

# Saga of the Siberian Plutonium-Production

## Reactors

By Frank N. von Hippel and Matthew Bunn

This story concerns the effort to shut down or convert three unsafe Russian plutonium-production reactors which together still produce over a ton of weapon-grade plutonium each year -- enough for 200 Nagasaki bombs.

They continue to operate because, without them, one quarter of a million people would be without adequate heat during the long Siberian winter. It is also a tale of the tangles into which government policy can wander -- some of which would have been avoidable had the government been more open to informed, independent peer review.

### The reactors

The three reactors are the last operating Soviet plutonium-production reactors out of an original fleet of 13. They are located in two of the ten secret cities in which the Soviet Union built the key parts of its nuclear-weapons production complex. Until the end of the Cold War, the cities had no names -- only postbox numbers in nearby cities. Tomsk-7, now named Severusk, has a population of 120,000 and is 15 kilometers down the Tom River from Tomsk. Krasnoyarsk-26, now named Zheleznogorsk, has a population of 70,000, and is 50 kilometers down the Yenisey River from Krasnoyarsk. The nuclear cities are still fenced and guarded and outsiders have to apply to visit and be cleared by the FSB, Russia's counterpart of the FBI. One of the authors, Frank von Hippel, visited Krasnoyarsk-26 in June 1996.

The reactors are patterned on the eight plutonium-production reactors that the United States built at Hanford on the Columbia River. The latter were in turn descendants of the graphite-uranium "pile" that Fermi's team built in 1942 under the University of Chicago's football stands. The core of each of the Russian reactors is a huge graphite block, penetrated by 2700 vertical fuel channels. The channels are lined with aluminum and typically each contains a stack of 70 cylindrical aluminum-clad slugs of natural uranium. When a reactor is operating at its current licensed power of 1600 megawatts, each of these slugs of uranium puts out about 10 kilowatts of heat, which is carried away by cooling water flowing through the narrow annular gap between the fuel and the channel wall.



**Fig. 1** *The fence around the Siberian plutonium city of Krasnoyarsk-26 encloses fields and forest as well as the city.*<sup>1</sup>



**Fig. 2** *The central square of Krasnoyarsk-26.*<sup>2</sup>

Like the Chernobyl reactors which were patterned on them, the Siberian plutonium-production reactors lack a robust containment building, such as the one which, in 1979, prevented the escape into the atmosphere of the radioactive gases released from the partially melted reactor core of Three Mile Island unit #2. They also lack an emergency core-cooling system in case a pipe break allows the cooling water to escape.

Furthermore, the Russian production reactors have two unfortunate features characteristic of many graphite-moderated reactors, which contributed to the severity of the 1986 Chernobyl accident:

1. Loss of the cooling water does not shut down the chain-reaction automatically. Indeed, it can increase the reactivity of the core.
2. If the thin aluminum liners of more than a few channels were to break, allowing water to flow into the hot graphite, the steam pressure within the graphite block would rise until it blew the 2000-ton reactor lid off, dispersing a large fraction of the core and its contained radioactivity into the atmosphere.

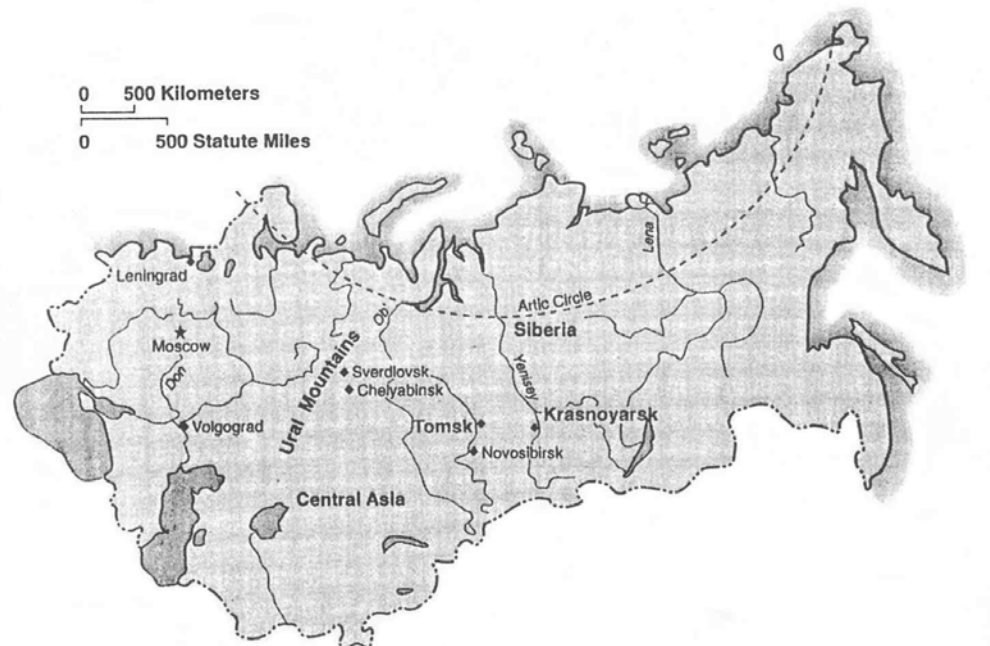
Steam produced by the reactors generates a modest amount of power for the local grids, but the primary reason that the reactors continue to operate is because they are major sources of heat for the hot-water-district-heating systems of the two plutonium cities and of the larger "open" city of Tomsk.

