Nuclear Weapons Databook

The Amount of Plutonium and Highly-Enriched Uranium Needed for Pure Fission Nuclear Weapons

by

Thomas B. Cochran
and
Christopher E. Paine

Revised
13 April 1995

Natural Resources Defense Council, Inc.
1350 New York Avenue, NW, Suite 300
Washington, D.C. 20005
Tele: 202-783-7800
FAX: 202-783-5917

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I. Introduction

The criterion used by the International Atomic Energy Agency (IAEA) to assess the proliferation risk of inventory differences routinely encountered during safeguards inspections of weapon-usable nuclear materials is called the "Significant Quantity (SQ)." This quantity is said to represent the minimum amount of fissile material which, if diverted from peaceful nuclear activities, could be used "directly" (without further chemical separation or enrichment) to manufacture a nuclear explosive device. The primary function of safeguards on such "direct-use materials" is to deter their diversion from peaceful use by imposing a high risk of early detection, before the diverted material can be converted to metal, machined into weapon components, and integrated with a nuclear weapon assembly system. This criterion is often referred to as constituting "timely warning" of diversion to weapons use.

The overall level of assurance against diversion also importantly depends on two other factors – the frequency of inspections, and the accuracy of the measurement techniques employed. Containment and surveillance systems limiting access to strategic points within a facility are an important adjunct to the IAEA's materials balance system, but they do not assure detection of a carefully planned diversion by the authorized operators of a facility.

The IAEA's official "SQ" values also form the basis for public, media, and policymaking assessments of the bomb-making potential of nations or terrorist groups seeking to acquire nuclear weapons. Unfortunately, as shown in this report, the IAEA persists in using SQ values that are outdated, technically erroneous, and even dangerous in light of the recent seizures of kilogram quantities of stolen Russian nuclear materials for sale on the black market, and the persistent reports of large accounting discrepancies at plutonium production facilities intended for peaceful use. In August 1994 the Natural Resources Defense Council (NRDC) called upon the IAEA to tighten its criteria for safeguarding weapon-usable material by adopting an eightfold reduction in the agency's "significant quantity" values for plutonium and highly-enriched uranium (HEU). This report represents a revised version of our previous (22 August 1994) report.

II. IAEA Safeguards and the Role of the "Significant Quantity"

In 1953 the United States proposed the establishment of the IAEA to provide a means of verifying that nuclear materials and equipment provided for peaceful purposes would not be used for explosive or military purposes. After three years of debate the IAEA was established in 1957. To carry out the safeguards obligations subsequently assigned to the IAEA under the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), and other multinational and bilateral agreements, the IAEA has devised a system of safeguards, one objective of which is to assure the detection of – and thereby deter – the diversion of safeguarded nuclear materials to the production of nuclear explosives.[1]

The principal safeguards documents of the IAEA, both of which have been revised over the years, are "Information Circulars" INFCIRC/66 and INFCIRC/153. Nuclear materials and nuclear facilities in all non-weapon NPT member states, and other states accepting NPT or IAEA safeguards, would be covered under either INFCIRC/66 and INFCIRC/153. The main difference between INFCIRC/66 and INFCIRC/153 is the "full-scope" intent of the latter – it applies to all nuclear material in all peaceful nuclear activities of the non-nuclear weapon state. The technical objective of safeguards, made explicit in paragraph 28 of INFCIRC/153, is "the timely detection of the diversion of **significant quantities of nuclear material** from peaceful nuclear activities to the manufacture of nuclear weapons or other explosive devices or for purposes unknown and deterrence of such diversion by risk of early detection."[2]

For safeguards purposes the IAEA defines a "significant quantity" (SQ) of nuclear material as "the approximate quantity of nuclear material in respect of which, taking into account any conversion process involved, the possibility of manufacturing a nuclear explosive

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[1] *IAEA Safeguards: An Introduction*, IAEA, IAEA/SG/INF/3, 1981, p. 12.

[2] Ibid., p. 14.

device cannot be excluded."[3] Significant quantity values currently in use by the IAEA are given in Table 2, at the end of this report.[4]

The SQ values were recommended to the IAEA by a group of experts, namely, the IAEA's Standing Advisory Group for Safeguards Implementation (SAGSI), and "relate to the potential acquisition of a first nuclear explosive by a non-nuclear weapon state."[5]

The direct-use values in Table 2, that is, 8 kg of plutonium, 8 kg of uranium-233, and 25 kg of contained U-235, are also referred to by the IAEA as "threshold amounts," defined as "the approximate quantity of special fissionable material required for a single nuclear device."[6] The IAEA cites as a source for these threshold amounts a 1967 United Nations document.[7] The IAEA states:

> These threshold amounts include the material that will unavoidably be lost in manufacturing a nuclear explosive device. They should not be confused with the minimum critical mass needed for an explosive chain reaction, which is smaller.[34]
>
> [34] Using highly sophisticated techniques available to NW States, the critical mass and the corresponding threshold amount can also be significantly reduced, but these are special cases that need not be considered here [footnote in original document]."

As seen from Figures 1 and 2 and Table 1 at the end of this paper, the direct-use SQ or threshold values currently used by the IAEA are technically indefensible. The IAEA is clinging to incorrect values for the minimum quantity of nuclear material needed for a nuclear weapon, even for a low-technology first nuclear explosive by a non-nuclear weapon state, including consideration of unavoidable losses. The reasons given for this reliance on an invalid

[3] *IAEA Safeguards Glossary, 1987 Edition*, IAEA, IAEA/SG/INF/1 (Rev. 1), 1987, p. 23.

