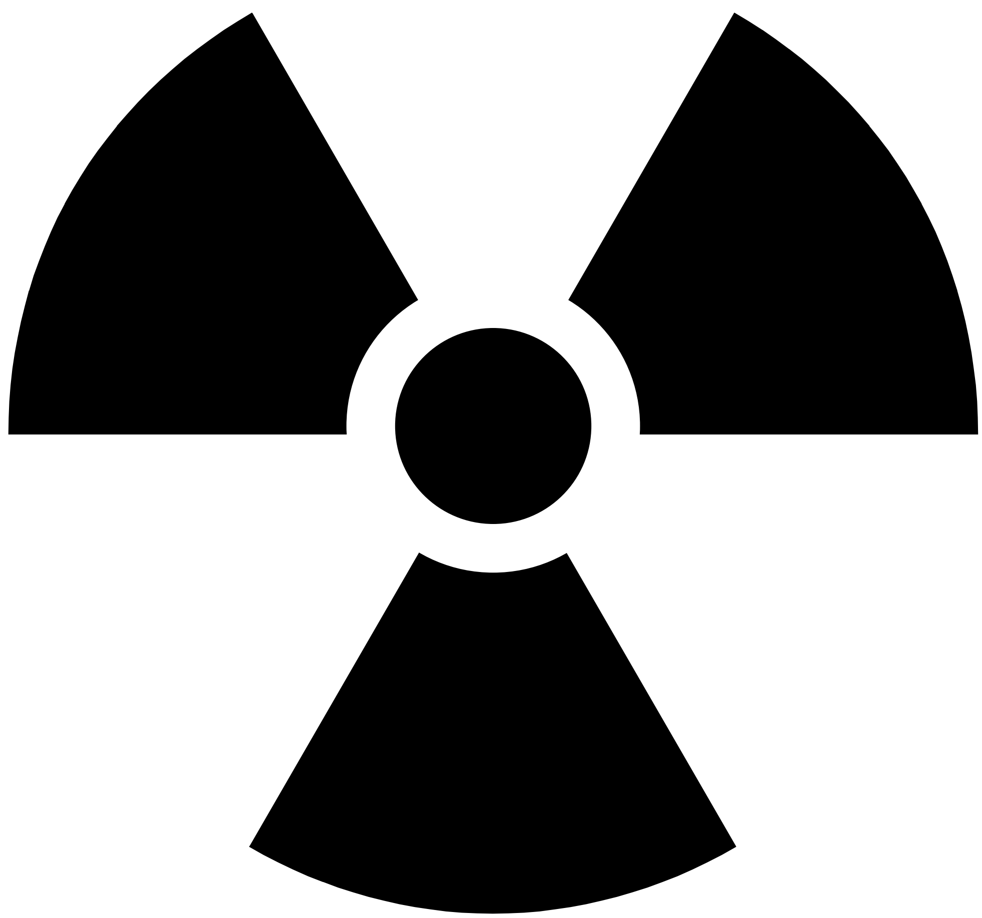
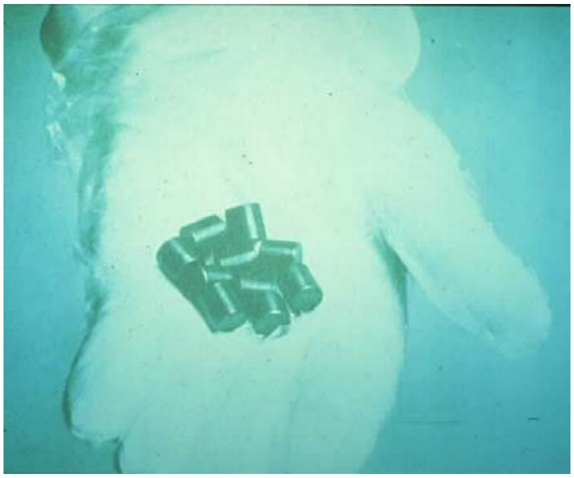
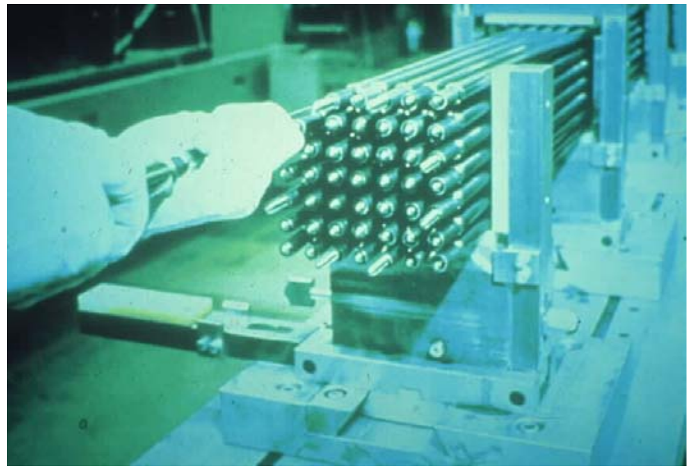
Radiation Sources at Nuclear Plants



