Renewable energy sources will help put chlorophyll to work collecting sunshine

By Guy Webster

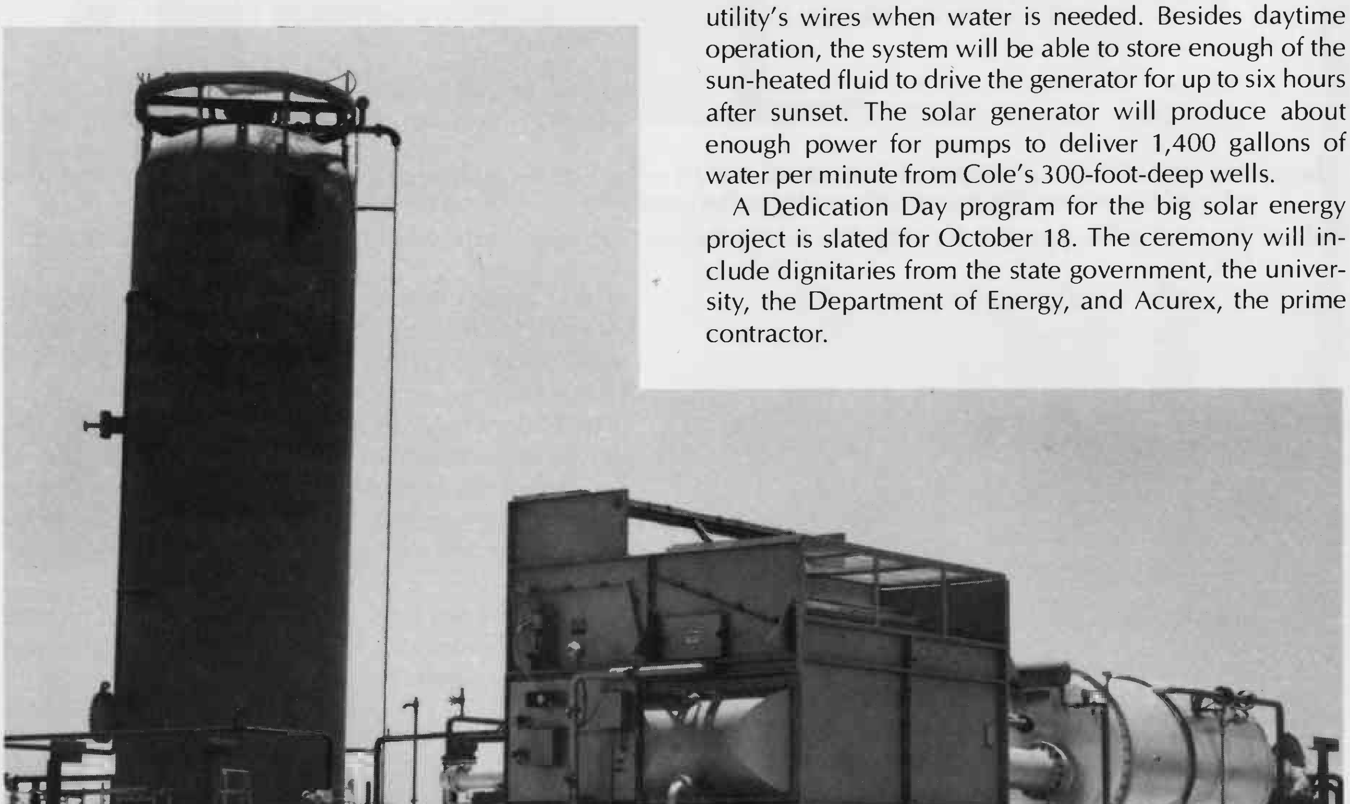
A field of green crops is a solar energy collector. Agriculture turns sunshine into energy-containing materials that people can use more directly, like food for themselves and their animals, or raw materials for clothing and industry.

But the pump must be primed. Energy must be expended to get that field of crops into condition for efficient sunlight-collecting and to harvest the yield. The mechanization of agriculture has meant that most of those energy requirements are now met by using petroleum or electricity instead of food-powered muscle.

