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Fontenay-aux-Roses

MODIFICATION OF THE CELLS OF THE FONTENAY-AUX-ROSES RADIOMETALLURGY LABORATORY

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1. INTRODUCTION

The Radiometallurgy Laboratory at Fontenay-aux-Roses was set up in order to carry out tests on fast reactor fuels, and more particularly plutonium-base fuels (Refs. 1-3).

The draft design was begun in 1962; the ground was broken in 1964, and the laboratory went into operation in February 1967 (Fig. 1).

1.1 Test Programme

The radiometallurgy work programme is very extensive, although it is centred on only one subject: the study of fuels for fast reactors. This very complex subject includes:

1. Applied research experiments, i.e., irradiations in experimental thermal reactors, such as EL-3, Osiris, Siloé and others such as the EBR-2 at Mol and the DFR at Dounreay. These various irradiations were carried out in instrumented capsules in which the parameters could be varied (fuel composition and character, burnup, specific power, etc.).

2. Definition and observation of the Rapsodie reactor fuel. Initially, this reactor was to have operated with a 20 MW power rating and a burnup of 30,000 MWd/t. In fact, the operating power was pushed up to 24 MW and the burnup of the most heavily loaded assemblies is 60,000 MWd/t. During the first half of 1970, the original core was replaced by a "Rapsodie Fortissimo" performance core with which a power rating of 40 MW can be reached and the flux multiplied by a factor of 1.6.

3. The study of fast neutron experimental irradiations at assembly level. These irradiations, which are inserted in the core of the Rapsodie reactor, are of a "quantitative" nature. This third type of irradiation is partly intended to obtain a better knowledge of the fuel to be used in the next French fast reactor, named Phénix, which is being built at Marcoule. As the Phénix criticality is planned for the first half of 1973, we shall of course have to study its fuel as from that year.

We might also mention the marginal tests in the form of experiments carried out on the fuel element clad or those performed for outside French or foreign clients.

1.2 Safety

From the very beginning, during construction of the laboratory, we knew that the precautions taken when handling the alpha-emitter plutonium should be the most stringent type, which is why we used three types of cell for carrying out operations where there is a risk of contamination (Fig. 2).

a) The non-destructive tests, which are not contaminating, are carried out in beta/gamma cells which are exactly the same as those in a standard beta/gamma laboratory. Nevertheless, with a view to safety and homogeneity, the leaktightness of the locks and the ceiling shields were of very good quality. This leaktightness is provided by two rubber seals laid on a perfectly machined faying surface.

b) More particular or specific tests are carried out in large cells (3 x 3 m) of the alpha/beta/gamma type. A skin formed by a sheet of mild steel 3 mm thick laid onto the concrete ensures leaktightness. These tests are carried out on prepared samples (impregnation, polishing, etc.) and produce little contamination.

c) The machining and preparation of the samples, on the other hand, were carried out in a leaktight caisson in a beta/gamma cell. This type of cell, called "alpha in beta/gamma, has a useful hot surface area of 4 m^2 for a beta/gamma cell area of 9 m^2.

During the first two years of operation, we realised that working in caissons was a solution which met all the requirements as regards the safety of both the personnel and the surrounding population.*

On the other hand, however, this attention to safety hampered us considerably in two very important respects:

First, with regard to the number of square metres of hot surface area, and therefore the number of tests we could carry out, this limitation was qualitative because of the small amount of equipment which could be installed in the caissons.

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* The surrounding population is included because the Radiometallurgy Laboratory is situated in the middle of the urban population of the southern region of Paris.

Second, as regards the working rate possible with the magnetic transmission telemanipulator, and difficult utilization due to the maintenance of the "alpha in beta/gamma" cells, particularly in the decontamination and re-equipping of the caissons. This greatly reduced the number of tests which could be carried out.

On the other hand, the Radiometallurgy Laboratory is the only French laboratory which conducts complete studies on plutonium-base fuels in the metallurgy field. After 1969 it was therefore necessary, having used the equipment at our disposal, to modify the laboratory in order to possess a greater quantity and variety of equipment which would enable us to increase the number and rate of tests.

