

FACTSHEET:

Spent fuel reprocessing

Overview

In the UK, all of the commercial nuclear power reactors use uranium as fuel. The isotope uranium-235 is necessary for sustaining the nuclear fission chain reaction, which generates the heat needed to power the electrical generators.

Over time, the amount of uranium-235 in the fuel decreases as it is gradually used up in the fission reactions and is converted to other fission product isotopes. This reduces the efficiency of the reactor.

To maintain power output, some of the used fuel is periodically removed from the reactor and replaced with fresh fuel. This spent fuel still contains some uranium-235 and also plutonium that was created as a consequence of the nuclear reactions.

The spent fuel can be reprocessed to recover the remaining uranium and the plutonium. These can then be used to manufacture new nuclear fuel.

Reprocessing is a complex process that is undertaken on an industrial scale at the Sellafield site in Cumbria. It involves dissolving the spent fuel and separating out the uranium and plutonium products from other elements that are not useful.

The process produces very highly radioactive wastes that contain most of the fission products. These are converted into a glass wasteform through a process called vitrification, and then stored until they can be finally disposed.

About reprocessing

Spent fuel from both Magnox and AGR reactors in the UK (and from some overseas reactors) is reprocessed at facilities in Sellafield. The processes used for managing both types of spent fuel are broadly similar, although there are some technical differences which are not detailed here.

Magnox fuel is a uranium metal. The use of reprocessing technology to manage Magnox spent fuel has been ongoing for over 50 years. Approximately 50,000 tonnes of Magnox spent fuel has been produced in this time. The Magnox reactors have now reached or are reaching the end of their operational lifetimes. When all have closed, no further spent fuel from Magnox facilities will be produced.

AGR and PWR fuel is uranium oxide (UO₂). A large proportion of the spent AGR fuel produced has already been reprocessed in the industrial scale thermal oxide reprocessing plant (THORP).

Decisions made recently mean that no spent fuel will be reprocessed in existing facilities after 2020. The spent fuel that is not reprocessed will need to be stored until the disposal route becomes available. Work is underway to develop a Geological Disposal Facility (GDF) for higher activity wastes and spent fuel requiring disposal.

Stages in spent fuel reprocessing

There are a number of stages involved in spent fuel reprocessing.

Decanning and shearing

The first step of reprocessing is the removal of the metal fuel cladding, to leave just the spent fuel material. In the case of Magnox fuel, the decanning produces Magnox swarf (irradiated magnesium non-oxidising cladding material) which is a waste.

The dismantling of the AGR and other fuels is more complex. The fuel assemblies first need to be disassembled to remove any stainless steel and graphite components. The AGR fuel rods are then sheared into pieces.

Acid dissolution

After decanning, the separated spent fuel is dissolved in nitric acid to produce a radioactive solution containing the uranium, plutonium and fission products that were contained in the spent fuel.

The nitric acid does not dissolve any remaining metallic components, so some insoluble solid items, such as the fuel cladding, and particulate fines are separated and treated as waste.



Image: Aerial image of Sellafield site where spent fuel reprocessing occurs

Uranium and plutonium extraction

The uranium and plutonium in solution needs to be extracted and separated from the remaining and unwanted fission products. This is done using a sequence of chemical extractions in a process known as PUREX (Plutonium Uranium Redox Extraction).

The extraction process takes advantage of the natural affinity of uranium and plutonium to associate with organic materials.

In the first step, the organic, oily liquids kerosene and tri-butyl phosphate (TBP) are added to the acidic solution, and intensively mixed. During mixing, the uranium and plutonium becomes concentrated in the organic liquid phase, and the fission products remain in the acidic solution.

When mixing stops, the organic liquid and the acidic solution naturally separate out from each other due to their different physical properties. Almost all of the fission products remain in the aqueous acidic phase which is drawn off as a separate liquid waste stream. This liquid waste (known as a raffinate) is highly radioactive.

A chemical reducing agent is then progressively added to the remaining organic solution which causes the plutonium and uranium to separate. Finally, the separated liquid uranium and plutonium product streams are solidified for safe storage.

