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MANAGEMENT OF DECOMMISSIONING PROGRAMME AT SCK•CEN

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ABSTRACT

An intensive decommissioning programme at SCK•CEN was executed during the period 1989 to 1998. This programme included the decommissioning of the BR3 reactor and heavy equipment in the BR2 reactor as well as the clean up of several nuclear laboratories. The management of these **D**ismantling and **D**econtamination activities (**D&D**) along with the evaluation of the costs and the financing of the liability fund requires the use of a data processing system. SCK•CEN designed in 1994 a **de**commissioning **ma**nagement **to**ol (DEMATO) to perform these assignments. The tool was successfully used in 1995 for the set-up of the decommissioning plan and in 1999, to perform its revision.

The comparison between these two successive evaluations allows to observe the influence of changes in strategy and the evolution of waste prices on the costs of the D&D activities and this for the period 1995-1998. As a result of this exercise one notices that:

1. for the back end of the HEU BR2 spent fuel, the processing of the spent fuel without recovery of the uranium, allows to reduce the costs by 25 %;
2. the dry storage of the LEU and MOX spent fuel is, up to now, performed within the dedicated budget;
3. the costs of the other D&D activities are roughly 5 % more expensive that the estimated budget, if the increase of the waste costs is disregarded and 15 % of the inflation of the waste costs is taken into account.

INTRODUCTION

Financing of SCK•CEN Nuclear Liabilities is ensured by two funds. One fund covers the decommissioning of SCK•CEN nuclear facilities existing before 1989. The Belgian Federal Government secures this fund, raised in 1990. The other fund is secured by SCK•CEN and allows the clean up of the nuclear facilities created since 1989. Both funds together represent roughly 490 M$[1].

Decommissioning of nuclear facilities is a complex process involving operations such as detailed surveys, decontamination and dismantling of equipment, demolition of buildings and management of resulting waste and other materials. Safety and costs aspects have to be taken into account at each step of the decommissioning programme. To manage its decommissioning programme, SCK•CEN, the Belgian nuclear research centre, has designed a tool aiming at:

1. recording the physical and radiological inventory of the components of the nuclear facility;
2. assessing the performances of dismantling and decontamination techniques;
3. managing the waste resulting from decommissioning activities;

4. evaluating the decommissioning programme;
5. optimising the decommissioning strategies;
6. follow up of ongoing D&D activities

This tool is already successfully used in the case of nuclear power plants and laboratory buildings.

According to the legal rules and the good practices in management, SCK•CEN regularly performs new evaluations of its decommissioning programme. The new evaluations have as purpose to control the performance of decommissioning projects, to analyse the impact of new techniques, to follow up the waste costs evolution and changes in the regulation and above all to check that the decommissioning fund still covers the costs of the cleaning activities.

DECOMMISSIONING MANAGEMENT TOOL

The **de**commissioning **ma**nagement **to**ol (DEMATO) [1] designed by SCK•CEN is an interactive database covering all aspects of the physical, chemical and radiological inventory of the site infrastructure and its installations as well as the performance of the decommissioning techniques and the waste costs.

In the case of SCK•CEN site, the inventory concerns:

- the BR1 facility, a 3.5 MW natural uranium-graphite moderated-air cooled reactor;
- the BR2 facility, a high flux material testing reactor using highly enriched uranium, moderated by a beryllium matrix and cooled with pressurised water;
- the BR3 facility, a 40 MW_{th} pressurised water reactor which has served both as pilot and as an experimental reactor and which is now in dismantling since 1989;
- the nuclear laboratories buildings where research is performed on reactor constitutive material, fuel and waste conditioning;
- a farm with pastures where the effects of a contamination on the biosphere are studied.

A sheet into the database describes each object present inside the nuclear installation in terms of material, mass, surface and volume. The sheet also identifies the localisation of the object (installation, building, zone and circuit) and the category (infrastructure, equipment, waste and fissile material) to which it belongs.

The performances of the decommissioning techniques are assessed based on the know-how gained from the D&D activities performed at SCK•CEN sometimes completed by experiences form other D&D projects. Particular attention is paid at analysing each step of the use of a decommissioning technique *i.e.* preparation, operation, maintenance, secondary waste and dose uptake. A table into the database contains the list of industrial decommissioning techniques with their performances in terms of manpower by category of workers, purchase, investment, secondary waste and applying field. When no industrial technique is available to meet the requirements, a specific R&D project is launched with the aim at defining a solution. It is particularly the case of the sodium treatment [2].

Waste produced by the decommissioning activities is categorised in terms of:

1. high, medium and low level waste as a function of the dose-rate at the contact of the primary package;
2. $\beta\gamma$, α suspected and $\alpha\beta\gamma$ bearing waste;
3. liquid or solid waste;
4. burnable, compactable and supercompactable waste.

