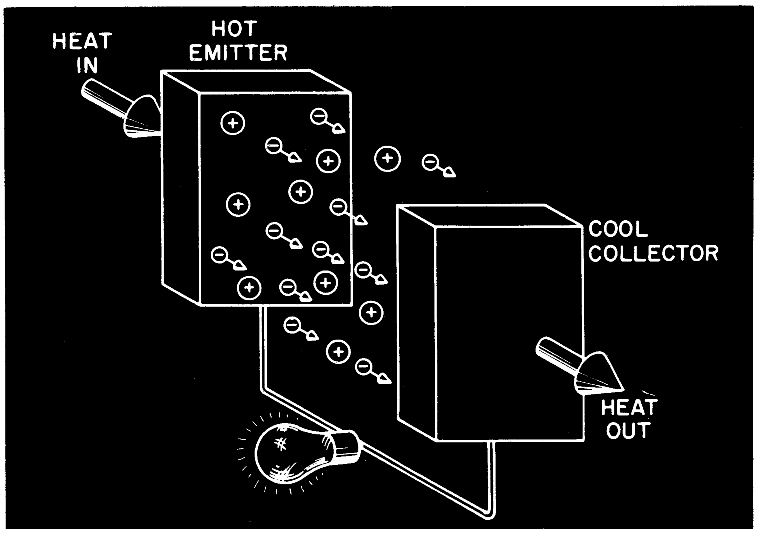
THERMIONICS
A Versatile Energy Saver

An advanced contender in the lineup of maturing energy technologies offers to squeeze more work out of fossil, nuclear and solar energy

BY JANET RALOFF



Thermionic devices convert heat to electricity directly. Electrons "boil" off the heated emitter, condensing on the collector; they return to the emitter via a completed circuit.

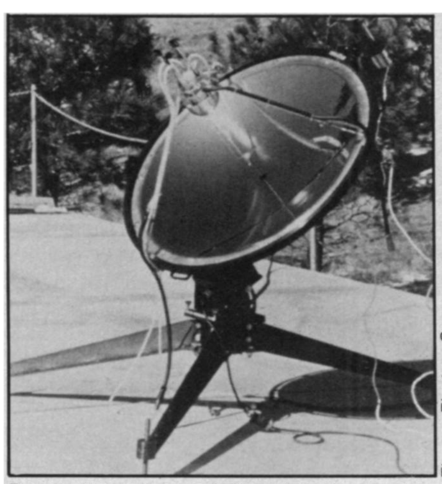
While it is important to develop new energy supplies, it is also important to reduce the waste that occurs in the conversion of a fuel to usable energy, such as coal to electricity. "Recent projections," according to the Department of Energy, "indicate that, by the year 2000, one-half of all energy consumed in the United States may be used for electric-power generation. If correct, present electric powerplant designs would waste one-third of the energy consumed by the country — a waste equivalent to over eight billion barrels of oil per year at a cost of $120 billion."

That "waste" is not due to sloppy design and engineering so much as to the Carnot theorem, which explains mathematically that the optimal efficiency of any heat engine — such as a piston or turbine — is determined by the range of temperatures over which it operates. The greater the differential between input and output temperatures, the greater the theoretical efficiency. However, no heat engine is able to convert 100 percent of the available heat; it uses what it can and rejects the remainder, at a lower temperature, as waste.

One way to reduce this waste is to employ a "cascading" system of two or more heat engines. For the cascade to work efficiently, each succeeding cycle must be able to convert unused heat from the previous cycle at or near the temperature it was rejected. It sounds simple. Engineering it isn't nearly so simple, and each additional cycle increases the complexity.

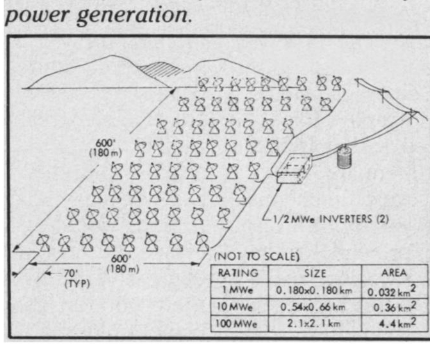
But soaring energy costs and dwindling fuel supplies are making cascading systems increasingly attractive. And here's where thermionic-energy conversion currently looks most promising. As a "topping" cycle, it could increase the overall efficiency of coal or other powerplants by up to 15 percent — to more than 50 percent.