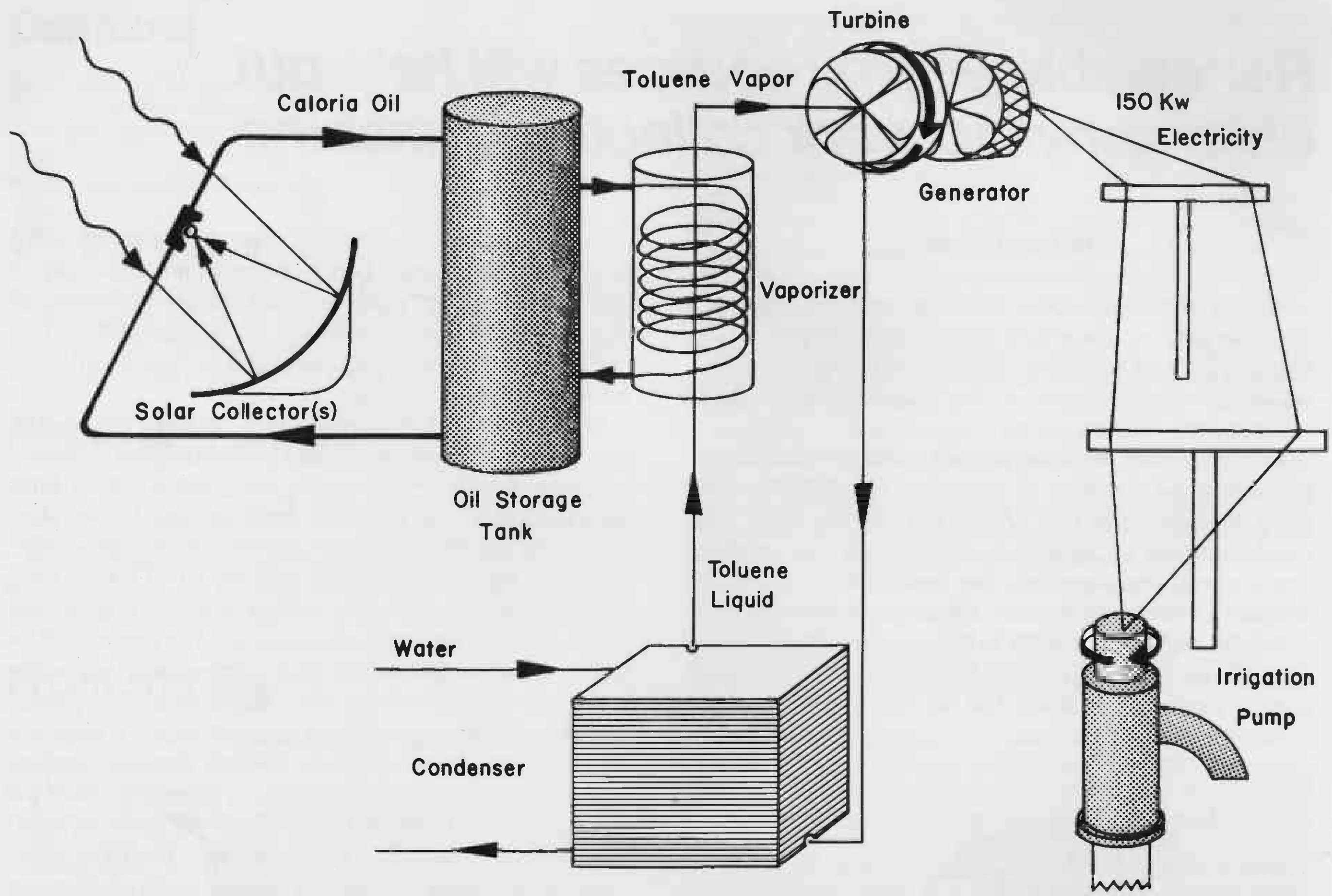
As the nation cuts back on petroleum consumption through the 1980s and '90s, allocation systems may well protect agriculture's share, but the higher costs are setting off reactions. Agricultural engineers and inventive farmers are checking scores of possibilities for cutting costs by using less "store-bought" energy. University of Arizona scientists are working on several projects to conserve energy in agriculture and to use alternative, renewable energy sources.

The most dramatic agricultural alternative energy project in the state is the largest solar-powered irrigation pumping system in the world, on Dalton Cole's farm near Coolidge. The privately designed and built system should be operating this fall after 15 months under construction. Heat from the sun, striking 2,140 square meters of parabolic collector surface will run a generator producing 150 kilowatts of electricity. The power will be fed into the local Electric District Number Two wires rather than directly to the irrigation pumps. The pumps can then draw an exchange amount of juice from the utility's wires when water is needed. Besides daytime operation, the system will be able to store enough of the sun-heated fluid to drive the generator for up to six hours after sunset. The solar generator will produce about enough power for pumps to deliver 1,400 gallons of water per minute from Cole's 300-foot-deep wells.

A Dedication Day program for the big solar energy project is slated for October 18. The ceremony will include dignitaries from the state government, the university, the Department of Energy, and Acurex, the prime contractor.

