Richard L. Garwin
IBM Fellow Emeritus
Thomas J. Watson Research Center
P.O. Box 218
Yorktown Heights, NY 10598-0218
(914) 945-2555
FAX: (914) 945-4419
INTERNET: RLG2@us.ibm.com
URL: www.fas.org/RLG/

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(Via email to jsct@aph.gov.au)

Mr. Jerome Brown
The Secretary of the Joint Standing
Committee on Treaties
P.O. Box 6021
Parliament House
Canberra ACT 2600
AUSTRALIA

Dear Mr. Brown,

I have long worked with the U.S. government and its contractors on nuclear weapons, their creation, testing, care, and control.

I have also worked with the U.S. government and other organizations to control and reduce nuclear weapons in the world and to reduce the hazards of nuclear weapons and nuclear-weapon material. My biography and many of my papers and relevant testimony are posted at www.fas.org/RLG/. I will cite several of these in connection with the inquiry into Nuclear Non-Proliferation and Disarmament.

I have read only two of the submissions—that by Dr. Frank Barnaby and by the Australian Uranium Association. Barnaby's facts are correct, but I differ with his policy recommendations. The submission of the AUA I find troubling. In particular, in regard to the contribution of uranium enrichment systems to proliferation, the AUA writes (unfortunately their pages are not numbered)

> "Uranium processed for electricity generation is not useable for weapons. … to be useable in weapons, uranium must be enriched to over 90% U-235.
>
> "It is technically possible for civil enrichment technology to be used illicitly to produce weapons-grade uranium."

Indeed, and that is what all the argument is about in regard to Iran. The gas-centrifuge system widely used throughout the world in commercial uranium enrichment is fully capable (with the simple redeployment of the small tubing connecting stages) of producing 90% U-235. In fact, 65% of the centrifuge effort required to produce 90% U-235 has already been expended in the production of 4.4% U-235 for reactor fuel, and is not lost in further enrichment to produce weapon material.[1].

This is the commonly recognized proliferation hazard of the "front end" of the fuel cycle. In regard to the "back end" of the fuel cycle, the AUA position is even more dismissive:

> "The only use for 'reactor-grade' plutonium is as a nuclear fuel, after it is separated from high-level wastes by reprocessing.
>
> "It is unlikely reactor-grade plutonium has ever been used for weapons or would be."

And

> "The question of the usefulness for weapons of 'reactor grade' plutonium seems to be a technical issue. The Association urges the Committee to examine the evidence on this issue and to consult with independent experts to arrive at its own conclusion about the proliferation risks associated with the production of 'reactor-grade' plutonium."

I am such an "expert."

Many statements in regard to impediments to weapon use of reactor-grade plutonium ("RG-Pu") are true, but their import is often exaggerated. It is true that the additional heat from the Pu-238 and Pu-240 isotopes is a problem for weapon builders. It is true that the much larger neutron generation rate in RG-Pu compared with weapon plutonium ("W-Pu") can reduce the explosive yield. But these were all considered by Dr. J. Carson Mark in his 1993 publication on this matter, drawing on his decades of experience as head of the Theoretical Division at the Los Alamos National Laboratory. A carefully considered statement by an informed, responsible group is to be found on pp. 32-33 of a report of a committee of the National Academy of Sciences of which I was an author.[2] I incorporate those pages at this point in the PDF of this document.

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[1] http://www.fas.org/rlg/SWU_Calculations_version_3_1.xls

[2] "Management and Disposition of Excess Weapons Plutonium," Report of the National Academy of Sciences, Committee on International Security and Arms Control, W.K.H. Panofsky, Chair, National Academy Press, Washington, DC, January 1994.
http://www.nap.edu/catalog.php?record_id=2345

REACTOR-GRADE AND WEAPONS-GRADEPLUTONIUM IN NUCLEAR EXPLOSIVES

Virtually any combination of plutonium isotopes—the different forms of an element having different numbers of neutrons in their nuclei—can be used to make a nuclear weapon. Not all combinations, however, are equally convenient or efficient. The most common isotope, Pu-239, is produced when the most common isotope of uranium, U-238, absorbs a neutron and then quickly decays to plutonium. It is this plutonium isotope that is most useful in making nuclear weapons, and it is produced in varying quantities in virtually all operating nuclear reactors.

As fuel in a reactor is exposed to longer and longer periods of neutron irradiation, higher isotopes of plutonium build up as some of the plutonium absorbs additional neutrons, creating Pu-240, Pu-241, and so on. Pu-238 also builds up from a chain of neutron absorptions and radioactive decays starting from U-235.[1] Because of the preference for relatively pure Pu-239 for weapons purposes, when a reactor is used specifically for creating weapons plutonium, the fuel rods are removed and the plutonium is separated from them after relatively brief irradiation (at low "burnup"). The resulting "weapons-grade" plutonium is typically about 93 percent Pu-239. Such brief irradiation is quite inefficient for power production, so in power reactors the fuel is left in the reactor much longer, resulting in a mix that includes more of the higher isotopes of plutonium ("reactor-grade" plutonium).

