

Nuclear Power – including Manufacturing Nuclear Fuel

This file was generated from one produced by BNFL in the early 2000s and gives a good summary of the reactor types in use in UK as well as fuel fabrication

Generating electricity from nuclear fuel



Magnox Fuel Elements being inspected

- Fuel for nuclear reactors (power stations) in the UK and overseas is made at our Springfields site, near Preston, in the UK, our Columbia Plant in the USA and our Vasteras Plant in Sweden. We also make Mixed Oxide (MOX) fuel (a mixture of uranium and plutonium) at our Sellafield site in West Cumbria. We have the ability to make fuel for all major designs of nuclear reactors.

- Fuel for nuclear reactors is made from uranium ore or a mixture of uranium and plutonium that is recycled from used nuclear fuel. The fuel is used in nuclear reactors to generate electricity. In 1999, on average, around 16% of the world's electricity supply was generated by nuclear power.

- Nuclear energy makes a significant contribution towards reducing greenhouse gas emissions. Globally, electricity supplied by nuclear power stations avoids the emission of around 2 billion tonnes of carbon dioxide annually.

- The raw material used to make nuclear fuel is uranium. Rock is taken from mainly open-cast mines all over the world. The ore that is taken contains around 1.5% uranium. To concentrate the uranium content, the ore is ground, treated and purified using chemical and physical processes. This results in a solid uranium ore concentrate which contains around 80% uranium.

- When the uranium ore arrives at our fuel manufacturing plants from mines around the world, it passes through a number of chemical processes that change it to uranium tetrafluoride (UF₄). It then follows different processes depending on the type of fuel we are making.

Light Water Reactors

- Light Water Reactors (LWRs) are used throughout the world. Pressurised Water Reactors are a type of Light Water Reactor. They are the most modern type of nuclear reactor to be used in the UK. Sizewell B, in Suffolk, is the UK's first type of this reactor, which is operated by British Energy.

- The fuel for Light Water Reactors is a type of oxide fuel. The fuel elements from these reactors are made up of uranium dioxide fuel pellets stacked inside zirconium alloy fuel tubes. We then group these tubes together to form a fuel assembly. For example, a Sizewell B fuel assembly is made up of 264 zirconium alloy tubes, each containing about 300 pellets.

How do we make Light Water Reactor fuel?

- We make this type of fuel by first changing the UF₄ to uranium hexafluoride (UF₆). We then send it to be enriched.

- The isotope found in uranium which most readily splits (fission) in a nuclear reactor is U-235, but only 0.7% of naturally-occurring uranium is U-235. By enriching Uranium we can increase the U-235 content to around 3%. Enriched fuel can reach much higher temperatures in a reactor and is more efficient in generating electricity.

- Uranium contains two isotopes (atoms) - uranium 235 (U-235) and uranium 238 (U-238). Both isotopes have identical chemical properties so the only way they can be separated is by their weight. U-238 is heavier than U-235.

- The method we use to separate them is the 'gas centrifuge process' which involves spinning the uranium as a gas (uranium hexafluoride) in a 'centrifuge'. As the centrifuge spins at a very high speed, the heavier U-238 moves to the outside and the U-235 stays near the middle. This separates the isotopes. This process is repeated in a large number of centrifuge machines to produce the right quality of enrichment needed.

- After UF₆ is enriched, it is converted to uranium dioxide (UO₂) powder in a kiln using process called the 'Integrated Dry Route' (IDR).

- The Integrated Dry Route is a unique process we developed which changes UF₆ into a ceramic grade uranium dioxide powder, in a single stage. We do this by mixing it with steam and hydrogen in a kiln. IDR is the most environmentally friendly conversion technique now available.

- We then process the UO₂ powder again, press it, heat it on a furnace and grind it to produce the fuel pellets. The fuel pellets are then loaded inside zirconium alloy tubes, which are about three metres long. We then pressurise and seal them and fit them inside a pre-assembled framework. We then inspect the assembly before we send it to the

reactor.