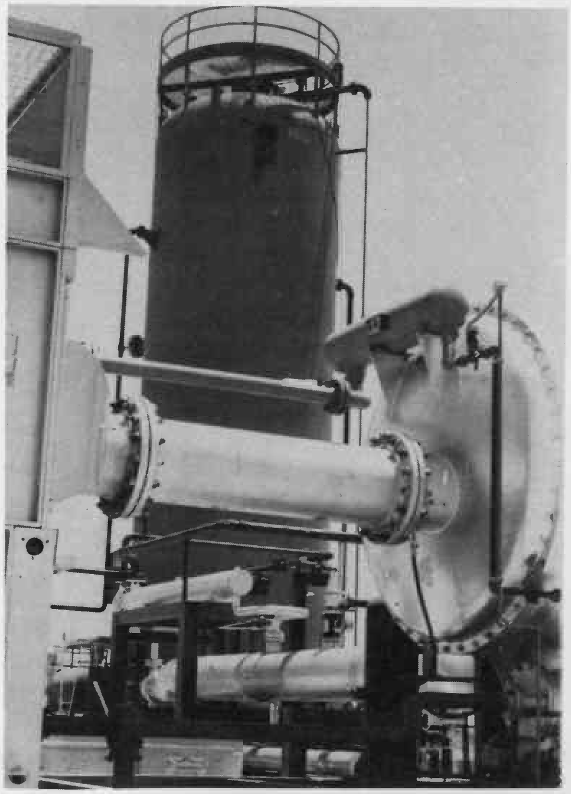


The heat storage tank of the Coolidge solar generator (left) will hold enough of the 600 degree Fahrenheit oil to run the electric generator for up to six hours after sundown.



Above: 150 KW SOLAR GENERATOR FOR IRRIGATION—The Caloria oil heated by the sun heats the toluene from a liquid to a vapor. The heated toluene turns the generator that powers the electric irrigation pump.

Below: The $5.5 million project for irrigation on the Dalton Cole farm is scheduled to begin full-scale operation this fall.



The U.S. Department of Energy is funding the project. A team of UA scientists headed by agricultural engineer Dr. Dennis Larson is studying the costs and performance of the system.

The $5.5 million cost of the Coolidge project includes research costs as well as pumping costs. But the cost of solar-powered pumping is still much higher than that for gas or electric pumping. The project will provide careful assessment of fuel savings and maintenance needs over the years.

Fortunately, this large solar generator should provide information for making future ones more cost-efficient. The Coolidge project is costing considerably less per kilowatt than the first major solar pumping system that was constructed. As power for irrigation, the project will be compared to earlier solar irrigation systems in Gila Bend and in Willard, New Mexico. In those two systems, the thermal engine directly drives water pumps, rather than generating electricity into a utility company's network.

Smaller scale

Even before large-scale solar irrigation economically merits common use, smaller solar pumps may find a role in some situations, says Larson. He is monitoring a 10 gallon-per-minute solar pump for use with the College of Agriculture's water-harvesting and grape-growing project at Page Ranch near Oracle.

