COST ESTIMATION OF THE DECOMMISSIONING OF NUCLEAR FUEL CYCLE PLANTS : APPLICATION TO REPROCESSING PLANTS

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ABSTRACT

Most studies conducted to date on the cost of decommissioning nuclear facilities pertain to reactors. Few such studies have been performed on the cost of decommissioning nuclear fuel cycle plants, particularly spent fuel reprocessing plants.

Present operators of these plants nevertheless need to assess the magnitude of such costs, at least in order to include the related expenses in their short-, medium- or long-term projections. They also need to determine now, for example, suitable production costs that the plant owners will have to propose to their customers.

Unlike nuclear reactors for which a series effect is involved (PWRs, BWRs, etc.) and where radioactivity is relatively concentrated, industrial-scale reprocessing plants are large, complex installations for which decommissioning is a long and costly operation that requires a special approach.

Faced with this problem, Cogema, the owner and operator of the La Hague and Marcoule reprocessing plants in France, called on SGN to assess the total decommissioning costs for its plants.

This assessment led to development by SGN engineers of a novel methodology and a computerized calculation model described below. The resulting methodology and model are applicable to other complex nuclear facilities besides reprocessing plants.

COMPLEXITY OF THE PROBLEM

The specific problem raised by nuclear fuel cycle facilities, particularly reprocessing plants, is their extreme diversity. This diversity is reflected in:

- the functions of the areas to be dismantled (fuel assembly shearing cells, dissolution cells, incoming fuel storage pools, glove box systems, active ducts for interconnecting facilities, etc.);
- different types of equipment (chemical and mechanical process components) in these plants;
- the levels and types of contamination (alpha, beta, gamma) encountered;
- the number of active cells to be decontaminated;
- the design of each cell, which may be equipped with openings and/or remote maintenance facilities.

This diversity therefore makes it impossible to prepare a single decommissioning scenario applicable to the entire reprocessing plant. Each cell is thus a special case.

Assessment of the decommissioning costs for such plants also involves another difficulty, namely knowing how far the decommissioning of the facilities must be taken. This raises the problem of acceptable contamination limits and decommissioning levels to be achieved. Several levels may be allowed depending on whether or not the decommissioned facilities are to be partially or completely reused for nuclear or other applications.

These limits and levels have a significant impact on decommissioning costs.

Another parameter that has a substantial impact on costs is the average radiation exposure allowed for decommissioning personnel when decommissioning is performed.

Increasing the size of decommissioning staff to reduce personnel exposure time and/or increasing the number of remote-controlled operations is more expensive but less demanding inn terms of integrated doses for the decommissioning personnel. A tradeoff must therefore be found, which was the goal set for the model developed by Cogema and SGN.

The above considerations illustrate that caution is required when talking about decommissioning costs for a nuclear facility, and that the basic assumptions employed must be clearly stated from the outset.

The studies conducted by SGN make it possible to determine the sensitivity of decommissioning costs to variations in these assumptions (decommissioning levels, personnel exposure, etc.). The inventory of COGEMA's reprocessing plant areas to be dismantled are in Table I hereafter.

METHODOLOGY DEVELOPED BY SGN

The CEA and Cogema have several years of experience in the decommissioning of large facilities. After shutdown of some facilities, decommissioning work was undertaken at La Hague and Marcoule to fully renovate these facilities or to reuse the space made available for other purposes. This experience, which involved costs of several hundred million francs over several years, includes both facilities with high-level radioactive environments (e.g., spent fuel dissolution facilities) and facilities with medium-level alpha radioactiv-

TABLE I
Inventory of Reprocessing Plant Areas to be Dismantled

	(Number of rooms / areas)		
AREAS	*Marcoule*	*La Hague*	*TOTAL*
Active Areas			
Cells with high-level radioactive environments (remote operations required)	119	244	363
Cells with medium-level radioactive environments	192	304	496
Cells with low-level radioactive environments (accessible without extensive decontamination)	73	548	621
Pools and basins	74	40	114
Subtotal Active areas	458	1,136	1,594
Hazardous areas			
Maintenance, utility systems and sewer areas	344	667	1,011
Pool or storage halls	17	18	35
Subtotal Hazardous areas	361	685	1,046
Shielded or unshielded enclosures (laboratory, glove boxes)	231	359	590
Interconnecting ducts	6	12	18
GRAND TOTAL	1,056	2,192	3,248

These 3,248 rooms have a total volume of 1,139,000 m^3.

ity environments that accommodate large quantities of plutonium.

