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German utilities start up advanced nuclear reactor

William Engdahl reports on the advanced West German High Temperature Gas Reactor, HTGR, which began operation Sept. 17.

This writer was part of the first official delegation invited to tour the advanced West German Thorium High Temperature Reactor, HTGR, at Hamm-Uentorp, northeast of the German steel center of Dortmund, on Sept. 17. Ten days before, the reactor was put into service, operating initially at 10% of capacity, while various testing is carried out. Within three weeks, the reactor is expected to be operating at 40%, at which point it will actually start delivering power sufficient to produce electricity commercially. By year-end, it should be at its full power capacity, 300 megawatts.

The successful operation marks the realization of the first commercial prototype of the so-called pebble-bed reactor design, which was pioneered by Dr. Rudolf Schulten of Aachen University, a former student of Dr. Werner Heisenberg. The design dates back more than 25 years, when Schulten developed it while working with Brown Boveri Corporation of Mannheim, Germany. The concept, in essence, is remarkably simple and effective. Designing the fuel elements in the form of hundreds of thousands of spherical balls, approximately the size of golf balls, enables the spent fuel elements to be removed and new fuel added in a continuous process. As a result, there is no need to shut the reactor down to refuel, as is necessary in conventional Pressurized Water Reactor types. The pebble-bed, sometimes called potato-bed reactor, is the only such reactor design which permits this continuous operation for the entire life of the reactor.

The original design intent is to develop a reactor which will both produce efficient electric power, as well as commercial heat for industrial processes or, if desired, for district heating. With the successful operation of this 300 MW prototype, the 500 MW reactor will be the next generation, possibly to be begun before the end of 1985, according to officials of Brown Boveri.

Major boon for developing sector

Because of several aspects of its design, the HTGR is extremely suitable for countries which are initiating nuclear power. The reactor design is extraordinarily well built to give it inherent safety. It is designed around a ceramic core which has high thermal capacity. There is no possible "core meltdown" or any such danger. This means siting of the reactor can also be in the immediate proximity of urban locations. Further, unique design of the special dry-cooling tower heat dispersion, makes possible siting away from any river or water source normally used for cooling. This aspect of the design, as well as extremely simple operating and safety design, means that, in event of malfunction, there is no possibility of such reactor damage as occurred at the Three Mile Island reactor in 1979.

In event of loss of coolant, the high temperature resistance of the ceramic fuel elements and structure of the graphite reactor core, the temperature can rise to 3,000° C. before affecting structural strength. Other safety redundancies make the reactor perhaps the safest design presently existing in nuclear-reactor technology. Notable is the special characteristic of the uranium-thorium fuel elements used. Because the reactor core is designed to have a negative coefficient of temperature during all operating conditions, in event of accidental temperature rise in the reactor core, the negative coefficient of temperature causes a reduction in reactivity of the fuel elements because of the inherent properties of the fuel. Higher temperatures cause higher neutron absorption by the thorium.

The design features of the HTGR have been successfully tested since 1967 in an experimental 15 Megawatt pebble-bed research reactor, AVR, at Jülich, in the state of North Rhine-Westphalia, near Hamm-Uentrop. Their 18-year experience with that reactor confirmed the feasibility of the pebble-bed continuous fueling concept, which significantly increases reactor operating efficiencies.

Utilizing the largest vibration test facility presently in Western Europe, the SAMSON (Simulation Apparatus for Modeling Seismic Oscillations of Nuclear components), Brown Boveri Corporation verified the safe functioning of the loaded reactor core under seismic conditions. The tests were sponsored by the North Rhine-Westphalian Ministry for Economics and Transport. Because of incredible (and often unnecessary) regulatory changes introduced during the period of construction, which began in 1971, the completion of the reactor was delayed approximately 10 years. A spokesman for Brown Boveri noted that much of this time was due to demanded retroactive design changes, often based on requirements for conventional light-water reactors as West Germany—as most Western countries—underwent a major

About this series

This is the first in a two-part series featuring new designs for nuclear power.

While the nuclear industry has stagnated internationally, even in France, relative to the plans of a decade ago, in the United States the situation is worse. The nuclear industry in the United States has been virtually destroyed by the anti-nuclear lobby, through direct political intervention and, indirectly, through financial warfare. Costs have mounted as the time of construction has been irrationally extended, and the utilities made the target of attack by disgruntled rate-payers and tax-payers, egged on by this same anti-nuclear lobby.

U.S. design of light-water reactors set the pace internationally. Yet many of their features were determined by extraneous pressures on the utility companies, who were forced to justify their investment in nuclear power on the basis of narrowly construed cost-benefit analysis. In the early days, they opted to achieve economies of scale. As the plants became larger, safety features necessarily proliferated and became increasingly complex. Because the industry was continually defending its very life, the development of new conceptions for nuclear power plants was largely frozen in the design stage.

This series will review several next generation nuclear plants. In the first, we will be looking at the high temperature gas reactor. This is by far the most promising road of development for nuclear power, pending the development of commercially feasible fusion energy for the generation of electricity. Notwithstanding, there are other plans for the modular production of light-water reactors which are attractive, particularly because they can go into production immediately, while there may be a need for further testing of modular design conceptions for high temperature gas reactors.

