# SOLAR ASSISTED HOT WATER SYSTEM

WATERFORD WELCOME CENTER

WATERFORD, VERMONT

FINAL REPORT 86-2
August, 1986

Reporting on
Work Plan 82-R-5

State of Vermont
Agency of Transportation
Materials & Research Division

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16. Abstract


A solar system was installed on the newly constructed Welcome Center on Interstate 93 in Waterford, Vermont. Bascially, the system uses exteriorly mounted solar panels to transfer solar heat to antifreeze which transfers heat to a hot water tank by means of a heat exchanger.

Monitoring equipment installed on the solar system revealed that 97% to 99% of the hot water used was supplied by the solar system.

Cost of the solar system with back-up equipment was $5755.00. Projections indicate that the cost of the system would be recovered in 10 years of service and save an estimated 58,000 kilowatt hours of electricity.


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# INTRODUCTION

Increased concern for conservation of energy and natural resources led to the initial consideration by the Vermont Agency of Transportation to try a solar project. The added enhancement of Federal money to construct such a project resulted in the installation of a solar hot water system for the newly constructed Welcome Center on Interstate 93, in Waterford, Vermont. This report describes the construction, type, operation, and performance of the system used.

## LOCATION AND BUILDING DESCRIPTION

The solar system was installed on a newly constructed Welcome Center on Interstate 93 in the town of Waterford, Vermont. See Location Map, Appendix A. The location is at latitude 44°-22' north and 71°-52' west longitude. The building is approximately 930 feet above sea level.

The building has a floor area of 2200± square feet of which 1670 square feet are devoted to public use. The longitudinal axis of the building is 10° east of due south. The southern roof exposures are on a 39.8° incline and free of shading. See site plan, Appendix B.

Welcome Center - Southern Exposure

## CLIMATOLOGICAL INFORMATION

Climatological data obtained from the U.S. Department of Commerce Environmental Data Service for the site of the Welcome Center is as follows:

| | |
|---|---|
| Mean annual number of days maximum temperature 90°F and above ... | 2 |
| Mean annual number of days minimum temperature 32°F and below ... | 180 |
| Mean annual total heating degree days (base 65°F) ............... | 8500 |
| Mean length of freeze-free period (days) ........................ | 120 |
| Normal monthly total precipitation (inches) ..................... | 3.3 |
| Mean annual number of days with 0.01 inch or more precipitation . | 175 |
| Mean annual total snowfall (inches) ............................. | 100 |
| Mean monthly percentage of possible sunshine for: January ....... | 40 |
| July ....... | 40 |
| Mean annual percentage of possible sunshine ..................... | 40 |
| Mean annual total hours of sunshine ............................. | 1800 |
| Mean daily solar radiation (Langleys) for: January ............. | 117 |
| July ............. | 500 |

## SOLAR SYSTEM DESCRIPTION

Construction on the building by Hare Construction Co., began in November, 1983. The solar portion of the project was constructed between March 23, 1983 and April 15, 1983. Normally, construction of the system would take two or three days, but in this case construction was not conducted in one continuous operation. The contractor obtained parts as construction progressed and performed many other operations at the same time.

Basically, the closed-loop system consists of four Grumman model #332A solar collectors, Grumman Sunstream CF-100A heat exchanger, X-trol #3 auxiliary pressure tank and Solarstream hot water heater tank. The closed-loop sytem used antifreeze to transfer heat from exterior mounted solar panels to the interior mounted heat exchanger where energy is transferred to the hot water system. This allows for year round operation. The collectors are 4' x 8', weighing 120 pounds per panel, insulated with 7.7 R value foam type insulation and single glazed with low iron tempered glass. Resulting transmissivity of the panel is 89%. Mounting brackets were manufactured to obtain ideal collection angles on the southern exposure roofs.

ROOF MOUNTED SOLAR PANELS

Panels were mounted in two separate banks of two panels each because of building design. The two banks were connected in series with the panels in each bank connected in parallel/reverse return.

The Sunstream heat exchanger module consists of a double-wall, center flow heat exchanger which provides insurance against potable water contamination; two sealed, no-maintenance circulator pumps, one for collector fluid and one for water; an expansion tank; check valve; relief valve; C-30 differential temperature controller with high-temp cut off; two manual hose bibs for easy filling; solar loop pressure temperature gauge, three position operating mode switch and molded cover. Manufacturer's detailed description and schematic of the heat exchanger can be found in Appendix C.

