A FIRST LOOK AT THE SOVIET BOMB COMPLEX

By THOMAS B. COCHRAN and ROBERT S. NORRIS

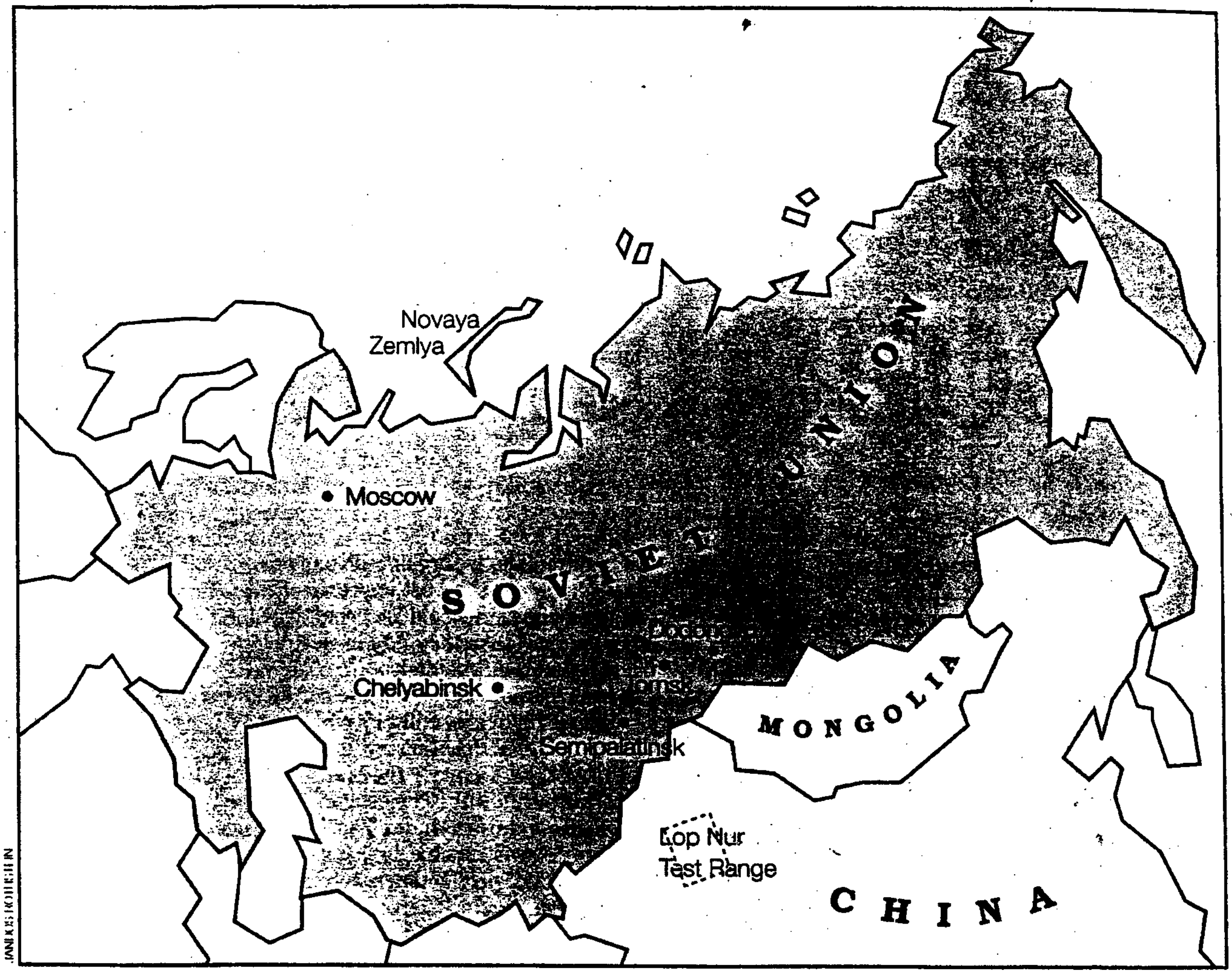
After decades of secrecy, some information about the Soviet nuclear weapons complex is now coming to light. The Soviet press has begun to report on operations in the complex and on its appalling environmental problems, which appear to be even greater than those in the U.S. nuclear weapons complex. Foreign visitors were first invited to tour one of the sites in 1989. Although significant gaps remain, we are now able to provide a general view of the vast operation the Soviets set up to meet the Cold War challenge, and the monumental task they face in cleaning up the devastation it left behind.

