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More power to thorium?

By John S. Friedman

Alvin Radkowsky, a pioneer nuclear scientist now living and working in Israel, is a man with a mission. At 81, he still hopes to create a "new era of nuclear power" based on one of the oldest of the Nuclear Age's ideas-electricity generated by thorium-fueled reactors.

Radkowsky headed the elite team in the 1950s that designed the first reactors for submarines and aircraft carriers. More recently, he has invented-at least on paper-a fuel core for light-water reactors that, he says, "may eliminate many problems that have bedeviled the nuclear industry."

Unlike current reactors, the Radkowsky Thorium Reactor, a joint U.S.-Russian project still in the research and development phase, would produce little weapons-usable material. Because of its thorium-fuel design, the amount of plutonium produced by a Radkowsky reactor would be about 20 percent of the plutonium produced by a more conventional uranium-fuel reactor.

Michael Higatsberger, a nuclear physicist at the University of Vienna, called the design a "creative breakthrough" that "may put nuclear energy back on an upward track again." Higatsberger's remarks were included in a letter sent to the Energy Department recommending Radkowsky for an Enrico Fermi Award. Yuval Ne'eman, the father of Israeli nuclear research, describes the design in a letter to Radkowsky as "a most impressive achievement" that "will undoubtedly have an important impact on the future of nuclear power."

The Radkowsky design comes at a time when nuclear power is on the ropes, largely because it has proven to be far more expensive than anyone dreamed 30 or 40 years ago. Radkowsky has watched the ups and downs of nuclear power from center stage since the 1950s, when he was chief scientist in the U.S. nuclear submarine program directed by Adm. Hyman Rickover. Radkowsky later headed the design team that built the world's first civilian nuclear power plant at Shippingport, Pennsylvania, which was essentially a scaled-up version of the first naval reactor.

Radkowsky retired from the navy in 1972 and became an academic scientist. Now a professor emeritus at Tel Aviv University, he has headed the scientific effort of the Radkowsky Thorium Reactor project for five years. In effect, the project is an extension of work he did at Shippingport. Although that reactor was fueled with uranium when it went on-line in 1957, it was retrofitted with an experimental thorium-uranium core in 1977, which operated for about five years.

Almost all of the world's 400-plus power reactors rely on uranium fuel rather than thorium. Natural uranium is 99.3 percent uranium 238, which cannot sustain a chain reaction. But it also contains 0.7 percent uranium 235, a fissile isotope that can sustain a chain reaction. Most power reactors operate with slightly enriched uranium-typically, about 4 percent uranium 235.

In contrast to natural uranium, thorium lacks a fissile isotope. But it is "fertile." When bombarded with neutrons, a portion of the thorium is converted to uranium 233, a fissile isotope. As early as World War II's Manhattan Project, nuclear scientists were certain that a thorium reactor could be built if it incorporated an initial neutron source-uranium 235 or plutonium 239. The source or "seed" fuel would breed uranium 233. The uranium 233 then could be unloaded from the reactor, separated from the thorium fuel, and fed back into the reactor in a closed-fuel cycle. Alternatively, the uranium 233 could remain in the reactor, eventually becoming a key component in the chain reaction.

Over the decades, several nations, including the United States, experimented with thorium-uranium fuel, but the economics of it never seemed to work, in part because the physics of thorium and uranium differed greatly, thus leading to inefficient operation. And, too, most thorium-cycle schemes relied on reprocessing, and in the late 1970s the United States came to oppose the recycling of nuclear fuel because of proliferation concerns. Today, only India remains a strong proponent of the thorium fuel cycle.

The Energy Department recently announced a policy of burning some surplus weapons plutonium as mixed oxide (mox) fuel in a few existing commercial power reactors. The developers of the Radkowsky design believe that it can play a role in disposing of weapons plutonium, in which plutonium could be used as a fuel component.

The Radkowsky design avoids recycling by envisioning a complex fuel core in which uranium "seeds" enriched to about 20 percent uranium 235 are kept separate from a surrounding thorium-uranium "blanket." The uranium 235 produces the neutrons that sustain the chain reaction while slowly creating uranium 233 in the blanket. As burnup continues, the newly created uranium 233 picks up an increasingly greater share of the fission load.