2. MODIFICATION OF A CELL

In order to convert an alpha in beta/gamma cell into a high capacity alpha/beta/gamma cell, two tests were carried out. The first consisted in testing the leaktightness of the concrete walls which acted as the biological shield. The second was to determine the efficacy of a direct manipulator with a protective sleeve.

2.1 Wall

As previously mentioned, we had two types of leaktightness: the first was ensured by an alpha caisson in a beta/gamma biological shield, while the second, which concerned the old alpha/beta/gamma cells, consisted of a skin of black-painted steel covering the concrete. As laying a leaktight steel skin requires delicate workmanship, we tried to find a type of cell in which alpha work may be carried out and which may be re-lined in the shortest possible time.

To do this, we carried out a large number of tests on cell No. 6. We will only say here that, as a result of these tests, we obtained leaktightness which was highly satisfactory in most cases, and in one specific case better than that with the "caisson" solution. The leakrate in the new type of cell is approximately $2 l/h/m^3$ with an underpressure of 20 mm WG, whereas a caisson shows a value of $3 l/h/m^3$ for the same underpressure (Ref. 7).

The new cell is one of the old type, and includes leaktight seals on a milled faying surface on the lock and top shield openings. The very low leakrates (of the order of 13 cm^3/h/linear metre with an underpressure of 20 mm WG needed no improvement. The locks and top shields are therefore the original ones (Fig. 3).

Inside the cell, the locks, top shields and the concrete itself received several coats of an "epicote" paint. The concrete was very carefully prepared: the cracks were plugged with an epoxy filler and all the microcracks with polyvinyl acetate. This last product of very fine grain size (3-5μ) was injected into the microcracks after atomization of a fog suspended in the air in the cell and pressurization of the cell (60-80 mm WG).

This method of injecting fine particles of polyvinyl acetate into the microcracks produced the best results, it being seen that cell integrity was greatly improved.

Thus, by using the standard methods, i.e., painting after filling in cracks visible to the naked eye, the leakrate did not go below 500 l/h for a volume of 36 m^3 with an underpressure of less than 20 mm WG.

After the first polyvinyl acetate spraying, as a result of which the microcracks were plugged, the leakrate went down by a factor of 10 to give a value of only 50 l/h in the same conditions. We believe that during the life of the cell, the integrity of the microcracks may be reduced by irradiation of the polyvinyl acetate, but this can always be corrected by respraying a new microparticle fog into the cell and pressurizing the cell while it is in operation. Safety precautions must, of course, be taken when pressurizing a contaminated cell. Nonetheless, such an operation is perfectly feasible, and will be conducted outside normal working hours.

Cell No. 6 was the first to undergo this treatment. This cell has been in operation for 18 months, and so far no reduction in leaktightness has been observed. This is very important, as cell No. 6 is the storage cell and contains the largest number of fuel elements, subjecting the equipment and the biological shield to the highest integrated dose.

In 18 months of operation, the average integrated dose on the concrete inside the cell is 10^9 rad.

Generally speaking, cracks or "air pockets" are consistently found in the lower part of the metal tubes (windows, plugs, manipulators, periscopes, etc.). These defects occurred while the concrete was setting. On the other hand, the microcracks are situated around the penetration tubes and the interior reinforcements. In both cases, since there is relative underpressure on both sides of the concrete walls, the crack and microcrack lips are ventilated, thus drying the concrete. The concrete loses its humidity at these points and the surface crumbles, which is bound to widen the cracks and thus raise the leakrate. This highlights the importance of ensuring maximum integrity for the concrete walls used for biological gamma shielding and alpha leaktightness.

