energy complex), and Energoatom to develop by Jan. 1, 2007, a feasibility study on prospects for development of Ukraine's uranium resources.

DNPI and Energoatom also were directed to carry out surveys in 2006-2007 to find new uranium deposits and in 2006-2010 to replenish the state reserve of nuclear fuel and nuclear materials (natural uranium concentrate and enriched uranium hexafluoride).

By July 1, the Department of European Integration and International Cooperation, DNPI and Energoatom are to conclude international agreements on peaceful uses of atomic energy between Ukraine and states which host existing nuclear fuel cycle facilities.

This is in line with earlier agreements aimed at integration of the uranium industries in Russia, Ukraine, Kazakhstan and Uzbekistan (*FCW*, Jan. 17).

The same agencies are expected to organize an international open tender on July 1, 2007, for supply of enriched uranium hexafluoride within the framework of phase two of an agreement signed by the Ukrainian and U.S. governments in June 2000.

On Jan. 25, the cabinet approved a co-operation agreement with Euratom. The same day Energoatom and Russian nuclear fuel producer TVEL signed a contract on the supplies of fresh fuel for this year. ●

Russian Revolution Part III

NNSA Assessors: Russians' Thorium Fuel Risky, Expensive

Last May, three Republican members of the House sent an upbeat letter to Paul Longsworth, then National Nuclear Security Administration deputy administrator for nuclear nonproliferation, about a U.S. Department of Energy-funded thorium-fuel development project in Russia.

The letter, signed by Jim Gibbons (Nev.), Curt Weldon (Pa.) and Roscoe Bartlett (Md.), pointed out that a provision of fiscal 2004 appropriations granting $4 million to support testing of the Radkowsky Thorium Plutonium Incinerator (RTPI) fuel stipulated that the technology be independently assessed. Westinghouse Electric Co. had been hired to perform the assessment, which it had delivered on April 1. The results, said the congressmen, were "extremely encouraging."

"As the report finds that 'the technology is well founded and has a good prospect for success' and that it would be 'prudent' to proceed to the lead test assembly (LTA) phase," the letter said, "we finally have before us the prospect of actually beginning to dispose of [weapons-grade plutonium] in as soon as two years…."

Longsworth responded June 1. "For almost a year we have worked closely with the Kurchatov Institute to evaluate the feasibility of using thorium fuel for plutonium disposition in Russia," his letter said. "Our assessment has shown that this technology cannot be successfully implemented in the near future.

"The Westinghouse report you reviewed does not represent NNSA's assessment of the use of thorium fuel for plutonium disposition. Our own assessment…found that the thorium fuel approach proposed by Kurchatov was technologically immature and that thorium fuel could not likely be loaded into a Russian reactor before 2018."

Absence of Key Information

FCW sought out sources in NNSA to elaborate on the findings and conclusions of the technology assessment team, which contrast markedly not only with those of the Westinghouse assessment but with a technical report on the thorium fuel cycle that the International Atomic Energy Agency published in May 2005 (IAEA-TECDOC-1450).

In its own evaluation document, completed last April, NNSA questioned four key aspects of the RTPI fuel technology: technical feasibility, cost, development schedule, and its efficacy in disposing of weapons-grade material.

In many instances, as the authors noted in an introduction, and as NNSA sources repeatedly asserted to *FCW*, the team did not receive from the Russian developers enough data to perform a complete assessment, and were also denied access to critical facilities. They therefore resorted to supplementing what data they had with data based on technologies known to them, using their best technical judgment.

The assessors also made cost and scheduling assumptions based on worst-case scenarios, such as the need for brand-new fuel processing and manufacturing facilities and for thorium feedstock, including mining, milling and purifying, which added a great deal to the NNSA cost and schedule assessment.

Radkowsky Fuel Design Questioned

The Radkowsky fuel employs a seed-blanket design that is meant to substitute for a conventional pressurized water reactor fuel assembly.