[4] Ibid., p. 24.

[5] Thomas Shea, "On the Application of IAEA Safeguards to Plutonium and Highly Enriched Uranium from Military Inventories," IAEA, (June 1992, with additions: December 1992).

[6] Ibid., p. 23.

[7] *Effects of the Possible Use of Nuclear Weapons ...*, United Nations, A/6858, 6 October 1967.

standard range from shortfalls in the safeguards budget to the inability of certain fuel cycle facilities under IAEA safeguards to meet even current, much less higher, standards for nuclear material control and accounting.

In concept, the lower the "significant quantity," the more demanding the safeguards system must become in resolving or plausibly explaining nuclear material inventory differences, and in physically recovering material that is said to be temporarily unaccounted for in production machinery, waste tanks, and "losses" to the environment. Moreover, to maintain the timely warning criterion when employing lower SQ values, small inventories of direct-use material would have to be inspected more frequently, to guard against their potential combination into one or more significant quantities.

For the purposes of illustration, consider the following simplified case of a small plutonium fuel fabrication plant in a non-weapon NPT state. This plant might have an annual plutonium throughput of about 700 kilograms. Each year plutonium scrap accumulates in the tightly sealed, remotely operated process lines, where the flow of plutonium through the system is measured indirectly with an inherent and possibly varying degree of error in the measurement. Each year the plant reports a difference of about 15 kilograms between the amount of plutonium oxide entering the plant and the amount of plutonium oxide leaving the plant in "Mixed-Oxide" (MOX) fuel. Containment and surveillance measures -- when they are operating -- and remote process line measurements suggest that the material is not really "missing", but is being "held-up" in the production equipment. According to the plant operators, these indirect measurements are accurate to perhaps 10%, assuming the equipment is working and properly calibrated. Under this scenario, when the "SQ" for plutonium is set at 8 kilograms, the IAEA will become seriously concerned about the threat of diversion when the uncertainty in measuring the accumulated plutonium "holdup" reaches or exceeds this level – that is, after about five years of plant operation [0.1 * (15 kg * 5) = 7.5 kg]

If, as we argue in this paper, the SQ is reduced to one kilogram to accurately reflect longstanding technical realities of bomb design now accessible to many nations, the uncertainty in measuring the "plutonium holdup" would exceed the SQ *within one year* of plant operation. The IAEA would have to request a plant shutdown and physical "clean-out inventory" at that point, instead of waiting another four years, during which diversion of another 6 bombs worth of plutonium could be concealed within the cumulative measurement error and secretly withdrawn from the plant for conversion into weapons. As is readily evident from this scenario, timely warning of a diversion is virtually impossible to achieve under such circumstances -- the time lag between diversion and detection must be on the order of 1-3 weeks, not years! In reality, the situation is even worse than this simplified example suggests, because there are additional errors associated with measuring the precise plutonium input to the plant and the exact Pu content of the fuel rods leaving the plant.

III. The Amount of Fissile Material Required to Make a Pure Fission Weapon.

For single-stage pure fission weapons, a spherically symmetric implosion design requires the least amount of fissile material to achieve a given explosive yield, relative to other possible designs. For this type of device the amount of fissile material required depends primarily upon the type of fissile material used, e.g., plutonium, U-233, or HEU, the desired explosive yield of the device, and the degree to which the fissile material is compressed at the time disassembly of the fissile material begins due to the release of energy from the rapid nuclear chain reaction. The degree of compression achieved depends on the sophistication of the design and degree of symmetry achieved by the imploding shock wave. There are, of course, other factors -- such as the timing of the initiation of the chain reaction and the type of neutron reflector used -- but we will assume that the proliferant state or subnational group already has acquired the necessary skills so that these factors are of secondary importance.

In Figures 1 and 2 we plot the explosive yield of a pure fission weapon as a function of the quantity of fissile material (weapon-grade plutonium (WGPu) in Figure 1 and HEU in Figure 2) for three degrees of compression. In the figures the degree of compression is labeled according to our judgement as to the sophistication of the design; that is, whether it represents low, medium or high technology.

As seen from Figure 1, the Nagasaki bomb, *Fat Man*, which produced a 20 kilotons (kt) explosion with 6.1 kilograms (kg) of WGPu, falls on the "low technology" curve. However, only three kilograms of WGPu compressed the same amount would still have produced a 1 kt explosion. A non-nuclear weapons state today can take advantage of the wealth of nuclear weapons design information that has been made public over the past 50 years, and do even better. As seen from Figure 1, to achieve an explosive yield of 1 kt, we estimate that from 1 to 3 kg of WGPu is required, depending upon the sophistication of the design. And from Figure 2, we estimate that some 2 to 7 kg of HEU is required to achieve an explosive energy release of 1 kt. Table 1 presents the same results of tabular form. We estimate, for example, that as little as 2 kilograms of plutonium or about 4 kilograms of HEU are required to produce a yield of 10 kilotons.

IV. U.S. Government Requirements.

As noted above the first nuclear weapon developed by the United States – *Fat Man* – first tested at the *Trinity* site in New Mexico on July 16, 1945, and dropped on Nagasaki on August 9, 1945, reportedly used 6.1 kg of WGPu. The United States first tested so-called "fractional crit" weapon designs during Operation *Ranger* which took place from 27 January to 6 February 1951. Two of the four "fractional crit" tests during this series involved reducing the amount of fissile material in the *Mark 4* bomb to about 1 to 2 kg of plutonium and about 5 to 6 kg of HEU, respectively. The yields of these two tests were about 1 kt.[8]

Light weight boosted-fission weapons with yields up to about 15 kt can be made with as little as 3.5 kg of plutonium; and in fact, modern boosted-fission primaries of U.S. thermonuclear weapons are made with less than 4 kg of plutonium. U.S. Government classification policy now permits USDOE nuclear weapon experts to acknowledge that nuclear weapons can be constructed with as little as 4 kg of plutonium.