### Why plutonium is still being separated

Plutonium is made in all power-reactor fuel as a result of the capture of neutrons on uranium-238. The fuel used in ordinary power reactors is made out of ceramic pellets of uranium dioxide enclosed in zirconium tubes and is so durable that it can operate for years in the high-temperature, high-pressure environment of the reactor core and be stored for decades after discharge in cooling ponds.

In contrast, the aluminum-clad uranium-metal fuel used in plutonium-production reactors has been deliberately designed to last only for a few months in the reactor core and to be easily dissolved in acid to facilitate recovery of the plutonium. After a year or so in water, the thin aluminum cladding begins to develop pinhole leaks, allowing water to come into contact with the uranium metal underneath. The uranium oxidizes and swells, and absorbs some of the hydrogen released by the uranium-water reaction. "Hydrided" uranium fuel has been known to burst spontaneously into flames when exposed to air.

While such fuel corrosion can be prevented by carefully controlling the water chemistry, the ponds at the plutonium-production reactors are not designed for such control, and the huge quantity (about 1000 tons) of spent fuel each reactor churns out each year also makes long-term storage problematic. Hence, Russia's Ministry of Atomic Energy (MINATOM) has continued to chemically reprocess the fuel discharged by the three production reactors and is storing the resulting weapon-grade plutonium on site. As a result, more than a ton of weapons



**Fig. 3** Russia still has three operating plutonium-production reactors located in towns downstream from Tomsk and Krasnoyarsk.<sup>3</sup>

plutonium is added annually to the massive Russian stockpile - estimated at some 160 tons, including 30 tons of separated, weapons-usable civilian plutonium. This stockpile is already vastly in excess of Russia's post-Cold War needs. In fact, Russia and the United States have agreed to each dispose of 34 tons of their excess plutonium by mixing it with depleted uranium and manufacturing it into "mixed-oxide" fuel for light-water power-reactors. They are currently trying to convince the other G-8 countries to chip in to help pay the estimated \$2 billion net cost of disposing of the 34 tons of Russian plutonium.

### **Origin of US involvement**

The issue of cutting off the production of weapons plutonium has been on the international agenda for decades. In 1989, Soviet President Mikhail Gorbachev announced the end of Russia's production of highly-enriched uranium and the shutdown of three of its plutonium production reactors. In January, 1992, Russian President Boris Yeltsin announced that the remaining reactors would be closed by the year 2000. Only the three that are the subject of this article were still operating as of the end of 1992. With US plutonium production shut down, both Congress and the new Clinton Administration were eager to shut down the remaining three Russian plutonium-production reactors. But how to do it, since the nearby communities needed the heat?

In the fall of 1993, Evgeny Velikhov, Director of the Kurchatov Institute of Atomic Energy, came to Frank von Hippel, then working on nuclear security issues on the White House staff, with a clever proposal.

FAS had begun to have exchanges with Velikhov in 1983, shortly after he had established a committee within the Soviet Academy of Sciences to brainstorm on possible new disarmament initiatives with concerned foreign scientists (including FAS). These brainstorming sessions helped lay the basis for a number of the bold unilateral initiatives that Gorbachev later took to help end the Cold War.

Velikhov had found a Russian manufacturer of jet engines for supersonic bombers interested in going into the business of producing gas turbine, electric-power generators for the Russian market. US manufacturers, such as General Electric and Pratt and Whitney, had already done this very successfully in the US. The management of the Russian combine thought that its retooling costs would be about \$25 million.

Velikhov was convinced that, if such small, domestically-manufactured, gas-turbine generators became available, Russia's national gas utility, GazProm, would pay for their installation in the two nuclear cities because it was interested in getting into the electric-power generation business.

