CEA Strategy for Civil Spent Fuels

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Abstract. As a heritage of CEA history, the Nuclear Energy Division has to manage different types of spent fuels issued from its experimental reactors or from post-irradiation examinations in its hot laboratories. For significant quantities such as Osiris MTR and Orphée fuels assemblies, the priority solution is reprocessing to value their energetic content. Further contracts should be negotiated with AREVA for Phénix FBR and Phébus. However specific spent fuels are not easily reprocessed, because quantities are too small for an economic treatment, or because they are embedded in epoxy. CEA manages interim storage facilities for spent fuels, such as PEGASE and CASCAD in Cadarache and other facilities (ISAI, STAR) for putting spent fuels inside welded canisters. But underwater storage in Pegase does not comply with current seismic standards. So these spent fuels are sent to STAR for new containerization before interim storage in dry wells at Cascad or under water in RES canal. Other old fuels are stored in INB 72 Saclay facility. Phénix fuels should be sent to La Hague inside canisters to be welded in ISAI in Marcoule. Retrieving old canisters of spent fuels requires safety demonstrations and sometimes R&D. One problem is to demonstrate that no water has penetrated inside the canister. Another is to find a way to remove the epoxy embedding of former metallographic samples or to deal with potential hydrogen due to radiolysis of epoxy. A stabilization treatment should be performed on metallic fuels from graphite reactors, to avoid a pyrophoric reaction. For very old fuels, surveillance of canisters inside dry wells or finding all necessary data before a new containerization is not easy. Sending small quantities of PWR fuel remnants to La Hague has been investigated recently. If this way is opened, it can be enlarged to other laboratory spent fuels.

1. INTRODUCTION

During its history, CEA has produced a relatively large quantity of spent fuels. It has also received fuels from Nuclear Power Plants for R&D purposes, and performed Post-Irradiation Examinations (PIE) in its hot laboratories. The present stockpile represents more than a hundred tons of heavy metal. This amount of spent fuels has been and has to be managed, either through reprocessing, or through containerization and interim storage. This induces a need for dedicated facilities and in some cases for the development of in-cell processes to perform the containerization.

2. SPENT FUELS TO MANAGE

The spent fuels to be managed are coming from:

- Old fuels coming from heavy water and natural uranium, graphite, gas 1st generation of reactors;

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- material testing reactors, like Siloe dismantled in Grenoble, Osiris running in Saclay and in the future from Jules Horowitz reactor in Cadarache;
- prototype fast breeder reactors, namely Rapsodie and Phénix, both of them shutdown;
- safety test reactors: Phébus, Scarabée both shutdown and later Cabri;
- critical mock-ups and teaching mock-up, e.g. Ulysse decommissioned in Saclay and later Masurca, Eole, Minerve;
- PWR fuels coming mainly from the PIE on EDF rods and similar reactors (irradiation in the BR3 reactor in Belgium, for instance);
- etc.

As a consequence, the physical and chemical forms of all these fuels are very different.

3. GENERAL STRATEGY

The reference strategy is based on sending spent fuels to La Hague reprocessing plants. This enables to recuperate the energetic value of the fissile materials, instead of considering spent fuels as a waste. However, this strategy has some restrictions:

- Technical difficulties for reprocessing due to the chemical or physical form of the spent fuel,
- technical difficulties for La Hague to handle fuels whose geometrical forms are quite different from standard PWR or BWR fuels,
- lack of economic and strategic interest to reprocess low quantities of spent fuels.

So it is possible to distinguish 3 cases:

- Fuels which could be sent, as soon as possible, to La Hague reprocessing plants,
- fuels which cannot be reprocessed now, but can be later when the corresponding processes will be available,
- fuels waiting for final underground storage, due to the above-enumerated restrictions.

4. REPROCESSING

4.1. The 1993–1997 period

Due to a common funding agreement between CEA, EDF and COGEMA, more than 20 tons of various types of spent fuels were reprocessed in the UP1 plant located in Marcoule. Half of this quantity was constituted by old fuels from heavy water reactors and natural uranium graphite gas (UNGG in French), irradiated in the 1st generation of reactors. Rapsodie fast breeder upper blankets were also treated. For several tons of PWR type fuels, plate type fuels from Osiris reactor and other various MTR fuels e.g. the Orphée reactor, a preliminary cutting of the fuel was performed in other facilities, and in some cases, the dissolution itself was performed in the APM facility, before reprocessing of the chemical solutions in UP1. But the UP1 plant was closed in 1997.

4.2. From 1997 to the present

After closure of UP1, and waiting for new reprocessing agreements with La Hague plants and for the opening a national underground storage facility, CEA has gathered its spent fuels in some facilities in Cadarache: the PEGASE pool received most of PIE residues from hot laboratories, whereas the CASCAD dry storage received in its wells spent fuels from the EL4 heavy water power plant (Brennilis).

