Breaking the fuel/weapons connection

Stopping both military and civilian production of weapons-usable material could halt the spread of nuclear weapons and put a lid on superpower arsenals.

by Harold A. Feiveson, Frank von Hippel, and David Albright

THE SUPERPOWERS together have produced about 200 tonnes (metric tons) of plutonium and 1,000 tonnes of highly enriched uranium for use in nuclear weapons. If current plans go forward, hundreds of tonnes of additional weapons-usable plutonium will be separated from civilian nuclear power reactor fuel throughout the world over the next decades. This production of weapons-usable material for both military and civilian purposes must be constrained to the maximum extent possible if efforts to reduce nuclear arsenals and to prevent the spread of nuclear weapons to additional countries and to terrorist groups are to succeed. To this end, we have proposed the following:

- that the separation of plutonium from spent reactor fuel and the use of plutonium and highly enriched uranium to fuel civilian nuclear reactors be halted indefinitely.
- that the nuclear-weapons states halt production of fissile material for nuclear weapons and put their existing stocks of civilian fissile material and facilities capable of producing such material under international safeguards.[1]

These two measures—one relating to the spread of nuclear weapons to additional national and to terrorist groups (horizontal proliferation) and one relating to the expansion of already existing nuclear weapons arsenals (vertical proliferation)—are linked politically and technically. It is time to combine them in a single package.

CIVILIAN NUCLEAR power reactors are operated today almost exclusively on a "once-through" fuel cycle (figure 1), in which weapons-usable material is never easily accessible. The uranium in the fresh fuel is low-enriched (typically 2–5 percent uranium-235) and is therefore, like natural uranium (0.7 percent uranium-235), unsuitable for weapons use without further isotopic enrichment—a difficult technical process available today on a significant scale only in a few major industrial states. The plutonium in spent fuel rods discharged from reactors is not separated from the highly radioactive fission products in the fuel and is therefore not available for weapons use.

Unfortunately, however, there is a growing international movement toward the reprocessing of spent reactor fuel to separate the contained plutonium—a chemical process which requires special facilities providing heavy shielding (figure 1). Already, France and Great Britain together are separating over five tonnes of plutonium each year—enough to make hundreds of nuclear weapons—and they have undertaken as a commercial enterprise the reprocessing of nuclear fuel from other countries. As a result, increasing amounts of separated plutonium are being returned to non-weapons states.

Among France's and Britain's leading customers are West Germany, Japan, and Switzerland, who contracted for these services during the 1970s in large part because of strong pressures from domestic antinuclear groups to demonstrate a solution to the problem of nuclear waste disposal. However, since the contracts stipulate that the high-level radioactive waste produced by reprocessing will ultimately be returned to the countries of origin, this solution is only a postponement. Furthermore, the nuclear industry now generally agrees that the storage and final disposal of spent fuel are not intrinsically more difficult than disposal of the high-level wastes created by reprocessing the fuel. Reprocessing is therefore not essential to radioactive waste disposal. Indeed, the United States, Canada, and Sweden—all countries with strong nuclear programs—have recently decided to forego reprocessing and to allow the radioactivity in their spent fuel to die down in storage for a few decades before making a final decision on disposal.

Japan, West Germany, and India, however, are following the example of France and Britain and have already built their own small- or intermediate-scale reprocessing facilities. Argentina, Brazil, and Pakistan are also developing reprocessing capabilities.[2] Through the year 2000, existing and proposed reprocessing plants could separate about 400 tonnes of plutonium—more than exists in the superpower arsenals (figure 2). What will become of all this dangerous material?

Most countries originally expected to use the separated plutonium to provide startup cores for plutonium-breeder reactors. By converting the abundant uranium-238 isotope into chain-reacting plutonium, breeder reactors would extract 100 times more energy from natural uranium than do current nuclear power plants, which derive their energy primarily from the fission of the rare uranium-235 isotope. As long as projections of nuclear power growth remained high and low-cost uranium resources seemed scarce, the development and deployment of plutonium-breeder reactors appeared an urgent task.

