surface of the panel, thereby structurally tying the two together at several points of the height of the panel. While the geometric shape of the final internal baffle is complex, it has proven to be no problem in production (see Fig. 19).

We have resolved the gelcoat bubbling problem by allowing a short curing time between the second and third layer of fiberglass lay-up; this allows the fiberglass to cure to the gelcoat before pressure is applied in order to clamp the two halves together. Since this method was adapted, no problems have occurred.

The initial 2' x 8' module seems to work best in conjunction with plastic glazing (Exolite by Cy/Ro, or clear acrylic fiberglass) applied to the outside face of the studs. Because such glazing is either expensive, labor-intensive, or visually objectionable, other glazing alternatives were evaluated. Standard size patio door replacement glass is two layers insulated, tempered, and available nationwide at low costs. The cost of these glazing units is approximately 40% of the cost of custom size untempered glazing. Because of these cost advantages, we have developed a second size

Fig. 19a: TANKWALL mold (solar side) with Stiffening Rib

Fig. 19b: Room Side TANKWALL Mold with Stiffening Ribs (two sizes shown)

standard tankwall unit to allow the utilization of 34" by 76" standard patio door glass. Both units are currently in production.

While none of these units have been sold commercially, a number of home builders and manufactured house companies have expressed interest in these units. We feel that there is a cost advantage in these units compared with conventionally constructed passive solar systems of comparable performance and quality. We estimate the installed incremental cost of the 2' by 8' unit (compared with standard non-solar wall construction) to be between \$16 and \$18 per square foot retail. We expect the 34" by 76" unit to reduce this cost by \$2.00 per square foot. This size unit has the additional advantage that it can be installed horizontally which would allow a direct gain window unit above. This seems logical in northern climates where the only overheating problem seems to occur during autumn periods. At October, sun angles, all of the solar radiation would strike the tankwall unit and be stored to prevent overheating. At winter sun angles, the sun would be allowed to penetrate above the Tankwall unit for direct gain. This configuration has the obvious additional advantage of allowing view above the thermal storage. The two tanks are shown in Fig. 4.

Thermal Analysis using Passive Solar Test Cells

Prior to constructing the passive solar test cells, Mr. Moore

visited the Los Alamos Scientific Laboratory to study their test cell configuration monitoring equipment and procedures. Based on his study, we have constructed two separate passive solar test rooms in which to evaluate the components developed under this grant (see Figs. 20 and 21).

SERI has selected Aeolian Kinetics Data Acquisition System for their Class B monitoring program. After studying the manufacturer's literature and specifications on these units, their model PDL-24 unit was selected and ordered. However, as time went by, it became obvious that Aeolian Kinetics was substantially behind in production schedule, and delivery could not be affected before early Spring, 1981. At that point we examined alternative systems, and with the assistance of Dr. Joseph Simpson, have purchased and assembled a data acquisition system based on the Apple II plus microcomputer. This unit is adapted for data acquisition storage and processing through the use of hardware and software obtained from Connecticut Microcomputer Company.

By mid-January 1981 all the components of the system had been received. Assembly, software modifications and debugged delayed installation until mid-March. This phase took considerably longer than anticipated, principally due to problems of compatibility between components from various manufacturers and inexperience with thermal data acquisition systems. (Under an unrelated grant, Mr. Moore has acquired and installed an Aeolian Kinetics PDL-24 60 channel system to monitor the performance of a passive solar building. By comparison with the present custom Apple system, the AK system is judged superior in almost

Fig. 20: Test Cells; shows 4' x 8' solar aperture

Fig. 21: Test Cell Access Door,
North Side

every relevant respect. Specifically, it is a completely engineered system designed for passive solar monitoring, well documented and simple to install. The software was particularly well thought out and very flexible. This system is strongly recommended to other researchers who, like ourselves, lack extensive experience with DAS hardware and software.)

The present system's 16 channels were dedicated as follows:

- total radiation on south vertical surface (Licor pyronometer)
- ambient air temperature (thermistor with radiation shield)
- inside air temperature, each cell, 4' (thermistor with radiation shield)
- inside globe temperature, each cell, 4' (thermistor in black polyethylene globe)
- four additional temperature data points, each cell (thermistor)
- outside wind speed (maximum anemometer)
- outside wind direction (maximum indicator)

See Appendix A for D.A.S. technical description.

The test cells are of standard wood frame construction, with 3/8" painted plywood exteriors. The insulation is fiberglass (R-14 walls and floor and R-22 roof). All joints are tightly caulked, with a standard 2'8"x 6'8" insulated metal door with magnetic weatherstripping on the north. Except for the plywood floor, insulation was left exposed. A small induct fan provides a constant, forced infiltration rate; a

U-tube manometer was used to compare and match the rate in each cell (estimated at 1.2 ACH). No auxillary heat was provided.

Test Cells Calibration Tests (data: Appendix B)

Two tests were run to compare the non-solar heat losses of the test cells. In both tests, the south solar aperture was covered with R-21 foam insulating panels with edge seals. In the first test, a constant 1707 BTU/H auxillary heat source (two 250 watt heat lamps) was provided. During a representative period (Dec. 2 through 6) cell A maintained a relatively constant inside/outside temperature difference of 68°F, while cell B maintained a difference of 75°F. Using the equation:

$$HL = UA \text{ (temp. difference)}$$

and solving for UA (where HL = heat loss = heat gain), the rate of heat loss for cell A = 25.1 BTU/H°F and cell B = 22.8.

Based on A.S.H.R.A.E. published values, the R-value for the foam panel/glazing south wall is 23.2, which translates to a UA of 1.38 BTU/H°F for the 32 sq. ft. area.

Subtracting from the gross rate for each cell, the net non-solar measured loss rate is:

$$UA_a = 23.72 \text{ BTU/H°F}$$

$$UA_b = 21.42 \text{ BTU/H°F}$$

A similar test was run using a constant 852 BTU/H auxillary heat rate; these translated to

$$UA_a = 24.61 \text{ BTU/H°F}$$

$$UA_b = 22.14 \text{ BTU/H°F}$$

Averaging the results from these two tests, the non-solar heat loss rates were determined to be:

$$UA_a = 24.15 \text{ BTU/H}^\circ\text{F}$$

$$UA_b = 21.78 \text{ BTU/H}^\circ\text{F}$$

Because of the similarity of test cell construction, it is assumed that this difference is not due to conduction loss, but is attributable to differences in infiltration rate. Without the test equipment to immediately measure the infiltration rate directly (and thereby adjust the fan-forced infiltration rate with each cell), all of the following comparison tests were run with the infiltration rates unchanged. Therefore, the above heat loss differences will be considered in the interpretation of the test results.

Selective Surface vs. R 4.5 Night Insulation (data: Appendix B)

Two tests were conducted to compare the effectiveness of selective surfaces on TANKWALL to that of R 4.5 night insulation in March and October. After an initial stabilization period, the selective surface (with no night insulation) substantially out-performed the flat black absorber with R-4.5 night insulation. In the March tests, when the outside air temperature was higher, the difference was less (about 5° daily average). In the colder October, the selective surface performed even better with a daily average difference of about 10°. As expected the difference increased in both tests during the day and decreased at night.

Although insulation data was erratic (due to D.A.S. pro-

blems), it appears that selective surface performance is relatively better during cloudy periods. Notice that the selective surface cell maintains a higher interior temperature in spite of the greater net non-solar heat loss. When this is taken into account the difference is even greater.

These results seem consistent with those reported by Hyde (1) at Los Alamos, which indicated comparable performance with R-9 insulation.

TANKWALL (selective surface/no N.I.) vs. 7" dia. Metal Tubes
(flat black/R 4.5 N.I.) (data: Appendix B)

Because of D.A.S. system malfunction, further testing could not be resumed until May 15, 1981. Because of the small insulation available and small interior/exterior temperature difference, only general trends can be interpreted from this data. Recalling the higher non-solar heat loss rate of cell A, the data (pg. 21-27, Appendix B) indicates that the TANKWALL (selective surface) maintains a consistently higher interior air temperature than the black tubes with R 4.5 night insulation. Both seem to flatten interior temperatures almost identically (expected due to similar amounts of thermal mass). Neither introduces the time delay associated with masonry storage walls because internal convection of water results in the immediate (although reduced) effect of exterior temperature variations on interior air temperature.

Pages 28-32 show that the selective surface absorber maintains a consistently higher surface temperature than did the

flat black with the difference being greatest during daytime hours. These results are reasonable due to the lower emissivity of the selective surface and the reduction of radiant loss to the glazing.

Pages 33-37 show water temperatures at 2' and 6' heights in the TANKWALL vs 7" water tubes in the same test. As expected relatively small vertical temperature variation (4°F average, 8° max.), while there was more variation in the water tubes (8°F average, 17° max.): This is attributable to the internal structural ribs in the TANKWALL which serve as baffles restricting vertical circulation.

TANKWALL (selective surface/ no N.I.) vs Clear F.G. 11" dia.
Water Tubes (with R 4.5 N.I.) (data: Appendix B

In the Oct. 31 tests, the inside air temperature in the tube cell averaged 8°F warmer than the TANKWALL cell; however, considering the greater non-solar losses in the TANKWALL cell the overall performance of the two is about equal (see pg 38). As expected, the selective surface helped the TANKWALL during the day.

These results are surprising as better performance of the TANKWALL was expected; further testing is indicated for the clear tubes.

CONCLUSIONS

Based on these thermal tests, the following conclusions have been reached:

1. The overall thermal performance of selective surfaced water wall is better than flat black with R-4.5. night insulation (and is probably comparable to R-9 as reported by Hyde).
2. The selective surfaces offer their greatest performance advantage under cloudy or cold conditions.
3. The interior baffles in the TANKWALL are effective in reducing internal water temperature stratification.
4. The TANKWALL configuration outperforms black metal water tubes with R-4.5 night insulation.

FUTURE PLANS

1. TANKWALL, TUBE WALL, and fiberglass tubes are in production. We are negotiating with two different firms to handle the marketing of these products.
2. A number of developments have resulted from this contract; we are continuing work on these under a second grant recently received under this same program. These are described in the application for that grant, a copy of which is attached as Appendix C.

REFERENCES

- Balcomb, J. D., et al., Passive Solar Design Handbook, Vol. 2., National Technical Information Service, Springfield, Virginia, 1979.
- Buckley, S., "Thermic Diode Solar Panels," Proceedings, Passive Solar Heating and Cooling Conference, Albuquerque, New Mexico, 1976, p. 288.
- Hyde, J. C., "Performance of Night Insulation and Selective Absorber Coatings in LASL Test Cells," Proceedings 5th National Passive Solar Conference, Amherst, 1980, p. 277-281.

Budget Data

Item	Budget	Interim	Total Cost
1. Salaries & Wages			
Paul Hemker	7200	3000	7200
Fuller Moore	2400	2400	2400
Other	1800	1498.50	1829.54
Total	11400	6898.50	11429.54
2. Fringe Benefits	-	-	-
3. Equipment	11070	10315.32	11429.54
4. Materials	4425	4215.60	4831.34
5. Space Rental	600	300	600
6. Supplies	300	75	467.19
7. Travel	-	-	-
8. Consultants	400	-	330
9. Other Direct Costs	75	45	45
10. Indirect Costs	-	-	-
11. Total Project	28270	21849.42	28553.75
12 Cost Sharing	3200	-	3483.75
DOE Share	25070	21849.42	25070

Voucher Paymnets:

#1	3000
#2	18849.42
#3	3220.58

APPENDIX A

TECHNICAL DESCRIPTION: SOLAR ENERGY DATA ACQUISITION SYSTEM

A microcomputer-based data acquisition system was designed to support experimental comparison of passive solar energy heating systems. Seven temperature probes and one silicon cell pyranometer are monitored in each of two test sheds.

An Apple II Plus microcomputer was selected to collect and analyse data on the basis of ease of programming, ease of interfacing, and availability of local maintenance. Although a single disk system would support the actual data collection process, a second disk was acquired to support program development and maintenance. The hardware configuration and a list of suppliers can be found in Appendix A. Figure 1, EQUIPMENT CONFIGURATION, may be referred to during the following discussion of the interfacing hardware.

Date and time information are an integral part of both the data acquisition process and data record. A CSS7424 Clock Calendar card was included to provide data and time information accurate to one second. This card has a battery backup to preserve time and date when the computer is powered down. PROM software supports business data processing applications, but interface software was written to support this application.

A Connecticut Microcomputer AIM16, 16 channel, 8 bit, analog-to-digital converter was selected to convert temperature and pyranometer data. This product is fast, easy to control in software, and expandable. A screw terminal accessory makes testing and hookup simple. The external power supply has two advantages. First, it conserves power in the Apple II power supply. Second, it offers an additional degree of electrical isolation of A/D signal and power lines from the Apple II. The same company supplied TEMPSENS2 temperature sensor modules. Each module allows easy hookup of two diode temperature sensors

to the AIM16 through a shared operational amplifier module. The probes are linear over a 170°F range and are accurate to 1°F. The low resistance of the diode sensors improves noise immunity. LICOR silicon cell pyranometers were fed through a custom built operational amplifier designed for extreme temperature stability to avoid spurious correlations between ambient temperature and radiant solar energy readings. These sensors have a rated accuracy of +5%. The circuit diagram for this amplifier can be found in Appendix A.

A Maximum Wind Direction sensor is interfaced to a 16 bit parallel input port through a second custom interface. The same custom interface converts the AC signal from a Maximum type 40 anemometer to a square wave which is counted by a CCS7440 programmable timer. Wind direction can be resolved to 16 points of the compass. The threshold for wind speed indication is approximately three miles per hour. The resolution is approximately one mph. The circuit diagram for the interface to these devices is in Appendix A.

The test sheds are located approximately 150 feet from the computer. Over this distance noise and signal lease is a real concern. Analog signals are fed over 18 gauge paired conductor wire to minimize resistance and eliminate common impedance signal coupling. The amplifiers for the diode sensors are located near the computer. The low resistance of the diode sensors alleviates noise pickup. The silicon cell pyranometers present a more difficult problem. They are high impedance, very low voltage devices. The operational amplifiers are located approximately 30 feet from the sensors and 100 feet from the analog to digital converter. Even with coaxial cable, care had to be exercised to avoid noise pickup. The custom pyranometer amplifier and weather station interfaces were designed with overvoltage protection for the Apple II.

SOFTWARE

The software written to support this application comprises three programs: the CONFIGURATION MANAGER, the DATA COLLECTOR, and the DATA ANALYSOR. Data is sensed at user selected intervals. A user defined number of sensor sweeps are aggregated to form a single sample. Each sample is written to disk immediately after its formation. This minimizes data loss in the event of system failure. The stored sample includes a time and date stamp, the number of sensor sweeps, and (for each sensor), the minimum, maximum, mean, and variance. Time is computed as seconds past midnight of the current day. The exact timing of sensor sweeps and sample storage is computed in such a manner that these events are independent of the exact time at which an experiment is started. For example, if an experiment is started at 8:15:10 with a 60 second sweep interval and 60 sweeps per sample, the first sensor sweep will occur at 8:16:00 and the first sample will be stored at 9:00:00. Query of interface boards was done via an assembly language accessed from Applesoft as a USR function. The argument to the function determines which data element should be returned. This USR simplifies the programming of the BASIC language data collection program. Listings of all programs can be found in Appendix B.

The three programs discussed above use two data files on disk, a CONFIGURATION file and a DATA COLLECTION file. The CONFIGURATION file contains a description of the experimental configuration, including sensor labels and scaling information used to convert the data from raw form to standard measurement units. Each data file contains as a preface, a copy of the CONFIGURATION file defining the experimental equipment setup. An arbitrary number of samples is appended to this preface.

Exercising the software to conduct an experiment requires three separate

steps. First an appropriate CONFIGURATION FILE must be identified or created with the CONFIGURATION MANAGER. Second, the DATA COLLECTOR must be run to collect the data. The first time the DATA COLLECTOR is run the user will have to supply the name of an existing CONFIGURATION FILE defining the experimental setup, a name to be used to identify the DATA COLLECTION file, a title to be used as internal documentation for the DATA COLLECTION file, and sample rate and aggregation information. If the experiment is interrupted and restarted, the user will have to supply the DATA COLLECTION file name. The DATA COLLECTOR will then retrieve the configuration definition from the file and ask the user to confirm the accuracy of the DATA COLLECTION file name. If the user confirms the file, sample rate and aggregation will be requested and data collected will be added to the existing file. During data collection the user can request a display of the current sample to verify the integrity of the data collection.

A printed record of the experiment is obtained as the third step. Data may be displayed on the monitor, printed on a printer, or graphed on a printer. The graph is a character cell plot and may be printed on any 80 column printer connected to the Apple. Data reports can be restricted to a consecutive set of days.

APPENDIX A

Table of Hardware.

Table of Suppliers.

Pyranometer operational amplifier circuit diagram.

Weather station interface circuit diagram.

EQUIPMENT

Apple II Plus microcomputer. 48K RAM, 2 disk drives, printer, monochrome monitor.

CSS7424 Clock Calendar. Year, month, day of month. Hours, minutes, seconds.

CSS7440 Programmable Timer. Three 16 bit gates counters.

AIM16 A/D Converter from Connecticut Microcomputer. APSET1a option. 16 channels, 8 bits, 100 microseconds maximum conversion time.

SSM A/10 Serial and Parallel Interface. Two 8 bit parallel ports, 1 serial port (unused).

Maximum type 40 generator anemometer.

Maximum Wind Direction Sensor. Contact sensor resolves 16 points of compass.

Custom built 2 channel operational amplifier for pyranometers.

Custom built weather data interface.

LICOR LI-200SB silicon cell pyranometer with CALCONNECTOR $\pm 5\%$

TEMPSENS2 diode temperature sensors. 170⁰F linear range, 1⁰F accuracy.

EQUIPMENT SUPPLIERS

Maximum Inc.
42 South Avenue
Natick, Mass 01760
(617) 785-0113

California Computer Systems

Santa Clara, California 95050

Connecticut Microcomputer, Inc.
150 Pocono Road
Brookfield, Connecticut 06804
(203) 775-9659

LI-COR, Inc.
4421 Superior Street
P.O. Box 4425
Lincoln, Nebraska 68504
(402) 467-3576

Analog Devices Inc.
Route 1 Industrial Park
P.O. Box 280
Norwood, Mass 02062
(617) 329-4700

SSM Microcomputer Products
2190 Paragon Drive
San Jose, CA 95131
(408) 946-7400

Fig 1: System Schematic

SOURCE FILE: SOLARUSR

```

0000:      1 *ROUTINE      SOLARUSR
0000:      2 *ENVIRONMENT  APPLEII PLUS
0000:      3 *FUNCTION      USR ACCESS TO SEVERAL INTERFACES
0000:      4 *ORIGON        JOSEPH C. SIMPSON
0000:      5 *USAGE          ?CHR$(4);"BRUN RBOOT"
0000:      6 *               XO=USR(0),"SOLARUSR.OBJ0"
0000:      7 *               CALL XO:REM INITIALIZE USR
0000:      8 *               ?USR(I)
0000:      9 *               I      VALUE RETURNED
0000:     10 *               0-15   AIM16 A/D CHANNELS
0000:     11 *               16     READ PARALLEL PORT A
0000:     12 *               17     READ 7440 PROG TIMER 3
0000:     13 *               18     READ CCS7424 CLOCK/CAL.
0000:     14 *               RETURN SECONDS PAST MIDNIGHT
0000:     15 *
000A:     16 USRVEC      EQU  $0A      ;APPLEII USR VECTOR(JUMP USRRoutine)
009D:     17 FAC         EQU  $9D      ;APPLESOFT FLT.PT.ACCUMULATOR
00A0:     18 FACMD       EQU  $A0      ;APPLESOFT ELEMENT OF FAC
00A1:     19 FACLO       EQU  $A1      ;APPLESOFT ELEMENT OF FAC
E10C:     20 AYINT      EQU  $E10C    ;APPLESOFT FAC=>INT AT FAC(MD,LO)
E2F2:     21 GIVAYF     EQU  $E2F2    ;APPLESOFT INT IN A,Y TO FP IN FAC
E301:     22 SNGFLT     EQU  $E301    ;FLOAT UNSIGNED INTEGER IN Y
FDDA:     23 FRBYTE     EQU  $FDDA
0000:     24 *
0003:     25 TIMRSLOT     EQU  3        ;CCS7440 PROGRAMABLE TIMER SLOT
C0B0:     26 TCR1       EQU  $10*TIMRSLOT+$C0B0 ;CNTL REG 1(CR20=0)
C0B1:     27 TCR2       EQU  TCR1+1    ;CNTL REG 2
C0B0:     28 TCR3       EQU  TCR1      ;CNTL REG3 (CR20=1)
C0B6:     29 TMSB3      EQU  $10*TIMRSLOT+$C0B6 ;TIMER MSB COUNTER 3
C0B7:     30 TLSB3      EQU  TMSB3+1    ;TIMER LSB COUNTER 3
0000:     31 *
EB63:     32 MOVAF      EQU  $EB63     ;APPLESOFT MOVE FAC TO ARG
E7BE:     33 FADD       EQU  $E7BE     ;APPLESOFT FAC=ARG+FAC
E97F:     34 FMULT      EQU  $E97F     ;APPLESOFT FAC=ARG X FAC
EB21:     35 MOV1F      EQU  $EB21     ;APPLESOFT PACK FAC TO TEMP ARG #1
0093:     36 TEMP1      EQU  $93        ;APPLESOFT FP TEMP REG #1
FCA8:     37 WAIT       EQU  $FCA8     ;APPLE II WAIT ROUTINE
0005:     38 AIM16SLOT    EQU  5        ;AIM16 A/D CONVERTER SLOT
C0D0:     39 AIM16REG    EQU  $10*AIM16SLOT+$C0D0
0000:     40 *
0002:     41 SSMSLOT     EQU  2          ;SSM AIO SLOT
C0A0:     42 ADATA      EQU  $10*SSMSLOT+$C0B0 A DATA AND DATA DIRECTION REGI
TER
C0A1:     43 ACON       EQU  ADATA+1    ;PORT A CONTROL REG
0000:     44 *
0004:     45 CCALSLOT    EQU  4          ;CCS7424 CLOCK/CALENDAR SLOT
C0C0:     46 CCALDR     EQU  CCALSLOT*$10+$C0B0 ;CCS7242 DATA REGISTER
C0C1:     47 CCALCR     EQU  CCALDR+1    ;CONTROL REGISTER
0000:     48 *
0000:     49 *
0000:     50 * PATCH =1 =>FORCED WAIT FOR AIM16
0000:     51 *
0000:     52 PATCH       EQU  0          ;FORCE AIM16 TO WAIT 100 MICROSEC
--- NEXT OBJECT FILE NAME IS SOLARUSR.OBJ0
0000:     53             ORG  $8000
0000:A9 4C          54 INIT      LDA  #$4C      ;LOAD APPLESOFT USR VECTOR
0002:85 0A          55             STA  USRVEC

