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FINAL REPORT

FREEZE-PROTECTION LOOP FOR DIRECT SOLAR-WATER-HEATING SYSTEMS

Even a one-time freeze condition can do destructive damage to a direct solar water heating system. The project funded under grant DE-FG4480R4, 1-1-80 to 8-1-81, proposed to demonstrate a simple installation procedure whereby thermosiphoning warm water from storage would prevent solar collectors from freezing.

Installing the freeze protection loop in owner maintained solar systems was inconclusive. Owners were not attentive to freeze warnings or did not understand the simple instructions.

A controlled situation was established using a refrigerator to produce below freezing temperatures. Experiments conducted with this equipment showed that the thermosiphoning principle could not be relied on to prevent freezing.

Thermosiphoning cannot be relied on to prevent freezing in a direct solar water heating system. The direct system is an effective means of heating water in north Florida, but the system must be drained, either manually or automatically, to provide reliable system protection.

FINAL REPORT

FREEZE PROTECTION LOOP FOR DIRECT SOLAR WATER HEATING SYSTEMS

The objective of the project funded under Grant No. DE-FG4480R4 was to investigate the feasibility of preventing freeze damage to direct solar water heating systems by allowing thermosiphoning to occur when there was a danger of freezing. The damage caused by freezing of solar collectors containing water is the gravest deterrent to acceptance of this relatively simple system.

A number of situations had become known to grantee wherein collectors had not frozen during sub-freezing conditions. In one situation, two solar systems, both direct solar water heating systems (DSWHS) on the same house, experienced freezing temperatures. One froze, the other did not. As reported, the second system had a malfunctioning check valve which permitted the storage tank water to thermosiphon to the collector on the roof. Normally thermosiphoning is to be avoided in a pumped system because all the heated water can be lost in the course of the night.

Another method of preventing freezing this type solar system is to drill a small hole in the flapper in a swing check valve. However, there is no control of this ploy. The unit will lose hot water even when there is no danger of freezing.

Neither of these methods apply to solar collectors mounted lower than the storage tank.

A method of regulating the flow produced by the pump in a solar system has been to install a bypass around the pump. If the bypass loop also bypasses the check valve, purportedly this technique can be used to prevent freezing.

That is to say, opening the regulating valve in the bypass loop "may" prevent freezing if the freezing conditions are not severe and are not protracted.

While exploring the above proposal, we received a number of complaints which in trouble-shooting, were attributable to malfunctioning check valves. We were using a STRATOFLO 400, half-inch, metal poppet, check valve. Similar complaints were received from system owners who had swing check valves installed by others. Neither the poppet-type or swing-type check valve was reliable in controlling undesired thermosiphoning.

We began to use a Honeywell V4043A motorized valve, normally closed. When the pump was energized, the valve, wired in parallel with the pump motor, would also be energized, and open. When the pump is de-energized, the valve is likewise de-energized and a spring forces the valve to close. Use of this valve stopped thermosiphoning.

Before the winter of 1980-81 grantee obtained permission from several owners, usually those who had experienced freeze damage to collectors, to install the Freeze Protection Bypass Loop (FPBL) at no expense to them. Any repairs necessitated by freeze damage likewise would be made by us and charged to the grant. Owners who agreed to participate were instructed in the theory of the FPBL and seemed to understand the application. Drawings of each installation were likewise provided. The owners were also instructed in how to manually drain down their systems.

All three of the owners were older. All three had had systems freeze the previous year. The systems as originally installed were not provided with isolation valves or with drain down valves. Two systems were equipped with Hawthorne controls and depended on pumped recirculation to prevent freeze damage.

One system had no isolation valves, no drain down valves and no recirculation circuit. It was inevitable that this system should freeze.

The two owners with the systems that were drainable became alarmed when weather reports predicted a severe freeze. Both attempted to drain their collectors, but closed only one of the two isolation valves. When the drain down valves were opened, water flowed like a tap had been opened--which is what happened. Both owners gave up and retired without reopening the isolation valve they had just closed. Now their recirculating systems could not recirculate and their collectors froze.

The results of the above freeze ups proved nothing.

In order to have more control over the experiment we employed a refrigerator (used) to obtain below-freezing temperatures. A five gallon electric water heater was configured with tees to simulate a solar storage tank. This was placed at floor level. Ambient temperatures were indoors 68-70°F. Temperatures in the freezing compartment were 20-25°F. The refrigerator was elevated, freezing compartment was about 84" above floor level. Holes were drilled in the freezing compartment and about four feet of 3/4" fin tube (base board heating elements) were run back and forth, graded up. Outside the freezing compartment a standpipe arrangement ensured that the loop was filled with water at all times. A gate valve in the return line simulated a check valve or motorized valve. An FPBL was installed to bypass this valve. Tubing was half inch and the bypass loop was quarter inch. Water in the tank was not heated initially.