The proponents of the fuel design have emphasized that the seed-blanket unit was specifically engineered for existing Russian VVER-1000 reactors with minimal adaptation of reactor hardware and systems. But the NNSA evaluators questioned the composition of the seed fuel on two grounds.

Although the design is based on Russian experience with uranium-zirconium fuel used in naval propulsion reactors, the assessment said that experience might not translate smoothly to a Pu-Zr fuel alloy, in which the plutonium would be uniformly distributed, likely causing significant swelling compared with the uranium fuel, which takes the form of particles.

The NNSA team did note that an alternative fuel design uses a plutonium dioxide and zirconium ceramic-metallic (cermet) fuel instead of the Pu-Zr alloy. The cermet fuel likely would meet fuel design requirements, they said, but still would probably present technical problems during extrusion, and therefore would need an extensive research and development effort.

Extrusion Issues

A second technical criticism focused on the developers' apparent lack of experience in extruding fuel to lengths greater than one meter, because VVERs require fuel rods nearly 4 meters long.

In additional comments, NNSA sources told *FCW* that they had never been able to verify the actual extrusion of the assembly, although they asked to see the process that the developers were using. Even though the developers may well have had success at the laboratory scale, the technology did not appear to the team to be ready for full-scale operation.

In regard to the blanket fuel, the assessors said the most significant problem was the proposed nine-year blanket life. They said that because the Russian regulatory agency has not yet licensed the zirconium alloy cladding tubes for such a long life, the risk of using the blanket fuel for that long was significant. A shortened lifespan for the rods however, would increase the spent-fuel and life-cycle costs.

The investigators also reported that the Russian team had not provided them with reactor-physics, thermal-hydraulics, fuel-performance and safety calculations for review.

In their conclusion the team wrote that although the blanket fuel technology could be proven with sufficient effort, "we see no benefit in retention of the blanket, which was required to achieve an economic fuel cycle with the U-Zr seed fuel. Optimization of the RTPI fuel design for plutonium disposition would almost certainly result in elimination of the blanket."

Cost, Schedule Estimates Off

The NNSA assessment team thought the Kurchatov Institute's cost estimate for the project inadequately accounted for plutonium conversion, purification and metal preparation, and so added an estimate of those costs to the data they had received.

They also believed that more facilities would have to be built from scratch for the plutonium purification and seed-fuel fabrication, rejecting the Kurchatov assertion that Russia's Siberian Chemical Compound could produce the seed and blanket fuel as well as purify the plutonium.

In their comments to *FCW*, NNSA sources said that the assessment team was not permitted by Russian authorities to visit the Siberian facilities, and so could not verify the fuel processing and fabrication facilities there. Having nothing else to go by, they said, they added the cost of building those facilities to their cost assessment.

The NNSA "most likely" total life cycle costs for 38.25 MT of blended plutonium amounted to about $5.7 billion. Nearly $1.9 billion stemmed from the capital costs for the design, construction and startup of separate seed fuel and blanket fuel fabrication facilities design, construction and start-up, while another $3.3 billion was estimated to operate both facilities.

The assessment team drew from available Kurchatov data an estimate of $1.2 billion in total life cycle costs for the disposition of the same amount of plutonium, of which $870 million came from the capital costs of assembling the manufacturing processes (presumably in existing facilities) for the blanket fuel and seed fuel ($150 million), and for operational costs of the fabrication process ($720 million).

No Advantage for Plutonium Destruction

The Russian institute had submitted in draft reports preliminary scheduling information indicating that the thorium fuel lead test assembly would go into a reactor by 2008, with a mission fuel assembly to be put in by 2013. NNSA did not find these estimates realistic because the tasks were not presented to show the logic that connected them, and instead set the two milestones for 2011 and 2018, respectively.

The assessment team also flunked the Radkowsky fuel on its nonproliferation characteristics. An analysis of the material balances Kurchatov provided found the entire amount of uranium left in the blanket after irradiation to be weapons-usable with a mass-weighted equivalent fissile content of 20.8 percent—higher than the Kurchatov's own design limit of 20 percent, which is accepted as the standard level of fissile material needed to make weapons.

