GETTING WATE

by Dennis L. Larson an

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Man has put in harness rivers, wind, the fossil remains of plants to furnish him energy—they have been diligent servants—and he has even put the sun in traces to do his work.

So when the Arabs shut the valves on oil, and when El Paso Natural Gas announced its commodity was in short supply, and when utility firms raised and raised their rates, the riverless farmers of Arizona naturally turned their eyes to their bright, hot sun, with the thought of harnessing that limitless energy supply to run their irrigation pumps. How attractive that thought: no utility lines, no meter dials spinning—just pure, free energy.

But the price of yoking the sun comes high, so high that it does not presently appear that the growers of Arizona can expect much relief from solar energy in the near future, unless they are willing to pay as much as $200,000 for a unit that could run an irrigation pump of average size during the hours of sunlight only. That figure is not an unreal one for the cost of collection and pumping alone. It does not take into account what added expenses there would be in order to run an irrigation pump 24 hours a day, as Southwestern farmers are accustomed to do.

This is one conclusion, among many, arrived at in a study of the feasibility of using solar energy for irrigation pumping currently being conducted by the University of Arizona in conjunction with the University of Houston and Texas Tech University. The research at Arizona is aimed at determining how solar energy can be tied in with irrigation systems farmers are now using. Houston is evaluating the various methods of collecting solar energy and turning it to heat, while at Texas Tech researchers are looking into various ways of getting the heat to do work, to power machinery.

In the course of our investigation it become instantly clear that while the use of solar energy is nothing new, intensive research into making it a more efficient form of energy is very new indeed.

About the turn of the century, one of the first attempts to irrigate using solar energy was made by the Solar Motor Co. of Boston, under the direction of A.G. Eneas. Near Tempe a conical collector 33 feet in diameter was erected, with a reflecting surface of 1700 small mirrors focused on a central axis where a steam boiler was located.

The steam powered an engine that produced between 4 and 15 horsepower, and irrigation water was lifted. But the unit lasted only a short period before being destroyed accidentally by a mechanical failure. A second unit like it was constructed near Phoenix in 1904, moved to Willcox and then to Cochise, a short distance west of Willcox, where it too pumped irrigation water, and where it too came to a fairly quick end—this time apparently in a storm.

By far the largest and most successful of solar irrigation units was designed by C.V. Boys and Frank Shuman and installed near Meadi, Egypt. It used trough-like, parabolic collectors with a collection area of 13,000 square feet, drove a steam engine that produced 50-60 horsepower, and did quite nicely for several years until WWI ended its operation.

FROM THE SUN

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ils Water and Engineering, respectively

But with gas, coal, oil, and hydroelectric sources becoming more and more common, and cheaper and cheaper, engineers and scientists knew even before World War I that, on the basis of cost alone, solar energy couldn't compete.

John Ericsson, the American inventor who built the ironclad, *Monitor,* several solar collectors, and the hot-air cycle engine which bears his name, calculated in the 19th century that to generate power with solar energy would cost 10 times as much as it would to generate comparable power with other energy sources.

And so, from shortly after the turn of the century until the early 1970's—with a brief flurry of interest in the 1950's—solar energy was a subject much ignored. Ignored to the point that in the 1960's the Association for Applied Solar Energy Research moved its offices from Phoenix to Australia.

Then came the "energy crisis" and sudden interest in the single most powerful and continual source of energy—the sun.

But even with the advances in technology achieved during the space race of the '60's, capturing the sun in sufficient and efficient quantities is a difficult business at best.