The results obtained from the completely finished cells are as follows:

Description	Leakrate	Volume	Underpressure mm WG	in $l/h/m^3$ per cell
Alpha caisson	15 l/h	5 m^3	- 20 mm	3 $l/h/m^3$
Cell 6	70 l/h	36 m^3	- 20 mm	2 $l/h/m^3$
Cell 4	125 l/h	36 m^3	- 20 mm	3.5 $l/h/m^3$
Cell 1	200 l/h	36 m^3	- 40 mm	5.5 $l/h/m^3$
Cell 13	2000 l/h	36 m^3	- 20 mm	55 $l/h/m^3$ *

*NB. Cells 6, 4, 1 and 13 had satisfactory leakrates with regard to the operations carried out in each of them, but we experienced some difficulties with respect to cell 13, which has a stainless steel leaktight skin. Here we noted major leaks between the steel and the concrete. These leaks cannot be sealed with polyvinyl acetate and are very difficult to locate as they are never opposite each other on the two sides of the wall (cell interior - cell exterior.

2.2 Handling

The second test consisted in replacing the leaktight manipulator (CRL Mod.A) in cell 3 with a normal manipulator (CRL Mod 8), the leaktightness of which was ensured by a PVC protective sleeve (Ref. 9).

Over a one-year period, we measured the defects in leaktightness in relation to the deterioration of the protective sleeve, and in particular, we noted the contamination and variations in underpressure of the cell compared with the working area. Taking an overall view, tests showed that in the worst case there was no rise in contamination towards the front area and therefore no specific risk due to the protective sleeve (Ref. 10).

On the other hand, the time required for changing a defective manipulator has been definitely lowered compared with the time normally taken. In order to change the magnetic transmission telemanipulator on a caisson it was essential to transfer the caisson into a decontamination chamber, completely dismantle it, and then change the telemanipulator. This method clearly was not viable, for in order to ensure maximum speed and efficiency it would have been necessary to possess all the equipment and caissons in duplicate so that the caissons could be changed immediately if a breakdown occurred. This solution is obviously not feasible, as it is very expensive and moreover requires a great amount of flexibility and speed in operation as regards the decontamination chamber, in order that this facility be available each time a breakdown occurs on any one of the caissons (Refs. 4 and 5).

Alpha/beta/gamma cells are fitted with a guillotine trap-door in the top-shield which enables the "slave" portion of the telemanipulator to be withdrawn from inside the cell. When a defect occurs in the inside portion of the telemanipulator, it is therefore necessary to open this trap-door and to work over the shield and thus be exposed to direct gamma radiation, which results in a rise in the irradiation dose received by the maintenance personnel. On average, a cell which has a 1000 rad/h dose rate at the working level has a value of 50-100 rad/h at the top shield, whereas in the axis of the telemanipulator tube there is only 100-500 mrad/h at the front wall. Moreover, the standard telemanipulator costs only half the price of the "leaktight" model. We therefore unhesitatingly chose a standard telemanipulator with a protective PVC sleeve for leaktightness. Standard manipulation procedures were thus resorted to, as utilized in laboratories such as Los Alamos (Pu metallurgy), Karlsrühe (Pu metallurgy and transplutonium elements), Oak Ridge (transplutonium elements).

2.3 Decontamination

As regards access, experience was acquired with the alpha/beta gamma cells with a leaktight steel skin, namely, Nos. 2, 3, 10, 11 and 0 (henceforth 12 and 13) (Ref. 6).

Work in the cells covered 13 months of actual experience on decontamination and repairs in an active environment.

The choice of the possibilities for the erection of the partitioned areas at the back was very good. During the various decontaminations, we did not note any spreading of contamination beyond the back areas. The method used for decontamination and work in the alpha/beta/gamma cells is completely conventional. Cell access is via a back door after actuation of the additional air-extractor, which sets up a 1 m/s air current at passage level. The inside wall of the door is obviously contaminated, and as soon as it is opened it must therefore be decontaminated.

The initial contamination rates are very high (10^4 - 10^5 MPC). The cell cannot be entered during this period. The first operation is therefore to ventilate the cell vigorously while reducing the beta/gamma activity by remote pressurization of the "hot spots" (50-100 rad/h on contact). Generally speaking, after removal of the mobile equipment, the dose rate ratios measured on the surfaces or by wipe-tests are as follows, in relation to the working area (Ref. 10).

