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HTGR—second nuclear generation

by Marsha Freeman

Within the next few years, the United States and West Germany could begin the mass production of High Temperature Gas-Cooled Nuclear Reactors (HTGRs) which could supply both the electrical and industrial energy needs of the advanced and developing nations. These versatile reactors represent the second-generation of nuclear technology which can form the bridge between conventional nuclear power and even higher-temperature fusion energy.

The HTGR, using helium gas as a coolant, is an important advance over current nuclear power plants, which use water as a coolant, because it can operate at much higher temperatures. The HTGR produces steam and process heat at temperatures appropriate for many processing industries. Making use of advanced fuel assemblies and materials, the HTGR is also safer, as well as more economical and flexible, than its predecessor, the light-water reactor.

Gas-cooled nuclear reactors have been under development since the beginning of the nuclear era in the 1950s, and should have become commercially available during the past decade. The collapse in electric utility nuclear-reactor orders since the late 1970s in the United States stopped the HTGR program in its tracks.

HTGR technology has already been demonstrated in both the United States and West Germany, where power plants of more than 300 megawatts (MW) have been operating. Now the HTGR is being reconsidered in a small-scale, modular design for both domestic use and export, particularly to developing nations.

A crash program to make this technology available on a mass-production basis, would mean that nuclear-centered agro-industrial complexes could be built around new cities everywhere—from earthquake-devastated Mexico City, to nearly abandoned former-industrial cities in the United States.

The advantage of higher temperature

The HTGR that is now being designed for commercial use, will produce process heat or steam at about 1,000° F, compared to the limit of about 600° for water-cooled reactors. For the production of electricity using steam turbines, this means a greater conversion efficiency, since that efficiency is a function of the difference between the inlet and outlet temperature. The HTGR has demonstrated a heat-to-electricity conversion efficiency of nearly 40%, compared to about 32% for light water reactors.

But the uniqueness of the HTGR lies in the fact that, at the same time the reactor is designed to produce electricity, it can also have some or even all of its nuclear energy diverted to produce process heat and steam for industry, as required. Over 70% of the energy used in American industry is non-electric, in the form of heat or steam.

At 1,000° F, the reactor can provide at least half of the steam and process heat to American industry which is now supplied by the burning of finite fossil fuels. In 1981, U.S. industry used approximately 20 quadrillion BTUs of primary energy for heat. Of that, 15 quads were at temperatures of 1,000°, or lower, and about 9 quads were in the form of steam. The current HTGR design could supply all of that industrial energy requirement.

Some estimates indicate that by the year 2000, the potential industrial steam market could be over 100 equivalent HTGR units of 1,170 MW thermal each. This use of nuclear-generated process heat will extend finite oil, coal, and natural gas resources, and allow the industrialization of countries that do not have their own reserves of fossil fuels.

For example, today nearly all hydrogen that is produced worldwide uses methane, or natural gas, as both a chemical feedstock and source of heat in the steam reforming process. If the steam reformer used the heat from an HTGR, rather than burning methane, the same amount of hydrogen could be produced, using 40% less natural gas. The conversion efficiency is about 90%, from nuclear fission energy to process heat.

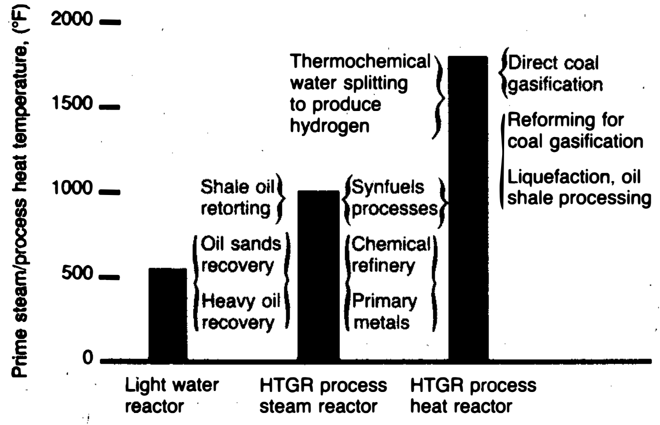
At GA Technologies, Inc. in California, HTGR developers have envisioned an evolutionary series of reactors, going to higher and higher temperatures (see **Figure 1**). This array of HTGR reactors provides heat at various temperatures, along with electricity, and could eventually meet the total energy needs of industry, agriculture, and cities.

