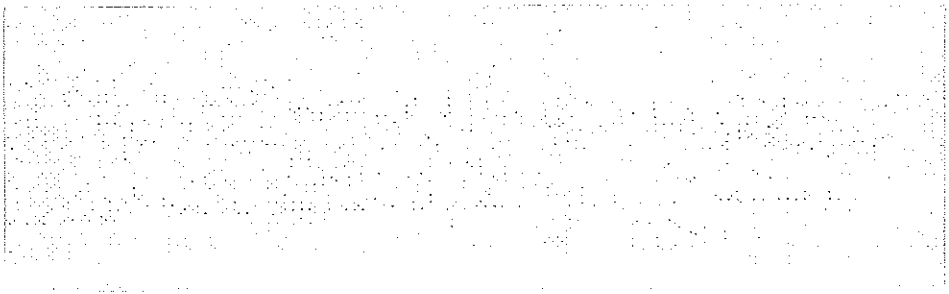
SOLAR HOT WATER SYSTEMS IN MICHIGAN REST AREAS
Second Report

MATERIALS and TECHNOLOGY DIVISION



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Solar hot water systems in Michigan rest areas second report

SOLAR HOT WATER SYSTEMS IN MICHIGAN REST AREAS
Second Report

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Research Laboratory Section
Materials and Technology Division
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Michigan Transportation Commission
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Lansing, March 1988

Introduction

On December 13, 1976, Public Act 502 mandated that the Michigan Department of Transportation utilize solar energy systems, integrated with conventional systems, to heat water for highway rest areas and travel information centers.

Four such facilities have subsequently been built in Michigan with solar systems providing a portion of the energy to heat tap water. One system, on I 75 south of Bay City, was described in an Interim Report (MDOT Research Report No. R-1260) with the same title as this report. The second facility—the subject of this report—was opened April 19, 1983 on I 94 in Battle Creek. The other two systems, a travel information center located on US 23 south of Dundee and a rest area located on US 23 north of Ann Arbor, have not been monitored.

This report summarizes the data monitored from the solar hot water system at the I 94 rest area in Battle Creek from December 1984 to October 1986.

Solar Energy System and Monitoring Equipment

The solar system and monitoring equipment installed at the I 94 rest area in Battle Creek were similar to the system and equipment installed at the rest area on I 75 south of Bay City (1). The system and equipment at the rest area in Battle Creek are described in the Appendix.

Data Collection

The rest area attendant recorded water meter and electric hour meter readings daily. Thermocouples were connected to a recorder and temperatures were recorded every 30 minutes. When the new recording equipment was installed data were transferred to magnetic tape as well. As shown in the Appendix (Fig. A1), temperatures were recorded for cold water (T1), solar tank water (T2), hot water (T3), and tap water (T4). (Tap water is hot and cold water mixed in a tempering valve.) Outside air temperatures were also recorded.

The system was monitored from December 1, 1984 to October 30, 1986. The data gathered between July 16, 1985 and March 14, 1986 were omitted from this report because valve #2 was left open during the period and, therefore, the system did not operate efficiently.

Data Analysis

Data were entered into a computer for subsequent analysis. Daily values of electrical energy, cold and tap water use, solar input energy, and solar stored energy were calculated by the computer. A typical daily graph showing semi-hourly values of the various water temperatures in the system is shown in Figure 1. Monthly graphs were also plotted of