The need for such mass production is especially acute in the United States. By the year 1994, about 100,000 megawatts of electric producing capacity, in the United States, will be 30 years old, and due for replacement. Even under present depression conditions, utility planners are increasingly worried that there will be brownouts and blackouts during peak periods of power demand in New England, the Gulf Coast, Florida, the Northwest, and Midwest. In all of these places, surplus generating capacity is shrinking and power transmission lines are overburdened. Peak demand is expected to rise from the present 465 gigawatts to 566. Even with the presently planned increase of capacity to 704 gigawatts, a reduction from the 175 gigawatts scheduled to be added to the grid a mere two years ago, the reserve margins for demonstrated capacity will fall below 21%. Such a reduction in excess capacity places the whole national grid in jeopardy.

At present the United States has about 650 gigawatts of electrical capacity. If it is to contribute to reversing the present economic depression, this capacity must be more than doubled by the end of the century. Without mass production of nuclear plants, such a goal would be virtually impossible, particularly if the United States also undertakes to export nuclear plants to the developing sector, where they are urgently needed.

—Carol White, Science & Technology Editor

political scare offensive from the well-organized anti-nuclear lobby. One result, however, is that such thorough testing has been carried out on the HTGR that it can hardly be considered as experimental at this point.

Given the special features of the HTGR, its flexibility, its extreme safety features, and its ability to be built in urban centers, and especially its co-production of energy in the form of heat which can be used, for example, in the chemical industry, or to produce gas from coal economically, it is excellently suited for construction in developing nations. Nations with existing nuclear industry infrastructure, such as India, Mexico, Argentina, Brazil, the Philippines, or South Korea, are excellent candidates. India, which has some of the world's largest reserves of thorium, used in the reactor fuel, would be a superb candidate. A spokesman for the reactor consortium emphasized that the only constraint existing is that of financing. The power range, according to Brown Boveri, which they are presently making available, ranges from 100 to 600 megawatts. This is also ideally suited to medium-range power grid requirements of developing countries, where the conventional 900 or 1,300 MW versions of light water reactors from Westinghouse, GE, or KWU are too large to be economical for the foreseeable future. Its seismic and safety features mean that it is excellent for such regions as Mexico. What better way to rebuild infrastructure in devastated Mexico than to launch a major nuclear complex—tapping the existing petrochemical resources there—by the West German government to guarantee long-term low-interest financing to export several HTGR turnkey projects to select sites in Mexico. It would have the added feature of providing badly-needed employment in the most skilled sectors of the German economy.

Because of its design, the HTGR is extremely suitable for countries which are initiating nuclear power. It is designed around a ceramic core with high thermal capacity. Siting can be in the immediate proximity of urban locations. The design of the special dry-cooling tower makes siting possible away from water sources normally used for cooling.

Using the economics of the largest conventional light-water reactor presently on the market, the West German 1,230 megawatt PWR, Brown Boveri calculates that its 550 MW version is fully cost competitive in terms of cost of electricity per kilowatt-hour. For two twin 550 MW HTGRs, generating costs are actually lower than for the 1,230 MW reactor. Brown Boveri expects to sign a contract for construction of the 550 MW version before the year end, based on successful operation of the 300 MW Hamm-Uentrop reactor. Based on experience to date, Brown Boveri estimates a 6-year completion time for the reactor.

Because of its simple design features, capital construction costs are far lower than for the conventional nuclear units presently available. Its economics are greatly assisted by the higher thermal efficiency for power generation. The HTGR operates at approximately 41% efficiency, significantly higher than conventional light-water reactors, as well as conventional fossil power plants. This further makes the HTGR economical. The high temperatures of the HTGR, up to 950° C., allow use of steam turbines at conditions corresponding to conventional power plants. Conventional light-water reactors are only able to reach maximum heat of 300° C. at about 33% thermal efficiency. This makes feasible process heat for coal gasification.

The fuel pebbles in the 300 MW Hamm-Uentrop reactor consist of 675,000 spherical balls each machined to 6-cm size. Inside is a kernel of uranium oxide and thorium oxide. The core is a graphite shell of layered pyrocarbon. The fuel elements are fabricated at the West German Nukem near Frankfurt. The thorium is converted to fissile uranium by neutron absorption. The heat generated in the reactor core is then transferred to the inert helium coolant gas which flows down through the pebble-bed reactor core. Because of the special properties of the graphite shells of the fuel elements, little radioactivity is released to the coolant gas.

The coolant gas is then transferred to the steam generators where the heat is absorbed by a steam-feedwater system and transferred to a turbine. Helium is ideal for its specific physical and thermodynamic properties. The radioactive primary circuit is fully separated from the non-radioactive secondary circuit. As it goes through the reactor core, the helium is heated to approximately 750° C. In the steam generators, feedwater is evaporated and superheated. Leaving the steam generators, the steam goes to the high pressure section of the Brown Boveri turbine, where it is then reheated in the steam generator, whence it drives the medium and low pressure sections of the turbine before it is finally condensed by heat absorption. The mechanical energy of the turbine is transformed into electrical energy by a generator coupled to the turbine which is converted to 220,000 volts by a power transformer.

The inauguration of the 300 MW high-temperature reactor at Hamm-Uentrop is a long-overdue advance in development of reactor technology.