```


8004:A9 22	56	LIA	#>USR	
8006:85 0B	57	STA	USRVEC+1	
8008:A9 80	58	LIA	#<USR	
800A:85 0C	59	STA	USRVEC+2	
800C:	60 *			
800C:	61 *	INITIALIZE AIM16 A/D		
800C:	62 *			
800C:A9 00	63	LIA	#0C	
800E:8D D0 CO	64	STA	AIM16REG	
8011:	65 *			
8011:	66 *	INITIALIZE TIMER		
8011:	67 *			
8011:20 78 80	68	JSR	TIMERINIT	
8014:	69 *			
8014:	70 *	INITIALIZE PARALLEL I/O		
8014:	71 *			
8014:A9 00	72	LIA	#0	
8016:8D A1 CO	73	STA	ACON	;SELECT DDR
8019:8D A0 CO	74	STA	ADATA	;8 LINE INPUT
801C:A9 04	75	LIA	#4	
801E:8D A1 CO	76	STA	ACON	;SELECT DATA REGISTER
8021:	77 *			
8021:	78 *	INITIALIZATION COMPLETE		
8021:	79 *			
8021:60	80	RTS		
8022:	81 *			
8022:	82 *	USR ENTRY		
8022:	83 *			
8022:20 0C E1	84	USR	JSR AYINT	;CONVERT ARG TO INTEGER
8025:A5 A0	85	LIA	FACMO	
8027:F0 06	86	BEQ	USR1	;ARG IS SMALL POSITIVE INTEGER
8029:A9 00	87	BADARG	LIA #0	;PUT ZERO AND EXIT ON INVALID ARG
802B:A8	88	TAY		
802C:4C 74 80	89	JMP	EXIT	
802F:A5 A1	90	USR1	LIA FACLO	;ARG OF USR
8031:C9 10	91	CMF	#16	;IS IT AIM16?
8033:10 1A	92	BFL	PARALLEL	;NO
8035:	93 *			
8035:	94 *	AIM16 READ ROUTINE		
8035:	95 *			
8035:8D D0 CO	96	STA	AIM16REG	;SELECT CHANNEL AND START CONVERSION
8038:A9 28	97	LIA	#40	
803A:8D D0 CO	98	STA	AIM16REG	;ENABLE DATA
803D:AD D0 CO	99	ADCONVT	LIA AIM16REG	
0000:	100	D0	PATCH	
8040	101	LIA	#06	
8040	102	JSR	WAIT	
8040:	103	FIN		
8040:10 FE	104	BFL	ADCONVT	;WAIT UNTIL CONVERSION COMPLETE
8042:A5 CO	105	LIA	#CO	
8044:8D D0 CO	106	STA	AIM16REG	;START STROBE , PUT DATA IN REGISTER
8047:AC D0 CO	107	LDY	AIM16REG	
804A:A9 00	108	LIA	#0	
804C:4C 74 80	109	JMP	EXIT	
804F:	110 *			
804F:	111 *	SSM AIO PARALLEL PORT A		
804F:	112 *			
804F:C9 10	113	PARALLEL	CMF #16	;IS REQUEST FOR PARALLEL?
8051:D0 0B	114	BNE	TIMER	
8053:AD A0 CO	115	LIA	ADATA	

8056:25 0F	116	AND	%OF	%ONLY NEED 4 BITS
8058:A8	117	TAY		
8059:A9 00	118	LDA	%0	
805B:4C 74 80	119	JMP	EXIT	
805E:	120 *			
805E:	121 *			
805E:	122 *			
805E:C9 11	123	TIMER	CMP	%17 ;IS TIMER REQUEST?
8060:D0 31	124		BNE	SECONDS ;NO
8062:AD B6 C0	125		LDA	TMSB3
8065:49 FF	126		EOR	%OFF ;1'S COMPLEMENT SINCE TIMER COUNTS DOWN
8067:48	127		PHA	
8068:AD B7 C0	128		LDA	TLSEB3
806B:49 FF	129		EOR	%OFF
806D:48	130		PHA	
806E:20 78 80	131		JSR	TIMERINIT
8071:68	132		PLA	
8072:A8	133		TAY	
8073:68	134		PLA	
8074:20 F2 E2	135	EXIT	JSR	GIVAYF ;TRANSFER A,Y TO FT IN FAC
8077:60	136		RTS	
8078:A9 02	137	TIMERINIT	LDA	%2
807A:8D B1 C0	138		STA	TCR2 ;SELECT REG 3
807D:8D B0 C0	139		STA	TCR3 ;REG 3 CONTINUOUS,NO DIVIDE,EXT.CLK.
8080:A9 FF	140		LDA	%FF ;WRITE TIMER LATCHES
8082:8D B6 C0	141		STA	TMSB3
8085:8D B7 C0	142		STA	TLSEB3
8088:A9 01	143		LDA	%1
808A:8D B1 C0	144		STA	TCR2 ;SELECT REG 1
808D:	145 *	STA	TCR1	;RESET TO TRANSFER LATCHES TO COUNTER
808D:A9 00	146		LDA	%0
808F:8D B0 C0	147		STA	TCR1 ;ENABLE COUNTER
8092:60	148		RTS	
8093:	149 *			
8093:	150 *			
8093:	151 *			
8093:C9 12	152	SECONDS	CMP	%18
8095:F0 03	153		BEQ	SECOK
8097:4C 29 80	154		JMP	BADIARG
809A:20 26 B1	155	SECOK	JSR	SAVMUL
809D:A0 25	156		LDY	%25
809F:A2 05	157		LIX	%5
80A1:8C C1 C0	158	SLOOP	STY	CCALCR
80A4:8C C1 C0	159		STY	CCALCR
80A7:8C C1 C0	160		STY	CCALCR
80AA:AD C0 C0	161		LDA	CCALDR
80AD:29 0F	162		AND	%F ;BLANK HIGH NIBBLE(ALWAYS =F)
80AF:9D 1B B1	163		STA	TREG,X
80B2:88	164		DEY	
80B3:CA	165		DEX	
80B4:10 EB	166		BPL	SLOOP
80B6:AD 20 B1	167		LDA	TREG+5 ;GET HOURS
80B9:29 03	168		AND	%3
80BB:20 42 B1	169		JSR	MUL10
80BE:18	170		CLC	
80BF:6D 1F B1	171		ADC	TREG+4
80C2:AC 20 B1	172		LDY	TREG+5
80C5:C0 08	173		CPY	%8 ;IS 24 HOUR FORMAT?
80C7:10 07	174		BPL	HEND ;YES

80C9:C0	04	175	CPY	#4	;PM?
80CB:30	03	176	BMI	HEND	;NO
80CD:18		177	CLC		
80CE:69	0C	178	ADC	#12	
80D0:A0	3C	179	LDY	#60	
80D2:20	4B 81	180	JSR	MUL8X8	;CONVERT TO MINUTES
80D5:8D	1F 81	181	STA	TREG+4	
80D8:8C	20 81	182	STY	TREG+5	
80DB:AD	1E 81	183	LDA	TREG+3	;GET MINUTES
80DE:29	07	184	AND	#7	
80E0:20	42 81	185	JSR	MUL10	
80E3:18		186	CLC		
80E4:6D	1D 81	187	ADC	TREG+2	
80E7:6D	1F 81	188	ADC	TREG+4	
80EA:90	03	189	BCC	MIN1	
80EC:EE	20 81	190	INC	TREG+5	
80EF:A8		191	TAY		
80F0:AD	20 81	192	LDA	TREG+5	
80F3:20	F2 E2	193	JSR	GIVAYF	;CNVT TO FF MIN
80F6:A9	21	194	LDA	#>SIXTY	
80F8:A0	81	195	LDY	#<SIXTY	
80FA:20	7F E9	196	JSR	FMULT	
80FD:20	21 E8	197	JSR	MOV1F	
8100:AD	1C 81	198	LDA	TREG+1	
8103:29	07	199	AND	#7	
8105:20	42 81	200	JSR	MUL10	
8108:18		201	CLC		
8109:6D	1B 81	202	ADC	TREG	
810C:A8		203	TAY		
810D:20	01 E3	204	JSR	SNGFLT	
8110:A0	00	205	LDY	#00	
8112:A9	93	206	LDA	#TEMP1	
8114:20	BE E7	207	JSR	FAID	
8117:20	31 81	208	JSR	RSTMUL	
811A:60		209	RTS		
811B:		210	TREG	DS 6	;CLOCK CALENDAR SCRATCH SPACE
0006:		211	TEMP	EQU #6	;USE 6,7,8 OF ZERO PAGE FOR SPEED
8121:86	70 00	212	SIXTY	DFB \$86,\$70,\$00,\$00,\$00	;APPLESOFT PACKED 60.0
8124:00	00				
8126:		213	*		
8126:		214	*		
8126:		215	*		
8126:A2	05	216	SAVMUL	LIX #5	
8128:B5	D0	217	SAVMUL1	LIA #I0,X	
812A:9D	3C 81	218		STA SVI0,X	
812D:CA		219		DEX	
812E:10	FB	220		BPL SAVMUL1	
8130:60		221		RTS	
8131:A2	05	222	RSTMUL	LIX #5	
8133:BD	3C 81	223	RSTMUL1	LIA SVI0,X	
8136:95	D0	224		STA #I0,X	
8138:CA		225		DEX	
8139:10	FB	226		BPL RSTMUL1	
813B:60		227		RTS	
813C:		228	SVI0	DS 6	;SAVE 6 BYTES FOR #I0,#I5 RESTORE
8142:0A		229	MUL10	ASL A	
8143:85	06	230		STA TEMP	
8145:0A		231		ASL A	
8146:0A		232		ASL A	
8147:18		233		CLC	

8148:65 06	234	ADC	TEMP	
814A:60	235	RTS		
814B:	236	*		
814B:	237	* 8X8 UNSIGNED INT MULT FROM MICRO DEC 1980		
814B:	238	* MULTIPLYING ON THE 6502, BROOKE W. BOERING		
814B:	239	*		
0006:	240	FLIER	EQU	TEMP
0007:	241	CAND	EQU	TEMP+1
0008:	242	ANSLO	EQU	TEMP+2
814B:85 06	243	MUL8X8	STA	FLIER ;SAVE (MULTI)PLIER
814D:84 07	244		STY	CAND ;SAVE (MULTIPLI)CAND
814F:A9 00	245		LIA	#\$00 ;RA=RESULT HIGH
8151:A0 08	246		LIY	#\$08 ;SET 8 BIT COUNTER
8153:46 06	247	MUL1Y	LSR	FLIER ;TEST NEXT BIT
8155:90 03	248		BCC	MUL2Y ;IF OFF, GO ROUND
8157:18	249		CLC	
8158:65 07	250		ADC	CAND ;IF ON, ADD
815A:6A	251	MUL2Y	ROR	A ;SHIFT ANSWER 1 BIT
815B:66 08	252		ROR	ANSLO
815D:88	253		DEY	;DECREMENT 8 BIT COUNTER
815E:D0 F3	254		BNE	MUL1Y ;LOOP UNTIL DONE 8 BITS
8160:A8	255		TAY	;Y=RESULT HIGH BYTE
8161:A5 08	256		LIA	ANSLO ;A=RESULT LO BYTE
8163:60	257		RTS	

*** SUCCESSFUL ASSEMBLY: NO ERRORS

COA1 ACON
05 AIM16SLOT
07 CAND
8074 EXIT
E7RE FAID
8000 INIT
8142 MUL10
804F PARALLEL
8131 RSTMUL
809A SECDK
E301 SNGFLT
COB1 TCR2
8078 TIMERINIT
COB6 TMSB3
0A USRVEC

COA0 ADATA
08 ANSLO
COC1 CCALCR
9D FAC
E97F FMULT
80EF MIN1
8153 MUL1Y
00 PATCH
8133 RSTMUL1
8093 SECONDS
02 SSMSLOT
COB0 TCR3
805E TIMER
811B TREG
7FCAB WAIT

803D ADCONVT
E10C AYINT
COC0 CCALDR
A1 FACLO
E2F2 GIVAYF
EB21 MOV1F
815A MUL2Y
06 FLIER
8128 SAVMUL1
8121 SIXTY
813C SVD0
06 TEMP
03 TIMRSLOT
8022 USR

COD0 AIM16REG
8029 BADIARG
04 CCALSLOT
A0 FACMO
80D0 HEND
7EB63 MOVAF
814B MUL8X8
7FDDA PREYTE
8126 SAVMUL
80A1 SLOOP
COB0 TCR1
93 TEMP1
COB7 TLSB3
802F USR1

00 PATCH	02 SSMSLOT	03 TIMRSLOT	04 CCALSLOT
05 AIM16SLOT	06 TEMP	06 FLIER	07 CAND
08 ANSLO	0A USRVEC	93 TEMP1	? 9D FAC
A0 FACMO	A1 FACLO	?8000 INIT	8022 USR
1029 BADIARG	802F USR1	803D ADCONVT	804F PARALLEL
105E TIMER	8074 EXIT	8078 TIMERINIT	8093 SECONDS
809A SECONK	80A1 SLOOP	80D0 HEND	80EF MIN1
811B TREG	8121 SIXTY	8126 SAVMUL	8128 SAVMUL1
8131 RSTMUL	8133 RSTMUL1	813C SVD0	8142 MUL10
814B MUL8X8	8153 MUL1Y	815A MUL2Y	COA0 AIDATA
COA1 ACON	COB0 TCR1	COB0 TCR3	COB1 TCR2
COB6 TMSB3	COB7 TLSB3	COC0 CCALDR	COC1 CCALCR
COD0 AIM16REG	E10C AYINT	E2F2 GIVAYF	E301 SNGFLT
E7BE FADD	E97F FMULT	EB21 MOV1F	?EB63 MOVAF
?FCAB WAIT	?FDIA FRBYTE		

LOAD DATA ANALYSOR
LIST

26 JUNE 81

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10 REM DATA ANALYSIS ROUTINE
20 DEF FN HOUR(X) = INT (X / 3600)
30 DEF FN MIN(X) = INT ((X - 3600 * FN HOUR(X)) / 60)
40 DEF FN SEC(X) = X - 60 * INT (X / 60)
50 DIM MTH$(12):SLOT = 4: REM CCS7424 CLOCK/CALENDAR SLOT
60 MT$(1) = "JAN":MT$(2) = "FEB":MT$(3) = "MAR":MT$(4) = "APR":MT$(5) = "M
  AY":MT$(6) = "JUN"
70 MT$(7) = "JUL":MT$(8) = "AUG":MT$(9) = "SEP":MT$(10) = "OCT":MT$(11) =
  "NOV":MT$(12) = "DEC"
80 COM$ = "DPGE":NC = LEN (COM$)
90 PLN = 60: DIM PP(PLN): REM PRINTER WIDTH
91 DEF FN ROUND(X) = INT (10 * X + .5) / 10
95 DIM PS(50),PC(50)
100 PSLOT = 0: REM PRINTER SLOT NUMBER
110 D$ = CHR$(4):SAFE = 1:KBD = - 16384:KSTRB = - 16368:CL = - 958
120 HOME
122 SPEED= 255
125 PRINT TAB( 10);"DATA ANALYSIS ROUTINE"
290 PRINT "D)ISPLAY P)RINT G)RAPH E)XIT"
300 INPUT "ENTER COMMAND:";C$: IF C$ = "" THEN 300
310 C$ = LEFT$(C$,1): FOR IC = 1 TO NC: IF C$ = MID$(COM$,IC,1) THEN 3
  80
320 NEXT IC: PRINT "COMMAND NOT RECOGNIZED"
330 PRINT "D-DISPLAY      DISPLAY DATA ON SCREEN"
340 PRINT "P-PRINT      PRINT DATA ON PRINTER"
350 PRINT "G-GRAPH      GRAPH DATA ON PRINTER"
360 PRINT "E-EXIT      EXIT PROGRAM"
370 GOTO 290
380 IF IC = NC THEN END
390 INPUT "ENTER STARTING AND ENDING DATES";DL$,DH$
400 C$ = DL$: GOSUB 9500:DL$ = C$: IF I = 1 THEN PRINT "ENTER TWO DATES S
  EPARATED BY A COMMA": GOTO 390
410 C$ = DH$: GOSUB 9500:DH$ = C$: IF I = 1 THEN PRINT "ENTER TWO DATES S
  EPARATED BY A COMMA": GOTO 390
415 IF IC = 3 THEN GOSUB 6200: REM INITIALIZE PLOTTING
420 GOSUB 1200
430 PRINT TI$
450 ON IC GOSUB 7000,7500,7612
505 PRINT D$;"CLOSE ";F$
510 GOTO 120
1200 : REM LOAD AN EXISTING DATA COLLECTION FILE
1205 INPUT "ENTER NAME OF DATA FILE:";F$: IF F$ = "" THEN 1205
1207 IF IC = 2 OR IC = 3 THEN PRINT D$;"PR#";PSLOT
1210 GOSUB 1540: INPUT TI$
1230 LO = 0:HI = NS: GOSUB 3030
1240 RETURN
1500 : REM LOAD CONFIGURATION DEFINITION
1540 PRINT D$;"OPEN ";F$: PRINT D$;"READ ";F$
1560 INPUT NS: INPUT T$:
1562 DIM L$(NS),S(NS),C(NS),D(NS),V(NS),DL(NS),DH(NS)
1565 FOR I = 0 TO NS: INPUT L$(I): INPUT S(I): INPUT C(I): NEXT I
1590 RETURN
3000 : REM DISPLAY COMMAND
3030 UTAB (3): CALL CL: IF F$ > < "" THEN PRINT "FILE ";F$: " ";
3040 PRINT "TITLE=";T$

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3042 PRINT "SENSOR LABEL"; SPC( 11);"SLOPE"; SPC( 4);"CONSTANT"
3044 C$ = " "
3050 FOR I = LO TO HI: PRINT RIGHT$ ( " " + STR$ (I),2); LEFT$ (L$(I) +
C$,20); RIGHT$ (C$ + STR$ (S(I)),10); RIGHT$ (C$ + STR$ (C(I)),10)
3060 NEXT I: RETURN
4500 : REM READ ONE OBSERVATION
4530 INPUT DA$: INPUT TIME: INPUT IAVE: INPUT SS
4540 FOR I = 1 TO NS: INPUT D(I): INPUT V(I): INPUT DL(I): INPUT DH(I)
4547 NEXT I
4560 RETURN
6000 : REM YESNO
6010 C$ = LEFT$ (C$,1): IF C$ = "Y" THEN I = 1: RETURN
6020 IF C$ = "N" THEN I = 2: RETURN
6030 I = 3: RETURN
6200 : REM INITIALIZE PLOTTING
6210 VTAB (3): CALL CL
6220 PRINT TAB( 10);"INITIALIZE PLOTTER"
6225 FOR I = 1 TO NS:PS(I) = 0:PC(I) = 0: NEXT I
6230 INPUT "ENTER A SENSOR NUMBER(NN) OR A SENSOR RANGE(MM-NN) ";C$
6240 GOSUB 9100
6250 PRINT "FOR SENSOR ";LO;
6260 IF HI > < LO THEN PRINT " TO ";HI;
6270 PRINT : INPUT "ENTER MIN,MAX VALUES FOR THE AXIS";MIN,MAX
6271 IF MIN > = MAX THEN 6270
6280 FOR I = LO TO HI:PS(I) = (PLN - .001) / (MAX - MIN):PC(I) = 1 - MIN *
PS(I): NEXT I
6290 INPUT "PLOT MORE SENSORS?";C$
6300 GOSUB 6000: ON I GOTO 6230,6310,6290
6310 RETURN
6500 : REM INITIALIZE PRINTER
6520 PRINT CHR$ (4);"PR#";PSLOT
6590 RETURN
6600 : REM TURN OFF PRINTER
6610 PRINT CHR$ (4);"PR#0"
6690 RETURN
7000 : REM DISPLAY COMMAND
7010 GOSUB 4500
7012 C$ = DL$: GOSUB 8700
7013 ON I GOTO 7014,7014,7010
7014 C$ = DH$: GOSUB 8700
7016 ON I GOTO 7235,7019,7019
7019 REM DISPLAY COMMAND
7160 PRINT DA$: SPC( 4); FN HOUR(TIME);":": FN MIN(TIME);":": FN SEC(TIME)
);" N ";IAVE;" SENSOR SWEEP";SS
7170 PRINT "SENSOR"; SPC( 5);"MEAN"; SPC( 5);"VAR"; SPC( 6);"HIGH"; SPC(
5);"LOW"
7180 C$ = " " : FOR I = 0 TO NS
7200 PRINT RIGHT$ ( " " + STR$ (I),4); SPC( 4); RIGHT$ (C$ + STR$ (D(
I)),7);
7210 PRINT RIGHT$ (C$ + STR$ (V(I)),07);" "; RIGHT$ (C$ + STR$ (DH(I)
),07); RIGHT$ (C$ + STR$ (DL(I)),07)
7220 NEXT I
7230 GOTO 7000
7235 RETURN
7500 : REM PRINT COMMAND
7510 GOSUB 4500:C$ = DL$: GOSUB 8700: ON I GOTO 7520,7520,7510
7520 C$ = DH$: GOSUB 8700: ON I GOTO 7630,7630,7530
7530 PRINT DA$;" " : GOSUB 8500: PRINT
7540 FOR J = 0 TO NS STEP 8:K = J + 7: IF K > NS THEN I = PS
7550 PRINT "SENSOR " : FOR I = J TO K: PRINT RIGHT$ ( " " + STR$ (I),4); SPC( 4);

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(I),9): NEXT I: PRINT
7560 PRINT "MEAN " ;: FOR I = J TO K: PRINT RIGHT$ (" " + STR$
(D(I)),9): NEXT I: PRINT
7570 PRINT "VAR " ;: FOR I = J TO K: PRINT RIGHT$ (" " + STR$
(V(I)),9): NEXT I: PRINT
7580 PRINT "HIGH " ;: FOR I = J TO K: PRINT RIGHT$ (" " + STR$
(DH(I)),9): NEXT I: PRINT
7590 PRINT "LOW " ;: FOR I = J TO K: PRINT RIGHT$ (" " + STR$
(DL(I)),9): NEXT I: PRINT
7600 NEXT J
7610 GOTO 7510
7611 GOSUB 6600: RETURN
7612 : REM GRAPH COMMAND
7615 FOR I = 0 TO NS: IF PS(I) = 0 THEN GOTO 7625
7620 PRINT CHR$(I + 65); " IS "; RIGHT$ (" " + STR$(I),2); " "; L$(I)

