The Infrastructure Road to Recovery

Go Nuclear!

The High-Temperature Reactor is Coming

by Jonathan Tennenbaum

At the beginning of 2001, in the vicinity of China's capital, Beijing, a unique nuclear reactor was put into operation, which is destined to play a key role in the development of the Eurasian infrastructure corridors. This is the "pebble-bed" high-temperature reactor (HTR), first developed in Germany. After decades-long, highly successful operation of the first HTR test reactor AVR in Jülich, and the construction and operation of a 500MW HTR power plant at Hamm-Uentrop, this revolutionary technology became the victim of the politically manipulated hysteria against nuclear energy in Germany. The pebble-bed reactor subsequently emigrated—exactly like the German-developed Transrapid—to China, and also to South Africa.

In the Institute for Nuclear Energy Technology (INET) of the Chinese Tsinghua University, the HTR was realised in an especially promising form for worldwide application. The 10MW Chinese HTR-10 is the prototype of a standardised modular reactor of approximately 200MW-thermal capacity, which can be mass-produced at low cost in the future. On account of its simple construction and operation, inherent safety, small unit-size, flexibility, and ease of maintenance, this reactor is eminently suited for use in developing nations.

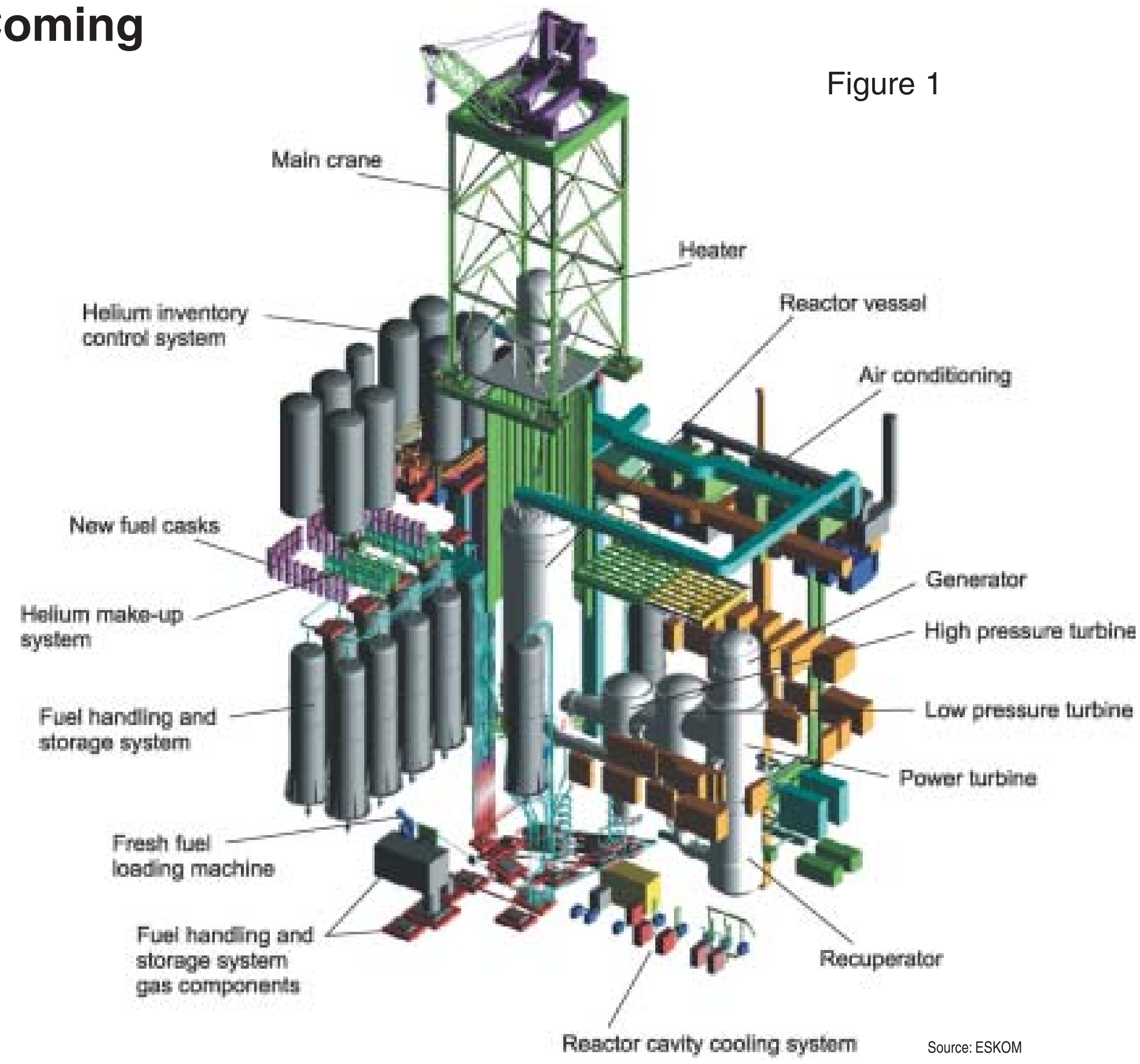
Apart from China, these advantages of the HTR have moved the large South African electric power company, ESKOM, to launch an ambitious program for the development and assembly-line production of HTR modules. ESCOM plans, after the success of a first, prototype project, to produce 30 modules every year: 10 for internal consumption and 20 for export (illustrated in Fig. 1). The Chinese HTR-10, already in operation, is supplying important advance data and practical experience for the South African program. In the area of HTR development, a comprehensive international cooperation has emerged in recent years, with the participation of China, South Africa, Germany, France, Russia, and the United States.