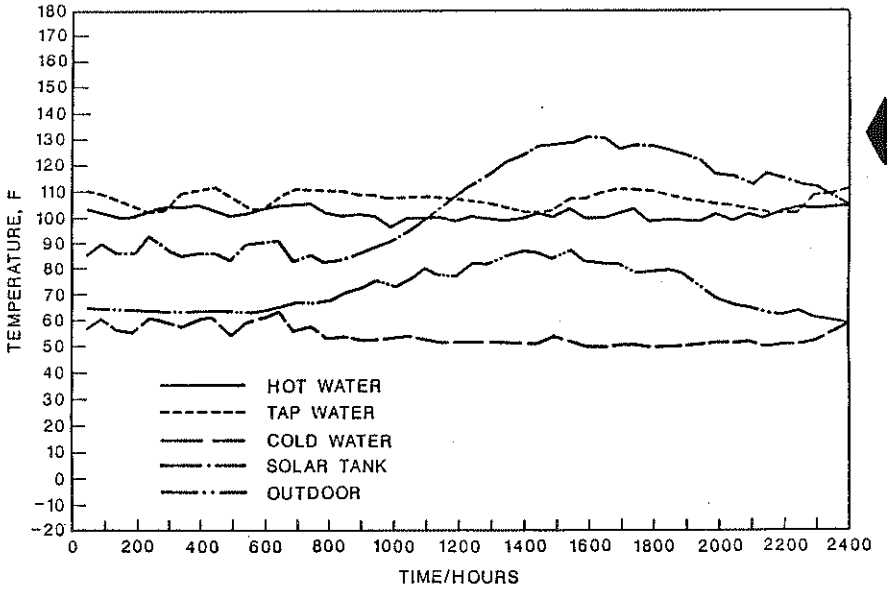

Figure 1. Daily temperature graph for June 1986.

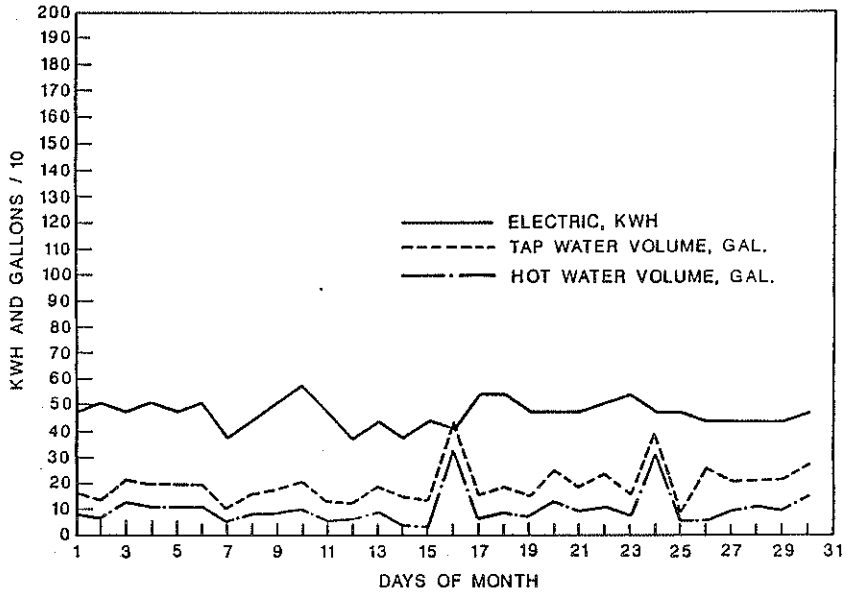

Figure 2. Monthly water volumes and electrical energy values for June 1986.

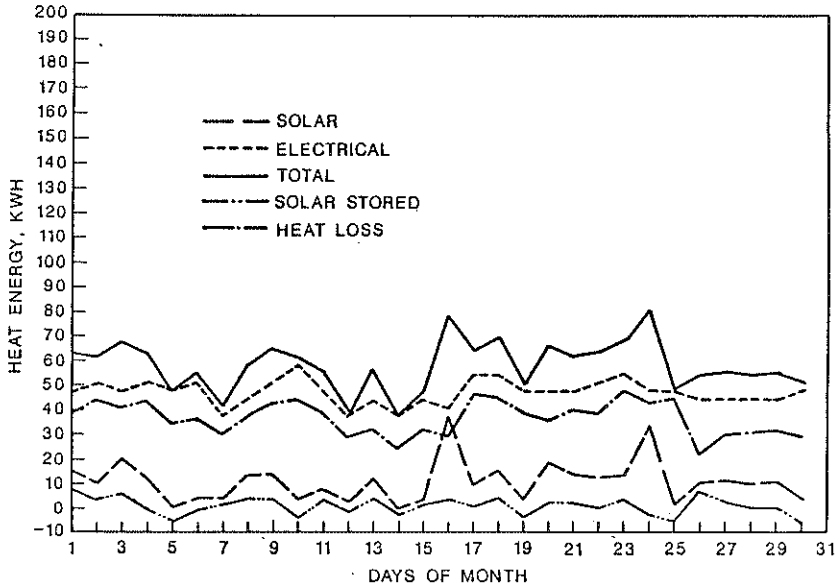

Figure 3. Monthly energy graph for June 1986.

the daily electric energy, tap, and hot water volumes (Fig. 2). Monthly graphs were plotted of the solar, electric, and total energy input, stored energy, and heat loss in the hot water system (Fig. 3).