For the generation of HTGRs that will be commercially produced first, the 1,000 degree heat will be useful for many aspects of fossil fuel refining. This could include the refining of petroleum, the production of fertilizers, paper production, and other chemical processes.

At the same time, the economical electricity produced by

FIGURE 1

Process heat applications for the HTGR



The HTGR makes a higher temperature process heat and steam available for industrial processing than today's generation of light water reactors. At 500°, the nuclear power plants on-line today are only used to produce electricity. The HTGR process steam reactor, ready for commercial production, will extend that temperature to 1,000°, making it possible to use that energy for the refining of oil, and other chemical industries. The next-generation process heat reactor will allow the production of hydrogen, and other fuels, at a temperature of about 1,800°.

the HTGR would be the engine for the refining of aluminum and other metals, advanced plasma steelmaking technologies, all applications of laser metalworking, lighting cities, powering transport systems, and pumping ground water for irrigation in agriculture.

Steam could be piped to nearby factories of all kinds for space heating and manufacturing needs, and district heating and cooling of homes and commercial buildings would also be provided by the central power station.

As the later-generation and more advanced HTGRs came on-line, high-temperature water electrolysis for hydrogen production, the steam reforming of methane to produce hydrogen, desalination, and other processes would be added to the capabilities of the HTGR nuclear-complex. In one design, six million gallons a day of fresh water could be produced from seawater, for drinking and irrigation.

Modular design

plants as requirements increased. Studies done by the Oak Ridge National Laboratory and others in the late 1960s indicated that entirely new cities could be designed and built using clusters of nuclear power plants to supply all energy needs. Sites were studied in Peru, India, Australia, and other nations, where other forms of energy are not available or practical.

In many parts of the world, only these nuplexes will enable whole nations to enter the 21st century. The HTGR allows processing industries to be closely connected to the energy supply, and the siting of cities in arid regions where water-cooled reactors could not be placed.

The gas-cooled reactor

There are operating, maintenance, and safety advantages in going from a water- to a gas-cooled nuclear power reactor. If a chemically inert gas, such as helium, is circulated through the reactor core as the coolant, there is no possibility of corrosion in the piping or other metal reactor parts because the helium does not react with other materials.

Helium is also a gas in every phase of its use in the HTGR. In a light-water reactor, the original coolant is water, which becomes steam in its gaseous phase during cooling. These phase changes make it more difficult to accurately measure the pressure and other parameters of the coolant, which is not a difficulty in the helium-cooled reactor. In addition, the gaseous helium makes it possible to visually inspect the inside of the reactor during all phases of operation, which is not possible if the operator has to try to see through water.

Unlike water, helium is also virtually radioactively inert. The gas has a low neutron-absorption cross section, which means that even if the coolant were bombarded by neutrons from the fissioning fuel, which is extremely unlikely, it would not become radioactive. If any of the helium escaped, there would be absolutely no danger to the public.

The major safety breakthroughs made in developing the HTGR was a product of the research and development work done in the 1960s in nuclear reactors designed for use in space. When the United States was still planning to send a manned mission to Mars, nuclear reactors were under development for both baseload power generation and propulsion.

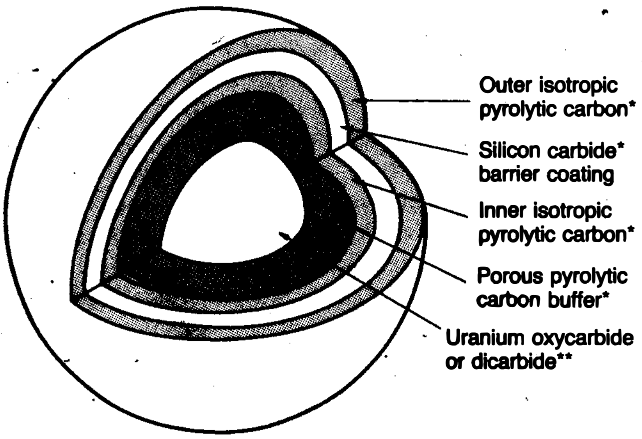
Pebbles for fuel

In order to generate nuclear power in space, compact, high temperature designs are highly desirable. The reactor would also have to be virtually maintenance-free due to its inaccessibility, and safe, because people would be very close by, especially for propulsion applications. Experienced nuclear industry contractors worked with the National Aeronautics and Space Administration to design fuel pellets that could withstand high temperatures, with thermal insulation to keep the fuel intact. The Fort St. Vrain HTGR in operation today in Colorado, and the HTGRs in operation in West Germany, make use of those fuel "pebble" designs.

