Reprocessing

Currently, all spent fuel from UK AGR & Magnox power stations is taken to the British Nuclear Fuels plant at Sellafield for 'reprocessing'. This process extracts any unused uranium and the plutonium formed during fission in the reactor.

Using nuclear fuel

The chain reaction which generates heat in a reactor is known as fission. During this process a proportion of the uranium atoms are transformed into other elements, either by fission or by absorbing free neutrons. These elements are known as fission products and actinides, and build up until the fuel is no longer efficient to use. These by-products are extracted during reprocessing.

Composition of Spent Fuel

Fuel is considered spent after about five years, when it is no longer capable of efficient fission due to the partial loss of fissile material and the build up of impurities such as fission products and actinides. In some respects the word 'spent' is inappropriate, as there is still a significant uranium 235 content.

Since the fuel continues to change once removed from the reactor, due to radioactive decay it is stored for a further four years before reprocessing. This reduces the amount of fission products which have to be dealt with by waste processing.

'Head End' Operations

The actions carried out before the separation process begins are called the 'head end' operations. These include receiving the fuel at the head end plant and reducing the fuel elements to aid the processes to follow. This involves dismantling the graphite sleeves, grids and braces which held the fuel at the reactor and during transit.

Once free of the supporting structure, the elements are cut up and dissolved in hot nitric acid. All of these radioactive ‘dissolver off-gases’, except krypton and xenon which are chemically inert, are trapped or recycled for re-use. Any further particles of fuel cladding or undissolved fission products are removed by filtering them out in a centrifuge.

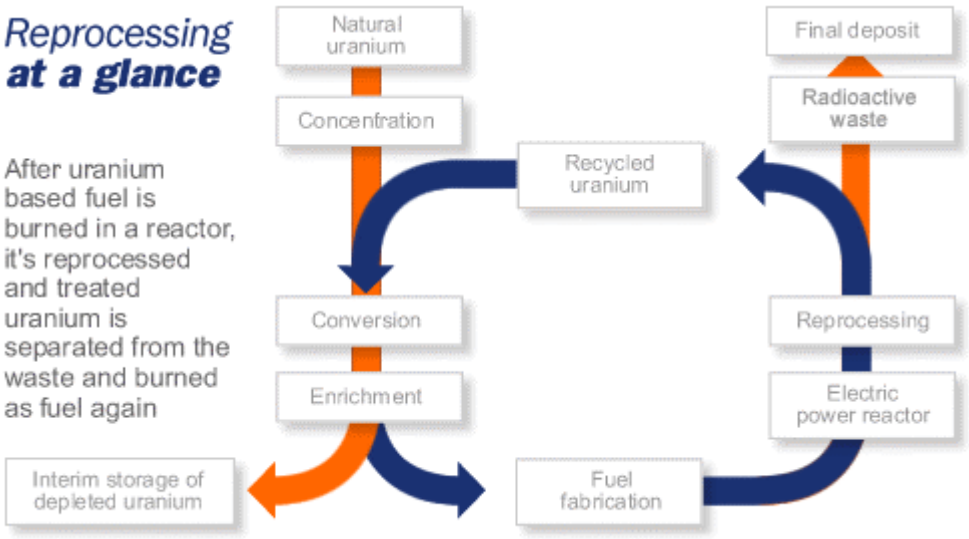
The Separation Process

Although the actual chemistry of the separation process is very complex, the principle involved – solvent extraction – is very simple. The solvent is a mixture of tri-n-butyl phosphate and odourless kerosene (known as TBP/OK), which does not mix with the liquor containing the dissolved spent fuel and fission products. It does, however, dissolve uranium and plutonium – making it easy to separate them out.

The uranium and plutonium are separated by the same technique by converting them into uranium nitrate and plutonium nitrate by dissolving them in nitric acid.

These are then subjected to even simpler chemical reactions which involve heating the uranium nitrate solution and precipitating the plutonium as a solid powder. The final products are oxides: UO_2 in the case of uranium and PuO_2 in the case of plutonium, both in the form of powders.

The separation process is able to extract uranium and plutonium products of high purity. One reason for this is its efficiency at removing unwanted fission products – typically greater than 99.9%.



High Level Wastes

The residue products from the separation process are intensely radioactive High Level Waste or HLW. Its volume is reduced by evaporation before being stored in specially designed cooling tanks at Sellafield, which can remove the heat generated by ongoing radioactive decay.

The HLW produced from reprocessing one tonne of fuel typically contains about 25g of uranium, 5g of plutonium, 180g of americium and 11g of curium. The radioactivity content from the fission products is around about 17,000 terabecquerels and it generates about 1.8 kilowatts of heat (equivalent to two small electric fires).

Intermediate Level Waste

Reprocessing also gives rise to Intermediate Level Waste or ILW. These waste products do not generate significant heat and are much lower in radioactivity, by total and per unit volume, than HLW. In the case of AGR fuel, this waste comes from fuel cladding, graphite, fuel element structural components, the conversion of nitrates to oxides, the dissolver off-gas filters and materials used in the treatment of liquid before discharge.

Low Level Waste

In addition, reprocessing generates Low Level Waste or LLW. Gases and liquids are discharged into the environment under strict authorisations issued by the relevant government regulatory bodies. Solid LLW, consisting mainly of wrapping and cleaning materials and protective clothing, is also subject to authorisation and sent for disposal to the licensed LLW repository at Drigg in Cumbria.