With no heat applied, tank temperature was 72°F. The gate valve was left open to observe thermosiphoning. Thermosiphoning occurred counter-clockwise. Neverthelessin one and one-half hours freezing occurred and a pipe broke in the freezing compartment. The broken pipe was replaced and the unit then circulated CW, the opposite direction. The circulation continued for five hours without freezing.

-Next the water in the tank was heated to 80°F. The gate valve was closed and the FPBL opened. Flow was detected (by temperature) in the quarter inch line; however, flow stopped due to freezing. Experiment was terminated and no damage occurred.

Experiment was conducted one evening 7PM. System froze. Opened half-inch gate valve. Thermosiphoning occurred at 10PM when heat was applied to tank. Tank was 110°F, returning (subsiding) water was 80°F.

Next morning at 7:50Am unit was frozen. Applied heat to tank. Gate valve closed, FPBL open. Freezing terminated, tank temperature 150°F, returning water 70°, eventually dropping to 54°F.

Experiment terminated.

OBSERVATIONS

Results could not be predicted. At times thermosiphoning would occur in one direction, the next time circulation would occur in the opposite direction. Any circulation would prevent freezing.

In some instances circulation would not occur even with all valves open.

If there was a significant temperature differential, as when the back up elemnet was energized, circulation would occur and prevent freezing.

If the tank cooled to ambient, about 70°F while the freezing compartment was at 20°F or lower, circulation would stop and the pipes in the freezing compartment would freeze. This means that leaving all the valves open, as in a house unoccuppied in the winter, would not prevent freeze damage--probably.

If the half inch valve was left fully open, freezing occurred less frequently than when only the FPBL was open.

Circulation was discernible by comparing temperatures in the feed and return lines. When the temperatures equalized, freezing had occurred.

CONCLUSIONS

Energizing the back-up heating element will probably prevent freezing a solar collector located above the storage tank in a direct solar water heating system; however, this is deemed wasteful. A better procedure would be to manually drain the collector.

The FPBL may prevent a solar collector from freezing, but the risk is great and results are not reliable.

Collectors on direct solar water heating systems must be drained when ambient temperatures reach 36°F, preferably 40°F, to prevent freeze damage.

ADDITIONAL INFORMATION

Water may be drained from solar collectors even if the system is not equipped with isolation valves or draindown valves--if the collectors are above the storage tank.

Close the cold water supply to the tank.

Turn off the electrical power to the element.