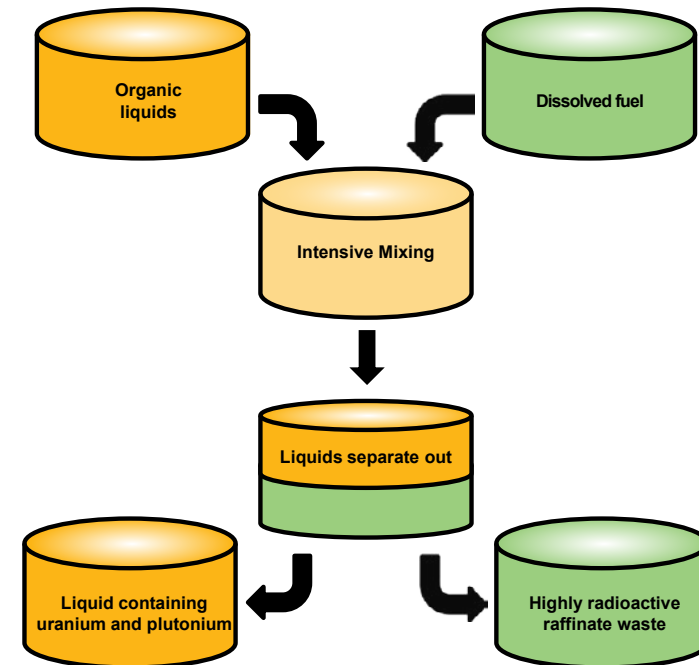


Image: Diagram illustrative the PUREX process. Source - European Nuclear Society

Vitrification of the liquid waste

The highly radioactive liquid waste (raffinate), which contains the fission products, has no further use and so is classified as a waste. This liquid is converted to a stable solid for safe storage, in a process called vitrification.

The liquid raffinate is first concentrated in an evaporator and then dried to granules in a furnace known as a calciner. The granules are mixed with borosilicate glass particles and melted in a metallic container.

In the molten state, the waste becomes intimately mixed with the borosilicate glass, and is then poured into a stainless steel container and left to cool and solidify. Once cooled, a stainless steel lid is welded on to the top of the container.

Borosilicate glass is used to solidify the raffinate because it is a corrosion resistant material suitable for final disposal in a geological repository. The resulting glass is robust and heat resistant.

The filled containers are stored on site at Sellafield until a Geological Disposal Facility (GDF) becomes available.

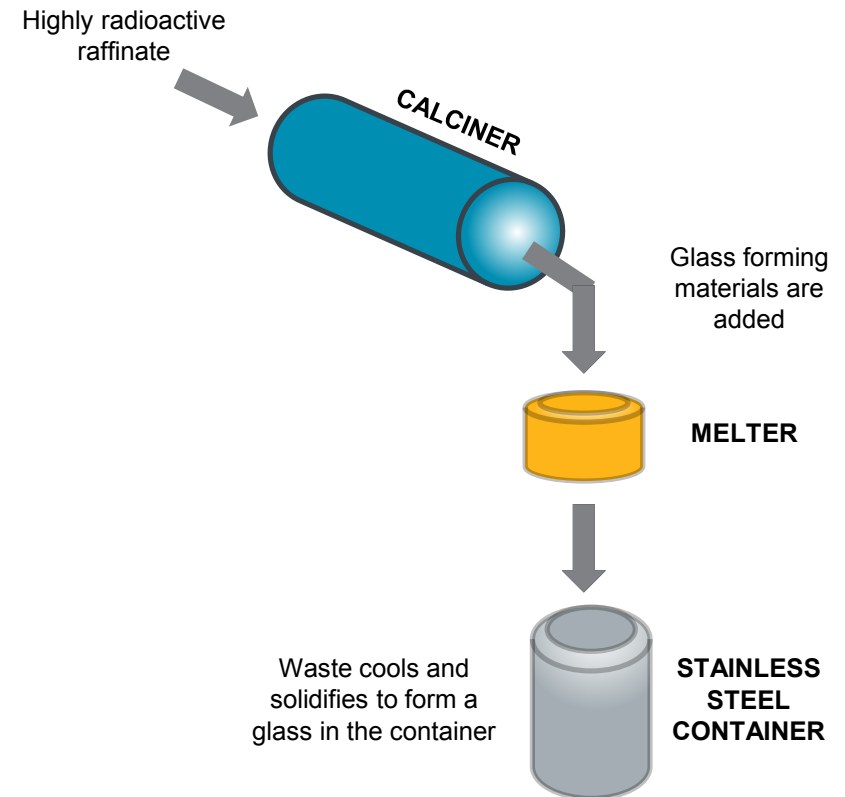


Image: The continuous vitrification process used to solidify the highly radioactive liquid wastes from reprocessing

Radioactive wastes produced during spent fuel reprocessing

Radioactive wastes are produced at each stage in spent fuel reprocessing.

At the earliest stage in the cooling ponds, corrosion of the fuel assemblies can cause the build up of sludge and metal items which require management. The treatment of cooling pond water also leads to contaminated ion exchange resins that are classed as ILW.

The metallic parts of the fuel assemblies are separated from the spent fuel itself during decanning and shearing. These metal parts are ILW.

When dissolved in acid, any remaining residues from the dissolution process will be wastes, such as sludges and remaining metallic components.

Highly radioactive liquid waste (raffinate) produced during spent fuel reprocessing is converted into a solid form in a process called vitrification. The vitrified waste contains all the fission products from the spent fuel and therefore contains most of the radioactivity.

The gases from vitrification facilities are treated using a series of scrubbers and absorbers before they can be safely discharged to the atmosphere.

Some operational LLW is also produced during spent fuel reprocessing, including redundant equipment, used tools and protective clothing.

Image: Stainless steel containers for the storage of vitrified waste.

