PROJECT FOCUS #7

Small Farm Energy Project

"Project Focus" is part of a primer on energy alternatives that would help lower the high costs of energy inputs on small farms. The examples are drawn from innovations built by northeast Nebraska farmers who are participants in the Small Farm Energy Project, a special 3-year research effort sponsored by the Center for Rural Affairs of Walthill, Nebraska and based in Hartington, Nebraska. The aim of Project Focus is to help small farmers discover and develop viable alternatives for their own farms.

Dairy Water Heating

NOVEMBER, 1979

Farmers Try Four Approaches To Cutting Costs

For most dairy farmers, the modern pipeline dairy represents a major investment which can bring a stable income. These dairies are dependent on reliable energy. Farmers cooperating with the Small Farm Energy Project are finding ways to cut their operating costs by pre-heating their dairy wash water. Three farmers have tried solar innovations and one farmer is using heat recycled from the bulk tank compressor. Their personal choices have contributed to the Project's emphasis on a common sense approach to on-farm research.

The venture into options for dairy water heating began in February, 1977 as cooperating farmers heard solar architect Gary Harley describe solar water heating systems. After discussion with project staff, several farmers were interested in these systems for dairies and farm homes. In May, 1977, project staff and cooperator Edgar Wuebben helped build a solar water collector at Halsey National Forest in the Nebraska Sand Hills.

At the same time, cooperator Gary Young included a solar water collector in his loan application to FmHA for a new dairy barn. The county supervisor was supportive, but the solar portion of Young's loan request was denied at the state level. Though Project complaints were taken to the federal level, the commercial solar unit Gary wanted to put in was considered uneconomical.

Despite this setback, or perhaps because of it, Wuebben pushed ahead with his own collector by beginning construction in September, 1977. Soon afterwards, cooperator Linus Lange became involved with solar water heating in an October construction workshop. Details on their **drain-down solar water heaters** are on page PF4.

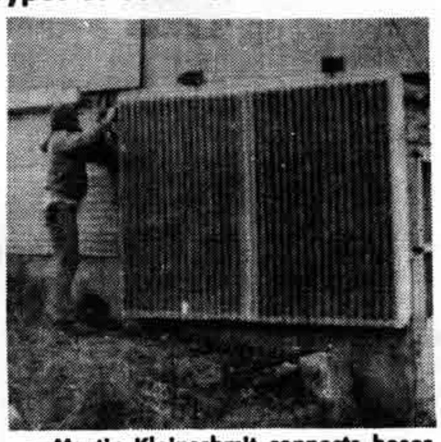
While Edgar and Linus were busy with their solar systems, cooperator Martin Kleinschmit was thinking of ways to use solar energy in his dairy. Since early 1977, Kleinschmit dreamed up several variations of solar water heaters. Finally, early in 1979, he decided on a **thermosiphon system** with a heat exchanger and antifreeze. He built the system in August, 1979. See page PF3 for details.

Determined to reduce his energy expenses, Gary Young chose another approach to heating his dairy water. After considering it for a year, Gary had a **heat exchanger installed** in October 1979. As described on page PF5, this commercially available device **uses heat taken from the bulk tank cooler compressor to heat water** for washing dairy equipment.

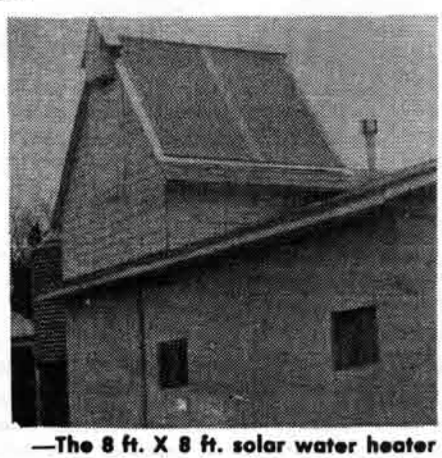
To add to the farmer's options, the project staff decided to design and build a simple, inexpensive solar water heater. With the help of Tim Bowser, summer intern from Pennsylvania, **the bread box water heater** described on page PF2 was constructed in August, 1979.

Three Types of Solar Collectors Are Tested

—The breadbox solar water heater is a low cost heater using a black tank under fiberglass.



—Martin Kleinschmit connects hoses to carry antifreeze to and from his solar water heater at the dairy barn.



—The 8 ft. X 8 ft. solar water heater on the roof of the dairy barn of the Edgar Wuebben farm, Wynot, Nebr.