7625 NEXT I: GOTO 7680
7630 PRINT "WITH VALUES": PRINT SPC( 10)
7640 FOR I = 1 TO PLN - 10 STEP 10
7650 PRINT LEFT$ ( STR$ (MIN + (MAX - MIN) * (I - 11) / (PLN - 10)) + "
",10);
7660 NEXT I: PRINT : PRINT SPC( PLN - 10); RIGHT$ (" " + STR$ (
MAX),10)
7670 PRINT SPC( 9); "I";: FOR I = 11 TO PLN - 4 STEP 5: PRINT "----+": NEXT
I
7680 GOSUB 4500: C$ = DL$: GOSUB 8700
7690 ON I GOTO 7700,7700,7680
7700 C$ = DH$: GOSUB 8700: ON I GOTO 7850,7720,7720
7720 PRINT RIGHT$ (" " + STR$ ( FN HOUR(TIME)),2); ":"; RIGHT$ (" " + STR$
( FN MIN(TIME)),2); ":"; RIGHT$ (" " + STR$ ( FN SEC(TIME)),2); " I";
7730 FOR I = 1 TO PLN - 10: PF(I) = 0: NEXT I
7740 FOR I = 1 TO NS: IF PS(I) = 0 THEN GOTO 7790
7750 J = INT (D(I) * PS(I) + FC(I))
7760 IF J < 0 OR J > PLN - 10 THEN GOTO 7790
7770 IF PF(J) = 0 THEN PF(J) = I + 33: GOTO 7790
7780 PF(J) = 10
7790 NEXT I
7800 FOR I = 5 TO PLN - 10 STEP 5: IF PF(I) = 0 THEN PF(I) = 11
7810 NEXT I: REM FOR LOOP MARKS OF INCS OF 5
7820 FOR I = 1 TO PLN - 10: PRINT CHR$( PF(I) + 32);: NEXT I
7830 PRINT : PRINT SPC( 9); "I"
7840 GOTO 7680
7850 GOSUB 6600
7860 RETURN
8500 : REM PRINT TIME STRING
8510 PRINT RIGHT$ (" " + STR$ ( FN HOUR(TIME)),2); ":"; RIGHT$ ("0" + STR$
( FN MIN(TIME)),2); ":"; RIGHT$ ("0" + STR$ ( FN SEC(TIME)),2);
8520 RETURN
8700 : REM COMPARE C$ TO DA$ FOR DATE I=1 C<DA$ I=2 C$=DA$ I=3 C$>DA$
8710 IF RIGHT$ (C$,2) = RIGHT$ (DA$,2) THEN 8740
8720 IF RIGHT$ (C$,2) < RIGHT$ (DA$,2) THEN I = 1: RETURN
8730 I = 3: RETURN
8740 J = 13: FOR I = 1 TO 12: IF MID$ (C$,3,3) = MT$(I) THEN J = I
8750 NEXT I
8760 IF MID$ (DA$,3,3) = MT$(J) THEN GOTO 8800
8770 FOR I = 1 TO J: IF MID$ (DA$,3,3) = MT$(I) THEN 8790
8780 NEXT I: I = 1: RETURN
8790 I = 3: RETURN
8800 IF LEFT$ (C$,2) = LEFT$ (DA$,2) THEN I = 2: RETURN
8810 IF LEFT$ (C$,2) < LEFT$ (DA$,2) THEN I = 1: RETURN

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```

8820 I = 3: RETURN
9000 : REM GET DATE
9010 FOR J = 1 TO 6:V = 38 + J: GOSUB 9700
9020 GOSUB 9800:N(J) = V: NEXT J
9025 IF N(2) > 2 THEN N(2) = N(2) - 4
9030 DA$ = STR$(N(2)) + STR$(N(1)) + MTH$(10 * N(4) + N(3)) + STR$(N
(6)) + STR$(N(5))
9040 RETURN
9100 : REM GET A RANGE
9110 FOR I = 1 TO LEN(C$): IF MID$(C$,I,1) = "-" THEN GOTO 9130
9120 NEXT I:LO = VAL(C$):HI = LO: RETURN
9130 LO = VAL(LEFT$(C$,I - 1))
9135 HI = VAL(MID$(C$,I + 1))
9140 IF HI < LO THEN HI = LO
9150 RETURN
9500 : REM VALIDATE A DATE
9510 I = LEN(C$): IF I < 6 OR I > 7 THEN GOTO 9580
9514 IF I = 6 THEN C$ = "0" + C$
9516 IF LEFT$(C$,1) = " " THEN C$ = "0" + RIGHT$(C$,6)
9520 IF "0" > RIGHT$(C$,1) OR "9" < RIGHT$(C$,1) THEN GOTO 9580
9530 IF "0" > MID$(C$,I - 1,1) OR "9" < MID$(C$,I - 1,1) THEN GOTO 9
580
9540 IF "0" > LEFT$(C$,1) OR "9" < LEFT$(C$,1) THEN GOTO 9580
9550 IF "0" > MID$(C$,2,1) OR "9" < MID$(C$,2,1) THEN GOTO 9580
9560 FOR I = 1 TO 12: IF MTH$(I) = MID$(C$,3,3) THEN 9590
9570 NEXT I
9580 I = 1: PRINT "A VALID DATE IS DDDMMYY(E.G. 17JUN73)": RETURN
9590 IF VAL(LEFT$(C$,2)) > 31 THEN PRINT "DD CANNOT EXCEED 31": GOTO
9580
9600 I = 0: RETURN
9700 : REM POKE CR
9710 POKE CR,V: POKE CR,V: POKE CR,V: RETURN
9800 : REM READ DATA REGISTER ROUTINE
9810 V = PEEK(DR):V = V - 16 * INT(V / 16)
9820 RETURN

```

J&X

```

C$ 300, 310, 400, 410, 3044, 3050, 6010, 6020, 6230, 6290, 7012, 7014, 7180,
200, 7210, 7510, 7520, 7680, 7700, 8710, 8720, 8740, 8800, 8810, 9110, 9120,
, 9135, 9510, 9514, 9516, 9520, 9530, 9540, 9550, 9560, 9590
CL 110, 3030, 6210
CO$ 80, 310
CR 9710
C( 1562, 1565, 3050
D$ 110, 505, 1207, 1540
DA$ 4530, 7160, 7530, 8710, 8720, 8760, 8770, 8800, 8810, 9030
DH$ 390, 410, 7014, 7520, 7700
DH( 1562, 4540, 7210, 7580
DL$ 390, 400, 7012, 7510, 7680
DL( 1562, 4540, 7210, 7590
DR 9810
D( 1562, 4540, 7200, 7560, 7750
F$ 505, 1205, 1540, 3030
HI 1230, 3050, 6260, 6280, 9120, 9135, 9140
HOC 20, 30, 7160, 7720, 8510
I 400, 410, 1565, 3050, 3060, 4540, 4547, 6010, 6020, 6030, 6225, 6290, 70
7013, 7016, 7180, 7200, 7210, 7220, 7510, 7520, 7550, 7560, 7570, 7580, 7590
15, 7620, 7625, 7640, 7650, 7660, 7670, 7690, 7700, 7730, 7740, 7750, 7770,
7800, 7810, 7820, 8720, 8730, 8740, 8750, 8770, 8780, 8790, 8800, 8810, 882

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IO, 9120, 9130, 9135, 9510, 9514, 9530, 9560, 9570, 9580, 9600
 IA 4530, 7160
 IC 310, 320, 380, 415, 500, 1207
 J 7540, 7550, 7560, 7570, 7580, 7590, 7600, 7750, 7760, 7770, 7780, 8740, 8770, 9010, 9020
 K 7540, 7550, 7560, 7570, 7580, 7590
 KB 110
 KS 110
 LO 1230, 3050, 6250, 6260, 6280, 9120, 9130, 9140
 L#(1562, 1565, 3050, 7620
 MA 6270, 6271, 6280, 7650, 7660
 MI 6270, 6271, 6280, 7650
 MI(30, 7160, 7720, 8510
 MT#(50, 60, 70, 8740, 8760, 8770, 9030, 9560
 NC 80, 310, 380
 NS 1230, 1560, 1562, 1565, 4540, 6225, 7180, 7540, 7615, 7740
 N(9020, 9025, 9030
 PC(95, 6225, 6280, 7750
 PL 90, 6280, 7640, 7650, 7660, 7670, 7730, 7760, 7800, 7820
 PP(90, 7730, 7770, 7780, 7800, 7820
 PS 100, 1207, 6520
 PS(95, 6225, 6280, 7615, 7740, 7750
 RO(91
 SA 110
 SE(40, 7160, 7720, 8510
 SL 50
 SS 4530, 7160
 S(1562, 1565, 3050
 T# 1560, 3040
 TI 4530, 7160, 7720, 8510
 TI# 430, 1210
 U 9010, 9020, 9710, 9810
 V(1562, 4540, 7210, 7570
 X 20, 30, 40, 91

JREM

LOAD DATA COLLECTOR LIST

26JUNE81

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4  DIM FP(PLN): REM  PRIN CHAR BUFFER
10  REM  FIRST LOAD THE LOADER!!
15  HIMEM: 32760: REM  $8000
20  PRINT CHR$(4);"BRUN SOLARUSR.OKJO"
50  DIM MTH$(12):SLOT = 4: REM  CCS7424 CLOCK/CALENDAR SLOT
60  MTH$(1) = "JAN":MTH$(2) = "FEB":MTH$(3) = "MAR":MTH$(4) = "APR":MTH$(5) = "M
    AY":MTH$(6) = "JUN"
70  MTH$(7) = "JUL":MTH$(8) = "AUG":MTH$(9) = "SEP":MTH$(10) = "OCT":MTH$(11) =
    "NOV":MTH$(12) = "DEC"
80  DR = 49152 + 16 * (SLOT + 8):CR = DR + 1: REM  DATA REGISTER,COMMAND
    REGISTER
82  PLN = 80: REM  PRINT WIDTH
90  DFLAG = 0:PFLAG = 0:LFLAG = 0:ENND = 0
91  DEF FN ROUND(X) = INT (100 * X + .5) / 100
92  DEF FN MEAN(I) = FN ROUND(D(I) / IAVE)
93  DEF FN VAR(I) = FN ROUND((DD(I) - D(I) * D(I) / IAVE) / (IAVE - 1))
94  DEF FN HOUR(X) = INT (X / 3600)
95  DEF FN MIN(X) = INT ((X - 3600 * FN HOUR(X)) / 60)
96  DEF FN SEC(X) = X - 60 * INT (X / 60)
97  DEF FN FPS(I) = INT (PS(I) * DA(I) + PC(I))
100 REM  DATA COLLECTION ROUTINE
110 D$ = CHR$(4):SAFE = 1:KBD = - 16384:KSTRB = - 16368:CL = - 958
120 HOME
122 SPEED= 255
125 PRINT TAB( 10);"DATA COLLECTION ROUTINE"
130 INPUT "DO YOU WISH TO USE AN EXISTING DATA    COLLECTION FILE?"C$: GOSUB
    6000
140 ON I GOTO 150,190,130
150 GOSUB 1200
160 PRINT TI$
170 INPUT "IS THIS THE FILE?"C$
180 GOSUB 6000: ON I GOTO 290,130,170
190 GOSUB 2000
200 PRINT : INPUT "ENTER DATA FILE TITLE"TI$: IF TI$ = "" THEN 200
210 PRINT TI$; INPUT "OK?"C$: GOSUB 6000
220 ON I GOTO 230,200,210
230 INPUT "ENTER DATA COLLECTION FILE NAME" F$: IF F$ = "" THEN 230
240 PRINT "CREATE FILE " F$; INPUT "?"C$: GOSUB 6000
250 ON I GOTO 260,230,240
260 PRINT D$;"OPEN " F$: PRINT D$;"DELETE " F$: PRINT D$;"OPEN " F$: PRINT
    D$;"WRITE " F$
270 PRINT NS: PRINT T$: FOR I = 0 TO NS: PRINT L$(I): PRINT S(I): PRINT C
    (I): NEXT I: PRINT TI$
280 PRINT D$;"CLOSE " F$
290 INPUT "ENTER NUMBER OF SECONDS BETWEEN SENSOR  SWEEPS:"SS
300 IF SS < 1 OR SS > 10000 THEN 290
310 INPUT "ENTER NUMBER OF SWEEPS TO BE AVERAGED  INTO A SINGLE OBSERVAT
    ION"NA
320 CTIME = SS * NA:J = INT (CTIME / 60):I = CTIME - 60 * J
330 PRINT J;" MINUTES ";; IF I > 0 THEN PRINT I;" SECONDS "
340 PRINT "PER OBSERVATION."
350 FOR I = 1 TO NS:DD(I) = 0:D(I) = 0:DL(I) = 1E30:DH(I) = - 1E30: NEXT
    I
360 INPUT "ENTER NUMBER OF OBSERVATIONS TO COLLECT"NOBS
370 IF NOBS < 1 THEN 360

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375 IAVE = 1E30: REM INITIALIZE REPORT TRIGGER
380 FOR OBS = 1 TO NOBS
382 PRINT "COLLECTION OBS ";OBS
384 TIME = USR(18):ETIME = CTIME * INT((TIME + CTIME) / CTIME)
390 IAVE = 0: REM COLLECT AS MANY AS IAVE OBSERVATIONS
395 START = USR(18):OTIME = SS * INT((START + SS) / SS)
405 PRINT " AT ";START;"SWEEP=";IAVE
410 FOR I = 1 TO NS:J = USR(I):J = S(I) * J + C(I):D(I) = D(I) + J:DD(I)
    = DD(I) + J * J: IF DL(I) > J THEN DL(I) = J
420 IF DH(I) < J THEN DH(I) = J
425 DA(I) = J
430 NEXT J
440 IAVE = IAVE + 1
450 IF ENND = 1 THEN GOSUB 4500
460 IF ENND = 1 THEN END
470 GOSUB 5000: REM WAIT FOR TIME TO EXPIRE
472 TIME = USR(18): IF TIME < START THEN TIME = TIME + 86400
473 PRINT "TIME=";TIME;" ETIME=";ETIME
475 IF ETIME > TIME THEN GOTO 395
477 GOSUB 4500
480 NEXT OBS
490 END

1200 : REM LOAD AN EXISTING DATA COLLECTION FILE
1205 INPUT "ENTER NAME OF DATA FILE:";F$: IF F$ = "" THEN 1205
1210 GOSUB 1540: INPUT T$:
1220 PRINT D$;"CLOSE ";F$
1230 LO = 0:HI = NS: GOSUB 3030
1240 RETURN

1500 : REM LOAD CONFIGURATION DEFINITION
1540 PRINT D$;"OPEN ";F$: PRINT D$;"READ ";F$
1560 INPUT NS: INPUT T$:
1562 DIM L$(NS),S(NS),C(NS),D(NS),DD(NS),DL(NS),DH(NS),DA(NS)
1564 FOR I = 0 TO NS:DL(I) = 1E30:DH(I) = - 1E30
1565 FOR I = 0 TO NS: INPUT L$(I): INPUT S(I): INPUT C(I): NEXT I
1590 RETURN

2000 : REM LOAD A CONFIGURATION FILE
2005 INPUT "ENTER NAME OF CONFIGURATION FILE:";F$: IF F$ = "" THEN 2005
2010 GOSUB 1500
2020 PRINT D$;"CLOSE ";F$
2030 LO = 0:HI = NS: GOSUB 3030
2050 RETURN

3000 : REM DISPLAY COMMAND
3030 VTAB(3): CALL CL: IF F$ > < "" THEN PRINT "FILE ";F$;" ";
3040 PRINT "TITLE=";T$
3042 PRINT "SENSOR LABEL"; TAB(25);"SLOPE"; TAB(33);"CONSTANT"
3050 FOR I = LO TO HI: PRINT RIGHT$(" " + STR$(I),2);". ";L$(I); TAB(
25);S(I); TAB(33);C(I)
3055 IF I > < 0 AND 16 * INT(I / 16) = I THEN INPUT "HIT RETURN TO CO
NTINUE";C$
3060 NEXT I: RETURN

4500 : REM DATA COLLECTED, NOW STORE
4505 HOME : PRINT "DO NOT HIT RESET, DATA BEING RECORDED"
4510 PRINT D$;"APPEND ";F$: PRINT D$;"WRITE ";F$
4520 GOSUB 9000: REM DATE STAMP
4530 PRINT DA$: PRINT TIME: PRINT IAVE: PRINT SS
4540 FOR I = 0 TO NS: PRINT FN MEAN(I)
4542 IF IAVE > 1 THEN PRINT FN VAR(I): GOTO 4544
4543 PRINT 0
4544 PRINT DL(I): PRINT DH(I)
4545 D(I) = 0:DD(I) = 0:DL(I) = 1E30:DH(I) = - 1E30

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```

4547 NEXT I
4550 PRINT I$;"CLOSE ";I$
4560 HOME
4565 PRINT TAB( 10);"DATA COLLECTION ROUTINE"
4570 RETURN
5000 : REM WAIT FOR TIME TO EXPIRE
5010 TIME = USR (18): IF TIME < START THEN TIME = TIME + 86400
5015 I = OTIME - TIME
5020 IF I <= 0 THEN RETURN
5030 IF I < 5 THEN 5010: REM DON'T CHECK KEYBOARD UNLESS THERE IS TIME
5035 GOSUB 7000
5040 X = PEEK (KBD): POKE KSTRB,0
5050 IF X < 127 THEN 5010
5060 C$ = CHR$(X - 128): REM PROCESS COMMAND
5070 IF C$ = "Q" THEN VTAB (2): CALL CL:IFLAG = 0:LFLAG = 0:PFLAG = 0: GOTO
5010: REM QUIET COMMAND
5080 IF C$ = "D" THEN IFLAG = 1: GOTO 5010: REM DISPLAY COMMAND
5090 IF C$ = "L" THEN LFLAG = 1: GOTO 5010: REM LOG COMMAND
5100 IF C$ = "P" THEN GOSUB 6200: GOTO 5010: REM PLOT COMMAND
5105 IF C$ = "E" THEN ENND = 1: PRINT "PROCESSING TERMINATES WITH THIS OB
SERVATION": GOTO 5010
5110 IF C$ = "R" THEN IFLAG = 0:PFLAG = 0:LFLAG = 0: GOTO 5010: REM RESE
T FLAG
5120 VTAB (3): IF C$ > "H" THEN PRINT "COMMAND NOT RECOGNIZED"
5130 PRINT "Q-QUIET DISABLE DISPLAY"
5140 PRINT "D-DISPLAY DISPLAY DATA AS COLLECTED"
5150 PRINT "L-LOG DATA PRINTED AS COLLECTED"
5160 PRINT "P-PLOT DATA PLOTTED AS COLLECTED"
5170 PRINT "R-RESET DISABLE ALL DISPLAY/PRINT"
5180 PRINT "E-END TERMINATE DATA COLLECTION"
5190 GOTO 5010
6000 : REM YESNO
6010 C$ = LEFT$(C$,1): IF C$ = "Y" THEN I = 1: RETURN
6020 IF C$ = "N" THEN I = 2: RETURN
6030 I = 3: RETURN
6200 : REM INITIALIZE PLOTTING
6210 VTAB (3): CALL CL
6220 PRINT TAB( 10);"INITIALIZE PLOTTER"
6225 FOR I = 1 TO NS:PS(I) = 0:PC(I) = 0: NEXT I
6230 INPUT "ENTER A SENSOR NUMBER(NN) OR A SENSOR RANGE(MM-NN) ";C$
6240 GOSUB 9100
6250 PRINT "FOR SENSOR ";LO;
6260 IF HI > LO THEN PRINT " TO ";HI;
6270 PRINT : INPUT "ENTER MIN,MAX VALUES FOR THE AXIS";MIN,MAX
6280 FOR I = LO TO HI:PS(I) = (PLN - .001) / (MAX - MIN):PC(I) = 1 - MIN *
PS(I): NEXT I
6290 INPUT "PLOT MORE SENSORS?";C$
6300 GOSUB 6000: ON I GOTO 6230,6310,6290
6310 PFLAG = 1: GOSUB 6500
6320 PRINT SPC( 9);"I";: FOR I = 5 TO P LEN - 10 STEP 5: PRINT "----+";
: NEXT I: PRINT
6325 GOSUB 6600
6330 END
6400 : REM INITIALIZE PRINTER
6410 PR = 1: REM PRINTER SLOT
6420 PRINT CHR$( 4);"PR$";PR
6430 RETURN
6600 : REM TURN OFF PRINTER
6610 PRINT CHR$( 4);"PR$0"
6620 RETURN

```

```

4547 NEXT I
4550 PRINT D$;"CLOSE ";F$
4560 HOME
4565 PRINT TAB( 10);"DATA COLLECTION ROUTINE"
4570 RETURN
5000 : REM WAIT FOR TIME TO EXPIRE
5010 TIME = USR (18): IF TIME < START THEN TIME = TIME + 86400
5015 I = OTIME - TIME
5020 IF I < = 0 THEN RETURN
5030 IF I < 5 THEN 5010: REM DON'T CHECK KEYBOARD UNLESS TERE IS TIME
5035 GOSUB 7000
5040 X = PEEK (KBD): POKE KSTRB,0
5050 IF X < 127 THEN 5010
5060 C$ = CHR$ (X - 128): REM PROCESS COMMAND
5070 IF C$ = "Q" THEN VTAB (2): CALL CL:DFLAG = 0:LFLAG = 0:PFLAG = 0: GOTO
5010: REM QUIET COMMAND
5080 IF C$ = "D" THEN DFLAG = 1: GOTO 5010: REM DISPLAY COMMAND
5090 IF C$ = "L" THEN LFLAG = 1: GOTO 5010: REM LOG COMMAND
5100 IF C$ = "P" THEN GOSUB 6200: GOTO 5010: REM PLOT COMMAND
5105 IF C$ = "E" THEN ENND = 1: PRINT "PROCESSING TERMINATES WITH THIS OB
SERVATION": GOTO 5010
5110 IF C$ = "R" THEN DFLAG = 0:PFLAG = 0:LFLAG = 0: GOTO 5010: REM RESE
T FLAG
5120 VTAB (3): IF C$ > < "H" THEN PRINT "COMMAND NOT RECOGNIZED"
5130 PRINT "Q-QUIET DISABLE DISPLAY"
5140 PRINT "D-DISPLAY DISPLAY DATA AS COLLECTED"
5150 PRINT "L-LOG DATA PRINTED AS COLLECTED"
5160 PRINT "P-PLOT DATA PLOTTED AS COLLECTED"
5170 PRINT "R-RESET DISABLE ALL DISPLAY/PRINT"
5180 PRINT "E-END TERMINATE DATA COLLECTION"
5190 GOTO 5010
6000 : REM YESNO
6010 C$ = LEFT$ (C$,1): IF C$ = "Y" THEN I = 1: RETURN
6020 IF C$ = "N" THEN I = 2: RETURN
6030 I = 3: RETURN
6200 : REM INITIALIZE PLOTTING
6210 VTAB (3): CALL CL
6220 PRINT TAB( 10);"INITIALIZE PLOTTER"
6225 FOR I = 1 TO NS:PS(I) = 0:PC(I) = 0: NEXT I
6230 INPUT "ENTER A SENSOR NUMBER(NN) OR A SENSOR RANGE(MM-NN) ";C$
6240 GOSUB 9100
6250 PRINT "FOR SENSOR ";LO;
6260 IF HI > < LO THEN PRINT " TO ";HI;
6270 PRINT : INPUT "ENTER MIN,MAX VALUES FOR THE AXIS";MIN,MAX
6280 FOR I = LO TO HI:PS(I) = (PLN - .001) / (MAX - MIN):PC(I) = 1 - MIN :
PS(I): NEXT I
6290 INPUT "PLOT MORE SENSORS?";C$
6300 GOSUB 6000: ON I GOTO 6230,6310,6290
6310 PFLAG = 1: GOSUB 6500
6320 PRINT SPC( 9);"I"; FOR I = 5 TO P LEN - 10 STEP 5: PRINT "----+";
: NEXT I: PRINT
6325 GOSUB 6600
6330 END
6500 : REM INITIALIZE PRINTER
6510 PR = 1: REM PRINTER SLOT
6520 PRINT CHR$ (4);"PR#";PR
6590 RETURN
6600 : REM TURN OFF PRINTER
6610 PRINT CHR$ (4);"PR#0"
6690 RETURN

```

