Generating Electrical Power ... And Atomic Bombs

The double role of nuclear power stations

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A common reactor type produces enough plutonium each year for dozens of atomic bombs.

A belief once widely held, that the plutonium made in a reactor is always so ‘contaminated’ that it is useless as bomb material, is not true.

If the nuclear fuel rods are removed earlier than in normal operation, a bomb of near Nagasaki strength can be readily made.

Documented studies on reprocessing of spent fuel show that extracting the plutonium is feasible, and can be kept secret.

From the very beginning, the so-called ‘peaceful’ or civil nuclear industry, with its reactors designed to generate electricity or for use in research, has in fact been linked closely to the making of nuclear bombs.

EnergyScience Coalition Briefing Paper 9 in this series describes some of the various ways in which one country after another – about two dozen in all – actually used the facilities of a civil industry to develop their bomb-making preparations, usually in secret.

This Briefing Paper asks the following questions:

* Is it really possible, without too much difficulty, to get usable bombs from the reactor in a nuclear power station?
* Can their manufacture be concealed from the world?
* Is the power of such bombs in the same range as the ones that destroyed Hiroshima and Nagasaki?
* Are there good reasons to believe that, if a new batch of countries adopt nuclear power, at least some of them will use it to produce weapons?

As we will now see, the answer to each of these questions is (unfortunately): yes.

In the course of answering them, it will also become clear why, in the early days of the nuclear industry, a quite mistaken idea was widely believed: that the most common type of reactor, the light-water reactor (LWR), did not lend itself easily to the production of nuclear bombs.

U.S. Army War College's Strategic Studies Institute: a handy guide

Here we rely on information from a book dated June 2006, available for downloading free of charge from the U.S. Army War College's Strategic Studies Institute (SSI), at the site <www.StrategicStudiesInstitute.army.mil>.

The book, edited by Henry Sokolski, is a product of cooperation between the SSI and the Nonproliferation Policy Education Center. Its title is "Taming the next set of strategic weapons threats", and it is referred to below as 'Threats'. The portion most relevant here is Chapter 5, 'A Fresh Examination of the Proliferation Dangers Of Light Water Reactors', by Victor Gilinsky; this chapter is referred to below as 'Gilinsky'. His 'End Notes' support the chapter with references. To help in evaluating his own qualifications, a brief summary of Gilinsky's career is included at the end of this Briefing Paper.

In giving reactor figures below (for example, the quantity of plutonium produced per year), this Briefing Paper follows Gilinsky in taking as its 'standard reactor' a light-water reactor of 1000 Megawatt (electrical) capacity.

How a reactor manufactures the filling for bombs

Summary: A common reactor type produces enough plutonium each year for dozens of bombs.

In more detail:

In the chain reaction inside the reactor's core, nuclei of the 'fissile' U235 split under the impact of a neutron, giving out energy in various forms that eventually convert to heat, and also some more neutrons. Enough of the latter will impact other U235 nuclei to keep this chain reaction going.

However, there is another kind of collision that a neutron can make once it is released: sometimes it does not strike another nucleus of U235 and split it, but instead hits a nucleus of U238, and is absorbed by it. The resulting nucleus (U239) quickly decays to plutonium, in the form (the 'isotope') Pu239.

This isotope of plutonium is itself 'fissile' like U235 – that is, it can split explosively when struck by a neutron, giving out a great deal of energy and also some more neutrons. Thus a piece of Pu239 can be used to set up a chain reaction of energy release.

If a sufficiently large mass of Pu239 - meaning about 5 kg – is quickly brought together at sufficient speed, a significant fraction of the whole of the fissile energy it contains will be released in an instant. In other words: it is a bomb, and it explodes.

The 'standard reactor' described above produces about 250 kg of plutonium a year. (Compare this with the plutonium content of the bomb that destroyed Nagasaki: about 6 kg.)