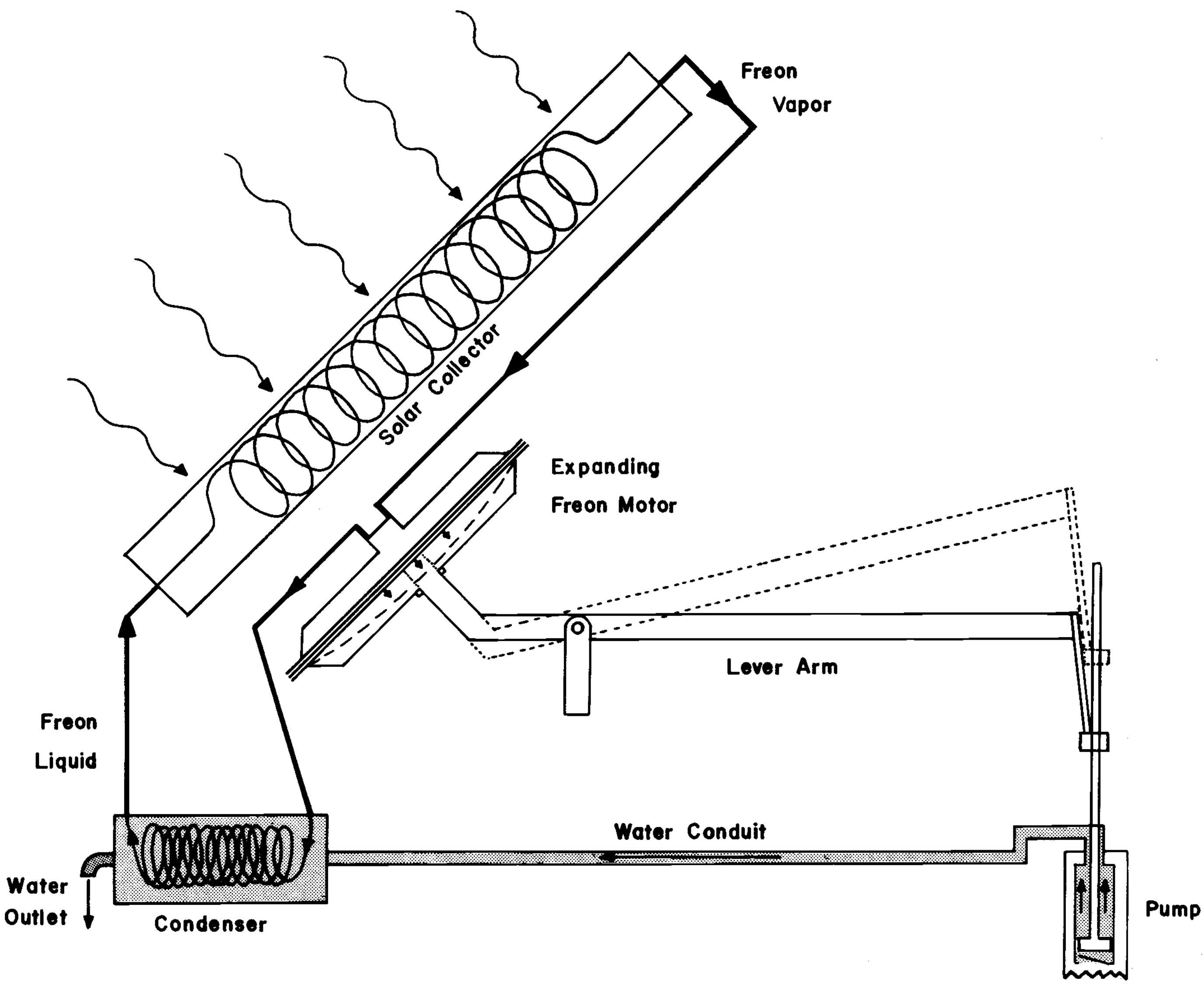
This pump uses no electricity. Solar heat expands freon from liquid to gas, which pushes the single cylinder, driving the pump. The circulating freon is then cooled by the freshly pumped water to condense before it is heated again. The Solar Pump Corporation of Las Vegas, Nevada designed and built the prototype. Larson and UA colleague Charles Sands set it in operation at the UA Campbell Avenue Farm in Tucson to check its performance and maintenance needs before moving it to Page Ranch. They have since suggested several refinements in the engine's design.

"We're working on the development of this device so that we'll have something to meet the specific needs at the Page site," said Larson this summer. "If we show that it works there, it will give people an extra choice for pumping water in relatively remote areas, far from a power line. A lot of livestock water tanks are in remote places, where the choices for pumping are small diesel, wind and solar. Some spots don't get enough wind, and if this solar plant works well, it could be operated with less attention than a diesel."

At Page Ranch, the pump is for watering plants, not livestock. The site is designed for collecting runoff water from between the widely spaced rows of grapes. The pump will move water from the downhill collection tank to an uphill storage tank so that it can be used to irrigate as needed.

Solar heating

The biggest increase in use of solar energy in the next couple of decades will probably be as heating for buildings and water. UA agricultural engineers Dr. Frank Wiersma and Dr. Dennis Larson have monitored a solar water-heater at the UA dairy farm since 1977. Two commercially manufactured solar collectors with 2.4



10 GALLON PER MINUTE SOLAR PUMP—The Freon heated by the sun expands to push the arm of the pump. Freshly pumped water then cools the Freon.

and 1.67 square meters of absorption area provide about 15 percent of the water-heating capacity needed for the milking parlor of the 130-cow dairy.

During the daytime, water circulates continuously through the collectors and a 480 liter (125 gallon), insulated storage tank. This preheated water is piped to the main, gas-fired water heater in controlled amounts. Another pipe to the main heater bypasses the solar heating system.