Advanced Gas-cooled Reactors

- The Advanced Gas-cooled Reactor (AGR) is unique to the UK and is the second type of nuclear reactor to be run in the UK. In all, 15 AGR reactors have been built and run in the UK since 1963. (All of the UK's AGR reactors are operated by a company called British Energy.)
- AGR fuel is also a type of oxide fuel and is made from uranium dioxide powder. An AGR fuel element is made up of uranium oxide pellets stacked inside stainless steel tubes. These tubes are then grouped together in a graphite 'sleeve' to form a 'fuel assembly'. An AGR assembly is made up of 36 steel tubes, each containing 64 pellets.

How do we make AGR fuel?

- AGR fuel uses the same manufacturing process as for LWR fuel. The fuel pellets (which are about the size of a thimble) are stacked inside a fuel tube.
- Once the tubes are sealed and pressurised, they are put together in the graphite 'sleeve' to form the AGR fuel assembly. After it is thoroughly inspected to check the quality of the fuel, we pack it ready to send to an AGR reactor.

Magnox reactors

- The name Magnox comes from the magnesium alloy casing which surrounds the fuel rod. Magnox reactors are the UK's pioneering nuclear reactors and in all, 26 Magnox reactors have been built and run solely in the UK since 1956. Calder Hall at our Sellafield site was the world's first industrial-scale nuclear reactor.
- Our Magnox Generation Business Group now runs all of the UK's 18 Magnox reactors still working today.
- We make fuel for all of these reactors. A Magnox fuel element is made up of a uranium metal fuel rod which has a magnesium alloy can around it.

How do we make Magnox fuel?

- We first change the uranium tetrafluoride (UF₄) to uranium metal by mixing it with magnesium metal. When we heat the UF₄ in a furnace to over 600°C, the UF₄ and magnesium metal react together. The uranium melts and flows into the bottom of the furnace. After cooling, we re-melt the block of uranium metal and cast it into rods.
- We then machine the uranium rods to size and length (a typical rod is about one metre long). We then put the uranium rods into the magnesium alloy cans and seal them. Very strict testing and quality assurance checks make sure that the fuel is made to the highest standard and is ready to be sent to a Magnox reactor.

Mixed Oxide (MOX) fuel

- We also make Mixed Oxide (MOX) fuel at Sellafield. MOX fuel is made up of plutonium (around 5%) and uranium (around 95%) both of which we can recover from reprocessing. This type of fuel manufacture produces fuel which can be burned in conventional nuclear reactors. About 400 tonnes of MOX fuel has been safely loaded into reactors around the world since 1963. More than 30 reactors in Europe are licensed to use MOX fuel and many reactors in the world plan to use this fuel, particularly in Japan.
- Using MOX fuel helps us to manage the plutonium stockpile which would otherwise grow if we only used conventional uranium fuel in reactors. Typical MOX fuel might contain between about 50 and 70 kilograms of plutonium for each tonne of fuel entering the reactor. After four years of generating electricity, the amount of plutonium in the fuel would have been reduced by about 18 kilograms in each tonne of fuel.
- We used a two-stage approach for developing our thermal MOX fuel business.
- The first stage was building a small-scale facility at our Sellafield site. This began working in 1993 and has produced fuel for Light Water Reactors.
- We announced the second stage in 1993, which was to build the Sellafield MOX Plant. This is now being made ready for use and is connected to our Thermal Oxide Reprocessing Plant (Thorp) at Sellafield. We use advanced technology, gained from our earlier work on developing Fast Reactor MOX fuel and from experience gained from our fuel manufacturing plants at Springfields and Sellafield.

How do we make MOX fuel? MOX powder

- We mix plutonium dioxide (PuO₂) powder and uranium dioxide (UO₂) powder to make MOX powder.
- We have developed new technology which has improved the way we make MOX fuel. This unique process is called the 'Short Binderless Route' and is used to make MOX powder. We take special strict measures to protect our workers from the plutonium.
- In the Short Binderless Route, we grind the powder and mix it with other agents and tumble it to make granules. This means that it takes less time to produce MOX powder and reduces the amount of loose powder left inside the

equipment.