Combustion temperatures of more than 3,000°F are available in fossil powerplants, yet the steam-turbines they commonly use to generate power operate over a range of only about 1,000° to 100°. Thermionic converters, which operate over a range of 3,000° to 700°, can top the power-generation cycle and still deliver virtually the same amount of energy as before to the steam turbines, says Fred Huffman, manager of the thermionics program at the Thermo Electron Corp. in Waltham, Mass. And the converters have the potential for efficiencies up to 40 percent, he says.



Thermo Electron Corp.

Parabolic collector (above) focuses solar energy onto a thermionic converter perched on struts above its center. Struts carry power and excess heat away. JPL's *solar farm (below) would employ a field of 11-meter (diameter) collectors for utility power generation.*



Jet Propulsion Laboratory

The principle behind thermionic conversion dates back to Edison's 1885 discovery that a current can be made to flow between electrodes of different temperatures, in a vacuum. In thermionics the vacuum is replaced by a sealed enclosure of electrically conducting gas — usually cesium — to neutralize any charge buildup that could halt electron flow. Electrons "boiled" off the hot electrode flow across the vapor gap, condensing on the cooler electrode. They return to the emitter via an electrical circuit.

Although the thermionics principle was developed in the 1920s, it lay virtually dormant until the late 1950s. By the '60s, thermionics research was being developed toward design of high-power-density and high-temperature systems to couple with fission reactors for nuclear-propelled long-mission spaceflights.

Huffman says that although his company was investigating topping-cycle concepts for thermionics 10 years ago, there was little federal-funding interest. Only after the National Aeronautics and Space Administration revised its mission plans deemphasizing thermionics in 1973, did the national thermionics program concentrate on terrestrial applications. It didn't hurt that the oil embargo occurred about the same period, he said.

Recent DOE-sponsored studies indicate that up to one-quarter of the heat wasted by conventional powerplants could be converted to electricity if thermionic converters — with performances no better than those already demonstrated — were used for topping. DOE expects improved converters to double their energy-saving potential.

When will thermionics make its commercial debut? Thermo Electron and Rasor Associates, of Sunnyvale, Calif., the two leading industrial developers of thermionics, both expect to have full-scale prototype converters ready for installation in an operating coal-fired powerplant by 1985. Although previously tested thermionic converters are fairly advanced today, Huffman says, they were never designed to withstand the corrosive environment inside a coal furnace. Developing ceramic and metal-alloy envelopes that conduct electricity well but seal out corrosive combustion gases are among current research aims. Developers are also working to increase both the current density that electrodes can handle and overall converter efficiency.

One thing that could hasten thermionic development is initiation of a joint U.S.-USSR technical exchange program, discussed last July when members of the U.S. thermionic community toured Russian research laboratories. Unlike its American counterpart, the Russian program focuses on coupling thermionics to nuclear-power systems for space applications. They are also investigating its potential in cascading of conventional-coal and magnetohydrodynamic powerplants (SN: 1/7/78, p. 6).

Following his visit to the Ioffe Physical Technical Institute in Leningrad, Ned Rasor, president of Rasor Associates, wrote "I continue to hold the work [of F. G. Baksht and his] group in awe." Several of their developments "are innovative and pioneering accomplishments" and certain of their results "continue to be far beyond those applied to such plasmas in the United States." Rasor said the program at the Kurchatov Institute of Atomic Energy in Moscow "could compensate for our virtual complete default" in thermionic work toward topping for high-temperature gas reactors. And of the Institute of Physics and Power Engineering in Obninsk (60 miles southwest of Moscow), site of the largest thermionic-conversion activity in the world, Rasor commented that "with its relatively good theoretical support and high practical motivation, this group is very likely to contribute useful basic data, discovery and leadership to a cooperative program."

On the same visit, representatives of the Italian Nuclear Energy Organization in Rome briefed the U.S. scientists on plans for a "cascaded thermionic-thermoelectric radioisotope generator" to drive an artificial heart.