The core of the HTR-10 consists of a graphite-lined cylindrical chamber of 1.8 meters diameter, filled with 27,000 spherical fuel elements ("pebbles"), each the size of a tennis ball. Each fuel "pebble" contains about 8,300 tiny particles of enriched uranium, about the size of a grain of sand, embedded in a graphite matrix. Each particle is encased in concentric layers of a high-temperature ceramic (silicon carbide) and carbon material.

The idea of such "coated particles" is that the radioactive substances which are generated by nuclear fission reactions, are permanently trapped within the particles themselves, and cannot escape to the environment. The fuel elements are so constituted, that they withstand even extreme temperatures—up to 1,000ºC in normal operation, and even peak temperatures of 1,600ºC in the event of a failure of the cooling system—without any considerable quantities of radioactivity escaping to the outside. In addition to this, the fuel pebbles permit a continuous fueling of the reactor. This eliminates the need to interrupt power operation for several weeks for fuel reloading, as is the case with conventional reactors. In the HTR, fuel pebbles are continuously fed in from the top of the reactor, while old ones are gradually removed from the core via its funnel-shaped bottom.

Through the use of ceramic, "sealed" fuel pebbles, it is possible to greatly simplify the entire construction of the reactor, making it inherently safe under all conditions. An accident leading to dangerous escape of radioactivity to the environment is precluded in this reactor, because of its special physical characteristics—above all, the "trapping" of radioactive process in the fuel elements up to high temperatures and the strong "negative temperature co-efficient," which prevents a "runaway" power increase in the reactor. The HTR does not need the intricate, expensive safety systems that are required for conventional nuclear power plants. Yet, this is only one of its many advantages.

Figure 1



Source: ESKOM

The elements of a pebble-bed modular reactor—the future in safe, efficient power production.

A decisive breakthrough over conventional nuclear technology lies in the fact, that the HTR has a much higher operating temperature—900ºC, or more. Therefore, the HTR can not only reach a higher thermodynamic efficiency in the generation of electric power, but can also serve as an economical source of *process* heat for various chemical and other industrial processes. Among these are the environmentally friendly generation of fuels such as hydrogen and methanol from natural gas; coal gassification; process steam generation, metallurgical processes, and so forth.

Where conventional nuclear plants are only suited to, and designed for, delivering *electrical* power, the HTR can be employed in many more sectors of the energy economy, where energy is needed directly in the form *of* heat. HTR process heat can replace a part of the costly and environmentally damaging burning of coal, oil, and natural gas.

Chinese experts have in mind, among other things, to use HTRs for generating high-temperature steam, whose injection underground can make it possible to exploit major heavy oil deposits in the country.

In a first period, the heat generated from the Chinese prototype HTR-10 will only be utilised, with the help of a conventional steam generator and a turbine, to generate electrical power. INET plans later to install a compact helium turbine in the primary cooling cycle, in order to explore the possibilities for a very much simpler, and at the same time more efficient conversion of reactor heat into electricity. There are also various possibilities for tapping the HTR's waste heat. The helium turbine plays a large role in the plans of the South Africans, who hope to be able to produce electricity at the extremely advantageous cost of about 1.6 U.S. cents per kilowatt-hour.

The majority of the components of the HTR-10 were produced in China itself, including the reactor vessel, steam generator, and the helium cycle cooling system. Exceptions are the graphite structures for neutron moderation in the nuclear reactor. The special graphite was imported from Japan; the precision machining of the material was done, however, in China.

