Chernobyl: an archaic reactor design

The Chernobyl reactor is a light-water-cooled, graphite-moderated, 1,000-megawatt plant, one of 17 such units operating in the Soviet Union. The design is vintage 1950s, and was considered inappropriate by Western nuclear constructors for development as a civilian power plant. Instead, the West went with the now standard light-water or pressurized water reactor.

According to U.S. nuclear analysts, in the early 1970s, the Soviets were finding it too difficult to keep up with their goal for advancing nuclear power using the conventional light-water reactor used by other nuclear nations. The usual pressurized water reactors were technologically "too difficult" for the Soviets to achieve in a hurry, according to several sources. Their Atommash factory, which was planned to "mass produce" standard pressurized water reactors, ran into trouble. So the Soviets decided, at the time of the oil crisis, to go nuclear using a simpler reactor—a light-water-cooled graphite reactor.

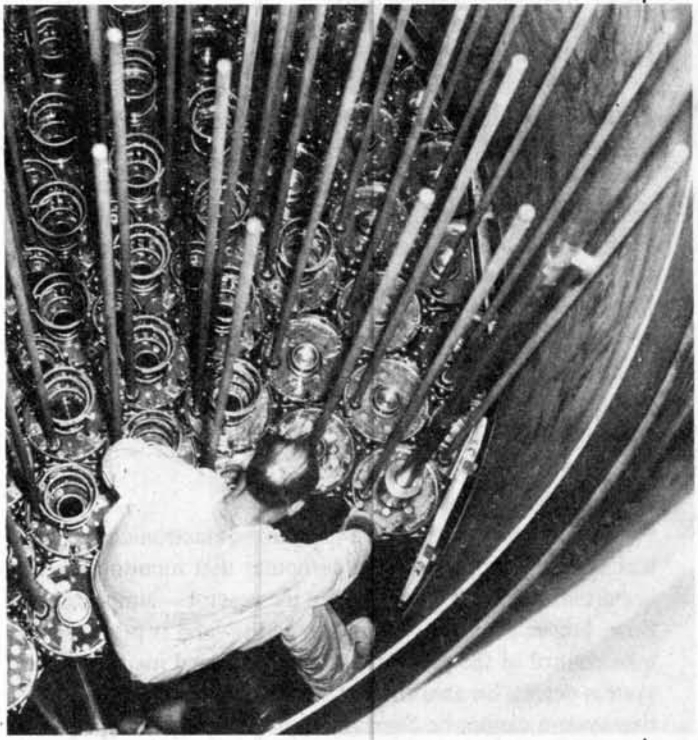
The graphite reactor was originally designed for military use to make plutonium fuel. It is a simple design of blocks of graphite with channels running through it for the fuel rods. The fuel elements are encased in zirconium and are water cooled both inside and out. The Soviets upgraded this military design to commercial-reactor size and began building many, designating them RBMK-1000. Of the 17 such reactors in the Soviet Union of varying size, 12 are 1,000-megawatt-electric plants. Chernobyl has four RBMK-1000s, and there is a similar 4,000-megawatt complex ringing Leningrad, another four-reactor complex at Kurchatov, and a two-reactor complex at Smolensk. A new generation of even larger 1,500-megawatt units is also believed in operation in Lithuanian Russia Baltic.

Why graphite?

The special characteristic of graphite, which was used in the Manhattan Project bomb research in the 1940s at Argonne National Laboratory, is that it is a good moderator of the rate of nuclear reaction and relatively cheap. The special problem with graphite is that it has a high chemical affinity for water vapor, carbon dioxide, and metals. Physicists refer to the "Wigner effect" to describe the reaction of graphite under radiation exposure in a reactor. Energy is stored in the graphite crystal lattice in unstable or metastable concentrations. If this stored energy is released suddenly, it causes an enormous release of thermal energy—a temperature increase. Graphite-moderated reactors, therefore, must follow procedures to allow for controlled and gradual periodic heating of the material so that "annealing" of radiation damage can take place in order to prevent a catastrophic temperature rise.

There cannot be a meltdown in a graphite reactor because the graphite will not get hot enough, even if it is burning. However, if the graphite catches fire, the fire is dangerous and very difficult to put out. If you pour water on it, the water attacks the zirconium, opens the casings of the fuel elements, and lets the fission products out.

The biggest difference between the graphite reactor and conventional nuclear plants in other nuclear nations is that the Soviet design has no containment dome. In addition, the U.S. Department of Energy notes, there are other weak points in comparison to U.S. reactors: The Soviets use long lengths of small piping with numerous valves, for example. The refueling entry ports and bi-metallic joints are subject to potential failure from corrosion. The pressure-tube system is also subject to failure, and the stability of the graphite is aggravated by power changes.



Atomics International

In the early years of nuclear power, graphite reactors were used for research and producing plutonium. In the 1950s, the Western nuclear nations decided not to develop the graphite design for civilian power reactors. Here, a technician works on the graphite moderated reactor core of the Sodium Reactor Experiment at Atomics International in 1956.