This idea came in just before the December 1993 Moscow meeting of the US-Russian Joint Commission on Economic and Technological Cooperation co-chaired by Vice President Gore and Russian Prime Minister Chernomyrdin, the "Gore-Chernomyrdin" Commission. At about the same time, Congress had passed the Markey Amendment, prohibiting the government from spending money to help Russia build a secure plutonium storage facility until Russia agreed to cut off further production of weapon-grade plutonium. Therefore, when one of Gore's staffers came around looking for possible new US-Russian cooperative initiatives, von Hippel suggested Velikhov's idea. A week or so later, Gore and Chernomyrdin agreed that the US and Russia would explore the possibility of a joint effort to shut down the reactors. On June 23, 1994, at their next meeting, they signed a formal government-to-government agreement calling for these reactors to be shut down by the year 2000, with all plutonium produced in the meantime to be placed under bilateral monitoring to ensure it would never be used in weapons. The United States committed in exchange to help Russia "identify" alternative sources of energy to replace these reactors - but not necessarily to actually pay for them. This agreement would, if carried out:

- End Russian production of weapon-grade plutonium,

- Shut down what were possibly the world's least safe reactors, and
  - introduce a clean source of electric power to Russia.
- At a cost of \$25 million, the idea seemed too good to be true!

Unfortunately, it was.

In March 1994, the US Department of Energy hosted a follow-up meeting to which Velikhov brought a representatives from GazProm. It turned out that GazProm wanted the US to pay for the turbines and new gas pipelines to Tomsk, at a total cost estimated in the range of \$360 million. And there did not appear to be a gas option for Zheleznogorsk, where a coal-fired power plant would have to be completed, whose \$300 million estimated cost would bring the total cost estimate to almost \$700 million.<sup>8</sup> Later estimates came in as high as \$1 billion.

In the United States, decentralized high-efficiency gas-turbine power plants have become the lowest-cost option for new power-generation capacity, with the use of the byproduct heat making it even more economical. In Russia, however, where a large fraction of electricity bills are not paid and most profits find their way into foreign bank accounts, neither domestic nor foreign private investors are interested in new power plants.

The local and regional governments were supportive of replacing the production reactors with coal- and oil-fired plants but MINATOM, which owns the reactors and dominates the closed cities where they are located, insisted that replacement nuclear plants also be studied.<sup>9</sup> The resulting studies found, however, that this option would take longer and cost about \$1.4 billion —still more than the fossil option.<sup>10</sup>

**Fig. 4** *The two plutonium-production reactors that still operate in Tomsk 7 are housed in the tall building at the right. The building in the middle is the hall in which the steam turbines and generators are housed. Behind it are the cooling towers and, in the distance, at the upper right, the long building is the chemical fuel reprocessing plant where the plutonium is recovered.*<sup>4</sup>

All these cost estimates were too high for the US government. At the same time, the Russian government refused to commit to shut the reactors down in the absence of financing for replacement heat. An alternative had to be found. It turned out to be core conversion.<sup>11</sup>

## **Core conversion**

Since the middle of 1992, the nuclear-reactor group of the Pacific Northwest National Laboratory (PNNL) had been discussing a less costly option with officials in the Russian Ministry of Atomic Energy: just change the fuel of the reactors so that it can be stored instead of being reprocessed. The natural uranium metal in the current fuel would be replaced by a more durable mixture of particles of enriched uranium dioxide dispersed in a solid aluminum matrix.

Initially, the leaderships of the US Department of Energy and Nuclear Regulatory Commission balked. Did the US really want to put itself in a position of sharing responsibility for extending the operation of these very unsafe, 1960s reactors?

The proponents of core conversion argued, however, that the reactors would be safer after conversion than before. They proposed to install emergency core cooling systems and also to include erbium-loaded neutron-absorbing elements in the new core design. The rare-earth isotope, erbium-167, has the wonderful property that its absorption of neutrons increases with increasing core temperature. This would help stabilize the reactivity of the cores. Thus, a key design weakness that had contributed to the Chernobyl accident would be fixed.

Ultimately, core conversion seemed the only path forward for a reasonable cost. The total cost for converting the three reactors was estimated at \$160 million of which the US would have to pay roughly half, or \$80 million. For the US government, the choice between a billion dollars and \$80 million was no choice at all. After the initial core conversion feasibility study was completed in December, 1995, the two governments quickly agreed to proceed to the detailed design phase and, in September, 1997, Gore and Chernomyrdin transformed the 1994 pact from a reactor shut-down into a reactor-conversion agreement.

Unfortunately, the completion of the initial feasibility study was followed by a particularly nasty turf war over whether the Department of Defense or Department of Energy should finance and control the conversion effort.<sup>12</sup> The Department of Defense ultimately won, but not before funding for the next round of conversion work had been delayed by nearly a year, a delay which seriously eroded the already difficult relationship between the US government and the Russian Ministry of Atomic Energy.

## **Choice of weapon-grade-uranium for the replacement fuel**

From the outset, one key question for the conversion effort was whether to use low-enriched uranium (LEU) or weapon-grade uranium in the fuel of the converted reactors. The Russian project managers strongly preferred to use weapon-grade uranium because the production reactors already use weapon-grade "spike" fuel in 100 of the 2700 channels of each reactor to boost the power density in the outer parts of the core. They therefore expected that the licensing process for conversion would be greatly facilitated if this proven fuel were used. A number of US officials preferred to use LEU, however, because it would pose less of a proliferation hazard.

