KYSHTYM VISIT GIVES FIRST LOOK AT SOVIET PLUTONIUM PRODUCTION COMPLEX

Last summer, for the first time ever, the USSR opened part of its plutonium production factory at Kyshtym—its equivalent of the Hanford Nuclear Reservation in the United States—to a group of foreign visitors. While the visitors did not see the reactors that are still producing fissionable materials for Soviet nuclear weapons at Kyshtym (and elsewhere), they toured two production reactors recently shut down, and they learned a great deal about other operating facilities and their history, including the catastrophic explosion of nuclear wastes that occurred in 1957. They also picked up more information about Soviet energy policies and returned with more definite impressions about where Gorbachev's government would like to head in arms control.

The visit to Kyshtym was part of a week-long visit that also included a stop at the Black Sea for an unusual experiment involving warhead detection techniques (see the box on page 45) and an unprecedented (and unscheduled) look at the laser test facility at Sary Shagan (see the box on pages 34 and 35). The tour group, which included three members of Congress and reporters for *The New York Times* and *The Washington Post*, was put together on the US side by Thomas Cochran, senior staff scientist for the Natural Resources Defense Council in Washington. Soviet arrangements were made, with Gorbachev's blessings, by Evgeny P. Velikhov, a vice president of the Soviet Academy of Sciences and the director of the Kurchatov Institute.

The general message that Gorbachev has been conveying by permitting this tour and similar visits by other US groups to sensitive military installations in the USSR is that he is willing to introduce *glasnost* into the realm of national security, too, for the sake of improving mutual confidence and prospects for arms control. The specific message of Kyshtym seems to be that he is interested in exploring the possibility of a bilateral freeze on the production of fissionable materials for weapons.

Boris V. Brokhovich (left), director of the Kyshtym complex (see map for location), and Evgeny I. Mikerin, manager of Soviet nuclear weapons production facilities, pose in front of a statue of Igor Kurchatov. (Photo by Robert Carr.)

But what did the group itself see, learn and conclude? Congressman John Spratt of South Carolina summarized his impressions for us as follows: "First, the two reactors that were shut down should have been shut down. [The decision to shut them down] had nothing to do with arms control. Second, there was more that we didn't see than we did see. Third, they seem willing to disclose more—willing at least to agree to a mutual exchange of information. Remember, however, the existing disparity: They can just go to DOE's office of public information to find out much of what they want to know!"

Spratt was asked last year by the chairman of the House Armed Services Committee, Les Aspin, to head up the committee's new Department of Energy Defense Nuclear Facilities Panel. As the head of that panel, it is Spratt's job to keep an eye on the US government's efforts to clear up the mammoth, multibillion-dollar prob-

lems in the US nuclear weapons complex (see PHYSICS TODAY, September 1988, page 47, and November 1988, page 49).

Would a bilateral agreement limiting plutonium production help the United States with the problems in its materials complex? Spratt expressed some skepticism: He points out that the most costly problems arise from past damage to the environment at the major facilities, which has to be cleaned up in any case; and while an agreement to limit or even stop plutonium production might be negotiable, if and when a strategic arms agreement is concluded, it is difficult to see how a freeze could include tritium. (Because of tritium's short halflife, it must be replenished to maintain existing nuclear stockpiles.)

Last July, the House passed an amendment to the defense authorization bill that contains "sense of Congress" language asking the President to begin negotiations on a cutoff of fissile-material production and calling on him to put together a joint working group with the Soviets to explore technical aspects of a plutonium production ban. The amendment originated in a stronger bill drafted on the Senate side, which was largely the work of Christopher Paine, an arms control aide to Senator Edward M. Kennedy of Massachusetts. Paine is relatively optimistic about the prospects for a plutonium freeze. He thinks the intelligence community would welcome an exchange of information that rounded out its knowledge of the Soviet production complex, and he says even some people in the national security establishment see a freeze as a complement to an arms reduction agreement—it would "reduce the error bars" (by limiting the plutonium available for clandestine weapons production).

Generally, however, members of the Kyshtym tour group have been hard pressed to find anybody in the Bush Administration who is seriously interested in exploring a plutonium freeze, and in Congress, there is some reluctance to push the issue too hard—Aspin argues that to do so would "crowd the negotiating table," and that concern is widely shared. The Administration's position regarding a freeze, like its predecessor's position on a nuclear test ban, would seem to be that there is no point in even thinking about such measures as long as the United States remains committed to the development and construction of new nuclear weapons.

The Kyshtym tour group included, besides Spratt, Cochran and Paine, Congressmen Bob Carr of Michigan and Jim Olin of Virginia; physicist Frank von Hippel of Princeton University; NRDC director John Adam and NRDC senior attorney Jacob Scherr.

