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Energy for an Older Home: A Solar Retrofit

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Abstract

Our hundred year-old house was retrofitted with a solar system designed to produce hot water and to heat space. Installation was relatively simple and the system requires little maintenance. Its estimated payback period is eight years.

1. INTRODUCTION

Four years ago, we bought a hundred year-old house at 300 West Third Street in Rolla, Missouri. It is a two story frame house with twenty-six windows and five exterior doors. It has no basement and only a small attic. When we bought the house, it used propane for cooking and heating water and space. The previous owner had installed sidewall insulation and six inches of attic insulation, but no storm doors or windows.

There are six people in our family: myself, my wife, a daughter (15), a son (13), a son (11), and a daughter (9). Needless to say, we use a lot of energy washing clothes and dishes, taking showers, keeping warm, and operating appliances ranging from food blenders to stereos to curling irons.

Making the best use of energy can be approached from two directions: energy sources and energy conservation. Since buying the house we have taken some steps to conserve energy: lowering our thermostat, installing storm windows and weather-stripping, and caulking around windows and doors. But until we were able to acquire a HUD 312 loan, we could not consider alternate sources of energy.

2. CHOOSING SOLAR

2.1 THE HUD 312 LOAN PROGRAM

The Hud 312 loan program is primarily intended to bring older housing up to local code standards, but the program also provides for general property improvements and for the installation of new or alternate energy sources. When applying for our loan, we asked Rolla's Community Development Department to request bids for solar energy for our house. The program also encourages energy conservation, and enabled us to improve the insulation in our house, and to complete the installation of storm windows and doors.

2.2 BASIC REASONS FOR SOLAR

One of our reasons for choosing solar is based on values: solar energy is clean, as unlimited as the sun, and is most effective when decentralized. We believe that once the problems of cost and storage have been solved, solar will be a nearly ideal energy source. We see our installation as a small step in encouraging the research and development necessary to realize the full potential of solar energy.

The HUD loan solved the problem of cost for us; I will discuss the economics of our system below. I will also discuss how our system deals with the problem of storage.

Our other possible energy sources were (1) new propane equipment to replace that currently in use, (2) electric heating, (3) a heat pump, (4) wood stoves. We did not feel that further investment in limited and increasingly expensive petroleum energy was practical; supplies of electricity are also potentially limited and increasingly expensive. Further, petroleum and electricity are highly centralized technologies, and we believe that decentralization is desirable in itself, both for our stewardship of the Earth's resources and for preserving political freedom.

Although wood is decentralized and renewable, we did not consider it because several members of our family are allergic to wood smoke. Further, wood smoke is a pollutant, and wood supplies are ultimately limited. Practically, the flues in our house would have needed extensive repairs to be safe.

2.3 THE BIDS FROM EARTH ENTERPRISES

Earth Enterprises, of Annapolis, Missouri, proposed three different systems for our house.* All three were designed to supply part, not all, of our energy. The first system supplied only hot water; the second, only space heat; and the third supplied both.

Bid for Solar Hot Water. This system would have supplied approximately 50% of our hot water. Its actual cost, after considering the federal tax credit in effect last winter, would have been $2,012, with an estimated payback period of 11 years. Considering that the system's life would be at least 20 years, the system would provide free hot water for at least nine years. (See Table 1.)

Bid for Solar Space Heating. This system would have cost nearly twice the first one. Its actual cost, after deducting the federal tax credit, would have been $3,965, with an estimated payback time of 13 years. But its first year savings were estimated at $210 dollars, as opposed to the estimated first year savings of $123 for the first system. This system would have supplied at least 25% of our space heating. (See Table 2.)

Bid for Combined Solar Hot Water and Space Heat. This system would have cost nearly three times the hot water only system, and about 50% more than the second system. Taking the federal tax credit into consideration, its actual cost would have been $6,822. Significantly, however, estimated first year savings were $471 dollars, more than three times those of the first system, and more than twice those of the second system. Further, the estimated payback is only eight years, as opposed to 11 for the first system and thirteen for the second. (See Tables 3 and 4.)

