LIQUID-METAL SOLAR POWER

Without moving mechanical parts, this system cogenerates heat and electricity with an efficiency surpassing steam turbines

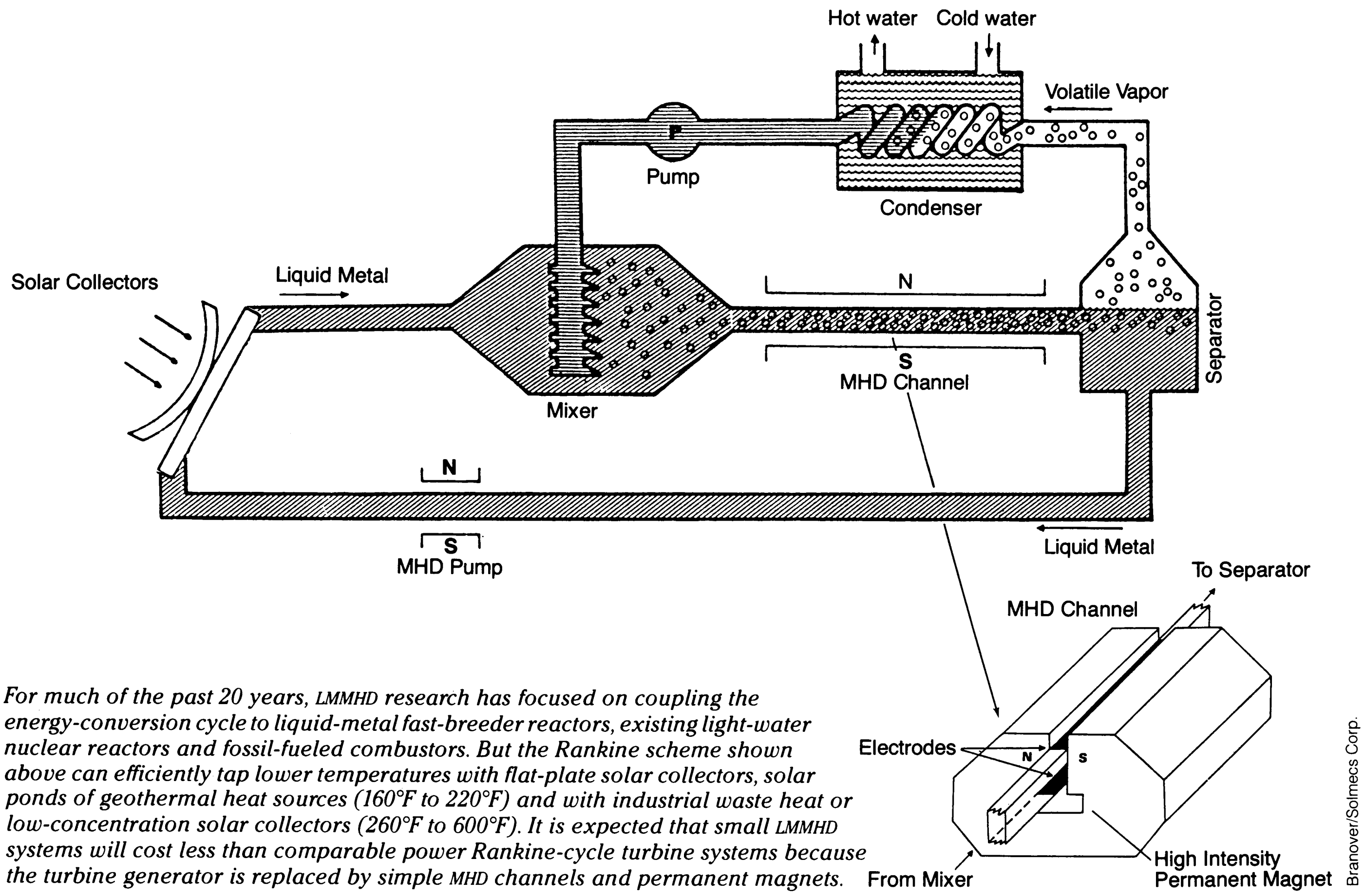
BY JANET RALOFF

Israeli researchers claim to have found the key to making solar-generated electricity cost effective. It's liquid-metal magnetohydrodynamics (LMMHD). The system under design at Ben Gurion University of the Negev in Beersheba would tap relatively low-temperature—200°F to 600°F—heat sources with solar concentrators, flat-plate collectors or geothermal reservoirs. But any low-temperature source will do. In fact, its developers anticipate the first commercially marketed systems will derive their power from industrial waste heat.

