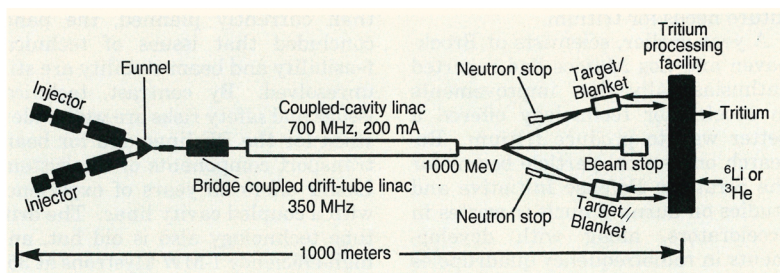


AS ARMS RACE ENDS, DOE PULLS PLUG ON TRITIUM PRODUCTION—FOR NOW

One by one, breakdown after breakdown, the aging nuclear reactors that produced plutonium and tritium for US nuclear weapons were shut down. The first to be turned off was the N reactor at the sprawling Hanford reservation, outside Richland, Washington. It was closed for repairs in December 1986 and never restarted. In June 1988, the plug was pulled on the decrepit K reactor, the last working reactor of the five at the Savannah River complex in South Carolina. It was shut down after numerous incidents of radioactive leaks and procedural violations. Over the next four years all attempts failed to get the K reactor started again. Finally, on 24 March the new Clinton Administration's Energy Secretary, Hazel R. O'Leary, reversed a decision by her predecessor, Admiral James D. Watkins, when she decided not to restart the K reactor. O'Leary's order placed the K reactor in "cold standby"—though it is unlikely the reactor will ever resume operation.

The Energy Department has spent about \$1.5 billion since 1988 to repair and modernize the K reactor, with the avowed intention of running it again. The department even built a \$75-million cooling tower after the Natural Resources Defense Council got a court order directing DOE to end the discharge of heated water into adjacent streams on the wooded 300-square-mile site. For Watkins, restarting the K reactor had been among his highest priorities. He commanded Westinghouse Electric to resume operating the K reactor no later than this summer. Running the reactor without mishap for five or six months, Watkins reasoned, would demonstrate DOE's ability to produce tritium, the rare second isotope of hydrogen, used to "boost" the explosive power of thermonuclear weapons.

Tritium is not normally found in nature but can be created in a nuclear reactor by bombarding lithium with neutrons. Because of tritium's rapid decay rate of about 5.5% per year (its radioactive half-life is 12.3 years), fresh quantities of the isotope are needed to replenish nuclear warheads every five or six years. As the sole



Tritium accelerator designed by Los Alamos, Sandia and Brookhaven is one of the options being considered to meet the needs of the nation's reduced nuclear weapons stockpile.

source of tritium, the reactors at Savannah River were held by DOE and the Pentagon to be essential to keep the weapons stockpile in a state of readiness. In fact, as late as 1990 the Bush Administration wanted to restart three of the five Savannah River reactors as well as to build two new ones to ensure a reliable source of tritium. One of the proposed new reactors was to be a heavy-water plant located at Savannah River and the other a novel helium-cooled, graphite-moderated reactor to be constructed at the Idaho National Engineering Laboratory near Idaho Falls. The cost of both reactors was estimated at nearly \$8 billion. (See *PHYSICS TODAY*, September 1988, page 47.)

Since then, all assumptions about the size and scope of the world's nuclear stockpile have changed drastically. The START I agreement reduced the number of strategic warheads for both the US and USSR, and START II calls for the elimination of all land-based multiple-warhead missiles on each side. With the collapse of the USSR, even the first treaty will need to be ratified and implemented by the countries of the former Soviet Union, though the US has already done so. It turns out that when President Bush and Russian President Boris Yeltsin met last June they decided that their respective nuclear arsenals would still be too large after START II, which limits each country's own stockpiles to some 3000 to 3500 warheads each. At that level, the need for tritium would drop significantly.

Though DOE had decided to delay building the new reactors even before the Bush-Yeltsin summit, Watkins insisted on keeping all the options open. One of the options was to produce tritium with a proton accelerator rather than a reactor.

The idea has been around since the 1950s. Tritium was first created more than a decade earlier in a cyclotron at Berkeley, but accelerators were unsuited to producing the quantities used during the nuclear arms buildup. The Atomic Energy Commission relied entirely on reactors. In the early 1980s a panel headed by Keith Glennan, who had been the first administrator of NASA from 1958 to 1961, advised DOE, the successor to the AEC, that tritium from an accelerator was technically feasible, but the reliability, efficiency and cost of such an accelerator were uncertain without further engineering design and development. But by 1988 it was clear that the reactors producing the basic ingredients for nuclear warheads were either rapidly nearing or already past their expected lifetimes and, much worse, were disasters waiting to happen. Congress demanded that DOE should act to ensure adequate supplies of weapons materials.

ERAB's 'attractive option'

Late in 1989, DOE's Energy Research Advisory Board examined the potential of an accelerator for tritium and reported to Watkins in February 1990 that such a facility was "an attractive option in terms of safety, environmen-

tal impact and public acceptance." An accelerator would offer low residual radioactivity, low operating temperature and pressure, and rapid shut-down capability in the event of an emergency, said ERAB. It also cautioned that electricity costs might make the machine more expensive to run than a reactor. Nonetheless, operating costs might be held down because it is unlikely that the accelerator would run continually to meet future needs for tritium.