The Breadbox, A Simple Solar Collector

The breadbox solar water heater is simply a black water tank, placed in an insulated box, which is heated by the sun. It may remind some resourceful people of a black barrel they put on a tower for hot showers after a long summer's day. The bread box solar collector can be used during warm seasons but must be **drained during winter months** to prevent damage from freezing. A simple design was developed by Project staff so farmers could quickly construct a collector using salvaged materials.

A 30-gallon propane-fired water heater tank was used as the collector/storage tank because its long, narrow shape provides a large surface area to collect solar heat and transfer the heat to the water. The flue pipe through the center of the tank adds to the surface area and increases heat transfer to the water.

The black tank was placed in a well insulated U-shaped box. The inside of the box was covered with **aluminum foil to reflect the sunlight onto the tank** and increase the amount of heat gained. A fiberglass covering over the box keeps the weather out and the heat in. The 4' x 6' box can be installed in the roof of a dairy barn, or a home, and between the rafters, if it is properly supported. (see figure 1).

Plumbing connections are quite simple with this system. A hose or pipe brings cold water to the bottom of the tank, and another hose or pipe takes the warmed water from the top of the tank directly to use or to the cold water inlet of the conventional water heater. Well pressure provides sufficient water flow so that no pumps or controls are necessary. Cold water flows into the tank as hot water is used.

Options and Operation

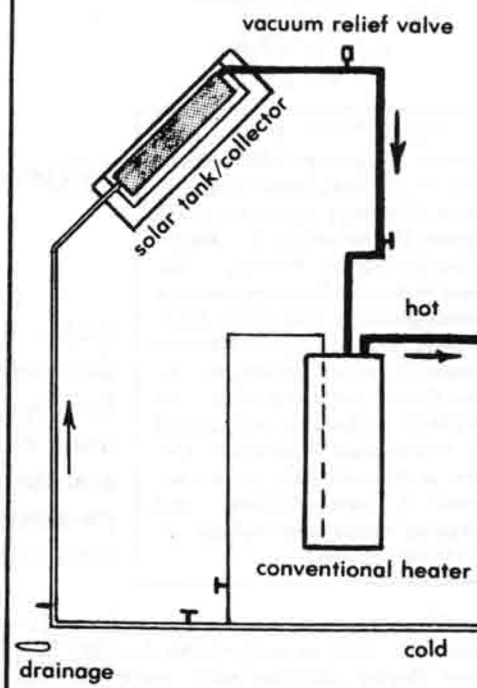
Some persons may wish to place an **insulated cover over the breadbox** water heater at night to conserve the heat generated during the day unless most of the water is used in the evening. Another storage method would be to place a second fully insulated tank over the breadbox water heater, such that heated water rises to the insulated tank, where it retains its heat until it is used. This minimizes the requirement of covering the breadbox at night.

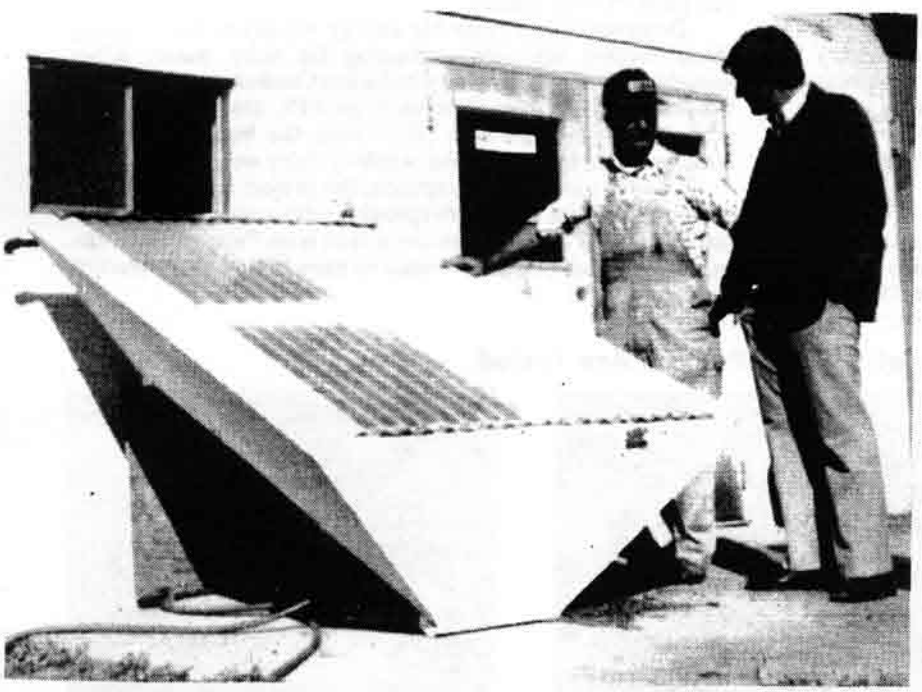
To find out how well the breadbox system works, the tank was filled with cold water at 54°F on **September 7, 1979;** a crisp, clear fall day. Because of shading, the collector was in full sunlight from 10:30 a.m. to 5:30 p.m. That evening, the tank was drained from the bottom inlet into a five-gallon pail. Temperatures of the water were taken each time the pail was filled. Water at the bottom of the tank was 98°F but at the top of the tank it was 120°F. **The average temperature was 110°F. The water temperature was raised an average of 56°F for a collection of 14,450 Btu that day.**