Thus, since we could afford the initially higher cost of the combined system (due to the HUD loan with 3% interest), the combined system was economically superior to the other two, having a shorter payback period and higher yearly savings, as well as supplying energy in two areas rather than one. In fact, the federal tax credit has been raised, lowering our actual costs to $5,568, and so reducing the payback period to about seven years. We expect this system to provide at least 90% of our hot water and at least 25% of our space heat.

3. DESIGN AND PERFORMANCE OF OUR SYSTEM

3.1 DESIGN

The components of our solar system are (1) the solar collector array, (2) the hot water tank, (3) the fan-coil unit, (4) a heat exchanger in the water tank, (5) a 1/4 hp pump for the solar loop, (6) an expansion tank in the solar loop, (7) balancing valves in the solar loop, (8) isolation valves, (9) a 1/12 hp pump for the fan-coil unit, (10) a microprocessor to control the system. (See Figure 1 for a schematic.)

The collector array. This array consists of 15 three by eight foot panels. Each panel has an aluminum collector plate with channels through which the heat transfer fluid circulates. (This fluid is a silicon-based oil). The panels are glazed with fiber glass coated with acrylic lacquer. Each panel has foam insulation on the back, and a sheet of mylar under the glazing, to limit heat-loss. The collector plates are painted with a heat-absorbant black paint. (See Figure 2 for an exterior view of the house showing the array.)

The hot water tank. The heat transfer fluid is pumped from the collectors to a 120 gallon hot water tank, where the heat is transferred to the water through a double-walled heat exchanger. The tank is over-sized for domestic hot water so that the excess hot water can be pumped into the fan-coil unit and used for space heat. Our system does not include storage, but the use of an over-size water tank allows us to get double use from the system. When more efficient storage media are available, it will not be difficult to add storage capability to our system. (See Figure 3 for a view of the tank, pumps, and fan-coil.)

The controller monitors water temperatures at the bottom and the top of the tank, as well as the temperature in the collectors. When the temperature in the collectors is 20° F. higher than the temperature at the bottom of the tank, the controller turns on the pump in the solar loop. The controller turns the pump off when the differential is down to 5° F. or when the temperature of the water at the top of the tank reaches 180° F. (See Figure 4 for a close-up of the controller.)

The heat transfer fluid freezes at -50° F. and boils at 500° F., so, with the expansion tank to absorb excess pressure, the solar loop is secure from boiling or freezing or bursting.

Hot water from the solar tank is piped under the house to another closet containing a gas water heater. There, the solar-heated water can either be fed into the gas heater, which is our backup, or the gas heater can be by-passed entirely and shut down during periods when solar energy supplies all our hot water.

Fan-coil unit. The fan-coil unit is located in our dining room, just on the other side of the wall from the closet containing the water tank, pumps and controller. When the water temperature at the top of the tank exceeds 120° F. (or another selected temperature), and the room temperature is less than the setting of the thermostat, the controller turns on the 1/12 hp pump to circulate hot water through the fan-coil unit, and blowers move the heat out into the house where it circulates by convection.

*The bids, the schematic, and other technical information in this report were supplied by Donald Palmer of Earth Enterprises. Mr. Palmer received a B.S. in Mechanical Engineering from UMR in 1977.

Previous experience with a propane floor furnace adjacent to the fan-coil indicates that convection heating is efficient in our house. We have also added a vent between the stories to aid in the circulation of heated air.

3.2 PERFORMANCE

Earth Enterprises designed our system for these conditions: a day in winter when the temperature is 7^{o} F. and there is a 15 mph wind. (See Table 4.) They estimated that under those conditions we would need 89,000 Btu/h. They also estimated an average heat load of 56,000 Btu/h when the ambient temperature is 32^{o} F. They estimated a solar maximum input of 50,000 Btu/h. (For comparison, 1.5 gallons of propane produces 140,000 Btu/h.) (See Table 5.)

My own best estimate of our previous use is a maximum of 80,000 Btu/h during Earth Enterprises' design heat load conditions. Their estimate takes into consideration the insulation, weather-stripping, and storm-windows and doors added in our rehabilitation project. We thus found their estimate of our needs to be reliable and even overstated, leading us to believe that the system's design is well-suited to our needs.