SUNSTREAM HEAT EXCHANGER

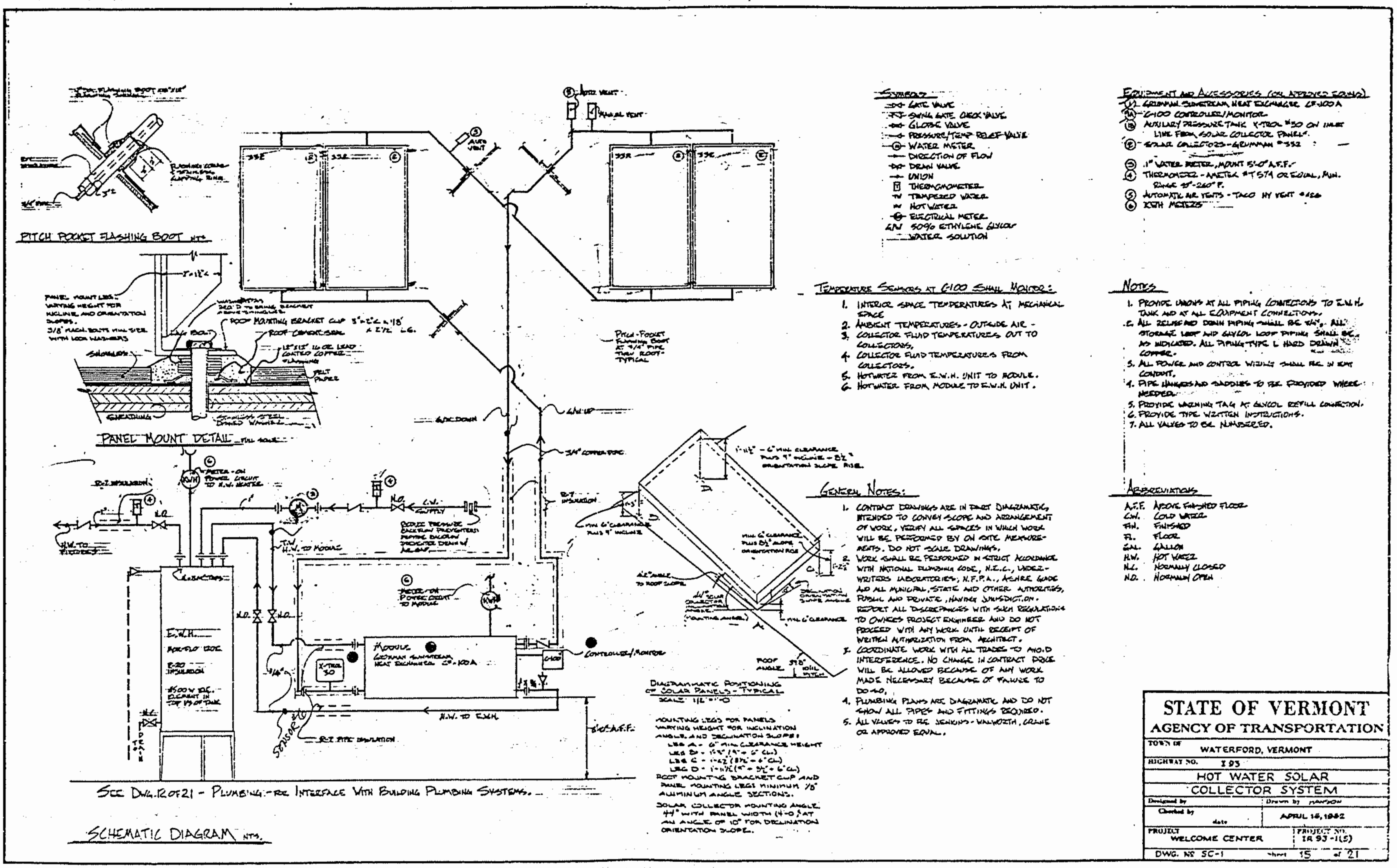
The hot water tank is a 120 gallon tank insulated to R-20. The top third can be heated with a backup 4500 watt electric element. The tank is tapped on top with four internal pipe legs of varied length extended into the tank to prescribed depths to gain maximum efficiency from the solar system. The system requires no other backup. The Vermont Agency of Transportation plans of the hot water solar collector system are shown in Figure 1, page 7.

## MONITORING EQUIPMENT AND PROCEDURES

Various monitoring equipment was used to keep records on solar fluid temperature, water temperature, ambient temperature and quantity of water used.

A C-100 differential temperature control/performance monitoring unit was installed to monitor the following items:

Solar collector temperature
Glycol temperature as it enters heat exchanger
Glycol temperature as it exits heat exchanger
Hot water temperature from heater tank as it enters heat exchanger
Hot water temperature to heater tank as it exits heat exchanger
Mechanical room temperature



SYMBOLS
GATE VALVE
SWING GATE CHECK VALVE
GLOBE VALVE
PRESSURE/TEMP RELIEF VALVE
WATER METER
DIRECTION OF FLOW
DRAIN VALVE
UNION
THERMOMETER
TW TEMPERED WATER
HW HOT WATER
ELECTRICAL METER
G/W 50% ETHYLENE GLYCOL WATER SOLUTION
EQUIPMENT AND ACCESSORIES (OR APPROVED EQUAL)
1 GRUMMAN SWEETREAM HEAT EXCHANGER CF-100A
1A G100 CONTROLLER/MONITOR
1B AUXILARY PRESSURE TANK X-TROL #30 ON INLET LINE FROM SOLAR COLLECTOR PANELS.
2 SOLAR COLLECTORS - GRUMMAN #332
3 1" WATER METER, MOUNT 5'-0" A.F.F.
4 THERMOMETER - AMETEK #T574 OR EQUAL, MIN. RANGE 30°-260° F.
5 AUTOMATIC AIR VENTS - TACO HY VENT #426
6 KWH METERS
TEMPERATURE SENSORS AT G100 SHALL MONITOR:
1. INTERIOR SPACE TEMPERATURES AT MECHANICAL SPACE
2. AMBIENT TEMPERATURES - OUTSIDE AIR -
3. COLLECTOR FLUID TEMPERATURES OUT TO COLLECTORS,
4. COLLECTOR FLUID TEMPERATURES FROM COLLECTORS.
5. HOTWATER FROM E.W.H. UNIT TO MODULE.
6. HOTWATER FROM MODULE TO E.W.H. UNIT.
NOTES
1. PROVIDE UNIONS AT ALL PIPING CONNECTIONS TO E.W.H. TANK AND AT ALL EQUIPMENT CONNECTIONS.
2. ALL RELIEF AND DRAIN PIPING SHALL BE 3/4". ALL STORAGE LOOP AND GLYCOL LOOP PIPING SHALL BE AS INDICATED. ALL PIPING TYPE L HARD DRAWN COPPER.
3. ALL POWER AND CONTROL WIRING SHALL BE IN EMT CONDUIT.
4. PIPE HANGERS AND SADDLES TO BE PROVIDED WHERE NEEDED.
5. PROVIDE WARNING TAG AT GLYCOL REFILL CONNECTION.
6. PROVIDE TYPE WRITTEN INSTRUCTIONS.
7. ALL VALVES TO BE NUMBERED.
GENERAL NOTES:
1. CONTRACT DRAWINGS ARE IN PART DIAGRAMATIC, INTENDED TO CONVEY SCOPE AND ARRANGEMENT OF WORK. VERIFY ALL SPACES IN WHICH WORK WILL BE PERFORMED BY ON SITE MEASUREMENTS. DO NOT SCALE DRAWINGS.
2. WORK SHALL BE PERFORMED IN STRICT ACCORDANCE WITH NATIONAL PLUMBING CODE, N.E.C., UNDERWRITERS LABORATORIES, N.F.P.A., ASHRAE GUIDE AND ALL MUNICIPAL, STATE AND OTHER AUTHORITIES, PUBLIC AND PRIVATE, HAVING JURISDICTION. REPORT ALL DISCREPANCIES WITH SUCH REGULATIONS TO OWNERS PROJECT ENGINEER AND DO NOT PROCEED WITH ANY WORK UNTIL RECEIPT OF WRITTEN AUTHORIZATION FROM ARCHITECT.
3. COORDINATE WORK WITH ALL TRADES TO AVOID INTERFERENCE. NO CHANGE IN CONTRACT PRICE WILL BE ALLOWED BECAUSE OF ANY WORK MADE NECESSARY BECAUSE OF FAILURE TO DO SO.
4. PLUMBING PLANS ARE DIAGRAMATIC AND DO NOT SHOW ALL PIPES AND FITTINGS REQUIRED.
5. ALL VALVES TO BE JENKINS - WALWORTH, CRANE OR APPROVED EQUAL.
ABBREVIATIONS
A.F.F. ABOVE FINISHED FLOOR
C.W. COLD WATER
FIN. FINISHED
FL. FLOOR
GAL. GALLON
H.W. HOT WATER
N.C. NORMALLY CLOSED
N.O. NORMALLY OPEN
PITCH POCKET FLASHING BOOT NTS
PANEL MOUNT DETAIL FULL SCALE
DIAGRAMMATIC POSITIONING OF SOLAR PANELS - TYPICAL SCALE: 1/2" = 1'-0"
SEE DWG. R OF 21 - PLUMBING - FOR INTERFACE WITH BUILDING PLUMBING SYSTEMS.
SCHEMATIC DIAGRAM NTS
E.W.H.
MODULE
X-TROL 30
SENSORS
STATE OF VERMONT
AGENCY OF TRANSPORTATION
TOWN OF WATERFORD, VERMONT
HIGHWAY NO. I 93
HOT WATER SOLAR COLLECTOR SYSTEM
APRIL 16, 1982
PROJECT WELCOME CENTER
PROJECT NO. IR 93-1(5)
DWG. NO. SC-1 sheet 15 of 21

