Spent fuel handling and interim storage

On-site storage

Figure 1: Spent fuel removal

After the reactor is shut down the spent fuel is removed from the reactor core and placed in a storage pool. Usually, about 1/3 or 1/4 of the core is replaced with fresh fuel elements each year. This is quite a task, because the whole reactor core arrangement needs to be altered. The oldest fuel elements (containing the least fissile material) should always be placed at the center of the core where the total neutron flux is at its maximum, while fresh elements are to be placed outwards (and normally they don't contain control rods).

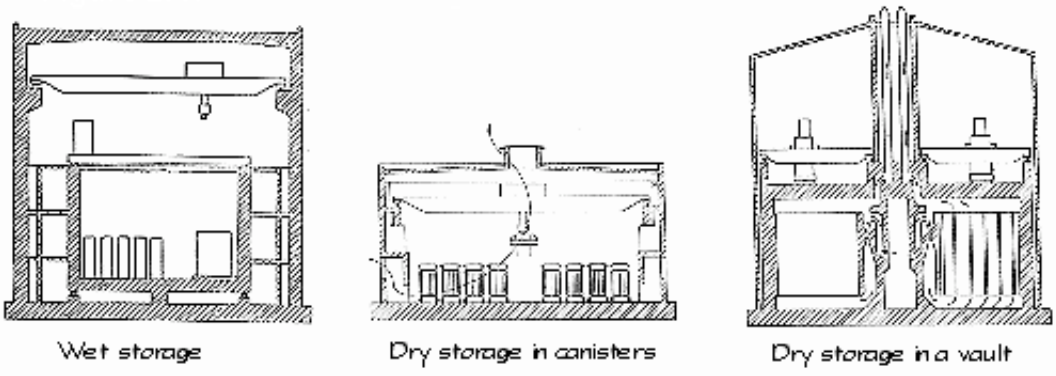
Everything is done under water using remote handling techniques. This is because the heat generation and radiation of the spent fuel is very high and the water serves both as a cooling medium and as a radiation shield. In the picture on the left, you can see how a spent fuel element is being moved from the reactor vessel space to the storage pool to be placed in a storage rack. You can also see a small storage rack for used control rods. This is how the fuel elements are stored **on-site** for at least a year.

Interim storage

Whether the spent fuel will be reprocessed or not, the next thing will always be another storage period in another storage pool. This can in principle be on-site as well, but in the reprocessing case the fuel is sent abroad for interim storage in La Hague or Sellafield, and in other cases, for states with more than one reactor it usually makes sense to have one central storage facility. Because LWR fuel element designs have proved to be able to withstand corrosion for up to thirty years so far, this period may even last a few decades. After this, in the reprocessing case, the fuel elements will be dismantled and the fuel dissolved (the tubes and stuff are also high level waste).

If the choice is made not to reprocess or to wait longer before deciding, the elements will need to be re-packed, usually in steel vessels (in Sweden they use copper). For prolonged interim storage one has several options: once again **wet** storage, like in Sweden, or **dry** storage which uses air cooling by natural convection. The latter can be either in separate storage canisters similar to transportation canisters, which is attractive for countries that have not yet made up their minds about their next move and for prolonged on-site storage, or in a vault, which is also used to store the glass blocks resulting from reprocessing by the French and -- not entirely surprising -- most of their client countries came up with similar designs. The vault method can be used for storing glass blocks as well as entirely packed fuel elements prior to final disposal. The method seems quite reliable on paper, although to me the Swedish solution using a big underground storage pool for fuel elements probably looks best. However, this also looks like the most expensive choice and the situation in Sweden is a little different from most others, since the Swedish cancelled their reprocessing contracts long ago and therefore only store spent fuel for a relatively short time (40 years). Storage in a vault is planned to last for 50 to 100 years and eventually, this might even be prolonged.

Figure 2: HLW interim storage methods



In Germany, prolonged interim storage is performed in separate CASTOR containers (also used for transportation) and in Gorleben, they also store reprocessing waste, and medium and low level waste. In the US, on site interim storage in separate canisters is generally becoming more common. This has a lot to do with licensing procedures for off-site storage, since in the US the relationships between federal and local government and electricity companies are historically of a different nature than European habits, both having their pros and cons. Also, this is probably the cheapest path for US utilities, because the public's attitude towards final geological disposal is very negative and there seems to be a slow drive towards fewer but larger sites for prolonged interim or final disposal of waste from an entire state or so. Even reprocessing is being considered again now and then. If you don't know what to do with them and when, the fuel elements are best packed rather then kept in a pool. Pools become full, of course, and due to corrosion the fuel rods can eventually start "leaking". Usually, the fuel elements are placed in compact storage racks. A loss-of-coolant situation will cause criticality hazards, which in the worst case may even lead to a melt-down. European choices are largely determined by their choice for reprocessing, which means among other things that there are distinct types of waste to be stored. For final disposal requirements and designs, the differences largely disappear.

The Swedish CLAB interim storage facility of SKB shows an example of well-developed interim storage without taking the reprocessing path. Sweden is also ahead of the OECD on final disposal. This link will take you to SKB's WWW site. Do have a look at their method of spent fuel handling. You can get there by choosing the English version, then the storage pictogram, then the item "This is how the waste is stored today", and then "CLAB". I am sorry about the fuss, but a direct link is not accepted by the script they run. If you view their site from within this frame, you can easily resume reading by using the "back" button on the left.

Figure 1 is a scan from a public brochure of EPZ, the owner of the Dutch Borssele PWR, and figure 2 has been scanned from an article on behalf of the Dutch research institute KEMA.