Because sunlight is diffuse, solar energy power units on earth are probably limited to efficiencies of no more than

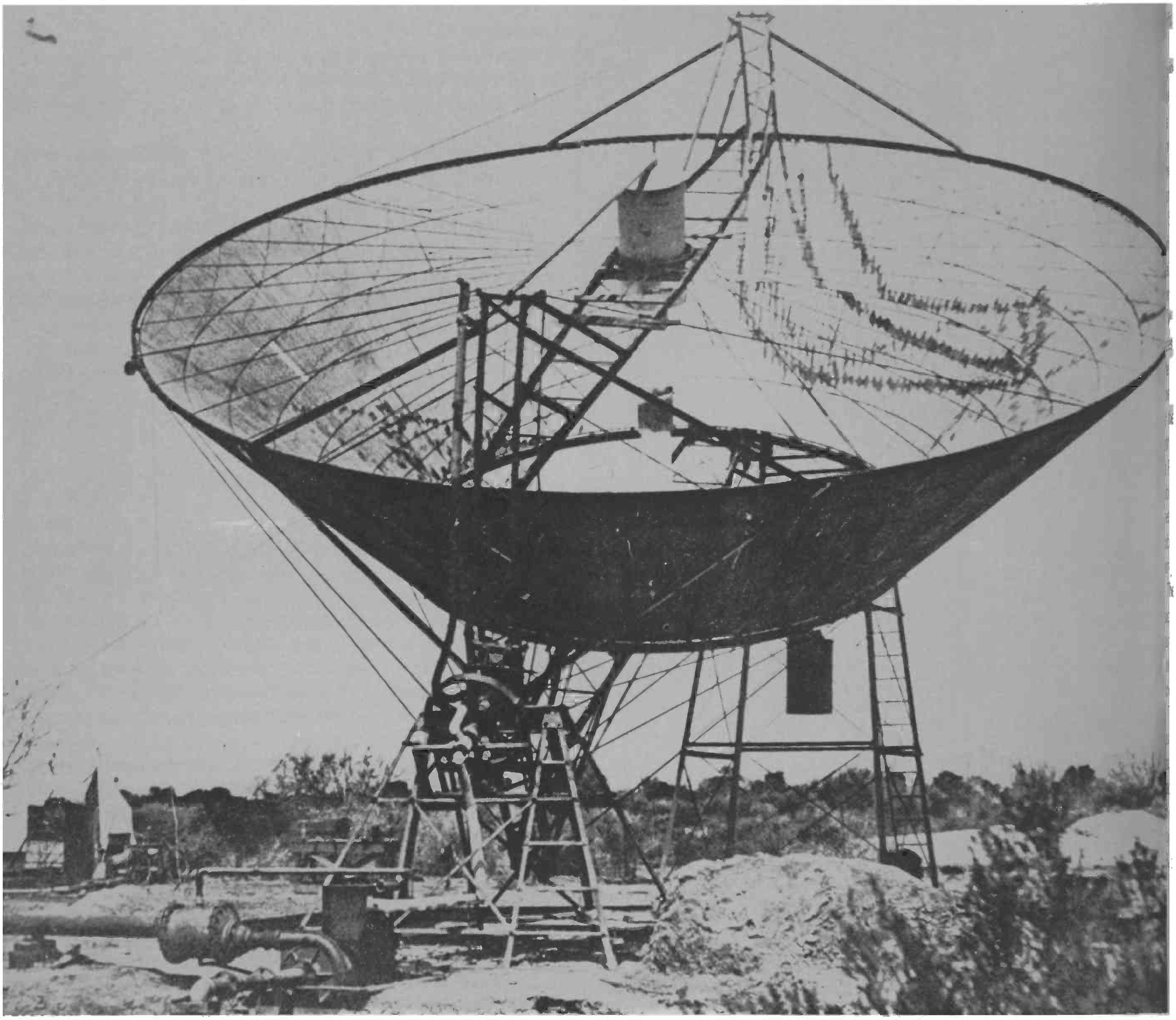
Solar energy powered units as discussed in this article function by collecting and concentrating the sun's radiation. The resultant thermal energy is then transferred to another point for either direct use of the heat or for conversion into mechanical energy that operates a pump or electrical generator. The "fluid" used as the method of transmitting the heat may be in the form of a gas or a liquid.

15-20 per cent (compared to an internal combustion engine's 25 per cent), and generally much lower efficiencies are currently being obtained.

Furthermore, solar energy is a source of energy that is variable. You can collect the stuff only when the sun is shining during daylight hours, and collections may be interrupted then by airborne dust, or clouds, and either the user must find a way to store it at night or plan on using it only during the day.