After a lively interagency debate in 1996, it was agreed that *both* the LEU and weapon-grade uranium options would be pursued in the design phase, allowing a final decision to be made later. Unfortunately,



however, the Department of Defense project managers quietly dropped the LEU option. Because of lax oversight, this was not noticed until much later.

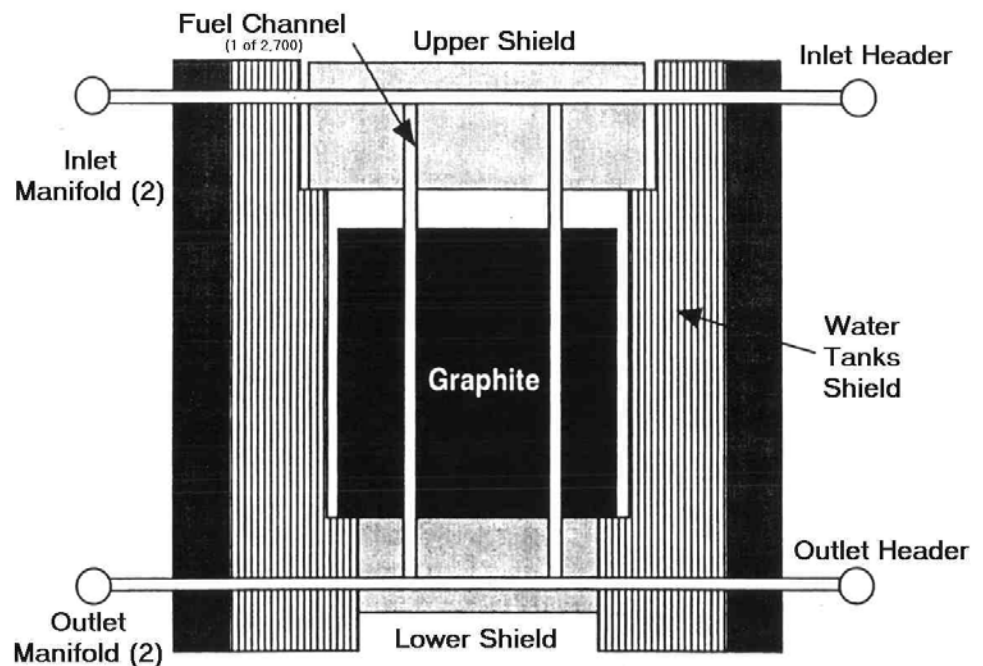
The authors became engaged with the course of the project again in the fall of 1997 when Frank von Hippel attended a briefing for independent nonproliferation analysts by the National Security Council's Senior Director for Nonproliferation.

During the briefing, Tom Cochran, an arms-control physicist with the Natural Resources Defense Council, asked whether a choice had been made between weapon-grade or low-enriched uranium for the replacement fuel. The answer was that this was a technical and not a policy issue.

This was an absurd statement \_ and reflected, in part, the fact that technical expertise from the White House Office of Science and Technology Policy had by this time been largely excluded from the policy-making process on this and many other nuclear material issues.

From a nonproliferation point of view, the "cure" of using weapon-grade uranium (which contains some 90 percent U-235) would be worse than the original plutonium "disease." As was discovered in the US nuclear-weapons program during World War II, weapon-grade uranium is significantly easier to make into a bomb than plutonium. The uranium-based "gun-type" bomb that was exploded over Hiroshima was never tested because its operation was completely predictable. It simply involved firing one subcritical mass of highly-enriched uranium into another to make a super-critical mass inside a sealed gun barrel.

Such a slow assembly of a critical mass would not work for plutonium because of the spontaneous fission of Pu-240. The chain reaction would begin as soon as the two subcritical pieces got close enough to go critical, and they would be blown apart again before a large release of energy could occur. The amount of Pu-240 is minimized in weapon-grade plutonium but, at 6 percent, is still too high for use in the gun-type design. This is why an "implosion" design was developed for plutonium. A subcritical mass of plutonium is surrounded with "lenses" of high-explosive and precision implosion crushes it to a density where it becomes supercritical.