In line thermometers were installed on water lines entering and exiting the hot water tanks.

Water meters were provided on the water supply to the building and on the inlet line to the hot tank.

Electrical supply lines to the solar equipment and the hot water heater were equipped with kilowatt-hours meters.

Readings were taken from the monitoring equipment at various time periods, ranging from two weeks to a month. The monitoring period was from June of 1983 to December of 1984, approximately 518 days. Due to a delay in the installation of the kilowatt meters, readings of the electrical usage were only taken from November, 1983 to November, 1984. Visits to the facility were all midday and under varied weather conditions. Periodically, temperature readings were taken by fulltime Welcome Center personnel.

Data was used to determine temperature exchanges between glycol and domestic water, heat exchange between glycol and solar collector, electrical energy used for heating hot water and operating solar equipment and quantities of water used.

## RESULTS OF DATA OBTAINED

Traffic flow, accessible to the Welcome Center, averaged 1,050 vehicles per day and approximately 5,600 people used the facility during the monitoring period. Water meter readings showed that approximately 9% of the total water usage was hot water. Throughout the monitoring period, 122,718 gallons of water were used, of which 10,997 gallons were hot water. Daily usage of hot water fluctuated from 13 to 49 gallons and the temperature of non-tempered hot water ranged from 120° to 185°F. On no occasion was there any report of shortage of hot water. Incoming water temperatures from the drilled water well ranged from a low 56°F during the coldest months to a high of 64°F during the summer months. On the average, water to the hot water tank was raised 90°F.

Electricity demands to operate the solar system equipment and maintain hot water on occasion when the solar system could not were minimal. Daily electrical usage of the solar equipment averaged 0.5 kilowatt hour, and ranged from a low of 0.2 to 0.8 kilowatt hour. During the summer and fall months, power to the electric heating element of the hot water tank was turned off because the solar system could more than adequately supply hot water. Average daily electrical usage when the electrical back-up was needed averaged 0.9 kilowatt hour and ranged from 0.3 to 2.5 hours, indicating that the solar system was supplying the majority of hot water.

Temperature readings of fluids passing through the heat exchanger revealed that at peak operating times the temperature of domestic hot water was raised an average of 10±°F, while glycol temperatures were lowered by 14±°F. The temperature of glycol from the collector during periods the system was collecting solar energy ranged from 130° to 212°F. After reviewing all the data, it is estimated that during the evaluation period, 97% to 99% of all hot water was supplied and maintained by the solar system. Detailed results of readings taken can be seen in Appendix D, page 18.

## COST AND PAYBACK OF SOLAR SYSTEM

The contract cost of the completed solar system with back-up system was $5,755.00. For the purpose of computing payback, $355.00 for a conventional electric hot water heater was deducted from the total cost.

Yearly cost was based on the present rate of 8¢ per kilowatt hour, increasing 4% yearly, and increased water demands of 3% per year. Initial yearly cost figure was obtained form documented consumer data for an 80 gallon hot water tank with R-11 insulation jacket. Cost of operating the solar system was increased with considerations that the back-up electrical needs would increase with the increase in hot water demands. Maintenance fees for minor service and glycol changes were incorporated at 5 year intervals.

Another type of payback is the savings of an estimated 58,000 kilowatt-hours of electricity over a 10 year period.

Projections indicate that the cost of the solar system would be recovered by the 10th year of service. Payback Estimate Table may be seen in Appendix E, page 19.

## PUBLIC INFORMATION DISPLAY

Signs were placed at the entrance to the building and within the building informing the public that the solar panels were assisting in supplying hot water for the Welcome Center.

On numerous occasions, the public questioned attendants on how well the system worked, or asked to see the system. The attendants themselves seemed impressed with how well the solar hot water system worked, becoming well informed and promoters of the system.