The well-known fact that hot water rises shows that solar heated water works like any other tank of water. It explains why hot water should be taken from the top of the tank and cold water fed into the bottom. This fact also makes possible the thermosiphon water heater that Martin Kleinschmit uses on his dairy barn.

Figure 1

One Type of Breadbox Design





—Edgar Wuebben describes the function of the breadbox water heater with Spencer Schram of Minn., a visitor to the Wuebben farm. The 30 gallon tank, painted black, rests in the insulated box beneath corrugated fiberglass. Aluminum foil is used to line the interior of the box and reflect sunlight onto the tank. The system has proved quite effective for its low cost of approximately $175.

Breadbox Materials Cost

Lumber and fiberglass	$ 65.00
Paint and caulk	27.00
Copper tubing and fittings	27.00
Tank and repair	25.50
Misc. materials	30.50
Total Cost	**$175.00**

A Passive Design

It took Martin Kleinschmit a while to decide just how he was going to rig up his solar collector but he is well pleased with his arrangement. Basically, his system involves a **flat-plate liquid solar collector and a storage tank/heat exchanger.** Antifreeze solution circulates through the collector and into the larger of two tanks. The **antifreeze then heats a smaller tank within the large tank. Water contained in the small tank is then heated for use in the dairy.**

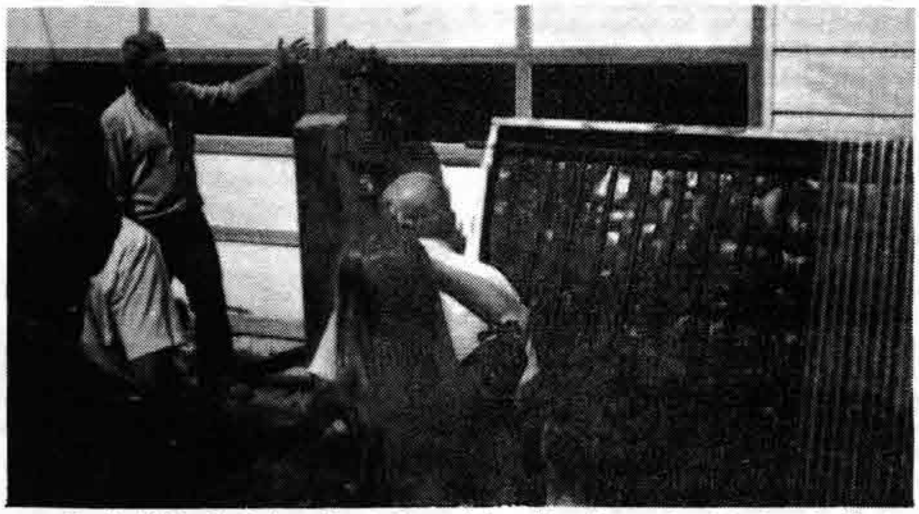
No pumps are used because the system operates on the principle that hot liquids tend to rise. As the black collector becomes hot from the sun, the liquid in the pipes absorbs heat and rises from the top of the collector into the outer storage tank. From the bottom of the tank, cooled liquid flows into the bottom of the collector to be warmed again. As the liquid continues to make this cycle, water in the inner storage tank picks up the heat for use in dairy washing. It is **necessary that the storage tank be located above the collector [See Figure 2].**

Because only antifreeze circulates through the collector, the system may be operated throughout the winter (it has not been through a winter yet). The 4:1 mixture of propylene glycol and water should not freeze above -20°F.

