ENERGY

UK PLUTONIUM THE WAY FORWARD

Institution of MECHANICAL ENGINEERS

The UK is currently storing 112 tonnes of civil held plutonium, which includes about 28 tonnes of material belonging to overseas customers. Plutonium is long-lived, toxic and radioactive. It is a material that can be processed for use with nuclear weapons and for these reasons must be handled safely and securely. The future management of this stockpile, largely the by-product of reprocessing spent fuel from UK nuclear power plants, is more complex than was originally anticipated.

The Government is reassessing future options[1] for plutonium. Given that the volume has almost doubled since 1997, it is important that decisions on a way forward are made urgently. Since plutonium is fissionable, the Government has previously recognised that it provides a potential fuel source for nuclear reactors. However, officially it is not classified as a waste or an asset, but treated as a zero-value asset[1]. Current policy may be missing commercial opportunities and enhanced energy security.

The Institution of Mechanical Engineers recognises that not all UK plutonium is equal in terms of its isotopic mix or its potential for chemical contamination, and therefore recommends that:

1. Government adopts a portfolio of options to address these problematic stocks, rather than seeking a single solution. To this end the Nuclear Decommissioning Authority (NDA) needs to categorise UK plutonium stock and identify the quantities associated with each, so that the most appropriate routes forward can be chosen and best aligned to the condition of the materials.
2. Plutonium of sufficiently high grade should be considered for manufacture into mixed oxide (MOX) fuel in a plant similar to the approach successfully adopted in France, which is simpler than previously used in the UK. Lower-grade material should be identified for recycling by use in a fast reactor. This would extract useful energy from the fuel and reduce the volume and toxicity of long-term waste, as well as make a small but useful contribution to UK energy security. Investment is needed now by the NDA to demonstrate the potential range of grades that could be used as fast reactor fuel. This, along with fast reactor assessment and development, could prove to be the most economic option.
3. Plutonium of poor quality should be prepared for disposal in a Geological Disposal Facility (GDF) via a process that could be expanded, if for any reason the fast reactor option failed to materialise.

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THE UK PLUTONIUM STOCKPILE

The plutonium stored in the UK is derived largely from nuclear fuel reprocessing activities that have been ongoing at Sellafield since the 1950s, with the bulk of the UK's material owned by the NDA and a smaller amount by EDF (previously British Energy)[1].

In the 1950s, plutonium separation was carried out in support of military requirements for defence purposes. In the 1960s, when it was widely believed that fossil fuels would be imminently exhausted, plutonium was considered to have a future as fuel for the fast reactors, then under development. The amount of accumulated plutonium was therefore increased by reprocessing spent fuel at Sellafield. In 1994 the UK Government abandoned almost all research into fast reactors as, at that time, it was thought that the technology would not be commercially viable. The legacy of the UK's accumulated stockpile of plutonium then came into question. This has not been resolved to date despite further plutonium stock accumulations (plutonium from the Sellafield reprocessing plants is stored in a number of forms, but mainly as plutonium dioxide powder in stainless-steel cans).

The UK has previously sought to develop MOX fuel capability as a route to utilising plutonium from reprocessing. In MOX fuel fabrication, plutonium is mixed with uranium dioxide powder. This process was undertaken at the Sellafield MOX plant. However, from an engineering perspective the scope of that facility was too ambitious and its throughputs too low. In 2011 the decision was taken to close this facility. The UK however retains much good MOX experience and a deep understanding of the technical requirements.

Today, none of the present generation of UK nuclear reactors is licensed to use MOX fuel, although worldwide there is both increasing production and use of MOX fuel[2]. Although Sizewell B and future new-build nuclear units are technically capable of running with MOX fuels, there is unlikely to be a demand for such fuel in the UK until 2030. From a security point of view, it would however be better to convert the appropriate part of the stockpile as soon as possible.

A simpler and more cost-effective MOX plant, such as that developed by AREVA in France, could deal with fresh, uncontaminated plutonium. However, to process all the variations of material in the UK stockpile would be, as in the previous Sellafield plant case, over ambitious. Given that simpler MOX technology is well understood, pursuing such an option for some of the stockpile would not demand significant investment in developing the technology. It should however be recognised that implementation of a plant in the UK similar to the French design may encounter unforseen time and resource burdens, as experienced in the USA[3,4].

OPTIONS UNDER CONSIDERATION

In February 2011 the Government undertook a consultation on the management of the UK's plutonium stocks[1] and proposed three possible options for dealing with this material:

Government Option 1: Continued long-term storage (prior to disposal)

This option is to continue to store the plutonium above ground in its current form for the near term, which is estimated to be currently costing the UK taxpayer about £80 million per year[5]. This is an approach that would leave the UK with escalating costs for security, radiation protection and the ultimate handling of the stock, as well as proliferation sensitivities for the future. Such a proposal can be only an interim measure, as storage at Sellafield is limited to 2120.

Government Option 2: Prompt immobilisation and disposal as soon as practicable

The plutonium stockpile could be immobilised so as to be 'proliferation-resistant' in several ways: through vitrification, ceramics or using cement based grouts. Using existing technologies, the only way to store the plutonium waste in the Government's proposed GDF (Geological Disposal Facility) would be to deposit small concentrations in cement. To deposit all the plutonium in this way would require around 200,000 tonnes of cemented waste. The lifetime cost to the UK taxpayer for this option has been estimated to be up to £8 billion in 2010 prices. The process of combination and vitrification is not yet technically proven and would still require long-term storage underground at an estimated cost of £5–7 billion (until technically proven, this figure is no more than a rough estimate). Developing a ceramic either through low-specification MOX, or by using the Hot Isostatic Press process, is also unproven in such a volume, although the NDA is assessing this option through studies at the National Nuclear Laboratory.