```

7000 : REM  COMMAND PROCESSOR
7010 IF DIAVE = IAVE THEN RETURN : REM  DID IT ALREADY
7015 DIAVE = IAVE
7018 IF DFLAG >  < 1 THEN GOTO 7080
7019 REM  DISPLAY COMMAND
7020 HOME : PRINT TAB( 8);"DATA COLLECTION": PRINT "SAMPLE = ";OBS; TAB(
20);"SCAN ";IAVE
7030 PRINT "SENSOR"; TAB( 8);"CURRENT"; TAB( 20);"MEAN"; TAB( 32);"VARIAN
CE"
7040 FOR I = 0 TO NS: PRINT TAB( 4);I; TAB( 12);DA(I); TAB( 22); FN MEAN
(I);: IF IAVE > 1 THEN PRINT TAB( 32); FN VAR(I);
7050 PRINT
7070 NEXT I
7080 IF LFLAG >  < 1 THEN GOTO 7240: REM  LOG COMMAND
7100 GOSUB 6500: PRINT : PRINT
7140 PRINT "OBSERVATION ";OBS;"SCAN ";IAVE;" ";
7150 PRINT RIGHT$ (" " + STR$ ( FN HOUR(TIME)),2);":"; RIGHT$ ("0" + STR$
( FN MIN(TIME)),2);":"; RIGHT$ ("0" + STR$ ( FN SEC(TIME)),2);
7160 GOSUB 9000: PRINT " ";DA$: PRINT
7170 PRINT "SENSOR      ";:J = 11
7171 FOR I = 0 TO NS: IF J + 9 > PLN THEN PRINT : PRINT SPC( 10);:J = 1
1
7172 PRINT RIGHT$ ("      " + STR$ (I),10);:J = J + 10: NEXT I: PRINT
7173 PRINT "VALUE      ";:J = 11
7174 FOR I = 0 TO NS: IF J + 9 > PLN THEN PRINT : PRINT SPC( 10);:J = 1
1
7175 PRINT RIGHT$ ("      " + STR$ (DA(I)),10);:J = J + 10: NEXT I
7176 PRINT
7230 GOSUB 6600
7240 IF PFLAG >  < 1 THEN GOTO 7400
7250 GOSUB 6500
7260 PRINT RIGHT$ (" " + STR$ ( FN HOUR(TIME)),2);":"; RIGHT$ (" " + STR$
( FN MIN(TIME)),2);":"; RIGHT$ (" " + STR$ ( FN SEC(TIME)),2);" I";
7270 FOR I = 1 TO PLN - 10:PF(I) = 0: NEXT I
7280 FOR I = 1 TO NS: IF PS(I) = 0 THEN GOTO 7330
7290 J = FN PPS(I)
7300 IF J < 0 OR J > PLN - 10 THEN GOTO 7330
7310 IF PF(J) = 0 THEN PF(J) = I + 33: GOTO 7330
7320 PF(J) = 28
7330 NEXT I
7340 FOR I = 5 TO PLN - 10 STEP 5: IF PF(I) = 0 THEN PF(I) = 11
7350 NEXT I: REM  FOR LOOP MARKS OF INCS OF 5
7360 FOR I = 1 TO PLN - 10: PRINT CHR$ (PF(I) + 32);: NEXT I
7370 PRINT : PRINT SPC( 9);"I"
7380 GOSUB 6600
7400 RETURN
9000 : REM  GET DATE
9010 FOR J = 1 TO 6:V = 38 + J: GOSUB 9700
9020 GOSUB 9800:N(J) = V: NEXT J
9025 IF N(2) > 2 THEN N(2) = N(2) - 4
9030 DA$ = STR$ (N(2)) + STR$ (N(1)) + MTH$(10 * N(4) + N(3)) + STR$ (N
(6)) + STR$ (N(5))
9040 RETURN
9100 : REM  GET A RANGE
10 FOR I = 1 TO LEN (C$): IF MID$ (C$,I,1) = "-" THEN GOTO 9130
20 NEXT I:LO = VAL (C$):HI = LO: RETURN
9110 LO = VAL ( LEFT$ (C$,I - 1)
9125 HI = VAL ( MID$ (C$,I + 1)
9140 IF HI < LO THEN HI = LO

```



```

9150 RETURN
9700 : REM POKE CR
9710 POKE CR,V: POKE CR,V: POKE CR,V: RETURN
9800 : REM READ DATA REGISTER ROUTINE
9810 V = PEEK (DR):V = V - 16 * INT (V / 16)
9820 RETURN

```

J&X

```

D$ 130, 170, 210, 240, 3055, 5060, 5070, 5080, 5090, 5100, 5105, 5110, 5120,
010, 6020, 6230, 6290, 9110, 9120, 9130, 9135
CL 110, 3030, 5070, 6210
CR 80, 9710
CT 320, 384
C( 270, 410, 1562, 1565, 3050
D$ 110, 260, 280, 1220, 1540, 2020, 4510, 4550
DA$ 4530, 7160, 9030
DA( 97, 425, 1562, 7040, 7175
DI( 93, 350, 410, 1562, 4545
DE 90, 5070, 5080, 5110, 7018
DI( 350, 420, 1562, 1564, 4544, 4545
DL( 350, 410, 1562, 1564, 4544, 4545
DR 80, 9810
D( 92, 93, 350, 410, 1562, 4545
E3 350, 375, 1564, 4545
EN 90, 450, 460, 5105
ET 384, 473, 475
F$ 230, 240, 260, 280, 1205, 1220, 1540, 2005, 2020, 3030, 4510, 4550
HI 1230, 2030, 3050, 6260, 6280, 9120, 9135, 9140
HO( 94, 95, 7150, 7260
I 92, 93, 97, 140, 180, 220, 250, 270, 320, 330, 350, 410, 420, 425, 430, 1,
4, 1565, 3050, 3055, 3060, 4540, 4542, 4544, 4545, 4547, 5015, 5020, 5030, 5010,
6020, 6030, 6225, 6280, 6300, 6320, 7040, 7070, 7171, 7172, 7174, 7175, 7270, 7,
0, 7290, 7310, 7330, 7340, 7350, 7360, 9110, 9120, 9130, 9135
IA 92, 93, 390, 405, 440, 4530, 4542, 7010, 7015, 7020, 7040, 7140
J 320, 330, 410, 420, 425, 7170, 7171, 7172, 7173, 7174, 7175, 7290, 7300,
10, 7320, 9010, 9020
KB 110, 5040
KS 110, 5040
LF 90, 5070, 5090, 5110, 7080
LO 1230, 2030, 3050, 6250, 6260, 6280, 9120, 9130, 9140
L$( 270, 1562, 1565, 3050
MA 6270, 6280
ME( 92, 4540, 7040
MI 6270, 6280
MI( 95, 7150, 7260
MT$( 50, 60, 70, 9030
NA 310, 320
NU 360, 370, 380
NS 270, 350, 410, 1230, 1560, 1562, 1564, 1565, 2030, 4540, 6225, 7040, 717,
7174, 7280
N( 9020, 9025, 9030
OB 380, 382, 480, 7020, 7140
OI 375, 7010, 7015
OT 395, 5015
P 6320
PC( 97, 6225, 6280
PF 90, 5070, 5110, 6310, 7240
PL 4, 82, 6280, 7171, 7174, 7270, 7300, 7340, 7360
PP( 4, 97, 7270, 7290, 7310, 7320, 7340, 7360

```

PR 6510, 6520
PS(97, 6225, 6280, 7280
RO(91, 92, 93
SA 110
SE(96, 7150, 7260
SL 50, 80
SS 290, 300, 320, 395, 4530
ST 395, 405, 472, 5010
S(270, 410, 1562, 1565, 3050
T# 270, 1560, 3040
TI 384, 472, 473, 475, 4530, 5010, 5015, 7150, 7260
TI# 160, 200, 210, 270, 1210
V 9010, 9020, 9710, 9810
VAC 93, 4542, 7040
X 91, 94, 95, 96, 5040, 5050, 5060

JREM

CONFIGURATION

MANAGER

26 JUNE 81

LIST

```

10 REM SENSOR CONFIGURATION FILE MANAGER
20 MSSENS = 18: REM SET TO MAX # OF SENSORS
30 SAFE = 1: D$ = CHR$(4): NS = - 1: REM INIT TO ZERO SENSORS
35 CL = - 958
40 DIM L$(MSSENS), S(MSENS), C(MSENS): COM$ = "CALSMITH": NC = LEN (COM$)
50 HOME: PRINT TAB( 5); "SENSOR CONFIGURATION MANAGER"
60 VTAB (3)
70 PRINT "C)CLEAR A)ADD L)LOAD S)SAVE M)MODIFY D)DISPLAY T)TITLE"
80 PRINT "H)HELP E)EXIT": INPUT " ENTER COMMAND:"; C$
90 IF C$ = "" THEN 80
100 C$ = LEFT$(C$,1): FOR IC = 1 TO NC: IF C$ = MID$(COM$,IC,1) THEN GOTO
    120
110 NEXT IC: PRINT "COMMAND NOT RECOGNIZED - ENTER H": GOTO 70
120 ON IC GOSUB 500,1000,1500,2000,2500,3000,3200,3500,4000
130 GOTO 70
500: REM CLEAR COMMAND
510 IF SAFE = 1 THEN GOTO 530
520 INPUT "CLEAR CURRENT CONFIGURATION?"; C$: GOSUB 6000: ON I GOTO 530,54
    0,520
530 NS = - 1: F$ = "": T$ = "": SAFE = 1
535 PRINT TAB( 10); "CONFIGURATION CLEARED."
540 RETURN
1000: REM ADD COMMAND
1010 IF NS = MSSENS THEN PRINT "MAXIMUM NUMBER OF SENSORS REACHED": RETURN

1015 IF NS = - 1 THEN GOSUB 3200
1020 PRINT "SENSOR "; NS + 1; " ENTER LABEL(HIT RETURN TO EXIT)"
1040 INPUT C$: IF C$ = "" THEN RETURN
1050 IF LEN (C$) > 20 THEN PRINT "LABELS ARE LIMITED TO 20 CHARACTERS":
    GOTO 1020
1060 INPUT "ENTER SLOPE, CONSTANT "; I, J: SAFE = 0
1070 IF I = 0 THEN PRINT "SLOPE OF 0 NOT PERMITTED.": PRINT "SLOPE 1, CO
    NSTANT 0 DOESN'T CHANGE DATA": GOTO 1060
1080 NS = NS + 1: L$(NS) = C$: S(NS) = I: C(NS) = J: GOTO 1010
1090 RETURN
1500: REM LOAD A PREVIOUS CONFIGURATION FROM A FILE
1510 IF SAFE = 1 THEN GOTO 1530
1515 INPUT "CLEAR CURRENT CONFIGURATION?"; C$
1520 GOSUB 6000: ON I GOTO 1530,1590,1510
1530 SAFE = 1: INPUT "ENTER NAME OF CONFIGURATION FILE:"; F$: IF F$ = "" THEN
    1530
1540 PRINT D$; "OPEN "; F$: PRINT D$; "READ "; F$
1560 INPUT NS: INPUT T$: IF NS > MSSENS THEN PRINT "TOO MANY SENSORS FOR
    THIS PROGRAM TO READ": NS = 0: F$ = "": GOTO 1590
1565 FOR I = 0 TO NS: INPUT L$(I): INPUT S(I): INPUT C(I): NEXT I
1570 PRINT D$; "CLOSE "; F$
1580 LO = 0: HI = NS: GOSUB 3030
1590 RETURN
2000: REM SAVE COMMAND
2010 IF F$ = "" THEN GOTO 2040
2020 PRINT "SAVE AS FILE"; F$: INPUT C$: GOSUB 6000
2030 ON I GOTO 2060,2040,2020
2040 INPUT "ENTER FILE NAME"; F$: IF F$ = "" THEN 2040
2050 GOTO 2020
2060 PRINT D$; "OPEN "; F$: PRINT D$; "DELETE "; F$: PRINT D$; "OPEN "; F$: PRINT
    D$; "WRITE "; F$

```

```

2070 PRINT NS: PRINT T$
2080 FOR I = 0 TO NS: PRINT L$(I): PRINT S(I): PRINT C(I): NEXT I:SAFE =
1
085 PRINT I$;"CLOSE ";F$
2090 RETURN
2500 : REM MODIFY
2510 INPUT "ENTER SENSOR NUMBER(RETURN TO EXIT)";C$
2520 IF C$ = "" THEN 2670
2530 I = VAL (C$): IF I < 0 OR I > NS THEN PRINT "SENSOR NUMBERS LIE IN
THE RANGE 0 TO ";NS: GOTO 2510
2540 PRINT "SENSOR ";I;" LABEL=";L$(I):SAFE = 0
2550 INPUT "ENTER NEW LABEL OR RETURN TO ACCEPT OLD";C$: IF C$ = "" THEN
2580
2560 L$(I) = C$
2570 IF LEN (C$) > 20 THEN PRINT "LABELS ARE LIMITED TO 20 CHARACTERS":
GOTO 2550
2580 PRINT "ENTER NEW NUMBER OR RETURN TO ACCEPT SLOPE=";S(I);: INPUT "-";
C$
2590 IF C$ = "" THEN 2620
2600 J = VAL (C$): IF J = 0 THEN PRINT "ZERO IS INVALID. ENTER 1 TO LEA
VE SENSOR READING UNCHANGED.": GOTO 2580
2610 S(I) = J: GOTO 2580
2620 PRINT "ENTER NEW NUMBER OR RETURN TO ACCEPT CONSTANT=";C(I);: INPUT
C$
2625 IF C$ = "" THEN GOTO 2640
2630 J = VAL (C$):C(I) = J
2640 PRINT "FOR SENSOR ";I;"LABEL=";L$(I)
2650 PRINT "OBS=SENSOR TIMES ";S(I);" PLUS ";C(I)
2660 GOTO 2510
2670 RETURN
3000 : REM DISPLAY COMMAND
3010 INPUT "DISPLAY SENSORS. ENTER SENSOR1-SENSOR2 OR HIT RETURN";C$
3020 IF C$ = "" THEN LO = 0:HI = NS: GOTO 3030
3025 GOSUB 7000
3030 VTAB (3): CALL CL: IF C$ > < "" THEN PRINT "FILE ";F$;" ";
3040 PRINT "TITLE=";T$
3042 PRINT "SENSOR LABEL"; TAB( 25);"SLOPE"; TAB( 33);"CONSTANT"
3050 FOR I = LO TO HI: PRINT RIGHT$ ( " " + STR$ (I),2);" ";L$(I); TAB(
25);S(I); TAB( 33);C(I)
3055 IF I > < 0 AND 16 * INT (I / 20) = I THEN INPUT "HIT RETURN TO CO
NTINUE";C$
3060 NEXT I: RETURN
3200 : REM TITLE COMMAND
3210 IF T$ = "" THEN INPUT "ENTER TITLE ";T$
3220 PRINT "THE CURRENT TITLE IS "; PRINT T$
3230 PRINT "ENTER NEW TITLE(HIT RETURN TO EXIT)"
3240 INPUT C$: IF C$ = "" THEN 3260
3250 T$ = C$: GOTO 3220
3260 RETURN
3500 : REM HELP
3510 VTAB (3): CALL CL: PRINT TAB( 10);"LIST OF COMMANDS"
3599 RETURN
4000 : REM EXIT
4010 IF SAFE = 1 THEN 4050
4020 INPUT "DISCARD CONFIGURATION IN MEMORY?";C$: GOSUB 6000
4030 ON I GOTO 4050,4040,4020
4040 RETURN
4050 END
6000 : REM YESNO
6010 C$ = LEFT$ (C$,1): IF C$ = "Y" THEN I = 1: RETURN

```

```

6020 IF C$ = "N" THEN I = 2: RETURN
6030 I = 3: RETURN
7000 : REM GET A RANGE
7010 LO = 0:HI = NS: IF LEN (C$) = 0 THEN RETURN
7020 FOR I = 1 TO LEN (C$): IF "-" = MID$ (C$,I,1) THEN 7040
7030 NEXT I:LO = VAL (C$): RETURN
7040 LO = VAL ( LEFT$ (C$,I - 1)): IF I = LEN (C$) THEN RETURN
7050 HI = VAL ( RIGHT$ (C$, LEN (C$) - I)): RETURN

```

J&X