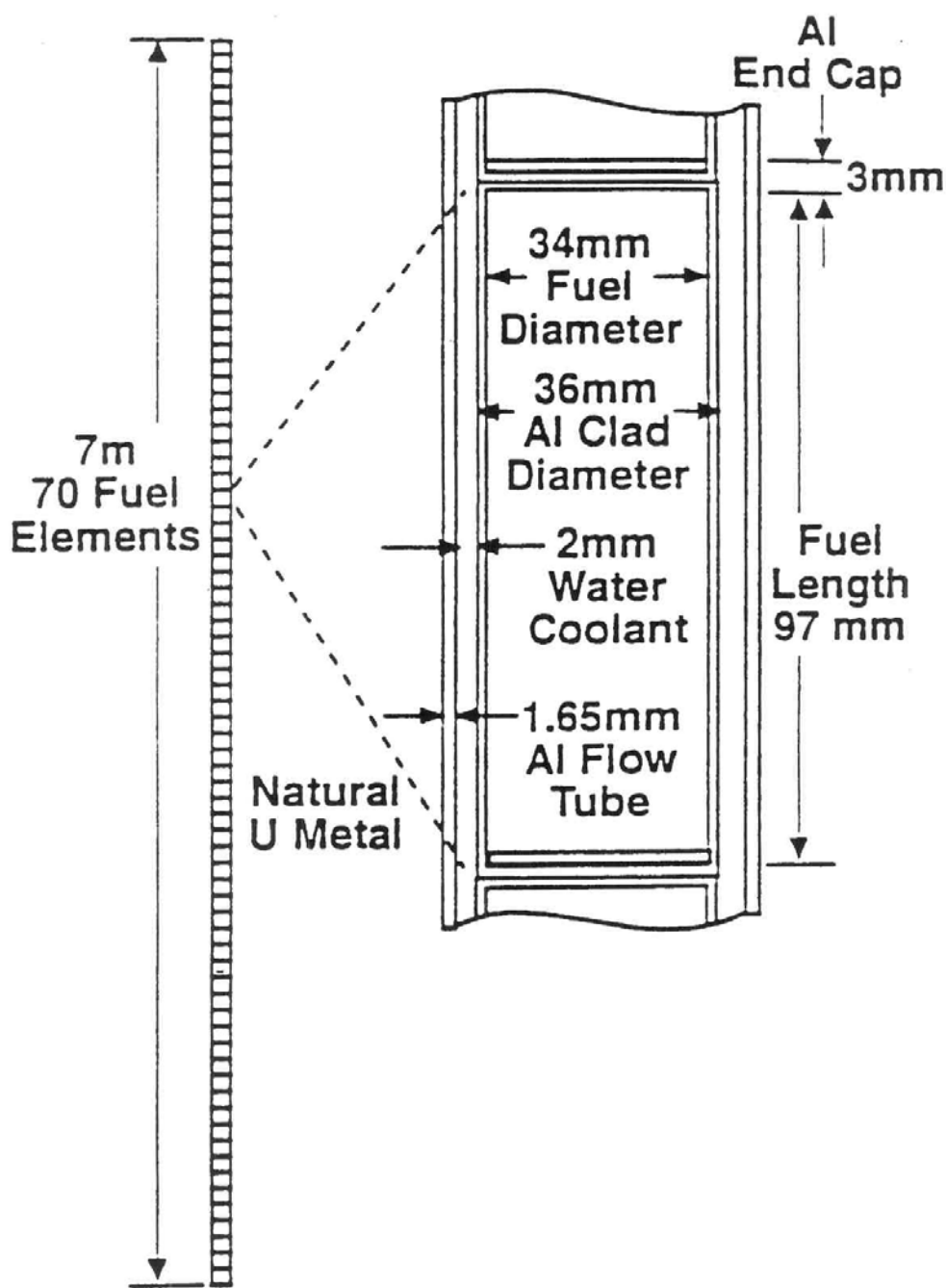
**Fig. 5** Vertical cross-section through one of the plutonium-production reactors.<sup>5</sup>

Weapon-grade uranium therefore seems a much more likely target of theft by potential nuclear terrorists. Furthermore, a process in which hundreds of thousands of pocket-sized weapon-grade-uranium-containing fuel elements are fabricated each year and transported hundreds of miles to the reactors seems much more vulnerable to theft than the short trip within a high-security area to on-site storage currently taken by the unwanted plutonium.

Having focused their entire design effort on weapon-grade uranium, however, the project design team \_ both the Americans and the Russians \_ had become thoroughly invested in the weapon-grade uranium option. Accordingly, the PNNL team produced an analysis that argued that using LEU containing less than 20 percent U-235 would cause a two-year delay or a \$60 million cost increase and that the higher cost of producing the LEU fuel would increase the cost of fuel by \$40 million over the following eight years.<sup>13</sup>

### **LEU fuel development**

After some struggle, Frank von Hippel and Matthew Bunn were able to obtain a copy of the PNNL report for review, and challenged the cost and schedule analysis by which the preference for weapon-grade uranium was principally justified. Indeed, they concluded that LEU might even be cheaper. As a result, the Director of the Department of Energy's Office of Nonproliferation and Arms Control asked a group at the Argonne National Lab to look into the matter. This group has been working successfully since 1978 converting research and test reactors from weapon-grade to low-enriched uranium fuel. After consulting with Russian fuel-fabrication experts, the Argonne group also concluded that there would be no significant additional cost for LEU. The DoE commissioned Argonne to launch a parallel LEU-fuel licensing effort, but the DoD intervened and insisted that the program be managed by the same PNNL team that had fought so wrong-headedly against the LEU option.