For each waste category, the costs are defined for its treatment, conditioning, interim storage and disposal.

Most of the costs of a decommissioning programme are function of the quantities to be treated allowing to use a unit cost system for their assessments. Other costs are to be estimated case by case taking into account the specificity of the nuclear installation and the legislation aspects. It is the case of management, survey and maintenance, licensing, taxes, insurance and contingencies.

DECOMMISSIONING ACTIVITIES 1989-1999

The main decommissioning activities at SCK•CEN are focused around the BR3 reactor. The BR3 reactor is a low rated PWR plant (40 MW_{th}, 10 MW_e). It has been used for the training of operators and for the testing of fuel assemblies. Besides the pressure vessel itself (28 tons), it contains 3 highly activated pieces *i.e.* the thermal shield (6 tons) and two sets of internals (11 tons) (Fig.1).

Its decommissioning [3][4], launched in 1989, started with the chemical decontamination of the primary loop using the CORD® process (1989-1992) and carried on with the dismantling of the thermal shield (1989-1995). The thermal shield was used as benchmark of different underwater cutting techniques such as circular milling cutter, plasma arc torch and electro discharge machining. The results of this benchmark are summarised in Table I. Based on a cost benefit analysis of the whole process *i.e.* preparation, operation, maintenance, secondary waste and dose uptake, mechanical cutting technique was preferred for the cutting of the two sets of internals (1992-1996) and the dismantling of the reactor pressure vessel (1997-2000). The BR3 team is now preparing the cutting of the large components of the primary loop (2000-2001) and the neutron shield tank (2000-2002). Their dismantling will be performed using the high-pressure water jet cutting technique, with abrasives.

Table I: Comparison of cutting techniques during the dismantling of the Thermal Shield (mechanical cutting method has been taken as reference)

Parameter Cutting Method	Cutting speed	Operation duration	Dose Uptake	Secondary waste volume
Mechanical	1	1	1	1
Plasma	50	0.63	~1	~5
EDM	1/10	4	~3	~5

Two decontamination workshops [5], one called MEDOC using the oxidation with cerium and the second one ZOE using the wet sandblasting technique are now fully operational and allow to minimise the amount of radioactive waste produced by the dismantling of the contaminated circuits. The MEDOC installation is devoted to the decontamination of metal pieces heavily contaminated e.g. up to 20,000 $\beta\gamma$-Bq/cm^2. The installation is in service since mid September 1999. 4 tons of SS pieces of different origin and geometry were successfully treated. Based on the first measurement, one can consider that they will easily be free released.