And the German Organization for Air and Space Travel (DFVLR) in Stuttgart claimed a contract by a major German auto maker for design and construction of a gasoline-fired auxiliary-power unit for vehicles was "imminent." Rasor was told that the rapid increase in vehicle electric-power requirements was expected to continue as new equipment, such as electromagnetic brakes, radar and location trackers, is marketed. Projections by Mercedes show future automotive electrical requirements of 1,500 to 2,000 watts and operating lifetimes of 2,000 to 3,000 hours, he said. Current automotive electrical systems—with an overall efficiency of only 5 to 10 percent — now require running the engine to keep the battery charged. "The [proposed thermionic unit] could match or exceed this efficiency to automatically keep the battery fully charged," Rasor said, "and the waste heat could be used for standby passenger space and engine heating in cold weather." Cost will be important, however.

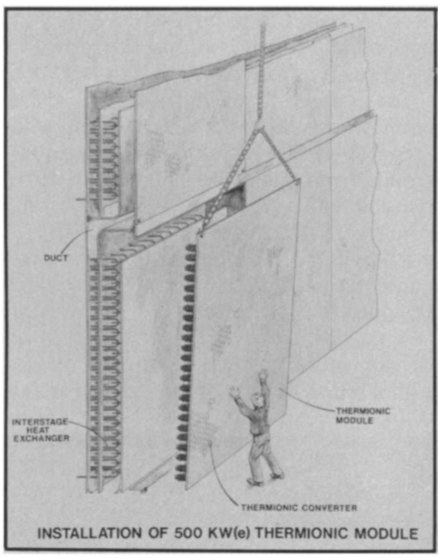
In this country, the Jet Propulsion Laboratory in Pasadena is investigating thermionics for converting sunlight into electricity. JPL's K. Shimada and M. Swerdling see possible applications in: powering remote sites not served by electric utilities, powering apartment complexes, driving hydrogen-production plants and even in aiding utilities in better use of solar power. In a study they presented at the 12th Intersociety Energy Conversion Engineering Conference in Washington last fall, their projected costs for a solar-thermionic power farm were higher than for conventional baseload generation plants, though "encouraging."

Despite optimism about its near-term applications and "reasonable" development costs, the U.S. thermionics program nearly faded into oblivion several times in recent years. Vic Russo of Rasor Associates felt the program's low visibility was a major factor. Ironically, he said, federal budget planners have presumed its low-level funding was indicative of the priority that federal development agencies attach to its potential. In fact, the groundwork and testing of thermionic systems in the late '60s and early '70s meant that fossil applications could be pursued relatively inexpensively.

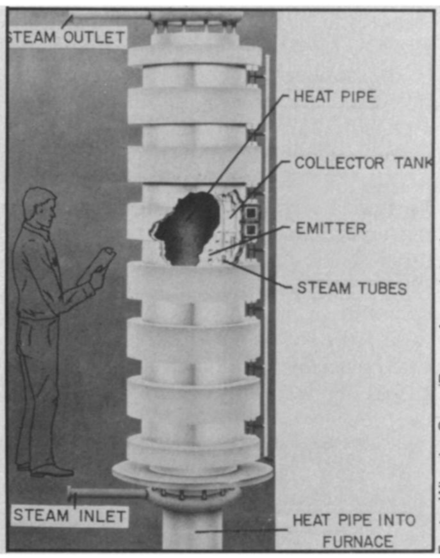
Thermionic systems have already operated successfully in excess of 10,000 hours in solar applications and 40,000 hours in nuclear applications in this country alone. The Russian program is currently estimated to be 10 times larger and has already operated four nuclear reactors using thermionic converters. (There is also speculation among the thermionic community in this country that the nuclear-propelled Russian Cosmos 954 spacecraft that went down over Canada January 24 [SN: 2/4/78, p. 69] used a thermionic generator).

Russo claims the organizational structure of energy-funding agencies posed further funding impediments to thermionics support. He says the program virtually got lost in the shuffle as it was divided among several divisions of the former Energy Research and Development Administration. Creation of a special power systems division within the energy department, and thermionics' inclusion within it, should make a big difference, Russo says.

The future of thermionics energy conversion can only get better as people learn more about what it is and what it has to offer, Russo says. □



Thermo Electron Corp.



Foster Wheeler Corp./Rasor Associates Inc.

The two major design concepts for fossil-plant topping by 1985. Thermo Electron is developing 500-kilowatt panels, each consisting of many small converters. Rasor Associates is working on large modules (right) capable of providing several hundred kilowatts each. The first concept is better suited for using reject heat to preheat furnace air; the latter is better for direct generation of steam. Both are designed for insertion directly into the corrosive combustion atmosphere of coal-fired furnaces.