**Fig. 6** Fuel stack surrounded by cooling water in one of the 2700 channels.<sup>6</sup>

By the end of 1999, however, the estimated cost to the US of the conversion project had increased to \$335 million. This four-fold increase was a result of a two-fold increase in the estimate of the total cost and a Russian-government decision, following the August 1998 crash of the economy, that it would not be able to pay its half of the cost.

This development, in combination with a stalling of progress on the project, put the future of the conversion project into question.

### Licensing problems

Within the DoD, the reactor-conversion project had been assigned to the Department of Defense's Cooperative Threat Reduction (CTR) program, whose projects are managed by military officers. The primary concern of these officers was to achieve their assigned goal: converting the reactors by the end of the year 2000. They were therefore concerned that the LEU fuel was not as far along in development. Of course, this was mainly because the DoD had not insisted that LEU be developed in parallel, despite the original interagency agreement to do so.

After another interagency debate, in 1999 the US government adopted a compromise policy that weapon-grade uranium fuel would be used for the initial replacement cores and that a second conversion to LEU would be considered if and when qualified LEU fuel became available.<sup>14</sup> What would motivate MINATOM to convert a second time after conversion to weapon-grade uranium was already paid for was left unspecified.



The schedule slippage was partly due to an impasse in the process of licensing the reactors to operate with the new core design. Russian law requires that, since the mission of the converted reactors will be entirely civilian (heat and electricity production), they must receive safety licenses from Russia's State Atomic Inspectorate, known by its Russian acronym, GAN.

Ordinarily, GAN is regarded as relatively ineffective. In this case, however, one of its senior officials, Alexander Dmitriev, had formerly been responsible for the operation of the two production reactors at Tomsk-7 and had supervised the safety upgrades that had been carried out on them after the Chernobyl accident. He knew more about the reactors than almost anyone. Given the serious safety deficiencies already described, Dmitriev insisted that a wide range of issues be thoroughly analyzed before granting them a permanent operating license and, in the interim, required that they operate at less than 80% of their previous power levels.

Dmitriev was also worried about the safety of the new core design developed by the Kurchatov Institute and PNNL. Erbium-loaded neutron absorbers were to be inserted between the fuel elements to soak up the extra neutrons that are absorbed in the current fuel by the production of plutonium. The resulting uneven power distribution along the length of the fuel channels was extraordinarily complex to model, and resulted in intense "hot spots" in the middle of the fuel sections of the stacks, which made Dmitriev very nervous. He raised these safety concerns in a technical article in 1998 but the leader of the PNNL team wrote a reply dismissing Dmitriev's concerns and plunged ahead with the design.<sup>15</sup> Dmitriev remained unsatisfied and also felt that the analyses that he was being provided in support of licensing were grossly inadequate. He sent a message of complaint to that effect to the DoD and DoE in September 1999.<sup>16</sup>

As the licensing process went nowhere fast, it became increasingly uncertain when - and even whether — GAN would ever grant a license for the proposed design.

### **Fossil-fuel replacement again**

All this left MINATOM with a dilemma. Even if core conversion could get licensed, more than \$300 million of the US government's money would have been spent converting reactors that might then have only a few years of operating life left. MINATOM would then be left with no money to provide alternative heat sources for the cities, and no remaining US interest in paying for something new.

In the winter of 1999-2000, therefore, despite having opposed the fossil replacement option years before, MINATOM officials surprised the US government by proposing to abandon core conversion. Instead, they proposed to use the money to refurbish some coal- and oil-fired plants in both cities and to build a new coal-fired heating-power plant in Krasnoyarsk-26. The officials claimed that this could be done at no higher cost than the \$335 million cost for converting the reactors. In essence, they claimed that the cost of the fossil-fuel replacement option could be decreased two- to three-fold, which, in combination with the fourfold increase of the cost to the United States of the conversion option, eliminated the price differential that had driven the earlier decision. Part of the explanation for the reduced cost estimate was that Tomsk would be told to find its own replacement for the heat currently provided by the reactors in Tomsk-7, reducing the amount of heat required. It would then only be necessary to refurbish already-existing coal-fired plants in Tomsk-7.

The US government reacted cautiously, but agreed to a reopen the fossil-fuel replacement option. Natural gas was ruled out by the nuclear cities because they did not want to put themselves at the mercy of GazProm, which prefers to export its gas rather than sell at low domestic prices and is inclined to cut off customers who don't pay.

In September 2000, the two governments agreed in principle that the fossil-fuel alternative would be competitive with reactor conversion in Tomsk-7. A decision on Krasnoyarsk-26 was delayed until December, 2000.