A particle of either fissile uranium or non-fissionable but fertile thorium the size of a grain of sand, is coated with a graphite and silicon carbide shell. In tests conducted on the small, 15 MW electric AVR reactor in Germany, these fuel pellets have remained intact at temperatures up to 3,600° (see **Figure 2**). The shell acts as a "miniature pressure vessel" around each pebble of fuel, containing all of the fission products.

FIGURE 2

Fuel pebbles for the HTGR



*Trisco coating

**Fuel kernel

The design of each fuel pellet for the HTGR makes each one of the particles a small "pressure vessel" which keeps within it all of the fission products from the fission reaction. The core of the pellet is a kernel of uranium carbide, and can also include readily-available thorium. A series of coatings, largely of carbon, provides a temperature buffer around the fuel. If there is a loss of helium coolant during the operation of the power plant, the fission process stops. The afterheat from the core is absorbed by the carbon/graphite coating surrounding each fuel pellet. This is the safest nuclear fuel design that has been used for power production.

The German reactors use 35,000 of these encapsulated fuel particles in a "pebble-bed" reactor design, where, over a period of months, each fuel particle percolates through the reactor about 10 times, using up its fuel as it produces neutrons and heat through fission reactions.

The United States has decided to take these same fuel pellets and mix them with a binder, so they form compacts that are one-half-inch in diameter and 2.25 inches long. These compacts are sealed into fuel rods that are placed vertically through 31-inch high hexagonal graphite fuel elements. The core consists of stacks of these graphite fuel elements, through which the helium coolant flows in vertical channels.

The advantage to the German pebble-bed reactor is that it is continuously refueled. When the spherical fuel particle is spent, it is removed from the reactor as it drops down to the bottom on one of its circulating passes.

In comparing the two designs, U.S. experts found that since the other parts of the nuclear plant, such as the steam generator and turbines, have to be shut down periodically for maintenance anyway, the non-refueling feature of the pebble bed design was not a significant advantage. They have, therefore, opted for the prismatic annual core configuration, described above.

This pebble fuel design has performed up to expectation under many different operating conditions in both U.S. and German HTGRs. The U.S. HTGR, designed to use thorium, which is converted to fissile uranium-233 under fission conditions in the core, means that the reactor uses between 25% and 50% less uranium than a light-water reactor. Either low or highly enriched uranium can also be used.

Fail-safe safety

In 1974, the 330 MW Fort St. Vrain HTGR, built by GA Technologies Inc. (then, General Atomic Company), began operation. Since then it has generated more than 3 billion kilowatt hours of electricity for the Public Service of Colorado utility. It has demonstrated a conversion efficiency of nearly 40% and has been used for extensive safety tests.

Unlike any of the other nuclear power plants in operation, Fort St. Vrain is not required to keep a full-time nuclear expert on site, which indicates the confidence even the regulatory-mad Nuclear Regulatory Commission has in the HTGR technology. A nuclear expert must be on call, within an hour's reach of the plant.

The way former NRC Commissioner Joseph Hendrie described the HTGR, was that if you had a loss of coolant, the operator could go down the street, have a cup of coffee, and take his time deciding how to proceed. It would take hours, not minutes, for even a small amount of heat to build up inside the reactor core.

Like today's light-water reactors, the HTGR fuel will stop fissioning if there is a loss of coolant and the temperature in the core rises. In conventional power plants, within the first couple of minutes, the afterheat can bring the core temperature up to 3,000°. Like the Three Mile Island situation, this can begin to melt the fuel elements, causing damage to the reactor.

In the HTGR, the graphite surrounding each fuel pellet absorbs almost all of the residual heat inside. There is also graphite in-between the fuel rods, which in the Fort St. Vrain plant, weighs more than 1,500 tons. In addition to being an excellent heat absorber, graphite gains strength with an increase in temperature. Tests at Fort St. Vrain have demonstrated almost immeasurable core temperature rises even when all the coolant is stopped.

In the HTGR, all of the helium coolant stays within the core. Therefore, a break in a pipe outside the reactor cannot effect the cooling system, unlike the water circulating in a light-water reactor.