Thomas B. Cochran directs the Nuclear Weapons Databook project for the Natural Resources Defense Council in Washington, D.C., where Robert S. Norris is a senior staff analyst.

Nuclear weapons and the entire nuclear fuel cycles, for both civilian and military purposes, are the responsibility of the Ministry for Atomic Power and Industry—formerly the Ministry of Medium Machine Building. The current minister is Vitali Konovalov. Under Konovalov, Evgeni I. Mikerin is responsible for isotope production, including the production reactors and enrichment plants.

It took only 18 months—but 70,000 slave laborers—to build the "Anotchka," or A Reactor. Shown is part of that first plant, which opened in June 1948.

THOMAS B. COCHRAN



Soviet test sites are at Novaya Zemlya and Semipalatinsk; reactors are at Chelyabinsk, Tomsk, and Dodonovo. Also shown, China's nuclear test site.

Plutonium and tritium for Soviet nuclear weapons are produced at three closely guarded locations, each of which includes a "closed" city for workers. These cities do not appear on maps, and until recently, travel to and from them was all but prohibited. Even now, foreign visitors have been allowed to see only two of the sites. Each of the sites has an official name, often including a number that indicates a post office address, but each is also known by another name or names abroad as well as in the Soviet Union. The sites are Chelyabinsk-40, near Kyshtym; the Siberian Atomic Power Station located near Tomsk and sometimes called Tomsk-7; and a mining-chemical combine near Dodonovo, a small town northeast of Krasnoyarsk.

Before 1987 there were 14 production reactors at these sites. Between 1987 and December 31, 1990, seven were shut down. That leaves a single heavy-water reactor operating at Chelyabinsk-40 and three reactors, also believed to be of the heavy-water type, at Dodonovo, as well as three graphite reactors at Tomsk. The Soviets announced in October 1989 that they planned to shut down all plutonium-producing reactors by the year 2000—presumably including the three Tomsk reactors. But this leaves ambiguous the status of the four heavy-water reactors, which are believed to be dedicated to tritium production.

Chelyabinsk-40

The complex officially known as Chelyabinsk-40 is located in Chelyabinsk province, about 15 kilometers east of the city of Kyshtym on the east side of the southern Urals. It is situated in the area around Lake Kyzyltash, in the upper Techa River drainage basin among numerous other interconnected lakes. Between Lake Kyzyltash and Lake Irtyash is Chelyabinsk-65, the military-industrial city built to house the workforce. The city was once called Beria, but today inhabitants call it Sorokovka ("forties town").

In 1989 a visiting U.S. delegation was told that there were 10,000 employees and 40,000 dependents at the site. But in 1990 the city, Chelyabinsk-65, was variously reported to have 83,000 inhabitants and "almost 100,000 people."[1] Chelyabinsk-40, the reactor complex, covers some 90 square kilometers, according to a recent ministry report, and is run by the production association Mayak ("beacon" or "lighthouse"). All the reactors are located near the southeast shore of Lake Kyzyltash and relied on open-cycle cooling: water from the lake was pumped directly through the core. A plume from hot water the reactor discharged into Lake Kyzyltash was visible in a Landsat image taken before 1989.

Probably fashioned after the U.S. Hanford Reservation in the state of Washington, Chelyabinsk-40 was the first Soviet plutonium production complex. Construction was started on the first buildings of the new city in November 1945. Some 70,000 inmates from 12 labor camps were reportedly used to build the complex. It was here that the physicist Igor Kurchatov, working under Stalin's deputy Lavrenti Beria, built the first plutonium production reactor, called "Anotchka" or A Reactor, in just 18 months. The graphite-moderated 1,168-channel reactor, designed by Nikolai Dollezhal, was originally to operate at 100 megawatts-thermal but was later upgraded to 500 megawatts. It was loaded with all the uranium then available in the country and began operating on June 19, 1948. Its plutonium was used to fabricate a ball 10 centimeters in diameter, which was the core of the first Soviet atomic bomb tested on August 29, 1949. A Reactor was shut down in 1987 and is now being dismantled.