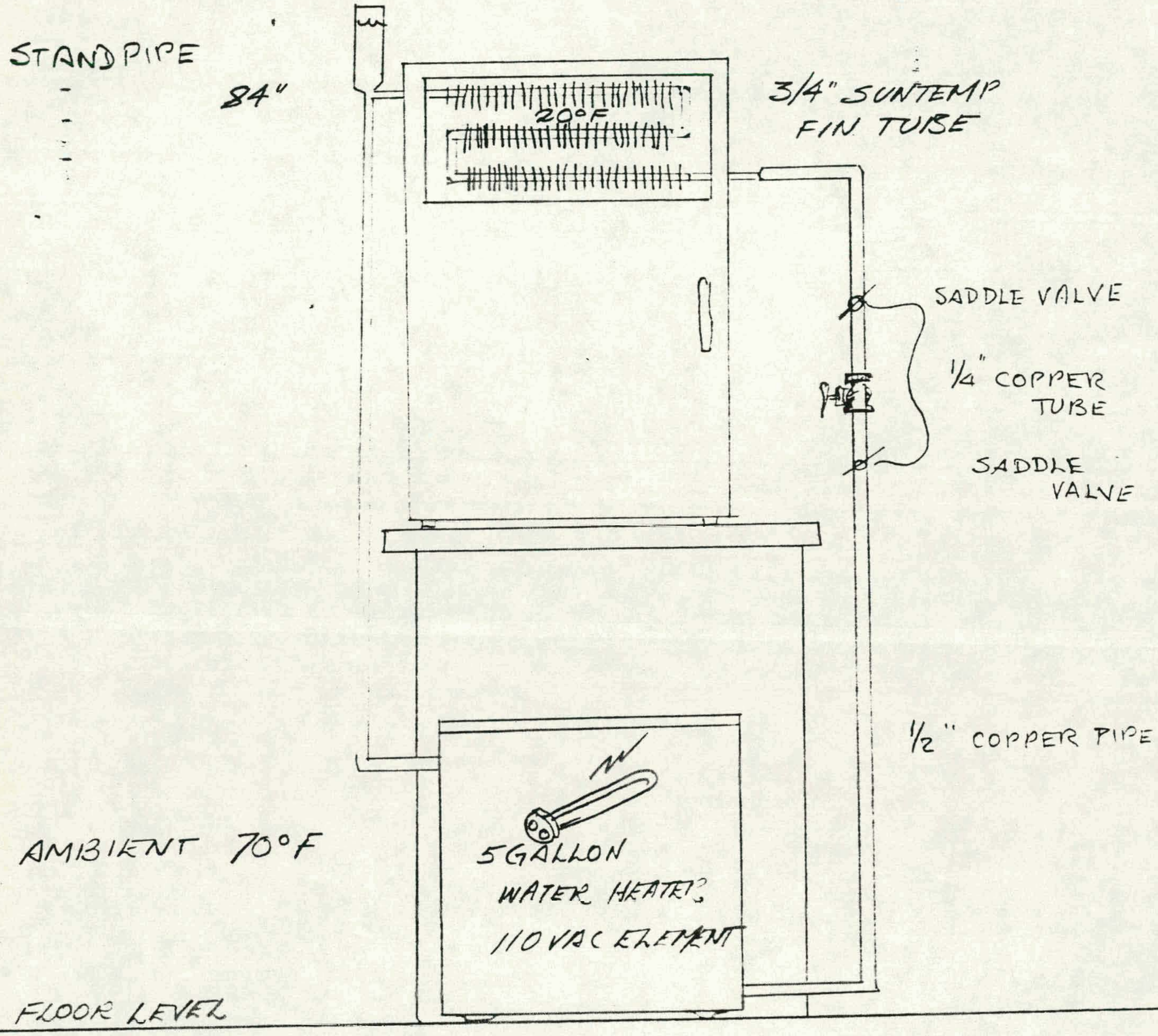
Open a hot water tap.

Open the lever-type pressure temperature relief valve on the tank.

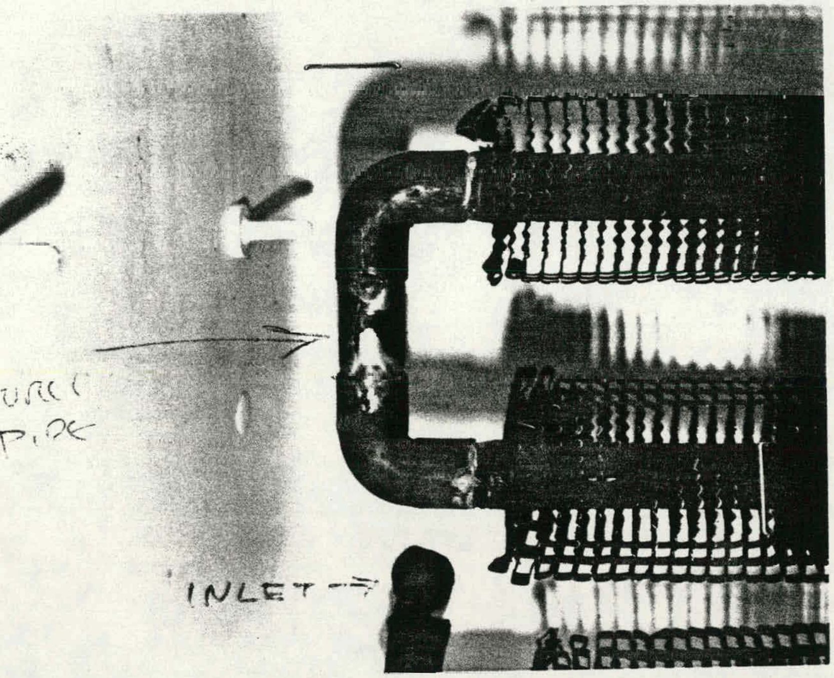
If a motorized valve is installed in the system, manually open same.

Unplug control so that pump cannot operate dry.

When draindown is the means of freeze protection, solar collectors with water passages smaller than one-half inch should be installed with water passages running up and down the slope. Small diameter tubing installed with only a slight down grade may not drain completely due to capillary action and suffer freeze damage.



FREEZE PROTECTION BYPASS - | SOLARFIN - | 11-6-81



INTERIOR OF FREEZING COMPARTMENT