Nuclear Energy

China Is First With Advanced Reactor

by Jonathan Tennenbaum

While much of the world is gripped by a steep economic downturn following the collapse of the U.S. "New Economy" bubble, China continues its strong growth, driven by large-scale government investment into infrastructure and the expansion of internal demand. But the abrupt end of the export boom, which supported much of the rapid modernization of China's coastal provinces, is forcing certain key fundamental economic issues, that have so far not been adequately addressed by government policy.

Central among these problems is the "two-tier" structure of China's economy: the growing gap between a rapidly developing urban-industrial sector with a relatively prosperous middle class, on the one hand, and a relatively stagnant, low-income rural sector of nearly a billion people, on the other.

Many Chinese economists are acknowledging, that the urgent need to compensate lost export growth by a sustained expansion in domestic demand—and not least of all to ensure the social and political stability of the country—cannot be accomplished without a drastic improvement in the quality of employment, education, and material consumption for the vast majority of China's households living in the rural areas. That, in turn, can only be accomplished by combining advanced technologies with an accelerated program of infrastructure development, industrialization, and urbanization reaching throughout the interior regions of China.

The same applies, of course, to the urgent requirements of development of the Eurasian landmass as a whole, in the context of LaRouche's Eurasian Land-Bridge strategy, as well as for Africa and Ibero-America.

One of the advanced technologies, key to the success of such an effort, is the modular high temperature gas-cooled nuclear reactor (MHTGR, or HTR for short). The MHTGR combines several essential advantages over conventional nuclear technology. These include: a much higher operating temperature (900°C or more) using helium as a coolant; higher efficiency for electricity generation; potential application as a source of industrial process heat and steam; simplicity and inherent safety; smaller unit size and greater flexibility, ideally suited to the need of developing countries; and the possibility of standardized "assembly-line" production, greatly reducing the cost.

The Payoff of '863'

A 10 megawatt prototype of the MHTGR, called "HTR-10," was completed last year by the Institute of Nuclear Energy Technology (INET) of Tsinghua University, China's leading institution for science and technology. Based on the so-called "pebble-bed" technology originally developed in Germany, INETs HTR-10 is designed as a test bed and demonstration reactor for future full-scale HTR modules having a thermal output on the order of 200 MW.

China's investment in this technology is motivated not only by the need to supply its 1.3 billion population with increasing per-capita amounts of low-cost electricity, but also by such potential applications as the use of HTR-produced steam to extract the large heavy-oil deposits in Western China, and the use of HTR process heat for coal liquification and the production of other synthetic fuels.

China has enormous reserves of coal, but reliance on burning of well over a billion tons of coal a year, as the main source of electricity production and heat in the country, ties up a large part of the country's transport system, creates enormous pollution problems, and drags down the overall physical productivity of the economy. It is generally recognized, that China has no alternative to large-scale use of nuclear energy.

During our recent trip to Beijing in late July, I and my colleague Mary Burdman visited the HTR-10 project, and got a first-hand impression of the progress made in China in this technology. The HTR-10 project was officially launched in March 1992, as part of the Chinese government's so-called "863" program. "863" refers to the date March 3, 1986, when four of China's most respected scientists put forward a plan for domestic development of advanced technologies, including the areas of aerospace technology, biotechnology, lasers, automation, energy, new materials (including superconductors) and information technology. At the 15th anniversary celebrations earlier this year, it was noted that the "863" program had already yielded a 10-to-1 return on investment. As a result of this impressive performance, the Chinese government is increasing its support for "863" in the future.

The HTR-10 was built at a complex of research facilities located to the north of Beijing, on the highway to the Great Wall. Thanks to the rapid development of the superhighway system in and around Beijing, the trip from central Beijing to INET was much shorter and easier than it was a few years ago, when we last visited the site.

Helga Zepp-LaRouche had visited INET in June 1996, as part of her participation in the historic Eurasian Land-Bridge

Chinese scientists and technicians at the December 2000 startup of what is currently the world's only Modular High-Temperature Gas-Cooled Reactor (MHTGR), at Tsinghua.