However, the expectations on which breeder programs

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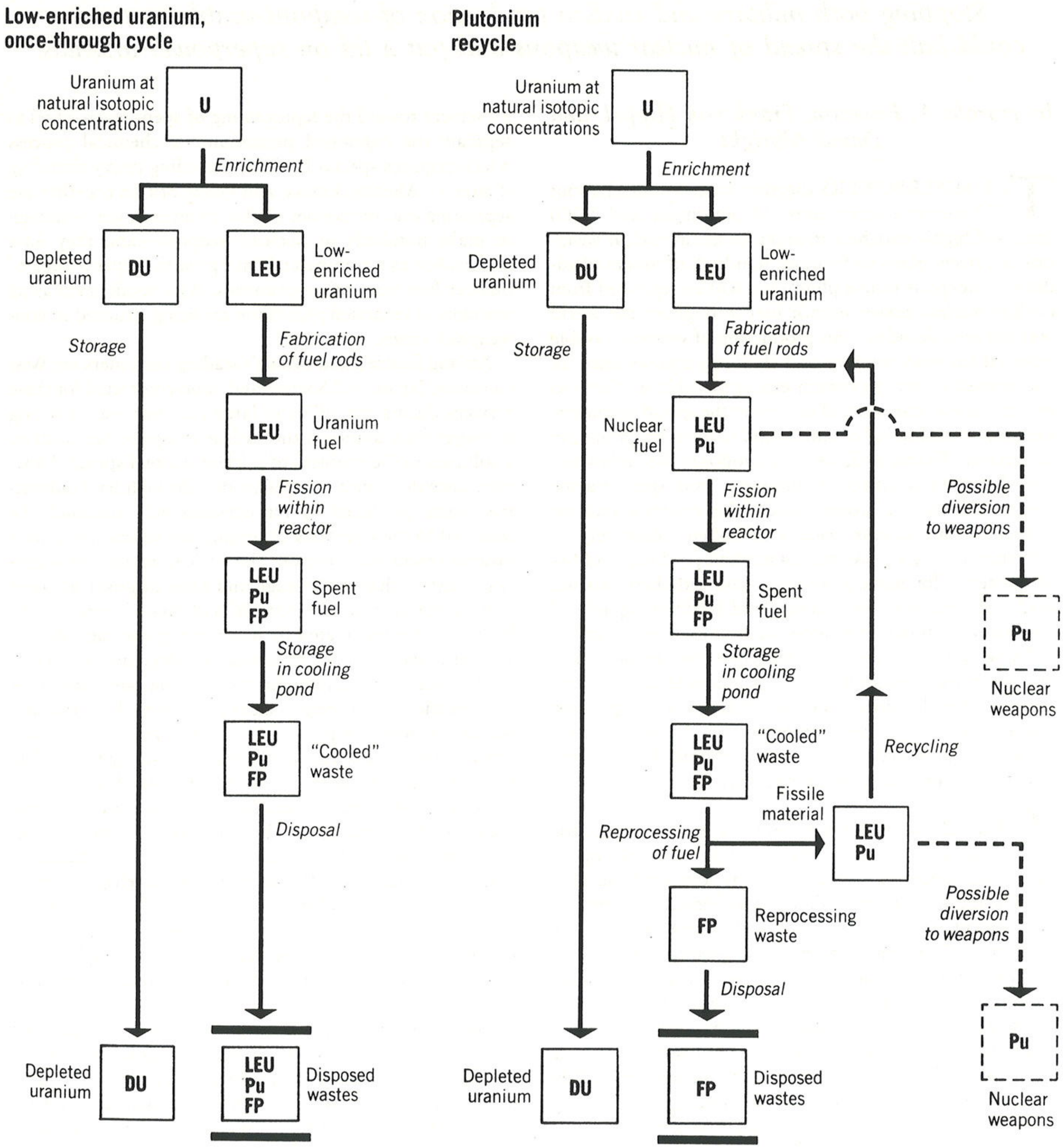
Figure 1.