U.S. Nuclear Regulatory Commission (USNRC) regulations define a *formula quantity* as "strategic special nuclear material in any combination in a quantity of 5,000 grams [5 kg] or more computed by the formula, grams = (grams containing U-235) + 2.5*(grams U-233 +

[8] Robert Standish Norris and Thomas B. Cochran, "United States Nuclear Tests: July 1945 to 31 December 1992," NRDC, Nuclear Weapons Databook Working Paper NWD 94-1, 1 February 1994, p. 22.

plutonium)," where *strategic special nuclear material* means "uranium-235 (contained in uranium enriched to 20 percent or more in the U-235 isotope), uranium-233, or plutonium."[9] Thus, considered separately 2 kg of plutonium constitutes a formula quantity, since 2.5*(2000 grams of Pu) = 5000 grams; and similarly 5 kg of contained U-235 is a formula quantity. USNRC applies its most stringent physical security and material control and accounting (MC&A) requirements to licensees possessing or transporting formula quantities of strategic special nuclear materials.

The U.S. Department of Energy (USDOE) has a more detailed categorization of nuclear materials in terms of the attractiveness of the materials for weapon purposes (defined in terms of Attractiveness Levels A through E) and the level of safeguards applied (defined in terms of Categories I through IV).[10] USDOE's most stringent physical security and MC&A requirements (Category I) apply to assembled weapons and test devices (Attractiveness A), and "Pure Products," defined as weapon pits, major components, buttons, ingots, recastable metal, and directly convertible materials (Attractiveness B) containing 2kg or more of Pu/U-233 or 5 kg or more of contained U-235. This is similar to the USNRC definition of a formula quantity. The USDOE defines high-grade plutonium, U-233 and contained U-235 in other chemical forms (including solutions, oxides and carbides) as Attractiveness C materials, and here the Category I safeguards are triggered at 6 kg or more of Pu/U-233, and 20 kg or more of contained U-235.

V. Conclusion.

The IAEA "threshold amounts" and "significant quantities" are not technically valid. If one took the same *Fat Man* design, first tested at the *Trinity* site in New Mexico and dropped on Nagasaki in 1945, and substituted a three kilogram plutonium core for the 6.1 kilogram core that was used in 1945, the yield of this device would be on the order of one kiloton, a very respectable atomic bomb. *Thus, the IAEA is in error to assert that "highly*

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9 USNRC Regulations as reproduced in 10 CFR 70.4, 73.2 and 74.4.

10 USDOE Order 5633.3B.

sophisticated techniques available to NW States" are needed to make nuclear weapons with "significantly reduced" quantities of materials. Also, the so-called "highly sophisticated techniques available to NW States" were known to U.S. weapons designers in the late-1940s and early-1950s, and nuclear devices using very small quantities of plutonium and HEU--so-called "fractional crit" weapons--with yields on the order of one kiloton were tested during the Ranger series in 1951. Furthermore, a well designed safeguards program for a given country or group of countries would set the "significant quantity" levels at values considerably less than the minimum amount needed for a weapon, in recognition of the fact that materials can be diverted from more than one source. The practice of setting higher levels to account for manufacturing losses is imprudent, particularly in view of the fact that a significant fraction of these "losses" are technically recoverable.

In sum, safeguards apply to all non-weapon countries, irrespective of their technological sophistication. Many countries, such as Japan, Germany, Israel, India and Pakistan, have highly developed nuclear infrastructures, and must be considered technologically sophisticated. Even for countries that are in general not sophisticated technologically, the key technical information needed to establish a program for achieving a high degree of compression by implosion techniques is now available in the unclassified literature. The quantities defining safeguards significance, therefore, must be based on the assumption that the proliferator has access to advanced technology. As a consequence, NRDC believes the IAEA's significant quantities should be lowered 8-fold to the values in Table 3 -- 1 kg of plutonium and U-233 and 3 kg of contained U-235.

Table 1. **Approximate Fissile Material Requirements for Pure Fission Nuclear Weapons.**

	WEAPON-GRADE PLUTONIUM (kg)			HIGHLY-ENRICHED URANIUM (kg)		
Yield	Technical Capability			Technical Capability		
(kt)	Low	Medium	High	Low	Medium	High
1	3	1.5	1	8	4	2.5
5	4	2.5	1.5	11	6	3.5
10	5	3	2	13	7	4
20	6	3.5	3	16	9	5

Values rounded to nearest 0.5 kilograms.

Table 2. IAEA Significant Quantities.

Material	Quantity of Safeguards Significance	Safeguards Apply to:
Direct-use nuclear material		
Plutonium	8 kg	Total element[1]
Uranium-233	8 kg	Total isotope
Uranium enriched to 20% or more	25 kg	U-235 isotope
Indirect-use nuclear material		
Uranium (<20% U-235)	75 kg	U-235 isotope
Thorium	20 t	Total element

[1] Does not apply to plutonium containing >80% Pu-238, e.g. in radioisotope thermoelectric generators (RTGs).

Table 3. NRDC's Proposed Significant Quantities.