Results

Rest areas have a different pattern of tap water use than homes or other public buildings. Moreover, the pattern of use at the Battle Creek rest area was different from the rest area south of Bay City. Both rest areas were used mostly during daylight hours but the Battle Creek rest area had a short period of heavy usage at about 7:00 to 8:00 a.m. when truckers started their runs. In comparison, the rest area south of Bay City had a gradual increase in usage that peaked in the afternoon.

The Battle Creek rest area had little day-to-day variation in usage. The rest area south of Bay City had high usage on Sundays and holidays because it is located on southbound I 75 where people are returning home to the southeast metropolitan area of Michigan (1).

Table 1 gives the average daily usage for each month of water volumes, hot water energy, and the percent hot water energy from solar that was used by the system.

TABLE 1
BATTLE CREEK REST AREA
AVERAGE DAILY USAGE PER MONTH

Year	Month	Number of Days	Water Volume (gal)		Hot Water Energy Used (kwh)			Percent Solar
			Well	Tap	Solar	Electrical	Total	
1984	Dec.	31	2,408	94.6	1.7	52.3	54.0	3.2
1985	Jan.	30	1,518	73.3	1.2	50.0	51.2	2.3
	Feb.	28	1,600	71.8	1.4	39.9	41.3	3.4
	March	30	2,511	100.5	3.0	38.4	41.4	7.2
	April	28	4,070	134.0	4.4	44.4	48.8	9.0
	May	29	3,569	197.7	8.0	40.3	48.3	16.6
	June	27	4,255	254.0	9.1	37.8	46.9	19.4
1986	April	27	2,499	188.0	8.0	38.3	46.3	17.3
	May	27	3,466	215.8	9.6	40.9	50.5	19.0
	June	30	4,290	195.9	9.7	46.9	56.6	17.1
	July	31	4,922	227.9	12.4	50.4	62.8	19.7
	August	31	5,229	244.4	11.5	44.6	56.1	20.5
	Sept.	29	3,164	143.2	7.7	70.5	78.2	9.8
	Oct.	29	2,752	115.6	3.9	45.4	49.3	7.9

There is an advantage in using solar hot water systems in rest areas over other types of buildings, as rest areas use more hot water in the summer when solar energy is readily available. The rest area south of Bay City used approximately four times as much tap water in the summer as was used in the winter (1). The Battle Creek rest area used approximately three times as much tap water in the summer (Table 1).

Recirculating systems are necessary to maintain warm water at the faucets when the lavatories are some distance from the hot water tank. This results in approximately 35 kwh of heat loss per day in both the Battle Creek rest area and the rest area south of Bay City (1).

The dollars saved on electric energy do not justify the installation of the solar energy system at the Battle Creek rest area or the rest area south of Bay City. The solar system at the Battle Creek rest area cost $12,360 to install. Table 2 shows the dollars saved each month for electricity to heat tap water. The total for the year was $254 with the November electric demand assumed to be equal to October (November data were not available). Also, the two values for April, May, and June were averaged (the reason for the two values for these months will be explained later). Based on an interest rate of 10 percent, a savings of $1436 per year would be required to amortize the cost of this system over a 20-year period. For the rest area south of Bay City the savings realized and those needed to break even were $220 and $1500 per year, respectively (1).

Little to no maintenance of the solar system has been needed at the Battle Creek rest area. In contrast, considerable system maintenance was required at the solar rest area south of Bay City, where a solar panel on the roof developed a hole and had to be repaired, and the circulation pump for the solar panels failed and had to be replaced.