This nation's electric utilities were so impressed with the safety performance and increased efficiency of the Fort St. Vrain HTGR, that 30 of them joined together in 1978 to form Gas Cooled Reactor Associates to commercially develop the technology. Even earlier, 52 utilities participated with Philadelphia Electric Company to put the small 40 MW electric

Peach Bottom HTGR on-line in 1967. Peach Bottom, which was decommissioned in 1974, had an availability rating of 88% (compared to about 66% for light-water reactors), and averaged over 37% efficiency.

In 1979 an Industrial Users Group was also formed, to encourage HTGR development. The major industries represented, who were looking forward to the availability of high-quality industrial process heat and steam from the HTGR, were from the chemical, oil, steel, glass, and coal industries.

Since the beginning of the HTGR program, industry has contributed more funding to develop the technology than has the federal government. Through 1982, over $1.5 billion had been spent on HTGR research, development, and demonstration. Over 70% of that funding came from the utilities and industries that would use the reactor, and the nuclear industry that would build it.

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By the early 1980s, the Fort St. Vrain plant had created enough confidence in the HTGR that the GCRA was ready to proceed with a "Lead Project" 820 MW electric commercial plant. In testimony before Congress on the fiscal 1983 budget, the GCRA identified five possible regional project sites, including one on the Gulf coast, which would provide process steam and electricity to the Port Arthur oil refinery.

The large Lead Project would produce 2,240 MW of thermal energy, which could be utilized in flexible electrical-heat configurations. It could, for example, provide 7.4 million pounds of process steam per hour to industry, in addition to 231 MW of electricity, or any mix of heat and electricity up to the full 820 MW of just electricity.

This co-generation flexibility would allow the plant to operate at full baseload capacity all the time. During non-peak periods, such as at night, the plant could be used to produce mostly steam, for delivery to industries that would run at night. If the steam turbines went down unexpectedly, rather than shutting the entire plant down, the reactor could just continue to produce process heat and steam.

In later versions, the plant would be designed to run at full capacity at night, producing and storing hydrogen, which would be delivered to the steel, transport, or fertilizer industries when needed.

The plan, up until 1983, was to have the large Lead Plant on line by the mid-1990s.
for by the utility industry, with the government contributing the other 25% to finish the required R&D. At the present time, the plan to build this industrial-sized cogeneration HTGR has been scrapped, due to the refusal of both the Carter and Reagan administrations to adequately fund the program, and the dim prospects, under current economic conditions, that utilities would be willing to order new, large nuclear reactors.

But the HTGR technology is too promising for either the utility industry or the nuclear suppliers to have given up completely. With agreement from the Department of Energy, the HTGR program was shifted last year toward the development of small, modular HTGRs, which could be factory fabricated, and added incrementally to the existing U.S. power grid.

There is also the expectation that developing nations, which could not easily absorb the large capacity of either conventional light-water reactors or U.S.-sized HTGRs, will be able to afford and use smaller reactors.

The modular HTGR

The modular HTGR now being designed in the United States will produce 350 MW of thermal energy, which can be converted to about 140 MW of electricity. A factory-produced modular reactor would have an upper limit on size of about double that amount. The major advantage of the modular concept is that all of the reactors will be identical, and mass produced in a factory, rather than constructed on site.

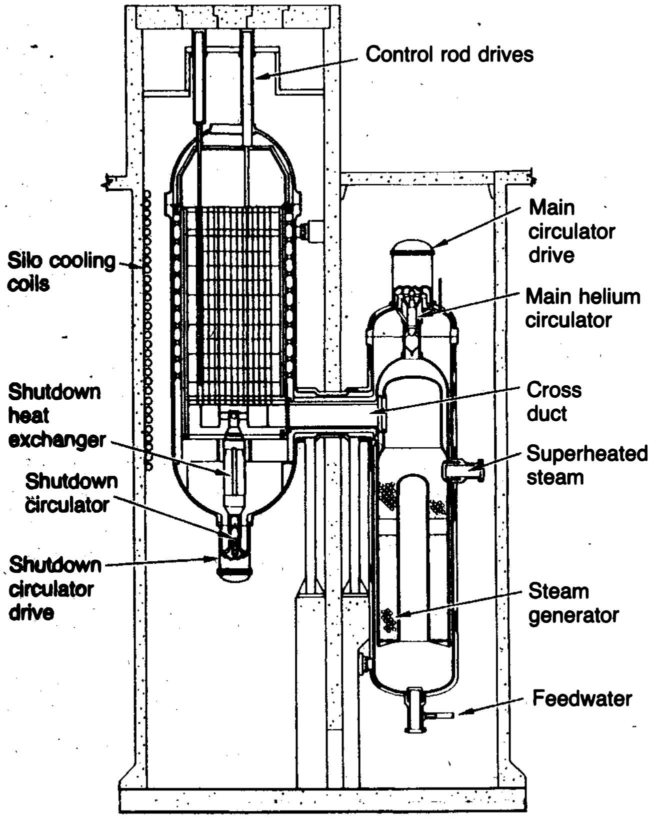
This factory mass-production method can reduce the time it takes to build a plant to less than three years, compared to the current six-year timetable in France, not to mention the 12-18 years it takes to put a light-water reactor on-line in the United States. The reactor will be inspected at the factory, and certified before its leaves the gate. It can be shipped, in one piece, to the site by truck, ship, or rail, and, when it arrives, it will simply be put into place. There will not be any licensing required for each plant, nor will there be any need for inspectors on site.