From 2001, new contracts were settled to reprocess UAl-type MTR fuels from Scarabée (Cadarache), Siloe and Siloette (Grenoble) and Orphée, as well as Ulysse (totally transferred in 2008) and silicide-type MTR fuels from Osiris. Regular shipments are organized for the operational reactors Orphée and Osiris. In 2003, it was decided to reprocess as well all Phénix fast breeder fuel elements and so to avoid the construction of a dedicated interim storage.

FIG. 4.1. 26 U-Al spent fuel assemblies from Osiris MTR have been placed inside the TN-MTR cask (left), and shipped from Saclay (right) to La Hague.

4.3. The near future

New reprocessing agreements are under negotiation with AREVA NC in order to:

- Continue to evacuate the fuels irradiated in both reactors in operation Orphée and Osiris,
- evacuate all the Phénix fuel pins after some preparatory work in CEA facilities (dismantling of fuel assemblies, gathering pins inside canisters),
- evacuate the Phébus assemblies and a few PWR rods from the 1st French PWR (SENA) under interim storage in a pool in Saclay.

In the case of Phébus assemblies, for instance, treatment at La Hague creates two issues: the small assemblies are not directly compatible with the first step of the process and the adaptation will be very costly, and they have been submitted to a very low irradiation thus a treatment together with other CEA fuels should be managed. The technical solution is first to dismantle the assemblies and then prepare special containers compatible with La Hague process and the dissolution could be performed during Phénix fuel pins dissolution campaigns.

Some discussions are also underway to evacuate small quantities of PWR segments issued from the R&D, directly from hot cells of LECI in Saclay to La Hague. A special campaign has already been performed successfully some years ago. This requires cutting the segments in hot cells before shipment to go directly to dissolution.

For the oxide, plate-type fuels burnt in Osiris until 1997, the strategy is not completely defined, either a reprocessing (it has already been performed on a few tons, but after cutting the plates in ISAI) or an underground storage as a waste.

5. UNDERGROUND STORAGE

Geological storage, hopefully available after 2025, is the chosen solution for the remaining fuels from heavy water and UNGG reactors, for some experimental fuels and PIE samples. The largest quantity is constituted by the spent fuel from the EL4 heavy water EDF reactor.

6. CONTAINERISATION FACILITIES AND INTERIM STORAGES

6.1. Containerisation

Before sending the spent fuels to interim storage, there is always containerization inside stainless steels canisters. This can mainly be performed in two facilities: STAR and ISAI. Both facilities will be needed for many years: so refurbishment programmes have been launched in order to upgrade both of them according to their latest safety reassessments.

FIG. 6.1. STAR working area.

Among other goals, STAR has been built in Cadarache to deal with spent fuels from natural uranium, graphite gas reactors. As these fuels are pyrophoric, they need a stabilization treatment (controlled oxidization) before containerization. So STAR was equipped with a stabilization furnace and reconditioning equipments for this purpose. During this campaign, between 1995 and 2004, about 2000 fuel elements of this type were stabilized and put into containers.

STAR is also used for containerization of other spent fuels as well, mainly PWR fuels after post-irradiation examination.

ISAI is located in Marcoule. At first, this large facility was designed mainly to work on fast breeder fuel pins. In the case of the Phénix reactor, the spent fuel assemblies are dismantled after irradiation in Phénix hot cells and fuel pins are placed inside welded containers, waiting for a shipment to La Hague reprocessing plant. The shipment will be performed by the TN 17.2 cask, which is very heavy (78.8 tons) and can be charged in ISAI.

ISAI has also been used for other campaigns, such as the preparation of Osiris spent fuels for reprocessing before 1997, by cutting the fuel plates and putting the chips inside aluminium canisters ready for dissolution.

6.2. Interim storages

CEA has mainly three interim storage facilities for spent fuels, all of them located in Cadarache. Two are pool-type: PEGASE and a canal of the RES reactor (CARES), whereas PEGASE consists of dry wells.

FIG. 6.2. ISAI is equipped to handle very heavy casks such as the TN 17.2 (at right on the picture on the left), which can be then shipped by railway (picture on the right).

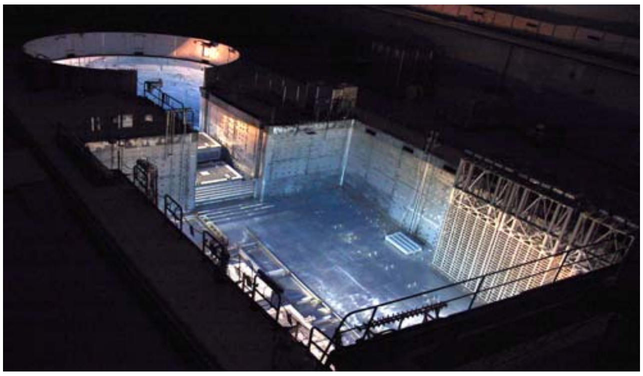


FIG. 6.3. The PEGASE pool, used for under water interim storage.