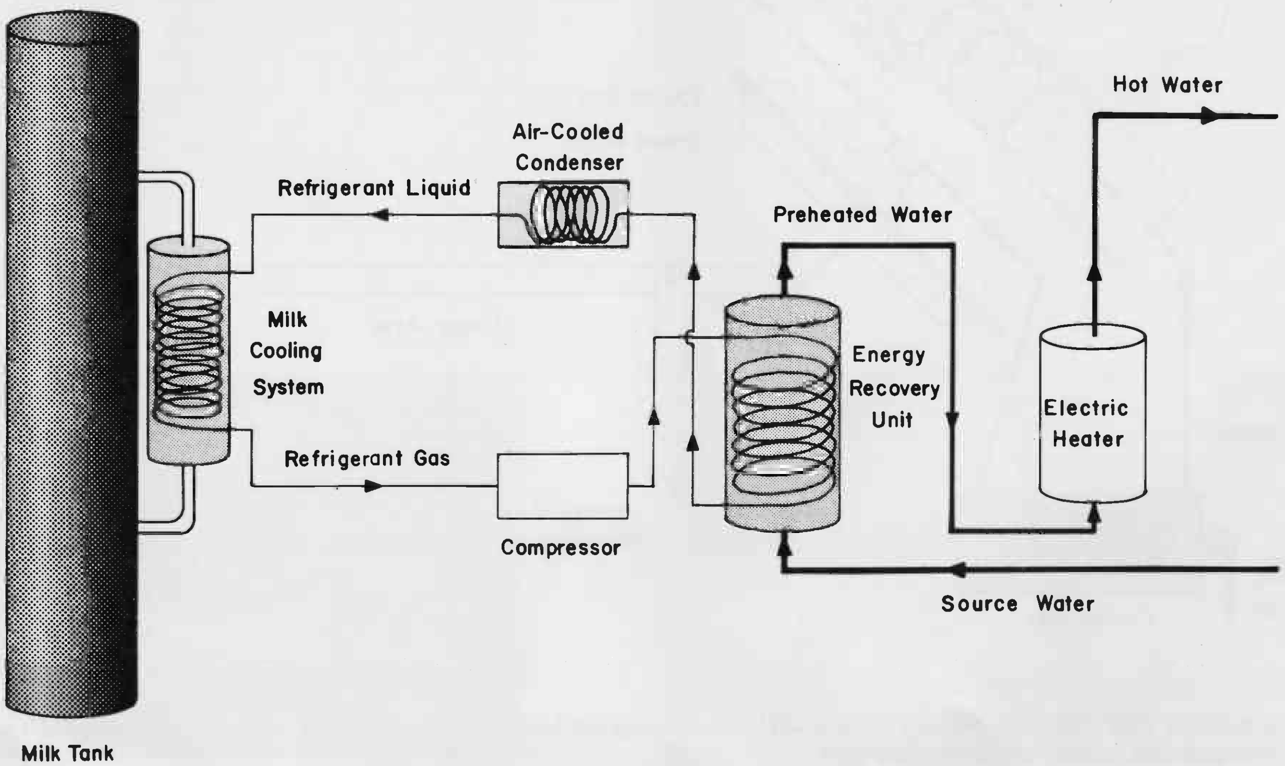
A fifth or less of the parlor's total hot water is channeled through the solar system. That way, the preheated water can be kept most of the day within 20 Centigrade degrees of the 70° C (158° F) needed for cleaning milking equipment. When a larger portion of the water is diverted through the solar heater, the water is preheated to a lower temperature.