Our experience with the system this summer indicates that it will supply nearly all our hot water during weather that does not require space heat. Since the system is oversized for hot water, it heats enough water to provide a supply through the night and even for several days when there is not enough sun for the collectors to provide heat. The collectors are efficient enough to harvest the sun on overcast and partly cloudy days as well as days of full sunshine. The collectors are very sensitive to slight changes in the degree of sunlight available. I have watched the temperature in the solar loop go up one degree Fahrenheit every 15 or 20 seconds. But because of efficient insulation, it does not cool off that rapidly.

4. INSTALLATION AND MAINTENANCE

4.1 INSTALLATION

The three major considerations in installing the solar system in our house were (1) location of the collecting array, (2) location of the water tank, and (3) the path of the loop between them.

Fortunately, our house is on a hill, with a roof facing south. (We are just north of the Phelps County Court House). There are no high trees or structures to shade the roof. In fact the angle of the roof is at the best angle for the collectors, so the array is mounted in a frame paralleling the pitch of the roof. Also, the roof is quite solid and might have been able to bear the load of the array without reinforcement, but we added braces under the slope carrying the collectors to be sure of adequate support.

Location of the water tank was the biggest problem. The tank weighs 500 lbs empty and 1500 lbs filled. Therefore, it had to be located on the ground floor. We used a closet in an alcove off the dining room for this purpose. It was necessary to enlarge the closet and add support under the floor.

The path for the solar loop runs from the attic through a closet on the second story, through an access next to a flue on the first story, under the house and then up to the pumps and water tank. The closet and access already had plumbing and electrical wiring in them, so they were convenient to use for the solar loop, and did not require much alteration. All of the piping for the solar loop and for hot water is insulated.

The tie-in to the gas water heater was complicated, as the hot water line had to run under the house back up to the closet with the gas heater. And the plumbing for the by-pass is a bit unusual but efficient.

We feel that our house proved remarkably well-suited to a solar retrofit. Assemblying and installing the system in our house caused no structural changes. The only thing we lost was the use of the closet where the solar water tank, the pumps, and the controller are. As we had the house reroofed as part of the rehabilitation, we are certain of a good roof under the collector array.

4.2 MAINTENANCE

Maintenance is simple. Every fall, three things must be done.

(1) The collectors must be washed with a mild, non-abrasive detergent and hosed off.

(2) The oil level in the pump for the solar loop must be checked. (It uses a light machine oil.)

(3) The air filter in the fan-coil unit must be changed.

Every fifth year, another maintenance procedure is necessary: After the collectors have been washed, they must be re-lacquered with an acrylic lacquer.

Earth Enterprises also suggested that we watch for the following signs of problems:

(1) If the hot water becomes pink, a leak in the heat exchanger is indicated. (The heat transfer fluid is nontoxic and non-corrosive, so there would be no health danger from the leak.)

(2) There is a gauge which registers the pressure in the solar loop. It should normally vary between 15 and 40 psi. A reading below 15 psi indicates a leak in the solar loop. A reading above 60 psi would only occur if the expansion tank lost its air bubble, and would mean the system should be shut down and repaired.

(3) Bottom of the tank temperature should never exceed 180^{o} F. However, the pressure relief valve will open if it does.

So far, we have had three significant problems. One of the collector plates ruptured and leaked heat transfer fluid. Since the collector plates have a five-year warranty Earth Enterprises replaced it. Also, the diaphram in the expansion tank ruptured, causing the solar loop to lose pressure. The expansion tank is also under warranty and has been replaced.

The most serious problem involved the controller. It did not operate the fan-coil properly and had to be returned to the manufacturer. It took the manufacturer six weeks to repair the controller and return it, depriving us of the use of the system during that time. The controller is now functioning properly.

The controller is also programmed to shut the system off when the temperature of the solar loop reaches 200° F. This is a safety feature for systems circulating water, but it reduces the efficiency of our system, which is designed to function at temperatures well beyond boiling. Earth Enterprises did not know of this feature of the controller when they ordered it. On the manufacturer's suggestion, they installed a resistor and a switch in the sensor circuit that tells the controller what the collector temperature is. The result is that the controller believes the temperature is lower than it really is and allows the system to run at temperatures higher than 200° F. This alteration appears to be working satisfactorily.