The next reactor built on the site was designed by Abram Alikhanov and is heavy-water moderated. Shortly after it began operating, between late 1948 and late 1951, the heavy water in the two heat exchangers froze. Yefrim P. Slaviski, then chief engineer of the complex, claims he had to enter the radiation area and place his hand on one of the heat exchangers to convince the designers that the heavy water had frozen.[2] This reactor is still presumably used for tritium production and is the only operating reactor at the site.

Four other graphite-moderated reactors—all presumably shut down by now—are located on the site: The IR Reactor in building 701 is a small, 65-megawatt reactor that was used for military and civilian purposes. It was brought on line December 22, 1951, and shut down May 24, 1987. In addition to producing plutonium, the reactor was used for fuel-rod research and for testing fuel assemblies for the RBMK graphite-moderated (Chernobyl-type) civilian power reactors. The AV-3 Reactor was brought on line in September 15, 1952, and was shut down November 1, 1990. With 2,001 channels, its size is comparable to C Reactor at Hanford, which had an initial power level of 650 megawatts and was upgraded to 2,310 megawatts. Both the IR and AV-3 reactors are located near A Reactor. The AV-2 and another reactor of unknown designation (perhaps AV-4) are 2,001-channel reactors located in a separate area of the complex. The AV-2 was brought on line in April 1951 and decommissioned July 14, 1989; the other was decommissioned August 12, 1990.

A chemical separation or reprocessing plant went into operation at Chelyabinsk-40 in December 1948, six months after the startup of A Reactor. The plant separates plutonium and uranium from the highly radioactive fission products contained in the irradiated reactor fuel elements. After 1978, however, fuel from the military reactors at Chelyabinsk was sent by train to Tomsk for reprocessing. The Chelyabinsk plant was modified to process fuel from civilian power reactors and naval reactors for use in an ambitious civilian breeder reactor program.

Mikerin says "around 20 tons" of plutonium have been stockpiled for use in liquid-metal fast-breeder reactors, although the breeder program is floundering. Even the program's backers cheerfully admit that breeder-generated electricity is "2.5 times more expensive" than power from conventional power plants,[3] and the program has been plagued by safety concerns. At one time two breeder reactors were under construction at Chelyabinsk and a third was planned; only the concrete footings are in place for the first two, and no progress has been made at the site since 1987. A 600-megawatt breeder at Beloyarski, just north of Kyshtym, is operating with highly enriched uranium rather than plutonium.

Not even on the map, Chelyabinsk-65, a once-secret city, has nearly 100,000 inhabitants.

The 1957 explosion

Chelyabinsk-40, or the Kyshtym complex, is best known to the outside world as the site of a disastrous explosion in 1957, only recently acknowledged by Soviet officialdom. According to Soviet accounts, when the chemical separation plant first began operating, the irradiated fuel elements were treated by an "all-acetate settling arrangement."[4] After the fuel had been dissolved in nitric acid, and the uranium and plutonium had been isolated from the solutions, highly radioactive waste solutions were formed which contained as much as 100 grams per liter of sodium nitrate and 18 grams per liter of sodium acetate. The solutions were stored in tanks for a year in order to reduce the radioactivity and to cool before further treatment to extract more plutonium and uranium. After treatment, a portion of the solutions was returned to the storage tanks, and the less radioactive part was dumped into a "storage reservoir," presumably Lake Karachay.

An intermediate storage facility put into operation in 1953 consisted of a rectangular underground concrete canyon with walls 1.5 meters thick, designed to hold 20 stainless steel

Chelyabinsk's deadly legacy includes the 1957 explosion of a tank filled with radioactive wastes.

tanks, each 300 cubic meters in volume. The tanks were entirely immersed in, and cooled by, water. But the monitoring system was defective. As the solution in the tanks evaporated, the tanks rose, breaking seals in the waste transfer lines and contaminating the cooling water. In attempting to clean the cooling water a "periodic cooling mode" was used, that is, the tanks were cooled intermittently.[5] The system failed in one of the tanks, however, and the waste began to dry out. Nitrates and acetates precipitated, heated to 350 degrees celsius, and, on September 29, 1957, exploded with a force equivalent to 70–100 tons of TNT. Seventy or 80 metric tons of waste containing some 20 million curies of radioactivity was ejected—about one-fourth the amount released in the 1986 Chernobyl accident.