The Kyshtym visit

Shortly before the group left for the USSR in June, Soviet authorities confirmed that a large explosion took place in a nuclear waste repository at Kyshtym in 1957. For many years Soviet authorities had denied or refused to comment on the claim by dissident biologist Zhores Medvedev, who lives in London, that such an event had happened. Medvedev hypothesized the accident on the basis of a wide variety of evidence, detailed in his book *Nuclear Disaster in the Urals* (Norton, 1979).

The 1957 accident was described to the visitors as follows: In 1956 there was a leak in coolant pipes at a waste repository. Calculations indicated, incorrectly, that the wastes were stable and not highly radioactive, and the coolant was shut off. The wastes then dried, leading to a buildup of highly explosive nitrate salts and acetate.

Soviet scientists continued to deny, at the time of and after the Kyshtym visit, that deaths resulted from the explosion, despite a massive release of radiation. Soviet officials have conceded that a large number of people were evacuated from the surrounding area, but their claims about the number evacuated have varied from as low as 10 000 to as high as 300 000. (It is not known what evacuees were told, though we may learn more from an investigation into the disaster by a newly established commission of the Supreme Soviet.)

The visitors to Kyshtym did not go near a lake where large quantities of high-level waste from chemical separation plants were simply dumped for many years. The wastes contained an estimated 120 million curies of strontium-90 and cesium-137. Soviet scientists said that standing by the lake would result in an immediate per-person exposure of 500 millirems—about 20 times the current permissible limit for civilians (non-radiation workers) near nuclear plants in the United States.

The two shut-down reactors that the visitors saw—"Anotchka" or Little Anna, which provided plutonium for the first Soviet bomb, and a follow-up research reactor for testing materials—showed every sign of having been built simply and in great haste, at a time when Soviet scientists were working furiously to match US nuclear capabilities. Even after the Soviets more or less achieved strategic parity with the United States, they continued to rely on these early reactors: Anotchka was shut down only in 1987, after 39 years of operation. "It's as though the museum-piece reactor at Oak Ridge were still operating," Cochran commented.

The second reactor the visitors saw, built in the early 1950s, was shut down this year. A third aged reactor was shut down shortly after the visit, and the other two plutonium production reactors still operating at Kyshtym are to be closed during the next few years.

Commenting on the early history of Kyshtym, Boris V. Brokhovich, the director of the complex, told the American visitors: "You sat the Rosenbergs in the electric chair for nothing. We got nothing from them. I stood beside [Igor] Kurchatov [the leader of the Soviet atomic weapons program]. I knew what he knew. If we'd known more, we wouldn't have made so many mistakes."

Other findings

The group came away with somewhat mixed impressions regarding the future of the USSR's advanced reactor program. A fact sheet prepared by NRDC suggests the breeder program is on hold pending resolution of a number of issues, including concern about the possibility of runaway reactors that could lead to Chernobyl-like explosions (or worse). Spratt, on the other hand, came away convinced that the Soviets are proceeding with plans to build three 800-MW breeders at Kyshtym—ground already is broken for one, he says—and that they still intend to build a 1600-MW breeder as well. When Cochran remarked on the high cost of breeder electricity to Yevgeny I. Mikerin, chief of manufacturing for the State Committee for Utilization of Atomic Energy, Mikerin replied: "Your thoughts coincide with mine exactly. I think we should build just one breeder, to study it."

In the local election for the newly created Congress of People's Deputies last March, a candidate opposing construction of breeders at Kyshtym (the head of a collective farm) defeated a breeder advocate (the chief of construction at the Kyshtym complex).

The US group learned that the Soviet nuclear fuel cycles differ markedly from practices in the United States. According to Paine, spent fuel from RBMK reactors—the Chernobyl type—is not reprocessed, and there may be no economic incentive to do so because initial enrichment is low and burnup is high. Spent fuel from the

440-MW VVER reactors—the non-Chernobyl type that more closely resemble US light-water reactors—*is* reprocessed, and the separated uranium is sweetened with highly enriched uranium from the weapons stockpile to make 2–4% enriched fuel for RBMKs. The feedstock for Soviet enrichment plants contains reprocessed spent fuel from plutonium production reactors, as well as virgin uranium concentrate.

Soviet commercial uranium enrichment now takes place entirely by means of the centrifuge method, the visitors were told. The Soviets said they have ten centrifuge plants, each with a capacity of 1 million SWU (separative work units) per year. Plutonium production takes place in reactors at three sites: Kyshtym, Tomsk and Dodomovo, near Krasnoyarsk. When Cochran asked how much plutonium the Soviet Union has stockpiled, he was told, "A little more than you."