SGN relied on this concrete experience to develop a methodology for assessing the cost of decommissioning French reprocessing plants that can easily be applied to any other complex nuclear facility. This methodology may be summarized as follows:

Definition Of Three Consecutive Phases The three phases defined are: rinsing, decontamination and decommissioning.

They constitute a logical approach to decommissioning which involves eliminating a maximum of radioactivity by rinsing and then implementing more aggressive decontamination before cutting, removal and packaging of contaminated equipment. These three phases lead to a specific assessment.

Selection of 25 standard cells representing nearly all of the 3,000 active cells present in French reprocessing plants.

This approach based on standard cells is necessary because it was not physically possible to study the decommissioning of all 3,000 cells. Furthermore, the 25 standard cells are fairly representative of all cells in a nuclear facility.

The selection criteria for the principal standard cells are as follows :

- cells housing mechanical components with high-, medium- and low-level radioactive environments (2 standard cells);
- cells housing chemical components with high- or medium-level radioactive environment (2 standard cells);
- chemical or mechanical process equipment cells with low-level radioactive environments (1 standard cell);
- shielded laboratory enclosures;
- spent fuel storage pools (2 *standard types*);
- interconnecting ducts (5 standard cells);
- waste storage basins (2 standard cells), etc.

Development of a standard detailed decommissioning scenario for each of the 25 standard cells prepared on the basis of French decommissioning experience.

French decommissioning experience was used to prepare a standard decommissioning scenario for each standard cell. Scenarios were broken down into around 50 basic tasks described with enough precision to provide numerical data for each scenario: decommissioning time, quantities of waste, effluents, operations time, integrated personnel dose.

One basic principle adopted in the study is that the concrete structures will remain in place after decontamination.

Detailed inventory of the main characteristics of the 3,000 cells to be dismantled.

Each of the 3,000 cells to be dismantled in French reprocessing plants required an inventory of its characteristics (dimensions, presence or absence of stainless steel linings, remote operation facilities, air locks, doors, size and weight of equipment in place, etc.), which provided the basic data for the design model. A total of 60,000 parameters were entered.

Grouping of the 3,000 cells in 25 cells
each family corresponding to a standard cell as defined above

The previously determined parameters were consolidated for each standard cell. The standard scenario was then applied to the standard cell on the basis of these consolidated data.

Development Of A PC-based Design Program

Output of numerical results mainly decommissioning times, volume of unpackaged and packaged waste, volume of active effluents to be treated

Computers were used to obtain all the statistics required per building, plant, waste category, etc.

Economic Enhancement Of The Numerical Data

Combination of the above numerical data and unit costs (cost of one hour of decommissioning; cost of waste treatment, effluent treatment; permanent waste disposal, etc.) enables an overall assessment of the decommissioning costs for a facility, plant or site.

All these unit costs are derived from Cogema's experience (operating costs for facilities in rinsing phase, waste and effluent treatment costs, etc.) or are estimated on the basis of regularly updated studies (e.g., permanent waste disposal costs).

Simulation and Sensitivity Studies

Parameterizing of the study and development of a computer model enable performance of all the desired sensitivity studies: sensitivity of decommissioning costs for residual contamination, average radiation exposure of decommissioning personnel, etc.

PRACTICAL APPLICATION OF SGN STUDY TO COGEMA PLANTS

The SGN study was initiated in November 1987 and is continuing with the annual updating of results. This assessment of decommissioning costs for Cogema's La Hague and Marcoule plants has accounted for about 15,000 hours of work to date.

Three major scenarios have been investigated with estimation of related costs:

- Total decommissioning for the plants, except for the concrete structures assumed to be cleaned but not destroyed

This scenario assumes that all radioactivity is removed, all wastes are packaged and stored and residual contamination permits unrestricted use of the buildings without any specific constraints.

- Partial decommissioning.

As its name indicates, this scenario assumes that radioactivity is maintained in some areas with, for example, reuse of cells for interim waste storage.

It is also assumed that reduced surveillance is maintained for all facilities.

- Rinsing-decontamination/no decommissioning. In this case, no actual decommissioning is undertaken and the facilities are only rinsed. surveillance and ventilation of the facilities are maintained.

SAMPLE TECHNICAL RESULTS FOR NONE FACILITY OF THE UP3 PLANT

(The financial assessment and for this example was not available and related commercial information is confidential.)

The example considered is the **T1 fuel shearing/dissolution facility** of the UP3 reprocessing plant at La Hague, France. This plant has a spent fuel reprocessing capacity of 800 t a year.