TABLE 2
MONTHLY INSOLATION (SOLAR ENERGY) ANALYSIS
AT BATTLE CREEK REST AREA

Month	Year	Theoretical Available (kwh)	Percent Available Sunshine	Approximate Sunshine Received (kwh)	Solar Energy Used (kwh)	Percent Solar Efficiency	Savings (Dollars)
Dec.	1984	632	30	189.6	52.7	27.8	5.02
Jan.	1985	729	36	262.4	37.2	14.2	3.52
Feb.	1985	899	44	395.6	39.2	9.9	3.66
Mar.	1985	1,197	49	586.5	93.0	15.9	9.01
Apr.	1985	1,302	52	677.0	132.0	19.5	12.91
	1986	1,302	52	677.0	240.0	35.5	12.85
May	1985	1,442	64	922.9	248.0	26.9	14.36
	1986	1,442	64	922.9	297.6	32.2	36.51
June	1985	1,420	68	965.6	273.0	28.3	26.58
	1986	1,420	68	965.6	291.0	30.1	37.72
July	1986	1,420	71	1,008.2	384.4	38.1	41.98
Aug.	1986	1,326	69	914.9	356.5	39.0	54.97
Sept.	1986	1,116	60	669.6	231.0	34.5	34.15
Oct.	1986	944	55	519.2	120.9	23.3	15.41

Table 2 shows an estimated efficiency of the solar hot water system. The percent of possible sunshine available at Battle Creek was multiplied by the theoretical solar energy available for clear sky conditions at the Battle Creek latitude (2). Estimated efficiency was calculated using the product of the above computation and the solar energy values converted to monthly totals obtained from Table 1. This is an estimated value because even with zero percent sunshine there can be varying amounts of

radiation received by the solar panels depending upon the thickness of the cloud cover.

In July 1985 the hot water tank thermostat at Battle Creek was lowered from 130 to 110 F. The percent efficiency increased for the months of April, May, and June where two years of data are available (Table 2). The average percent efficiency for the three months of 1985 was 25 percent and for the three months of 1986 was 33 percent. The efficiency increased because more solar hot water was mixed with the electrically heated tap water.

Possible Design Improvements

The solar hot water systems installed at the Battle Creek rest area and the rest area south of Bay City could only provide 2 to 20 percent of the energy needed to heat hot water in the winter and summer, respectively. If the heat loss from the recirculating system is excluded, the solar system provided one-half the energy needed to heat hot water in the summer.

More energy could be obtained from the solar system if an electronic control and associated valves were added. These controls would direct recirculating water from its present path (through the hot water tank) to the solar tank when solar tank temperature is above recirculating water temperature. This should be done in conjunction with an increase in capacity of the solar system.

Of course, increasing the size or number of solar panels would collect more solar energy which is needed at both the Battle Creek and Bay City rest areas; however, system cost would be increased as well. Increasing the solar tank capacity at the rest area south of Bay City would also improve system performance. This is because that rest area south of Bay City has a more cyclic use on Sundays and holidays than does the Battle Creek rest area. An excessive amount of stored hot water at the Battle Creek rest area would mean a greater amount of heat loss through the tank insulation. The saying, "if you don't use it, you lose it" applies in this case. Improved insulation is a benefit in any type of hot water installation.

A different type of solar collector is now being sold in Michigan. The system utilizes the phase change of refrigerant (such as R11 or R114) to transfer the solar energy from the solar panels to a single-wall heat exchanger. A pump isn't required to pump a fluid from the panels to the exchangers. These systems are twice the cost of conventional solar panels but are reported to produce twice the efficiency. They are more adapted to Michigan weather because they respond more quickly to the presence of solar energy during partly cloudy conditions (3).

The solar system in the new Michigan Department of Transportation office building in Kalamazoo has solar tubes that utilize the phase change

of refrigerant. The tubes are evacuated to improve the efficiency even more than phase change solar panels which use atmospheric air in the panels. These tubes can produce water temperatures from 160 to 200 F and can be used to supply hot water to special absorptive chillers for cooling buildings in the summer months. The cost of this kind of solar array is approximately three times the cost of the panels on the Battle Creek rest area or the Bay City rest area.

Conclusion

Solar hot water systems, installed in Michigan rest areas are not justified economically at the present over alternative energy. Design improvements of present systems can increase efficiency because rest areas use three to four times as much hot water in the summer as they do in winter. Also, more efficient systems which use refrigerant in the solar panels to transfer energy by phase change instead of using a pump, are presently being sold by solar system companies in Michigan. Significant future changes in energy costs would be cause to re-evaluate this conclusion.