True the Southwest does enjoy 14 hours of sunlight per day in the summer and 10 in the winter, and the sunlight in this land of low humidity is intense, but you currently need 130 square feet of collector for one kilowatt of usable power. A collector of 325 square feet will provide two and a half kilowatts—enough to meet the peak demand of the average residential user in the Tucson area. The same scale shows that it would take at least a half acre of collector (actually it would cover more like an acre and a half to avoid any of the collectors being shaded by the others) to provide the 150 kilowatts needed to power a medium-sized irrigation pump, and during the time of day when the sun is giving maximum radiation.

Then comes the problem of operating such a pump 24 hours a day or providing for an equivalent amount of water. To do this, one must (1) collect more energy than is needed while the sun shines and then store it somehow for use later, (2) provide for an alternate power source during time of darkness and cloudiness or (3) pump enough water into



SHORTLY AFTER the turn of the century, this solar power plant was pumping irrigation water near Phoenix. The conical collector was 33 feet in diameter.

storage during sunlight hours to provide for irrigation during the hours of dark.

If it is surplus power at a uniform rate that is needed to run machinery, 24 hours a day, then three times as much energy must be collected during the approximately 8 hours of effective solar energy collection as we use during the sunlight hours. This, because there is a 10-25 per cent loss involved in storing the energy and retrieving it. One advantage that may occur in storing energy lies in being able to select a solar power system that will meet average daily power demand rather than peak use, thereby reducing the needed size or power capability of the collector.

The efficiency of a solar energy unit is most important because the more efficient it is, the smaller the collector can be, and the collector is the major investment.

The overall efficiency of a solar energy unit—whether it is used to produce electricity or whether it is used directly to power machinery—is expressed in terms of the percentage of the incoming solar energy that can be used.

The two major components of overall efficiency are the collection efficiency (the increase in fluid thermal energy divided by the solar energy falling on the collector) and the conversion efficiency (the usable energy produced by the motor divided by the increase in the thermal energy of the fluid). Overall energy efficiency then is equal to collection efficiency multiplied by conversion efficiency.

Take the 130-square-foot collector discussed earlier, giving 1 kilowatt at 10 per cent overall efficiency. Raise efficiency to 15 per cent and an area of less than 90 square feet is needed to produce the same amount of power. This means in the case of our solar energy pumping unit that the one-and-a-half acres of collector could be reduced to one acre by increasing the efficiency by five per cent.

Such comparatively high efficiencies, however, lie somewhere in the future. Current, on-line units generally are flat plate collectors, operating at five per cent (or less) efficiency.

In Mexico, for example, where the French firm of Sofretes has installed 10 solar energy units under contract with the Mexican government, flat plate units are estimated to be operating at efficiencies of no more than 2-3 per cent. Nine of the units are small installations used to pump water for either irrigation or drinking. The tenth, located at San Luis de la Paz, 200 miles northwest of Mexico City powers a 30 kilowatt electricity plant. The plant is served by 1500 square meters of collectors which drive an organic fluid (Freon II) turbine to produce the electricity. This unit, too, is used for pumping water.

The installation pictured is located on the south-facing, sloped roof of a school house west of the town of Caborca, south of the border, near the Gulf of California. The heat collected runs a thermal engine, pumping water for the school and some neighboring houses.