This chapter will discuss the sources of radiation at nuclear power plants. These sources are:

- Nuclear fuel decay
- Fission process
- Fission product decay
- Activation products
- Calibration sources

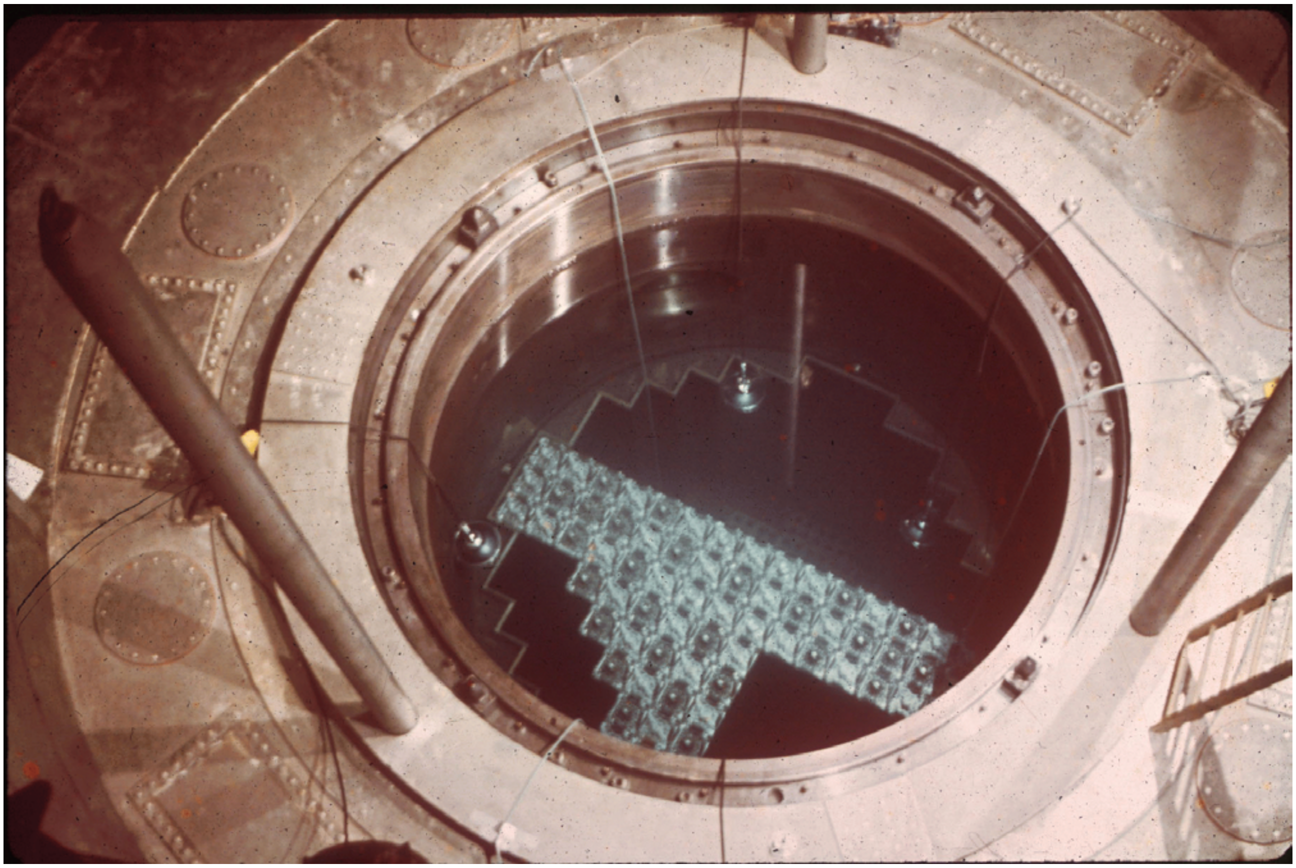




Nuclear Fuel Natural Decay Process

Uranium-238 (about 96% of the fuel) and uranium-235 (the remaining 4%) are naturally radioactive and disintegrate (decay) by the emission of alpha particles and gamma rays into daughter products. Beta particles are also released from the fuel as the