Construction and Safety

Safety considerations would not allow this design for home water heating systems because antifreeze might leak into the inner tank and contaminate the water supply. Most safety codes require two metal surfaces separating antifreeze from potable water. Kleinschmit has incorporated two safety features into his system. First of all, the propylene glycol is classified as non-toxic. Secondly, a one-way valve is used on the cold water line from the farm water well, to prevent water flowing back to the well, especially if the inner tank leaked at that time, allowing antifreeze to also potentially flow to the well.

The Kleinschmit Thermosiphon Collector

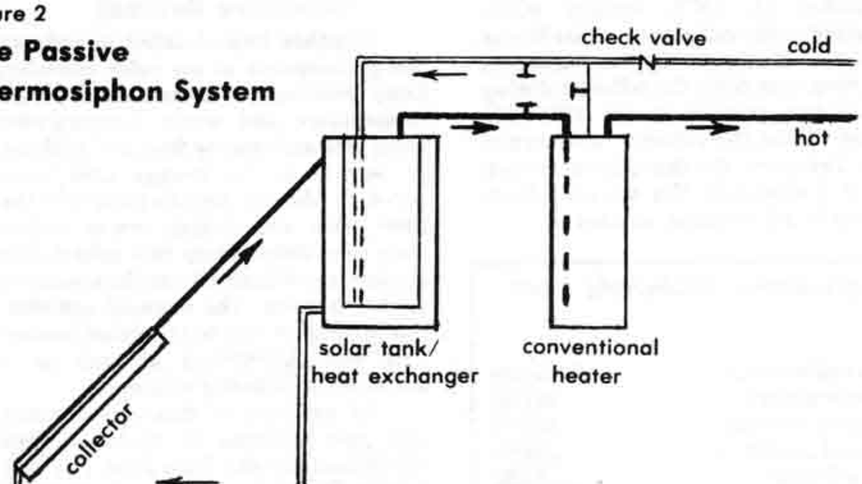


—Martin Kleinschmit describes to farm visitors his solar pre-heat tank and collector under construction at the time.

The collector plate was made from special tubing designed for solar collectors. The 5' long copper tubes have copper fins which are electronically treated with a black finish. The half-inch tubing is soldered to 1" tubing to form the 5' x 8' collector. Corrugated fiberglass covers the collector.

Kleinschmit built his **storage tank/heat exchanger from 50 and 80 gallon tanks** salvaged from around the area. He cut the top out of the 80 gallon tank so the 50 gallon tank would fit into it. The seam was sealed with an epoxy. Fittings to connect the outer tank with the flat plate collector were installed at the top and bottom of the outer tank. Because the 50 gallon inner tank came from a water heater, fittings for cold water inlet and hot water outlet were intact on the top of the tank.

Figure 2
The Passive Thermosiphon System



Operating Results

To find out how well his system worked, Kleinschmit kept track of temperatures before morning and evening milkings over a 1½ week spell of clear weather in late September, 1979. At about 8:00 in the morning the average temperature of water going into the collector from the bottom of the outer tank was 74°F. Average temperature at the top of the outer tank was 103°F. At about 6:30 in the evening, the average temperature at the bottom of the tank was 106°F and at the top of the tank, 124°F. This means that in the evening there was 18,000 Btu more heat in the tanks than there was in the mornings. However, Kleinschmit uses about 30 gallons of water each milking. One evening, he found that the temperatures in the tank had dropped from 126°F to 123° at the top, and from 110° to 85° at the bottom after milking. That amounts to 10,000 Btu that went to warm 30 gallons of water 40°. **So an estimate of clear-day heat gain from Kleinschmit's thermosiphon collector is 28,000 Btu,** giving an estimated efficiency of near 40% for the system.