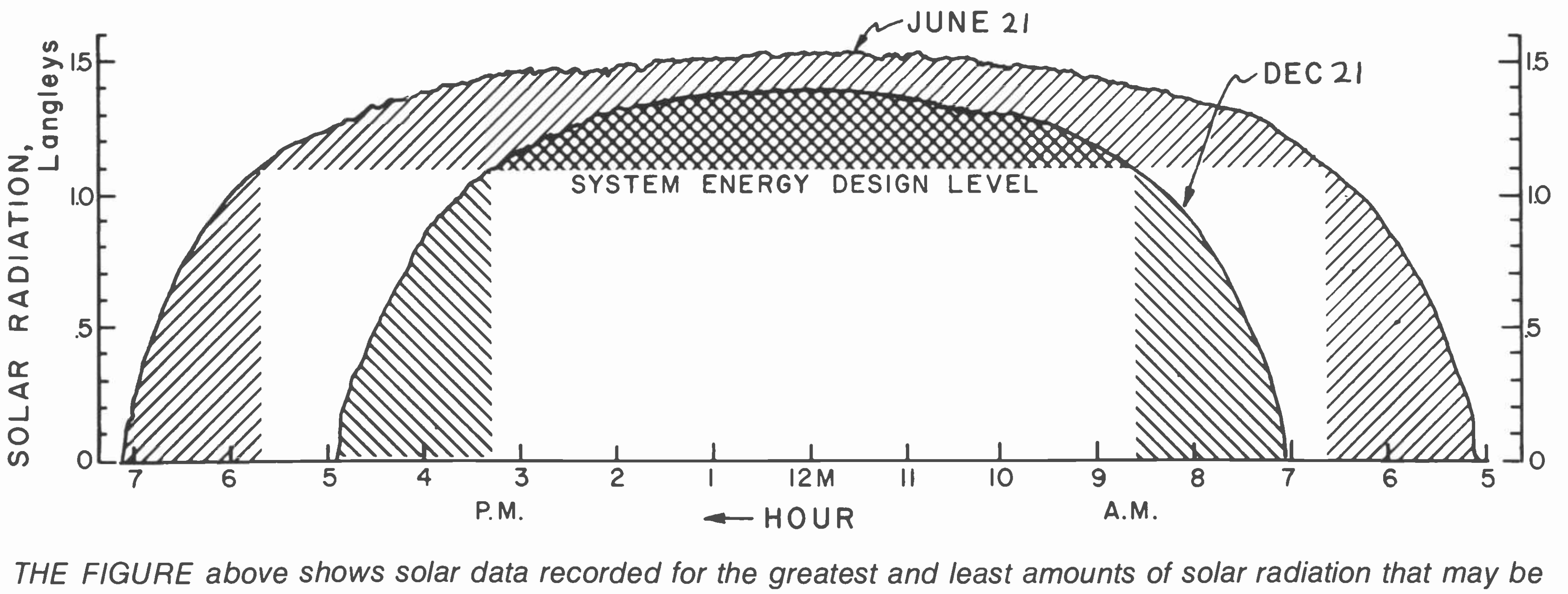
The problem with flat plate collectors is that they do not multiply the energy density of the sun, and can only maximize its absorption by being coated with special materials which increase absorption of sunlight and discouraged re-radiation and attendant heat loss. They are generally glass covered and backed by insulation to prevent heat loss. Fluid is circulated across the surface in tubes, tubes that are linked to a rotary or piston engine where the thermal energy is converted to mechanical energy by expansion. Typical fluid temperatures range from 140-200 degrees farenheit.

To improve the operating efficiency of a solar energy unit, you must raise the temperature of the fluid. This can be achieved by using lenses or reflectors to increase energy density and certain, sophisticated coatings to prevent the escape of heat. Parabolic reflectors can commonly attain temperatures of 400-600 degrees farenheit or higher.

One of the most advanced and promising systems now being investigated is what might be called the "power tower" concept. It involves a series of ground-mounted mirrors concentrating the power of many suns on a heat absorber unit at the top of a very tall tower. Here, rather than fluid being circulated through great lengths of tubing and/or across many collector units, heat energy is focused on one spot—an absorber—through which fluid is circulated. The fluid, whose temperature is expected to range from 600 to 1000 degrees, is then directed to a turbine for production of mechanical power and an estimated overall operating efficiency of 10 per cent. The first such system is being set up at the Sandia Laboratories outside Albuquerque, although it may not actually produce power.

Even this system may not be entirely novel. Legend has it that in 1212 B.C. Archimedes caused the sails of an enemy fleet to burst into flame by focusing the sun on them—a mirror trick, with shields most likely used as reflectors.