Main characteristics of T1 facility :

- 2 shearing/dissolution systems
- floor area: 92 m x 74 m
- height: 42 m
- concrete volume: 60,000 m^3
- concrete rebars: 5,400 t
- number of rooms: 650, including 90 active or hazardous
- 90 active cells:

21	with high dose rate	(10,400 m^3)
6	with medium dose rate	(1,300 m^3)
35	with low dose rate	(11,500 m^3)
28	with radioactive hazard	(11,600 m^3)
90		(34,800 m^3)

- 28,200 m^2 of cell wall area, including 2,000 m^2 lined with stainless steel
- piping: length 105 km; 430 t weight
- 910 tones of mechanical and chemical equipment
- 24,000 m^3 of shielding, including 45 tones of lead; 1,810 tones of cast iron and steel
- 1,080 m^3 of tank internal volumes to be decontaminated
- instrumentation and control cables: 500 km
- electric cables: 300 km

Application of SGN methodology :

Inventory of cells and their characteristics :

- 90 cells

Recorded Characteristics	dimensions (w x l x h)	m
	wall thicknesses	m
	density of equipment relative to cell volume	kg/m^3
	% piping	%
	drainage area	m^2
	stainless steel lining	m^2
	shielding volume	m^3
	lead shielding	t
Calculated Characteristics	internal area	m^2
	cell volume	m^3
	weight of equipment + piping	kg
	weight of piping	kg

Grouping of 90 cells in 10 standard cells:

10 Standard Cells	13	high dose rate (HDR) chemical process cells
	8	HDR mechanical cells
	6	medium dose rate (MDR) mechanical process cellls
	34	low dose rate (LDR) chemical/ mechanical process cells
	1	LDR inner duct
	6	Z2Z3 transmitter cells
	1	production/vacuum/filter/VCV cell
	2	Z2Z3/distribution/utilities rooms
	2	Z2Z3/distribution/reagents rooms
	17	air locks or servicing areas
	90	T1 cells

One decommissioning scenario is considered per standard cell. Approximately 50 tasks are identified per scenario and enhanced in terms of manpower hours and waste generated.

TABLE II

Preparation of entrances, decontamination	*139,000 h*	*14%*
Perforation of concrete, removal of barytes bricks, chipping, concrete stripping	*56,000 h*	*6%*
cutting of internal equipment and bituminization	*313,000 h*	*31%*
Subtotal In-cell operations	*508,000 h*	
Waste removal, transportation and packaging	*87,000 h*	*9%*
Technical management of operations	*178,000 h*	*18%*
Radiological monitoring of personnel and environment	*232,000 h*	*22%*
TOTAL	***1,005,000 h***	***100%***

Main Numerical Results (summary For T1 Facility)

The assessment of decommissioning manpower (hours) for the T1 facility is in Table II hereafter.

These hours are doubled (2,320,000 h) if the manpower hours of the plant operator during the phases prior to decommissioning (rinsing, extensive decontamination) and during the actual decommissioning (minimum operator teams maintained) are considered.

The integrated dose for all this personnel was evaluated at 18,000 mSv, including 11,000 for the 508,000 hours of in-cell operations. This yields an equivalent dose rate of 0.008 mSv/h or a yearly average integrated dose of 0.008 x 1,500 h = 12 mSv/yr.

The assessment of radioactive effluents generated (m^3)by the decommissioning of the T1 facility is in Table III.

Solid Waste Generated

Expressed in tons and m^3 of packaged permanent waste ready for surface or underground storage. The assessment of solid waste generated by the decommissioning of the T1 facility is in Table IV hereafter. The following Table V resumes the SGN's methodology, adapted for the assessment of the decommissioning costs of complex nuclear facilities.

TABLE III
Radioactive Effluents Generated by (m^3)

	Low-level activity (< 5 Ci/m³)	*Medium-level activity (< 60 Ci/m³)*	*High-level activity (To be vitrified)*
Rinsing phase	*828 m³*	*271 m³*	-
Internal decontamination (tanks, systems, etc.)	*1,397 m³*	*6,356 m³*	*1 m³*
HP decontamination of walls and equipment	*4,115 m³*	-	-
Decontamination of certain waste for declassification (suitable for surface storage)	*3,244 m³*	-	-
	9,584 m³	*6,627 m³*	*1 m³*
TOTAL : 16,212 m³			

TABLE IV
Solid Waste Generated

	FINAL DISPOSAL	
Phase	*m³ surface*	*m³ underground*
Rinsing	*105*	*38*
Decontamination	*315*	*152*
Decommissioning	*15,152*	*897*

TOTAL:16,659 m^3 of permanent volume packaged waste
WEIGHT:6,276

TABLE V
SGN Decommissioning Study Methodology