How the threat of nuclear proliferation was played down

Summary: It was widely believed that the plutonium made in a reactor is always ‘contaminated’, tending to reduce its explosive yield (true!) and making it quite unsuitable for a bomb (not true!).

In more detail:

It may seem puzzling that greater emphasis was not placed on the role of nuclear power as a source of bomb material. As Gilinsky writes (p.67): ‘It has long been understood that the most difficult hurdle for a country seeking nuclear weapons is getting the nuclear explosive materials … By comparison, the design and fabrication of the nuclear weapon itself poses a less difficult obstacle.’

But there was an argument for the ‘safety’ of reactor plutonium that can be put like this:
* ‘There is another type of collision a neutron undergoes, once it has been released inside the reactor core:
* ‘It will sometimes happen that the uranium nucleus absorbing a neutron has done so once already, so that it now has two added neutrons, becoming U240, and gives rise to the heavier isotope of plutonium, Pu240. Obviously there will be a much smaller amount of it than of the PU239 itself, but it can be said to ‘contaminate’ the bomb material because it reduces its explosive power.
* ‘This reduction occurs, not because the added Pu240 is less ready to fission explosively, but because it is more ready.
* ‘To make the bomb explode, a ‘critical mass’ of the plutonium (5 kg or so) must be compacted, usually by ordinary explosives distributed over its surface (‘implosion’). It is while the bomb material is being thus brought together that the ‘contaminant’ Pu240 is liable to fission too early – that is, before the main bulk of the Pu239 has got its chain reaction going.
* ‘The explosive power of this ‘premature’ fission will scatter the main bulk into pieces less than the critical mass, so that only a small fraction of its (much more powerful) fission energy is released. This means that the bomb will produce a relatively harmless “fizzle”. Thus a nuclear bomb cannot be made with the plutonium from a reactor.’

How much of this argument is true? All of it – except the conclusion reached in the last paragraph!

How plutonium from a reactor can be ‘de-contaminated’ for use in bombs

Summary: To keep the level of ‘contamination’ low, just remove the fuel rods from the reactor earlier than in normal operation.

In more detail:

A typical refuelling schedule sees a third of the fuel elements being replaced each 18 months or so. This means that a particular fuel element will figure in the chain reaction, and thus in the neutron bombardment, for four to five years – with its fraction of ‘contaminant’ Pu240 increasing throughout this time as more and more ‘double collisions’ occur, in which a nucleus with a neutron already absorbed collects yet another one.

This makes it obvious, how one can accumulate plutonium having only a small fraction of the contaminant Pu240: just leave the fuel in the reactor long enough to ensure plenty of Pu239, but unload it well before its scheduled time for refuelling, to halt the growth in the fraction of contaminant.

Plutonium is taken to be ‘weapons grade’ if it has less than 7% or so of contaminant; it would be close to this, perhaps about 10%, if it came from fuel unloaded after about eight months, by which time there would be material for about 30 bombs (Gilinsky, p.78).

Of course, this means departing from the normal refuelling schedule, and so risking detection. But there is an alternative way to obtain a stock of bombs, while (to all appearance) sticking to the expected schedule: remove, not those fuel assemblies which have actually completed their four or five years, but some or all of those loaded into the reactor only at the last refuelling operation. These, having been irradiated for only 18 months or so (‘first cycle’ fuel), will be close to weapons grade, with only about 15% of their plutonium the contaminant Pu240 (Gilinsky, p.79).

Plutonium from a reactor can make powerful bombs

Summary: If the rods are removed early enough, these methods will give bombs of near Nagasaki strength. Even the ‘first cycle’ fuel will still give bombs of power equivalent to thousands of tons of TNT.

In more detail:

To evaluate the explosive power of these bombs, Dr. Harmon W. Hubbard was consulted. He is described as an experienced physicist who had worked on nuclear weapons at the Livermore Laboratory and served for several years on the panel that evaluated foreign nuclear explosions for the U.S. Government … (Gilinsky, p.80)

His conclusions are given in Table 1 (Gilinsky, p.82). In kilotons of TNT-equivalent, weapons grade gives an estimated average yield of 13 kilotons. The ‘first cycle’ plutonium, with reduced contamination, gives an estimated average yield of 5 kilotons.