Material	Quantity of Safeguards Significance	Safeguards Apply to:
Direct-use nuclear material		
Plutonium	1 kg	Total Element[1]
Uranium-233	1 kg	Total isotope
Uranium enriched to 20% or more	3 kg	U-235 isotope

[1] Does not apply to plutonium containing >80% Pu-238, e.g. in radioisotope thermoelectric generators (RTGs).

Figure 1. Yield vs. Pu Mass

(As a Function of Technical Capability)

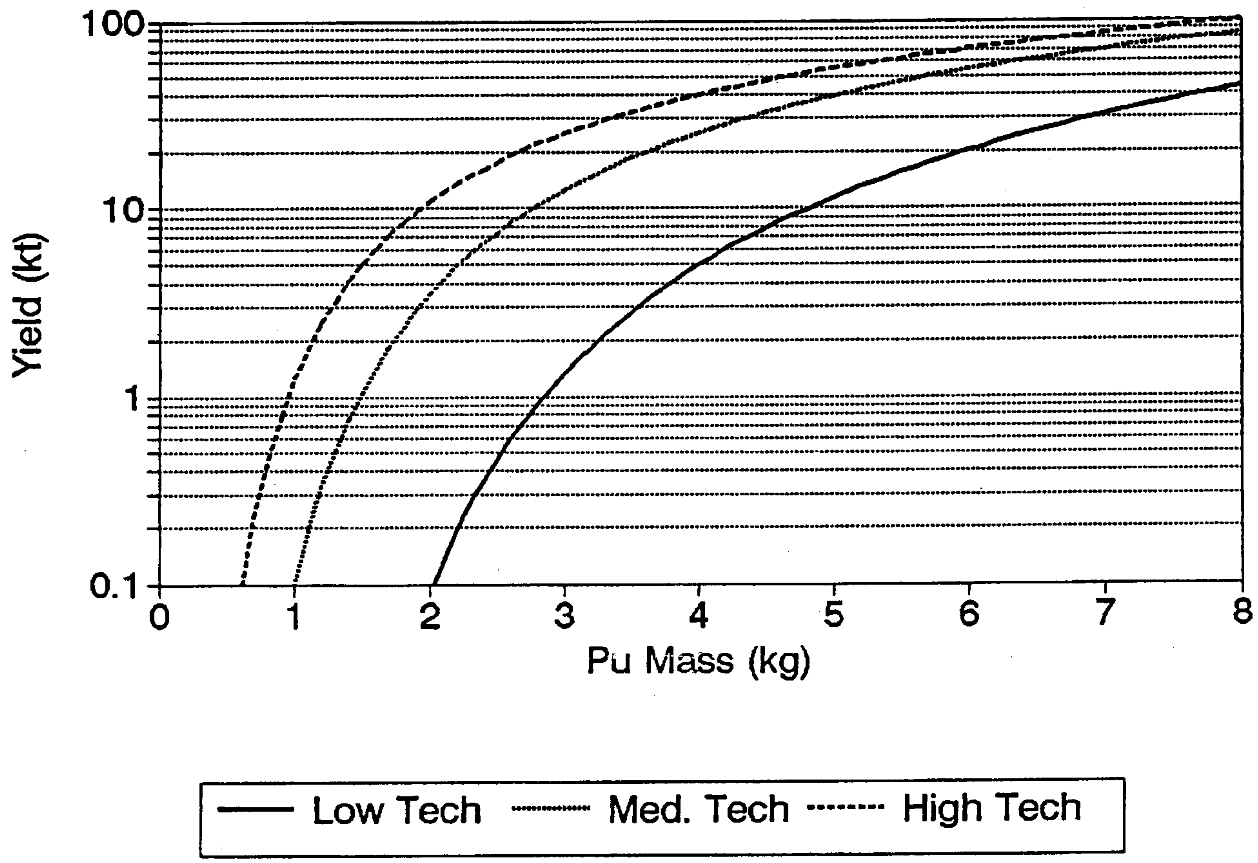
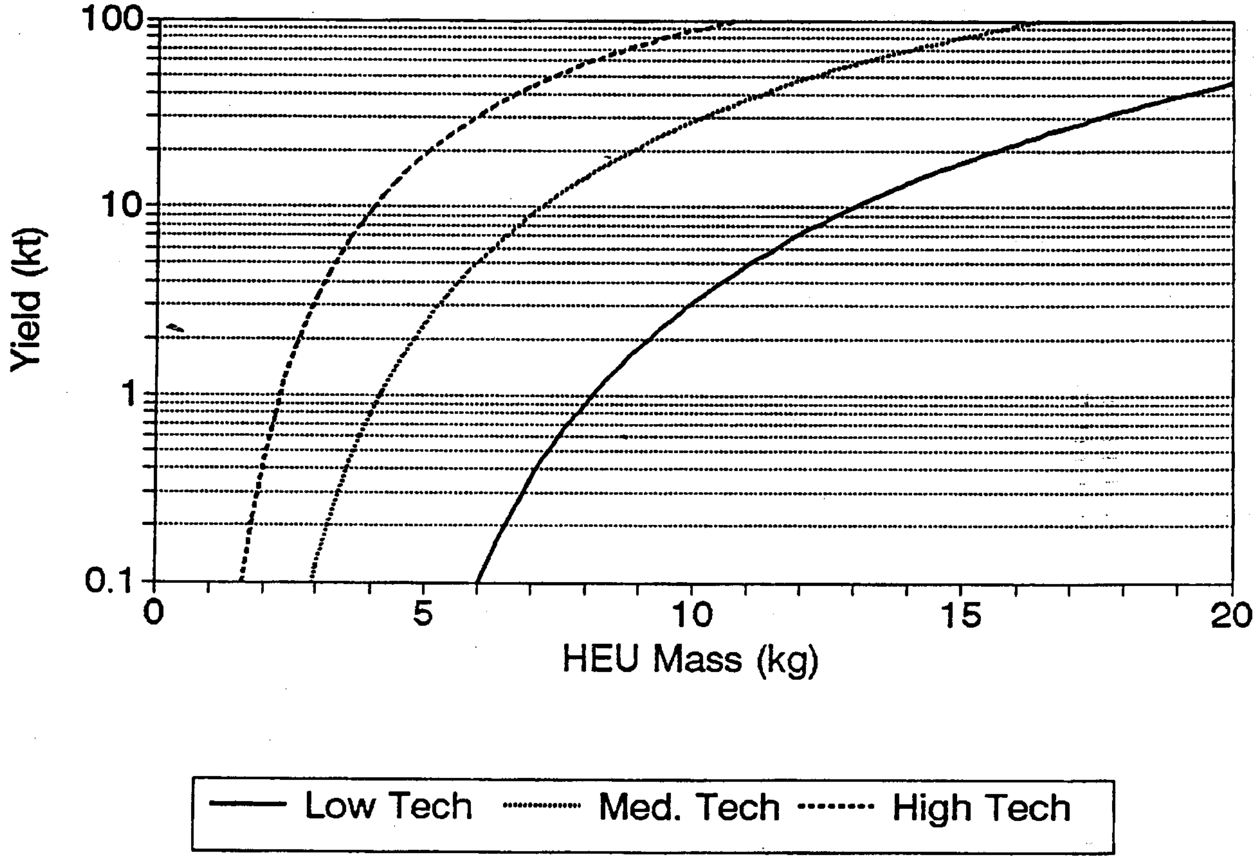