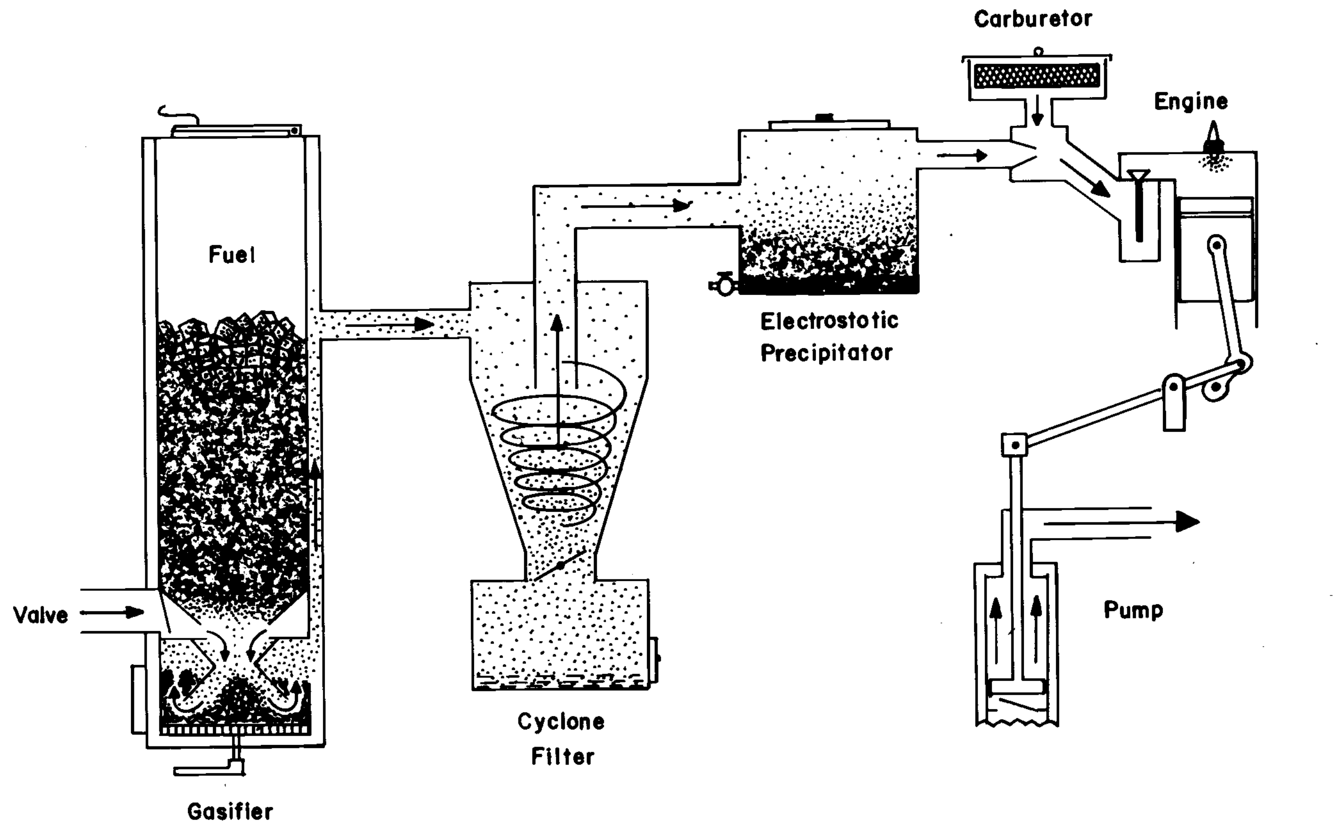
To plan for appropriately designed water-heating systems for dairies, Wiersma and his colleagues are compiling records of hot-water use from more than 100 dairies in 17 states. The dairies were selected with the help of Extension Service agents around the country, and include a range of sizes of operation in each region of the country.

Besides solar heat, a good source for heating water for dairies may be the waste heat produced from the cooling of the milk. The UA scientists are keeping performance records on a commercial heat-exchange system that has been installed on Baca Linda Dairy, a 600-cow-dairy near Litchfield Park. Intake water is heated by using it to

Above: Dr. Dennis Larson checks operation of the small-scale solar pump he is monitoring at the UA farm in Tucson.

Below: DAIRY HEAT-EXCHANGE SYSTEM — Refrigerant draws heat from the milk, is compressed, and transfers heat to water bound for the electric water heater. The water-cooled, then air-cooled refrigerant continues the cycle to cool the milk.





PRODUCER GASIFIER TO FUEL PUMP ENGINE—Straw or other fuel is partially oxidized in the gasifier. The valve lets in only enough air for combusion to continue, but not enough for complete oxidation. The reaction produces flammable hydrogen and carbon monixide gases, which are cleaned in the filter and precipitator, then burned in the internal-combustion engine that drives the pump.

cool and condense the refrigerant gas from the milk cooling system. The preheated water then flows on to the main heater, and the condensed refrigerant circulates to chill the milk. The heat for the water comes from the heat of the newly given milk.

Manure gas

Solar heating plays a minor role in another alternative energy project at the UA dairy farm. Agricultural engineer Dr. Douglas Williams built an anaerobic digester to convert some of the dairy's manure into flammable methane gas. Anaerobic means oxygen-free. The bacteria that turn the manure into methane don't like oxygen. They do like temperatures around 38° C (95° F), which is where the solar energy comes in. Williams' black-painted digester sits under a clear plastic covering in the winter to absorb heat from the sun.

The digester itself is simply three 55-gallon drums, without tops and bottoms, welded together into one long cylinder, with an inlet on one end and an outlet on the other. When filled with 150 gallons of fresh manure and water mixed in equal amounts, the sealed and virtually odorless tank puts out 20 cubic feet of methane gas daily. Williams puts five fresh gallons of the diluted dung into the digester every day, and takes out five gallons of used slurry, which is as good as new for fertilizer.

For now, he collects the methane in tractor-tire inner tubes and takes it home for fueling a gas stove. The output is enough for the cooking needs of a four-person family. Methane burns much like natural gas, but contains less energy per cubic foot.

Williams forsees digesters on a larger scale meeting many of the energy demands of dairy or feedlot operations. "They could generate electricity to run lights, motors, refrigeration units—even milking machines," he says. Another use may be in countries that have livestock but little cooking fuel.