Use of reactor-grade plutonium complicates bomb design for several reasons. First and most important, Pu-240 has a high rate of spontaneous fission, meaning that the plutonium in the device will continually produce many background neutrons. Second, the isotope Pu-238 decays relatively rapidly, thereby significantly increasing the rate of heat generation in the material. Third, the isotope Americium-241 (which results from the 14-year half-life decay of Pu-241 and hence builds up in reactor-grade plutonium over time) emits highly penetrating gamma rays, increasing the radioactive exposure of any personnel handling the material.

In a nuclear explosive using plutonium, the plutonium core is initially "subcritical," meaning that it cannot sustain a chain reaction. Chemical high explosives are used to compress the plutonium to higher than normal density (so that the neutrons released in each fission have a higher probability of hitting other atoms and causing more fissions). In a well-designed nuclear explosive using weapons-grade plutonium, a pulse of neutrons is released to start this chain reaction at the optimal moment, but there is some chance that a background neutron from spontaneous fission of Pu-240

will set off the reaction prematurely. With reactor-grade plutonium, the probability of such "pre-initiation" is very large. Pre-initiation can substantially reduce the explosive yield, since the weapon may blow itself apart and thereby cut short the chain reaction that releases the energy. Calculations demonstrate, however, that even if pre-initiation occurs at the worst possible moment (when the material first becomes compressed enough to sustain a chain reaction), the explosive yield of even a relatively simple device similar to the Nagasaki bomb would be of the order of one or a few kilotons. While this yield is referred to as the "fizzle yield," a 1-kiloton bomb would still have a radius of destruction roughly one-third that of the Hiroshima weapon, making it a potentially fearsome explosive. Regardless of how high the concentration of troublesome isotopes is, the yield would not be less. With a more sophisticated design, weapons could be built with reactor-grade plutonium that would be assured of having higher yields.[2]

Dealing with the second problem with reactor-grade plutonium, the heat generated by Pu-238 and Pu-240, requires careful management of the heat in the device. Means to address this problem include providing channels to conduct the heat from the plutonium through the insulating explosive surrounding the core, or delaying assembly of the device until a few minutes before it is to be used.

The radiation from Americium-241 means that more shielding and greater precautions to protect personnel might be necessary when building and handling nuclear explosives made from reactor-grade plutonium. But these difficulties are not prohibitive.

In short, it would be quite possible for a potential proliferator to make a nuclear explosive from reactor-grade plutonium using a simple design that would be assured of having a yield in the range of one to a few kilotons, and more using an advanced design. Theft of separated plutonium whether weapons-grade or reactor-grade, would pose a grave security risk.

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[1] For a useful figure showing the buildup of these isotopes as a function of irradiation time, see J. Carson Mark, "Explosive Properties of Reactor-Grade Plutonium," *Science and Global Security*, Vol. 4, no. 1, 1993, pp. 111-128.

[2] See W. G. Sutcliffe and T.J. Trapp, eds., *Extraction and Utilityof Reactor-Grade Plutonium for Weapons*, Lawrence Livermore National Laboratory, UCRL-LR-115542, 1994 (S/RD). For unclassified discussions, see J. Carson Mark, op. cit.
The Pu-240 content even in weapons-grade plutonium is sufficiently large that very rapid assembly is necessary to prevent preinitiation. Hence the simplest type of nuclear explosive, a "gun type," in which the optimum critical configuration is assembled more slowly than in an "implosion type" device, cannot be made with plutonium, but only with highly enriched uranium, in which spontaneous fission is rare. The makes HEU an even more attractive material than plutonium for potential proliferators with limited access to sophisticated technology. Either material can be used in an implosion device.

Without explaining to a proliferant how precisely to use RG-Pu, the NAS Committee thus judges that it is a serious proliferation hazard.

In my own writings, I have supported the conclusion of the NAS CISAC, based on my work with the group, as well as on my own experience with early nuclear and thermonuclear weapons at Los Alamos. I have explained to my colleagues sharing appropriate security clearance how one would go about accommodating the extra heat evolution without degradation in the explosive yield of a proliferant nuclear weapon or an improvised nuclear weapon based on RG-Pu metal.

The Global Nuclear Energy Partnership (GNEP) announced by President George W. Bush in February 2006 was the subject of my testimony of April 2006 to the Joint Committee of the House of Representatives.[3]

I strongly support the goals of GNEP, but it was technically poorly founded. Those goals are to make available to countries wishing a nuclear power industry an assured supply of reactor fuel, so long as they maintain strong barriers to the development of nuclear weapons or the diversion of nuclear materials to that end.

Unacceptable was the commitment of GNEP to early reprocessing of U.S. power reactor fuel, and to so-called "proliferation resistant" reprocessing systems elsewhere. Unfortunately, the adjective "proliferation resistant" included approaches that were manifestly not so—including those in which the product of the reprocessing is not RG-Pu, but RG-Pu mixed with a similar amount of uranium.