Two fuel cycles

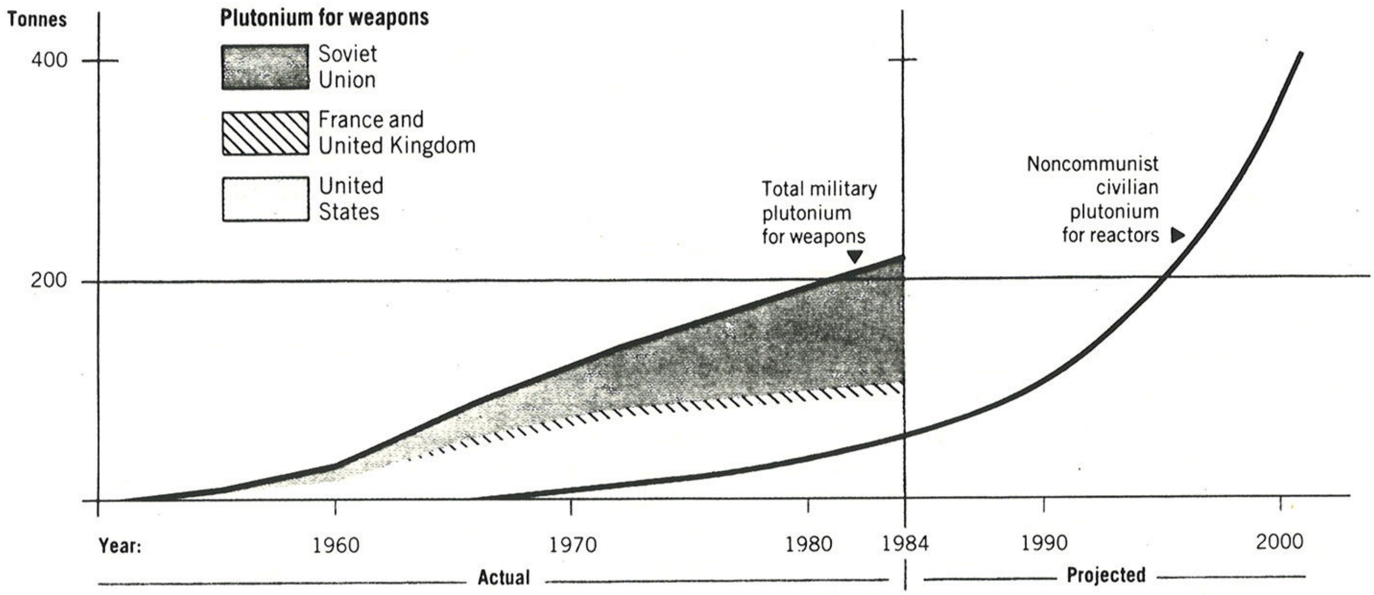
Symbols: **U** = Uranium at natural isotopic concentrations (0.7% U^{235}; 99.3% U^{238})
LEU = Low-enriched uranium (less than 5% U^{235}; over 95% U^{238})
DU = Depleted uranium (0.2% U^{235}; 99.8% U^{238})
Pu = Plutonium
FP = Fission products (including some "heavy" transuranic isotopes)



In the low-enriched uranium once-through fuel cycle, the spent fuel discharged from the reactor is not reprocessed, so that the contained plutonium and uranium remain locked with the highly radioactive fission products. With plutonium recycling (at right), the plutonium is separated at the reprocessing plant and therefore becomes more accessible for potential diversion to weapons by governments or terrorists.