Returning to the problem of integrating solar energy use with existing irrigation systems and practices of farmers in the southwest, our investigations centered on finding how best to provide 24-hour-a-day pumping (or its equivalent in wa-



THE FIGURE above shows solar data recorded for the greatest and least amounts of solar radiation that may be expected in Southern Arizona. The dates represent the summer and winter solstices, and the white areas within the shaded areas represent the time during which a solar energy system could function efficiently.

A FLAT PLATE collector mounted on the roof of this school near the Mexican town of Caborca provides energy for pumping water for the school and for nearby residences.

ter) such as farmers generally do in spring and summer months in order to get the most out of their very costly investment in wells ($60,000 would not be an unusual sum for a central Arizona cotton grower to invest in a conventional well).

The simplest method of using solar energy for irrigation purposes appears to be integrating solar energy units with existing electric power pumps, and two-thirds of the pumps are electric—not natural gas—powered.

This would involve using the solar energy unit to power an electric generator, which would, in turn, drive the pump motor. By using the solar energy unit to pump during the hours of effective daylight, and switching to conventionally supplied electricity during nighttime, growers might actually prompt utilities to give them a break on their nighttime rates. This is so because the greatest demand on Arizona utilities comes from 1 p.m. to 7 p.m. in the summer. This peak demand is the most expensive to meet, involving as it does the production of an extra five per cent or so of power. It requires the start up of small, expensive to operate generating units which mean greater use of manpower. If the utilities would trade cheaper nighttime rates to farmers for solar energy pumping in the day, it would make investment in such equipment far more attractive.

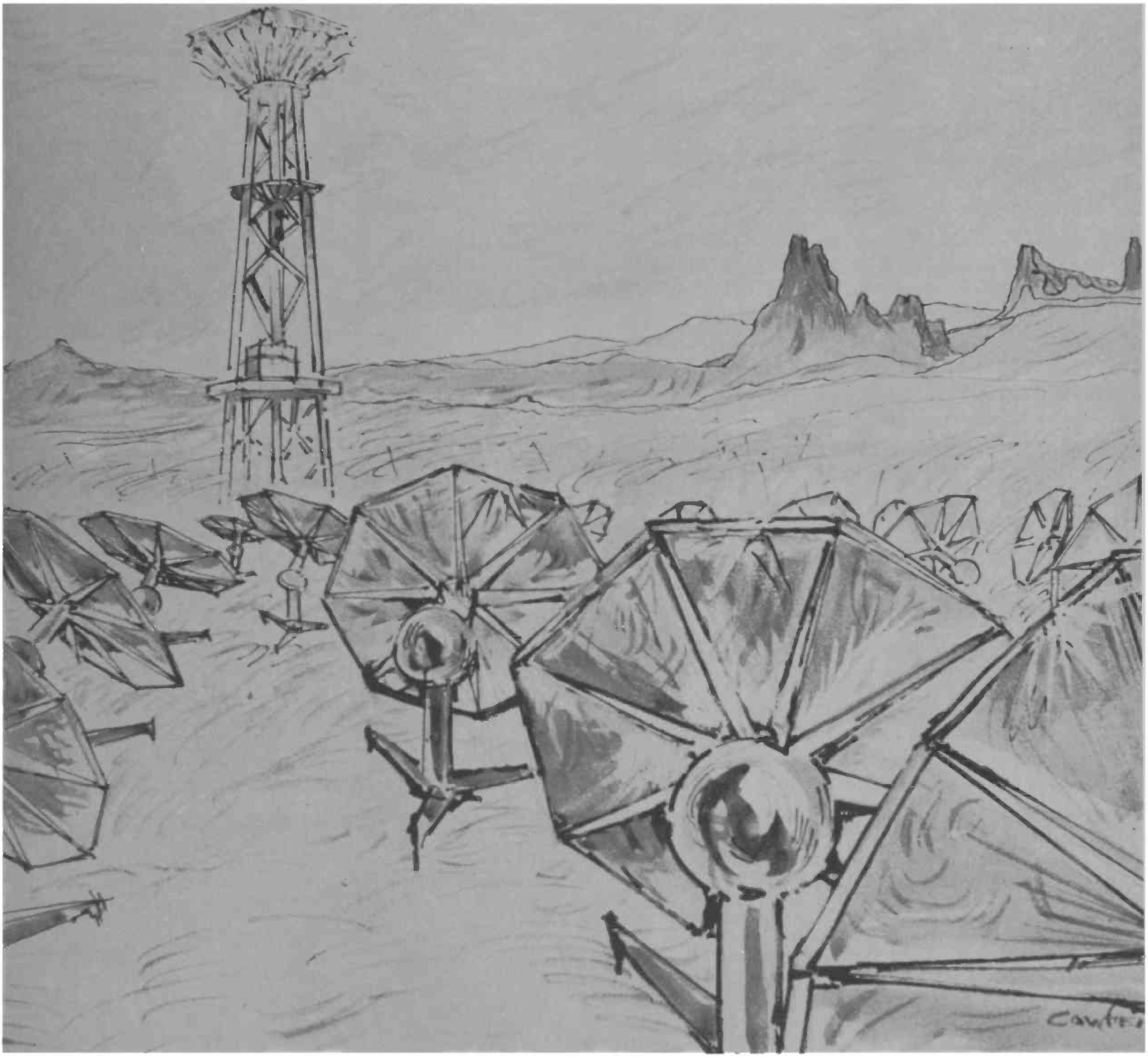
It would also be possible to use a solar unit itself to pump the water directly, switching to another fuel during nighttime or cloudy days. But this is not as attractive as the solar-electric method, since use of alternate fuels would require the handling of the fuels burned and the cleanup of residues.