Gasifier

Williams has another project in Tucson for turning other agricultural by-products into useful fuel. This one, a producer gasifier, turns straw into gases that will power an internal combustion engine hooked to an irrigation pump. The same setup could run the pump with corncobs, cotton gin trash, pecan shells or other crop residues.

The gasifier, like the anaerobic digester, depends on keeping out air when it's not wanted. The idea is to burn the straw or other fuel without allowing in enough air for complete oxidation. So instead of turning all of the organic matter into the usual oxidation products of carbon dioxide and water, the gasification produces useful amounts of flammable carbon monoxide and hydrogen gases (CO_2 and H_2O minus some O).

Dr. Douglas Williams savors a breakfast cooked with methane generated from manure in the anaerobic digester behind him.

This summer Williams was working on a couple of snags: getting the cubed straw to feed smoothly into the airtight combustion chamber and getting all of the tar and ash out of the produced gas before it gets to the pump engine. But he has no doubts about whether gasification works.

"This isn't a new technology, even though it hasn't been used much in the past 30 years," he said. "During World War II, Sweden rigged up thousands of tractors and trucks with gasifiers so that they could run on charcoal instead of gasoline. Almost 80 percent of their buses and about 34,000 cars during the war were using gasification." The units installed on cars looked like plain woodstoves sitting on the trunk with a pipe around to the engine.

"It ought to be even easier to hook up a gasifier to a stationary irrigation pump than it was to make mobile ones you could drive around with," said Williams.

Conserving energy

Abundant sunshine is Arizona agriculture's advantage. It gives the region an edge that has made up for the handicap of low rainfall. But because of that handicap, irrigation has been necessary for almost every commercial crop to take advantage of the solar energy. And though the state has built elaborate river-water irrigation systems, begun on the ruins of Indian canals, almost two-thirds of the irrigation water now used in Arizona is pumped from wells. Four out of five irrigated acres use at least some well water.

The energy expense of pumping is why most of the agricultural alternative-energy projects in the state use energy for pumping water. Larson and fellow UA engineer Dr. Del Fangmeier determined in 1977 that pumping can represent up to 80 percent of the total energy cost of producing irrigated cotton using well water.

Other UA projects are examining ways to cut energy consumption by reducing tillage steps and by irrigating only in every-other furrow or in other combinations. On the Marana Experiment Farm in both 1977 and 1978,

Dr. Williams (left) and student Ed Jorgensen discuss the routing of fuel gas into a pump engine. The hydrogen and carbon monoxide gas is produced by a gasifier and cleaned in the electrostatic precipitator at left.

cotton on plots with reduced tillage yielded as much lint as that grown with conventional tillage. The reduced-tillage treatment substituted chiseling for the plowing step of conventional tillage and eliminated one of two diskings and the mulching step. Engineers Larson, Walt Hinz and Fangmeier, and Pima County Extension Agent Jim Armstrong ran the tests and are repeating them in 1979.

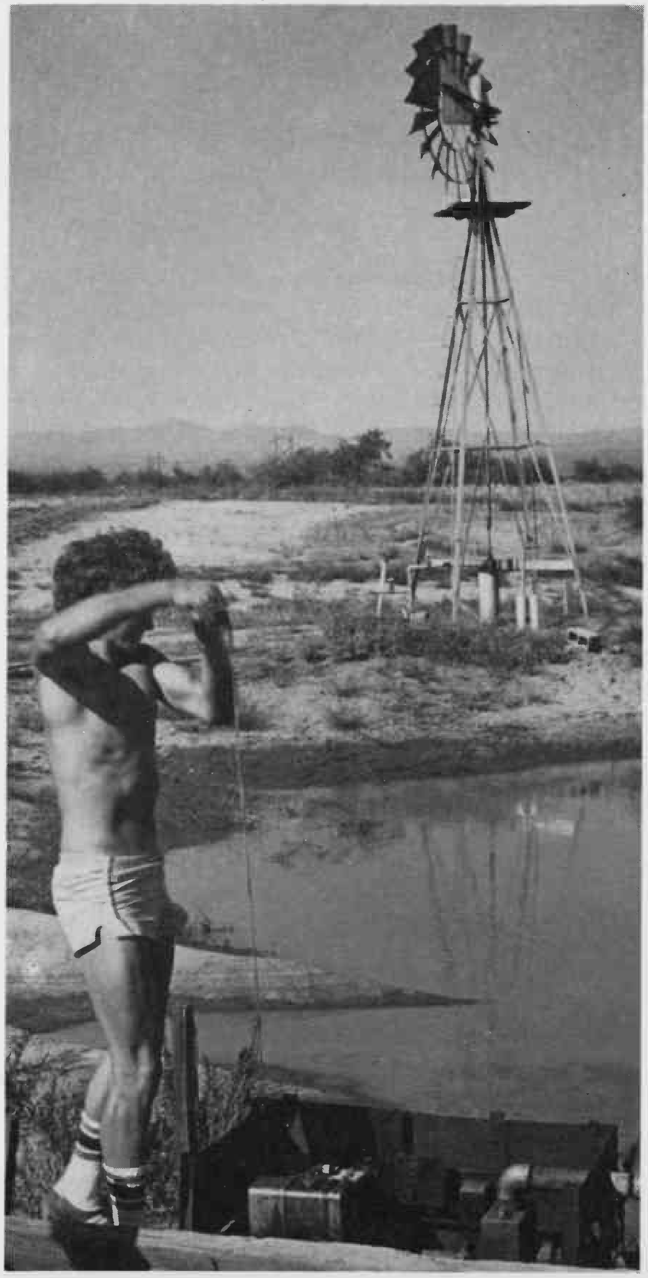
They are also comparing every-row irrigation to alternate-row irrigation, both with the reduced tillage treatment. Irrigating only in alternate rows used about one-third less water than every-row irrigation, but resulted in comparable lint yeilds: 5 percent lower in 1977, but 10 percent higher in 1978.