MOX pellets

- We feed granules of MOX powder into pellet presses. The presses produce tiny cylindrical MOX pellets. We then load these into 'boats' and transfer them to a sintering furnace (in a sintering furnace the pellets are hardened by heating). Once the pellets are sintered they are unloaded from the boats and transferred using our 'soft handling process' to a machine, where they are ground down to specific measurements. Next we inspect them using special equipment. We then load the pellets into trays and transfer them into storage.

MOX rods

- We transfer the trays containing the MOX pellets to a stack preparation area. Here we load them into fuel tubes and seal them to form a completed fuel rod. After the rods are inspected, they are then loaded into magazines in the same way they will appear in the final fuel assembly.

MOX fuel assemblies

- To make fuel assemblies, we automatically transfer fuel rods from the pre-loaded fuel magazines into a fuel 'skeleton' (framework). We attach top and bottom end fittings and carry out checks before we move the assembly to a storage area.

Intermediate products

- As well as making nuclear fuel, we also produce intermediate uranium products such as uranium hexafluoride, enriched uranium dioxide powder, granules and pellets.

How do we make uranium hexafluoride (Hex)?

- We produce natural uranium hexafluoride (UF₆) at our Springfields site in a new plant which began running in 1993.
- We react the UF₄ that has been processed from the uranium ore with fluorine gas to produce a uranium hexafluoride (UF₆) gas. We then heat the UF₆ to about 95°C and at this temperature, under pressure, the UF₆ turns into a liquid. We then run the liquid UF₆ into transport cylinders using remote handling equipment. We then transport the UF₆ to enrichment organisations throughout the world. These organisations can then change the enriched UF₆ into oxide fuels for AGR and LWR reactors.

How do we make uranium dioxide powder, granules and pellets?

- UF₆ is turned into a gas which we then feed into the IDR kiln. Here the gas is changed into UO₂ using the IDR process. The UO₂ powder is then sifted and blended and either granulated and pelleted to be produced into nuclear fuel or stored before it is exported to customers throughout the world.

Recycling nuclear fuel

- When the fuel rods in a nuclear reactor become less efficient we remove them and replace them with new fuel. We carry out a chemical operation called reprocessing which separates out around 96% uranium and 1% plutonium from the 3% waste in the fuel.
- Reprocessing used nuclear fuel means that we can recycle the uranium and plutonium to make new fuel. We carry out reprocessing at our Thermal Oxide Reprocessing Plant (Thorp) and Magnox Reprocessing Plant at Sellafield.
- Recycling uranium means that we do not have to mine as much new uranium. For example, we have already recycled 15,000 tonnes of uranium from used nuclear fuel from the UK's Magnox nuclear power stations and made it into new fuel for the UK's Advanced Gas-cooled Reactors. This fuel is now generating electricity.
- By reducing the amount of fresh uranium that is mined, we are lowering the overall radiation dose which the world population receives. And we are also producing around 25% less waste than if we dispose of the fuel after using it only once and replacing it with new uranium.
- Recycling the uranium and plutonium contained within one tonne of used nuclear fuel provides as much energy as at least 100,000 barrels of oil. By recycling nuclear fuel we are making sure that this valuable energy source does not go to waste.

Summary

- We can make fuel for nuclear power stations from uranium and plutonium.
- Around a quarter of electricity generated in the UK in 1999 came from nuclear power. The world's nuclear electricity supply avoids around 2 billion tonnes of CO₂ being released into the air annually.
- We make fuel for LWR, Magnox and AGR reactors as well as intermediate products for our overseas customers.

- Our Springfield site was the first place in the world to make nuclear fuel and to date has produced over eight million fuel elements and pins.