Figure 2. Yield vs. HEU Mass
(As a Function of Technical Capability)



APPENDIX A

Natural Resources Defense Council

News Release

For Release Monday
22 August 1994

Contact: Thomas B. Cochran 202-624-9329
Christopher E. Paine 202-624-9350

NUCLEAR EXPLOSIVES CAN BE CONSTRUCTED WITH FAR LESS MATERIAL THAN CURRENTLY ACKNOWLEDGED BY THE INTERNATIONAL ATOMIC ENERGY AGENCY

A Bomb Using a Little More than Two Pounds of Stolen Plutonium Could Destroy a 40 Block Area

The Natural Resources Defense Council (NRDC) today called upon the International Atomic Energy Agency (IAEA) and the United States government to revise their criteria for estimating the bomb making potential of nations seeking to acquire nuclear weapons, and the criteria for safeguarding nuclear weapon-usable materials. The NRDC documented its call for an eightfold reduction in the "threshold quantity" for monitoring stocks of nuclear weapon-usable materials by releasing a technical report entitled, "The Amount of Plutonium and Highly-Enriched Uranium Needed for Pure Fission Nuclear Weapons."

"The criteria now in use are out of date, technically erroneous, and clearly dangerous in light of the recent seizures of stolen Russian nuclear materials for sale on the black market, and the persistent reports of large accounting discrepancies at plutonium production facilities intended for peaceful use," said Dr. Thomas B. Cochran, Senior Scientist at NRDC, and co-author of the report.

"Ever since the atomic bombing of Nagasaki, government spokespersons typically have used five to six kilograms (11-13 pounds) as the minimum amount of plutonium needed for a first-generation, low-technology atomic bomb. The IAEA includes an additional amount to account for unavoidable losses in the manufacturing process, and uses eight kilograms (17.6 pounds) as the 'threshold quantity' needed for a weapon," Cochran noted.

But the NRDC analysis reveals that using the same outmoded Nagasaki design technology, a one kiloton nuclear bomb could be made with only three kilograms of plutonium. Using more sophisticated but easily deduced techniques -- known to U.S. bomb designers as early as 1951 and now discussed in the unclassified literature -- a one kiloton atomic bomb can be made using as little as one kilogram of plutonium. "Detonated in or above a city center, one such 'small' weapon would be sufficient to cause severe blast damage over roughly a 40 block area, and many thousands more would likely die from the ensuing fire and radiation effects," said Christopher Paine, co-author of the study.

1350 New York Ave., N.W.
Washington, DC 20005
202 783-7800
Fax 202 783-5917

"The technical community has known for more than 40 years that it is possible to make an atomic bomb with very little material. If we are going to honestly deal with the problem of proliferation, which the Clinton Administration rightly claims is at the top of its security agenda, then we should deal with the facts as they are, and not as the advocates of 'peaceful' plutonium use might wish them to be," Paine noted. "As evidenced by recent news reports, there continues to be widespread confusion regarding the minimum quantities of nuclear explosive materials needed to make a bomb," Paine added (see attachment to this release).

The study uses the example of North Korea to illustrate its case. The CIA estimates that North Korea has separated 8-9 kilograms of plutonium, enough to make one or two bombs. This estimate is apparently based on the old rule of thumb. If the North Koreans used more sophisticated techniques, a point acknowledged recently by Secretary of Defense Perry, then they potentially could have as many as five atomic bombs, or even more.

Attachment: Recent Media References to the Amounts of Fissile Materials Needed to Make a Nuclear Weapon.

"Four kilograms [8.8 pounds] would be nearly enough to make a bomb."