The hesitation about the fossil-fuel option in Krasnoyarsk-26 relates to the high cost of MINATOM's proposal to build a new coal-fired power plant there. Here again, however, the value of independent analysis and review of assumptions comes into play. A study by the Moscow Center for Energy Efficiency, funded by the W. Alton Jones Foundation, examined the energy demand and energy efficiency opportunities in Krasnoyarsk-26, and found that refurbishing and expanding existing fossil-fuel plants may suffice in Krasnoyarsk-26 as well. Heat from a new plant may not be required. Because the cost of heat and electricity to consumers is heavily subsidized in Russia, this may be the first time that the cost of efficiency has been compared with the cost of new energy supply in the nuclear cities.



**Fig. 7** Top of one of the shut-down Krasnoyarsk-26 reactors. Each square covers one channel. The raised covers indicate the locations of control rods. The two pipe tops show the diameter of the fuel channels.<sup>7</sup>

The situation has been complicated, however, by inclusion of language in the fiscal year 2001 Defense Authorization bill which bars Department of Defense from funding any fossil-fuel replacement plan. The bill suggests that the money be sought in the budget of another agency -- perhaps the Department of Energy. However, no funds were provided for that purpose in the Congressional budget for DoE. It has not yet been explained what logic led the Congress to conclude that it is alright for the Department of Defense to refurbish dangerous reactors but not to refurbish old coal plants to make it possible to shut the reactors down. Shutting the reactors would clearly be a better option for the United States, if it could be done at comparable time and cost. It would end Russia's production of weapon-grade plutonium without getting the United States embroiled in extending the lives of aging, Chernobyl-style reactors whose safety would still fall far short of modern standards, even with the proposed safety improvements.

Some advocates of the conversion option have raised the possibility that MINATOM might simply keep the plutonium reactors going, without conversion, even after fossil fuel replacement plants are built. To address this, it will be important to have a formal government-to-government agreement specifying that the reactors will be shut as soon as the alternative energy supplies come on line. Given its heavy dependence on US good will in other areas, it is highly unlikely that MINATOM would violate such a formal agreement for the very limited value it might get from continuing the costly operation of these aging reactors whose plutonium and energy are no longer needed.

## **GAN and LEU Win**

In the meantime, the managers of the core-conversion project have reversed their positions on both core design and LEU -- in effect acknowledging that the critics of their previous approaches were correct. The

proposal to replace some fuel elements with absorbers that drew fire from GAN has been replaced by a design blessed by GAN in which the fuel would be designed with axial holes through which absorber rods would be inserted. In addition to resolving Dmitriev's concerns with the previous design, the annular fuel elements have a major safety advantage in that they would be cooled both in the middle and on the outside. But this shift also means that the entire core licensing process is nearly starting over.

Similarly, at a conference in Washington in September, the Department of Defense official responsible for the program acknowledged that weapon-grade fuel had been abandoned in favor of LEU. The Russian chief designer for the conversion project explained that LEU fuel would be far less expensive — precisely the opposite of the PNNL team's conclusion three years before — and its use would slow the swelling of the graphite due to accumulated neutron damage.

With these changes, the conversion team also argues that the reactors' lives might be extended for as much as 20 years, potentially resolving the concerns that drove MINATOM to propose fossil fuel replacement. But it should be remembered that whatever safety improvements are made, these reactors would never be remotely safe enough to be allowed to operate elsewhere in the world.

### **Monitoring impasse**

In the meantime, much of the government-to-government negotiation over this project has actually focused on another issue -- how to implement the US-Russian agreement to monitor:

1. The shutdown status of all other US and Russian production reactors.
2. That the plutonium produced by the three operating Russian production reactors during the conversion project will not be used to make nuclear weapons.

After the 1994 shutdown agreement was signed, the Russians dragged their feet on the monitoring arrangement, to ensure that the accord would not go into force until some arrangement for replacement energy was available. Even after the two governments had agreed to shift to the conversion strategy in 1996-1997, and changed the cutoff date for the production of unmonitored plutonium to 1997, progress was still slow. One problem was that the proposed monitoring arrangement was inherently more intrusive on the Russian side than on the US side, since all that had to be done in the United States was to confirm that long-shut reactors stayed shut. An added complication is that in Russia, unlike in the United States, the isotopic makeup of weapon-grade plutonium is still classified. Today, there is still no monitoring in place. The problem of convincing Russia to agree will therefore be left to the next administration.

### **The value of outside ideas and peer review**

This story illustrates the strengths and weaknesses of outside ideas and peer review. Sometimes outside ideas provoke new thinking without being quite on target. In this case, Velikhov's \$25 million proposal helped launch a program, but his specific idea did not pan out, and it took a lot of thrashing around to find a way forward.

With regard to peer review, government officials ordinarily do not have the background to be able to challenge arcane technical arguments such as those behind the claims that LEU fuel would be excessively costly and might not even be feasible. Nor can they easily find key experts, such as those of the Moscow Center for Energy Efficiency. Independent experts from outside can be crucial in providing fresh perspectives, examining the validity of key assumptions, and offering informal channels of communication.