- Working area	:	100%
- Walls at working area level and prefilter extraction louvres	:	60%
- Ground at elevation 0 on the grid	:	40%
- Window	:	35%
- Walls above the working area	:	25%

- Back door above the working area : 20%
- Walls at ceiling level and ceiling : 5%

After pre-decontamination, entry into the cell is allowed. The contamination rates then range between 10^2 and 10^3 MPC. It would be rash to think that, because of the back zones, the additional air extraction and the contamination rate in the 100-1000 MPC range, decontamination is an easy operation which may be carried out by anyone. In fact, at this stage, the real work has yet to start, and the smooth running of decontamination operations depends solely on the experience and competence of the decontamination team as a whole.

2.4 Equipment

We used an identical working area to that of the other cells for the basic equipment of the high-capacity alpha cells. The main problem was to ensure that the entire working area could be dismantled and evacuated by remote control. It is therefore made of a metal structure with demountable IPN steel sections on which a number of stainless steel plates (500 x 500 and 3 mm) with a resistance of 300 kg/m^2 are laid.

The electrical and pneumatic (fluid) circuits converge in cabinets along the sides of the cell (Ref. 17).

Special equipment is usually kept down to the minimum volume and cost. The waste from equipment which can no longer be used is evacuated via the top shield and packaged in the tunnel running above the cells.

Transfers, or more generally the connections which enable the various materials to be inserted into or withdrawn from the cells, are carried out with the help of leaktight devices, i.e., double-lid door, glove-box, plugs and carousels.

Communication between the cells remains the same, i.e., by means of a magnetic transmission carrier for cells 12, 13, 1, 2, 3, 4, 5, 6 and 7a, or using inter-cell carousels between 7-8, 8-9 and 10-11, or by a pneumatic circuit between cells 1-2 ↔ 11, 3 ↔ 10, and 7 ↔ the hot laboratory.

3. CONVERSION OF LABORATORY

3.1 Cells

The laboratory is made up of two rows of perpendicular cells. The main row comprised cells 0-7 (now cells 12, 13, 1-7a). A tunnel runs above these cells. Previously, this tunnel was used for transferring caissons to the decontamination cell. In the small 7b-11 row the roof of the cells comes directly out at the back. These cells mainly include cells 7, 8 and 9 for non-destructive beta/gamma tests, and the alpha/beta/gamma cells 10 and 11, which are used for specific tests and metallography. The small row did not include a caisson, and therefore underwent no major modifications. The only changes were for improvements to equipment or for re-equipment purposes.

The main row included caissons in cells 1, 4, 5, 6 and 7a. Cells with an alpha in beta/gamma caisson were modified, together with the decontamination cell, ex-cell 0.

We retained the same (concrete) structures, and the same general circuits (fluids, ventilation in air and closed circuit ventilation) to modify the following cells (Fig. 4) (Ref. 8):

- Cell No. 6 - storage (Ref. 16)
- Cell No. 2 - machining (Ref. 11)
- Cell No. 4 - specific tests and micro-machining (Refs. 11 and 12)
- Cell No. 1 - metallography (Ref. 13)
- Cell No. 13 - machining, density (Refs. 11, 14 and 15)
- Cell No. 7 - packaging, transfer (Ref. 16)

Cells where alterations are not yet complete are:

- Cell No. 12 - non-destructive tests (Refs. 12, 18 and 19)
- Cell No. 5 - not yet decided.

These modifications have enabled 46 m^2 of hot surface area to be recovered, made up of 21 m^2 decontamination cell and 5 m^2 left by each caisson, i.e., 25 m^2, making a total of: 21 + 25 m^2 = 46 m^2.

In 1971, the reconstruction programme is almost finished, and, as Fig. 5 shows, cell unavailability for the first five years was only just over 10% (12.86%). Roughly, this represents 513 months' work and 67.5 months' outage for repairs, decontamination, equipping, etc. It can thus be seen that conversion of the laboratory was carried out in almost the normal operating time, since for a laboratory with an equivalent number of cells it is standard practice to have one cell permanently shut down for repairs. Nevertheless, it should be noted that the greatest load was carried out during 1970 with 34 months of cell re-equipping (Ref. 17).