A year earlier, scientists at Brookhaven and Los Alamos had reported enthusiastically that improvements in accelerator technology offered a better way to produce tritium. Research on neutral particle beams for the Strategic Defense Initiative and studies on burning nuclear wastes in accelerators, along with developments in radiofrequency quadrupoles for electron accelerators, suggested to these scientists that the time had come to consider an RF linac for tritium production. They produced a preliminary design for the accelerator and recommended that it be built at Hanford.

After reviewing ERAB's conclusions in the light of the report from Los Alamos and Brookhaven, Watkins called for another evaluation of the feasibility and practicality of using particle accelerator technology to produce enough tritium to meet weapons goals. To that end, William Happer Jr, DOE's research director for both civilian and defense programs, approached Jason, a group of eminent scientists who advise the government on defense related issues. One major change in the need for tritium had occurred since the ERAB report: DOE's goal for producing tritium was reduced to one-half or even three-eighths of the cold war targets and new tritium supplies were not expected to be needed until 2005—five years later than the date once set for restarting production.

In January 1992 a panel of 15 physicists and engineers was assembled under the chairmanship of Sidney Drell, deputy director of SLAC and former co-director of the Stanford Center for International Security and Arms Control. The Jason panel examined two approaches for a proton accelerator: a continuous wave RF linac based on a scale-up of the Los Alamos Meson Physics Facility and a pulsed-power linear induction machine based on technology under development at Sandia and Lawrence Livermore National Laboratories. Of these, the panel concluded, "only the RF linac is a candidate meriting further consideration if a decision to

proceed is to be made in the next few years." Pulsed-power technology has an advantage over an RF system when a large ratio of peak-to-average power is required, the panel stated, but that is not the case for the proposed tritium accelerator. In addition, while the Sandia-Livermore team claims that an accelerator of their design would be less costly to run if it became necessary to meet significantly higher goals of tritium than currently planned, the panel concluded that issues of technical feasibility and beam stability are still unresolved. By contrast, technical issues and safety risks are well understood for the RF linac and for beam transport components of the system. LAMPF offers 20 years of experience with a coupled cavity linac. The drift tube technology also is old hat, and high-efficiency 1-MW klystrons at 350 and 500 MHz have been in use for years at electron storage rings.

The proposed target systems are very different, however, and in one case far less advanced than the accelerator itself, said the Jason group. The lithium-aluminum target is similar to the technology used in Savannah River reactors for 35 years, so there is unlikely to be any showstopper in fabricating the targets or extracting the tritium. Nevertheless, the panel stated, "the irradiation environment... will be significantly different, requiring study of source terms, tritium retention in the target, operating characteristics of the accelerator (particularly the frequency of beam cycling) and materials properties." Much less seasoned, the more innovative helium-3 gas target offers the potential of significant safety and operational advantages, "including continuous processing (which assures that there are only a few grams of tritium in the target system at any one time), ease of fabrication and the absence of possible metal-water reactions in the event of a temperature excursion." Because of these factors, the panel urged DOE to continue developing the ^3He target while the relative merits of the Li-Al system are being evaluated.

While the panel was not asked to compare the advantages and disadvantages of an accelerator against a reactor for producing tritium, it did so anyway. The accelerator, it observed, doesn't require fission in generating neutrons and hence doesn't produce the high-level radioactive waste associated with reactor operations. In addition, the accelerator targets do not contain radioactive actinides or fissile material and hence are free of criticality concerns. For those rea-

sons and because of the reduced requirement for tritium under current and foreseeable scenarios for nuclear weapons, the Jason panel asserted that there is no need to build and operate a new fission reactor to power the proposed accelerator. After discussing the prospective design for the accelerator with its progenitors at Los Alamos, Brookhaven and Sandia, the panel decided the beam energy and other components and characteristics ought to be changed. The report calls for beam energy of 1.6 GeV, beam current of 125 mA and beam power of 200 MW. It also eliminated the injection funnel (shown in the diagram), a device for increasing current by combining the output of two separate injectors. The panel recommends a single RFQ and drift-tube linac of 350 MHz and a coupled-cavity linac in the main accelerator of 700 MHz. Such specifications aside, the group was reluctant to give unqualified approval for the accelerator concept until all the safety risks and operating costs were resolved relative to the proposed technologies for a new production reactor. Indeed, the panel didn't rule out using a conventional light-water nuclear reactor to make tritium.

Of costs and contractors

Though it admitted that a reliable cost estimate was impossible without a definitive design, the panel gave a wide ranging sticker price of \$4.5 billion to \$7 billion and observed further that operating costs would depend on the accelerator's electric power use. Other estimates are much less—between \$3 billion and \$5 billion. While DOE continues to cannibalize its warhead stockpile for tritium to top up those warheads it wants to keep in readiness, there is probably no need for new tritium supplies until possibly 2012.

A year ago DOE directed Los Alamos to seek the help of industrial firms in designing the accelerator. Some 40 companies submitted proposals and six were chosen: Babcock & Wilcox, Bechtel Corporation, General Atomics, Grumman Aerospace, Maxwell Balboa, and Merrick and Co. In his letter to DOE, Drell noted that the labs had informed the Jason panel that an accelerator R&D program might cost as much as \$70 million over an 18-month period. DOE, for its part, set aside \$30 million in fiscal 1993 for the design but so far has allotted only \$21 million for the work. With little urgency to make tritium, the department has decided to put off its decision on a machine to 1995.

—IRWIN GOODWIN ■