About 90 percent of the radioactivity fell out immediately around the vessel. The rest formed a kilometer-high radioactive cloud that was carried through Chelyabinsk, Sverdlovsk, and Tumen provinces. A kilometer away, radiation levels were 20 roentgens per hour. Guards received the largest reported doses, about 100 rem—20 times current limits for nuclear workers in a year.

There were 217 towns and villages with a combined population of 270,000 people in the area that was contaminated to greater than 0.1 curies of strontium 90 per square kilometer. By comparison, the total strontium 90 fallout at this latitude from past atmospheric tests is 0.08 curies per square kilometer. Virtually all water supply sources in the area were contaminated. Evacuation of the most highly contaminated areas, where 1,100 people lived, was not completed until 10 days after the accident. Other areas were evacuated a year later, after the population had consumed radioactive food. In the years following the accident, 515 square miles of land was plowed under or removed from agricultural use; all except 80 square kilometers was returned to use by 1978.

About 10,000 people lived in the 1,000-square-kilometer area contaminated with more than two curies of strontium 90 per square kilometer. One-fifth of these people eventually showed a reduction of leukocytes in their blood. In rare cases, thrombocyte levels were also reduced. But Soviet investigators claim to have found no deviation in the incidence of blood diseases and malignant tumors in the affected population. There are no records of deaths caused by the accident.

A population at risk

This accident is only part of Chelyabinsk-40's deadly legacy, because there was no management of radioactive waste at all before September 1951: for two years the high-level nuclear waste was simply discharged directly into the Techa River. And over the years, workers at the complex have been exposed to astonishing levels of radiation.

During 1949, the first full year of operation, workers at A Reactor received an average dose of 93.6 rem—three times the standards then set by the ministry, which were too high to begin with: about 30 rem per year. (Standards for nuclear workers in the Soviet Union, as in the United States, are now 5 rem per year, although they are about to be lowered in the United States to 2 rem.) Workers were exposed to an average of 113.3 rem in 1951, and a small percentage received more than 400 rem annually during this early period.[6] According to risk estimates recently established by the U.S. National Research Council, workers at the A Reactor during its first decade of operation have a 14 percent higher chance of contracting cancer than the normal population, and the cancer risk for separation plant workers is elevated by 26 percent.

One official report explains blandly, "During the first five years of the operation of the enterprise in this branch of industry there was no experience or scientific development of questions of protecting the health of the personnel or the environment. Therefore, during the fifties there was pollution of individual parts of the territory and around the enterprise."

In 1951, radioactivity carried by the Techa River from Chelyabinsk-40 was found in the Arctic Ocean—although 99 percent of the radioactive material was deposited within the first 35 kilometers downstream. This discovery prompted a change in dumping policy: The Techa and its floodlands were excluded from human use, some inhabitants were evacuated, and others were supplied with water from other sources. Reservoirs were created to keep water from flowing out of the most contaminated areas, and plant wastes were discharged into Karachay Lake, which has no outlet, instead of into the river.

The lake, actually a bog, eventually accumulated 120 million curies of the long-lived radionuclides cesium 137 and strontium 90. By comparison, the Chernobyl accident released one million curies of cesium 137 and 220,000 curies of strontium 90. In 1967, wind dispersed radioactivity from the lake, contaminating about 1,800 square kilometers. Today, radioactivity in the ground water has migrated two to three kilometers from the lake. A person standing on the lake shore near the area where wastes are discharged from the plant would receive about 600 roentgens of radiation, a lethal dose, in an hour.

The lake is now slowly being filled with hollow concrete blocks, rock, and soil to reduce the dispersion of radioactivity. A vitrification plant was put into operation in 1986 and ran 13 months before it broke down: about 162 tons of phos-


THOMAS B. COCHRAN

Evgeni Velikhov, vice-president of the Soviet Academy, and Cong. James Olin, Virginia Democrat, drew a crowd at Chelyabinsk-65 in 1989.

phate glass containing 4 million curies of radioactive waste were poured into 366 canisters and stored on site. The facility is expected to be restarted this year. The government is looking in the Ural region for a permanent granite burial site for the waste.