Government Option 3: Re-use as MOX fuel followed by disposal

Plutonium can be combined with uranium and made into a MOX fuel. After use in conventional nuclear reactors, MOX leaves spent fuel in a state where it can be prepared for permanent disposal. The material is radioactive, which further reduces the risk of theft or diversion for weapons purposes. The disposal of spent MOX fuel would require sizeable storage in the GDF, but much less than if the plutonium was stored as cemented waste. The potential cost of a MOX manufacturing facility is conservatively estimated at £3 billion for construction and a further £2 billion to operate, but the cost of the enlarged GDF to accommodate the spent fuel could also cost a further £2 billion, leading to an overall bill to the taxpayer of about £7 billion.

The third option, currently being promoted most vigorously by Government, is through the construction of a MOX plant at Sellafield with the produced MOX fuel sold to power plants around the world. If sold to overseas countries, the plutonium could effectively be exported. This is highly contentious and would need to recognise the Non-Proliferation Treaty. While it is unlikely that 'unfriendly powers' could extract the plutonium from MOX fuel, as it would require a complex reprocessing plant, this option still has serious proliferation issues.

THE FAST REACTOR OPTION

Despite the potential for using spent fuel in a fast reactor, and it being a viable route for plutonium of intermediate quality, this option was not considered by the Government in the 2011 consultation. Two paths to UK use of a sodium cooled fast reactor are visible: one is based on well-established US technology and the other is a French led project, similar to UK technology developed at Dounreay prior to 1994.

Since 1981, GE Hitachi has been developing the 'Power Reactor Innovative Small Modular' (PRISM) technology in the USA[6]. This sodium-cooled fast reactor has the ability to burn spent fuel from conventional reactors, including a significant quantity of the plutonium in UK storage. Material from the stockpile would be used to make metal fuel containing plutonium, uranium and zirconium in a specialised fuel manufacturing facility (because the facility is best located near to the spent fuel store, and close to the PRISM reactor, it has been called a nuclear 'recycling' facility). This would then be used in PRISM's reactors to generate electricity. When the plutonium and other long-lived isotopes are burnt up, the used fuel would be taken out of PRISM for final reprocessing, or it could be stored in the Government's proposed GDF when it becomes available. If reprocessed, while some nuclear waste would be produced, it would be much smaller in volume and have a considerably shorter half-life than the plutonium in its current form. Some uranium could be extracted from the waste to make fuel for conventional reactors. Using a fast reactor in this way, combined with conventional reactors, maximum use can be made of the mined uranium and high-level waste can be minimised.

The PRISM approach is attractive not only technically but also because of its innovative business model, in which revenues come from electricity sales and a plutonium disposition fee levied only on results. As a first-of-a-kind deployment of US technology outside US borders, PRISM is in principle eligible for Export Credit Guarantees, lowering economic risk for the UK. The Institution of Mechanical Engineers estimates that the capital costs to develop and build a PRISM facility would be about £5 billion. The net operating costs would generate about £20 billion over a 60-year life, giving a potential net income to the NDA of about £15 billion.

Another route to fast reactor technology would be the French-led 'Astrid' (Advanced Sodium Technological Reactor for Industrial Demonstration) proposal[7]. In contrast to PRISM, which is a small, modular concept, this technology is a large, loop reactor plant being developed as a prototype through a project that is open to international participation. It is not characterised by the entrepreneurial approach of the PRISM project and is likely to be delivered on a much longer timeframe with a less-commercial focus.

If fuel manufacturing technology for a fast reactor proves to be successful, then it has the potential to deal with a much larger proportion of the stockpile but it may not be cost-effective to process the most contaminated material. US metal fuel manufacture has been demonstrated extensively resulting in acceptable plutonium characteristics being known and these are quite broad[8].

The development investment should therefore be on demonstrating that fast reactor fuel could be manufactured from the more difficult element of the UK stockpile and developing the maturity of the fast reactor technology so that it becomes ready for deployment before further elements of the stockpile become too difficult to deal with.

As an option for dealing with a proportion of UK-separated plutonium, sodium-cooled fast reactor technology (eg PRISM or Astrid) deserves serious consideration by government.

CONCLUSION

The Institution of Mechanical Engineers urges the NDA to re-assess UK plutonium stocks with a view to publishing a forward-looking assessment for management of the stockpile. If all three grades of material are present in quantities that are sufficient, then all three of the following routes should be advanced without delay:

- High-grade plutonium should be considered for manufacture into MOX fuel.
- Lower-grade plutonium should be identified for potential recycling in a fast reactor. The UK Government, through the NDA, should fund modest assessment and development of the available fast reactor technologies. At this stage future licensing decisions cannot be prejudged, but the sodium-cooled fast reactor route is sufficiently attractive to merit significant immediate UK support.
- Poor-quality material should be earmarked for safe disposal in the proposed GDF, with investment required to develop appropriate storage solutions.

Finally, there may be some plutonium material in the stockpile which is in a condition that makes a sensible rapid decision on next steps difficult to reach. Any such plutonium should be retained in safe storage pending later policy proposals. The existence of any plutonium in this category should not in any way delay forward progress on the other routes.

RECOMMENDATIONS

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