One configuration which looks very promising is to place the HTGR module, along with its attached steam generator, underground in a silo (see **Figure 3**). Rather than using prestressed, reinforced concrete for containment, the reactor would be inside a steel pressure vessel, similar to today's nuclear plants, surrounded by a concrete-lined silo.

When the module arrived on site, the bottom half would be lowered into the silo, attached at the bottom, and then the

FIGURE 3

Silo-basing for the modular HTGR



The most promising basing mode for the modular HTGR is to place it into a concrete-lined silo, under the ground. The design being developed by GA Technologies places the steam generator on the side of the nuclear reactor. The helium coolant flows through the cross duct to the steam generator. Colder feedwater is provided from the bottom. The Superheated steam, which has absorbed heat from the hot helium, is removed from the right side of the generator. The reactor is refueled from the top, where the fuel assemblies, made up of pellets, is removed about once every four years.

upper half would be secured. The preparation of the silo, and the non-nuclear balance-of-plant above ground, would be proceeding at the same time the factory was producing the module. When the module arrived and was "plugged in," the entire plant would be ready for operation. In this way, the plant could be on-line in about 33 months.

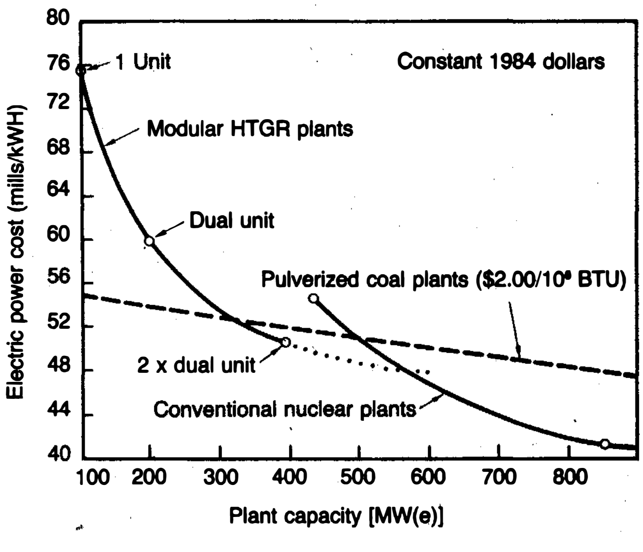
The Department of Energy evaluated four possible modular HTGR designs in 1984, and in February 1985 selected one which will include the prismatic annular-core fuel design, the steam generator side-by-side the reactor, and a steel pressure vessel. They have placed requirements on the reactor that it be available 80% of the time, that unscheduled down-time be less than 10%, that it have a cost advantage of 10% over a comparably-sized advanced coal power plant, and that it be operational by the mid-1990s.

The target cost for the modular reactor is about $2,200 per kilowatt of installed capacity. GA Technologies has estimated that, for the United States, if the units were sited in pairs, two dual-unit pairs would bring the cost of delivered electric power down below the cost of power from an advanced pulverized coal plant, and below the cost for a single, comparably-sized light-water reactor (see **Figure 4**).

Siting only one module would increase the total cost dramatically, mainly because the balance-of-plant equipment costs (for turbines, control room, etc.) would be incurred anyway. The modules are being designed so that a pair would share one turbine, and the same site preparation and balance-of-plant facilities and costs. For the developing nations, the site would be prepared and facilities built to house more than one module, even if they were ordered years apart.