Informational graphics: Michael Yanoff, United States

Figure 2.
Supplies of separated plutonium



The amount of plutonium in the nuclear weapons stockpiles of the United States, the Soviet Union, France, and the United Kingdom at the beginning of 1984, compared with the growing stockpile of separated civilian plutonium in noncommunist countries intended as fuel in civilian power reactors. Most, but not all, of the weapons plutonium is actually in weapons. Estimates of the inventories are based primarily on the following data:

United States: historical data on the heat output of Department of Energy plutonium-production reactors; *Soviet Union*: estimate of the releases of krypton-85 to the atmosphere from Soviet reprocessing, assuming the same proportionality between this krypton-85 release and plutonium production as in the United States; *France and United Kingdom*: the capacity of their production reactors. The historical estimates of the civilian inventories of plutonium are based on public information; the projections are based on the capacities of the major commercial reprocessing facilities operating, under construction, and planned, in noncommunist countries. The uncertainties in the estimates of the 1984 stockpiles are all on the order of 15 percent.

Source: Frank von Hippel, David H. Albright, and Barbara G. Levi, *Quantities of Fissile Materials in the U.S. and Soviet Nuclear Weapons Stockpiles*; David H. Albright, *World Inventories of Plutonium* (Princeton, N.J.: Princeton University, Center for Energy and Environmental Studies, forthcoming).

were founded have changed markedly over the past decade. Due to greatly reduced growth rates in electricity demand, among other factors, the nuclear power capacity growth rate has declined sharply. For example, projections made in 1985 by the U.S. Department of Energy for U.S. nuclear capacity in 2010 are less than 10 percent as large as those made in 1974 by the U.S. Atomic Energy Commission. Uranium resources now seem adequate to support the projected capacity of current-generation nuclear power plants for a very long time. The total nuclear capacity projected for the year 2000 in non-Communist countries could be fueled for 50–100 years from already discovered uranium available at recovery costs of less than $130 per kilogram—less than one-tenth the cost of oil measured in terms of energy content releasable in current reactors.[3] (High capital costs, not fuel, are responsible for the high cost of nuclear power.) Analysts from the Organization for Economic Co-operation and Development (OECD) believe that several times more uranium remains to be discovered in this cost category. This fact, and the recognition that capital costs of breeder reactors will greatly exceed those of conventional reactors have made breeders uneconomical for the foreseeable future.

Programs to commercialize the breeder reactor are therefore grinding to a halt all over the world, and it is clear that the startup cores of the few demonstration breeder reactors which will be completed will not absorb a significant fraction of the world's rapidly growing accumulation of separated plutonium.

FACED WITH growing unused stockpiles of plutonium, Japan and several European countries have decided to recycle this plutonium into their current light-water reactors. These plans, however, are economically dubious as well as dangerous.

Plutonium and uranium recycle could reduce the uranium requirements of a system of current-generation reactors by approximately 20 percent. Even if the separated plutonium is considered cost-free, however, extra safety-related costs associated with the fabrication of nuclear fuel containing plutonium would offset virtually all savings due to reduced uranium and uranium-enrichment requirements. If the costs of reprocessing are included—as they should be—the price of uranium would have to increase more than threefold before reprocessing and plutonium recycle could be justified economically.[4] This is one reason why there is little current interest in commercial nuclear fuel reprocessing in the United States. It is also a major reason why Sweden has decided to drop its reprocessing contracts with France and Great Britain.

In view of the unfavorable economics, reprocessing proponents in many West European countries and in Japan now point to energy security as a prime rationale for plutonium recycle. However, uranium costs so little and takes so little storage space in comparison to oil that vulnerability to import interruptions or temporary exorbitant price increases could easily be avoided by stockpiling. Indeed, a number of nations have already acquired, almost absentmindedly, stockpiles equivalent to several years' uranium requirements—something they could not dream of doing with oil. At current prices, a 25-year supply of uranium for one of today's nuclear power plants could be bought for the price of a six-month supply of oil for equivalent generating capacity. Extra costs associated with purchasing this stockpile so far in advance of its use would still not bring the cost of the once-through fuel cycle up to that of plutonium recycle.

THE DUBIOUSNESS of rationales for reprocessing and plutonium recycle creates an opportunity to develop an international consensus to stop these activities. This opportunity must be exploited, for if nuclear fuel reprocessing and plutonium recycle become the norm, any country with a nuclear power plant will soon possess large quantities of readily accessible, weapons-usable plutonium—thus destroying a crucial barrier to nuclear weapons proliferation.