Thermosiphon Materials Cost

Copper tubing and fittings	$275.50
Two tanks	150.00
Propylene glycol	141.00
Insulation	138.50
Lumber and fiberglass	104.00
Misc. materials	70.00
Total Cost	**$879.00**

The First Effort

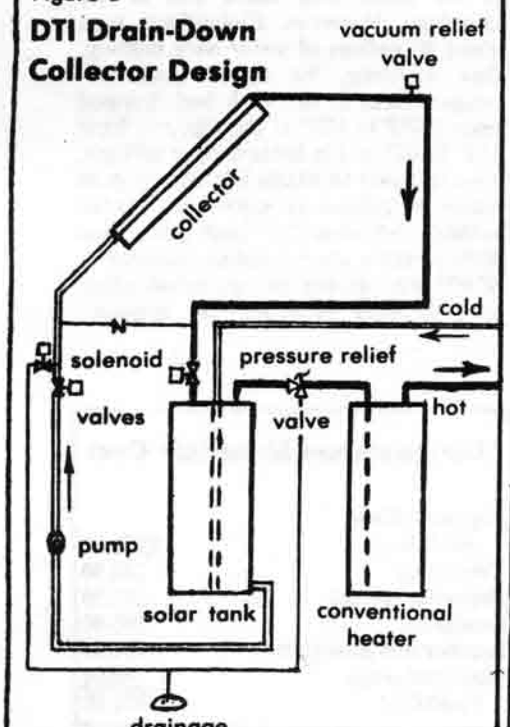
The drain-down system adopted by Edgar Wuebben for his dairy provides for year-round use by depending on thermostatic controls to protect the plumbing from freeze damage. The system includes a flat plate liquid collector, a storage tank and a pump with control devices for automatic operation. **The drain-down system may be more efficient than the antifreeze type system, since water is heated directly in the collector, but the system may have a higher initial cost,** due to special controls.

Wuebben's adoption of this system is the result of a pioneering effort. Though Project staff were not aware of any on-farm experience with dairy solar water heaters in the region, Wuebben travelled to a Halsey, Nebraska workshop to learn about the solar innovation. It may have been easier to sit back and watch others break the ice, but Wuebben took the lead in constructing his collector. Wuebben soon had company as Linus Lange became involved with a solar water heater for his dairy.

The system functions with a pump that circulates water from the 120 gallon storage tank through the 8 ft. x 8 ft. collector and back to the storage tank. As hot water is used from the electric water heater, solar heated water flows from the top of the storage tank into the electric water heater. Cold water simultaneously flows into the bottom of the storage tank. (see figure 3).

Figure 3

DTI Drain-Down Collector Design



The Wuebben/Lange Drain-Down Collector

—Edgar Wuebben, left, and Linus Lange, both cooperators of the Energy Project, constructed one of the first solar water heaters at the Energy Project during the fall of 1977. Copper tubing is mounted to corrugated metal to provide the collector plate.

Construction and Operation

Wuebben and Lange built their collector plates using corrugated sheet metal and copper tubing set in the corrugations and bonded together with a heat transfer cement. The 8' x 8' collectors were set in well-insulated boxes to increase the heat efficiency. After modification of the roof, the collectors were mounted. Plumbing to control panels was installed.

A defective sensor in a component of the drain-down mechanisms did pose problems for Linus Lange. Until it was replaced, the collector had to be manually drained during the crisp fall weather in 1978. **The Lange collector also had a defective vacuum relief valve.** Though it had apparently drained on November 11, 1978; enough water remained in the collector to **cause freeze damage.** Because of this concern, Wuebben shut down the collector during the coldest portion of the 1978-1979 winter. When the collector was turned on in February, the drain-down system operated efficiently. The system collected heat in sub-freezing weather.

Drain-Down Materials Cost

Pump and controls	$ 455.00
Collector materials	331.50
Housing materials	220.00
Tank and insulation	204.00
Misc. materials	67.50
Total Cost	**$1278.00**

Wuebben has had to live with one minor problem in his system. The design, by Domestic Technology Institute of Lakewood, Colo., called for a pump which was inadequate for pumping water to the collector at the specified flow rate. As a consequence, **a low water flow rate of 9 gallons/hour** resulted in excessive heating of the water. Visitors were well impressed with the high temperatures coming out of the collector but more heat escaped the collector than would occur if greater flow rates were attained. **Though partially corrective measures increased the flow rate to 11.4 gallons/hour** in March, 1979, the expenses of a larger pump may be necessary to substantially increase flow rates.

Extensive Records

Wuebben kept detailed records on the performance of his solar collector. Daily readings of solar intensity, air temperature and water temperatures going into and coming from the collector as well as in the storage tank were noted. In addition, electric meters on the dairy barn and electric water heater were read daily. From this information an estimate of heat gain on clear summer days was made. The seasonal contribution of solar energy to the water heating load was determined as well as a indication of collector efficiency.