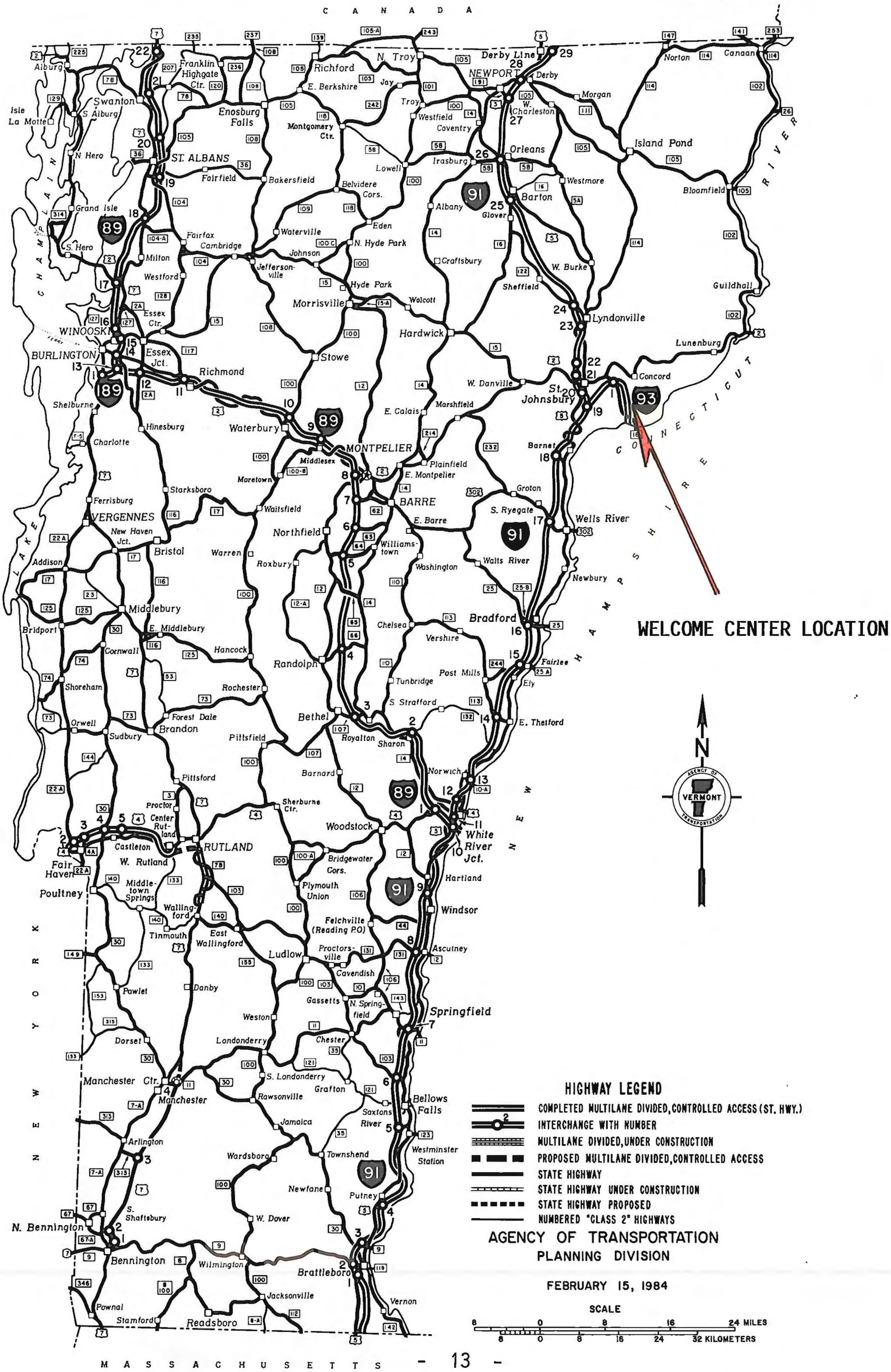
## SUMMARY

A closed-loop domestic hot water solar system was installed in the newly constructed Waterford Welcome Center. Basic solar components were four Grumman model #332A solar panels, a Grumman Sunstream CF-100A heat exchanger and a Solarstream solar hot water heater tank. The solar hot water system was monitored for hot water demands and electricity usage over an 18 month period.

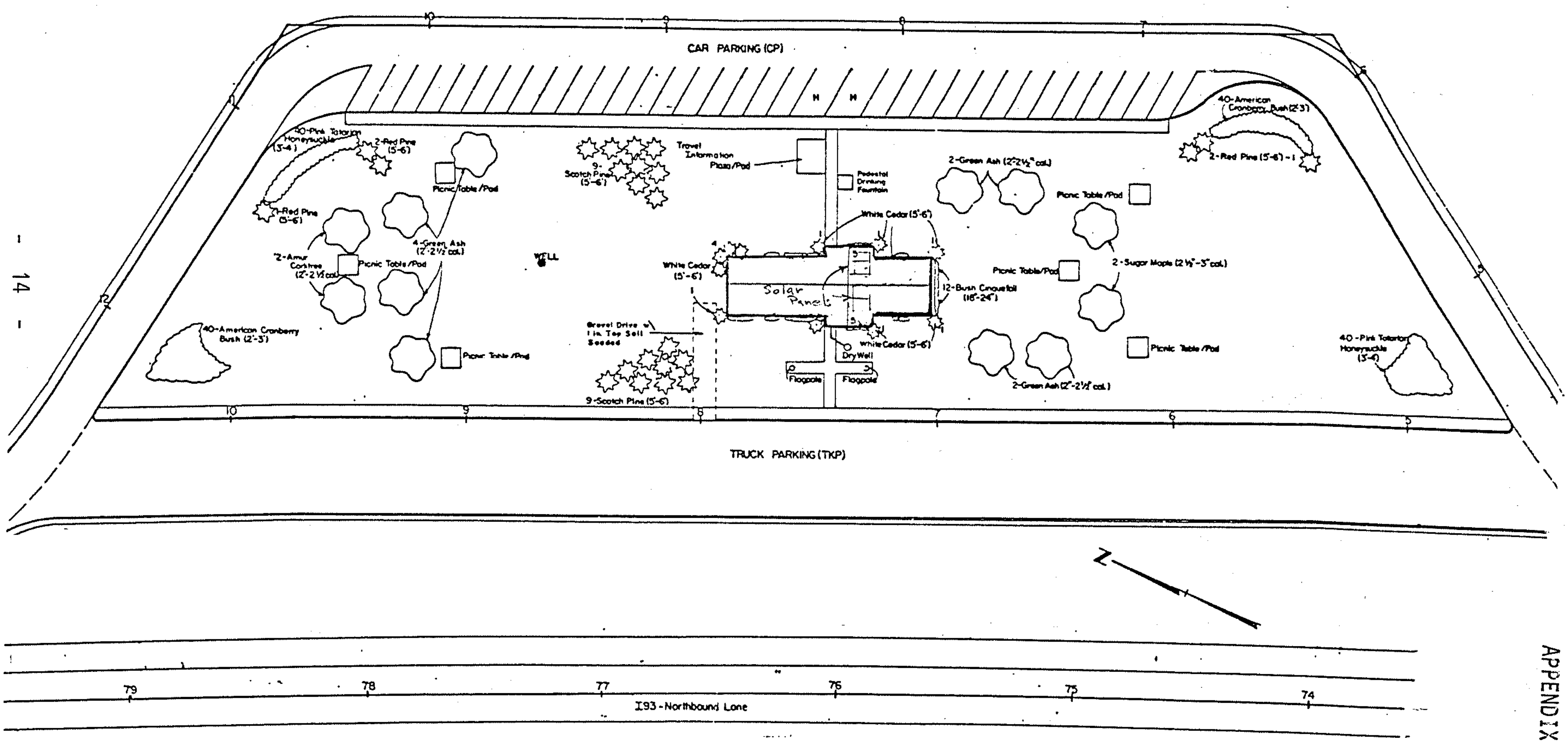
Daily usage of hot water for the entire evaluation averaged 21 gallons per day, or a total of 10,997 gallons. Temperatures of the water out of the solar system ranged from 120°F to 185°F. On no occassion was there a hot water shortage, even during the 8 months the power to the back-up system was turned off. Average daily electrical usage of the solar equipment was 0.4 kilowatt-hour per day. The back-up electric heat system required only an average of 0.9 kilowatt-hour per day.