5. CONCLUSION

I do not want to leave the impression that we chose solar in preference to other energy systems by making detailed comparisons. We did not seriously consider other possibilities. We requested a bid for solar, liked one, and chose it. Our commitment to solar is based as much on values as it is on practical considerations. We feel that by choosing solar we can help influence the future use of energy as well as providing ourselves with an economical source of energy.

We especially appreciate the fact that the technology of our solar retrofit is both sophisticated and decentralized. Since Earth Enterprises not only designed the system specifically for our house and our needs, but also installed it, we were able to talk to everyone involved in the retrofit personally, receiving detailed explanations and a care for our needs that a larger, centralized business could not have shown.

6. BIOGRAPHY

Born in Colorado in 1941, Eugene Warren received an MA in English from Emporia State University in 1967. He began teaching at UMR in 1967, and is currently an Associate Professor of English. He is also a correspondent of Sojourners magazine and poetry editor for Christianity & Literature. His articles and poems have appeared in many magazines and anthologies, and in three books. The sun and light are major images in his work.

TABLE 1: BID FOR SOLAR HOT WATER

initial equipment cost	$1,925.00
installation labor	840.00
total	$2,765.00
federal tax credit	(753.00)
actual cost	$2,012.00
first year savings (estimated)	123.00
payback period (estimated)*	11 years

TABLE 2: BID FOR SOLAR SPACE HEATING

initial equipment cost	$4,107.00
installation labor	1,100.00
total	$5,207.00
federal tax credit	(1,241.40)
actual cost	$3,965.60
first year savings (estimated)	210.00
payback period (estimated)*	13 years

TABLE 3: BID FOR COMBINED HOT WATER AND SPACE HEAT

initial equipment cost	$7,518.00
installation labor	1,260.00
total	$8,778.00
federal tax credit	(1,955.60)
actual cost	$6,822.40
first year savings (estimated)	471.50
payback period (estimated)*	8 years

*Assumes 12% inflation rate for energy and $300.00 maintenance cost over ten year period.

TABLE 4: ESTIMATED PAYBACK PERIOD

	$ PRICE LP	$ SAVINGS	$ ACCUM.
1981	.70	510	510
1982	.78	571	1081
1983	.88	640	1721
1984	.98	717	2438
1985	1.23	896	3334
1986	1.38	1004	4338
1987	1.54	1124	5462
1988	1.73	1259	6721
1989	1.93	1410	8131
1990	2.17	1580	9711

Notes:

Assumes 12% inflation rate of fuel, with 25% jump in 1985 as gas is deregulated.