An estimate of clear-day summer heat gain is based on readings taken throughout the day from June 1 to July 7, 1978. The average temperature rise of

(continued on page 33)

Using Waste Heat

Though FmHA decided solar water heating wasn't economical for Gary Young's dairy barn in 1977, he was determined to try something to cut back on his energy expenses. The heat exchanger he purchased is a commercial item which **heats water by heat taken from the bulk tank coolant lines.** Cool water is pumped from a storage tank to pick up heat from the coolant when it flows from the bulk tank.

The idea behind the heat exchanger suggests that when heat is taken from the process of cooling milk, 50% or more of the heat can be transferred to wash water. For example, about 82,000 Btu are given off by the milk Young cools on an average day. About 160,000 Btu of propane* are needed to heat the 95 gallons used daily. Young has one water heater set at 110° for washing udders and another water heater set at 160° for washing pipes and bulk tank. The heat exchanger pre-heats the wash water so less propane is needed.

The heat exchanger is simply a box which pumps water from the warm wash tank into a four foot coil which contains the coolant lines from the bulk tank compressor (see figure 4). Water used to wash udders is taken directly from the warm tank (or heat exchanger if its pump is operating). When hot water is taken from the hot tank it is replaced by water from the warm tank (or the heat exchanger if its pump is operating). So all the heated water used in the dairy is pre-heated by the heat exchanger.

The Young Heat Exchanger

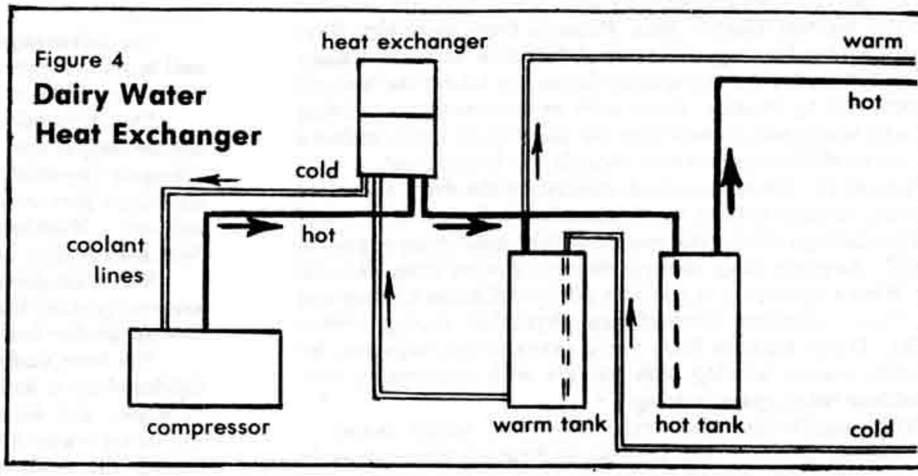


Figure 4
Dairy Water Heat Exchanger

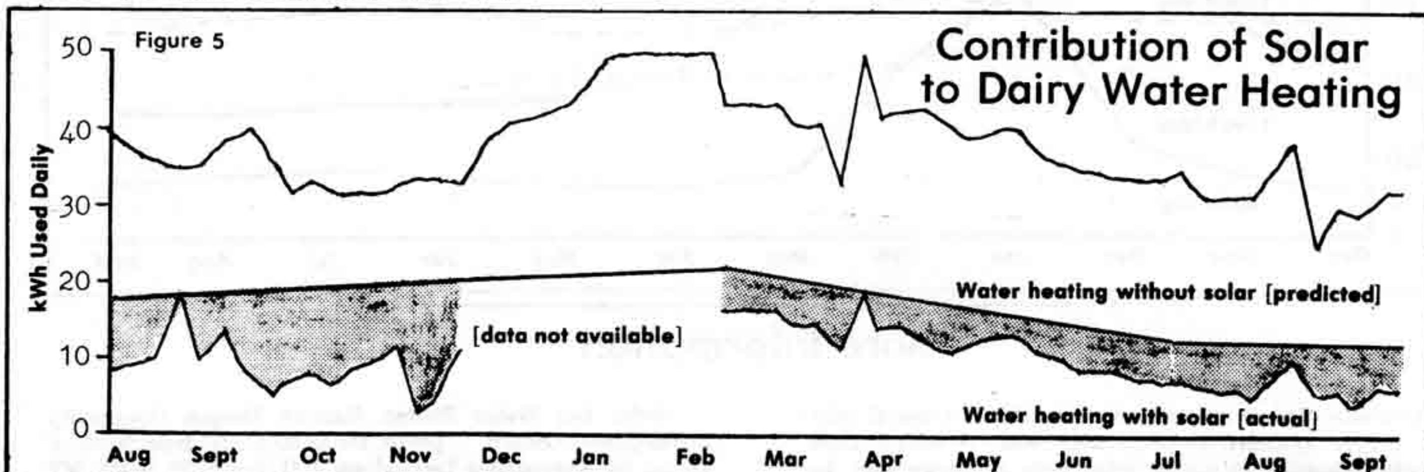
As a new commercial item, Young did have difficulty locating the heat exchanger and it took four months from order date to time of installation. Though it was the first unit installed in the area, two men installed the system in five hours. **Installed cost including labor was $630.**