The solar system provided 97% to 99% of all required hot water. At the present operating performance, it is expected that the solar system will provide virtually all the hot water need of the facility.

The added $5,400.00 cost of the solar system will be fully recovered within ten years of service and will have saved approximately 58,000 kilowatt-hours of electrical power. The success of this solar project should be the stimulus for development of other solar energy projects for other rest areas and maintenance facilities.


CANADA
NEW YORK
NEW HAMPSHIRE
MASSACHUSETTS
LAKE CHAMPLAIN
CONNECTICUT RIVER
WELCOME CENTER LOCATION
Alburg
Swanton
S. Alburg
Isle La Motte
N Hero
Grand Isle
S. Hero
Franklin
Highgate Ctr.
Richford
E. Berkshire
N. Troy
Jay
Troy
Derby Line
NEWPORT
Derby
Norton
Canaan
Enosburg Falls
Montgomery Ctr.
Westfield
Coventry
W. Charleston
Morgan
Island Pond
ST. ALBANS
Fairfield
Bakersfield
Belvidere Cors.
Lowell
Irasburg
Orleans
Barton
Westmore
Bloomfield
Albany
Glover
Fairfax
Cambridge
Waterville
Eden
Milton
Johnson
N. Hyde Park
Jeffersonville
Hyde Park
Craftsbury
W. Burke
Westford
Morrisville
Wolcott
Sheffield
Guildhall
Essex Ctr.
WINOOSKI
BURLINGTON
Essex Jct.
Hardwick
Lyndonville
Stowe
Richmond
Lunenburg
Concord
W. Danville
St. Johnsbury
Shelburne
Hinesburg
Waterbury
E. Calais
Marshfield
MONTPELIER
Middlesex
Charlotte
Barnet
Plainfield
E. Montpelier
Moretown
Starksboro
Ferrisburg
VERGENNES
Waitsfield
BARRE
Groton
S. Ryegate
New Haven Jct.
Northfield
E. Barre
Wells River
Bristol
Warren
Roxbury
Williamstown
Washington
Waits River
Addison
Newbury
Middlebury
Bridport
E. Middlebury
Chelsea
Bradford
Vershire
Cornwall
Hancock
Randolph
Fairlee
Ely
Post Mills
Shoreham
Tunbridge
Rochester
S. Strafford
Orwell
Forest Dale
Sudbury
Brandon
Bethel
Royalton
Sharon
E. Thetford
Pittsfield
Barnard
Norwich
Pittsford
Proctor
Sherburne Ctr.
Center Rutland
Castleton
RUTLAND
Woodstock
White River Jct.
Fair Haven
W. Rutland
Bridgewater Cors.
Hartland
Poultney
Middletown Springs
Plymouth Union
Windsor
Wallingford
Tinmouth
East Wallingford
Felchville (Reading P.O.)
Ludlow
Proctorsville
Ascutney
Cavendish
Pawlet
Danby
Gassetts
N. Springfield
Weston
Springfield
Dorset
Londonderry
Chester
S. Londonderry
Grafton
Manchester Ctr.
Manchester
Rawsonville
Bellows Falls
Saxtons River
Jamaica
Arlington
Wardsboro
Townshend
Westminster Station
Newfane
Putney
S. Shaftsbury
W. Dover
N. Bennington
Bennington
Wilmington
Brattleboro
Jacksonville
Vernon
Pownal
Stamford
Readsboro
HIGHWAY LEGEND
COMPLETED MULTILANE DIVIDED, CONTROLLED ACCESS (ST. HWY.)
INTERCHANGE WITH NUMBER
MULTILANE DIVIDED, UNDER CONSTRUCTION
PROPOSED MULTILANE DIVIDED, CONTROLLED ACCESS
STATE HIGHWAY
STATE HIGHWAY UNDER CONSTRUCTION
STATE HIGHWAY PROPOSED
NUMBERED "CLASS 2" HIGHWAYS
AGENCY OF TRANSPORTATION
PLANNING DIVISION
FEBRUARY 15, 1984
SCALE
24 MILES
32 KILOMETERS
N
AGENCY OF TRANSPORTATION
VERMONT