REFERENCES

1. Harwood, F. W., and Holcom, R. J., "Solar Hot Water Systems in Michigan Rest Areas, Interim Report," Michigan Department of Transportation, Materials and Technology Division Report No. 1260, May 1985.

2. Fridgen, Cynthia; Mrozowski, Tim, and Zarka, Jim, "First Solar Catalog for Michigan." Department of Energy Grant, published 1984.

3. Bottum, R. W., "Heat Transfer in Solar Systems Through Phase Change," presented to the Solar Energy International Association Meeting in Las Vegas, 1981.

APPENDIX

Solar Energy System and Monitoring Equipment

A Grumman-Sunstream solar system was incorporated into the standard hot water system at the I 94 rest area in Battle Creek. Figure A1 is a schematic showing the solar hot water system with thermocouple and meter locations for sensing water temperatures and volumes, and Figure A2 shows the plumbing layout.

The solar energy portion of the system consisted of: 1) a 120-gal solar tank, 2) a heat exchanger outside and next to the solar tank which included dual circulating pumps, and 3) two 4 by 8-ft solar collectors. The ethylene glycol circulation system contains a pump, an air purge, an expansion tank, a differential thermostat, and a pressure gage. The water circulation pump is used to transfer the heat energy from the heat exchanger to the solar tank. Both pumps are switched on by the differential thermostat when the solar collector liquid is higher than the solar tank water temperature.

The 120-gal electric water heater is connected so that the amount of time the heating elements are on is measured by hour meters.

Temperatures were recorded using a Honeywell recorder with paper printout, from December 1984 to December 1985. The Honeywell recorder then was replaced with a new Kaye recorder with paper printout and a mini-cassette tape recorder and data were collected until October 1986. The new recording system provided semi-automatic data translation to the Department's main frame computer.

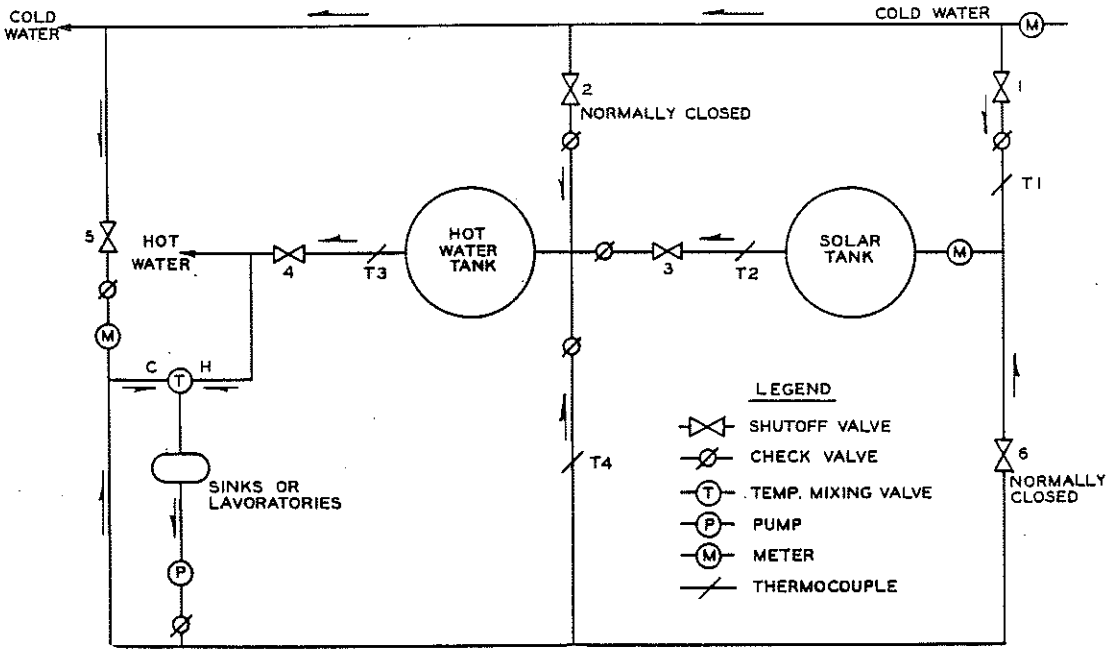

Figure A1. Schematic of hot and cold water system with thermocouples and water meters at Bay County rest area.