From September 17, 1979 to October 31, 1979, **an average of 1.7 gallons of propane were used to heat Young's dairy water each day.** According to Young's observations, the heat exchanger adds 50°F to the temperature of the 95 gallons he uses daily. That's a **contribution of 41,000 Btu or 36% of his daily water heating requirement.*** In addition the compressor fan operates one third of the time that it originally did, because its workload is reduced by the heat exchanger.

Young is very pleased with his dairy heat exchanger, and he says he will "promote" the concept with other dairymen.

*Assuming 70% efficiency of propane water heater.

[DRAIN DOWN, continued from page 32]



water passing through the 64 sq. ft. collector was determined for each hour between 9:00 a.m. and 8:00 p.m. Because it takes one Btu to raise the temperature of one pound of water one degree Fahrenheit it is possible to **estimate clear day summer heat gain at 48,000 Btu.**

An indication of the substantial contribution the solar collector made to dairy energy needs may be seen in figure 5. Actual daily electric consumption of the dairy and water heater are presented as well as estimates of water heating demand without solar (based on actual cloudy day readings). The shaded area indicates the energy contribution of the solar collector.

From Wuebben's extensive records, collector efficiency averaged 39.9% from July 10 to November 8, 1978. This figure is based on the flow rate of water through the collector, the increase in water temperature after going through the collector and solar energy readings. As recommended in **Analysis of Collector Array Performance from Field Derived Measurements** by W.H. McCumber and M.W. Weston, 1978 the following conditions were held: 1) a steady state collector temperature environment; 2) insolation greater than 200 Btu/sq. ft. hr; 3) wind speed less than 10 mph; 4) a range of ambient temperature, of less than 55 degrees during the testing. Supplemental data from the National Climatic Center was used to determine days of low wind velocity.

Dairy Water Heating, A Major Energy Use

According to the detailed production and expense records kept by the 48 farms cooperating with the Project, dairy farms have the highest electric bills. **Records from one dairy farm indicate water heating can account for 35% of normal dairy electric demand.** Four of the dairy farms are taking the bite out of those bills by heating water with on-farm resources. Using solar and waste compressor heat for dairy wash water makes a substantial difference as their records are bearing out.

To get an idea of how much electricity the dairy operation requires, electric meters were placed on selected dairies and weekly readings taken. The results of this monitoring appear in figure 6. Average daily electric demand ranges from 10 to 60 kwh. Where electricity is used for additional space heating and tank water heaters, demand can skyrocket during winter months. Dairy farmers have found ways to cut expenses by insulating barns, heating milk parlors with compressor heat and adding solar space heating.

The contribution of a drain-down solar water heater to dairy energy demand may be seen in figure 5 where over 14 months of records are summarized. Projected water heating without solar may be compared with actual electric demand with the solar contribution.

By applying ingenuity, determination and common sense, these farmers have demonstrated four options to cutting back operating expenses using on-farm resources. The particular designs these farmers chose are only a sample of the variety of solar water heating and heat exchanger designs available. For example, several designs for drain-down water heaters are available which reduce the complexity and expense of the system.