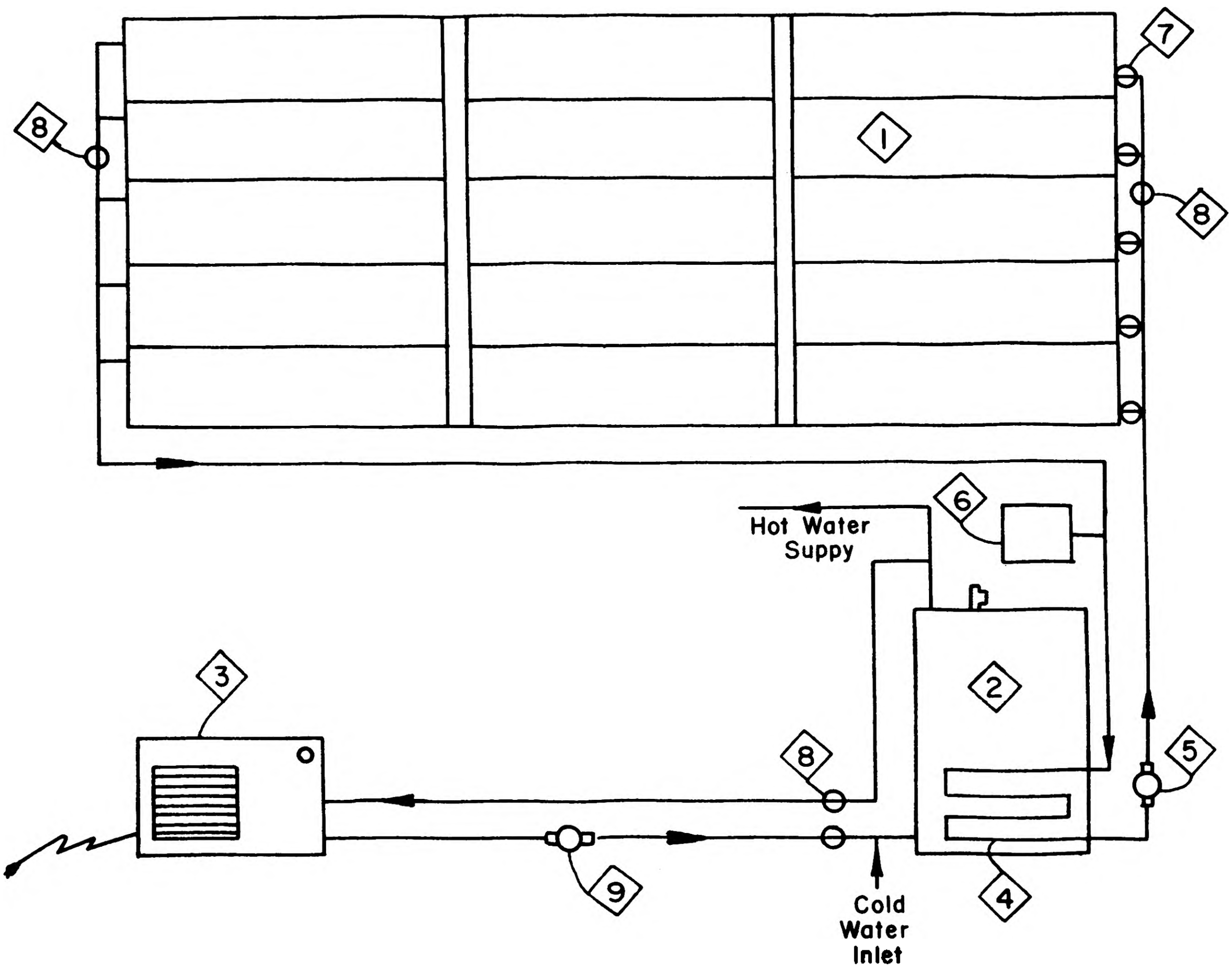
40% Federal tax credit (3885) not included.

TABLE 5: DESIGN BASE

DESIGN HEAT LOAD: 7°F DB, WINTER	15 Mph. wind
403-T^2 Window area 40% of Load infiltration	89,000 Btu/h
AVERAGE HEAT LOAD: 32°F DB	56,000 Btu/h
SOLAR MAXIMUM HOURLY INPUT	50,000 Btu/h

140,000 Btu = 1.5 gal. LP gas

SCHEMATIC SOLAR DEMAND HOT WATER AND SPACE HEATING



EQUIPMENT LIST

1 SOLAR COLLECTOR ARRAY, 15-3'x8' ALUMINUM, LIQUID; 330 SQ.FT. FOR USE WITH HEAT TRANSFER FLUID.

2 DOMESTIC HOT WATER TANK, 120 GAL. WITH PRESSURE AND TEMPERATURE RELIEF VALVE

3 FAN-COIL UNIT, WATER HOOK-UP, REQUIRES 110VAC.

4 HEAT EXCHANGER, DOUBLE WALL FOR HEAT TRANSFER FLUID.

5 PUMP, SOLAR ARRAY, 1/4 HP.

6 EXPANSION TANK

7 BALANCING VALVES, PERMANENTLY INSTALLED, FOR EQUAL DISTRIBUTION OF FLOW

8 ISOLATION VALVES, SOLENOID OPERATED, ELECTRIC.

9 PUMP, FAN-COIL UNIT, 1/12 HP.

CONTROLLERS, NOT SHOWN, 2-DIFFERENTIAL TEMPERATURE CONTROLLERS, FULLY AUTOMATIC SENSORS ON COLLECTORS, STORAGE TANK, HOUSE; CONTROLS BOTH PUMPS, ISOLATION VALVES, FAN-COIL UNIT.