```

C$      80, 90, 100, 520, 1040, 1050, 1080, 1515, 2020, 2510, 2520, 2530, 2550, 2
0, 2570, 2580, 2590, 2600, 2620, 2625, 2630, 3010, 3020, 3030, 3055, 3240, 3250
4020, 6010, 6020, 7010, 7020, 7030, 7040, 7050
CL      35, 3030, 3510
CO$     40, 100
C(      40, 1080, 1565, 2080, 2620, 2630, 2650, 3050
D$      30, 1540, 1570, 2060, 2085
F$      530, 1530, 1540, 1560, 1570, 2010, 2020, 2040, 2060, 2085, 3030
HI      1580, 3020, 3050, 7010, 7050
I       520, 1060, 1070, 1080, 1520, 1565, 2030, 2080, 2530, 2540, 2560, 2580, 26
, 2620, 2630, 2640, 2650, 3050, 3055, 3060, 4030, 6010, 6020, 6030, 7020, 7030,
040, 7050
IC      100, 110, 120
J       1060, 1080, 2600, 2610, 2630
LO      1580, 3020, 3050, 7010, 7030, 7040
L$(     40, 1080, 1565, 2080, 2540, 2560, 2640, 3050
MS      20, 40, 1010, 1560
NC      40, 100
NS      30, 530, 1010, 1015, 1020, 1080, 1560, 1565, 1580, 2070, 2080, 2530, 3020
7010
SA      30, 510, 530, 1060, 1510, 1530, 2080, 2540, 4010
S(      40, 1080, 1565, 2080, 2580, 2610, 2650, 3050
T$      530, 1560, 2070, 3040, 3210, 3220, 3250

```

JREM

APPENDIX B

TEST CELL DATA

PASSIVE SOLAR TEST CELL DATA

DATE FEB 2 1981

CELL A NO SOLAR / ADIABATIC WALL / AUX HEAT = 1707 BTU/HR

CELL B SAME

B = CELL A

L = CELL B

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PASSIVE SOLAR TEST CELL DATA

DATE DEC 3 1981

CELL A NO SOLAR / ADIABATIC WALL / AUX HEAT = 1707 BTU/HR

CELL B SAME

B = CELL A
L = CELL B

		20											130
D 1: 0: 0	I	0	+	+	+	+	+	B+	L	+	+	+	
3 2: 0: 0	I	0	+	+	+	+	+	B+	L	+	+	+	
3 3: 0: 0	I	+0	+	+	+	+	+	B+	L	+	+	+	
4: 0: 0	I	+ 0	+	+	+	+	+	B+	L	+	+	+	
5: 0: 0	I	+0	+	+	+	+	+	B+	L	+	+	+	
6: 0: 0	I	0	+	+	+	+	+	B+	L	+	+	+	
7: 0: 0	I	0	+	+	+	+	+	B	L	+	+	+	
8: 0: 0	I	0	+	+	+	+	+	B	L	+	+	+	
9: 0: 0	I	+0	+	+	+	+	+	B	L	+	+	+	
10: 0: 0	I	+	0	+	+	+	+	B+	L	+	+	+	
11: 0: 0	I	+	0	+	+	+	+	B	L	+	+	+	
11:49 30	I	+	+0	+	+	+	+	+B	L	+	+	+	
13: 0: 0	I	+	+	0	+	+	+	+	B	L	+	+	
14: 0: 0	I	+	+	0	+	+	+	+	B+	L	+	+	
15: 0: 0	I	+	+	0	+	+	+	+	B+	L	+	+	
16: 0: 0	I	+	+0	+	+	+	+	+	B+	L	+	+	
17: 0: 0	I	+	+0	+	+	+	+	+	B+	L	+	+	
18: 0: 0	I	+	0	+	+	+	+	+	B	L	+	+	
19: 0: 0	I	+	0	+	+	+	+	+	B	L	+	+	
20: 0: 0	I	+	0	+	+	+	+	+	B	L	+	+	
21: 0: 0	I	+	0	+	+	+	+	+	B	L	+	+	
22: 0: 0	I	+	0	+	+	+	+	+	B	L	+	+	
23: 0: 0	I	+	0	+	+	+	+	+	B	L	+	+	
24: 0: 0	I	+	0	+	+	+	+	+	B	L	+	+	

PASSIVE SOLAR TEST CELL DATA

DATE DEC 4 1981

CELL A NO SOLAR / ADIABATIC WALL / AUX HEAT = 1707 BTU / HR

CELL B SAME

B = CELL A
L = CELL B

		20										130
D	1: 0: 0	I	+	0	+	+	+	+	+	B + L	+	+
4	2: 0: 0	I	+	0	+	+	+	+	+	B + L	+	+
	3: 0: 0	I	+	0	+	+	+	+	+	B + L	+	+
	4: 0: 0	I	+	0+	+	+	+	+	+	B + L	+	+
	5: 0: 0	I	+	0+	+	+	+	+	+	B L	+	+
	6: 0: 0	I	+	0+	+	+	+	+	+	B L	+	+
	7: 0: 0	I	+	0+	+	+	+	+	+	+B L	+	+
	8: 0: 0	I	+	0 +	+	+	+	+	+	+B L	+	+
	9: 0: 0	I	+	0 +	+	+	+	+	+	+B L+	+	+
	10: 0: 0	I	+	0 +	+	+	+	+	+	+B L+	+	+
	11: 0: 0	I	+	0 +	+	+	+	+	+	+B L+	+	+
	12: 0: 0	I	+	0 +	+	+	+	+	+	+B L+	+	+
	13: 0: 0	I	+	0 +	+	+	+	+	+	+B L+	+	+
	14: 0: 0	I	+	0 +	+	+	+	+	+	+B L+	+	+
	15: 0: 0	I	+	0 +	+	+	+	+	+	+B L+	+	+
	16: 0: 0	I	+	0+	+	+	+	+	+	+B L+	+	+
	17: 0: 0	I	+	0+	+	+	+	+	+	+B L+	+	+
	18: 0: 0	I	+	0 +	+	+	+	+	+	+B L+	+	+
	19: 0: 0	I	+	0 +	+	+	+	+	+	+B L+	+	+
	20: 0: 0	I	+	0 +	+	+	+	+	+	+B L+	+	+
	21: 0: 0	I	+	0 +	+	+	+	+	+	+B L+	+	+
	22: 0: 0	I	+	0 +	+	+	+	+	+	+B L+	+	+
	23: 0: 0	I	+	0 +	+	+	+	+	+	B L +	+	+
	24: 0: 0	I	+	0 +	+	+	+	+	+	B L +	+	+

PASSIVE SOLAR TEST CELL DATA

DATE DEC 5 1981

CELL A NO SOLAR / ADIABATIC WALL / AUX HEAT = 1700 BTU / HR

CELL B SAME

B = CELL A
L = CELL B

		20					75					130
D 1:	0: 0	I	0	+	+	+	+	+	B + L	+	+	+
5 2:	0: 0	I	0+	+	+	+	+	+	B + L	+	+	+
3:	0: 0	I	0+	+	+	+	+	+	B + L	+	+	+
4:	0: 0	I	0+	+	+	+	+	+	B + L	+	+	+
5:	0: 0	I	0+	+	+	+	+	+	B L	+	+	+
6:	0: 0	I	0+	+	+	+	+	+	B L	+	+	+
7:	0: 0	I	0 +	+	+	+	+	+	B L	+	+	+
8:	0: 0	I	0 +	+	+	+	+	+	+B L+	+	+	+
9:	0: 0	I	0 +	+	+	+	+	+	+B L+	+	+	+
10:	0: 0	I	0	+	+	+	+	+	+B L	+	+	+
11:	0: 0	I	+0	+	+	+	+	+	+ B L	+	+	+
12:	0: 0	I	+0	+	+	+	+	+	B L	+	+	+
13:	0: 0	I	+ 0	+	+	+	+	+	+ B L	+	+	+
14:	0: 0	I	+ 0	+	+	+	+	+	B+ L	+	+	+
15:	0: 0	I	+ 0	+	+	+	+	+	B L	+	+	+
16:	0: 0	I	+ 0	+	+	+	+	+	B L	+	+	+
17:	0: 0	I	+ 0	+	+	+	+	+	B L	+	+	+
18:	0: 0	I	0	+	+	+	+	+	B+ L	+	+	+
19:	0: 0	I	0 +	+	+	+	+	+	B + L	+	+	+
20:	0: 0	I	0	+	+	+	+	+	+ B + L	+	+	+
21:	0: 0	I	0	+	+	+	+	+	+B L	+	+	+
22:	0: 0	I	0	+	+	+	+	+	B L+	+	+	+
23:	0: 0	I	+	+	+	+	+	+	B+ L	+	+	+
24:	0: 0	I	+	+	+	+	+	+	B + L	+	+	+

PASSIVE SOLAR TEST CELL DATA

DATE FEL 6 1981

CELL A NO SOLAR / ADIABATIC WALL / AUX HEAT = 1702 BTU / HR

CELL B SAME

B = CELL A

L = CELL B

		10											130
0	1: 0: 0	I	+	+	+	+	+	B + L	+	+	+	+	
6	2: 0: 0	I	+	+	+	+	+	B + L	+	+	+	+	
	3: 0: 0	I	+	+	+	+	+	B L	+	+	+	+	
	4: 0: 0	I	+	+	+	+	+	B L	+	+	+	+	
	5: 0: 0	I	+	+	+	+	+	B L+	+	+	+	+	
	6: 0: 0	I	+	+	+	+	+	B L+	+	+	+	+	
	7: 0: 0	I	+	+	+	+	+	B L+	+	+	+	+	
	8: 0: 0	I	+	+	+	+	+	B L+	+	+	+	+	
	9: 0: 0	I	+	+	+	+	+	B L+	+	+	+	+	
	10: 0: 0	I	0+	+	+	+	+	B + L	+	+	+	+	
	11: 0: 0	I	+	0	+	+	+	+	B L+	+	+	+	
	12: 0: 0	I	+	0+	+	+	+	+	B + L	+	+	+	
	13: 0: 0	I	+	0+	+	+	+	+	B L	+	+	+	
	14: 0: 0	I	+	0	+	+	+	+	+	B L+	+	+	
	15: 0: 0	I	+	0+	+	+	+	+	+	B L	+	+	
	16: 0: 0	I	+	0+	+	+	+	+	+	B L	+	+	
	17: 0: 0	I	+	0	+	+	+	+	+	+	B L	+	

PASSIVE SOLAR TEST CELL DATA

DATE DEC 9 1981

CELL A NO SOLAR / ADIABATIC WALL / AUX HEAT = 850 / HR

CELL B SAME

B = CELL A
L = CELL B

		20										130
18: 0: 0	I	0	+	+	+	+	+	+B	L	+	+	+
19: 0: 0	I	0	+	+	+	+	+	B+L	+	+	+	+
20: 0: 0	I	0	+	+	+	+	+	B	L	+	+	+
21: 0: 0	I	0	+	+	+	+	+	+B	L	+	+	+
22: 0: 0	I	0	+	+	+	+	+	B	L	+	+	+
23: 0: 0	I	0	+	+	+	+	+	B	L	+	+	+
24: 0: 0	I	0	+	+	+	+	+	B+L	+	+	+	+

PASSIVE SOLAR TEST CELL DATA

DATE DEC 10 1981

CELL A NO SOLAR / ADIABATIC WALL / AUX HEAT = 850 / HR

CELL B SAME

~~BE~~
B - CELL A
L = CELL B

		10										130
0	1: 0: 0	I	+	+	+	B + L	+	+	+	+	+	+
10	2: 0: 0	I	+	+	+	B L	+	+	+	+	+	+
	3: 0: 0	I	+	+	+	B L +	+	+	+	+	+	+
	4: 0: 0	I	+	+	+	B L +	+	+	+	+	+	+
	5: 0: 0	I	+	+	+	B L +	+	+	+	+	+	+
	6: 0: 0	I	+	+	+	B L +	+	+	+	+	+	+
	7: 0: 0	I	+	+	+	B L +	+	+	+	+	+	+
	8: 0: 0	I	+	+	+	B L +	+	+	+	+	+	+
	9: 0: 0	I	+	+	+	B L +	+	+	+	+	+	+
	10: 0: 0	I	+	+	+	B L +	+	+	+	+	+	+
	11: 0: 0	I	+	+	+	B L +	+	+	+	+	+	+
	12: 0: 0	I	0 +	+	+	B L	+	+	+	+	+	+
	13: 0: 0	I	0 +	+	+	B L	+	+	+	+	+	+
	14: 0: 0	I	0 +	+	+	B + L	+	+	+	+	+	+
	15: 0: 0	I	0 +	+	+	B L	+	+	+	+	+	+
	16: 0: 0	I	0 +	+	+	B + L	+	+	+	+	+	+
	16: 9: 0	I	0 +	+	+	B + L	+	+	+	+	+	+
	17: 0: 0	I	0 +	+	+	B + L	+	+	+	+	+	+
	18: 0: 0	I	0 +	+	+	B L	+	+	+	+	+	+
	19: 0: 0	I	+	+	+	B L	+	+	+	+	+	+
	20: 0: 0	I	+	+	+	B L +	+	+	+	+	+	+
	21: 0: 0	I	+	+	+	B L +	+	+	+	+	+	+
	22: 0: 0	I	+	+	+	B L +	+	+	+	+	+	+
	23: 0: 0	I	+	+	+	B L +	+	+	+	+	+	+
	24: 0: 0	I	+	+	+	B L +	+	+	+	+	+	+

PASSIVE SOLAR TEST CELL DATA

DATE DEC 11, 1981

CELL A NO SOLAR / ADIABATIC WALL / AUX HEAT = 850 BTU/HR

CELL B SAME

B = CELL A

L = CELL B

		20									130
		I	I	I	I	I	I	I	I	I	I
D 1: 0: 0	I	+	+	B+L	+	+	+	+	+	+	+
11 2: 0: 0	I	+	+	B L	+	+	+	+	+	+	+
	I										
3: 0: 0	I	+	+	B L	+	+	+	+	+	+	+
	I										
4: 0: 0	I	+	+	B L+	+	+	+	+	+	+	+
	I										
5: 0: 0	I	+	+	B L+	+	+	+	+	+	+	+
	I										
6: 0: 0	I	+	+	B L+	+	+	+	+	+	+	+
	I										
7: 0: 0	I	+	+	B L+	+	+	+	+	+	+	+
	I										
8: 0: 0	I	+	+	B L+	+	+	+	+	+	+	+
	I										
9: 0: 0	I	+	+	B L+	+	+	+	+	+	+	+
	I										
10: 0: 0	IO	+	+	B+L	+	+	+	+	+	+	+
	I										
11: 0: 0	I	0+	+	+B L+	+	+	+	+	+	+	+
	I										
12: 0: 0	I	0	+	+ B L	+	+	+	+	+	+	+
	I										
13: 0: 0	I	+0	+	+ B L	+	+	+	+	+	+	+
	I										
14: 0: 0	I	+0	+	+B L+	+	+	+	+	+	+	+
	I										
15: 0: 0	I	+0	+	+ B L+	+	+	+	+	+	+	+
	I										
16: 0: 0	I	0	+	+ B L+	+	+	+	+	+	+	+
	I										
17: 0: 0	I	0+	+	+B L+	+	+	+	+	+	+	+
	I										
17: 1: 0	I	0+	+	+B L+	+	+	+	+	+	+	+
	I										

PASSIVE SOLAR TEST CELL DATA

date 26 MAR 81

CELL A TANKWALL (SEL. SURF/NO N.I.) CELL B TANKWALL (FLAT BLACK R-4.5 N.I.)

B- INSIDE A

L- " B

O = 0.5 AIR

	40°	45°	49°	54°	58°	63°	67°	71°	76°	81°	85°	90°
1: 0: 0	+	+	+ M	+	+ O	+ N L+	+	+	BD	+	+	+
2: 0: 0	+	+	+ M	+	+ O	+ NL	+	+	BD+	+	+	+
3: 0: 0	+	+	+	+ M	O	+	+	+	BD+	+	+	+
4: 0: 0	+	+	+	+	O	+N*	+	+	+B D	+	+	+
5: 0: 0	+	+	+	M	O	+NL	+	+	+BD	+	+	+
6: 0: 0	+	+	+	+	M +O	+NL	+	+	BD	+	+	+
7: 0: 0	+	+	+	M+	+ O	+NL	+	+	BD	+	+	+
8: 0: 0	+	+	+	+	M + O	+NL	+	+	BD	+	+	+
9: 0: 0	+	+	+	+	M + O	+ NL	+	+	BD	+	+	+
10: 0: 0	+	+	+	+	M + O	+ N L+	+	+	B+D	+	+	+
11: 0: 0	+	+	+	M	+	O NL+	+	+	B +D	+	+	+
12: 0: 0	+	+	+	+	+	M O	++	+	BD	+	+	+
13: 0: 0	+	+	+	+	M + O	+ NL	+	+	B D	+	+	+
14: 0: 0	+	+	+	+	M O	+	+	+	+B D	+	+	+
15: 0: 0	+	+	+	+	+	O+	+	M	B D	+	+	+
16: 0: 0	+	+	+	+	M+	O +	NL	+	BD	+	+	+
17: 0: 0	+	+	+	+	M + O	+ NL	+	+	+	+	+	+
18: 0: 0	+	+	+	M +	+O	+	NL	+	BD	+	+	+
19: 0: 0	+	+	+	M +	+O	+	NL+	+	BD+	+	+	+
20: 0: 0	+	+	+	+	M O	+	N L+	+	BD	+	+	+
21: 0: 0	+	+	+	M +	O	+	N L+	+	+	+	+	+
22: 0: 0	+	+	+	+	O+	+M*	+	+	BD	+	+	+
23: 0: 0	+	+	+	M +	O+	+NL	+	+	+	+	+	+
24: 0: 0	+	+	+	M+	O +	+NL	+	+	B+D	+	+	+

PASSIVE SOLAR TEST CELL DATA

date 27 MAR 81

CELL A TANKWALL (SEL. SURF/NO N.I.) CELL B TANKWALL (FLAT BLACK R=4.5 N.I.)

B - INSIDE A
L - INSIDE B
O - O.S. AIR

	40°	45°	49°	54°	58°	63°	67°	71°	76°	81°	85°	90°
1: 0: 0	+	+	+	M+	O	+	+NL	+	B+D	+	+	+
2: 0: 0	+	+	+M	+	O	+	+NL	+	BD	+	+	+
3: 0: 0	+	+	+	+	OM	+	+NL	+	BD+	+	+	+
4: 0: 0	+	+	+	+	O	+M	+	+	BD+	+	+	+
5: 0: 0	+	+	+	+	O	+	++	M	+	BD+	+	+
6: 0: 0	+	+	+	+	O	+	++	M	B	D+	+	+
7: 0: 0	+	+	+	+M	O+	+	+NL	+	BD+	+	+	+
8: 0: 0	+	+	+	+	O	+	++L	+	B+D	+	+	+
9: 0: 0	+	+	+	+	+	O	+	NL+	M	BD	+	+
10: 0: 0	+	+	+	+	+	+	O	M*	+	BD	+	+
11: 0: 0	+	+	+	+	+	+	+	M*	+	M	BD	+
12: 0: 0	+	+	+	+	+	+	+	N	NL	O	+	++
13: 0: 0	+	+	+	+	+	+	M	+	+	NL	O	+BD
14: 0: 0	+	+	+	+	+	M+	+	+	N*	+	+	+
15: 0: 0	+	+	+	+	+	M	+	+	O	+NL	+	BD
16: 0: 0	+	+	+	+	+	MO+	+	+	NL	+	BD+	+
17: 0: 0	+	+	+	+	O	M	+	+	NL+	+	BD	+
18: 0: 0	+	+	+	O	N	+	+	+NL	+	BD	+	+
19: 0: 0	+	+	+	O	+	M	+	+	NL	+	BD	+
20: 0: 0	+	+	+	O	M	+	+	+	NL+	+	BD	+
21: 0: 0	+	+	O	+	+	M	+	+	NL	+	B	D
22: 0: 0	+	+	O	+	M	+	+	+	NL	+	BD	+
23: 0: 0	+	+	O	+	M	+	+	+	N+L	+	BD	+
24: 0: 0	+	+	O	+	M+	+	+	+	BD	+	+	+

PASSIVE SOLAR TEST CELL DATA

date 26 MAR 81

CELL A TANKWALL (SEL. SURF/NO N.I.) CELL B TANKWALL (FLAT BLACK R-4.5 N.I.)

B - INSIDE AIR A
K - 0.5 AIR B
O - 0.5 AIR

	40°	45°	49°	54°	58°	63°	67°	71°	76°	81°	85°	90°
1: 0: 0	+	+ O	+ M +	+	NL	+ BD	+	+	+	+	+	+
2: 0: 0	+	+ O	+ M	+	N+L	+BD	+	+	+	+	+	+
3: 0: 0	+	O	+ M+	+	+	BD	+	+	+	+	+	+
4: 0: 0	+	+ O	+	+	M +	NL+	BD	+	+	+	+	+
5: 0: 0	+	+	+	+ O	+	NNL	+	+	+	+	+	+
6: 0: 0	+	+	+	+	+M	+ONL	+	++	+	+	+	+
7: 0: 0	+	+	+	+	+	+	NL	++ BD	+	+	+	+
8: 0: 0	+	+	+	+	+	+	+	NL	MO BD	+	+	+
9: 0: 0	+	+	+	+	+	+	+	+	NL	MO+BD	+	+
10: 0: 0	+	+	+	+	+	+	+	+	+	NL	MO	BD
11: 0: 0	+	+	+	+	+	+	+M	+	+	NL	O	+ BD
12: 0: 0	+	+	+	+	+	+	+M	+	+	+ONL	+	BD
13: 0: 0	+	+	+	+	+	M +	+	+	+	+	N++	B
14: 0: 0	+	+	+	+	+	M +	+	+	+	+	O	NL B
15: 0: 0	+	+	+	+	+	M +	+	+	+	O	+	N+L B
16: 0: 0	+	+	+	M +	+	+	+	+	O	+	+	NL+ BD+
17: 0: 0	+	+	+	M +	+	+	+	O	+	+	+NL	+BD
18: 0: 0	+	+	+	+	M +	+	+	O	+	+	NL	BD
19: 0: 0	+	+	+	M+	+	+	+O	+	+	NL	BD	+
20: 0: 0	+	+	+	M	+	+	+O	+	+	NL+	BD+	+
21: 0: 0	+	+	+	M+	+	+	O+	+	+	NL+	BD	+
22: 0: 0	+	+M	+	+	+	+O	+	+	+NL	+BD	+	+
23: 0: 0	+	+	M+	+	+	+O	+	+	NL	BD	+	+
24: 0: 0	+	+M	+	+	+	+M	+	+	NL	BD	+	+

PASSIVE SOLAR TEST CELL DATA

date 29 MAR 61

CELL A TANKWALL (SEL. SURF/NO N.I.) CELL B TANKWALL (FLAT BLACK R-4.5 N.I.)

B = INSIDE AIR
A = " "
O = OUTSIDE AIR

	40°	45°	49°	54°	58°	63°	67°	71°	76°	81°	85°	90°
1: 0: 0	+	+M	+	+	+	+O	+	+	+NL	+BD	+	+
2: 0: 0	+	+	M+	+	+	+O	+	+	NL	BD	+	+
3: 0: 0	+	+M	+	+	+	+O	+	+	NL	BD	+	+
4: 0: 0	+	+	+	M+	+	+O	+	+	*	BD	+	+
5: 0: 0	+	+	+	+M	+	+	O	+	NL	BD	+	+
6: 0: 0	+	+	+	+M	+	+	O	+	NL	*	+	+
7: 0: 0	+	+	+	+	M+	+	+O	+	++	*	+	+
8: 0: 0	+	+	+	+	+	+	O	M+	NL	BD	+	+
9: 0: 0	+	+	+	+	+	+	M+	O	NL	BD	+	+
10: 0: 0	+	+	+	+	+	+	+	O	M+	+NL	+	+
11: 0: 0	+	+	+	+	+	M+	+	O	+	NL	+	+
12: 0: 0	+	+	+	+	+	+M	+	O+	+	NL+	BD	+
13: 0: 0	+	+	+	M+	+	+	+	O+	+	NL+	BD	+
14: 0: 0	+	+	+	+	M+	+	+	O	+	++	BD	+
15: 0: 0	+	+	+	+	M+	+	+	O	+	NL+	BD	+
16: 0: 0	+	+	+	+	M+	+	+	O	+	NL	+	BD+
17: 0: 0	+	+	+	+M	+	+	O+	+	+NL	+BD	+	+
18: 0: 0	+	+	+	M+	+	+	O	+	NL	BD	+	+
19: 0: 0	+	+	+	+	M+	+O	+	+	NL	BD	+	+
20: 0: 0	+	+	+	+	M+	O+	+	+	NL	BD+	+	+
21: 0: 0	+	+	+	+	+M	O+	+	+	NL	+	+	+
22: 0: 0	+	+	+	+	M+	O	+	+	NL	+BD	+	+
23: 0: M	+	+	+	+	NO	+	+	+	+NL	BD	+	+
24: 0: 0	+	+	+	M	O+	+	+	+	NL	BD	+	+

PASSIVE SOLAR TEST CELL DATA

date 30 MAR 81

CELL A TANKWALL (SEL. SURF/NO N.I.) CELL B TANKWALL (FLAT BLACK R-4.5 N.I.)

B - I.S. AIR A
5 - E.S. AIR B
0 - O.S. AIR

	40°	45°	49°	54°	58°	63°	67°	71°	76°	81°	85°	90°
1: 0: 0	+	+	+	+	+M	O+	+	+	NL	+	+	+
2: 0: 0	+	+	+	+M	+	O+	+	+	NL	+BD	+	+
3: 0: 0	+	+	+	+	MO	+	+	+	NL	BD	+	+
4: 0: 0	+	+	+	M	O+	+	+	+	NL	BD	+	+
5: 0: 0	+	+	+	+O	+M	+	+	+	NL	BD+	+	+
6: 0: 0	+	+	+	O	+M	+	+	+	+	+	+	+
7: 0: 0	+	+	+	+	O+	+	M+	+	NL	BD	+	+
8: 0: 0	+	+	+	+	+O	M+	+	+	NL	+	+	+
9: 0: 0	+	+	+	+	+	+O	+	+	M+N	+BD	+	+
10: 0: 0	+	+	+	+	+	+	O+	+	N+	BD	+	+
11: 0: 0	+	+	+	+	+	+	O	+	+	NL	+	+
12: 0: 0	+	+	+	+	+	+	+	O	+	+	N+	BD
13: 0: 0	+	+	+	+	+	+	+	O	M	+NL	+B	D+
14: 0: 0	+	+	+	+	+	+	M+	O	+	+	N	L+ B D+
15: 0: 0	+	+	+	+	+	M+	+	O	+	+	NL	+ B D+
16: 0: 0	+	+	+	M	+	+	+	O	+	+	NL	+ BD
17: 0: 0	+	+	+	+M	+	O+	+	+	+	+	NL	BD
18: 0: 0	+	+	+	M	O+	+	+	+	+	+	NL	+ BD
19: 0: 0	+	+	+	+O	M+	+	+	+	+	+	NL	B+D
20: 0: 0	+	+	+	MO	+	+	+	+	+	+	N+LB	D+
21: 0: 0	+	+	+	O	M	+	+	+	+	+	NL	+B D
22: 0: 0	+	+	+	+O	M+	+	+	+	+	+	N	LB+D
23: 0: 0	+	+	+	O+	M	+	+	+	+	+	NLB	D+
24: 0: 0	+	+	+	O	+	M+	+	+	+	+	NLB	D+

PASSIVE SOLAR TEST CELL DATA

date 31 MAR 81

CELL A TANKWALL (SEL. SURF/NO N.I.) CELL B TANKWALL (FLAT BLACK R-4.5 N.I.)

B - INSIDE AIR A
O - OS AIR B

	40°	45°	49°	54°	58°	63°	67°	71°	76°	81°	85°	90°
1: 0: 0	+	+	O+ M	+	+	+	+	NLB D+	+	+	+	+
2: 0: 0	+	+	O + M	+	+	+	+	NLB D +	+	+	+	+
3: 0: 0	+	+	O +	+	M	+	+	N++O	+	+	+	+
4: 0: 0	+	+	O +	+	M+	+	+	N++O	+	+	+	+
5: 0: 0	+	+	+O	+	M+	+	+	N++O	+	+	+	+
6: 0: 0	+	+	+	+O	+M	+	+	N++O	+	+	+	+
7: 0: 0	+	+	+	+	O +	M	+	N++O	+	+	+	+
8: 0: 0	+	+	+	+	OM	+	+	N++O	+	+	+	+
9: 0: 0	+	+	+	+	+O	+	M +	N++O	+	+	+	+
10: 0: 0	+	+	+	+	+	M O	+	+	NLB+ D	+	+	+
11: 0: 0	+	+	+	+	+	OM	+	+	N++O	+	+	+
12: 0: 0	+	+	+	+	+	O M	+	+	N++O	+	+	+
13: 0: 0	+	+	+	+	+	+	OM	+	NLB D	+	+	+
14: 0: 0	+	+	+	+	+	M+O	+	+	NLB D	+	+	+
15: 0: 0	+	+	+	+	M +	O	+	+	NLB D	+	+	+
16: 0: 0	+	+	+	+	M +	O +	+	+	NLB D+	+	+	+
17: 0: 0	+	+	+	M+	+	O +	+	+	NLB D +	+	+	+
18: 0: 0	+	+	+	+	M +	O	+	+	NLB D +	+	+	+
19: 0: 0	+	+	+	+	M +	O	+	+	NLB D +	+	+	+
20: 0: 0	+	+	+	+	M +	O	+	+	NLB D +	+	+	+
21: 0: 0	+	+	+	+	M O	+	+	+	N++O	+	+	+
22: 0: 0	+	+	+	M+	+	O +	+	+	N++O	+	+	+
23: 0: 0	+	+	+	M+	+	O +	+	+	N++O	+	+	+
24: 0: 0	+	+	+	M	+	O +	+	+	NLB D	+	+	+

PASSIVE SOLAR TEST CELL DATA

date 1 APR 81

CELL A TANKWALL (SEL. SURF/NO N.I.) CELL B TANKWALL (FLAT BLACK R-4.5 N.I.)

B - 1.5 AIR A
L - 1.5 AIR B
O - 0.5 AIR B

	40°	45°	49°	54°	58°	63°	67°	71°	76°	81°	85°	90°
1: 0: 0	+	+	+	M+	+ O	+	+	+N+	O	+	+	+
2: 0: 0	+	+	+	+M	+ O	+	+	++B	D	+	+	+
3: 0: 0	+	+	+	M	+ O	+	+	NLB	D	+	+	+
4: 0: 0	+	+	+	M +	+	O +	+	N++	D+	+	+	+
5: 0: 0	+	+	M	+	+	O+	+	NLB	D+	+	+	+
6: 0: 0	+	+	+	+	M	+	O +	++ B	D	+	+	+
7: 0: 0	+	+	+	+	+	+	M O	+	NL +BD	+	+	+
8: 0: 0	+	+	+	+	+	+	+	M	+	O NL	+	+
9: 0: 0	+	+	+	+	+	+	+	+	+	*NL+	BD	+
10: 0: 0	+	+	+	+	+	+	+	+	+	M ++L	B D	+
11: 0: 0	+	+	+	+	+	+	+	+	M	+	+	ONL B O
12: 0: 0	+	+	+	+	+	+	+	M	+	+	+	O+NL B
13: 0: 0	+	+	+	+	+	+	M	+	+	+	+	O NL +
14: 0: 0	+	+	+	+	M +	+	+	+	+	+	+	O + N L+
15: 0: 0	+	+	+	M	+	+	+	+	+	+	+	+O +NL +
16: 0: 0	+	+	+	+	M +	+	+	+	+	+	+	NL +
17: 0: 0	+	+	+	M+	+	+	+	O	+	+	+	NL B+
18: 0: 0	+	+	+	+M	+	+	+	+O	+	+	+	N L B O
19: 0: 0	+	+	+	+M	+	+	+	+O	+	+	+	NL + B D+
20: 0: 0	+	+	+	+	M+	+	+	+O	+	+	+	NL + B D+
21: 0: 0	+	+	+	+	M+	+	+	O +	+	+	+	+N L +BD +
22: 0: 0	+	+	+	+	M +	+	+	+ O	+	+	+	N L BD +
23: 0: 0	+	+	+	+	M+	+	+	+O	+	+	+	NL B+O +
24: 0: 0	+	+	+	+	M +	+	+	O	+	+	+	NL B D +

PASSIVE SOLAR TEST CELL DATA

DATE 16 OCT 1981