daughter products continue the natural decay process toward a stable form (lead). Since the fuel is sealed in airtight fuel rods, there should be little or no alpha or beta radiation problem at the nuclear plant due to the natural decay of the fuel unless there is some fuel rod damage.

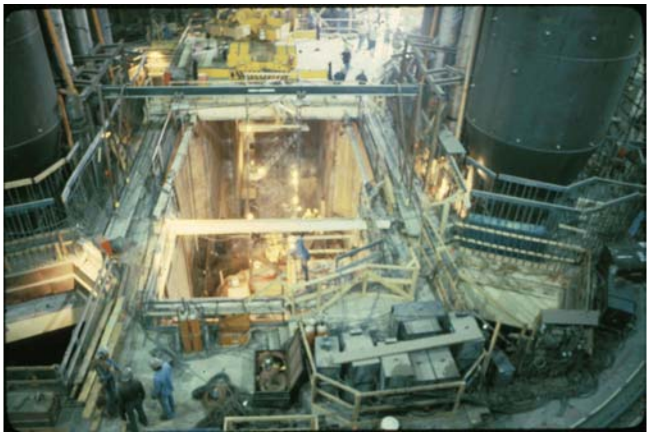
The natural decay process of the fuel is not a major contributor to a worker's dose at the power plants. This is because of the low radiation levels associated with fuel that has not operated in the reactor core.