The second method of dealing with the demands of all-day pumping would free the farmer from the utility pole, but involves the difficulty of storing either enough of the electricity or heat generated by a solar unit to provide for all-night pumping. It is possible to deposit electricity in storage batteries, but with the amount of electricity that would have to be stored and the price of batteries, the cost of doing so is currently prohibitive.

It is also possible to store the heat from a solar unit in inert material such as oil and rocks. Other means of energy storage might involve the use of a huge flywheel, or the practice of hydrostorage where water is pumped up to a reservoir during off-demand hours, and released downhill through a generator when electric power is needed. Hydrostorage is relatively efficient—65–75 per cent—but the costs of a reservoir large enough, and the need to locate it well above the source of the water present additional geographic and economic problems.

Although reversible chemical reactions or phase changes (e.g. from a liquid to a gas), and other methods of storage are under development, the storage of solar energy currently appears to be a very costly method of supplying power.

Yet another method of permitting the use of solar power alone—this time without need of energy storage—is to pump all the water needed for crops during sunlight hours and store the water in a reservoir for off-hour usage. This would probably require more wells, a larger solar collector for a more powerful unit, but the backup system would be



THIS CONCEPTION of a solar tower collector shows the reflectors surrounding the tower concentrating the sun's rays on the top of the tower. Such a tower is to be built for experimentation at the Sandia Laboratories in New Mexico.

simple and no great change in existing irrigation systems would be required.

So much for the various methods. Here are a few specific problems and points to consider:

—Many items of electrical equipment need a fairly constant level of power. Sizing the solar collector to provide for a constant power demand could result in the energy above this level going unused unless there is some provision for energy storage.

—Presently, irrigation pumps (submersible turbines) operate at specific speeds, yielding constant amounts of water. Energy from storage or from conventional sources would be needed to supply the constant energy these units require, during periods when power from solar energy is not available.

—While variable-speed turbine pumps are now available, variable-speed electric motors are expensive, suggesting that the best coupling here would involve hitching the variable speed pump directly to the solar energy collector. Variable speed-pumps could then yield a pumping rate with a curve similar to that of solar energy availability. Here again, a reservoir would most probably be needed to provide storage of surplus water to meet peak water demands when the variable speed unit was putting out less than its capacity.

We are presently looking into the tradeoffs between the cost of reservoirs, the cost of the solar energy plant and the costs of supplemental energy use.

