Why MOX fuels mean trouble

In this section, I will try to explain the problems and risks associated with MOX use in LWRs. It will become clear why it's only logical that the costs of MOX fuel elements are much higher than those of ordinary UOX fuel, and why utilities are not exactly enthusiastic about MOX use. In fact, the introduction of MOX fuel as the plutonium industry's "solution" for the civil plutonium glut gave rise to a debate within the nuclear sector as well. A debate which had been postponed for decades, until the reprocessing industry (in particular market leader Cogema) put the return of the plutonium to its owners on the agenda -- a very logical step, from their point of view.

For the first time since the beginning of the nuclear era, internal differences of opinion more or less caught the public eye. We should be aware that this is quite a radical break with the dogmatic consensus and the closeness the nuclear society always used to display. In Germany, this came with a change of law and the cancellation of several post-baseload reprocessing contracts, and in Belgium it was decided that no future contracts would be signed while the use of MOX was to be strictly limited to the plutonium recovered under baseload contracts. These are of course hopeful signs.

Making MOX fuel

According to the ICRP recommendations for public exposure to radiation, a plutonium processing plant may theoretically only release about 1 mg of plutonium into the environment. For an ordinary uranium fuel plant (not using *reprocessed* uranium!), the equivalent would be 2 kg uranium. While the latter seems reasonably achievable, the former would imply a two millionfold stricter safety regime in a MOX plant compared to an UOX plant. You don't need lengthy reports to understand that this is impossible.

When it reaches full production capacity (if ever), the French MELOX plant will process some 8 metric tons of plutonium annually. The plutonium oxyde powder must be mixed with uranium oxyde and then further processed (see the section about fuel fabrication). So, according to ICRP standards, only some 0.001% of this may be released. While the automated reprocessing plants show plutonium losses in the range of 0.5%, the different nature of the processes involving plutonium powder in MOX plants evidently predicts a higher process loss there. Suppose this would be about 1% (which is probably very optimistic). That would mean that only 1/1000 of the "lost" plutonium may theoretically end up in the environment. This can be nothing else than sheer fiction. In other words, **MOX plants are clearly much less safe for workers and for public health.**

Using MOX fuel

LWRs are designed for the use of enriched uranium fuel. MOX fuel behaviour should therefore be as equal to UOX fuel behaviour as possible. The reason why the fissile plutonium content in MOX is closely linked to the enrichment of the UOX lies in the fact that a nuclear reactor with local differences in power (essentially: in neutron flux) is likely to become unstable.

Nuclear reactors can be controlled by a *mechanical* control rod system for a very subtle reason. In a chain reaction there are only fractions of seconds between one fission event and the next one(s), initiated by the former. However, since a small fraction of the neutrons needed to keep the chain going are generated with a delay in the range of ten seconds the necessary response time of the control system is in the range of 0.1 seconds, thus making mechanical control possible in the first place. For plutonium the delayed neutron fraction is almost a factor of three smaller than for uranium, increasing demands on the control system. Furthermore, the reactivity of the fissile plutonium isotopes has a positive temperature coefficient, meaning that an increase in temperature (caused by "too much" fission) tends to increase the fission rate even further. A divergent chain reaction would so accelerate itself. With uranium fuel, the opposite is true.

Additionally, due to the higher capture to fission ratio, the neutron flux in a MOX element will be smaller. This means that **while control rods should ideally have a better response when using MOX, their efficiency will be lower instead.** It is clear that this decreases safety margins and this explains why the portion of MOX elements in an LWR is limited by the number of control rods. Since MOX use is only temporary for many utilities, an upgrade of the control system will be too expensive to be worth while. They already have to put up with a more expensive, less efficient fuel and additional costs because the reactor must be shut down when demands are too low instead of operating on low power in such periods.

Not only will an incident be more likely to occur, it would also be more likely to have serious consequences. This is due to the presence of much more plutonium in the fuel and, after a certain period of usage, of more other transuranics. In terms of radiotoxity there isn't much difference really between plutonium and, for example, neptunium or curium. If an accident like a fire would occur in an LWR with MOX resulting in a dust cloud, the contamination of the surrounding land would be more severe and longer lasting than in the case of an equivalent incident in an LWR with only UOX. There would be a much higher risk of people becoming sick because of inhalation of such radioactive particles.

Managing spent MOX fuel

Apart from the higher plutonium content, the levels of other transuranics such as americium and curium in spent MOX fuel are logically higher than in UOX fuel with a corresponding burn-up (factors 10-100). This means that the activity and heat generation will be higher. **Spent MOX fuels are simply "hotter", which decreases the safety of storage, from the pond on site to interim storage to final disposal. The residual long-term activity will be higher too.**

It is not expected to become the general trend, but if the choice is made to reprocess the spent MOX once more (the current "recycling" limit!) this has safety consequences as well. Notably, **the amount of non-soluble fission products is higher in spent MOX fuel** which makes the dissolution stage more complicated and vulnerable for clogging. The Windscale explosion in 1973 showed what the results of that may be. Because of the much higher plutonium content, one also has to be **extra cautious not to get near critical mass densities** in any part of the complex. Since the geometrical properties of a given reprocessing head-end will remain the same, it may be necessary to dilute the dissolved fuel more, which would decrease the throughput. **It is very conceivable that MOX reprocessing will be more expensive than UOX reprocessing.** Furthermore, since the quality of twice-used plutonium is inferiour (not to mention the higher radiation due to Pu-238) it has to be mixed with "fresh" plutonium. Currently, a mixture of only 1:10 seems to be good enough to re-use the plutonium from the spent MOX.

The back-end costs of thermal MOX will therefore be higher than for UOX anyhow, and if it is reprocessed the costs will only rise more. You may replace the word "costs" by "risks" to get the second, very familiar, conclusion. **More and worse waste, more costs, more risks, that is the vicious circle of nuclear fuel "recycling".**