With the extraordinarily effective separation of the highly radioactive fission products in normal reprocessing, even a 50-50% mixture of RG-Pu and uranium poses no significant barrier to using that material to feed a nuclear weapon production system. There is hardly any penetrating radioactivity in the material, so that laboratory bench-type chemical separation of Pu can readily be accomplished, followed by reduction to metal, as was accomplished at Los Alamos in 1945 with the plutonium oxide or nitrate coming from the production reactors.

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[3] "R&D Priorities for GNEP," by R.L. Garwin, prepared testimony for hearing of the Subcommittee on Energy of the Committee on Science, U.S. House of Representatives, "Hearing on R&D Priorities in the Global Nuclear Energy Partnership," April 6, 2006, Washington, DC. (Supplemented for the Record with material added 06/25/06). http://fas.org/rlg/062606GNEP5_1.pdf

"R&D Priorities For the Global Nuclear Energy Partnership," by R.L. Garwin, (Slides) 5-minute oral testimony at hearing of the Subcommittee on Energy of the Committee on Science, U.S. House of Representatives, "Hearing on R&D Priorities in the Global Nuclear Energy Partnership," April 6, 2006, Washington, DC. http://fas.org/rlg/060406-gnep_slides.pdf

Despite its flaws, the GNEP program evidently contradicts the AUA's position—else there would be no need for "proliferation resistant" reprocessing if normal PUREX separation yielding pure RG-Pu oxide were itself not useable for nuclear weapons.

My advice to the U.S. government has been and remains that it is urgent to bring all highly enriched uranium (greater than 20% U-235, by IAEA definition) under control and consolidation throughout the world, and that not only separated weapon plutonium but also separated reactor-grade plutonium should be protected as if it were nuclear weapons and properly managed and disposed of.

Judgments as Regards the Nuclear Power Sector

1. I am a strong supporter of nuclear power and of the Non-Proliferation Treaty that aims to make it possible to have nuclear power without contributing to nuclear weaponry. This will ultimately require remedying a deficiency in the NPT—that nations can acquire nuclear technology and nuclear materials as non-nuclear-weapon states under the NPT and with three months notice quite legitimately can then turn those facilities and the materials (for instance, a stockpile of LEU) to be the basis for a nuclear weapon program. What is needed is a further additional Protocol that states that undertake a nuclear weapon program after having been non-nuclear states parties to the NPT, would need to return or destroy facilities and materials acquired during their membership in the NPT. Such efforts to reduce the potential for nuclear weaponry would be accompanied by further reductions in U.S. and Russian holdings of nuclear weapons and weapon-useable materials, and by the permanent transfer of these materials to the civil sector.

2. It should be recognized that reprocessing and recycling of Pu into LWRs is an economic loss and does little to ease the problem of caring for spent fuel. This is discussed in detail in my GNEP testimony and in other papers that can be found by entering into the Google search box,
site:fas.org/RLG/ recycle MOX

At best, reuse of the uranium and of the Pu from spent fuel can save 20% of the raw uranium otherwise used. But it does this at a cost per kg of uranium spared of at least $1500/kg, on the assumption that the new spent-fuel processing plant at Rokkasho-Mura, Japan, has an annual operating cost of $2 billion for a throughput of 800 metric tons of heavy metal (800 MTHM).

3, The treatment of spent fuels from power reactors should be storage in the at-reactor pool for several years and then transfer of the annual fuel download per reactor (some 20 tons) to two steel and concrete dry-cask storage containers to be retained at the reactor until a permanent disposition system is created for spent fuel. This routine is now widely practiced in the United States.

The permanent disposition system is likely to be a mined geologic repository such as those variously under construction in Finland, Sweden, and the United States (Yucca

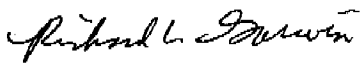
Mountain), but even after the fuel is emplaced there, it would be accessible to a major national operation to retrieve it for use, for instance, in breeder reactors.

4. I favor world research on breeder reactors with the goal of constructing a prototype when modern simulation and analysis tools and experiment show that a fast-neutron breeder reactor would be as safe and economical as a current light-water reactor. If that promise were fulfilled, and a generation of breeder reactors deployed, the Pu already separated by reprocessing spent power reactor fuel would be used to power the breeder in an absolutely essential cycle that would use almost 100% of the uranium from our resources rather than only 0.5% of the uranium.

5. In order to provide a cap on supply prices of uranium, governments should support research extending that done in recent years in Japan on the extraction of uranium from seawater. The 3.3 parts per billion concentration means that there are some 4000 million tons of uranium in the oceans, enough to sustain the present population of reactors for 64,000 years. Determining whether a small portion of this uranium could be extracted at a cost of, say, $300/kg would eliminate a lot of uneconomic activity now undertaken, such as recycle of Pu into light-water reactors.

Judgment on the technical question of use of reactor-grade plutonium in nuclear weaponry.
Although no nation is likely to prefer reactor-grade Pu for its nuclear weapons, RG-Pu is indeed eminently useable in improvised nuclear weapons and could, by a country with advanced skills, be used as the basis of a large force of high-performance nuclear weapons.

Sincerely yours,



Richard L. Garwin

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