Producing weapons-usable fissile material, if it is not already available to a weapons program, requires substantial resources in skilled personnel, time, and money. Pakistan's effort has taken over a decade.[5] With stockpiles of already separated plutonium, however, the length of time between the decision to develop nuclear weapons and the accumulation of a potentially sizable nuclear arsenal would shrink from years to weeks.

The difficulty of constructing a nuclear weapon without easy access to weapons-grade fissile materials is enormously stabilizing. It means that the leaders of a country contemplating a nuclear weapons program must think seriously about the potential negative reactions of those within and outside the country who will certainly become aware of the program before it is completed. If implementing the decision to acquire weapons takes long enough, awareness of the dangers and costs of joining in the nuclear arms race can even bring a nation to reverse the decision before the program is completed. This is, in fact, what happened in Sweden during the early 1960s [see the following article].

So far, commercial reprocessing and plutonium recycle have been confined largely to the nuclear-weapons states and to states which could have already developed nuclear weapons if they had wished. But such activities in these industrialized countries are legitimizing the demand for reprocessing technology in countries such as Argentina, Brazil, Pakistan, South Korea, and Taiwan, who have all shown interest in nuclear weapons at one time or another. It would be wishful thinking to believe that these countries—and, eventually, terrorist groups as well—could be prevented indefinitely from building up their own large stockpiles of separated plutonium if the industrialized states persist in following their present course.*

If a policy against reprocessing can be achieved, some countries will feel great urgency to devise some other solution to the disposition of their spent fuel stockpiles. Under these circumstances, we would find quite attractive the recent proposal by Jack N. Barkenbus, Alvin M. Weinberg, and Marcelo Alonso that the United States join the Soviet Union and China in storing spent nuclear fuel from reactors in other nations [see November 1985 *Bulletin*].

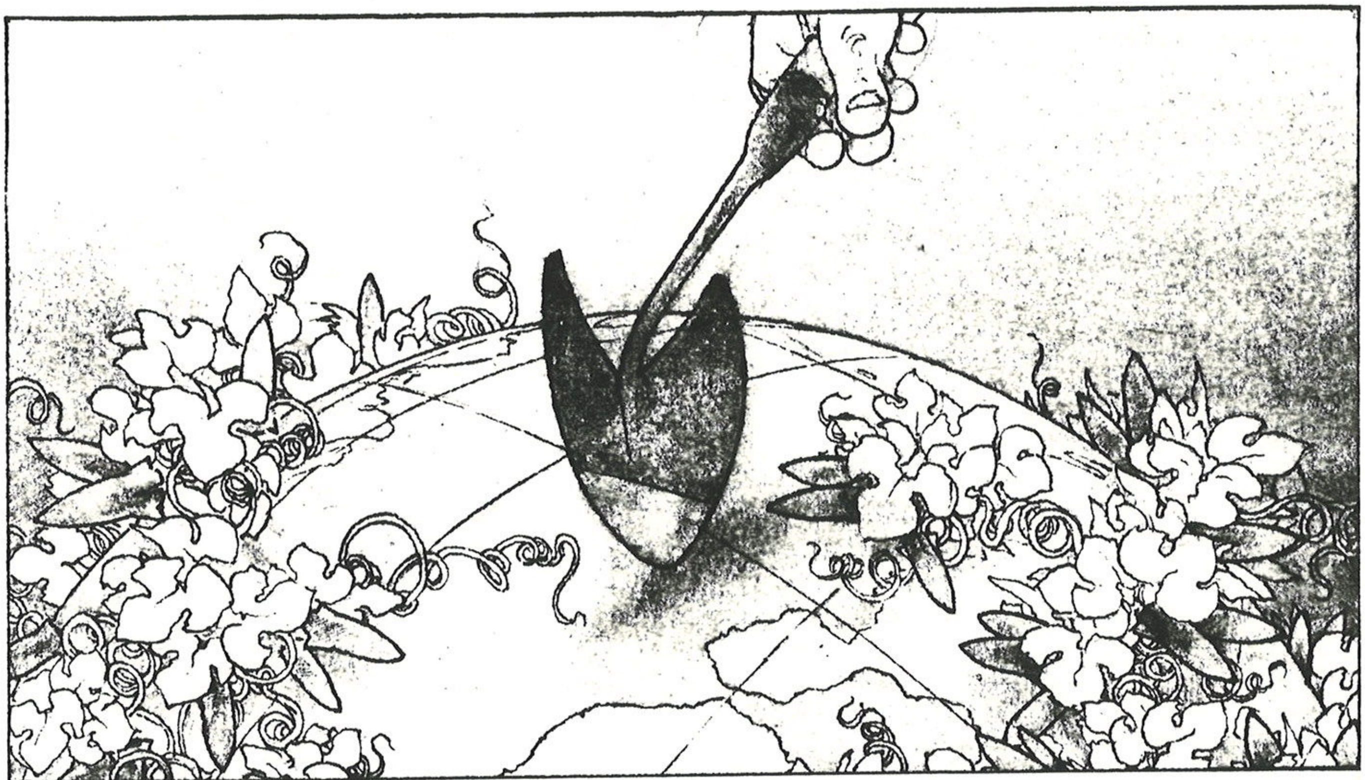
IT IS NOT reasonable, however, to expect a halt to civilian reprocessing if the nuclear-weapons states insist on continuing to produce plutonium and highly enriched uranium to build up their own weapons stockpiles. A cutoff of the production of fissile material for nuclear weapons is therefore a natural companion measure to halting commercial fuel reprocessing.

