Fissile Material Basics

What are fissile materials?

Fissile materials are composed of atoms that can be split by neutrons in a self-sustaining chain-reaction to release enormous amounts of energy. In nuclear reactors, the fission process is controlled and the energy is harnessed to produce electricity. In nuclear weapons, the fission energy is released all at once to produce a violent explosion. The most important fissile materials for nuclear energy and nuclear weapons are an isotope of plutonium, plutonium-239, and an isotope of uranium, uranium-235. Uranium-235 occurs in nature. For all practical purposes, plutonium-239 does not.

What is plutonium-239?

Plutonium-239 (hereafter referred to as “plutonium”) is a heavy element consisting of 94 protons and 145 neutrons. It can have a number of chemical forms. Nuclear weapons use plutonium metal. Plutonium dioxide is used as a component of some nuclear fuels. Plutonium has a half-life of over 24,000 years (a half-life is the time it takes for half of a given amount of radioactive material to decay into other elements).

How is plutonium made?

Two key facilities are needed to obtain plutonium. First, in a nuclear reactor, uranium-238 absorbs a neutron. This leads to nuclear reactions which convert it to plutonium. The plutonium ends up in the spent nuclear fuel along with unused uranium and highly radioactive fission products. Essentially all nuclear reactors in the world produce plutonium in this way, but plutonium in spent fuel is not usable for nuclear energy or nuclear weapons. To get plutonium into a usable form, a second key facility, a reprocessing plant, is needed to chemically separate out the plutonium from the other materials in spent fuel. Reprocessing is generally regarded as one of the key links between civilian nuclear power capability and nuclear weapons production capability (the other is uranium enrichment — see below).

What is plutonium used for?

Once plutonium is separated, it can be processed and fashioned into the fission core of a nuclear weapon, called a “pit”. Nuclear weapons typically require three to five kilograms of plutonium. Plutonium can also be converted into an oxide and mixed with uranium dioxide to form mixed-oxide (MOX) fuel for nuclear reactors.

As of 1995, there were approximately 270 metric tons of separated plutonium in military inventories and roughly 180 metric tons of separated plutonium in civilian inventories worldwide.

Where is plutonium produced?

Britain, France, Russia, India, Japan, Israel and China operate reprocessing plants to obtain plutonium (the last two only for military purposes). Other countries in Western Europe own plutonium that was separated in Britain and/or France. North Korea has also operated a reprocessing plant.

In the U.S., reprocessing for nuclear weapons occurred at the Hanford Reservation, Washington and the Savannah River Site, South Carolina. Some civilian and military reprocessing also occurred between 1966 and 1972 at West Valley, New York. U.S. plutonium production reactors were shut down in 1988, and halting reprocessing for military purposes was codified into formal policy in July 1992. The United States does not support reprocessing because of its proliferation dangers, but in practice the U.S. has been selective in opposing reprocessing in other countries

What is highly enriched uranium?

The other important fissile material that has been used for nuclear weapons is highly enriched uranium (HEU), usually defined as uranium whose proportion of uranium-235, the fissile isotope of uranium, has been increased to over 90%. The natural uranium mined from the earth consists of about 0.7% uranium-235 (U-235), and about 99.3% uranium-238 (U-238),, and enrichment is the process of increasing the ratio of U-235 to U-238. The half life of uranium-235 is 704 million years, while the half life of U-238 is about 4.5 billion years.

It is important to note that most nuclear reactors run on low-enriched uranium (LEU), which is usually 3%-5% uranium-235. LEU cannot be used in nuclear weapons.

How is highly enriched uranium made?

Traditionally, uranium has been extracted from underground and open pit mines. This natural uranium is processed and then enriched. Numerous technologies have been developed to enrich uranium, such as gaseous-diffusion, centrifuges, and electromagnetic separation. All of these technologies require a large initial investment and large amounts of energy to operate.

What is HEU used for?

HEU was first developed for use in nuclear weapons. It can be combined with plutonium to form the “pit”, or core of a nuclear weapon, or it can be used alone as the nuclear explosive. The bomb dropped on Hiroshima used only HEU. About 15-20 kgs of HEU are sufficient to make a bomb without plutonium.

HEU also has non-weapon uses. It is used as a fuel in research reactors and the nuclear reactors that power some naval vessels.

About 2300 metric tons of HEU have been produced for military purposes worldwide — primarily by the United States and the Soviet Union. About 20 metric tons of HEU have been used in research reactors worldwide.

Where is HEU produced?

HEU can, in theory, be produced in any enrichment plant. Several countries operate enrichment plants to produce LEU for nuclear reactors, but not all of these countries have used their plants to make highly enriched uranium. The International Atomic Energy Agency, a United Nations agency, is charged with ensuring that uranium from civilian nuclear programs is not diverted to weapons-purposes only in

non-nuclear weapon states who are signatories to the Non-Proliferation Treaty. HEU was produced in the United States at Oak Ridge, Tennessee and Portsmouth, Ohio. The United States no longer produces HEU. It continues to use HEU from its stockpile for research reactors and naval propulsion.

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