"A German expert said that it would take 6 to 10 kilograms, 13.2 to 22 pounds, of plutonium to build a bomb."

Craig R. Whitney
New York Times
16 August 1994, p. A1, p. A6

"It takes 10 kilograms, or 22 pounds, of plutonium to make one bomb."

Craig R. Whitney
New York Times
15 August 1994, p. A3

"The amount of plutonium found is a tiny fraction of the 13 pounds, or about 5.8 kilograms, needed to construct a bomb."

Daniel Benjamin
Wall Street Journal
18 July 1994, p. A8.

"Mr. Schuster said that up to 264 pounds of weapons-grade plutonium is being offered on the black market in Europe. Experts say that could be enough to make 15 nuclear bombs." [i.e. 17.6 lbs or 8 kg]

Ferdinand Protzman
New York Times
21 July 1994, p. 13

"They said they had seized the material, .028 ounces of highly enriched uranium-235 . . . The amount of uranium-235 seized is minute, about one-ten-thousandth of the amount necessary to build a nuclear explosive." [17.5 lbs]

Craig R. Whitney
New York Times
12 August 1994, p. A1

"Several kilograms of separated weapons-grade plutonium and a somewhat larger amount of 'reactor-grade' plutonium . . . would be enough to build a nuclear weapon."

National Academy of Sciences
Management and Disposition of Excess Weapons Plutonium
1994, p. 29.

APPENDIX B

Natural Resources Defense Council

1350 New York Ave. NW
Washington, DC 20005
202 783-7800
Fax 202 783-5917

August 18, 1994

The Honorable Hans Blix
Director General
International Atomic Energy Agency
Wagramerstrasse 5
P.O. Box 100
A-1400 Vienna, AUSTRIA

Dear Director Blix:

We are writing on behalf of the Natural Resources Defense Council (NRDC) to request formally that you take the necessary steps to reduce by 8-fold the current "significant quantities" (SQ) of direct-use nuclear materials. These SQ values -- also referred to by the IAEA as "threshold amounts" -- serve as the basis for determining whether the IAEA is meeting its technical objective of maintaining adequate safeguards against the diversion or theft of the direct-use nuclear materials needed to construct a nuclear weapon.

The IAEA's current SQ values for direct-use materials -- 8 kilograms (kg) of plutonium, 8 kg of uranium-233, and 25 kg of highly-enriched uranium (HEU) -- are given in *IAEA Safeguards Glossary, 1987 Edition*, IAEA, IAEA/SG/INF/1 (Rev. 1), 1987, p. 23-24. The basis for NRDC's view that these values should be reduced to 1 kg of plutonium and U-233, and 3 kg of HEU, is found in our forthcoming report, "The Amount of Plutonium and Highly-Enriched Uranium Needed for Pure Fission Nuclear Weapons," NRDC, 22 August 1994.

If it should prove beneficial, we would be pleased to discuss the details of our analysis with you or your staff.

Sincerely,

Thomas B. Cochran
Senior Scientist

Christopher E. Paine
Senior Research Associate

The New York Times

NEW YORK, SUNDAY, AUGUST 21, 1994

A Smuggling Boom Brings Calls For Tighter Nuclear Safeguards

World Rules Are Outdated, a New Report Says

By WILLIAM J. BROAD

Building a nuclear bomb takes so much less plutonium or uranium than generally believed that new safeguards must be adopted as part of a global tightening of defenses against the criminal diversion of atomic materials, private experts argue in a new proposal.

For plutonium, the experts say the official threshold of danger should be lowered from 8 kilograms to 1 kilogram, or from 17.6 pounds to 2.2 pounds. They also propose eightfold reductions for uranium, the other main fuel of atomic bombs.

The experts, from the Natural Resources Defense Council, a private group known for its nuclear expertise, wrote the Federal Government and the United Nations last week to urge such downward revisions. At a news conference tomorrow in Washington, the group is to make those letters public along with a report arguing for the proposed changes.

If adopted, the plan would result in more stringent safeguards meant to curb the spread of bombs.

The new proposals cast a harsh light on the recent seizures in Germany of atomic materials that are believed to have been smuggled out of Russia, making the amounts look quite serious. One deal broken up by German authorities was reportedly to have ultimately involved four kilograms of weapon-usable plutonium in exchange for $250 million. A kilogram is about 2.2 pounds.

Thomas B. Cochran, a senior scientist at the Natural Resources Defense Council and a co-author of the report, said, "The criteria now in use are out of date, technically erroneous and clearly dangerous in light of the recent seizures."

Resistance to the proposals is likely, however, because enhanced safeguards could be costly to enforce and might hamper or cripple some use of plutonium for the production of nuclear power overseas. The plan is also controversial because the minimal amounts of material needed to make a bomb have long been classified top-secret.

Even so, arms experts said they welcomed the airing of the issue by the council, which favors strict limits on nuclear arms and materials. Many experts said the old rules were dangerously out of date, even if the new proposals were perhaps too restrictive.

"It's important to have this debate," Energy Secretary Hazel O'Leary said in an interview. "Any number of people have the impression that the smaller the size under control, the better we are in the long term." Her agency oversees the nation's nuclear arsenal and plays a central role in limiting the spread of bombs.

Richard L. Garwin, a physicist who has long advised the Federal Government on nuclear-arms matters, suggested that revisions should fall somewhere between the old rules and the new proposals. "Clearly," he said,

Continued on Page 24, Column 1

Continued From Page 1

"the significant quantity of plutonium should be lowered, at least to four kilograms and perhaps somewhat less, if it is to represent the amount that is hazardous."