CELL A TANKWALL SEL SURF / NO N1 4.5

CELL B TANKWALL FLAT BLACK W/ R N1

OUTSIDE AIR TEMP - 0
INSOL ON VERT - M
INSIDE AIR CELL A - B
INSIDE AIR CELL B - L

	20											110
10: 0: 0	I	+	M	+	+	0	+	+	*	+	+	+
11: 0: 0	I	+		+	M	0	+	+	LB	+	+	+
12: 0: 0	I	+		+	+	M	0	+	+	L+B	+	+
13: 0: 0	I	+		+	+	+	MO	+	+	+	LB	+
14: 0: 0	I	+		+	+	+	MO	+	+	+	LB	+
15: 0: 0	I	+		+	+	+	M	0	+	+	+	LB
16: 0: 0	I	+		+	+	M	+	0	+	+	+	LB
17: 0: 0	I	+		+	M	+	+	0	+	+	+	L B
18: 0: 0	I	+	M	+	+	+	+	0	+	+	+	L B
19: 0: 0	I	+		+	+	+	0	+	+	+	+	L B
20: 0: 0	I	+		+	+	0	+	+	+	+	+	LB
21: 0: 0	I	+		+	0	+	+	+	+	+	+	LB
22: 0: 0	I	+		+	0	+	+	+	+	+	+	*
23: 0: 0	I	+		+	0	+	+	+	+	+	LB	+
24: 0: 0	I	+		0	+	+	+	+	+	+	LB	+

PASSIVE SOLAR TEST CELL DATA

DATE 17 OCT 1981

CELL A TANKWALL SEL SURF / NO NI

CELL B TANKWALL FLAT BLACK W/ R_S NI

OUTSIDE AIR TEMP - 0

INSOL ON VERT - M

INSIDE AIR CELL A - B

INSIDE AIR CELL B - L

	20										110
17 0	1: 0: 0	I	+	+	0	+	+	+	+	+	+
	2: 0: 0	I	+	+	0	+	+	+	+	+	+
	3: 0: 0	I	+	+	0	+	+	+	+	+	+
	4: 0: 0	I	+	+	0	+	+	+	+	+	+
	5: 0: 0	I	+	+	0	+	+	+	+	+	+
	6: 0: 0	I	+	+	0	+	+	+	+	+	+
	7: 0: 0	I	+	+	0	+	+	+	+	+	+
	8: 0: 0	I	+	+	0	+	+	+	+	+	+
	9: 0: 0	I	+	+	0	+	+	+	+	+	+
	10: 0: 0	I	M	+	+	0	+	+	+	+	+
	11: 0: 0	I	+	M	+	+	0	+	+	+	+
	12: 0: 0	I	+	+M	+	+	+0	+	+	+	+
	13: 0: 0	I	+	+	M+	+	+	0	+	+	+
	14: 0: 0	I	+	+	M+	+	+	+0	+	+	+
	15: 0: 0	I	M+	+	+	+	+	0	+	+	+
	16: 0: 0	I	+	+	+	+	+	0	+	+	+
	17: 0: 0	I	+	+	+	+	+	0	+	+	+
	18: 0: 0	I	+	+	+	+	+	+0	+	+	+
	19: 0: 0	I	+	+	+	+	+	0	+	+	+
	20: 0: 0	I	+	+	+	+	0	+	+	+	+
	21: 0: 0	I	+	+	+	+	0+	+	+	+	+
	22: 0: 0	I	+	+	+	+	0	+	+	+	+
	23: 0: 0	I	+	+	+	+	+0	+	+	+	+
	24: 0: 0	I	+	+	+	+	+0	+	+	+	+

PASSIVE SOLAR TEST CELL DATA

DATE 18 OCT 1981

CELL A TANKWALL SEL SURF / NO NI 4.5

CELL B TANKWALL FLAT BLACK W/ R⁵ NI

OUTSIDE AIR TEMP - 0
INSOL ON VERT - M
INSIDE AIR CELL A - B
INSIDE AIR CELL B - L

		20										110
18	1: 0: 0	I	+	+	+	+	+	0	+	L+	+B	+
0		I										
	2: 0: 0	I	+	+	+	+	+	0	+	L+	+B	+
		I										
	3: 0: 0	I	+	+	+	+	+	0	+	L+	B	+
		I										
	4: 0: 0	I	+	+	+	+	+	0	+	L+	B	+
		I										
	5: 0: 0	I	+	+	+	+	+	0	+	L+	B+	+
		I										
	6: 0: 0	I	+	+	+	+	0	+	+	L	+B	+
		I										
	7: 0: 0	I	+	+	+	+	0	+	+	L	+B	+
		I										
	8: 0: 0	I	+	+	+	0	+	+	+	L	+B	+
		I										
	9: 0: 0	I	+	+	+	0	+	+	L	B	+	+
		I										
	10: 0: 0	I M	+	+	+	0	+	+	L	B	+	+
		I										
	11: 0: 0	I	+	+	+	0	+	+	L	+B	+	+
		I										
	12: 0: 0	I	+	+	+	0	+	+	L	+B	+	+
		I										
	13: 0: 0	I	+	+	+	0	+	+	L+	B	+	+
		I										
	14: 0: 0	I M	+	+	+	0	+	+	L+	+B	+	+
		I										
	15: 0: 0	I	+M	+	+	0	+	+	L+	+B	+	+
		I										
	16: 0: 0	I	+	M	+	0	+	+	L+	+B	+	+
		I										
	17: 0: 0	I M	+	+	0	+	+	+	L	+	+B	+
		I										
	18: 0: 0	I	+	+	0	+	+	+	L	+	+B	+
		I										
	19: 0: 0	I	+	+	0	+	+	+	L	+	B	+
		I										
	20: 0: 0	I	+	+	0	+	+	+	L	+	B+	+
		I										
	21: 0: 0	I	+	+	0	+	+	+	L	+	B	+
		I										
	22: 0: 0	I	+	+	0	+	+	+	L	+	B	+
		I										
	23: 0: 0	I	+	+	0	+	+	+	L+	+	B	+
		I										
	24: 0: 0	I	+	+	0	+	+	+	L+	+	B	+

PASSIVE SOLAR TEST CELL DATA

DATE 19 OCT 1981

CELL A TANKWALL SEL SURF / NO NI

CELL B TANKWALL FLAT BLACK W/ R⁵ NI

OUTSIDE AIR TEMP - O

INSOL ON VERT - M

INSIDE AIR CELL A - B

INSIDE AIR CELL B - L

	20												110			
19 1: 0: 0	I	+	+	0	+	+	L	+	B	+	+	+	+			
0	I															
2: 0: 0	I	+	+	0	+	+	L	+	B	+	+	+	+			
	I															
3: 0: 0	I	+	+	0	+	+	L	+	B+	+	+	+	+			
	I															
4: 0: 0	I	+	+	0	+	+	L	+	B	+	+	+	+			
	I															
5: 0: 0	I	+	+	0	+	+	L	+	B	+	+	+	+			
	I															
6: 0: 0	I	+	+	0	+	+	L	+	B	+	+	+	+			
	I															
7: 0: 0	I	+		0	+	+	L	+	B	+	+	+	+			
	I															
8: 0: 0	I	+	0	+	+		L		B	+	+	+	+			
	I															
9: 0: 0	I	+	0	+	+		L		B	+	+	+	+			
	I															
10: 0: 0	I	+	M	+	0	+	L	+	B	+	+	+	+			
	I															
11: 0: 0	I	+	+	0	M	+	+	L	+	B	+	+	+			
	I															
12: 0: 0	I	+	+		0	+	+	L	M	+	+	B	+	+		
	I															
13: 0: 0	I	+	+		0	+	+	L	+	M	+	B	+	+		
	I															
14: 0: 0	I	+	+		+	0	+	L	+	M	+	+	B	+	+	
	I															
15: 0: 0	I	+	+		+	0	+	L	+	M	+	+	B	+	+	
	I															
16: 0: 0	I	+	+		+	0	+	M	L	+	+	+	B	+	+	
	I															
16:15:15	I	+	+		+	M	0	+	+	L	+	+	+	B	+	+
	I															
17: 0: 0	I	+	+		M	0	+	+	L	+	+	+	B	+	+	
	I															
18: 0: 0	I	+	M	+		0	+	+	L	+	+	+	B	+	+	
	I															
19: 0: 0	I	+	+		0	+	+	+	L	+	+	+	B	+	+	
	I															
20: 0: 0	I	+	+	0	+	+	+	L	+	+	+	+	B	+	+	
	I															
21: 0: 0	I	+	0	+	+	+	+	L	+	+	+	+	B	+	+	
	I															
22: 0: 0	I	+	0	+	+	+	+	L	+	+	+	+	B	+	+	
	I															
23: 0: 0	I	+	0	+	+	+	+	L	+	+	+	+	B	+	+	
	I															
24: 0: 0	I	+	0	+	+	+	+	L	+	+	+	+	B	+	+	
	I															

PASSIVE SOLAR TEST CELL DATA

DATE 20 OCT 1981

CELL A TANKWALL SEL SURF / NO N1

CELL B TANKWALL FLAT BLACK W/ R S N1

OUTSIDE AIR TEMP - 0

INSOL ON VERT - M

INSIDE AIR CELL A - B

INSIDE AIR CELL B - L

	20									110
201: 0: 0	I	+	0	+	+L	+	+	B+	+	+
0	I									
2: 0: 0	I	+	0	+	+L	+	+	B+	+	+
	I									
3: 0: 0	I	+	0	+	L	+	+	B+	+	+
	I									
4: 0: 0	I	+	0	+	L	+	+	B+	+	+
	I									
5: 0: 0	I	+	0	+	L	+	+	B+	+	+
	I									
REENTER										
6: 0: 0	I	+	0+	+	L+	+	B	+	+	+
	I									

PASSIVE TEST CELL DATA

DATE 15 OCT 1981CELL A TANKWALL (sel surf / no N.I.)CELL B 7" flat black steel water tubes (r-4.5 N.I.)

O = O.S. air temp
 B = I.S. air cell A
 L = I.S. air cell B

	20	65	110
15: 0: 0 I	+	+	+
16: 0: 0 I	+	+	+
17: 0: 0 I	+	+	+
18: 0: 0 I	+	+	+
19: 0: 0 I	+	+	+
20: 0: 0 I	+	+	+
21: 0: 0 I	+	+	+
22: 0: 0 I	+	+	+
23: 0: 0 I	+	+	+
24: 0: 0 I	+	+	+

PASSIVE TEST CELL DATA

DATE 16 OCT 1981

CELL A TANKTALL (sel surf / no 1. I.)

CELL A 7" flat black steel water tubes (1-4.5 M I)

O += 0.3 air temp

I = 1.3. air cell A

L = 1.3. air cell B

16	0: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	2: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	3: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	4: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	5: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	6: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	7: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	8: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	9: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	10: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	11: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	12: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	13: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	14: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	15: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	16: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	17: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	18: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	19: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	20: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	21: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	22: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	23: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+
	24: 0: 0	I	+	+	+	O+	LB+	+	+	+	+	+

DATE 17 OCT 1971

CELL A TANKWALL (sel surf / no n. i.)

CELL 9	7" flat black steel water tubes (R- 4.5 M.I.)
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Q = D. E. air tempo

Q = i.s. air cell A

L = 1.8. air cell a

[illegible]

PASSIVE TEST CELL DATA

DATE OCT 18 1931

CELL A TANKWALL (sel surf / no n. i.)

CELL B 7" flat black steel water tubes (R- 4.5 N.I.)

O = O. S. air temp

B = I.S. air cell A

L = I.S. air cell B

				20				65						110
18	1:	O:	O	I	+	+	+	+0	+	+	* +	+	+	+
	2:	O:	O	I	+	+	+	0+	+	+	* +	+	+	+
	3:	O:	O	I	+	+	+	0 +	+	+	+BL	+	+	+
	4:	O:	O	I	+	+	+	0 +	+	+	+*	+	+	+
	5:	O:	O	I	+	+	+	0 +	+	+	*	+	+	+
	6:	O:	O	I	+	+	+	0 +	+	+	BL	+	+	+
	7:	O:	O	I	+	+	+	0 +	+	+	BL+	+	+	+
	8:	O:	O	I	+	+	0	+	+	BL+	+	+	+	+
	9:	O:	O	I	+	+	0	+	+	* +	+	+	+	+
	10:	O:	O	I	+	+	0	+	+	* +	+	+	+	+
	11:	O:	O	I	+	+	0+	+	+	LB +	+	+	+	+
	12:	O:	O	I	+	+	0+	+	+	* +	+	+	+	+
	13:	O:	O	I	+	+	0+	+	+	+LB	+	+	+	+
	14:	O:	O	I	+	+	0+	+	+	+LB	+	+	+	+
	15:	O:	O	I	+	+	0	+	+	+LB	+	+	+	+
	16:	O:	O	I	+	+	+0	+	+	+LB	+	+	+	+
	17:	O:	O	I	+	+	+	0 +	+	+	+LB	+	+	+
	18:	O:	O	I	+	+	+	0 +	+	+	+LB	+	+	+
	19:	O:	O	I	+	+	+	0 +	+	+	+LB	+	+	+
	20:	O:	O	I	+	+	+0	+	+	LB	+	+	+	+
	21:	O:	O	I	+	+	0	+	+	LB	+	+	+	+
	22:	O:	O	I	+	+	0	+	+	LB	+	+	+	+
	23:	O:	O	I	+	+	0	+	+	LB	+	+	+	+
	24:	O:	O	I	+	+	0	+	+	LB	+	+	+	+

PASSIVE TEST CELL DATA

DATE 19 OCT

1991

CELL A TANKWALL (sel surf / no V.I.)

CELL P 7" flat black steel water tubes (r=4.5 V.I.)

O = O.S. air temp

I = I.S. air cell A

L = I.S. air cell P

		20				65					110
19	1: 0: 0	I	+	+	0	+	LB	+	+	+	+
		I									
	2: 0: 0	I	+	+	+0	+	++	+	+	+	+
		I									
	3: 0: 0	I	+	+	+0	+	LB+	+	+	+	+
		I									
	4: 0: 0	I	+	+	+0	+	LB+	+	+	+	+
		I									
	5: 0: 0	I	+	+	+0	+	LB+	+	+	+	+
		I									
	6: 0: 0	I	+	+	+0	+	L B+	+	+	+	+
		I									
	7: 0: 0	I	+	+	+0	+	LB +	+	+	+	+
		I									
	8: 0: 0	I	+	+	+0	+	LB +	+	+	+	+
		I									
	9: 0: 0	I	+	+	+0	+	LB +	+	+	+	+
		I									
	10: 0: 0	I	+	+	+0	+	LB +	+	+	+	-
		I									

END OF DATA

PAGES 26 to 27
WERE INTENTIONALLY
LEFT BLANK

PASSIVE SOLAR TEST CELL DATA

date 15 MAY 81

CELL A TANK WALL (SEL. SURF/NO N.I.) CELL B 7" WATER TUBES (FLAT BLACK R-4.5 N.I.)

E IS 4 ABSORBER SURF CELLS
I IS 8 ABSORBER SURF CELLS
M IS 12 PYRANOMETER CELLS
O IS 14 OUTSIDE AIR

		20°	28°	36°	43°	51°	58°	66°	74°	82°	90°
15: 0: 0	I	+	M+	+	+	+ O	+ IE	+	+	+	+
	I										
16: 0: 0	I	M+	+	+	+	+ O	+ IE	+	+	+	+
	I										
17: 0: 0	I	M+	+	+	+	+	O+IE	+	+	+	+
	I										
18: 0: 0	I	+	+	+	+	+	OIE	+	+	+	+
	I										
19: 0: 0	I	+	M+	+	+	+	OI E	+	+	+	+
	I										
20: 0: 0	I	+	+	M+	+	+	OI E	+	+	+	+
	I										
21: 0: 0	I	+	M+	+	+	+	O+I E	+	+	+	+
	I										
22: 0: 0	I	+	+	M+	+	+	O +IE	+	+	+	+
	I										
23: 0: 0	I	+	M+	+	+	+	O I E	+	+	+	+
	I										
24: 0: 0	I	+	M+	+	+	O	IE	+	+	+	+
	I										

PASSIVE SOLAR TEST CELL DATA

date 16 MAY 81

CELL A TANK WALL (SEL. SURF/NO N.I.) CELL B 7" WATER TUBES (FLAT BLACK R-4.5 N.I.)

E IS 4 ABSORBER SURF CELLS
I IS 8 ABSORBER SURF CELLS
M IS 12 PYRANOMETER CELLS
O IS 14 OUTSIDE AIR

			20°	28°	36°	43°	51°	58°	66°	74°	82°	90°
1:	0:	0	I	+M	+	+	+	O+	IE	+	+	+
2:	0:	0	I	+	M+	+	+	O+	IE	+	+	+
3:	0:	0	I	+	M	+	+	O+	IE	+	+	+
4:	0:	0	I	+	M	+	+	O	+	+	+	+
5:	0:	0	I	+	M	+	O	+	+	+	+	+
6:	0:	0	I	M	+	+	O	+	+	+	+	+
7:	0:	0	I	+	M	+	O+	+	+	+	+	+
8:	0:	0	I	M	+	O	+	+	+	+	+	+
9:	0:	0	I	M+	+	+	O+	+	IE	+	+	+
10:	0:	0	I	+	M	+	+	O	I+E	+	+	+
11:	0:	0	I	+	+	+	+M	+	I+O	E	+	+
12:	0:	0	I	+	+	+	M+	+	I+	O+E	+	+
13:	0:	0	I	+	+	+	+	+	M	+	I	+O
14:	0:	0	I	+	+	+	+	+	+	+	+	M
15:	0:	0	I	+	+	+	+	+	+	+	+	O
16:	0:	0	I	+	+	+	+	+	+	+	+	O
17:	0:	0	I	+	+	+	+	+	+	+	+	O
18:	0:	0	I	+	+	+	+	+	+	+	+	O
19:	0:	0	I	+	+	+	+	+	+	+	+	O
20:	0:	0	I	+	+	+	+	+	+	+	+	O
21:	0:	0	I	+	+	+	+	+	+	+	+	O
22:	0:	0	I	+	+	+	+	+	+	+	+	O
23:	0:	0	I	+	+	+	+	+	+	+	+	O
24:	0:	0	I	+	+	+	+	+	+	+	+	O

PASSIVE SOLAR TEST CELL DATA

date 17 MAY 61

CELL A TANK WALL (SEL. SURF./ NO N.I.) CELL B 7" WATER TUBES (FLAT BLACK R-4.5 N.I.)

E IS 4 ABSORBER SURF CELLS
I IS 8 ABSORBER SURF CELLS
M IS 12 PYRANOMETER CELLS
O IS 14 OUTSIDE AIR

			20°	28°	36°	43°	51°	58°	66°	74°	82°	90°
0: 0: 0	I		+	M	+	+ O	+	+	+	+	+	+
2: 0: 0	I		+	M	+	O	+	+	+	+EI	+	+
3: 0: 0	I		+	M	+	O+	+	+	+	E I	+	+
4: 0: 0	I		+	+M	+	O	+	+	+	E+I	+	+
5: 0: 0	I	M	+	+	+ O	+	+	+	+	EI	+	+
6: 0: 0	I		+	M	+	O	+	+	+	E I	+	+
7: 0: 0	I		+	M	+	+ O	+	+	+	EI+	+	+
8: 0: 0	I	M	+	+	+ O	+	+	+	+	EI	+	+
9: 0: 0	I	M	+	+	+ O	+	+	+	+	* +	+	+
10: 0: 0	I		+	+M	+	+	+	O	+	I E	+	+
11: 0: 0	I		+	+	M	+	+	+	O+	I	+ E	+
12: 0: 0	I		+	+	+	+	M+	+	+	O	+I	E
13: 0: 0	I		+	+	+	+	+	+	M	+	O	+ I
14: 0: 0	I		+	+	+	+	+	+	+	O	M+	I
15: 0: 0	I		+	+	+	+	+	+	+	+	O	+ M
16: 0: 0	I		+	+	+	+	+	+	+	+	O	M+
17: 0: 0	I		+	+	+	+	+	+	+	M	+	O
18: 0: 0	I		+	+	+	+	+	M	+	+	O	+
19: 0: 0	I		+	+	M	+	+	+	+	+	O	+
20: 0: 0	I		+	+	M	+	+	+	+	+	O	+
21: 0: 0	I		+	M	+	+	+	+	+	O	+	+
22: 0: 0	I		+	+	+M	+	+	+	O+	+	+	E
0: 0: 0	I		+	M	+	+	+	+	O	+	+	E
0: 0: 0	I		+	+	M	+	+	O	+	+	+	E

PASSIVE SOLAR TEST CELL DATA

date 18 MAY 81

CELL A TANK WALL (SEL. SURF./NO N.I.) CELL B 7" WATER TUBES (FLAT BLACK R-4.5 N.I.)

E IS 4 ABSORBER SURF CELLS

I IS 8 ABSORBER SURF CELLS

M IS 12 PYRANOMETER CELLS

O IS 14 OUTSIDE AIR

		20°	28°	36°	43°	51°	58°	66°	74°	82°	90°
0: 0: 0	I	+	+	M+	+	+O	+	+	+	+ E I+	
1: 0: 0	I	+M	+	+	+	O+	+	+	+	+ E I+	
2: 0: 0	I	+	+	M	+	+	O	+	+	+E I	+
3: 0: 0	I	+	+	M	+	+	O	+	+	+E I	+
4: 0: 0	I	M	+	+	+	O	+	+	+	E I	+
5: 0: 0	I	M+	+	+	+	O	+	+	+	E I	+
6: 0: 0	I	+	M+	+	+	O	+	+	+	E+I	+
7: 0: 0	I	+	M	+	+	O	+	+	+	E +I	+
8: 0: 0	I	+	+	+	NO	+	+	+	+	E I	+
9: 0: 0	I	+	+	+	**	+	+	+	+	E I+	+
10: 0: 0	I	+	+	+	O+	M+	+	+	+	E I+	+
11: 0: 0	I	+	+	+	O	+	M	+	+	E I	+
12: 0: 0	I	+	+	+	OM+	+	+	+	+	E I	+
13: 0: 0	I	+	+M	+	O	+	+	+	+	E I	+
14: 0: 0	I	+	+	+	*	+	+	+	+	+	+
15: 0: 0	I	+	M	+	O+	+	+	+	+	EI	+
16: 0: 0	I	+	+M	+	O	+	+	+	+	*	+
17: 0: 0	I	+M	+	+	+O	+	+	+	+	IE	+
18: 0: 0	I	M+	+	+	+	O	+	+	+	IE	+
19: 0: 0	I	+	M	+	+	O	+	+	+	IE+	+
20: 0: 0	I	+	+	+M	+O	+	+	+	+	*	+
21: 0: 0	I	+	+	+	M O+	+	+	+	+	*	+
22: 0: 0	I	+	M+	+	O+	+	+	+	+	*	+
23: 0: 0	I	+	+	M	+	O+	+	+	+	**	+
24: 0: 0	I	M	+	+	O+	+	+	+	+	**	+

PASSIVE SOLAR TEST CELL DATA

date 19 MAY 81

CELL A TANK WALL (SEL. SURF./ NO N.I.) CELL B 7" WATER TUBES (FLAT BLACK R-4.5 N.I.)

E 15 4 ABSORBER SURF CELLS
I 15 6 ABSORBER SURF CELLS
M 18 12 PYRANOMETER CELLS
C 14 OUTSIDE AIR

		20°	28°	36°	43°	51°	58°	66°	74°	82°	90°
1: 0: 0	I	+ M	+	+	0+	+	+	++	+	+	+
2: 0: 0	I	M +	+	+	0	+	+	*	+	+	+
3: 0: 0	I	+M	+	+	0	+	+	*	+	+	+
4: 0: 0	I	M+	+	+	0	+	+	EI	+	+	+
5: 0: 0	I	M	+	+	0	+	+	++	+	+	+
6: 0: 0	I	+	+	+	0	+	+	++	+	+	+
7: 0: 0	I	M +	+	+	0	+	+	* +	+	+	+
8: 0: 0	I	+	+M	+	0	+	+	* +	+	+	+
9: 0: 0	I	+ M	+	+	0	+	+	* +	+	+	+
10: 0: 0	I	M +	+	+	+0	+	+	IE +	+	+	+

PASSIVE SOLAR TEST CELL DATA

date 15 MAY 81

CELL A TANK WALL (SEL. SURF./NO N.I.) CELL B 7" WATER TUBES (FLAT BLACK R - 4.5 N.I.)

F IS 5 WATER CELLS 6' DEPTH
G IS 6 WATER CELLS 2' DEPTH
J IS 9 WATER CELLS 6' DEPTH
K IS 10 WATER CELLS 2' DEPTH
M IS 12 PYRANOMETER CELLS
O IS 14 OUTSIDE AIR

			20°	28°	36°	43°	51°	58°	66°	74°	82°	90°
15	0: 0	I	+	+	+	+M	+ O	++G	+	+	+	+
		I										
	6: 0	I	+	+	+	M +	+ O	++G	+	+	+	+
		I										
	17: 0	I	+	+	+	M +	+	O++G	+	+	+	+
		I										
	18: 0	I	+	+	M +	+	+	O+G	+	+	+	+
		I										
	19: 0	I	+	+	+	M	+	O+G	+	+	+	+
		I										
	20: 0	I	+	+	+	+	M +	O+G	+	+	+	+
		I										
	21: 0	I	+	+	+	+	M +	O++G	+	+	+	+
		I										
	22: 0	I	+	+	+	+	M O	++G	+	+	+	+
		I										
	23: 0	I	+	+	+	+M	+ O	++G	+	+	+	+
		I										
	24: 0	I	+	+	+	+	M O	++G	+	+	+	-
		I										

PASSIVE SOLAR TEST CELL DATA

date 16 MAY 81

CELL A TANKWALL (SEL. SURF/NO N.I.) CELL B 7" WATER TUBES (FLAT BLACK R-4.5 N.I.)

F IS 5 WATER CELLS 6' DEPTH
G IS 6 WATER CELLS 2' DEPTH
J IS 9 WATER CELLS 6' DEPTH
K IS 10 WATER CELLS 2' DEPTH
M IS 12 PYRANOMETER CELLS
O IS 14 OUTSIDE AIR

			20°	28°	36°	43°	51°	58°	66°	74°	82°	90°
- 16	0: 0: 0	I	+	+	+	M+	O+	**G	+	+	+	+
	1: 0: 0	I	+	+	+	+M	O+	F*G	+	+	+	+
	2: 0: 0	I	+	+	+	M	O+	F*	+	+	+	+
	3: 0: 0	I	+	+	+	OM	+	F*	+	+	+	+
	4: 0: 0	I	+	+	+	O + M	+	*G	+	+	+	+
	5: 0: 0	I	+	+	+MO	+	+	*G	+	+	+	+
	6: 0: 0	I	+	+	+O	M+	+	F*	+	+	+	+
	7: 0: 0	I	+	+	O	M +	+	F*	+	+	+	+
	8: 0: 0	I	+	+	+	M O+	+	F*	+	+	+	+
	9: 0: 0	I	+	+	+	+	M	+	F*	+	+	+
	10: 0: 0	I	+	+	+	+	M	+	O F*	+	+	+
	11: 0: 0	I	+	+	+	+	+	**O	+	+	+	+
	12: 0: 0	I	+	+	+	+	+	**G	O+	+	+	+
	13: 0: 0	I	+	+	+	+	+	JF * **	+	+	+	+
	14: 0: 0	I	+	+	+	+	+	+	JF G	* +	+M	+
	15: 0: 0	I	+	+	+	+	+	+	JF G	O+ K	+M	+
	16: 0: 0	I	+	+	+	+	+	+	+JF	GO	+K	+
	17: 0: 0	I	+	+	+	+	+	+	+	JMF *	+	K+
	18: 0: 0	I	+	+	+	+	+	+	+	M JFO	G+	K+
	19: 0: 0	I	+	+	+	+	+	M	+	**F	G	K+
	20: 0: 0	I	+	+	+	+	+M	+	+	O JF	+G	K+
	21: 0: 0	I	+	+	+	+	M +	+	+	O	+	JF +G K +