Conference in Beijing. At that time the foundation for the reactor building was just being laid, while production of key components had begun in various factories elsewhere in the country. The reactor building was completed in October 1997 and the reactor pressure vessel was installed in November 1998. Meanwhile, the key element of this reactor type was produced: the spherical fuel elements, which take the place of the fuel rods used in conventional reactors.

The core of the HTR-10 consists of a graphite-lined cylindrical chamber 1.8 meters in diameter, filled with about 27,000 fuel balls (the "pebbles" of the pebble-bed reactor), each the about the size of a tennis ball. Each spherical fuel element contains about 8,300 tiny particles of enriched uranium fuel, each of which is coated by a series of layers of high-temperature ceramic (silicon carbide) and carbon material, and embedded in graphite. The key idea in the use of "coated particles," is that the radioactive substances generated by the nuclear fission reactions which power the reactor, are effectively trapped inside the fuel elements themselves, even under the most extreme conditions. The fuel elements are designed to withstand extreme temperatures, up to 1,000 degrees in normal operation and even peak temperatures of 1,600 degrees—in case of a failure of the cooling system—without significant release of radioactivity. This provides the possibility for "inherent safety" and major simplifications in the construction of the reactor (see below).

Also, the use of fuel balls permits a continuous fuelling process, eliminating the need to shut down operations for several weeks for refuelling, as in conventional nuclear power plants. Fuel balls are introduced at the top of the reactor, and removed through its funnel-shaped bottom.

The initial loading of the reactor with fuel balls began in late November last year, and the reactor went critical in December. The HTR-10 is now going through the initial stages of a meticulous commissioning process, with full-power operation expected next year. At first the HTR-10 heat will be used to produce electricity, using a standard steam generator and turbine. Eventually, however, INET wants to introduce a compact helium turbine into the primary cooling circuit, investigating the possibility of much simpler and more efficient conversion of reactor heat into electrical power.

Simple and Safe

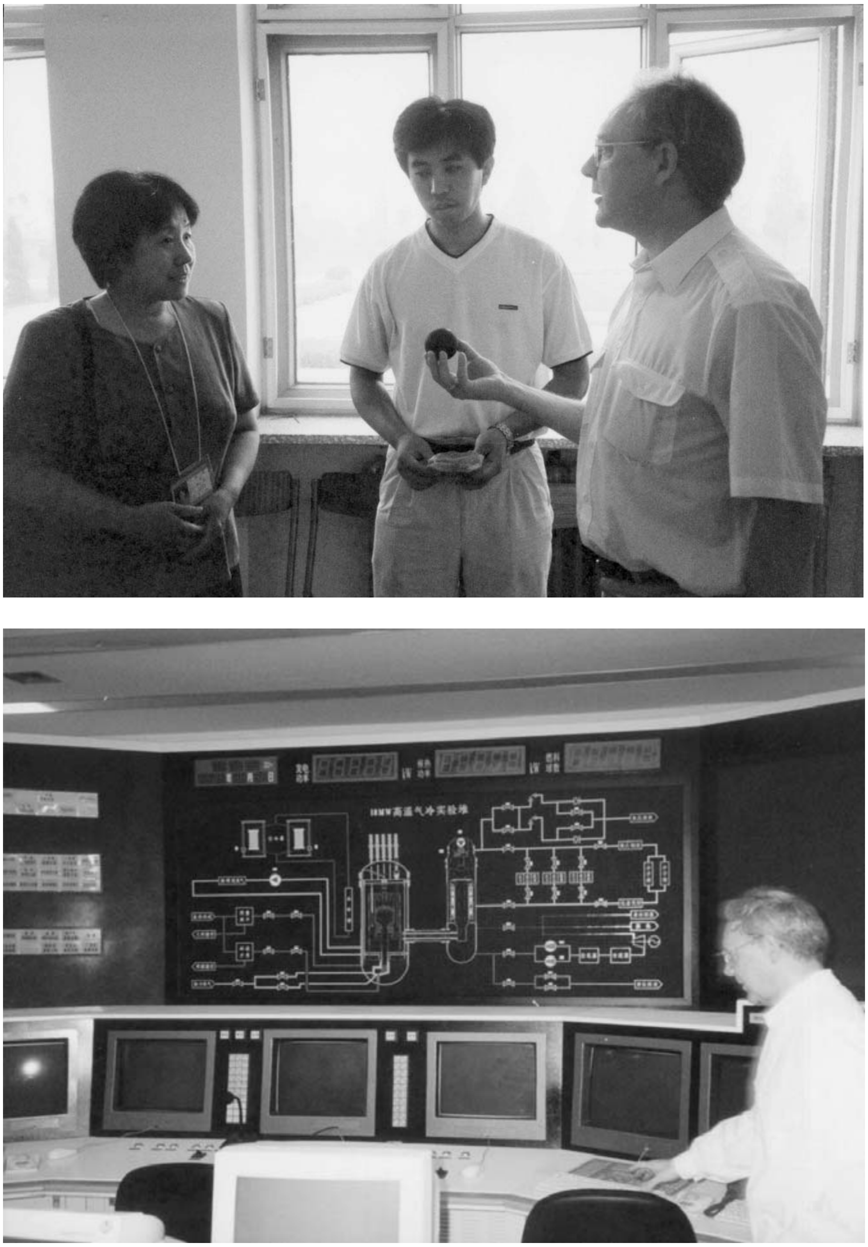
The reactor building consists of four stories plus a basement, and is topped by a large rectangular containment "dome." We visited the control room and related facilities, and could look down at the top of the reactor and steam generator from inside the containment dome. We were struck with the compactness and simplicity of the whole installation, including especially the control room, which benefits from progress in integrated digital control systems, as well as the underlying simplicity and inherent safety of HTR operation itself.

