Uranium Primer - The Nuclear Fuel Cycle

The Light water reactor, or LWR, is the most commonly used reactor in the nuclear fuel cycle. The cycle consists of a "front end" that comprises the steps necessary to prepare nuclear fuel for reactor operation and a "back end" that comprises the steps necessary to manage the spent nuclear fuel, which is highly radioactive. It is possible, as shown, to extract the unused uranium and plutonium from spent nuclear fuel through chemical reprocessing and to recycle the recovered uranium and plutonium as nuclear fuel.

The front end of the cycle is divided into the following steps:

Exploration: Ore bodies containing uranium are first located by drilling and other geological techniques. Ores in known deposits for which enough information is available to estimate the quantity, and which are considered to be economically minable, are called reserves. Ores inferred to exist but as yet undiscovered are called potential resources.

Mining: Uranium-bearing ores are mined by methods similar to those used for other metal ores. The uranium ore is removed from the ground by underground mining, open-pit mining, or by in-situ recovery. See Uranium Extraction page.

Milling: At uranium mills, usually located near the mines, uranium-bearing ores are crushed and ground, and the uranium oxide is chemically extracted. The mill product, called uranium concentrates or "yellowcake," is then marketed (and sold as pounds of U_3O_8 or kilograms of uranium content. Uranium can also be extracted as a by-product of other mining operations, in association with gold, copper, or phosphate fertilizer.

UF_6 Conversion: Next, the U_3O_8 is chemically converted to uranium hexafluoride (UF_6), which is a solid at room temperature but changes to a gas at slightly higher temperatures. This is a necessary feature for the next step, enrichment.

Enrichment: Natural uranium cannot be used as fuel in LWRs because its content of fissile U-235 is too low to sustain a nuclear chain reaction. The process of uranium enrichment currently consists of two different technologies. The first (gaseous diffusion) consists of forcing UF_6 gas under pressure through a long series of barriers that pass U-235 at a slightly faster rate than the heavier U-238 atoms. This differential treatment progressively increases the percentage of U-235 in the product stream. Another enrichment technology (gaseous centrifuge) uses spinning centrifuges to separate the heavier U-238 atoms from the lighter U-235 atoms. The work required to perform enrichment, and the units in which it is sold, is measured in terms of separative work units (SWU).

The back end of the cycle is divided in to the following steps:

Interim Storage: After its operating cycle, the reactor is shut down for refueling. The fuel discharged at that time (spent fuel) is stored either at the reactor site, or potentially, in a common facility away from reactor sites. If on-site pool capacity is exceeded, it may be stored in modular dry storage facilities at the site or at a facility away from the reactor site. The spent fuel rods are usually stored in water, which provides both cooling (the spent fuel continues to generate heat as a result of residual radioactive decay) and shielding (to protect the environment from residual ionizing radiation).

Reprocessing: Spent fuel discharged from LWRs contains appreciable quantities of unused U-235, Pu-239, and other radioactive materials. These materials can be chemically separated and recovered from the spent fuel. The recovered uranium and plutonium can, if economic and institutional conditions permit, be recycled for use as nuclear fuel.

Waste Disposal: A current concern in the nuclear power field is the safe disposal and isolation of high-level radioactive wastes in the form of either spent fuel rods or, if the reprocessing option is used, wastes from reprocessing plants. These wastes must be isolated from the biosphere until the radioactivity contained in them has diminished to a safe level. Current plans generally call for the ultimate disposal of the wastes in solid form in deep, stable geologic structures.

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