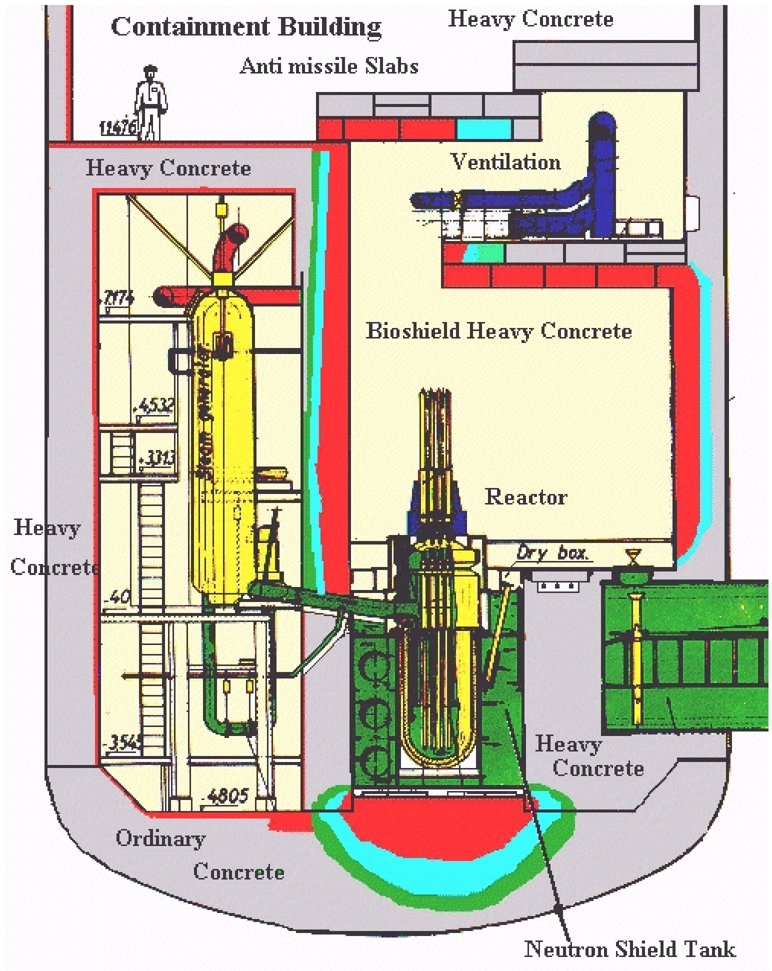

Fig. 1: Schematic view of the BR3 containment building

The ZOE installation is used for the decontamination of metallic pieces with a contamination up to 1000 $\beta\gamma$-Bq/cm^2 and 5 α-Bq/cm^2. Until now, 10 t were immediately free released after decontamination in the ZOE installation. 2.8 t were partially decontaminated to remove most of the alpha contamination and allow its free release after melting and 6.3 t of slightly activated material were also treated to allow this material to belong to a less expensive waste category. In general about 10 to 20 % of the materials could not be free released either due to difficult removable contamination or to inaccessibility for measurement. The materials not free released are normally sufficiently low to be sent to a dedicated nuclear foundry for free release by melting.

28 anti-missile heavy concrete slabs were installed in the refuelling pool above the reactor pressure vessel. Characterisation studies have shown that all the slabs were contaminated and that some were activated. Decontamination of 22 slabs representing 247 t was performed using mainly scabblers, shavers and jackhammers. After treatment, 205 t could be unconditionally free released and sent for recycling in the construction industry and 42 t still slightly activated are kept for further conditioning.

Besides the decommissioning of the BR3 reactor, various other D&D activities were performed. In the early nineties, the Belgian government decided to found a new research centre (Vito: Flemish Institute for Technological research) taking over all non-nuclear activities of the SCK•CEN. This splitting had as result that 4 nuclear installations of SCK•CEN had to be cleaned up allowing their transfer to the Vito [6]. Materials and equipment inside the controlled area were first scanned for α and $\beta\gamma$ contamination. Non contaminated objects were evacuated outside the controlled zone. Contaminated items were brought to the decontamination area and treated. Then the 13,300 m^2 of wall and floor (max. 500 $\beta\gamma$-Bq/cm^2 and max. 0.5 α-Bq/cm^2) were decontaminated to the free release level. Each time, the Vito has formalised its agreement for the transfer of the decommissioned building.

In the Nuclear Chemistry building (SCH) and in the installation for Low, High and Medium Activity (LHMA), a cleanup programme was launched to dismantle old equipment like hoods, glove boxes and hot cells. In the past, 100 m^3 of small glove boxes and 18 m^3 of hot cells were packed and transferred to BELGOPROCESS to be dismantled there. In 1995, a big L-shaped cell of 18 m^3 surrounded by a lead biological shield had to be dismantled *in situ* [7]. The in situ dismantling of cells and glove boxes minimises the waste production by using the BR3 decontamination workshops coupled if necessary, with the melting for free release or for recycling via a nuclear foundry. 34 m^3 of glove boxes and 16 m^3 of hot cells are now prepared for dismantling in a new installation at SCK•CEN.

At the BR2 reactor, some decommissioning activities were performed during the refurbishment of the reactor. After 17 years cooling time, the first beryllium matrix was dismantled in the hot cell of the BR2 facility. The beryllium was separated from the stainless steel extension pieces. The extension pieces were cut using a reciprocating saw. The waste was packaged and sent using a transport container to Belgoprocess, the subsidiary of NIRAS/ONDRAF, where it will be conditioned and stored.

Table II gives an overview of the material handled over the period 1989-1999. The masses of the laboratory buildings transferred to the Vito are not mentioned in the table.

Table II: Overview of the decommissioned material at SCK•CEN over the period 1989-1999.

Material stream	**Quantity**
Waste	
- HLSW (High Level Solid Waste)	41 m³
- MLSW (Medium Level Solid Waste)	37 m³
- LLSW (Low Level Solid Waste)	445 m³
Decontamination/Recycling	
- MEDOC	4 T
- ZOE	21 T
- Other decontamination process	435 T
- Recycling via nuclear foundry	35 T

The costs of the D&D activities performed over the period 1995-1998 roughly reach 19.5 M$. By updating the inventory at the end of 1998, the decommissioning management tool DEMATO assesses the costs estimated to complete the remaining D&D work. The difference between the assessments performed at the early 1995 and at the end 1998 is 20.5 M$. This evaluation only differs by 5 % from the real costs recorded over the period 1995-1998. The assessments were performed in money of 1995 without any changes in the assumptions and the tariff of waste. Also, the costs of the waste generated by the D&D activities were calculated using the waste tariff 1995.