But peer review cannot play its role if the key information needed for effective analysis is not made available. This is one of the reasons why FAS has Steven Aftergood's Government Secrecy Project. The traditional instinct of government officials eager to avoid having any mistake revealed is to release as little information as possible. In the case of the Siberian production reactors, the safety debate over the stacked fuel and absorber design, the arguments against LEU fuels, and the fact that the LEU option was not being actively pursued were all closely held.

Remarkably, in several cases the Russian system proved more open than the US system, with Russian officials making documents available that their US counterparts refused to provide. In one case, DoD officials declined to allow independent peer review of a paper because it was "pre-decisional." Obviously peer review would not have made much difference once the paper was "post-decisional!" Only through a combination of luck, a few officials in the system willing to share information with outside experts, and dogged persistence were outside analysts able to get enough information to help provide the missing peer review and analysis.

The lesson: every program where the stakes, in security and in dollars, are as high as this one should have some regularized approach to getting peer review from independent experts. And they must be given the information needed to play that role effectively. Without regular outside review, programs will miss opportunities or crash into ignored obstacles.

Unfortunately, seven years later, this saga is still far from over. This winter, as the reactors heat the Siberian cities, the separated byproduct plutonium continues to accumulate in storage \_ with no verification of its nonuse for weapons in place -- while both the conversion and replacement options struggle fitfully forward, with questionable support in Congress and a new set of players coming to Washington.

### ***About the Authors***

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<sup>1</sup> Photo taken by Frank Zanner, Sandia National Laboratory, June 1996.

<sup>2</sup> Photo taken by Frank Zanner, Sandia National Laboratory, June 1996.

<sup>3</sup> D.F. Newman, C.J. Gesh, E.F. Love, and S.L. Harms, *Summary of Near-term Options for Russian Plutonium Production Reactors* (PNL-9982/UC-520, Pacific Northwest Laboratory, 1994), Fig. 1.

<sup>4</sup> From Pacific Northwest National Laboratory web site: [http://atom.pnl.gov:2080/cgi-bin/photo/\\_cc\\_photo](http://atom.pnl.gov:2080/cgi-bin/photo/_cc_photo). See also FAS archive of circa 1970 US Corona satellite photos of this and other Russian nuclear sites: <http://www.fas.org/nuke/guide/russia/facility/nuke/index.html>.

<sup>5</sup> *Summary of Near-term Options for Russian Plutonium Production Reactors*, Fig. 2.

<sup>6</sup> *ibid*, right-hand side of Fig. 5.

<sup>7</sup> From Pacific Northwest National Laboratory web site. Also in the book *Atom Town*, Vladimir Medvedev, ed. ("Bear" Company, Zheleznogorsk, undated).

<sup>8</sup> *Plutonium Production Reactor Replacement*, Report of the US Replacement Power Fact Finding Mission to Tomsk and Krasnoyarsk-26, June, 1994.

<sup>9</sup> For a discussion of the complex politics between Minatom, the local and regional governments, and local environmental groups, see Mark Chao, *Prospects for Replacement and Shutdown of Russian Weapons-Plutonium Production Reactors*, MS thesis, Energy and Resources Group, University of California at Berkeley, 1995.

<sup>10</sup> *Nuclear Power Replacement Options Study for Seversk (Tomsk-7) and Zheleznogorsk (Krasnoyarsk-26): Technical Evaluation Report*, prepared by the Joint US/Russian Study Team for the US Department of Energy and Russian Ministry of Atomic Energy, December 1995.

<sup>11</sup> The shift of emphasis toward core conversion is evident in a sequence of Gore-Chernomyrdin Commission reports on nuclear-energy initiatives between June 1994 and July 1996 (<http://www.eia.doe.gov/gorec/rept.html>).

<sup>12</sup> This battle, and much of the early history of the project, is described in Todd Perry, "Stemming Russia's Plutonium Tide: Cooperative Efforts to Convert Military Reactors," *Nonproliferation Review*, Winter 1997, available at <http://cns.miis.edu/pubs/npr/perry.htm>.

<sup>13</sup> Darrell Newman, Max Freshly, Ken Mikkelsen, George Meriwether, and Georgi Tsiklauri, *Core Conversion Fuel Enrichment for Russian Production Reactors* (Draft, Pacific Northwest National Laboratory, February 1997).

<sup>14</sup> Letter from Vice President Gore to Alan J. Kuperman, Nuclear Control Institute, April 19, 1999.

<sup>15</sup> Alexander M. Dmitriev, "Conversion of Russian Plutonium-production Reactors" and Darrell Newman, "Comments on Alexander Dmitriev's Paper," *Science & Global Security* 7 (1998), pp. 209-226.

<sup>16</sup> Alexander M. Dmitriev, "Status on Conversion of ADE-2,4,5 Reactors," memorandum, 1999.