FIGURE 4

Power costs of the HTGR



The cost of delivered electric power, measured in mills per kilowatt-hour, is higher for a single modular HTGR, or one pair, than for either an advanced coal plant, or a conventional nuclear reactor. Sited in at least two pairs of two each, however, the cost is reduced and is competetive with both of those technologies. For use in advanced sector nations, the HTGR modules would be built in groups of at least two, and most likely, four or more. The four reactors can share the balance-of-plant, including the turbines and other equipment. For the developing nations, where the cost is not as important as ease of construction and operation, the modules can be added one at a time, as the need develops. The site would be prepared, from the beginning, to handle a group of reactors.

The modules in this HTGR "park" could be flexibly connected, so that if a turbine from one pair needed maintenance, but a module from another pair was down for refueling, they could be reconnected to keep the entire plant on-line. (Refueling needs to be done only every four years, with a plant shut-down time of 23 days.) This increased flexibility adds to the percentage of time the plant capacity is available.

In terms of safety, the goal is to have, not only a "walk-away" reactor, which requires virtually no attention from operators in case of any problem, but also a "walk-back" system, where the plant can simply be restarted, without suffering any damage, when the problem is corrected. The modular HTGR is being designed to be "passively safe."

The small size of the modular HTGR makes this possible. The power density of the core is actually lower than today's light-water reactors, and the plant has such a small thermal rating (350 MW) that, if there were a loss of helium coolant, the afterheat could simply be vented out toward the sides of the vessel, and if necessary, into the earth surrounding the silo. There is no possibility of a release of any radioactive fission products, since they are all contained inside each fuel pellet.

This feature, which means there can be no threat to the public, eliminates the need for NRC-mandated public evacuation plans, which has stymied the operation of already-completed nuclear power plants. The modular HTGRs could be sited directly under cities.

The fact that the reactor runs at higher temperatures, and therefore at higher conversion efficiencies, means there is about 26% less rejected waste heat. Estimates are that one-third less water will be needed for cooling, allowing the modules to be sited in semi-arid regions. Today's nuclear power plants must be sited on rivers, lakes, or ocean fronts.

The emphasis in the Department of Energy modular HTGR program is electric, but the modules could be used for the co-generation of industrial-quality heat and steam. It is feasible, at this small size, that a company that is either electricity intensive, such as aluminum and other metals refining, or heat and steam intensive, such as petroleum refining or paper production, could purchase one or two modules for their own production facilities. The military is also interested in these small power sources for situations where they need to be independent of the utility power grid system. Modular HTGRs could also provide the total energy requirements for isolated areas, as well as islands. In 1981, the House Armed Services Committee directed that a feasibility study be done to see if HTGRs could be used to meet the energy requirements for the government's Sandia and Los Alamos National Laboratories.

The useful temperature of the modular reactor under development will be set at 1,000°. This is lower than the outlet temperature of either the Fort St. Vrain or German HTGRs. Second-generation reactors would require the development of more advance materials, not for the reactor itself or the fuel elements, but for the interface between the reactor's helium coolant heat and the transfer through heat exchangers for the use of the heat or steam.

Advanced ceramics and carbon-carbon composites now under development for energy applications, such as high-temperature magnetohydrodynamic direct conversion, would allow the HTGR to go up to the more than 1,700°, which is an ultimate goal for the technology.

The higher temperatures would be the basis upon which economical production of hydrogen and other industrial applications would become available. In addition, it would become possible to eliminate the need for the century-old steam turbine production of electricity and use gas turbines.

The helium coolant could be used directly in turbines, rather than creating steam, which would increase conversion efficiency from 40% up to 50%. This closed-cycle system could recirculate the helium back to the reactor, at a temperature of about 300°, or this reject heat could be extracted and used as a bottoming cycle, for lower-temperature applications. HTGRs using these helium gas turbines could literally be sited in deserts, as no water is required either for cooling or electricity generation.

With the HTGR, there is no possibility of a release of any radioactive fission products, since they are all contained inside each fuel pellet. This eliminates the need for NRC-required public evacuation plans, which have stymied nuclear plant operations.

Helium-cooled breeder reactors have also been under investigation since the early 1960s to take advantage of the inherent safety and higher temperatures available using the helium gas. The lack of comitment in the United States to build any kind of breeder reactor has stalled this potential evolution of the HTGR.