The waste tariffing system up to 1995 was based on a unit cost system. In 1996, the tariff was replaced by a system comprising a fixed cost to use the treatment/conditioning installations and a variable cost function of the waste type. Due to a general reduction in the production of waste, the constancy of the fixed costs led to a supplementary increase of the unit costs. This new system raises the global bill of the 1995-1998 waste production by 2.7 M$.

MANAGEMENT OF SPENT FUEL

Back end options such as reprocessing and intermediate storage awaiting final disposal were studied for the HEU of the BR2 reactor and the LEU and MOX spent fuel of the BR3 reactor. The various options were evaluated against criteria like, *e.g.* available techniques, safety, waste production and overall costs (including the costs for the decommissioning of the interim storage equipment and infrastructures).

The management of HEU spent fuel concerns up to now almost 1400 fuel elements. The evaluation of the different back end options shows that the processing of the HEU spent fuel with or without recovery of uranium has to be preferred to the intermediate storage. Indeed the long term stability of the cladding (aluminium) during the interim storage and the risk of criticality during the final disposal were considered as major inconvenient for the intermediate storage solution [8], [9].

In 1994, an urgent relief of 240 elements was decided due to saturation of the on-site storage capacity. They were reprocessed at the UKAEA-Dounreay facility. This opportunity was taken to demonstrate the feasibility of fuel cycle closure. Up to now 26 fuel elements at 72 % U5, have been successfully fabricated. To optimise the operation of the BR2 reactor [10], they must be used together with standard fuel elements (89-93 % U5). In the near future the procedures required to permit the return of the cemented waste to Belgium will be launched.

At the end of 1996, it was decided to opt for a long-term commitment with COGEMA: reprocessing and dilution of the recovered uranium. Three transports with a total of 105 fuel elements were successfully carried out in 1998-1999. We intend to resume the transport to COGEMA (La Hague) in 2000 when the new transport cask TN-MTR designed by TRANSNUCLEAIRE will receive its agreement from the Belgian Authorities.

The long-term commitment with COGEMA allows reducing the provisions for the back-end option of the BR2 spent fuel by roughly 30 %. This percentage takes into account that the costs for processing the spent fuel and conditioning the secondary waste are less expensive than in the previous options. The percentage used to cover the contingencies is also minimised to take into account that the storage and disposal of the secondary waste represent only 2 % of the total costs and that a long-term commitment exists.

During its whole life, the BR3 reactor was used as test reactor for new fuel types and assemblies. So MOX fuel with enrichment up to 10,3 % Pu_{fiss}, fuel pins containing burnable poison (Gd-contents) and LEU fuel with enrichment up to 8,26 % U5 were tested. There are almost 200 fuel assemblies present in the plant representing about 5000 fuel pins (max. length 1235 mm; max. diameter 10,75 mm). Some pins have participated in R&D experiments in the BR2. Part of them have undergone destructive analyses (*i.e.* puncture test, cutting or decladding). All the remaining segments together represent an equivalent amount of 500 pins.

The possibility to reprocess the spent fuel was first studied [9]. It became evident that this solution has to be disregarded due to two major difficulties. The first one concerns the difficulty to reuse the recovered uranium and plutonium in the industrial production of fresh fuel. The second one consists in the low solubility of the Pu, which imposed to an additional dissolution step and the use of a pilot reprocessing facility. Amongst all the industrial options of dry storage, the use of thick containers was preferred to the solution using thin canisters. The transport and storage cask contains a basket which can be loaded with up to 30 spent fuel assemblies of bottles containing each 15 loading tubes for pin segments. The cask consists mainly of a thick-walled cylindrical cask body made of ductile cast iron and closed by two independent lids each bolted to the cask body and each sealed with a metal seal. The loading of the containers and the transport to Belgoprocess is scheduled in 2001. After interim storage, the assemblies can be retrieved, repacked and conditioned into welded canisters and disposed of in a geological formation.

Up to now the budget allocated for the dry storage of LEU and MOX spent fuel is respected. As far as the new tariffing system of the waste only influences the treatment and conditioning costs, it has no financial impact on the budget.

CONCLUSIONS

The paper provides the status of the decommissioning programme at SCK•CEN and in particular the decommissioning activities at the BR2 reactor, BR3 reactor and old laboratories building. For the management of this programme SCK•CEN has designed a model to compute the decommissioning costs of nuclear installations and to manage a large and diversified decommissioning programme. The costs estimated by the model are very close to the real D&D costs recorded during 4 years, which confirms the validity of the model. The updating of the decommissioning management tool with the feedback and experiences from ongoing decommissioning projects allows maintaining its quality in the future.

The control of the waste costs remains a major challenge in the management of the decommissioning programme. The decommissioning management tool allows analysing the impact of this kind of change.

FOOTNOTES

[1] assuming that 1 $ ≅ 1 € (monetary unit of the European Community)

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