PEGASE is an old reactor facility, in which the pool has been converted into an interim storage. As the pool is not complying with new seismic regulations, it has been decided to evacuate all the fuels from the pool. This is a complicated and time-consuming task. The fuel canisters are sent to STAR for reconditioning and then transferred to CASCAD. Part of the fuel segments are embedded in epoxy, because they are issued of metallographic examinations: in this case, the PEGASE canisters will be transferred to CARES.

CASCAD is a more recent facility, consisting of a series of dry wells. It is used to store mainly heavy water reactor fuel elements (EL4 reactor), natural uranium graphite gas reactor fuels, Phénix fuels, and few others such as Rapsodie fast breeder, Osiris or PWR fuels. Fuels canisters are leak tight welded and some have been filled by an argon-helium gas mixture and some have been previously dried out to limit the water presence (criticality issue). CASCAD is ventilated through a natural ventilation scheme (see Fig. 6.4). A peculiar attention is given to the balance between the quantities of canisters to be received to CASCAD (or CARES) or sent to La Hague, in order to avoid a saturation of all the wells. No extension of CASCAD is foreseen.

The CARES pool is only used for some oxide-type fuels from Osiris and as a back-up facility for PEGASE (mainly for epoxy-embedded samples) or for the Phébus assemblies if the agreement for reprocessing is too long to obtain. It is not foreseen to use it after 2024.

6.3. Evolutions

Basically, the final choices are either reprocessing in La Hague or interim storage inside CASCAD waiting for final disposal when the underground repository will be opened by 2025. They are other spent fuels stored in other facilities (for instance, in a pool in the INB 72 at Saclay), but sooner or later they will be transferred to CASCAD, if not reprocessed.

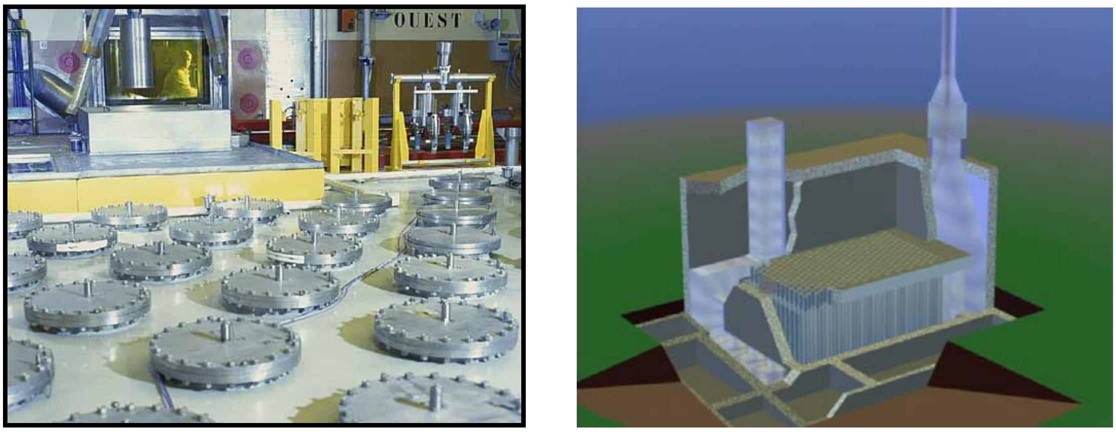


FIG. 6.4. CASCAD facility with the top of the dry wells (left) and a scheme of the building (right).

7. HOT CELLS PROCESSES

All these spent fuels need dedicated hot cell or in-pool equipments during the preparation for interim storage or prior to reprocessing.

7.1. Welding

The more classical equipment is welding the container. Such equipments are available in STAR and ISAI. They need very stringent quality insurance requirements, because the containers should be leak proof on a long term period.