The Southwest will see solar energy power pumps either when that energy form becomes competitive, or when alternate sources of power become unavailable. Hopefully, the cost at that time will not be so high as to drive farming from the Southwest. But the cost now runs between $5 to $30 per square foot of collector, putting solar, thermal power plant costs above $1,000 per kilowatt—about the same fiscal ballpark as nuclear generating stations. Solar power pumping costs based on this estimate would see water priced at $50—$100 per acre foot, or about two to four times as much as it presently costs in Southern Arizona.

Solar collection and conversion are still new and experimental arts, and the cost predictions are uncertain. It seems, really, that solar energy is in about the same position it was at the turn of the century—it doesn't pay yet, but the promise is great ■

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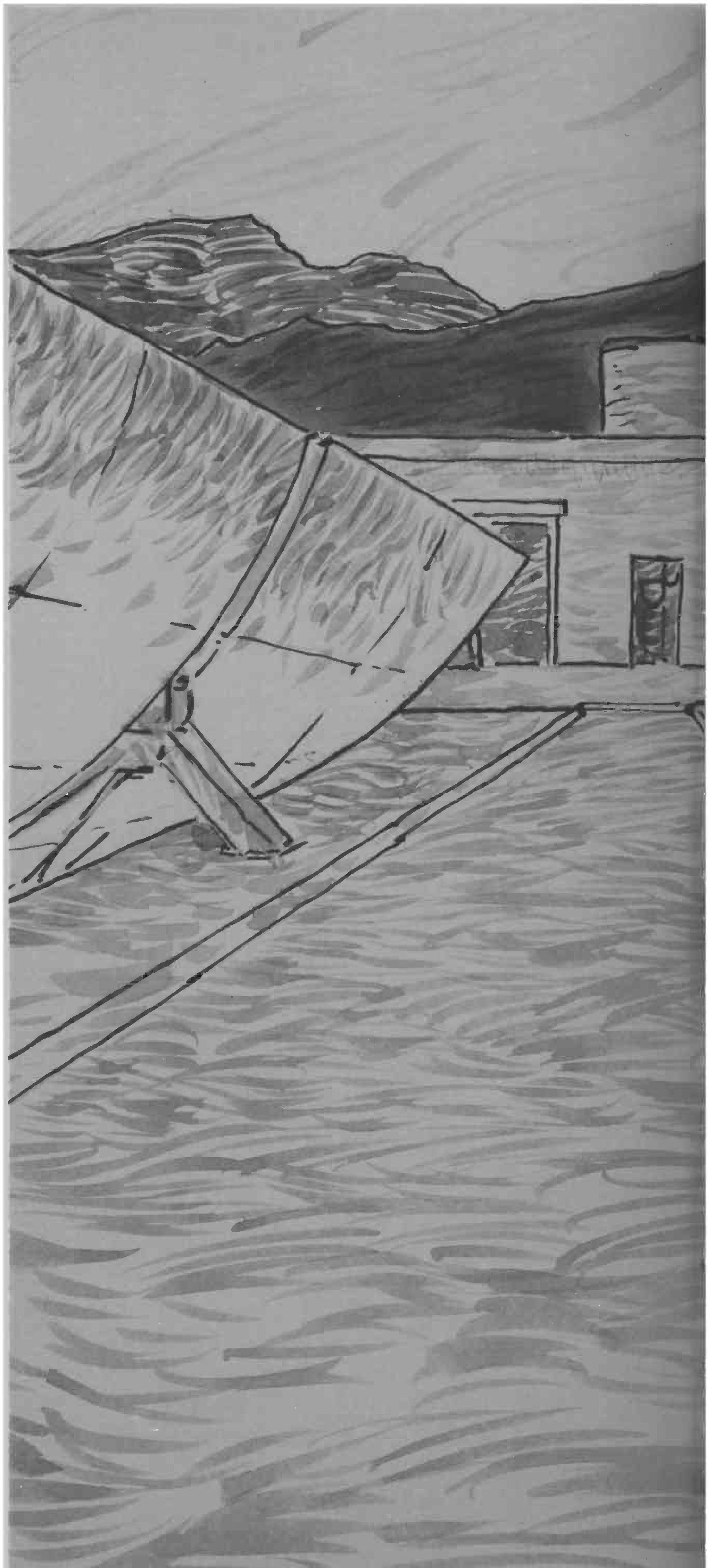