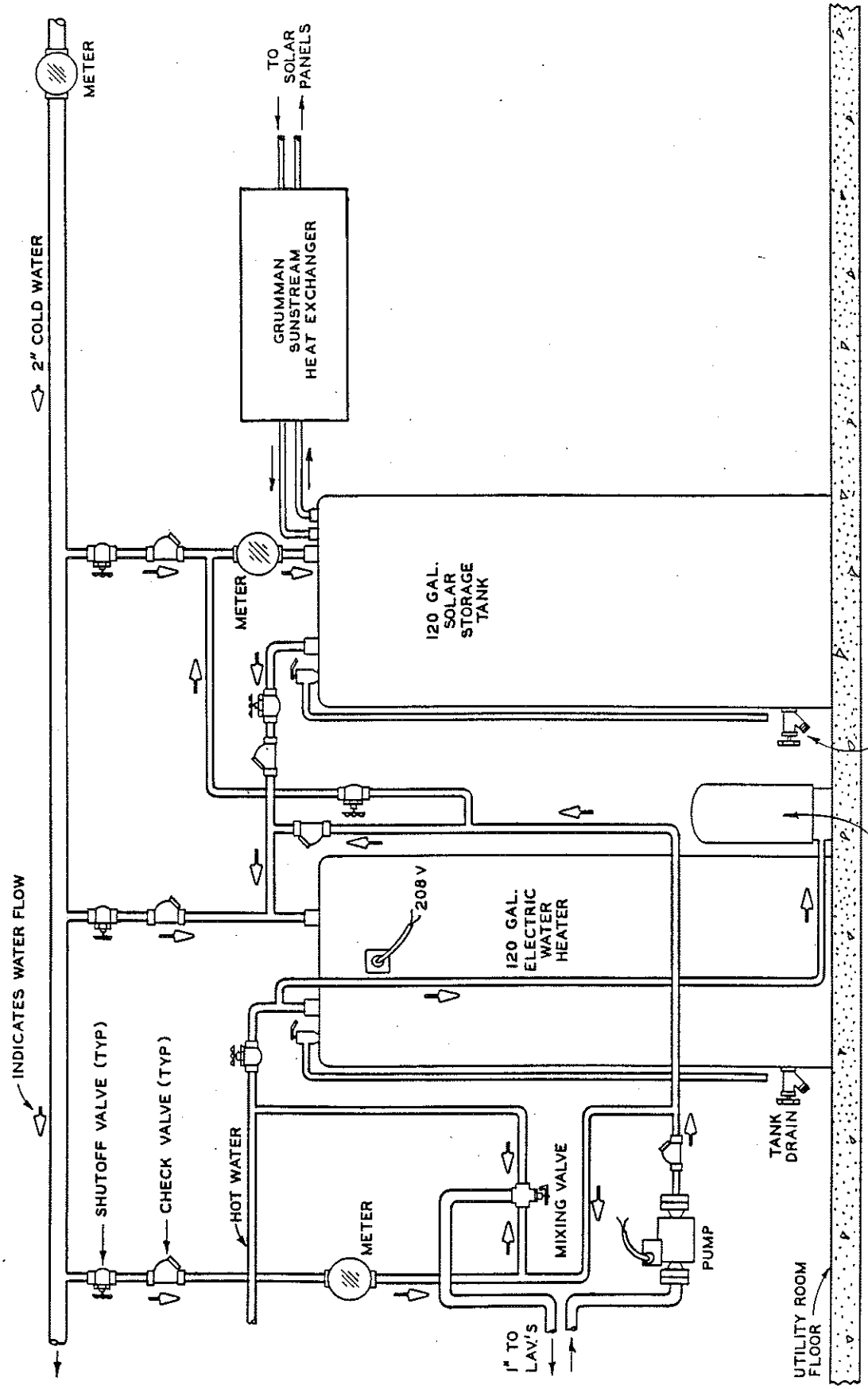

Figure A2. Diagram of hot and cold water system at Battle Creek rest area.