The basic concept for this energy-conversion system was developed during the 1960s by Michael Petrick at Argonne National Laboratory, near Chicago. But Yirmiyahu (Herman) Branover, a Russian LMMHD specialist, refined and patented a low-temperature Rankine cycle in 1979, seven years after emigrating to Israel. Recently, the Dutch-based investment firm Solmecs Corp., has acquired worldwide patent rights. Under its financial backing, Branover this year built and demonstrated a bench-scale working model. Now preparations are underway for the design and testing of a 10-kilowatt device — a truly international endeavor. Again with Solmecs support, research teams from Argonne and Ben Gurion will collaborate on the $2.5 million project, which should yield a commercial prototype within two and a half years.

In the device Branover demonstrated this year, mercury circulates through a solar collector, acting as its heat-transfer fluid. Upon entering a mixer (see diagram), a volatile liquid—in this case, freon—is injected as droplets. Heat transferred directly to the freon causes the droplets to boil, creating a two-phase liquid-metal and vapor-bubble flow. The continuing exchange of heat between the metal and vapor expands the bubbles. This swelling action mimics miniature pistons and imparts a mechanical energy to the circulating mixture. It actually drives the liquid through a converging nozzle and into the MHD channel. Here the high-velocity flow of metal through a magnetic field generates an electric current; electrodes tap the current. As the dual-phase mixture exits the channel, the metal and vapor are separated. The vapor is routed through a heat exchanger—where it condenses, releasing heat to warm air or water — and then on to the mixer. Mercury circulates from the separator back to the solar collector.

Branover claims a 13 to 15 percent system efficiency for his two-phase low-temperature LMMHD scheme. That is roughly two percent higher than would be expected from a steam-turbine system of



For much of the past 20 years, LMMHD research has focused on coupling the energy-conversion cycle to liquid-metal fast-breeder reactors, existing light-water nuclear reactors and fossil-fueled combustors. But the Rankine scheme shown above can efficiently tap lower temperatures with flat-plate solar collectors, solar ponds of geothermal heat sources (160°F to 220°F) and with industrial waste heat or low-concentration solar collectors (260°F to 600°F). It is expected that small LMMHD systems will cost less than comparable power Rankine-cycle turbine systems because the turbine generator is replaced by simple MHD channels and permanent magnets.

comparable power, notes Edward Pierson, manager of LMMHD programs at Argonne. Pierson credits the higher efficiency to several factors: Since MHD interaction is a volume effect, efficiency and cost are almost independent of the size of the system. Second, by using liquid metal — a good heat-transfer medium — in the solar collector, temperatures delivered to the system may be as much as 25 percent higher than in those using the standard air, water or oil. This translates to a higher overall system efficiency. Finally, direct contact between the liquid metal and volatile vapor leads to only a small temperature drop within the circulating system.

The solar collectors account for more than half the cost of a solar LMMHD system (or any solar-electric system), yet most of the thermal energy captured is ultimately rejected as waste heat, write Pierson, Branover and colleagues in the October 1980 MECHANICAL ENGINEERING. "Accordingly," they say, one "logical approach is to build a system that supplies both low-grade heat and electrical power... where the electricity is essentially a by-product of the heating system." They anticipate an LMMHD system could convert a small percent of the solar energy collected into electricity, making the rest available for heating — with no temperature penalty. The cost of the electrical system, they figure, "would be low because the solar collectors are paid for by their primary function, heating."

System-cost projections — while admittedly "guesstimates" — are encouraging. Assuming the energy-conversion units are mass produced, Branover estimates a 10-kw unit would cost $10,000, a 100-kw model only $70,000. And requiring "virtually no repair or maintenance," Branover brags that these systems should last 30 years.

What's more, generated electricity could be sold for 5.5 cents per kilowatt-hour, Branover's analyses suggest. That already compares favorably with the 10 cents per kwh charged Israeli electric consumers. And the rate is roughly a tenth the cost of photovoltaic-generated electricity. Cost studies conducted by the Argonne team — and looking at a broader range of temperature systems than the Solmecs developers now plan — show LMMHD far surpasses photovoltaics (for existing and anticipated mature technologies) in cost savings — particularly in the more favorable (in terms of efficiency) high-temperature ranges.

Although Branover's bench-scale device "demonstrates that the whole cycle will work," Pierson told SCIENCE NEWS, "its use for any practical measurements is limited." Hence, stronger efficiency and cost projections must await testing of the planned 10-kw prototype. And what it will look like remains a mystery. To date, not even the liquid metal has been selected, although both mercury and a sodium-potassium alloy are candidates. □