Inherent safety is a very major advantage of HTR technology. The reactor designs presently used for nuclear power generation in the world, all have the common drawback: safety depends on a complex and highly redundant array of "active" safety systems, providing for rapid shutdown, control, and back-up cooling of the reactor in the event of a component failure or accident. These safety systems make up a very substantial fraction of the cost of a nuclear power station.

In the case of the HTR, essential safety is guaranteed by the unique physical characteristics of the reactor itself, virtually eliminating the need for active safety systems. These unique characteristics include:

- The unusually large "negative temperature coefficient" of the reactor, which means that when the core temperature rises above a certain maximum design level, the nuclear chain reaction stops by itself, without any active intervention from outside.
- The provision for passive cooling, such that in the event of a failure or shutdown of the active cooling systems, the decay heat of the reactor will be removed by ordinary heat conduction and radiation to the outside.
- The highly effective ceramic "encapsulization" of radioactive material inside the fuel elements, which is preserved under even the highest temperatures that could be reached in any accident.

Thanks to these and related, built-in properties of the reactor, the danger of a major accident with massive release of radioactivity to the outside, is impossible on physical grounds alone. The result is a simple, robust system and large savings in construction costs through the elimination of most active safety systems.



The author in the advanced, yet simple control room of the HTR reactor (bottom); and holding one of the ceramic-capsule nuclear fuel elements (top) from which the reactor gets its nickname, "the pebble bed." The radioactive products remain trapped in the capsules at whatever heat.

The vast majority of the materials and components of HTR-10 were produced in China, including main components such as the reactor vessel, steam generator, helium circulators. A major exception is the graphite neutron reflector structures which surround the fuel in the reactor's core. Here the high-quality graphite material was imported from Japan, but the precision machining of the material into reflector components was done in China.

At present the Chinese HTR-10 is the only existing pebble-bed HTR in the world. South Africa, however, has also embarked on an ambitious program to develop and build "pebble-bed" modular HTR reactors both for internal use and for export. Interestingly, two large British and American energy companies have purchased shares in the South African "PBMR" project, anticipating a potential large worldwide market for modular HTR reactors in the future. Other nations are closely watching the Chinese and South African projects. South Africa, which has not yet begun construction of its first HTR, is profiting from the Chinese experience in the context of an international cooperation which includes scientists from the original birthplace of the "pebble-bed" HTR, the Juelich Research Center in Germany.