William J. Quirk, a nuclear-weapon expert at the Lawrence Livermore National Laboratory in California, said that for the moment the exact figure was less important than a public discussion.

"Whether the right number is four or one or two kilograms, it probably makes sense to lower the current number if it's feasible economically," he said. "I think it's the right thing to start the debate and then people can decide what they want to do."

Bombs in Small Packages

Building a nuclear bomb is well known to get progressively difficult as smaller amounts of fissionable material are used, the smallest requiring great expertise and special gear thought to belong only to advanced nuclear states. In addition, the size of the resulting blast decreases.

Nevertheless, 50 years of experimentation have allowed the United States and other nuclear nations to put powerful bombs in remarkably small packages.

In the early 1960's the United States stockpiled a bazooka-type weapon known as the Davy Crockett whose miniature atomic warhead weighed 51 pounds and had an explosive force equal to 22 tons of high explosive. At its core, the plutonium probably weighed several pounds.

In the 1950's and 1960's, amid a push for nuclear power and peaceful atomic industries, the United States championed an international system whereby safeguards would be applied to the handling and shipment of all kinds of nuclear materials to guard against diversions. The safeguards were enforced by an arm of the United Nations known as the International Atomic Energy Agency, or I.A.E.A., based in Vienna.

These safeguards in retrospect seem weak. Weapon experts say the rules were probably skewed by disinformation aimed at convincing aspiring nuclear states and terrorists that bomb-building was difficult, and by a desire to keep international controls loose enough to allow the rise of a robust nuclear industry.

The I.A.E.A. says the approximate amounts of fissionable material needed for a single nuclear weapon are 8 kilograms of plutonium, 8 kilograms of uranium 233, or 25 kilograms for uranium highly enriched in the 235 isotope.

These figures, known as threshold amounts or significant quantities, are used to establish a wide range of industrial safeguards meant to deter and detect the diversion of materials from peaceful purposes to the making of nuclear warheads.

Thus the Natural Resources Defense Council is proposing the eightfold reduction in these categories. For instance, the threshold amount of plutonium would drop from eight kilograms to one kilogram. On Thursday, the council wrote Hans Blix, the IAEA's director general, and to Mrs. O'Leary, the Energy Secretary, to call for the reductions.

Little Plutonium Required

Dr. Cochran, who is a physicist, said in an interview that his organization's proposed revision of the traditional figures was based on his personal calculations, a close reading of Government documents and statements, and discussions with weapon experts, who spoke on the condition of anonymity.

Based on his research and calculations, Dr. Cochran said, one kilogram of plutonium can be fashioned by a skilled designer into a bomb with a blast equal to 1,000 tons of high explosive.

"Detonated in or above a city center, one such 'small' weapon would be sufficient to cause severe blast damage over roughly a 40-block area, and many thousands more would likely die from the ensuing fire and radiation effects," said Christopher E. Paine, a co-author of the council's report. In comparison, the bomb that the United States dropped on Hiroshima in 1945 had a blast equal to about 15,000 tons of high explosive.

The council's report says that even a primitive bomb design like the implosion-type device pioneered by the United States in the mid-1940's would require only three kilograms of plutonium to create a blast equal to 1,000 tons of high explosive.

"The technical community has known for more than 40 years that it is possible to make an atomic bomb with very little material," said Mr. Paine. "If we are going to honestly deal with the problem of proliferation, which the Clinton Administration rightly claims is at the top of its security agenda, then we should deal with the facts as they are, not as the advocates of 'peaceful' plutonium use might wish them to be."

Power Industry's Concerns

Japan, Russia and several European countries, though not the United States, have recently made heavy investments in using plutonium for the production of nuclear power. In this approach, the plutonium from nuclear-reactor wastes, instead of being buried, is separated out and recycled through a reactor to produce more power.

Leaders of that industry argue that the council's new proposals are meant less to strengthen safeguards than to attack the civilian uses of plutonium, which they say are crucial for nations less richly endowed with energy resources than the United States.

"The hidden agenda is to shut down the reprocessing industry," said Marilyn Meigs, a senior official of BNFL Inc., in Washington, an American subsidiary of British Nuclear Fuels Limited, referring to companies that extract plutonium from nuclear waste.

Ms. Meigs said that the new proposals, if adopted, would force companies to install all kinds of new instrumentation in factories, trucks, planes and trains. "It would drive the economics haywire," she said. "We'd have to retrofit all the facilities to measure smaller quantities any place and time. It would be so expensive that nobody would do it."

No diversion has ever taken place from a safeguarded site, Ms. Meigs said. She added that the new international agenda ought to be getting renegade nations to adopt the current safeguards.

Dr. Cochran of the Natural Resources Defense Council contends that the industry has an obligation to confront the nuclear truth.

"The world would be a better place if it were not using nuclear weapons-usable materials in commerce," he said. "To the extent we cannot convince the rest of the world of this wisdom, we should have safeguards that can adequately protect these materials and the public."

"The safeguards," he added, "must be based on hard facts, not myths."

KEEPING TRACK

A New Threshold of Danger

The Natural Resources Defense Council proposes that the amount of weapons-grade nuclear fuel that is considered dangerous be lowered from the levels mandated by the International Atomic Energy Agency.