Somehow members of the group came away with the impression that Kyshtym may house a heavy-water tritium production reactor that they were not told about. Apparently tritium is produced in heavy-water reactors at the other two facilities.

Civilian conversion?

Kyshtym managers expressed concern about what will become of the population of some 100 000 that the facility supports as old reactors are retired and plutonium production is reduced or even entirely eliminated. Apparently there is serious talk about building facilities to manufacture milk processing equipment or VCRs.

Sensitive to constituent concerns of this kind, Congressman Olin commented to PHYSICS TODAY: "It will be hard for them to shut down the [plutonium production] facilities just for that reason [the difficulty of converting them], if nothing else." Nevertheless, Olin came away with the impression that the Soviets are "pretty serious" about the possibility of a limit or freeze on weapons material production. "The main message [of the visit]," Olin said, "was that the Soviet Union has far more reactor capacity than needed, especially if we go ahead with a strategic arms reduction treaty."

Congressman Carr shares Olin's impression that Gorbachev's government would like to negotiate a bilateral agreement on plutonium. His understanding is that the Supreme Soviet plans to consider new legislation this fall that would modify the USSR's atomic energy act to permit further disclosure of information about plutonium.

Regarding the more urgent and much more difficult question of tritium, Carr says one official told him during the visit—"half in jest"—that the USSR might be willing to sell the United States some!

—WILLIAM SWEET

US STUDENTS CONTINUE TO CHOOSE PHYSICS MAJORS

While the overall college-age population in the US is shrinking, the number of students choosing physics majors has remained stable, according to the latest figures on graduation and enrollment in physics programs at US universities gathered by the American Institute of Physics.

The survey of 800 physics and astronomy departments across the country found that 5152 physics bachelor's degrees were awarded during the 1987–88 academic year, down slightly from the 5253 awarded the previous year and about the same as in 1984–85. The number of undergraduates who declared physics majors in 1988 was roughly what it had been the previous several years.

"This comes as a pleasant surprise," says Susanne D. Ellis, one of the survey's authors. "We know that the college-age population is going down, so the fact that physics bachelors are only leveling off—and not slipping—is a good sign." She points out that in addition to those students who major in physics, over 300 000 students take an introductory physics course while in college. "That's a very large number," Ellis said. "And it's especially important now, when the need for scientifically literate people is so great."

This year's survey also turned up a surprising finding on student enrollment at the graduate level: The distribution of foreign students among US physics programs is very uneven. Since the early 1980s, the proportion of foreign students in US graduate physics programs has been high; foreign citizens now account for about two of every five graduate slots. But few schools actually fall at the 40% mark, Ellis says. After looking at individual schools' enrollments earlier this year, she discovered that "graduate programs seem to have either one-fourth or else three-fourths foreign students."

Why the disparity? "In general, those physics programs that are most attractive to US students tend to have fewer foreign students," Ellis says. For example, in the top ten physics departments (as ranked in "An Assessment of Research-Doctorate Programs in the United States: Mathematical and Physical Sciences," a 1982 report by the National Academy of Sciences), an average of 27% of the graduate students are foreign—compared with a combined average of 42% for all doctorate-granting institutions. At the University of Illinois at Urbana-Champaign—with 315 students, the country's largest physics graduate program—only 14% were foreign in 1988–89.

New highs in the number of physics graduate degrees were reached in 1988 compared with the preceding ten years. There were 1733 physics master's degrees granted last year, of which 1035 went to students interested in pursuing higher physics degrees and 698 to those ending their studies at the master's level. Eight years ago, when the number of physics master's degrees bottomed out, only 1370 degrees were awarded. A 4.1% increase was seen in physics doctorate recipients in 1988, with 1150 doctorates awarded, compared with 1105 the previous year.

Ellis attributes the rise in physics graduate degrees to the influx of foreign students enrolling in US graduate programs. Based on current enrollment and graduation trends, the survey projects that the number of physics doctorates granted will continue to rise into the early 1990s, to as many as 1300 per year, and will then either level off or begin to decline.

The number of women and minorities granted physics degrees in 1987–88 remained about the same as the previous year. Women accounted for 15% of the bachelor's degrees awarded in 1988 and 9.5% of the doctorates. Blacks made up 3.5% of physics bachelor's recipients, Asians (including Asian-Americans and Indians) 4.4% and Hispanics 1%.

In astronomy, only one in ten applicants to doctoral programs is accepted, this year's survey found, in contrast to physics programs, where there is a chronic shortage of qualified students. Graduate astronomy departments can draw from a large pool of applicants when selecting their doctoral students; the choice available to physics programs is more limited. Even so, the survey con-