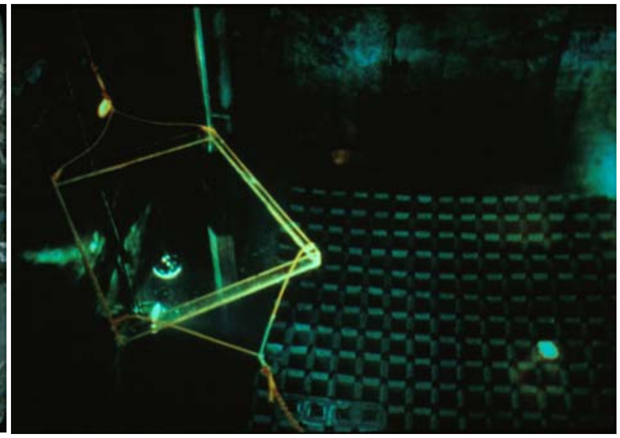


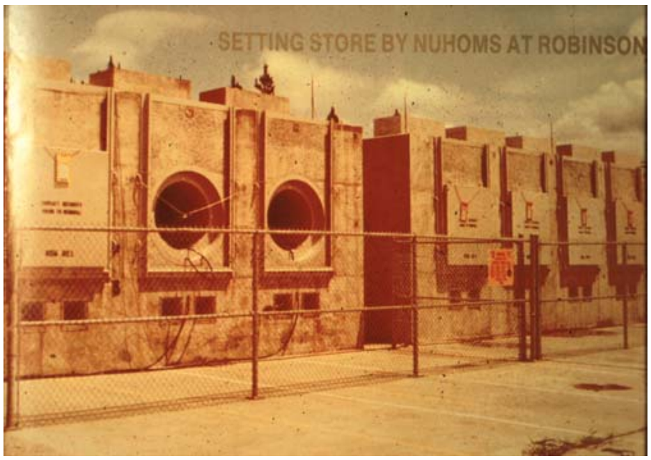
Fission Process

During the fission process, uranium atoms split into two or three smaller atoms, which are called fission products. Powerful (high energy) gamma rays and high speed neutrons are released during and immediately following the fission process. Since neutrons and gamma rays can travel long distances in air, very high radiation levels are present in the vicinity of the reactor vessel during power operation.

The fission process is not a major contributor to a worker's dose at the power plants. This is because the fission process is occurring in the reactor core which is contained in the reactor vessel. The reactor vessel is located within the reactor cavity inside the containment, and workers are not normally allowed around the reactor vessel during operation.



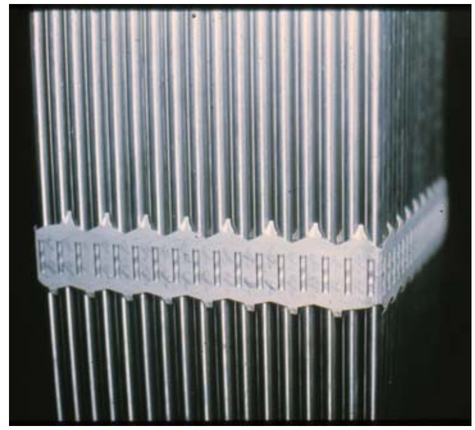


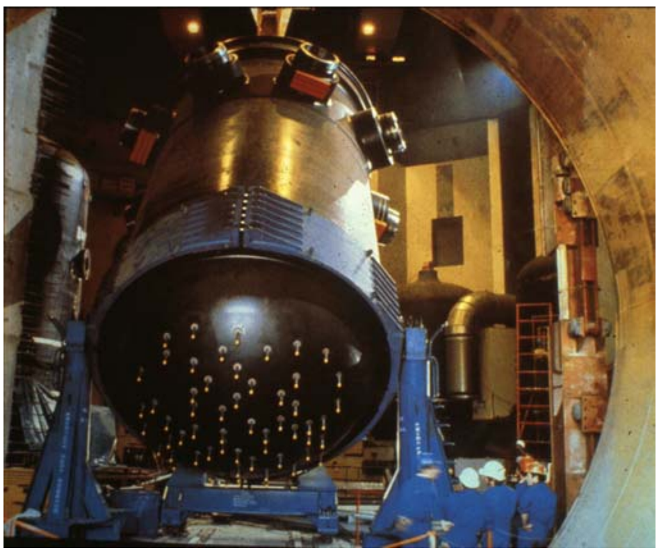


Fission Product Decay

The fission products, which are produced by the fissioning of the uranium fuel, are intensely radioactive. Most of these fission products will decay rapidly, since they have very short half-lives. However, several have very long half-lives and decay very slowly. Fission products generally decay by beta and gamma emission.

The decay of the fission products generally occurs within the reactor vessel, and, therefore, they are not a significant contributor to the radiation dose of workers at the power plant during operation. The gamma rays contribute to the radiation levels near the reactor vessel. Since workers are not normally present in the vessel area during operation, they are not a significant source of exposure. During refueling, however, the fuel is removed from the reactor vessel. At this time, the workers could be exposed to the radiation from the fission products. However, refueling is performed under water to limit the radiation dose the workers receive.