Fuel	Current U.N. regulations	Proposed regulations	Regulated substance
Plutonium	8 kilograms/ 17.6 pounds	1 kilograms/ 2.2 pounds	Total element
Uranium 233	8 kilograms/ 17.6 pounds	1 kilograms/ 2.2 pounds	Total isotope
Uranium enriched to contain 20% or more U-235	25 kilograms/ 55.1 pounds	3 kilograms/ 6.6 pounds	Total isotope

Source: Natural Resources Defense Council

A4 THE WALL STREET JOURNAL TUESDAY, AUGUST 23, 1994

IAEA Says Its Plutonium Threshold For Making Nuclear Bombs Is Too High

By JOHN J. FIALKA
Staff Reporter of THE WALL STREET JOURNAL

WASHINGTON—Nuclear weapons can be made with smaller amounts of plutonium and enriched uranium than the International Atomic Energy Agency has established as the benchmarks for its inspections, a spokesman for the IAEA acknowledged.

Responding to a Washington-based environmental group's claim that the agency's estimates were "totally out of line with reality," the IAEA spokesman, David Kyd, said the agency has known for some time that the estimates were too high. "We are in the hands of our member states," he explained. "They set the benchmarks."

Thomas B. Cochran, a physicist with the Natural Resources Defense Council, asserted yesterday that the IAEA's standards may overstate the amount of weapons materials needed to make nuclear bombs by as much as eight times and that recent quantities being smuggled out of Russia into Germany are "bumping up against" the real thresholds for making small nuclear weapons.

Lower Threshold

At a news conference held by the council, Dr. Cochran charged that while the IAEA estimates that it requires 8 kilograms, 17.6 pounds, of plutonium — a heavy, leadlike material—to make a bomb, his calculations showed it would require only one to three kilograms, or 2.2 to 6.6 pounds. The resulting weapon, he said, could devastate a 40-block area in a major city.

Dr. Cochran asserted that the use of higher threshold levels by the IAEA and public officials in the U.S and Japan seriously underestimates the danger of bomb materials being smuggled out of Russia, the size of North Korea's clandestine arsenal and the risk presented by plutonium that is missing from a nuclear processing facility in Japan. With a high degree of sophistication, he said, a nuclear weapon could be made with a chunk of plutonium no bigger than a cigarette package.

"It is true that in weapons-sophisticated countries you can do it [make a bomb] with less," said the IAEA's Mr. Kyd, but he said the 121 nations that make up the IAEA prefer the higher standards partly because setting the agency's inspection standards to the lower level would make its costs of inspection "substantially more."

Higher Inspection Costs

"If you want to drive the threshold down, the price would go up," he explained, estimating that the $68 million that the agency spends annually to inspect nuclear facilities could easily double if it were forced to account for cumulative losses at lower levels. The agency currently has 200 inspectors looking at some 1,000 nuclear facilities in 60 countries, most of them nonnuclear weapons states.

The Pentagon had no immediate comment on Mr. Cochran's statement. The U.S. Energy Department, which makes nuclear weapons, recently lowered its estimate of the amount of plutonium required for a small nuclear weapon to 4 kilograms, or 8.8 pounds.

Dr. Cochran said the disparity between the public figures and the real amounts of plutonium and highly enriched uranium needed to make bombs has been known within the nation's defense community since the early '50s. Ted Taylor, a former bomb designer at Los Alamos, N.M., lauded the Natural Resources Defense Council for "performing a public service" by disclosing the lower numbers.

But Carson Mark, who headed the nation's nuclear-weapons design laboratory at Los Alamos between 1950 and 1970, vehemently disagreed. He asserted that while sophisticated bomb designers could make weapons with less material, it wasn't clear that terrorist groups could. Announcing a lower standard, he said, would be a "self-deluding mistake."

Energy Secretary Hazel O'Leary said she has asked her experts to review the issue raised by the council. In a statement, she said she plans "to move forward quickly to open a dialogue" on the issue of what amounts of plutonium and uranium must be safeguarded to meet the nation's nonproliferation goals.

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13 September 1994

Dear Messrs Cochran and Paine,

On behalf of Dr Blix, Director General of the International Atomic Energy Agency, I would like to thank you for the 18 August 1994 letter that contained your views regarding the definitions of "significant quantities" (SQ) of direct-use nuclear materials.

As you correctly point out in your accompanying background paper the values of SQs currently used by the Agency derive from analyses first carried out more than 25 years ago. Since that time there have been repeated reviews of the values of SQs and other safeguards technical implementation parameters. At each juncture the Agency was left to conclude that when all factors - mass, isotopics, availability of weapons technology and the costs of safeguards implementation - were taken into consideration there was not sufficient justification to change SQ values.

International nuclear material safeguards is a complex control system based on the Agency's independent verification of a State's declared nuclear material holdings -- item-by-item, facility-by-facility and for the State as a whole. The extent of the Agency's independent verifications actually carried out depend upon three interrelated implementation parameters; probability of detection, SQ and timeliness. The level of assurance against diversion actually achieved varies as a function of a number of factors, however, it is a continuum (i.e., there is some probability of detecting the diversion of any amount of material) not a step function.

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Mr Thomas B Cochran
Senior Scientist

and

Mr Christopher E Paine
Senior Research Associate

Natural Resources Defense Council
1350 New York Ave, NW
Washington, DC 20005

The Agency is currently in the midst of a large development programme toward a strengthened and more cost-effective safeguards system. The technical, legal and cost implications of changes in the values of safeguards implementation parameters are being studied in concert with new safeguards measures designed to provide assurance regarding the absence of undeclared activities. A proposal for a strengthened, more cost-effective system will be presented to the Agency's Board of Governors in March 1995.

Yours sincerely,

B Pellaud
Deputy Director General
Head of the Department of Safeguards