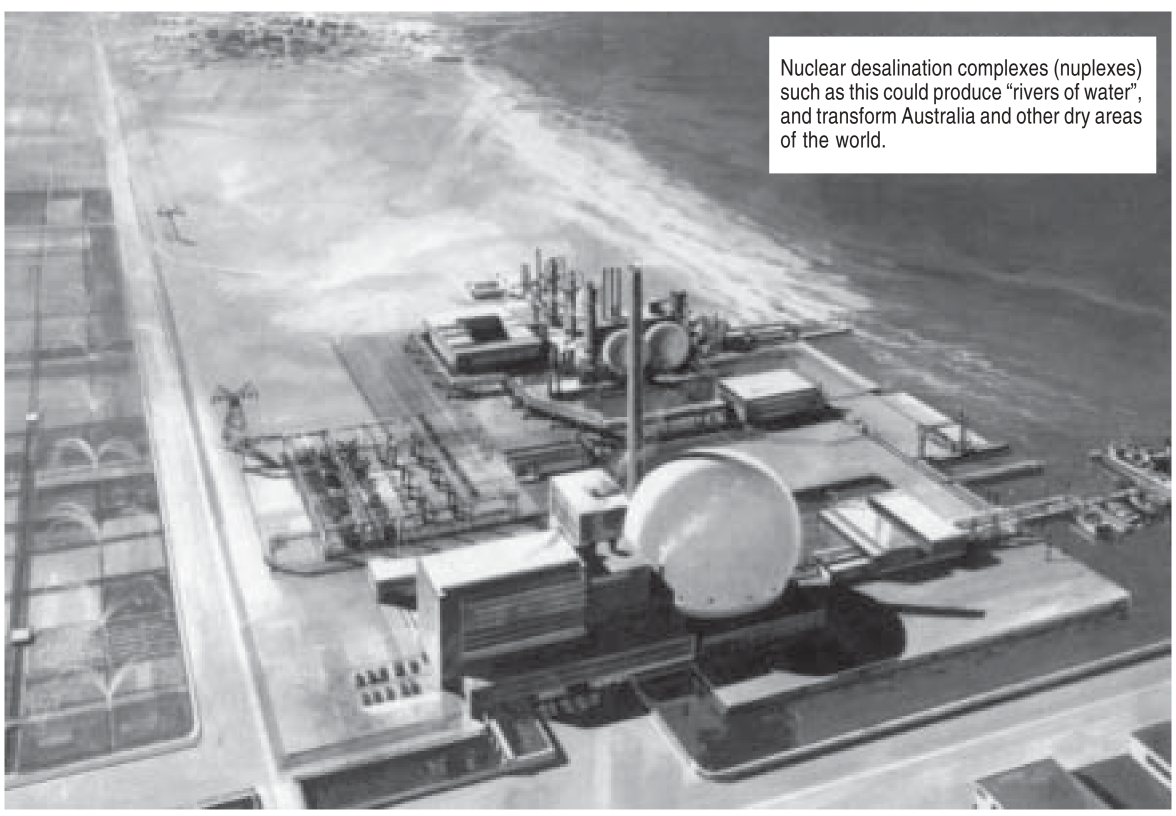
Projects for Seawater Desalination

Increasing shortage of freshwater has, in many regions of Eurasia and the world, become a serious economic and—as the case of the Middle East shows most explosively—also political problem. Conversely, the dry and desert areas of Eurasia could be turned into gardens, if we were in a position to efficiently produce sweet water from the practically limitless quantities of easily available salt water of the ocean and seas of the world (including inland salt seas such as the Caspian Sea).

There are today several well-established industrial processes for the desalination of salt water, processes which are constantly being improved, and which are already exploited in large scale, in Saudi Arabia and some other countries, for the supply of drinking water. All these processes use large quantities of energy, and providing the required energy makes up a large part of the overall cost of the water produced per cubic metre.

For this reason, the possibility of using nuclear energy has long been considered. On the basis of modular nuclear reactors, highly productive "nuplex" centres can be built—agroindustrial complexes which combine electricity production, desalination, artificial fertiliser production, and other industrial processes, together with the most modern irrigation and other agricultural techniques. Only recently, however, have concrete projects been launched, which could lead to a worldwide breakthrough for nuclear desalination.

In December 2000, China and Morocco signed an agreement on building a nuclear-powered seawater desalination facility near Tan Ten in southern Morocco. According to the agreements, China will provide a 10MW nuclear reactor, developed specifically for the production of low-temperature heat for desalination processes and other uses, at the Institute for Nuclear Energy Technology (INET) of Tsinghua University. This small reactor was specially designed for safety, reliability, and ease of operation, with a view to use in developing countries. The facility in Morocco, which will be constructed in cooperation with the International Atomic Energy Agency (IAEA), should produce 8,000 cubic meters of freshwater daily, enough for the water consumption of more than 70,000 people. If the project works out successfully, similar facilities will be set up elsewhere in Morocco and in other countries. At the same time, a large facility for seawater desalination on the basis of nuclear energy, is planned in China itself, to be built on the Pacific coast in the vicinity of Dalian.



Nuclear desalination complexes (nuplexes) such as this could produce "rivers of water", and transform Australia and other dry areas of the world.

The possibilities of desalination have been raised more and more frequently in China, in the framework of expert discussions on the solution of water shortage problems in the dry north of the country. For the western regions, the transfer of large amounts of water, with the help of pipelines, canals, and pump stations, is foreseen; but for the eastern region around Beijing, it appears that desalination may be more favourable in cost, than bringing in additional large quantities of sweet water from great distances. Scientists at the Beijing Institute of Nuclear Engineering are presently investigating the economic advantages of very large nuclear desalination sites. They are studying facilities with capacities of up to 100 million or more cubic metres per year, which could cost-effectively secure the water needs of large population concentrations in the northeast of the country.