	22: 0: 0	I	+	+	+	+	M+	+	O	+	+	JF +GK +
	23: 0: 0	I	+	+	+	+	M+ O	+	+	+	+	JF **
	0: 0: 0	I	+	+	+	+	* +	+	+	+	+	JF *

PASSIVE SOLAR TEST CELL DATA

date 17 MAY 81

CELL A TANK WALL (SEL. SURF./NO N.I.) CELL B 7" WATER TUBES (FLAT BLACK R-4.5 N.I.)

F IS 5 WATER CELLS 8' DEPTH
G IS 6 WATER CELLS 2' DEPTH
J IS 9 WATER CELLS 8' DEPTH
K IS 10 WATER CELLS 2' DEPTH
M IS 12 PYRANOMETER CELLS
O IS 14 OUTSIDE AIR

		20°	28°	36°	43°	51°	58°	66°	74°	82°	90°
17	0:00 I	+	+	+	+	+	+	+	+JF	+	-
	2:00 I	+	+	+	O M	+	+	+	+JF	++	+
	3:00 I	+	+	+	O+M	+	+	+	++	+	+
	4:00 I	+	+	+	O + M	+	+	+	* KG	+	+
	5:00 I	+	+	+	+	+	+	+	JF	+	+
	6:00 I	+	+	+	O + M	+	+	+	++KG	+	+
	7:00 I	+	+	+	O M	+	+	+	* KG	+	+
	8:00 I	+	+	+	+	+	+	+	++	+	+
	9:00 I	+	+	+	M+O	+	+	+	* KG	+	+
	10:00 I	+	+	+	+	M	O	+	* KG	+	+
	11:00 I	+	+	+	+	M+	+	O+ J*	G	+	+
	12:00 I	+	+	+	+	+	+	M	+	*F	++
	13:00 I	+	+	+	+	+	+	+	O*F	G K+	+
	14:00 I	+	+	+	+	+	+	+	O*	G+	+
	15:00 I	+	+	+	+	+	+	+	+	O* +G	M
	16:00 I	+	+	+	+	+	+	+	+	O	+
	17:00 I	+	+	+	+	+	+	+	+	+	+
	18:00 I	+	+	+	+	+	+	N	+	O	+
	19:00 I	+	+	+	+	+	+	+	+	O	+
	20:00 I	+	+	+	+	M	+	+	+	O	+
	21:00 I	+	+	+	+	M	+	+	+	O	+
	22:00 I	+	+	+	+	+	+	+	+	O	+
	23:00 I	+	+	+	+	+	+	+	+	O	+
	0:00 I	+	+	+	+	+	+	+	+	O	+

PASSIVE SOLAR TEST CELL DATA

date 18 MAY 81

CELL A TANK WALL (SEL. SURF./NO N.I.) CELL B 7" WATER TUBES (FLAT BLK, R 4.5 N.I.)

F IS 5 WATER CELLS 8' DEPTH
G IS 6 WATER CELLS 2' DEPTH
J IS 9 WATER CELLS 8' DEPTH
K IS 10 WATER CELLS 2' DEPTH
M IS 12 PYRANOMETER CELLS
O IS 14 OUTSIDE AIR

		20°	28°	36°	43°	51°	58°	66°	74°	82°	90°
1	0:00	+	+	+	+	MO	+	+	+	+	+
2	0:00	+	+	+	M+	O+	+	+	+	+	JF *
3	0:00	+	+	+	+	+	+	+	+	+	+
4	0:00	+	+	+	M	O	+	+	+	+	+
5	0:00	+	+	+	M	O	+	+	+	+	+
6	0:00	+	+	+	+	MO	+	+	+	+	+
7	0:00	+	+	+	M	O	+	+	+	+	+
8	0:00	+	+	+	O	+	M+	+	+	+	+
9	0:00	+	+	+	O+	+	M+	+	+	+	+
10	0:00	+	+	+	O+	+	+	M	+	+	+
11	0:00	+	+	+	O	+	+	+	M	+	+
12	0:00	+	+	+	O	+	+	M+	+	+	+
13	0:00	+	+	+	O	+	M	+	+	+	+
14	0:00	+	+	+	O	+	+	M	+	+	+
15	0:00	+	+	+	O+	M	+	+	+	+	+
16	0:00	+	+	+	O	M	+	+	+	+	+
17	0:00	+	+	+	M+O	+	+	+	+	+	+
18	0:00	+	+	+	M	O	+	+	+	+	+
19	0:00	+	+	+	+	+	+	+	+	+	+
20	0:00	+	+	+	+	O	+	M	+	+	+
21	0:00	+	+	+	O+	+	M	+	+	+	+
22	0:00	+	+	+	O+M	+	+	+	+	+	+
23	0:00	+	+	+	O+	M	+	+	+	+	+
24	0:00	+	+	+	+	+	+	+	+	+	+

PASSIVE SOLAR TEST CELL DATA

date 19 MAY 81

CELL A TANKWALL (SEL. SURF./NO N.I.) CELL B 7" WATER TUBES (FLAT BLACK R-4.5 N.I.)

F IS 5 WATER CELLA 8' DEPTH
G IS 6 WATER CELLA 2' DEPTH
J IS 9 WATER CELLB 8' DEPTH
K IS 10 WATER CELLB 2' DEPTH
M IS 12 PYRANOMETER CELLB
O IS 14 OUTSIDE AIR

		20°	28°	36°	43°	51°	58°	66°	74°	82°	90°
19	9: 0 I	+	+	+	OM	+	+	JFKG	+	+	+
	2: 0: 0 I	+	+	+	M O	+	+	*KG	+	+	+
	3: 0: 0 I	+	+	+	MO	+	+	JFKG	+	+	+
	4: 0: 0 I	+	+	+	M O	+	+	JF*	+	+	+
	5: 0: 0 I	+	+	+	M O	+	+	***	+	+	+
	6: 0: 0 I	+	+	M	O	+	+	JFKG	+	+	+
	7: 0: 0 I	+	+	+M	O	+	+	* *	+	+	+
	8: 0: 0 I	+	+	+	O M	+	+	*KG	+	+	+
	9: 0: 0 I	+	+	+	*	+	+	* **	+	+	+
	10: 0: 0 I	+	+	+M	+O	+	+	* **	+	+	+

PASSIVE SOLAR TEST CELL DATA

DATE 31 OCT 1981

CELL B CLEAR F.G. TUBES (VERT, 12") R² N.I. / DOUBLE GLAZED

CELL A TANKWALL SEL. SURF W/ NO N.I. / DOUBLE GLAZED

AMBIENT AIR TEMP. = P

INSOL. ON VERT. SURF. = N

INTERIOR AIR TEMP CELL A = C

INTERIOR AIR TEMP CELL B = M

		20					65						110
		I	I	I	I	I	I	I	I	I	I	I	I
31 OCT	9:00	0	I	+	P	+	+	+	+	+	+C	M	+
	10:00	0	I	+		P	+	+	+	+	+	C	+M
	11:00	0	I	+	+		P	+	+	+	+	C	M
	11:30:15	15	I	+	+		P	+	+	+	+	+C	+M
	14:00	0	I	+	+		+	P	+	+	+	+	+CM
	15:00	0	I	+	+		+	P	+	+	+	+	+MC
	16:00	0	I	+	+		+	P	+	+	+	+	+MC
	17:00	0	I	+	+		+	P	+	+	+	+	M+C
	18:00	0	I	+	+		P	+	+	+	+	+	M C
	19:00	0	I	+		+P	+	+	+	+	+	+	MC+
	20:00	0	I	+	P	+	+	+	+	+	+	+	+
	21:00	0	I	+	P	+	+	+	+	+	+	+CM	+
	22:00	0	I	+	P	+	+	+	+	+	+	CM	+
	23:00	0	I	+	P	+	+	+	+	+	+	C+M	+
	24:00	0	I	P	+	+	+	+	+	+	+	C M	+

PASSIVE SOLAR TEST CELL DATA

DATE 3 Nov 1981

CELL B CLEAR F.G. TUBES (VERT, 12") R⁹⁵ N.I. / DOUBLE GLAZED

CELL A TANKWALL SEL. SURF W/ NO N.I. / DOUBLE GLAZED

AMBIENT AIR TEMP. = P
INSOL. ON VERT. SURF. = N
INTERIOR AIR TEMP CELL A = C
INTERIOR AIR TEMP CELL B = M

		20					65					110
		I					I					I
3 Nov	1: 0: 0	I	+	P+	+	+	+	+C	+M	+	+	+
	2: 0: 0	I	+	P+	+	+	+	+C	+M	+	+	+
	3: 0: 0	I	+	P+	+	+	+	+C	+M	+	+	+
	4: 0: 0	I	+	P+	+	+	+	+C	+M	+	+	+
	5: 0: 0	I	+	P	+	+	+	+C	+M	+	+	+
	6: 0: 0	I	+	P	+	+	+	C	+M	+	+	+
	7: 0: 0	I	+	P	+	+	+	C	+M	+	+	+
	8: 0: 0	I	+	+P	+	+	+	C	+M	+	+	+
	9: 0: 0	I	+	+P	+	+	+	C	+M	+	+	+
	10: 0: 0	I	+	+ P	+	+	+	C	+M	+	+	+
	11: 0: 0	I	+	+ P	+	+	+	+C	+ M	+	+	+
	12: 0: 0	I	+	+ P+	+	+	+	+C	+ M	+	+	+
	13: 0: 0	I	+	+ P	+	+	+	+ C	+ M+	+	+	+
	14: 0: 0	I	+	+ +P	+	+	+	+	C	+	M	+
	15: 0: 0	I	+	+ + P	+	+	+	+	+ C	+	+M	+
	16: 0: 0	I	+	+ + P	+	+	+	+	+	C+	M	+
	17: 0: 0	I	+	+ 17	+	+	+	+	+	C M	+	+
	18: 0: 0	I	+	+ P	+	+	+	+	+	CM	+	+
	19: 0: 0	I	+	P+	+	+	+	+	+ C	M+	+	+
	20: 0: 0	I	+	P	+	+	+	+	+C	M+	+	+
	21: 0: 0	I	+	P	+	+	+	+	C	M	+	+
	22: 0: 0	I	+	P	+	+	+	+	C+	M	+	+
	23: 0: 0	I	P	+	+	+	+	+	C	+	M	+
	24: 0: 0	I	P	+	+	+	+	+	C	+	M	+

PASSIVE SOLAR TEST CELL DATA

DATE 2 NOV 1981

CELL B CLEAR F.G. TUBES (VERT, 12") R⁴ N.I. / DOUBLE GLAZED

CELL A TANKWALL SEL. SURF W/ NO N.I. / DOUBLE GLAZED

AMBIENT AIR TEMP. = P
 INSOL. ON VERT. SURF. = N
 INTERIOR AIR TEMP CELL A = C
 INTERIOR AIR TEMP CELL B = M

		20					65					110	
		I	I	I	I	I	I	I	I	I	I	I	I
2 NOV	0:00	I	P	+	+	+	+	+	C	M	+	+	+
	1:00	I	P	+	+	+	+	+	C	M	+	+	+
	2:00	I	P	+	+	+	+	+	C	M	+	+	+
	3:00	I	+P	+	+	+	+	+	C	M	+	+	+
	4:00	I	+P	+	+	+	+	+	C	M	+	+	+
	5:00	I	+P	+	+	+	+	+	C	M	+	+	+
	6:00	I	+P	+	+	+	+	+	C	M	+	+	+
	7:00	I	+P	+	+	+	+	+	C	M	+	+	+
	8:00	I	+P	+	+	+	+	+	C	M	+	+	+
	9:00	I	+P	+	+	+	+	+	C	M	+	+	+
	10:00	I	+	+P	+	+	+	+	C	M	+	+	+
	11:00	I	+	+	P	+	+	+	C	M	+	+	+
	12:00	I	+	+	P	+	+	+	C	M	+	+	+
	13:00	I	+	+	+P	+	+	+	C	M	+	+	+
	14:00	I	+	+	+P	+	+	+	C	M	+	+	+
	15:00	I	+	+	+P	+	+	+	C	M	+	+	+
	16:00	I	+	+	+P	+	+	+	C	M	+	+	+
	17:00	I	+	+	+P	+	+	+	C	M	+	+	+
	18:00	I	+	+	+P	+	+	+	C	M	+	+	+
	19:00	I	+	+P	+	+	+	+	C	M	+	+	+
	20:00	I	+	P	+	+	+	+	C	M	+	+	+
	21:00	I	+	P	+	+	+	+	C	M	+	+	+
	22:00	I	+	P	+	+	+	+	C	M	+	+	+
	23:00	I	+	P	+	+	+	+	C	M	+	+	+
	24:00	I	+	P	+	+	+	+	C	M	+	+	+

PASSIVE SOLAR TEST CELL DATA

DATE 1 NOV 1981

CELL B CLEAR F.G. TUBES (VERT, 12") R 3.5 N.1. / DOUBLE GLAZED

CELL A TANKWALL SEL. SURF W/ NO N.1. / DOUBLE GLAZED

AMBIENT AIR TEMP. = P

INSOL. ON VERT. SURF. = N

INTERIOR AIR TEMP CELL A = C

INTERIOR AIR TEMP CELL B = M

			20					65					110
			I	I	I	I	I	I	I	I	I	I	I
1 NOV	1	0:00	I	P	+	+	+	+	+	+	C	M	+
	2	0:00	I	P	+	+	+	+	+	+	C	M	+
	3	0:00	I	P	+	+	+	+	+	+	C	M+	+
	4	0:00	I	P	+	+	+	+	+	+	C	M+	+
	5	0:00	I	P+	+	+	+	+	+	+	C	M+	+
	6	0:00	I	P+	+	+	+	+	+	+	C+	M	+
	7	0:00	I	P	+	+	+	+	+	+	C+	M	+
	8	0:00	I	+P	+	+	+	+	+	+	C+	M	+
	9	0:00	I	+	P+	+	+	+	+	+	C+	M	+
	10	0:00	I	+	+	P	+	+	+	+	C	M+	+
	11	0:00	I	+	+	P+	+	+	+	+	C	M+	+
	12	0:00	I	+	+	+P	+	+	+	+	+	CM+	+
	16	0:00	I	+	+	+	P	+	+	+	+	+	+
	17	0:00	I	+	+	+	P	+	+	+	+	MC	+
	18	0:00	I	+	+	P+	+	+	+	+	+	MC	+
	19	0:00	I	+	+P	+	+	+	+	+	+	CM+	+
	20	0:00	I	+	P	+	+	+	+	+	+	CM	+
	21	0:00	I	+	P	+	+	+	+	+	+	C	M
	22	0:00	I	+P	+	+	+	+	+	+	C	M	+
	23	0:00	I	P	+	+	+	+	+	+	C+	M	+
	24	0:00	I	+P	+	+	+	+	+	+	C+	M	+

PASSIVE SOLAR TEST CELL DATA

DATE 4 NOV 1981

CELL B CLEAR F.G. TUBES (VERT, 12") R 8' 9" N.I. / DOUBLE GLAZED

CELL A TANKWALL SEL. SURF W/ NO N.I. / DOUBLE GLAZED

AMBIENT AIR TEMP. = P

INSOL. ON VERT. SURF. = N

INTERIOR AIR TEMP CELL A = C

INTERIOR AIR TEMP CELL B = M

		20					65					110
		I	P	+	+	+	+	+	C	M	+	+
4 NOV 1: 0: 0	I	I	P+	+	+	+	+	+	C	M	+	+
2: 0: 0	I	I	P+	+	+	+	+	+	C	M	+	+
3: 0: 0	I	I	P+	+	+	+	+	+	C	M	+	+
4: 0: 0	I	I	P	+	+	+	+	+	C	M	+	+
5: 0: 0	I	I	+P	+	+	+	+	+	C	M	+	+
6: 0: 0	I	I	+P	+	+	+	+	+	C	M	+	+
7: 0: 0	I	I	+P	+	+	+	+	+	C	M	+	+
8: 0: 0	I	I	+	P	+	+	+	+	C	M	+	+
9: 0: 0	I	I	+	P+	+	+	+	+	C	M	+	+
10: 0: 0	I	I	+	+	P	+	+	+	C	M	+	+
11: 0: 0	I	I	+	+	P+	+	+	+	C	M	+	+
12: 0: 0	I	I	+	+	+	P	+	+	C	+	+M	+
13: 0: 0	I	I	+	+	+	P+	+	+	+	C	+	M
14: 0: 0	I	I	+	+	+	P	+	+	+	+	C	+
15: 0: 0	I	I	+	+	+	P	+	+	+	+	+C	+
16: 0: 0	I	I	+	+	+	P	+	+	+	+	+CM	+
17: 0: 0	I	I	+	+	+	P	+	+	+	+	+	+
18: 0: 0	I	I	+	+	P	+	+	+	+	+	MC+	+
19: 0: 0	I	I	+	+	P	+	+	+	+	+	+	+
20: 0: 0	I	I	+	+	P	+	+	+	+	+	+	+
21: 0: 0	I	I	+	+	P	+	+	+	+	+	+CM	+
22: 0: 0	I	I	+	+	P	+	+	+	+	+	+CM	+
23: 0: 0	I	I	+	+	P	+	+	+	+	+	C	M
24: 0: 0	I	I	+	+	P	+	+	+	+	+	C	M

PASSIVE SOLAR TEST CELL DATA

DATE 5 NOV 1981

CELL B CLEAR F.G. TUBES (VERT, 12") R 3 N.I. / DOUBLE GLAZED

CELL A TANKWALL SEL. SURF W/ NO N.I. / DOUBLE GLAZED

AMBIENT AIR TEMP. = P

INSOL. ON VERT. SURF. = N

INTERIOR AIR TEMP CELL A = C

INTERIOR AIR TEMP CELL B = M

		20					65					110
		I	I	I	I	I	I	I	I	I	I	I
5 NOV	1: 0: 0	I	+	+P	+	+	+	+	+	C+M	+	+
	2: 0: 0	I	+	P	+	+	+	+	+	C+M	+	+
	3: 0: 0	I	+	P+	+	+	+	+	+	C+M	+	+
	4: 0: 0	I	+	P+	+	+	+	+	+	C M	+	+
	5: 0: 0	I	+P	+	+	+	+	+	+	C M	+	+
	6: 0: 0	I	+P	+	+	+	+	+	+	C M+	+	+
	7: 0: 0	I	+	P+	+	+	+	+	+	C M+	+	+
	8: 0: 0	I	+	P	+	+	+	+	+	C M+	+	+
	9: 0: 0	I	+	+P	+	+	+	+	+	C M+	+	+
	10: 0: 0	I	+	+P	+	+	+	+	+	+C M+	+	+
	11: 0: 0	I	+	+P	+	+	+	+	+	+C M	+	+

END OF DATA

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APPENDIX C

GRANT APPLICATION FOR PHASE II
(FUNDED)

XIII. GRANT APPLICATION FORM

U. S. DEPARTMENT OF ENERGY
MIDWEST APPROPRIATE TECHNOLOGY SMALL GRANTS PROGRAMFOR DOE USE ONLY

Date Received: _____ Proposal No.: _____

NOTICE FOR HANDLING PROPOSALS

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Project Title: WATER STORAGE TUBE SYSTEMS (PHASE II)

If this proposal is submitted by an individual:

Applicant Name (print or type) PAUL HEMKERSignature Paul HemkerDate: MARCH 26, 1981

If proposal is submitted by an organization, agency or firm:

Name P

Signature and Title of Responsible Officer _____

Date: _____

Applicant's

Initials
PA

DATA FORM - 1981 (Use only these blocks - abbreviate if necessary.)

(Circle One): MR / MS / MRS / MISS / PROF / DR

LAST NAME OF APPLICANT

HEMKER

FIRST NAME OF APPLICANT

PAUL

HOME AREA CODE & TELEPHONE NUMBER

513 437 7055

MAILING ADDRESS

% DYNAMIC PLASTICS

CITY

NEW PARIS

STATE

ZIP CODE

OH 45347

BUSINESS AREA CODE & TELEPHONE NUMBER

513 437 7261

APPLICANT'S SIGNATURE

DATE

GRANT

CATEGORY

B - 2

TOTAL GRANT REQUEST (to nearest dollar)

(From Page A-10a, Line 13)

24850.00

Choose the ONE applicant identification category that BEST describes you and put the corresponding number in the box.

C - 1. Individual(s)*

C - 4. Non-profit organization

C - 6. State or interstate agency

C - 2. Small Business

or institution

C - 7. Local or regional

C - 3. Indian Tribe

C - 5. College or university

agency

C - 1

*NOTE: If 1. is checked, and there is no co-applicant, go directly to next page.

LAST NAME OF OFFICER OR CO-APPLICANT

FIRST NAME OF OFFICER OR CO-APPLICANT

AREA CODE & TELEPHONE NUMBER

OFFICER TITLE?

ORGANIZATION NAME

SIGNATURE OF OFFICER OR CO-APPLICANT

DATE

A-3c

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PH

SECTION E

PROJECT TITLE

WATER STORAGE TUBE SYSTEM

MS (PHASE II)

PROJECT
CITYPROJECT
STATEPROJECT
ZIP CODE

NEW PARIS OH 45437

PROJECT
COUNTY

PREBLE

SECTION F

THE PRIMARY CATEGORY OF THIS PROJECT IS

F - 1 E

(Select project category from opposite page and put the corresponding number in the box.)

OTHER CATEGORIES OF MAJOR IMPORTANCE TO THIS PROPOSAL ARE

F - 6 B

F - 7 A

F - 7 C

SECTION G

Choose the ONE sector that will receive the GREATEST benefit from your project and put the corresponding number in the box.

G - 1. Agriculture, Forestry or
Fisheries

G - 3. Residential

G - 4. Governmental

G - 3

G - 2. Commercial or Industrial

G - 5. Transportation

SECTION H

Choose the ONE area that will be the MAJOR energy impact of your project and put the corresponding number in the box.

H - 1. Conservation

H - 3. Energy substitution

H - 2. Developing new
energy sources

(e.g., substituting solar for natural gas)

H - 3

H - 4. Public Awareness

SECTION I

Choose the ONE source from which you FIRST learned about the Small Grants Program and put the number in the box.

I - 1. Direct mail

I - 5. Radio/Television

I - 2. Newspapers

I - 6. Congressmen

I - 3. A.T. Publications

I - 7. Friends

I - 3

I - 4. Public meetings

I - 8. Other

A-4

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1. PROJECT SUMMARY

This summary may be used to assign your proposal to the proper reviewer.

1. Which of the following goals will be the focus of the project. Circle the corresponding letter(s):

- ☒ (a) The needs of local communities and the enhancement of community self-reliance through the use of available resources;
- ☐ (b) The use of renewable resources and the conservation of non-renewable resources;
- ☐ (c) The use of existing technologies applied to novel situations and uses;
- ☐ (d) Applications which are energy conserving, environmentally sound, small scale and low cost; and
- ☐ (e) Applications which demonstrate simplicity of installation, operation and maintenance.

2. In 150 words or less, provide a non-technical description of what you plan to do and the expected results.

I. Under a previous device development grant (passive solar "water storage tube systems"), from this same program we have accomplished the following:

- A. Designed, built prototypes and structurally tested several passive solar component that use water as the primary hot storage medium.
- B. Constructed two fully instrumented solar test rooms in order to thermally test these components.
- C. Presently conducting the thermal testing.

See the attached interim report for a complete explanation of progress to date.

II. The present application proposes to continue device development and demonstration in this area by doing the following:

- A. Constructing prototypes, structurally and thermally testing the following:
 - 1. round and elliptical glass tubes similar to above for horizontal positioning (a preliminary structural test has shown these thin tubes to be surprisingly strong in this configuration).
 - 2. a flat louver to be positioned in the center of the tube that can convert the clear water tubes to a solar absorber, transmitter, or reflector depending on position and color of the louver.
 - 3. a variation on the previously developed "Trombe-wall" suitable for mobile home application.
- B. Do the following to demonstrate the commercial potential of products developed under the previous grant and in "A" above:
 - 1. provide components to selected building contractors at reduced cost so that they can be demonstrated and evaluated in actual buildings.
 - 2. provide components (at no costs) for testing by independent agencies.
 - 3. resolve certain production and packaging problems related to components developed under the previous grant.
 - 4. prepare a portable demonstration exhibit for use at technical conferences, local appropriate technology meetings, state/local fairs, etc.
 - 5. prepare informational literature for distribution at the above.
 - 6. develop a computer program for analyzing the life-cycle costs of these

SECTION F

SECTION G

SECTION H

2. PROJECT RESULTS

1. Using only a few key words and phrases (instead of complete sentences), describe what devices, systems or information will exist as a result of your project.

- A. "SUNBEAMS:" round and elliptical thin wall fiberglass passive solar water tubes for horizontal mounting (fixed and pivoting)
- B. "SUNLOUVERS:" a two-sided solar absorbing reflecting flat louver for insertion in the water tubes (several fixed or adjustable configurations that allow the fiberglass water tubes to transmit sunlight, absorb/store sunlight, or reflect).
- C. A "TANKWALL" passive solar collection/storage/distribution panel designed specifically for the mobile home industry.