When could we have them?

The current Department of Energy timetable projects that two more years of final design work need to be done, and that the first "demonstration" module would be operational in the mid-1990s. But, unlike other advanced technologies, even larger sized HTGRs have already been operating in the United States and in Germany. There is no reason to build a "demonstration" reactor.

According to industry spokesmen, and common logic, there is no objective reason why the first factory-produced HTGR modules could not start rolling off an assembly line at the beginning of the next decade. The technology is proven, and the modular reactor has been conservatively designed, using only proven and available materials and technology. An HTGR factory could produce about one module per month.

When one considers that the United States has slowed its production and siting of any kind of baseload power plants (coal or nuclear) to a virtual standstill, and that even if there were no growth in demand, by the year 1995 about 100,000 MW of existing capacity should be retired as they near the end of their useful lives, we are going to need as many power plants as we can manufacture, as quickly as we can produce them.

The energy deficit in the developing nations in the world is staggering. In some studies, the suggestion has been made that the countries without indigenous reserves of fossil fuels should be immediately supplied with small, modular nuclear power plants. It is pointed out, however, that even in the oil producing countries, by at least the beginning of the next millenium, they will need nuclear power, as well.

For the already industrialized nations, a 100 MW electric plant could supply electricity and heating for about 100,000 people. This figure would be several-fold higher in nations where virtually no electricity production exists today. The plants could add small increments of power to new grids, and their size would quickly allow developing nations to participate in the fabrication and erection of new plants.

Interest in HTGRs has existed in the developing countries since the technology was demonstrated. In 1981, the Mexican Academy of Engineering held a symposium on nuclear energy in Mexico City and invited General Atomic Company to present a paper on the "Status of the HTGR." Because of the present "survival mode" of operation of the U.S. nuclear industry, and the economic disaster perpetrated in the developing sector by the International Monetary Fund, GA Technologies no longer has a marketing representative for Latin America.

An important paper presented in 1983 to an international conference session on compact nuclear reactors for emerging nations, states that there "would be substantial technology transfer between the developing nations in the areas of construction, operator training, maintenance, etc., made possible by the adoption of a standardized design."

This paper, optimistically titled, "A Small Modular HTGR Nuclear Power Plant Concept to Meet the Total Energy Needs of the Developing Nations," and presented by Colin F. McDonald from GA Technologies, also states, "This paper has been presented 30 years after the 'Atoms for Peace' proposal presented to the United Nations General Assembly by President Eisenhower in December 1953. The deployment of the small modular HTGR plant in the developing nations could well result in the realization of this proposal."

Considering that the United States's power-plant construction has slowed to a virtual standstill, and that, by 1995, about 100,000 MW of existing capacity must be retired, we are going to need as many power plants as we can manufacture as quickly as we can.

The United States is certainly not the only nation developing HTGR technology. The Germans have long realized that this nuclear advance could heat cities, run industry, and make more efficient use of their fossil-fuel reserves. The United States has had an active cooperation effort with German industry, and the HRB industrial group that is a partner in the current 300 MW Thorium Higher Temperature Reactor (THTR) plant is owned 45% by GA Technologies.

Funding for the HTGR in the Federal Republic of Germany has been at the $250 million per year level, and modular designs are now being evaluated in Germany, for commercial introduction. GA Technologies and German industry have been sharing data and operating experience on the four reactors that both nations have built.

The Japanese are interested in HTGR technology at higher operating temperatures, in the VHTR, or Very High Temperature Reactor. They are looking at this as a heat-source only, mainly for industry. On the current timetable, the Japanese plan to build a test reactor VHTR by 1990, of about 60 MW thermal, as a test bed to develop new high-temperature materials. They are cooperating with U.S. engineers, particularly on the development of graphite applications and technology.

The Soviets have apparently built a small, 5-MW thermal gas-cooled reactor, and have used nuclear reactors for space heating for district and industrial applications in the past.

The United States has been ready to "go commercial" with the HTGR since the successful operation of the Fort St. Vrain plant. If that step is not taken soon, the United States will find itself in the same position with the HTGR that exists now with the breeder reactor and nuclear fuel reprocessing. It will be faced with the prospect of importing advanced nuclear technology from other nations in the world which did not allow themselves to self-destruct at the beck-and-call of international financial interests who state that the advanced sector nations should become "post-industrial" societies.