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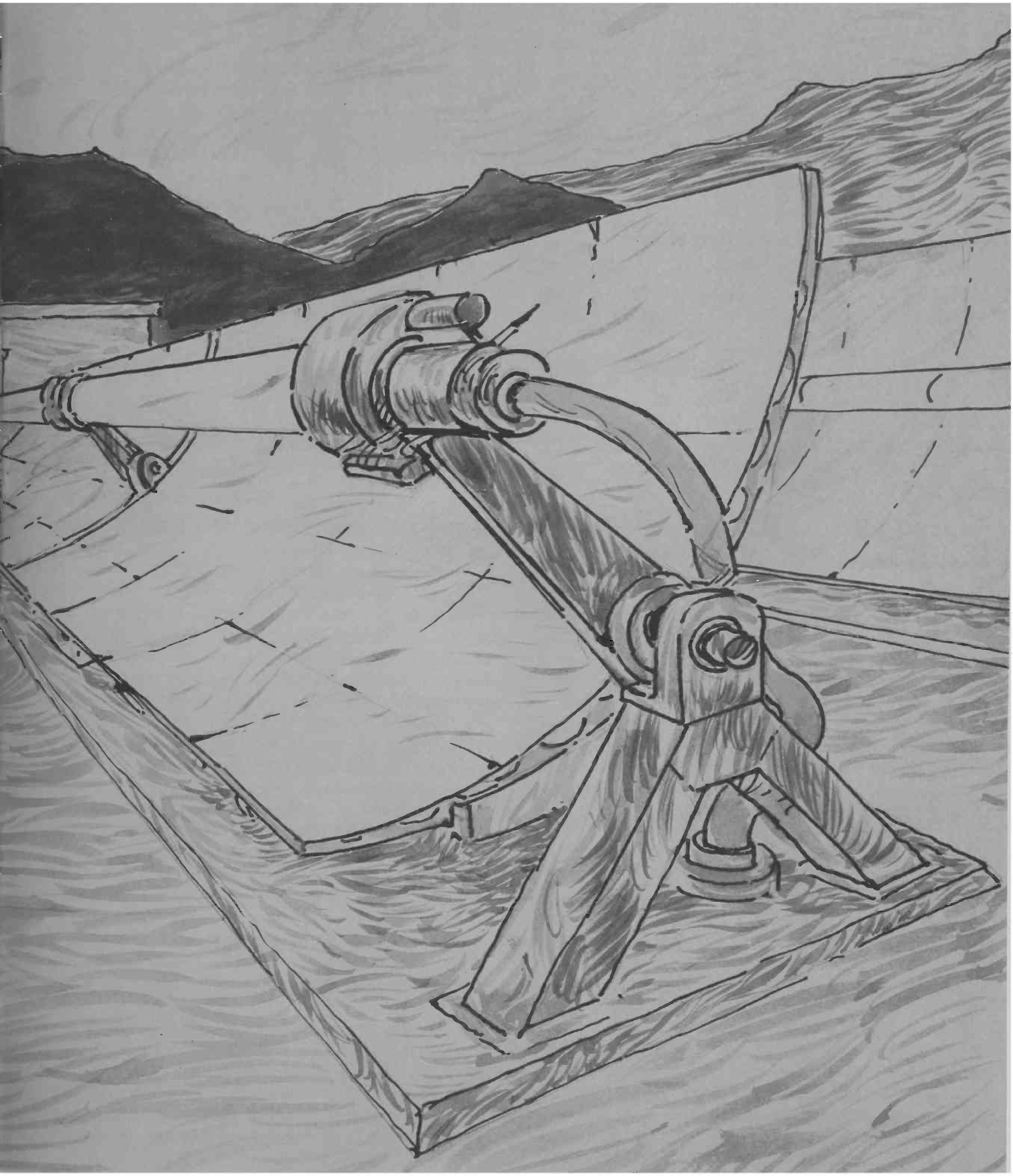

gy on a ranch near Gila Bend next year, with hopes