A cutoff of fissile material production, like a comprehensive test ban, would constitute an initial recognition by the superpowers of the fact that nuclear weapons are as illegitimate for them as for non-nuclear weapons states. Such a cutoff, moreover, would represent a real curtailment in the superpower nuclear arms race. It would halt superpower production activities at a time when Soviet production of plutonium, at least, appears to be relatively high and U.S. production is being increased to support the Reagan Administration's buildup in offensive forces.[6] There appears to be no public information on the current rate of Soviet production of highly enriched uranium for weapons, which was halted in the United States in 1964. The Reagan Administration, however, plans to restart production of highly enriched uranium for weapons.

Because no nuclear weapon can be built without at least a few kilograms of fissile materials, a freeze on fissile material in the superpower nuclear arsenals would ultimately limit the sizes of these arsenals. The SALT agreements have thus far been able to limit certain large objects such as missile silos, intercontinental bombers, and ballistic missile submarines (the latter are visible from space during construction). Such approaches have, however, been unable to limit shorter-range aircraft, missiles, and artillery which can also deliver nuclear weapons. Moreover, the trend in both the United States and the Soviet Union toward small, mobile land-based ballistic missiles and cruise missiles is making SALT-type counting rules less useful for the control of strategic nuclear arsenals as well.

A freeze on the amounts of fissile material in the superpower arsenals would also provide the basis for verifiable reductions, which could be accomplished by destroying

*We have focused here on plutonium because only research reactors and a few small power reactors currently use highly enriched weapons-usable uranium fuel. Furthermore, low-enriched uranium fuels are currently under development to replace highly enriched uranium in most of the 150 U.S. and foreign civilian research reactors being supplied with fuel by the United States. As a result, the amount of highly enriched uranium required for civilian reactors should decrease steadily during the next decade. With an enlarged effort, the use of highly enriched uranium for civilian purposes could be virtually eliminated. Elimination of highly enriched uranium in the fuel of naval reactors might be more difficult, but these reactors could be fueled for a very long time by making very modest withdrawals from the nuclear arsenals. For example, the annual requirements of highly enriched uranium for U.S. naval reactors could be satisfied with only about one percent of the highly enriched uranium in the U.S. weapons arsenal.



David Johnson, United States

nuclear weapons and putting their fissile material under international safeguards. The fissile production cutoff agreement would insure that the material being turned in would not be replaced.