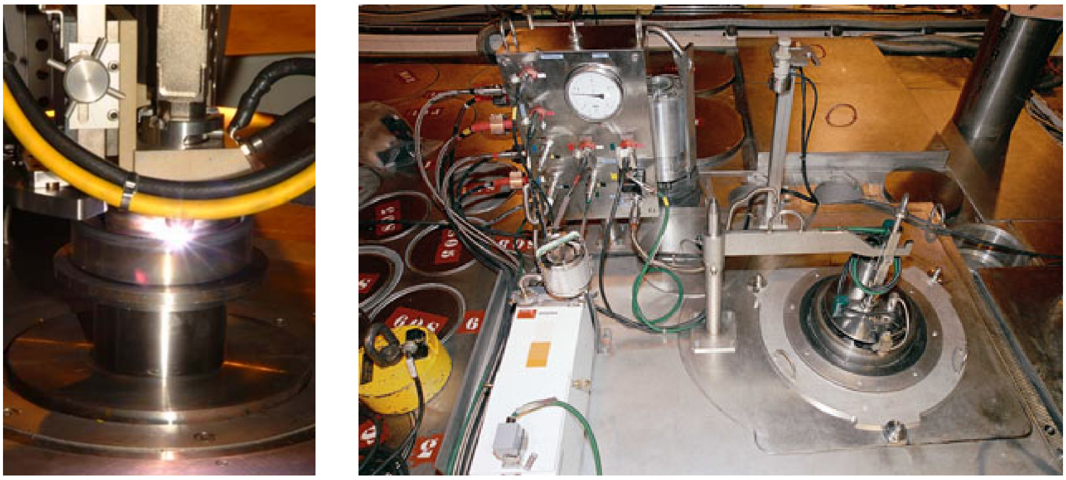
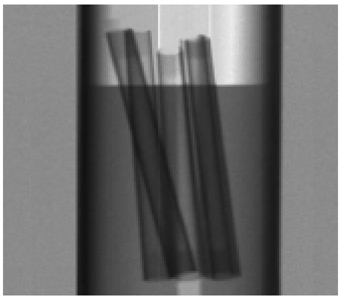


FIG. 6.5. TIG welding equipment for containerization in ISAI.

7.2. Checking the absence of water in the container

To avoid criticality concerns, STAR and CASCAD accepts only containers for which the absence of water inside has been demonstrated. For this reason, an under water X-rays equipment is being developed to check any ingress of water in the canisters directly inside the PEGASE pool. This checking will be performed for some highly-enriched spent fuels before shipment to STAR. If this technique is efficient, it can be also applied to the PWR-type fuel elements stored inside the INB 72 pool in Saclay.

STAR is also equipped with a device for drying the canisters. The drying is obtained by vacuum pumping and inert gas filling. The absence of water is checked before closing the canister.



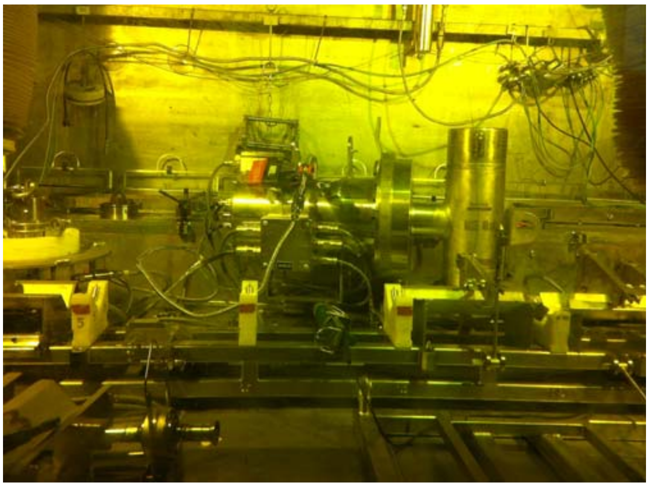


FIG. 6.6. Test of X-ray detection of water (left) – puncturing and drying equipment for containers in STAR (right).

7.3. Stabilization

As mentioned above, the old natural uranium fuels from UNGG are pyrophoric. For this reason, one of the STAR hot cells was placed under inert atmosphere, and all the UNGG fuel cartridges were submitted to a stabilization treatment consisting in a controlled oxidization. Then the stabilized fuels were containerized.

Some HTR fuels should also be treated before interim storage.

7.4. Epoxy removing

At the moment, this is the most difficult problem. For long term storage, it is considered necessary to remove the epoxy from the metallographic fuel segments. It is considered that epoxy can release hydrogen, thus inducing explosion hazard. Several thermal or chemical treatments have been investigated, but the final process has not yet been chosen. One of the difficulties is that there are different types of epoxy. It is then recommended to PIE hot laboratories to use metal embedding, but this is not always the case. The preferred option is a systematic mechanical removal of the epoxy, followed by a pyrolytic treatment above 550°C under inert atmosphere without post combustion. It is envisaged that the stabilization furnace for UNGG fuels in STAR could be compatible with the pyrolysis temperature for epoxy.

8. CONCLUSIONS

The CEA has to manage quite a large quantity of spent fuels under many different physicochemical shapes. The general strategy is to send them to reprocessing when it is possible, and to store them waiting for final underground storage when it is not realistic. This needs several facilities for interim storage and reconditioning, and also a few developments in hot cells to be able to stabilize, weld and control the containers. A careful optimization is required to minimize the costs of the reprocessing, storages, reconditioning and minimize transportations.