Studies of water-use requirements of several crops, by many scientists, are helping to reduce unnecessary irrigation.

Low-energy water

UA soil scientist Dr. Gordon Dutt is working with horticulturist Dr. Eugene Mielke on a system for harvesting rainfall to water plants where other sources for irrigation are unavailable or insufficient.

Their principal test site is at the Page Ranch west of Oracle. Ten acres of land there have been reshaped to drain onto long, four-foot wide waterways. Slightly sloped, 30-foot-wide catchment surfaces between the waterways were treated with salt to maximize runoff of water. Grapevines and fruit trees grow in the narrow waterways where the soil absorbs most of the runoff



UA worker John Chamberlain yanks cord to start the diesel pump at the Page Ranch near Oracle. Engineers plan to install a solar pump on the site to compare its performance to the diesel and wind pumps already there.

from the catchment surfaces. Water that's not absorbed flows into one of three storage ponds. From these, it can be pumped back onto the crops if needed.

Dutt reports that, though the area averages only 12 to 16 inches of rain a year, the grapes get almost all the water they need from the primary runoff. The added irrigation is usually about an inch and a half per year, about a tenth of what would be needed without the flow from the catchment surfaces.

"Having soil with a good water-holding capacity is an important part of this system," he explained recently. That allows the plants to get maximum use out of the sporadic rains.

On the other hand, the high absorption capacity of the local soil—a Whitehouse loam type—required that the catchment surfaces be treated to minimize infiltration and encourage runoff. The scientists rototilled the top couple inches of soil to break up soil structure, then mixed five tons of salt per acre into the top inch of the soil. After each of the next two rainstorms, they compacted the surface with a heavy roller. The four-foot wide rows for the plants were not salted and compacted, but the bottom and sides of the storage ponds were.

The salt separates into sodium and chlorine ions in the soil. The chlorine is leached further into the soil, but the sodium stays near the surface. It bonds with oppositely charged clay particles and causes them to stack more tightly together than they would otherwise. The clay makes such a tight, hard surface that water barely gets through: at the bottom of the storage pond, less than a tenth of an inch of water seeps in per day.

Since the water doesn't get into the catchment surfaces, the salt doesn't wash out. "There is no tendency for an increase of salt in the root zone of the grapes," said Dutt. The water in the storage pond is less salty than Tucson city water.

Fine wine

After a bout with Texas root rot, which is now under control with resistant root-stock and sulfur, the grapes are growing well. Grapes were chosen for the site because they require relatively little water, they have deep roots to make good use of stored soil moisture, and they have high economic value.

The researchers have begun a second site at Babocomari, south of Sonoita. There, the land was terraced, but not treated with salt. At Page Ranch, they will be comparing performances and costs of solar-powered, wind-powered, and gasoline-powered pumps for moving water between storage tanks. The fruit trees have become the basis for a study of solar food-drying. One hundred apricot trees of several varieties were planted at the site this year.

Some of the grapevines are yielding as much as vines in good California vinyards. Some varieties of wine made from Page Ranch grapes were judged by a taste panel to be as good as California's best. "Really, I think I can say, 'We're there. We've shown it will work,'" said Dutt.

The rows of grape vines and fruit trees at the Page Ranch are watered by the rainfall runoff from 30-foot wide, slightly sloped surfaces, plus drip irrigation pumped from lower catchment ponds.