To put these figures into perspective, recall that towards the close of World War 2 the Royal Air Force dropped bombs of 12,000 pounds weight on German cities, each containing about 9,000 pounds of explosive. Such bombs were called, with good reason, ‘blockbusters’.

The unit just used, the kiloton, exceeds the total power of two hundred such ‘blockbuster’ bombs.

As Richard L. Garwin and Frank N. von Hippel noted when commenting on the North Korean bomb test (Arms Control Today, Nov. 2006):
“A 4 kiloton or even a 1 kiloton explosive would still be a terrifying weapon. Recall that the 1995 Oklahoma City explosion involved only a few tons of ANFO. [ammonium nitrate and fuel oil] . A 1 kiloton (1,000 ton TNT equivalent) bomb could kill people in an area of about one square mile and would partially destroy a much larger area. Most of these deaths would be from fire or from the prompt nuclear radiation.”

Even a ‘small’ nuclear bomb can have international effect

Summary: The example of North Korea shows that, even if success is only partial, political results the bomb project is aiming for can still be obtained.

In more detail:

Inefficient assembly or firing of the bomb might reduce the explosive power below the values estimated above. But a yield even as ‘small’ as a few hundred tons of TNT-equivalent can still evoke the intimidation and alarming effect associated with nuclear arms.

This was shown convincingly in October 2006, when North Korea tested a plutonium bomb. Its yield was widely reported as ‘only’ about 600 tons of TNT-equivalent – far below the figures estimated above. But it was enough to make a significant change in international attitudes towards the country.

The United States, for instance, departed from its previous stance of hostility and threat towards North Korea as a member of the ‘axis of evil’, turning to persuasion and negotiation as the appropriate response. It can be assumed that this change was noted by other governments.

North Korea’s nuclear project was of course restricted by the small size and correspondingly small plutonium production of the Experimental Power Reactor it used. More and much bigger weapons could have resulted if a full-size power reactor had been available to it.

Separating out the plutonium from used fuel is not too difficult

Summary: Documented studies on ‘quick and dirty’ reprocessing of spent fuel show that extracting the plutonium is feasible, and can be kept secret.

In more detail:

To build a bomb, spent fuel from a reactor must be ‘reprocessed’ to separate the plutonium from unwanted material like the uranium and the fission products.

References are available for no less than four studies giving designs for a suitable small reprocessing plant (Gilinsky, pp.72-75).

One of the earliest, a 1977 study from Oak Ridge, proved that ‘a country with a minimal industrial base could quickly and secretly build a small reprocessing plant capable of extracting about a bomb’s worth of plutonium per day ... The structure housing the entire operation would be about 130 feet long [40 metres] and much less wide.’

Back in the 1950s, the Phillips Petroleum Company had produced a reprocessing design on which Gilinsky comments: ‘One of the striking features of the plant is its small size, about 65 feet [20 metres] square.’

Obviously, such small installations as those described would be far from easy to detect, and even harder for their purpose to be recognised.

The near future may well see an increased nuclear-proliferation drive

Summary: The global context of the near future is likely to incline a number of nations towards nuclear weapons, as a desirable advantage available along the nuclear-power path.

In more detail:

As already quoted from Gilinsky, the big obstacle to building nuclear bombs is the lack of a supply of the explosive material needed. Getting a nuclear power station brings access to this material. The country concerned may not proceed to acquire bombs, perhaps because of moral objections, perhaps because it does not seem worth the trouble. But if it wants to, the paths to nuclear arming, which include the ones sketched above, are open to it.