FIG. 1

Fig. 2

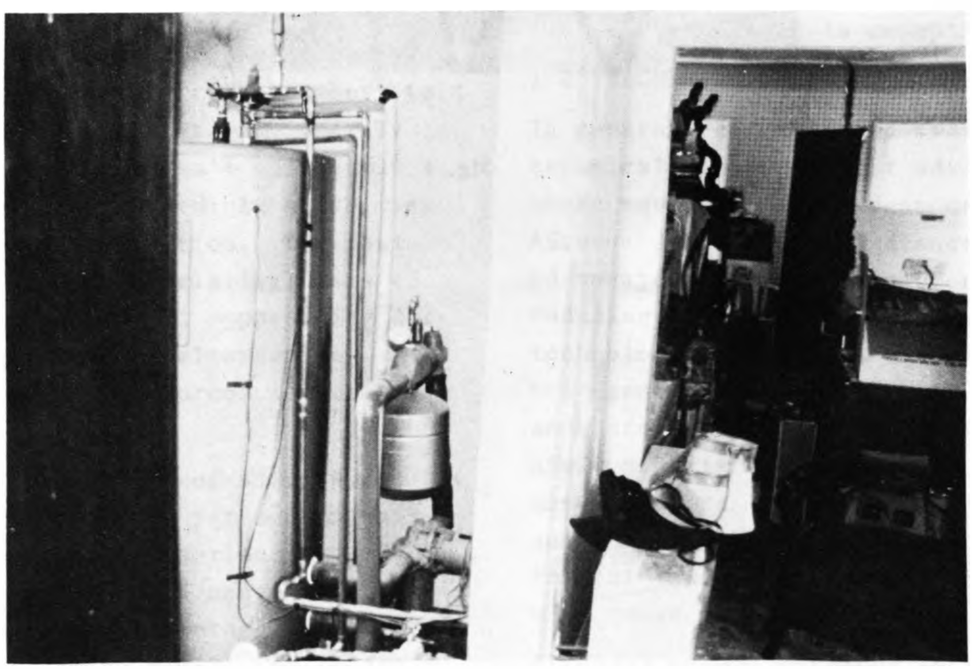


Fig. 3

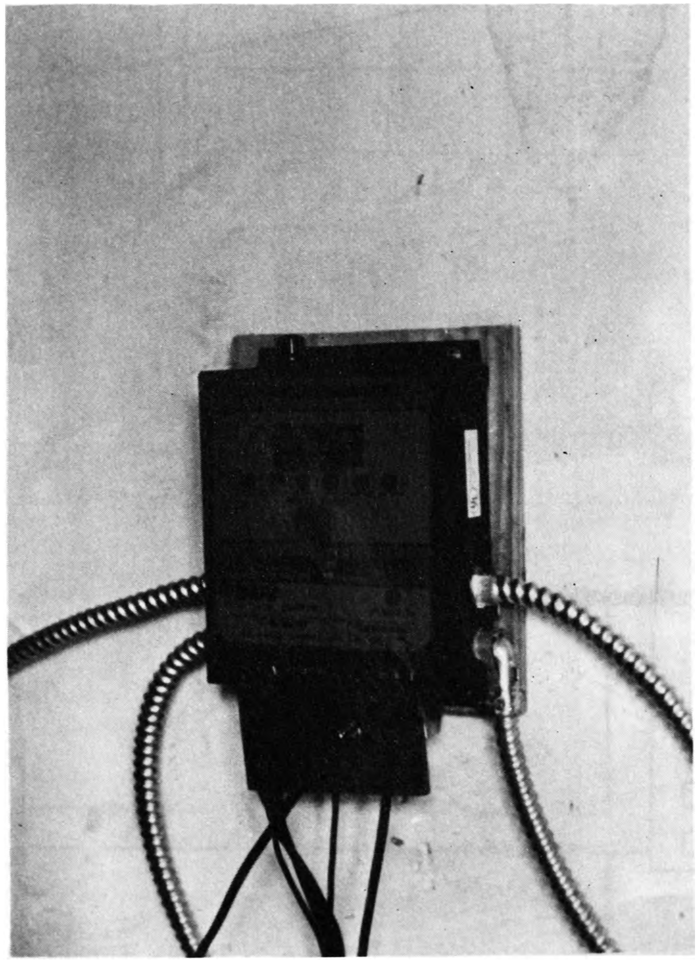


Fig. 4