The Techa River is cordoned off with a wire fence and people are forbidden to fish in it, or to pick mushrooms and berries or cut hay nearby. There are 400 million cubic meters of radioactive water in open reservoirs along the river. Fish in one reservoir are reported to be "100 times more radioactive than normal."[7] By using contaminated water to cool reactors, the production complex has regulated the water level in the reservoirs. But with most reactors shut down, a new danger is that the reservoirs will overfill with natural water and dams may fail, sending contaminated water into the rivers of the Ob basin. The breeder reactors, which may never be built, would have helped solve this problem by using radioactive water to cool turbine condensers, thus increasing evaporation.

Other facilities

The **Siberian Atomic Power Station** is located in the closed city of Tomsk-7, also called Seversk, on the Tom River, 15 kilometers northwest of the city of Tomsk. The station houses five graphite-moderated reactors, built in the 1950s and 1960s; a chemical separation plant; and an enrichment plant. At an international conference on peaceful uses of atomic energy in 1955, the Soviets said the nuclear reactors at this station were used solely to generate electric power. In 1981, however, a Soviet official admitted that the reactors produce plutonium for warheads as well.

The reactors have 2,101 channels; the total output of the units probably exceeded 600 megawatts-electric annually when all were operating. One of the five was shut down last August 21, and a second reactor was shut down December 31. According to the news agency Tass, "As a result the amount of harmful effluent going into the Tom River has been halved."

The chemical separation (reprocessing) and fuel storage facilities probably date from the mid-1950s, when the reactors went on line. When the Chelyabinsk-40 separation plant was shifted from military to civilian operations, to produce plutonium for breeders, the Tomsk separation plant began receiving military reactor fuel from Chelyabinsk for processing.

Problems with defense waste at Tomsk date back to the 1970s, when a senior engineer discovered a "vast quantity of radioactive output" at the plant. *Izvestiya* claims that the engineer was reprimanded and threatened with expulsion from the party when he wrote to the Central Committee and Leonid Brezhnev about the

Chelyabinsk director Boris Brokhovich (left), and Evgeni Mikerin, the official in charge of nuclear material production, in front of a statue of Igor Kurchatov.

problem. But the public learned of it only in April 1990 from a report on Tomsk-7.[8] *Izvestiya* also reported that the radioactive waste burial site at Tomsk-7 is poorly fenced and contaminated water areas are not fenced at all. Elk, hares, ducks, and fish are contaminated, and 38 people were found to have higher than permissible levels of radioactive substances in their bodies. Seven have been hospitalized.

Dodonovo. Little is known about the production reactors operating on the mountainous shores of the Yenisey River in the Siberian taiga, 10 kilometers north of Dodonovo and 50 kilometers northeast of Krasnoyarsk. Three reactors are reportedly operating at the site, which is known either as Dodonovo or Krasnoyarsk. Two streams of thermal effluents into the Yenisey are shown on a composite of 1989 Landsat images, but the reactors themselves are not visible and are apparently underground.

In 1975 authorities decided to build a reprocessing plant and a storage facility for irradiated fuel at Dodonovo's Site 27. The plant was to handle spent fuel elements from pressurized-water civil power reactors and "other" reactors—presumably the military reactors at this location. But construction of the reprocessing plant has been delayed by controversy and is only 30 percent complete. *Komsomolskaya Pravda* reported in June 1989 that about 60,000 people in Krasnoyarsk signed a protest against the plant. One reason for their anger was a revelation that the scientific study justifying the site selection was produced nine years after construction started. The proposed method of handling waste at the site has also generated controversy. According to *Moscow Trud,* waste is to be injected between layers of clay at a depth of 700 meters, some 20 kilometers from the reprocessing plant on the opposite side of the Yenisey River. A tunnel has already been dug 50 meters under the river to carry the waste.[9]

Meanwhile, spent fuel elements from power reactors have been shipped to the site and stored pending the plant's startup, now scheduled for 1997 or 1998.