One kind of reason which might prompt a country to secure nuclear arms has been pointed out by Lt. Gen. William E. Odom, writing in Foreign Policy, May/June 2007:
“[T]he United States pursues a destabilizing and feckless nonproliferation policy … Rather than recognizing that states most often seek nuclear weapons when they feel insecure, the administration has pushed the world’s most fragile and dangerous regimes into a corner. The results have been predictable. The invasion of Iraq has made that region less stable than at any time since 1945. U.S. policy in Northeast Asia has already yielded a nuclear capable North Korea.”

Even if General Odom’s view assigning responsibility to U.S. foreign policy is accepted, this does not necessarily imply a future world in which nuclear weapons proliferate widely - for a foreign policy can always be changed. But another class of reasons that favour nuclear proliferation has been recognised by a wide spectrum of analysts, and cannot be so easily disposed of.

These analysts point to the numerous sources of actual and potential conflict that abound in the world of today and are likely to worsen in the near future. They stem above all above all from competition over resources, combined with and sharpened by the stresses of global warming. (See for instance Resource Wars, by Michael Klare, Henry Holt and Company, 2001.)

We may well believe that countries seeking nuclear weapons are misguided, and going against their own best interests. But we must acknowledge that many governments have adopted a contrary view, and that some engaged in local conflict will believe there is a nuclear advantage to be gained.

We should face up, then, to what can follow any further spread of nuclear power throughout the world, and of the stocks of plutonium that go with it. Multiplying the opportunities for the spread of nuclear weapons, it is likely to produce, among the conflict situations foreseen for the near future, an unpredictable number of confrontations between opponents equipped with the nuclear means of mass destruction.

OVERALL SUMMARY:

A common reactor type produces enough plutonium each year for dozens of bombs.

It was widely believed that the plutonium made in a reactor is always ‘contaminated’, tending to reduce its explosive yield (true!) and making it quite unsuitable for a bomb (not true!).

To keep the level of ‘contamination’ low, just remove the fuel rods from the reactor earlier than in normal operation.

If the rods are removed early enough, these methods will give bombs of near Nagasaki strength. Even the ‘first cycle’ fuel will still give bombs of power equivalent to thousands of tons of TNT.

The example of North Korea shows that, even if success is only partial, political results the bomb project is aiming for can still be obtained.

Documented studies on ‘quick and dirty’ reprocessing of spent fuel show that extracting the plutonium is feasible, and can be kept secret.

The global context of the near future is likely to incline a number of nations towards nuclear weapons, as a desirable advantage available along the nuclear-power path.

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Threats, page 175, under the heading ‘ABOUT THE CONTRIBUTORS’:
VICTOR GILINSKY is an independent energy consultant and former Nuclear Regulatory Commissioner under Presidents Ford, Carter, and Reagan. He has been active on nonproliferation issues for many years, going back to his early work at RAND in Santa Monica, California. In 1971 Dr. Gilinsky moved to the Atomic Energy Commission in Washington, DC, where he was Assistant Director for Policy and Program Review. From 1973 to 1975, he was head of the RAND Physical Sciences Department. From 1975 to 1984, he served on the Nuclear Regulatory Commission, having been appointed by President Gerald Ford and reappointed by President Jimmy Carter. During his NRC tenure, Dr. Gilinsky was heavily involved in nuclear export issues. In 1982 he received Caltech’s Distinguished Alumni Award. Dr. Gilinsky has a Ph.D. in physics from the California Institute of Technology.

About the Author:
Dr Alan Roberts holds a Ph.D. in physics (University of Sydney) and has lectured in physics at Sydney and Monash universities. He formerly served on the advisory Nuclear Safety Committee of the Australian Radiation Protection and Nuclear Safety Agency. His research work is on problems of theoretical ecology.

About our organisation:

energyscience.org.au is a co-operative production by a group of concerned scientists, engineers and policy experts that seek to promote a balanced and informed discussion on the future energy options for Australia.
With increasing concern over the looming impact of global climate change the community needs to be aware of the issues involved. energyscience aims to provide reliable and evidence based information to our whole community

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