# WATERFORD WELCOME CENTER SITE PLAN



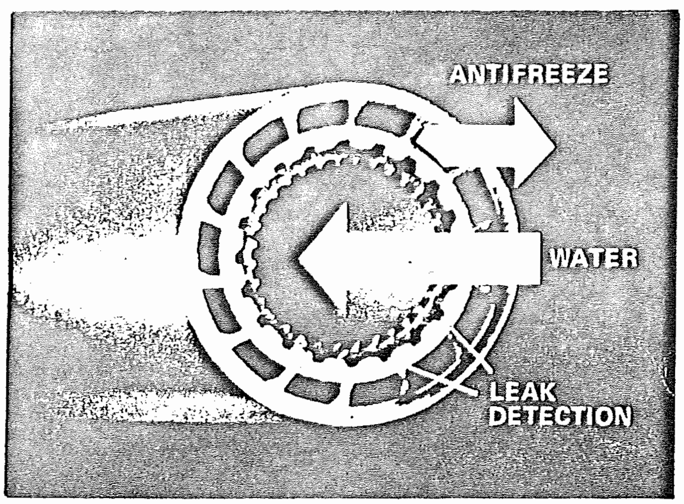
# DESCRIPTION OF SOLAR HEAT EXCHANGER

## Control System

Circulators for the water and collector loops are activated whenever enough solar energy is available to increase the temperature of the water in the solar tank. Circulators are activated by a *differential controller* within the module, which is connected to one temperature sensor located at the collector and one temperature sensor located at the storage tank.

The differential controller is activated by the module *front panel selector switch.* Its functions are:

- ☐ ON. Circulators are manually activated regardless of whether solar energy is available.
- ☐ OFF. Circulators are inoperative.
- ☐ AUTO. The controller automatically activates the circulators when preset conditions are met. When the collector sensor is 20°F above the temperature of the tank sensor, the system is activated. When collector and tank sensors are within 3°F of one another, the system is turned off.




## System Monitoring

An *indicator light* on the module front panel is operative when the selector switch is on AUTO. The light, when lit, indicates that necessary levels of solar energy are available, and that electrical current is being supplied to both circulators.

A *pressure/temperature gauge* located on the front panel monitors fluid pressure and temperature in the collector loop. Any leakage in the collector loop will be indicated by a substantial pressure drop. During normal system operation, the gauge will indicate gradual temperature increases. Collector loop fluid temperature is governed both by the intensity of the sun and by the temperature of water held in the storage tank.

## Systems Precautions

### Collector Loop Fluid

- ☐ Collector loop fluid is a solution of 50% ethylene glycol and 50% distilled water. System performance may be adversely affected unless proper proportions are maintained. An average installation will require four to six gallons of collector loop fluid. The recommended ethylene glycol solutions are listed on the following page. If these solutions are used, they need only be changed every FIVE YEARS.

section one

## System Operation

The CF-100A Module is designed to preheat water entering a conventional domestic water heater, thus reducing energy requirements.

The counterflow heat exchange module contains:

- ☐ A highly efficient double-wall exchanger
- ☐ Two low-power circulators
- ☐ A differential controller
- ☐ An expansion tank
- ☐ A pressure/temperature gauge
- ☐ Necessary switches and valves

## Liquid Loops

This Grumman Sunstream system uses two separate liquid loops. The first is the *collector loop,* which connects solar collectors to the module and contains an anti-freeze solution.

A separate *water loop* connects the module to the storage tank, and contains potable water.

Antifreeze is pumped through solar collectors, where it is heated and returned to the module heat exchanger by the *glycol circulator.* Heat from the antifreeze is transferred to water circulated through the module heat exchanger.

As indicated, the counterflow heat exchanger is constructed of three copper tubes fitted inside each other. Water flows in one direction through the center tube, which is rifled to increase heat transfer surface. An antifreeze solution moves in the opposite direction through parallel passages in the outer tube. Between the two are passages which provide leak detection and prevent any contamination of the potable water supply.

The module *expansion tank* keeps collector loop pressure at acceptable levels. A *pressure relief valve* backs up the expansion tank, and will operate only in the event of multiple system failures.

Water heated by the module system replenishes energy removed by domestic hot water demands. Since most existing systems are thermostatically controlled, conventional energy sources will be drawn upon when solar-heated water does not meet domestic use/temperature requirements.

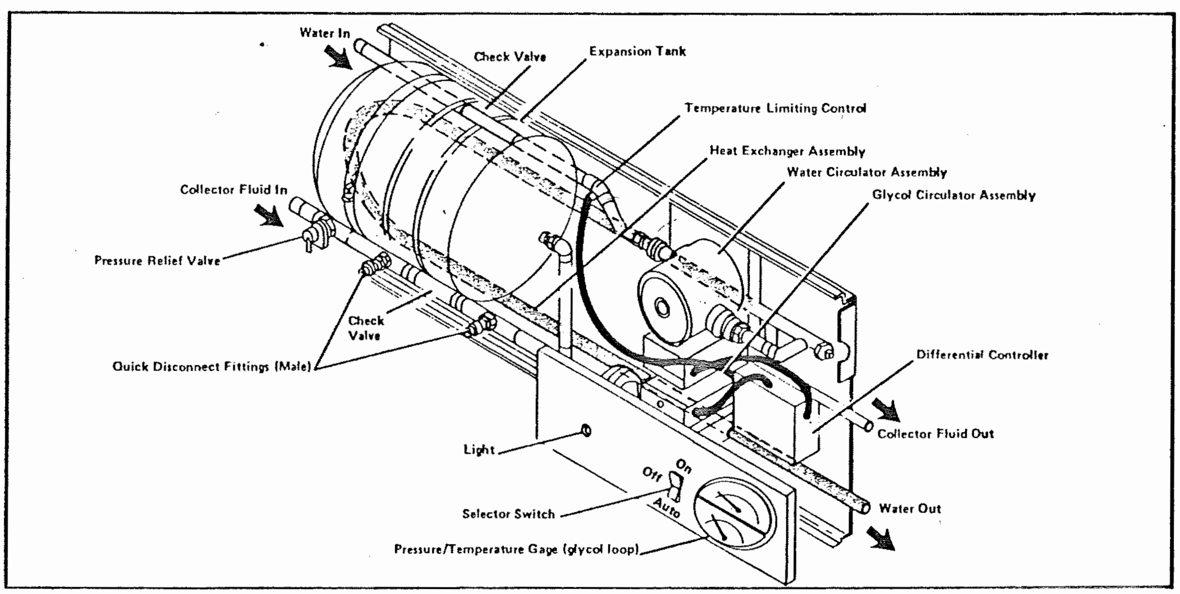



**Figure 1. Model CF-100A Components**

| | | |
|---|---|---|
| —Dow SR-1 | —Texaco P.T. | —Shellzone |
| —Dowgard | —Peak | —Atlas Permaguard |

DO NOT use any brand of antifreeze which contains leak inhibitors.