Deep reductions would also be more feasible if China, France, and Great Britain could be persuaded to join in a fissile material production cutoff. The combined sizes of the nuclear arsenals of these countries probably act as a floor for reductions in the superpower arsenals, and at present these middle-sized nuclear arsenals are being substantially expanded.

In the past, large disparities in the superpower fissile material stockpiles may have prevented serious negotiations on a production cutoff. During the period from 1956 to 1969, when the United States repeatedly proposed cutoffs in the production of both plutonium and highly enriched uranium for nuclear weapons, Soviet stockpiles were much smaller than those of the United States. Now the arsenals are of approximately equal sizes and appear to contain approximately equal amounts of weapons-grade plutonium. (Plutonium is preferred over highly enriched uranium by nuclear-weapons designers because it has a smaller critical mass and therefore allows the construction of more compact warheads.) Perhaps this approximate parity is why the Soviet Union in 1982 finally expressed support for a production cutoff agreement for the first time. Now, unfortunately, it is the U.S. government that is opposed.

When the United States last proposed a cutoff in 1969, the only verification condition that it put forward was that the superpowers open up their nuclear facilities to inspection by the International Atomic Energy Agency (IAEA).[7] This reflected the view that a cutoff could be adequately verified by safeguards applied to declared nuclear facilities, supplemented by surveillance satellites and other intelligence means to insure that there were no significant undeclared clandestine production facilities.

ALTHOUGH A HALT in the production of either weapons or civilian fissile material would be desirable, we believe that a combined agreement could be more feasible politically than either of its parts. A freeze on the amounts of fissile material in the superpower arsenals would appeal to the non-nuclear-weapons states. These states would also appreciate the fact that the weapons states were finally accepting the comprehensive international safeguards which have thus far been imposed only on nonweapons states which have signed the Non-Proliferation Treaty.

The package agreement should appeal to the superpowers as well, since the abandonment of nuclear fuel reprocessing throughout the world would greatly strengthen their efforts to prevent the spread of nuclear weapons. Eliminating civilian reprocessing and the associated large-scale flows of separated plutonium would also simplify the safeguards required to verify a superpower fissile production cutoff agreement.

We believe that the time is ripe to consider this cutoff package. The United States and the Soviet Union currently have approximately equal quantities of fissile material in their nuclear arsenals, and it is now perfectly evident to most observers that civilian reprocessing and plutonium recycle are unnecessary. Now is the time to end production of nuclear-weapons materials worldwide. □

1. See David Albright and Harold Feiveson, "The Deferral of Reprocess-

ing," Federation of American Scientists' *Public Interest Report* (Feb. 1985), p. 8; Frank von Hippel, David Albright, and Barbara Levi, "Stopping the Production of Fissile Materials for Weapons," *Scientific American* (Sept. 1985), pp. 44–47.

2. Leonard Spector, *The New Nuclear Nations* (New York: Vintage, 1985); Congressional Research Service, Library of Congress, *Nuclear Proliferation Factbook* (Washington, D.C.: Government Printing Office, Aug. 1985), p. 425.

3. U.S. Energy Information Administration, *Commercial Nuclear Power: Prospects for the United States and the World* (Washington, D.C.: U.S. Government Printing Office, 1985), p. 53; OECD and IAEA, *Uranium: Resources, Production and Demand* (Paris: OECD and IAEA, 1983).

4. *The Economics of the Nuclear Fuel Cycle,* A Report by an Expert Group, OECD, Nuclear Energy Agency (Paris: OECD, 1985).

5. Leonard S. Spector, *Nuclear Proliferation Today* (New York: Vintage, 1984), chap. 2.

6. Von Hippel, op. cit.

7. Statement by Adrian Fisher, deputy director of the U.S. Arms Control and Disarmament Agency, at the Eighteen Nation Disarmament Committee, April 8, 1969 in *Documents on Disarmament, 1969* (Washington, D.C.: U.S. Arms Control and Disarmament Agency), p. 158.