- D. Installations in new and retrofitted homes of these and previously developed products.
- E. The results of tests by independent laboratories of the same products.
- F. A portable demonstration exhibit explaining these systems.
- G. Informational literature describing these systems.
- H. Develop a microcomputer program for predicting the life-cycle savings of installations using these components.

2. How will others use what you have developed or learned?

- A. These products will be marketed commercially through Waterwall Engineering (a subsidiary company) to dealers, builders, mobile home manufacturers, and homeowners. In addition, many of the passive solar principles developed will be adaptable to the do-it-yourselfer. These principles will be presented at local, regional, and national presentations. Homebuilding and do-it-yourself publications will be especially targeted to receive information material.

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3. TECHNICAL DESCRIPTION OF PROJECT

- Provide a concise technical description of exactly what you propose to do and just how you will go about doing it.
- This description must contain sufficient detail so that the technical reviewer can judge your proposed project by the following criteria:
 1. Whether the project is technically feasible, including a determination as to whether the proposed energy savings or energy production can be technically achieved;
 2. Whether the results being proposed are capable of being measured;
 3. Whether the project has any potential environmental, health and safety impacts; and
 4. From a technical standpoint, whether the project can be carried out within the funds being requested.
- DO NOT include any benefits accruing from your project; they will be addressed elsewhere. This description must be free standing in that it must be understandable without reference to the Social and Economic Benefits Section of the application.
- Clearly identify any innovative aspects of the project.
- Blueprints, drawings, sketches, photographs and other supporting materials should be used ONLY if you consider that your explanation would be unclear without them. Write your last name on any such materials to avoid misplacement.
- Pages A-6 thru A-6d are provided to continue the technical discussion, if they are needed. Additional pages (should not exceed 5) may be added if necessary.

BACKGROUND

The following passive solar heating products have been developed under a previous grant under this program (See Appendix A, interim progress report):

1. "TUBEWALL:" a low-cost passive water tube system suitable for new or retrofit construction. Use of selective surfaces to eliminate night insulation (Hyde, 1980 has reported that for double glazed water-wall passive solar systems, selective black surfaces with no night insulation perform comparable with flat black surfaces with R-12 night insulation). TUBEWALL prototypes have been constructed and structurally tested (thermal testing using two identical monitored test cells is in progress). See Figures 1 and 2.
2. Fiberglass water tubes: similar to tubes being commercially marketed by Kalwall Corp., the tubes feature an improved end cap that resists impact damage that results in leakage.
3. "TANKWALL:" a complete, easy to install water panel that fits between standard 2 x 6 studs 24" O.C. The use of a selective black absorber eliminates night insulation (see Hyde, 1980). This system is particularly attractive because: (1) it requires no change in conventional carpentry construction; (it is installed in fifteen minutes; (3) completely separates room air from contact with glass; (4) room surface requires no further

3. TECHNICAL DESCRIPTION OF PROJECT (Continuation Sheet)

finishing; and (5) installed incremental costs are below comparable field built systems. A second size prototype has been built that is compatible with low-cost patio door glass sizes. This product was presented at the Sunburst passive solar conference (Moore, 1980) and enthusiastically received by builders, architects, and government representatives, because of its thermal design and integration with existing construction practices. See Figures 3 and 4. These units have been structural tested and being thermally tested at present.

4. Two identical test cells have been constructed and extensively instrumented with a pyrometer, anemometer, and thermistors, monitored continually by an Apple II micro-computer modified/programmed for data acquisition. The results will be reported in the final report and at the Philadelphia AS/ISES Conference.

Much has been learned under the previous grant about fabrication techniques and potential applications, as well as other potential developments.

The present application proposes to extend this work. The methods for accomplishing this are outlined briefly below, and then described in detail.

- A. SUNBEAMS: develop, construct and test prototypes of horizontal water tubes (Device Development)
- B. SUNLOUVER: develop, construct, and test louver inserts for vertical and horizontal transparent water tubes to provide controlled transmittance, absorption, or reflection of solar heat and light (Device Development)
- C. Adapt TANKWALL design for mobile home use (Device Development)
- D. Demonstrate these products and products developed under the present grant by installing them in new and retrofit home construction (Demonstration)
- E. Have these same components evaluated by an independent laboratory (i.e., National Bureau of Standards) to demonstrate their performance. (Demonstration)
- F. Construct a portable demonstration exhibit. (Demonstration)
- G. Prepare literature describing the features of these components. (Demonstration)
- H. Develop a calculation procedure for optimum size of the passive solar system for specific buildings. (Demonstration.)

DISCUSSION:

- A. SUNBEAMS: Clear vertical fiberglass passive solar water storage tubes have been available commercially for several years and extensively used because they are low cost, very efficient thermal storage containers (water is three times as effective as masonry per unit volume), that transmit light (absorptivity can be controlled by dyeing the water). Commercially available tubes have been delicate, and prone to leakage along the vertical seam and around the bottom cap. Under the previous grant the applicants developed an adhesion process that has resolved the seam leak problem, and an overlapping fiberglass end cap that has eliminated the leakage caused by impact damage to the end cap. (See Fig. 5).

While vertical tubes nesting on a floor work well for vertical glazing near the floor, they are ineffective for storing solar heat from clearstore windows or skylights. It is desirable for these applications to position the thermal mass near the glazing above the floor. Neither masonry nor vertical tubes are suitable because of the need for continuous structural support along their entire length.

Applicant's

Initials
 3. TECHNICAL DESCRIPTION OF PROJECT (Continuation Sheet)

The applicants attempted to modify a standard 8' x 12" Ø vertical tube for horizontal use by capping each end and supporting the tube at close intervals along its length with straps. The very flexible fiberglass skin (.040") deformed to an oval shape due to the pressure of the straps before breaking.

However, in observing the failure it was intuitively felt that the collapse occurred because of the localized distortion rather than the weight of the water on the strength of the tube in the round configuration. The tube was patched and refilled with water on a continuous support. It was then lifted by the end caps only. It not only supported its own weight, but could apparently support additional weight if detailed so as not to deform the tube.

The applicants feel that this discovery is significant as it allows the thermal mass to be supported at 8' intervals by beams, columns on cables. (Fig. 7).

In order to accomplish this, the applicant proposes (under this application) to:

1. develop and test alternative end caps/support systems.
2. resolve any problems associated with thermal expansion of the water (preliminary calculations indicate that the thermal expansion of the fiberglass will compensate for water expansion).
3. test various diameter and thickness tubes structurally to empirically determine design criteria. (Mathematical analysis of thin steel tubular beams is very complex; the glued seams and end cap details, etc., compound this problem and the applicants favor physical testing as more reliable.)
4. Because horizontal tubes inherently prevent the water temperature stratification associated with vertical tubes, it is anticipated that they will perform marginal better thermally. This would be tested using the passive test cells constructed under the previous grant.

B. SUNLOUVERS:

Clear fiberglass tubes can be used to: (1) absorb all solar gain (painting tube black or dying water black); (2) absorb a portion of solar gain and transmitting the rest (small amount of dye in the water); (3) transmit a large amount of solar gain through the tubes to the interior for quick morning warm-up (leave tube and water clear); and (4) reflect solar heat (paint tubes white) to reflect summer heat.

We propose to use this grant to develop a "louver" (black, one side, silver, one side) that could be placed in the center of a clear tube (See Fig. 8) that would accomplish these various functions automatically depending on the position of the sun and/or the louver, as follows:

1. vertical tubes: the louver would be fixed (probably) or made adjustable (possibly) to allow morning sun to be transmitted, afternoon sun to be absorbed in the tube (See Fig. 9), and summer heat to be reflected.
2. horizontal tubes: the "louver" would be fixed in the tube, and the tube made to be pivoted creating a "venetian blind" effect to transmit solar heat and light directly to the space, absorb the solar heat completely in the tube for storage, or reflect the light onto the ceiling for indirect daylighting illumination, (See Fig. 10).

We will fabricate and test a variety of louvers, including:

1. rigid-opaque (i.e, polished aluminum one side, black anodized opposite.

3. TECHNICAL DESCRIPTION OF PROJECT (Continuation Sheet)

- ✓ 2. rigid-semi transparent, (i.e., grey plexiglass with semi-transparent aluminized film applied).

3. flexible-opaque (or semi-transparent), (i.e., plastic films).

We will fabricate and test a variety of rotational systems to permit the louvers to be adjusted, including:

1. for vertical tubes, a foam disk that would float on the top of the water (creating a dust/evaporation seal) and support the suspended louver, allowing it to be rotated if required (See Fig. 11).
2. for horizontal tubes, a redesigned end cap with an integral pivot bearing to allow the entire tube and louver to be rotated as one unit (See Fig. 12).

C. TANKWALL for mobile homes

Since its invention the applicants have felt that TANKWALL was well suited for mobile home application because: (1) the component could be mass produced and easily shipped to mobile home manufacturers; (2) its light empty weight facilitated movement of the mobile home; (3) its filled weight is moderate (450# for a 4' x 8' panel) and would require little or no support or structural modifications; (4) unlike phase-change storage, water is a proven reliable thermal storage medium; (5) water is a cheap renewable resource; (6) the panels provide a finished interior surface; and (7) the water can be drained for home relocation.

The applicants propose to select a local mobile home manufacturer and develop a variation of TANKWALL to fit existing manufacturing practices in that industry. It is anticipated that the basic design would be unchanged.

- A number of home builders have expressed an interest in utilizing components developed under the previous grant and proposed under this application, if these could be provided at a reduced cost. See attached letters of interest. Builders would be selected on the basis of reputation and potential visibility of the installation.
- In order to demonstrate the performance of these components compared with competing systems, it is important that they be tested by an independent research organization using accepted standardized test procedures. The applicants propose to furnish samples to the National Bureau of Standards for testing under their Solar Component Evaluation Program.
- While photographs, drawings, diagrams, etc., are informative, experience has convinced the applicants that the actual products are the best medium for demonstrating the features of the various components. Under this grant a portable exhibit would be constructed for the purpose of demonstrating these components at various local, state, and national events (fairs, exhibitions, conferences, etc.).
- Literature would be prepared to describe the principles and application of the various components to an interested lay-person.

A-6d

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Initials

3. TECHNICAL DESCRIPTION OF PROJECT (Continuation Sheet)

H. In order for any passive system to be cost-effective, it must be properly designed (in integration into the building design, and proper sizing of the system). The applicants propose to develop an interactive program for the Apple II microcomputer (purchased under the previous grant for data acquisition). The program would be based on the Solar Savings Fraction method (Balcomb, 1979) with the performance formulas for Water Wall Systems modified for the present components based on test cell results from this and the previous grant. Inputs to the program would be:

- a. local climate data
- b. area available for collection
- c. building heating loads (BLC)
- d. auxiliary heating fuel, cost, and inflation rate
- e. local shading obstructions
- f. IRS tax credits
- g. system cost per unit area
- h. system life
- i. interest rate on solar loan
- j. enhancements (night insulation, selective surfaces, horizontal reflectors)
- h. enhancement costs.

The program would automatically evaluate various sized systems and calculate their life cycle savings and recommend the one that maximizes these savings.

With the cost of the software covered by this grant, an accurate detailed analysis would be provided through dealers to prospective purchasers at a nominal cost.

- I. In order to maximize the dissemination of information, the applicants propose to use the following channels:
1. local and regional public lectures
 2. national technical conferences
 3. homebuilder and mobile home trade shows
 4. local and national print media (especially newspaper feature sections and popular magazines).

Fig. 1: Isometric, TUBEWALL passive solar system

WINTER

reflector converts to patio with carpet cover

SUMMER

Fig. 2: TUBEWALL Modes of Operation

Fig. 5: Vertical Fiberglass Water
Tube End Cap (note overlapping
Construction to prevent leakage)

Fig. 6: Horizontal Span Structural Capability
of Fiberglass Water Tubes

Fig. 7: Various Horizontal Support Alternatives for SUNBEAMS

Fig. 8: SUNLOUVER Being Inserted into Fiberglass Tube

Fig. 9a: Vertical Fiberglass Water Tubes With SUNLOUVERS

Fig. 9b: Vertical Fiberglass Water Tubes With SUNLOUVERS

Fig. 10: Horizontal SUNBEAM Water Tubes with SUNLOUVERS

Fig. 11: Vertical SUNLOUVER Flootation Device

Fig. 12: SUNBEAM End Cap with Pivot Bearing for Rotation of Tube