As in any uranium-fuel reactor, the uranium portion of the core would produce plutonium, but in lesser quantities than in a conventional reactor and with far higher isotopic contamination. The latter characteristic would make the plutonium even less desirable for weapons than is ordinary reactor-grade plutonium, argues Radkowsky. That would make his reactor exceptionally unattractive to would-be weapons makers. Although uranium 233 can be used for weapons, it too would be isotopically contaminated, making its use in weapons unlikely.

Because Radkowsky's design focuses on modifying the composition and assembly of fuel cores, it is conceivable that Radkowsky's ideas can be tried out in existing light-water reactors. But would it be cost effective? Frank von Hippel, a Princeton physicist, has doubts. He lauds Radkowsky for "radically simplifying the fuel process," but adds that the price for conventional uranium fuel is now so low that there is little economic incentive to adopt a new fuel concept.

The consortium developing the Radkowsky reactor idea-the Radkowsky Thorium Power Corporation, Raytheon Nuclear Inc., Brookhaven National Laboratory, and the Kurchatov Institute in Moscow-faces the challenge of convincing utilities that significant financial savings will accrue from the new reactor before they put up money for licensing and technical development work in making the transition to the Radkowsky design.

"No one," says Marvin Miller, a Massachusetts Institute of Technology physicist and proliferation expert, "will buy a new line of reactors based on nonproliferation alone." But Seth Grae, president of the Radkowsky Thorium Power Corp., established in 1992, counters: "Our reactor cores are less expensive by up to 20 percent, and additional savings occur because our design reduces the storage of nuclear waste by up to 50 percent."

The projected savings are a function of the fuel core design. The thorium-uranium blanket would be left in place for about 10 years to maximize uranium 233 burnup. In contrast, the seed elements would be replaced every 18 months or so. The net result: Over its operating life time, the Radkowsky design would use less fuel than would a comparable uranium-fuel reactor.

Radkowsky partisans are also betting on a general uptick in the nuclear power industry as concerns about global warming increase. If that happens, utilities may be more willing to take another look at nuclear power and to adopt proliferation-resistant reactor concepts. Another boost could come from a study begun last fall by the International Atomic Energy Agency regarding the use of thorium in reactors. A central question being looked at is: Are thorium reactors, including the Radkowsky design, truly more resistant to proliferation?

The initial market for the reactors, according to its developers, is expected to be in Russia and Asia. They believe that Russia, with its vast stocks of separated civil plutonium as well as weapons-grade plutonium, might be receptive to the Radkowsky concept for some of its more advanced light-water reactors, the vver series. Plutonium, they note, can be used as core fissile material-the neutron source. Japan, Indonesia, Vietnam, Malaysia, and China are also seen as possible users of the Radkowsky design.

A $550,000 grant from the Energy Department is underwriting joint planning and research at Brookhaven National Laboratory and the Kurchatov Institute in Moscow. The first engineering phase, begun last fall, is scheduled to end late this year or in early 1998. By then, the U.S. and Russian researchers hope to have determined which experiments are necessary to test such things as fuel performance and safety. The researchers hope to conduct the tests in a limited number of reactors, almost certainly Russian vvers, and make the design available to commercial licensing early in the next century.

"But for the Russian involvement, we could not have begun this project in 1993," says Grae. "Expenses could have been several hundred million dollars in the United States. The cost of paying Russian scientists is substantially less than what it costs in the States."

Employing Kurchatov scientists was also an attractive proposition to the Energy Department, which approved the grant in late 1995. Besides the merit of the design, a department official notes that the project employs Russian scientists who might otherwise sell their weapons expertise elsewhere. And, also, Radkowsky uranium-thorium cores might be inherently safer than current Russian cores.

The main selling point of the Radkowsky concept, according to Grae, is that the reactor "helps sever the link between nuclear power generation and nuclear weapons." The new reactor, he says, will help fulfill the mandate of the Nuclear Non-Proliferation Treaty, which calls not only for a halt in the proliferation of nuclear weapons, but also for the transfer of peaceful nuclear technology.