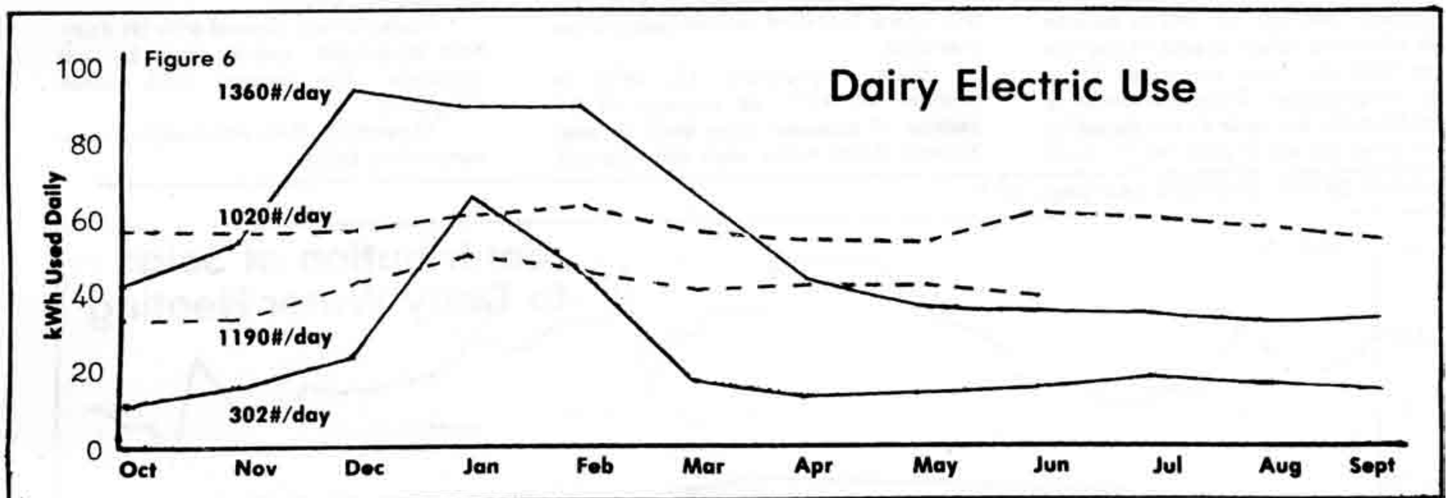
The advantage of the bread-box collector is its simplicity and low cost. For some, this may offset low heating capacity and restricted use to the warm months.

The thermosiphon collector can be a simple design too, yet higher output and year-round operation are also values. The sensitive operation of this system may not fit in many situations because the **storage tank must be located above the collector.** Whether this particular system can weather a Nebraska winter has yet to be proven.

The drain-down collector has the advantages of year-round use and greater heat gain although the complexity and cost of this particular design may discourage some.

The heat exchanger may be an effective device for some dairies since it has the advantage of operating daily, without sunshine, and throughout the year. It has the capability of capturing waste heat that otherwise may be lost, especially during the summer months. There are a variety of heat exchanger models on the market with a wide range of costs and efficiencies. Buyers should use caution in their selection.

All of the solar designs described previously offer other uses on the farm in addition to the dairy and are not limited to just dairy farms. **A solar water on the home may be a very cost effective energy saver,** especially with large families. For the family heating the home with wood during the winter, wood water heating makes a wonderful combination to solar water heating in the summer.



More Information

A variety of plans are available for different types of solar water heater systems. Readers may wish to assess their particular situation to decide what type of device may be suitable for them. The following sources comprise only a partial listing, some of the best the Energy Project has found for home-built systems. Many commercial systems are also available.

"Bread Box Water Heater Plans", Zomeworks Corp., P.O. Box 712, Albuquerque, NM 87103, $3.50. Plans for building a water heater from tanks painted black; includes 24" x 35" blueprints and a description of the principals involved.

"Solar Domestic Hot Water System Plans", Domestic Technology Institute, 12520 W. Cedar Dr., Lakewood, CO 80215. $25.00. Five basic low-cost solar hot water heating designs are provided in eight 18" x 24" blueprints with construction, performance and maintenance specifications.

Solar Hot Water Heater, Eastern Oregon Community Development Council, 72 pages, for $2.00. Order from National Center for Appropriate Technology, P.O. Box 3838, Butte, MT

Solar Hot Water Heater Manual, Akira Kawanabe and Arnie Valdez, San Luis Valley Solar Energy Association, P.O. Box 1284, Alamosa, CO 81101, $8.50. Fully illustrated with over 50 diagrams and photos, complete with blueprints, and material and tool lists for constructing a thermosiphon hot water heater.

"Direct Solar Hot Water System" available from the Solar Project, Community Action Program of Lancaster County, 127-133 North Concord St., Lancaster, PA 17602, $1.00. A seven page set of plans for construction of a simplified and low-cost, drain-down solar water heater.