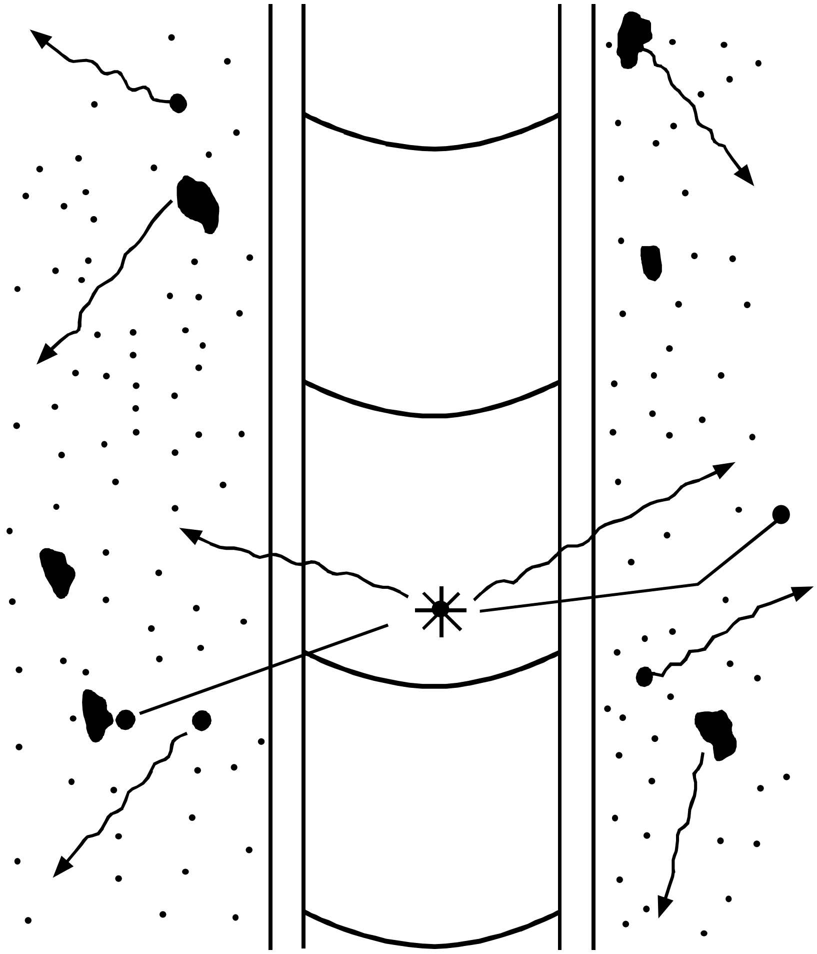




Fission Product Barriers

Since a significant fission product release could seriously jeopardize public health and safety (and the environment), a system of fission product barriers is part of every power reactor design. The barriers are designed to keep the highly radioactive fission products from reaching the environment by keeping the fission products within the reactor core area.

Most of the fission products will stay in the pellet. But, if the pellet is damaged or due to natural diffusion, the fission products could get out of the pellet into the fuel rod. Since the fuel rods are contained within the reactor vessel, any leakage from the fuel rods will be contained within the reactor coolant system. If the reactor coolant system loses its integrity, the containment would contain the fission products.



Activation of Water & Corrosion Products

Some materials in the vicinity of the reactor core (impurities in the reactor coolant and the reactor coolant itself) will absorb some of the neutrons produced during the fission process and will be changed from a stable form to an unstable (radioactive) form. This process is called activation, and the radioactive isotopes formed are called activation products. These activation products are located in the reactor coolant system, unlike the fission products which are located inside the fuel rods, and are, therefore, easily transported by the reactor coolant system to any support system that connects to the reactor coolant system. Activation products are the source of most radioactive contamination at nuclear power plants and are also the source of most occupational radiation exposure at the plants.