Laboratories. The All-Union Scientific Research Institute of Experimental Physics, the older of two principal nuclear weapons design laboratories in use today, is located at Sarova, 60 kilometers southeast of Arzamas, and dates back to 1946. In his memoirs Andrei Sakharov refers to it as "The Installation." It is known unofficially as Khariton's Institute, named after its longtime scientific director, Yuli B. Khariton.

The second laboratory, the All-Union Institute of Technical Physics, is located just east of the Urals, 20 kilometers north of Kasli. It is better known by its post office box, Chelyabinsk-70. It was opened in 1955, shortly after Lawrence Livermore National Laboratory in the United States. The current scientific director is Evgeni Avrorin, who has been at Chelyabinsk-70 since its beginning.

Nuclear weapons are tested at Semipalatinsk in Kazakhstan and on the Arctic island of Novaya Zemlya. The status of the program remains unclear as controversy over testing continues in the Soviet Union and elsewhere. Current locations of the principal warhead assembly plants are not publicly known, although some are presumed to be in the Chelyabinsk area. Others may be at Novosibirsk and Sverdlovsk.

How much plutonium?

During a 1989 visit to Chelyabinsk-40, American scientists asked Evgeni Mikerin how much plutonium the Soviet Union had produced for weapons. He replied, "A little bit more than you," implying just over 100 metric tons. Because the sizes and startup dates of some

Soviet production reactors have not been made public and the production efficiencies are unknown, estimating production is difficult. Assumptions based on intelligent guesses about these unknowns would suggest that the total Soviet inventory of weapon-grade plutonium is on the order of 115–140 metric tons.

Another method of estimation leads to a similar conclusion. The maximum plutonium-equivalent (plutonium and tritium) production can be determined from the quantity of krypton 85 the Soviets have added to the earth's atmosphere. Krypton 85 is an inert, gaseous product of the fission of uranium 235 or plutonium 239 which is ordinarily released into the atmosphere when spent nuclear fuel is reprocessed. The U.S. intelligence community monitors atmospheric concentrations of krypton 85 and estimates the Soviet contribution by subtracting the contributions of other known sources from total releases. The Soviets also presumably use a certain amount of their production capacity for tritium and for civil and research purposes. If these portions are similar to U.S. uses, the best estimate of how much plutonium the Soviets could have produced for weapons is 115 metric tons.

Since the Soviets will continue to produce plutonium at least for a few more years, the current inventory will grow at a rate of one or two tons per year. Mikerin also told visiting Americans in 1989 that, if a cutoff in the production of plutonium and highly enriched uranium for weapons were negotiated, the Soviets would still need "two to three tritium production reactors." ■

The best estimate of how much plutonium the Soviets could have produced for weapons is 115 metric tons.

Detailed documentation may be found in Thomas B. Cochran and Robert S. Norris, "Soviet Nuclear Warhead Production" (Washington, D.C.: Natural Resources Defense Council, Oct. 19, 1990).

1. *Nucleonics Week* reported 83,000 inhabitants (July 26, 1990), p. 12; the Soviet television newscast *Vremya* reported "almost 100,000" (Aug. 14, 1990).
2. "Annals of the Fatherland: A Reactor for Submarines," discussion recorded by Capt. S. Bystrov, *Krasnaya Zvezda* (Oct. 21, 1989), 1st ed., p. 3.
3. "Kyshtym and Soviet Nuclear Materials Production," fact sheet obtained during visit to Chelyabinsk-40, July 7–8, 1989, *Science and Global Security*, vol. 1, nos. 1–2 (1989), p. 174.
4. B.V. Nikipelov and Y.G. Droozhko, "Explosion in the South Ural Mountains," *Pirorda* (May 1990), pp. 48–49.
5. Ibid.
6. Boris V. Nikipelov, Andrei F. Lizlov, and Nina A. Koshurnikova, "Experience with the First Soviet Nuclear Installation," *Pirorda* (Feb. 1990).
7. *Nucleonics Week* (July 26, 1990), p. 11.
8. "Urgent Warning: Radioactive Waste Available to All," *Izvestiya*, May 4, 1990, p. 6.
9. "Secret Site," *Moscow Trud*, July 11, 1989.