**Circulator Pumps**

Circulators are fluid lubricated. Failure to charge the collector and water loops prior to operation may result in permanent circulator damage.

The entire system must be leak-tight and free of air to operate efficiently.

**Relief Valves**

DO NOT isolate the water side of the module from the pressure relief valve located on the solar storage tank by valving without proving additional relief capability.

DO NOT isolate collectors by valving from the module expansion tank or collector loop pressure relief valve.

**System Safety Features**

High Limit Temperature Protection—Thermal overload switches within the module provide high limit temperature protection. The thermal overload component is attached to the module water inlet pipe and breaks supply voltage to both circulators whenever storage tank water temperature reaches 170°F. Impedance protection devices within the motor windings of both circulators will protect these units from going above 275°F.

*Pressure within the collector loop* is limited to about 50 psi by the module expansion tank, which accepts increased fluid volume under increased temperature conditions. Collector loop pressure is further controlled by a pressure relief valve which will not permit system pressure to exceed 75 psi. The relief valve will be activated only in the event of multiple component failures.

When the water main pressure is in excess of 80 psi, a pressure regulating valve should be installed to make sure that the solar system does not receive more than 80 psi of pressure. To make sure that the pressure regulating valve operates properly, it is recommended that a strainer be installed in front of the valve.

WATERFORD - WELCOME CENTER
SOLAR HOT WATER MONITORING

STATE OF VERMONT A.O.T.
MATERIALS & RESEARCH DIVISION

| DATE OF READING | DAYS SINCE LAST READING | DAYS SINCE START OF STUDY | MECHANICAL RM. TEMP. | AMBIENT TEMP. OUTSIDE | COLLECTOR TEMP. | TO COLLECTOR | FROM COLLECTOR | DEGREES DIFFERENCE GYCOL TO & FROM COLLECTOR | HEAT EXCHANGER WATER IN | HEAT EXCHANGER WATER OUT | DEG. DIFF. WATER TO & FROM HEAT EXCH. | GAL. HOT WATER USED SINCE LAST READING | GAL. HOT WATER USED PER DAY SINCE LAST READING | GAL. HOT WATER USED PER DAY SINCE BEGIN STUDY | GAL. WATER USED SINCE LAST READING | GAL. WATER USED PER DAY SINCE LAST READING | GAL. WATER USED PER DAY SINCE STUDY BEGAN | KILOWATT HR. USED FOR HOT WATER SINCE LAST READING/Daily | KILOWATT HR. USED FOR HOT WATER SINCE STUDY BEGAIN | KILOWATT HR. USED FOR SOLAR SYSTEM SINCE LAST READING/Daily | KILOWATT HR. USED FOR SOLAR SYSTEM SINCE STUDY BEGAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6-17-83 | - | - | 78 | 74 | - | 155 | 169 | 14 | 147 | 155 | 8 | - | - | - | - | - | - | * | * | * | * |
| 6-30-83 | 13 | 13 | 75 | 60 | - | 136 | 140 | 4 | 139 | 142 | 3 | 230.8 | 18 | 13 | 3377 | 260 | 260 | * | * | * | * |
| 7-08-83 | 8 | 21 | 78 | 76 | - | 152 | 170 | 18 | 136 | 147 | 11 | 296.0 | 37 | 25 | 3041 | 380 | 306 | * | * | * | * |
| 7-15-83 | 7 | 28 | 84 | 82 | - | 159 | 170 | 11 | 148 | 160 | 12 | 222.0 | 32 | 27 | 3132 | 447 | 341 | * | * | * | * |
| 7-26-83 | 11 | 39 | 88 | 80 | 212 | 175 | 182 | 7 | 169 | 174 | 5 | 284.6 | 26 | 27 | 4915 | 447 | 371 | * | * | * | * |
| 8-10-83 | 15 | 54 | 85 | 67 | 189 | 175 | 188 | 13 | 162 | 171 | 9 | 465.8 | 31 | 28 | 6630 | 442 | 391 | * | * | * | * |
| 8-30-83 | 20 | 74 | 76 | 68 | | | | | 124 | 131 | 7 | 543.8 | 27 | 28 | 7725 | 386 | 389 | * | * | * | * |
| 10-05-83 | 36 | 110 | 73 | 63 | 131 | 110 | 132 | 22 | 93 | 131 | 38 | 979.4 | 27 | 27 | 11149 | 310 | 363 | * | * | * | * |
| 10-14-83 | 9 | 119 | 75 | 63 | 158 | 128 | 146 | 18 | 115 | 125 | 10 | 442.7 | 49 | 29 | 3989 | 443 | 369 | * | * | * | * |
| 11-01-83 | 18 | 137 | 79 | 58 | 168 | 154 | 149 | 5 | 156 | 156 | - | 272.7 | 15 | 27 | 2811 | 156 | 341 | * | * | * | * |
| 11-15-83 | 14 | 151 | 74 | 40 | 147 | 132 | 147 | 15 | 117 | 127 | 10 | 229.0 | 16 | 26 | 1435 | 103 | 319 | * | * | 6<br>0.43 | 0.43 |
| 1-04-84 | 50 | 201 | 71 | 28 | System was not operating at time of insp. | | | | | | | 667.0 | 13 | 23 | 4344 | 87 | 261 | * | * | 11<br>0.22 | 0.27 |
| 1-18-84 | 14 | 215 | 69 | 12 | | | | | | | | 222.5 | 16 | 23 | 1011 | 72 | 249 | * | * | 3<br>0.21 | 0.26 |
| 2-03-84 | 16 | 231 | 68 | 40 | | | | | | | | 243.8 | 15 | 22 | 1231 | 77 | 237 | * | * | 8<br>0.50 | 0.30 |
| 2-27-84 | 24 | 255 | 79 | 30 | 167 | 153 | 169 | 16 | 138 | 148 | 10 | 413.3 | 17 | 22 | 2968 | 124 | 227 | 61<br>2.54 | 2.54 | 8<br>0.33 | 0.31 |
| 3-22-84 | 24 | 279 | 73 | 45 | 148 | 133 | 118 | 15 | | 140 | | 312.9 | 13 | 21 | 2084 | 87 | 214 | 37<br>1.54 | 2.04 | 10<br>0.42 | 0.32 |
| 5-02-84 | 41 | 320 | 69 | 41 | System was not operating at time of insp. | | | | | | | 544.3 | 13 | 20 | 6259 | 153 | 207 | 13<br>0.32 | 1.25 | 20<br>0.49 | 0.36 |
| 5-23-84 | 21 | 341 | 81 | 84 | 184 | 169 | 183 | 14 | 156 | 165 | 9 | 309.9 | 15 | 20 | 3094 | 147 | 203 | 10<br>0.48 | 1.10 | 11<br>0.52 | 0.38 |
| 6-20-84 | 28 | 369 | 76 | 71 | 182 | 167 | 181 | 14 | 154 | 164 | 10 | 445.6 | 16 | 19 | 5594 | 200 | 203 | 9<br>0.32 | 0.94 | 18<br>0.64 | 0.41 |
| 7-10-84 | 20 | 389 | 76 | 76 | 151 | 131 | 150 | 19 | 136 | 141 | 5 | 537.7 | 27 | 20 | 7615 | 381 | 212 | | 0.82 | 12.5<br>0.63 | 0.43 |
| 8-03-84 | 24 | 413 | 80 | 78 | 172 | 157 | 171 | 14 | 144 | 153 | 9 | 693.5 | 29 | 20 | 9198 | 383 | 222 | | 0.71 | 18.5<br>0.77 | 0.46 |
| 8-31-84 | 28 | 441 | 76 | 70 | 123 | 109 | 124 | 15 | 101 | 107 | 6 | 906.0 | 32 | 21 | 11136 | 398 | 233 | | 0.62 | 20<br>0.71 | 0.48 |
| 9-18-84 | 18 | 459 | 79 | 76 | 212+ | 158 | 152 | 6 | 146 | 153 | 7 | 453.6 | 25 | 21 | 5706 | 317 | 236 | | 0.57 | 11<br>0.61 | 0.49 |
| 11-16-84 | 59 | 518 | 70 | 42 | | | | | | | | 1280.4 | 22 | 21 | 14274 | 242 | 237 | 27<br>0.46 | 0.55 | 33<br>0.56 | 0.50 |