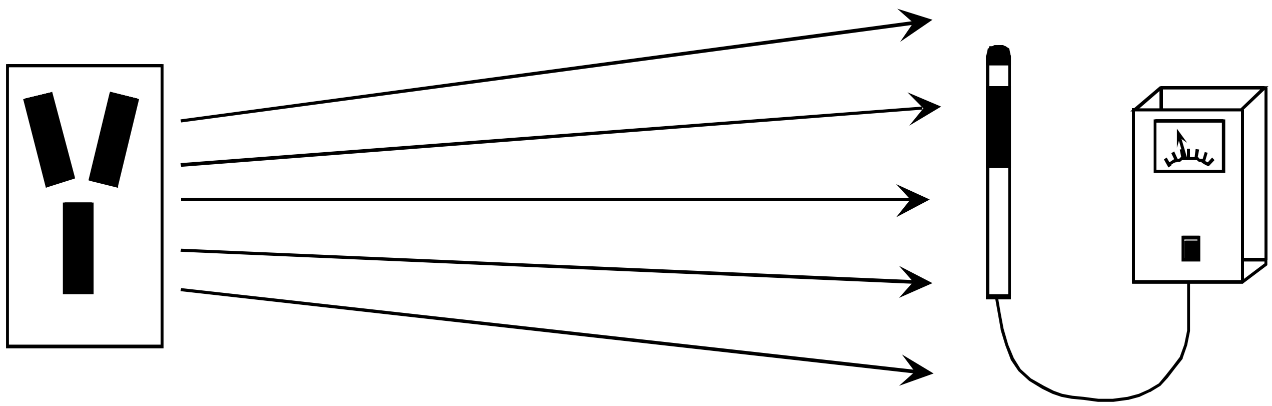
If the activation products or any other impurities plate out on reactor coolant system surfaces, the deposits are called CRUD. Prior to going into a refueling outage, some plants will add a chemical to the reactor coolant system to force the CRUD off the surfaces, and then use the cleanup system to remove the material from the coolant. This helps to reduce the radiation levels present during the refueling outage.

MATERIAL	RADIATION	HALF-LIFE
Krypton-85	Beta/Gamma	10 years
Strontium-90	Beta	28 years
Iodine-131	Beta/Gamma	8 days
Cesium-137	Beta/Gamma	30 years
Carbon-14	Beta	5770 years
Zinc-65	Beta/Gamma	245 days
Cobalt-60	Beta/Gamma	5 years
Iron-59	Beta/Gamma	45 days
Tritium (Hydrogen-3)	Beta	12 years

The list above shows some of the radioactive materials produced either by fission (fission products) or by neutron absorption (activation products). The first five isotopes on the list are fission products, and the remaining four are examples of activation products. These materials are of particular interest because of their:

- Relatively long half-life,
- Relatively large abundance in the reactor, and/or
- Ability to chemically interact in biological systems.

Not included in the list above, but of extreme importance, is the isotope nitrogen-16 (N-16). This isotope has a very short half-life (about seven seconds), but emits an extremely powerful gamma ray. N-16 is formed when an oxygen-16 atom absorbs a neutron and decays. Since every molecule of water has an oxygen atom, there is a large amount of N-16 produced in the core. N-16 is a major concern for shielding due to the high energy of the gamma ray emitted. Also, any system that contains primary coolant and exits containment must be of concern. One method of minimizing the radiation from N-16 is to allow the flow of coolant to circulate in a loop for a time period that permits the N-16 to decay, or by slowing down the flow to allow the decay (about a 1 minute delay is sufficient).



Instrument Calibration Sources

Small quantities of radioactive material (called sources) are stored on the plant site to allow instrument technicians to properly test and calibrate radiation detection instruments. These sources are completely sealed and are stored in isolated areas when not in use.

Plant calibration sources are not a major contributor to a worker's dose at a power plant.