in plentiful supply. Closed-cycle systems, involving wet or dry cooling towers, cooling ponds, lakes, or spray ponds, use 2-4% of the water employed in an open cycle "once-through" system. Or, they may not even use water at all. The water-based closed-cycle systems require more land than do the once-through systems, even though they use less water.

Agricultural requirements are simply what was used—water per irrigated area—in the United States. Use will depend on crops grown. California fruits and vegetables, and western cotton, are obviously very different than paddy rice production.

The industrial guideline is based on 3,000 gallons per day per manufacturing employee, the late 1960s construction standard for new manufacturing facilities. This, again, is a ballpark estimate. Water is used in industry for cooling thermal processes, for steam generation, as well as for processing, washing, and other sanitary purposes. Different types of products require different volumes of water, and different processes of making the same product require different volumes of water. A study sponsored by the American Waterworks Association prepared in the mid-1970s put the volume of water required per manufacturing employee at 12,600 gallons per day, more than four times the construction standard of the late-1960s. In the United States, Germany, and Japan, the chemical and iron and steel industries account for roughly half of industrial water consumption.

Lastly, the U.S. guidelines involve a 15-25% margin for system leaks and losses. The core water and sanitation systems of America's larger cities date from the end of the nineteenth century. That provision says something about the quality of a system which is approximately 100 years old (see **Tables 9** and **10**).

The overall situation is less complicated than all the provisos might make it appear. In India and China, 93% and 86%, respectively, of the water accounted for as withdrawn is used in irrigation for agriculture. Water use per irrigated

Energy and water for the future: the MHTGR

High-temperature gas-cooled reactors (HTGR) are an advanced form of nuclear fission reactor that originated as a spinoff of NASA's search for a nuclear propulsion system for manned missions to Mars in the 1960s, and prototype reactors have been operating for years at Fort St. Vrain, Colorado, and in the Federal Republic of Germany.

Modular reactors (MHTGRs) derive from the program of G.A. Technologies of San Diego, which has developed a standardized design for an HTGR module, able to produce 350 megawatts of thermal energy, which can be converted to about 140 MW of electricity. The General Atomics MHTGR has also been designed with a view to mass-producing the units, so that design, engineering, manufacturing, construction, and certification costs can be spread out over many units, making them much cheaper than previous nuclear power plants, which were each custom-designed and built from the ground up. This saving in capital costs, combined with the savings in fuel cost means, according to General Atomics estimates, that MHTGRs will be able to deliver electric power below the cost of a coal-fired power plant.

The MHTGR uses helium gas as a coolant, instead of water. Since helium gas is inert, and has very low neutron absorption charaterics, the MHTGR is top of the line in design safety. Pipes, valves, and other metal reactor parts will not react with helium, virtually eliminating corrosion. The inability of helium to absorb neutrons means it cannot become radioactive, so problems with embrittlement and possible fatigue-failure of metal parts are also eliminated. Moreover, since helium remains as a gas throughout the reactor cycle, there is no chance that the coolant will boil away; this also allows for visual television inspection of the inside of the reactor while in operation—something not possible during the steam phases of a water-cooled reactor.

MHTGRs for desalination

A unique advantage of high-temperature gas-cooled reactors is that their energy can be used as process heat or steam. Seventy percent of industry's energy needs are of this type. The advantage of MHTGRs, as the word modular implies, is their flexibility in siting. They can be placed where the heat energy or steam is to be used; designed not only for mass production, but also for ease of shipment.

For a thirsty world, MHTGRs could provide the thermal energy required for certain desalination processes. A study by the U.S. Department of Energy and the Metropolitan Water District of Southern California found that one single desalination plant, consisting of four 350 MW MHTGRs, could produce 106 million gallons of water per day, or 38.6 billion gallons per year. Thus, four such plants could meet the projected new water needs of Southern California, and provide 466 MW of electric power each as well.

As the study also pointed out, the only obstacle to immediately initiating a program of building desalination plants based on MHTGRs, is public acceptance of nuclear power waste disposal.