*Metering equipment not yet installed.

## PAYBACK ESTIMATE

| Years of Service | Yearly Cost to Operate an Electric Hot Water Heater* | Total Cost of Electricity | Cost of Electricity for Solar System ** and Back-Up System | Total Cost of Solar System $5,400.00 Initial Cost |
|---|---|---|---|---|
| 1 | $485.00 | $ 485.00 | $32.00 | $5432.00 |
| 2 | $509.00 | $ 994.00 | $35.00 | $5467.00 |
| 3 | $535.00 | $1529.00 | $39.00 | $5506.00 |
| 4 | $561.00 | $2090.00 | $43.00 | $5549.00 |
| 5 | $590.00 | $2680.00 | $47.00 plus maintenance cost of $150 | $5746.00 |
| 6 | $619.00 | $3299.00 | $52.00 | $5798.00 |
| 7 | $650.00 | $3949.00 | $57.00 | $5855.00 |
| 8 | $682.00 | $4631.00 | $63.00 | $5918.00 |
| 9 | $717.00 | $5348.00 | $69.00 | $5987.00 |
| 10 | $752.00 | $6100.00 | $76.00 | $6063.00 |
| 11 | $790.00 | $6890.00 | $83.00 plus maintenance cost of $200 | $6346.00 |

Payback in Ten Years

*Calculation based on initial rate of 8¢/kWh; 5% increase in hot water usage and 4% increase in electric rates.

**Calculation based on same rates as used for conventional heater but increased for solar not being able to supply total increased demand.

Appendix F

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

# WORK PLAN FOR CATEGORY III EXPERIMENTAL PROJECT

# SOLAR ENERGY FOR HIGHWAY USES (REGION 15 DEMONSTRATION PROJECT NO. 52) Work Plan 82-R-5

## OBJECT OF EXPERIMENT

To design, construct, and monitor the performance of a solar assisted hot water heating system.

## PROJECT AND LOCATION

Interstate 93 Welcome Center at Waterford, Vermont. Project Waterford - St. Johnsbury IR 93-1(5) (Number tentative as of 2/24/82)

## SOLAR APPLICATION

Solar assisted domestic hot water heating.

## TYPE OF SYSTEM

Active solar thermal energy system.

## CONVENTIONAL ENERGY SYSTEM BEING ASSISTED

Electric hot water.

## SYSTEM DESCRIPTION

Type of collector - Solar panels, closed fluid system
Type of storage - Heat exchanger and 120 gallon storage tank.
Backup system - Conventional electric hot water system.

## DEMAND POTENTIAL

The solar system is designed to meet 60% of the annual demand load.

## ADDITIONAL CONSERVATION MEASURES

Other conservation measures specified in the facility include triple glazed windows, entrance vestibules, 12 inch insulation in ceilings and 5½ inches in walls, wood stove, and peak power controller for off peak power.

## PRELIMINARY COST ESTIMATE

| | |
|---|---|
| Engineering and Design Costs | $ 500.00 |
| Total Installed Cost of Solar Energy System with Backup | $8000.00 |
| Cost of Monitoring Equipment,Evaluation and Reports | $4650.00 |
| Cost of Public Information Display | $ 75.00 |
| Total Installed Cost of a Conventional Energy System | $ 750.00 |
| Total Amount of FHWA Demonstration Projects Funds Requested | $12475.00 |

## CONTRACT TASKS

A. Prepare preliminary design and life cycle cost analysis.

B. Prepare monitoring plan and finalize design. Prepare public information display.

C. Procure and install solar energy system with monitoring equipment.

D. Operate, maintain, and monitor system.

E. Periodic data reporting and evaluation report.

## DURATION OF STUDY

The experimental feature will be evaluated for a minimum of two years following completion of the installation.

Reviewed by:
R. F. Nicholson
R. F. Nicholson, P.E.
Materials & Research Engineer

Date: 3/3/82

Vermont Agency of Transportation
Materials & Research Division
March 3, 1982