NNSA calculated that an irradiated RTPI fuel assembly at the end of life contains 21.8 kg of weapons-grade uranium and 4.6 kg of weapons-grade plutonium, for a total of 26.4 kg of weapons-grade material. When compared with the unirradiated RTPI fuel assembly, which has only 15 kg of weapons-grade plutonium, this amounts to a 76 percent increase of weapons-grade materials per seed-blanket unit above the original mass, the team wrote.

That analysis directly contradicts the May 2005 IAEA report's characterization of irradiated Radkowsky thorium fuel: "[The Radkowsky seed-blanket-unit approach assumes] a once-through fuel cycle with no reprocessing, with the bred 233U burnt *in situ*; the 233U that is produced, is denatured by admixed uranium isotopes in order to force isotopic separation should extraction and use of the bred 233U be attempted."

That is, whatever U-233 is not consumed during irradiation is combined in the spent fuel with other isotopes that make its extraction very difficult and expensive.

Finally, while acknowledging that RTPI spent fuel contains less plutonium than an equivalent MOX assembly, the evaluators stated: "…we attribute no advantage to the irradiation of plutonium below the spent-fuel standard" because the goal of the plutonium disposition program is to reduce weapons-grade plutonium to the level of reactor-grade plutonium in commercial spent fuel.

Given the difficulty and expense of disposing of commercial plutonium spent fuel, it would seem that even if the technology exceeds the standard, it would seem reasonable that the reduction or elimination of plutonium be acknowledged as an advantage of the technology. *FCW* questioned NNSA sources about this stance but did not elicit a clear response. ●

First Magnox Fuel Plant Closes At U.K. Springfields Site

By Judith Perera, European Correspondent

One of the oldest manufacturing plants on the U.K.'s Springfields site ceased operation on Feb. 6 after almost 50 years of continuous production.

Ownership of the Springfields site was transferred to the Nuclear Decommissioning Authority (NDA) in April 2005 and Westinghouse Electric UK Ltd. operates it on their behalf. The Magnox billeting plant is the first of the main Magnox production facilities to close as part of the Springfields' decommissioning plan, and the rest will close over the next two years.

The manufacture of uranium metal billets is an intermediate process in production of Magnox fuel. Uranium tetrafluoride is mixed with magnesium metal particles and the mixture is compressed to form pellets weighing approximately 3kg. The pellets are stacked within the graphite liners of a closed stainless steel reactor vessel, which, after pressure testing, is loaded into an electrically heated furnace.

In the mid-1950s the government announced that a fleet of 12 Magnox nuclear power stations would be built in the U.K. and would use fuel produced at Springfields. In addition two Magnox power stations were built overseas, at Latina in Italy and at Tokai Mura in Japan. Springfields also produced fuel for these. To cope with the fuel requirements, the original production facilities were replaced in 1958 by a completely new plant with larger production capacity.

Magnox Fuel Fab Ends in 2007

Springfields has produced a total of some 59,000 tonnes of uranium metal and fabricated almost 5.4 million Magnox fuel elements. Although Wylfa, the U.K.'s last operating Magnox station, is not scheduled close until the end of 2010, fuel fabrication at Springfields will end in 2007 following progressive closure of the facilities, which will be decommissioned as they close.

During their almost 50 years of operation, the Magnox plants have produced at least 1,035 TWh of electricity, equivalent to burning 260 million tonnes of coal, said Paul Green, head of Magnox plants. Work on Magnox fuel also helped develop fabrication processes for advanced gas-cooled reactors and other advanced fuels.

Following the closure of the Magnox plants, commercial operations at Springfields will comprise fuel production for the lifetime of the U.K.'s advanced gas-cooled reactors, production of uranium hexafluoride for the Canadian company Cameco, and production of uranium dioxide products for customers in Europe and the Far East.

Referring to the government's energy review, a local member of parliament, Michael Jack, said he hoped it wouldn't be too long before a new generation of nuclear plants leads to a new round of fuel fabrication at Springfields. ●