Uranium Primer - Uranium as Nuclear Fuel

Uranium in its naturally occurring form consists primarily of two "isotopes" with the same chemical characteristics, but different atomic weights due to the differing number of neutrons in their nuclei. Both isotopes have 92 protons in their nuclei (and, thus, the same chemical characteristics), but the lighter isotope (atomic weight of 235) has 143 neutrons and the heavier isotope has 146 neutrons. The lighter isotope, U-235, comprises only 0.7% of natural uranium, but it is the only isotope that can actually undergo fission and, thus, produce energy. The other isotope, U-238, comprises the remaining 99.3% of natural uranium. In order to be useful as fuel in the most prevalent nuclear power technologies, the percentage of U-235 must be increased to the level of 2-5% U-235, a process called "enrichment." Enrichment is a technically difficult process, the essence of which is highly secret because it is the same process used to produce some nuclear weapons material. (Nuclear weapons can be made from uranium of approximately 90% U-235.)

Unlike a fossil-fueled power plant, a nuclear power plant is not fueled continuously, but rather in batches. At its initial operation, the nuclear plant is loaded with what is called an "initial core" of fuel assemblies in a geometric configuration inside the plant's "reactor core." The plant is started up, and the fission of U-235 occurs in the fuel assemblies inside the core. Eventually (in 1-2 years of operation), the fission product level builds up inside the fuel and quenches the fission process. At this stage, the nuclear plant has finished an "operating cycle" and is shut down for refueling. A portion (typically 20-40%) of the fuel assemblies is replaced at refueling time, with U-235 enrichment levels specific for that plant and operating cycle, and the rest of the fuel is shuffled in the reactor core to optimize the plant's future operations. The nuclear plant is then started up again in a new operating cycle, which lasts from 12-24 months, depending on the design of the plant's operation. Utility companies like to shut down for refueling in their "off-peak" demand periods, which is usually in the spring or fall.

The company fabricating the fuel assemblies does not normally use the enriched uranium product (EUP) delivered by that customer to manufacture the customer's actual fuel assemblies. The fabricator is using its working inventory to produce the customer's assemblies. In actual practice, the utility customer is asked by the fabricator to deliver EUP of different characteristics (quantity and U-235 enrichment) than that used for that customer's fuel assemblies; in fact, the customer usually orders EUP matching a future fabrication customer's needs. In each such case, the customer delivers EUP of the same enrichment services (SWU) content, but different natural uranium equivalent. When the fabrication customer delivers the EUP for fabrication, the customer's EUP is broken up into "feed" (i.e., natural UF_6) credits and SWU credits for the customer's storage account at the fabricator. On a periodic basis (usually once a year), the fabricator and its customers reconcile their feed accounts, on the basis of the feed equivalent actually required to fabricate the customers' fuel. (Remember that the customers each deliver the proper SWU content in their EUP.) If the feed equivalence of a customer's actual EUP deliveries is less than the feed equivalence of the fabricated fuel delivered to the customer (after accounting for manufacturing losses), the fabrication customer delivers feed UF_6 to the fabricator's account somewhere, and vice versa for customers with excess delivered feed content.

To further complicate (or, actually, to simplify) matters, the enricher usually delivers the EUP prior to its customer's contractual delivery date. This EUP is then recorded as feed and SWU credits for the enricher's storage account at the fabricator. Then, when the enricher is required to make delivery of EUP to the enrichment/fabrication customer, the enricher just notifies the fabricator to make a book transfer of feed and SWU credits from the enricher's account to the utility enrichment/fabrication customer's account. Thus, the notion of a physically identifiable lot of EUP is meaningless in this industry, and the accounting concept of feed and SWU credits makes the feed and SWU fungible in their own right.

This accounting system does not mean that physical quantities of EUP are not important. There is a system of physical protection and nuclear nonproliferation safeguards that require a strict accounting for the physical inventory of EUP within the fabrication plant boundaries, so that any theft or diversion of EUP for military or terrorist purposes can be detected. The responsibility (including government inspection and reporting requirements) for this physical protection and the liability for any radiation-related accident is purely that of the fabrication facility owner, not the fabrication customer. It is tied to the physical possession of the EUP, not to the party with legal title to the EUP. The same situation occurs for the other processing stages of the nuclear fuel cycle.

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