K.Pidhoretskii, K.Chala

National University of Food Technologies, Kyiv, Ukraine

ATOMIC ENERGY. AND ITS SIGNIFICANCE IN THE SOVIET YEARS.

The Soviet Union had an extensive atomic energy program. The program included the use of isotopes as tracers for agricultural research and as ionizing sources for food irradiation, extensive applications in medicine, so-called peaceful nuclear explosions, and an ambitious effort to build scores of reactors to produce electrical energy. Under the regime of Josef Stalin, the military side of atomic energy was significantly more developed than its civilian application. Scientists and workers were gathered into closed cities to build the first Soviet atomic bomb, detonated in 1949, and to design and assemble tens of thousands of nuclear warheads. It is not certain what percentage of the nuclear program was civilian and what percentage was military, but it is clear that the military needs predominated during the Cold War. It is also difficult to draw a line between military and civilian programs. Nikita Khrushchev and Leonid Brezhnev made the peaceful atom a centerpiece of their economic development programs. The peaceful atom found expression in art and music, on stamps and lapel pins, and even in literary works. For instance, the Exhibition of the Achievements of the Socialist Economy (VDNKh) had a large hall devoted to atomic energy. However, even when the technology was ostensibly dedicated to peaceful goals, there were often military interests at stake as well. For example, Soviet scientists conducted 120 peaceful nuclear explosions (PNEs) for excavation, dam construction, and other purposes that were connected with the 1963 ban against atmospheric testing of nuclear devices.

Soviet engineers developed five major kinds of nuclear reactors. One design focused on compactness, and was intended to be used for propulsion, especially for submarines. The USSR also employed compact reactors on aircraft carriers, container ships, freighters, and icebreakers, such as the icebreaker *Lenin*, which was launched in 1959. Scientists also worked on reactor propulsion for rockets and jets, and nuclear power packs for satellites. There were several prototype land-based models, including

the TES-3, built in Obninsk, that could be moved on railroad flatbed cars or on tank treads. In the 1990s, Russian nuclear engineers designed a barge-based, floating nuclear unit for use in the Far North and Far East.

There was also an extensive breeder reactor program. The most common type was the liquid metal fast breeder reactor (LMFBR). Breeder reactors are so called because they use "fast" neutrons from fissile uranium (U235) to transmute non-fissile U238 into plutonium (Pu239). The plutonium can then be used to power other breeder reactors, or as fuel for nuclear weapons. Breeder reactors are highly complex. They have a liquid metal, usually sodium, coolant, which must be kept separate from the water used for power generation, because the sodium will burst into flame when mixed with water.

The mainstay of the Soviet (and Russian) atomic energy effort has been the development of 440 and 1,000 megawatt pressurized water reactors, known by the Russian designation as VVER reactors.

RMBKs have been even more problematic. Anatoly Alexandrov, later the president of the Academy of Sciences and Kurchatov's successor, pushed the RMBK reactor. Their advantages are that they continue to operate during constant refueling, theoretically could be built in sizes up to 2,400 megawatts (forecast, not built), and produce plutonium, which is coveted by military planners. Yet they use ordinary factory structures and have no containment whatsoever. On the other hand, they have suffered from premature aging. Worse still, the RBMK is highly unstable at low power, an inherent fault that contributed to the Chernobyl disaster. The flagship of the RBMK is the Leningrad station, with four units built between 1973 and 1984. In 2002 the Ministry of Atomic Energy (MinAtom) announced plans to attempt to prolong the operational lives of these four reactors and to build another two units on the site. This continues the Soviet practice of building reactors in close proximity to populated areas and industrial centers in so-called parks that have been designed to share equipment and thus to keep costs down.

A major research program centered on controlled thermonuclear synthesis, or fusion. Andrei Sakharov and Igor Tamm developed the idea for the electromagnetic

containment of a plasma in a toroid-shaped reactor at millions of degrees temperature. The plasma would fuse two lighter elements into a heavier one, releasing tremendous amounts of energy that could then be used to generate electricity. Cost efficiency has been a problem however. Since the program commenced in the early 1950s, it has yet to achieve the break-even point where the cost tooperate fusion devices has been offset by the returns gained through energy production. In 1985, Mikhail Gorbachev suggested a Soviet-American alliance in fusion research to President Ronald Reagan at their Geneva summit.

One of the legacies of atomic energy in the USSR has been the production of thousands of tons and millions of gallons of high- and low-level radioactive waste. The waste has been stored haphazardly, often in open areas, and for a number of years the Soviets dumped waste, including spent reactor vessels, into the world's oceans. The human and environmental costs of the Soviet atomic energy program thus remain extremely high. In spite of this, the Russian Ministry of Atomic Energy has established plans to expand the nuclear enterprise significantly by the year 2020, with the construction of up to forty additional reactors and the diffusion of floating nuclear power stations.

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