3.2 Equipment

The modification of all the cells stems from the desire to increase the amount of equipment in order to be able to carry out a wider range and a greater number of tests.

For a better assessment of the value of these modifications, the various items of equipment in each hot laboratory are compared in the following tables:

1967 Version	1971 Version
<u>Cell 0 (βγ)</u> - Decontamination of Caissons	<u>Cell 12 (βγ)</u> - Transfer: dia 270 mm - Length: 5 m Weight: 1 tonne - Gamma spectrometry: 2 m capacity GeLi-NaITl - 400 kV radiography: 2 m capacity - Kr^{85} extraction (can) - sampling of released fission gases 2 m capacity - Sodium loop (1972) - Metrology - Slow creep (600 bars) <u>Cell 13 (αβγ)</u> - 3 furnaces: Na compatibility + clad + fuel - Fast sectioning machine - Ultrasonic machining equipment - Balance - Storage in vacuum - Impregnation
<u>Cell 1(α→βγ)</u> - Microscope: Brachet St. Gobain - Polishing machines - Coating machine - Polishing machine	<u>Cell 1 (αβγ) (Fig. 7)</u> - Microscopy: Leitz MM 5 RT (Fig. 6) - 4 Tourret polishing machines - 1 Stella polishing machine - 2 ionic bombardments - Authogyr dentist's drill - Periscope: Kollmorgen - Coating machine - Impregnation

1967 Version	1971 Version
	- Hoops for tensile test specimens - Pneumatic tube conveyor via II
<u>Cell 2 ($\alpha \beta \gamma$)</u> - Storage: Pu: 1750 kg Pu + U^5 : 10 kg	<u>Cell 2 ($\alpha \beta \gamma$) (Fig. 8)</u> - 1 lathe - 1 dismantling unit - 2 fast sectioning machines - Ultrasonic machining equipment - Device for recovering Na and NaK - Periscope - Authogyr dentists' drill - Coating machine - Impregnation - Pneumatic tube conveyor via C II
<u>Cell 3 ($\alpha \beta \gamma$)</u> - Dissolver - Pneumatic tube conveyor via C 10	<u>Cell 3 ($\alpha \beta \gamma$) (Fig. 9)</u> - Ultrasonic machining equipment - Lathe - Fast sectioning machine - Pneumatic tube conveyor via C 10
<u>Cell 4 ($\alpha \rightarrow \beta \gamma$)</u> - Fast sectioning machine - MIME mechanical microsampling	<u>Cell 4 ($\alpha \beta \gamma$)</u> - MIME mechanical microsampling - MUSE ultrasonic microsampling - VEGA device for recovering occluded fission gases - Balance (10^{-5} g) - Furnace (1200°C) - Periscope

1967 Version	1971 Version
<u>Cell 5 (α – βγ)</u> - Slow sectioning machine - Na – NaK destruction	<u>Cell 5 (αβγ)</u> - To be defined
<u>Cell 6 (α→βγ)</u> - Dismantling unit	<u>Cell 6 (βγ)</u> - Pu storage: 25 kg Pu + U^5: 80 kg - Storage in vacuum
<u>Cell 7a (α→βγ)</u> - Transfer lock - Ultrasonic tank	<u>Cell 7a (αβγ)</u> - Transfer lock - Ultrasonic tank - Sectioning machine for pin channel - 2 ton press - Can-sealing device (5 l container)
<u>Cell 7b (βγ)</u> - 200 ton press - Pneumatic tube conveyor via hot laboratory	<u>Cell 7b (βγ)</u> - 200 ton press - Pneumatic tube conveyor via hot laboratory
<u>Cell 8 (βγ)</u> - 300 kV radiography - Sampling of fission gases	<u>Cell 8 (βγ)</u> - 300 kV radiography - Sampling of fission gases
<u>Cell 9 (βγ)</u> - γ NaITl spectrometry (600 mm capacity) - Metrology - Periscope	<u>Cell 9 (βγ)</u> - γ GeLi – capacity: 800 mm NaITl - Eddy currents - Metrology

1967 version	1971 version
	- Slow creep (150 bars) - Periscope - Fission radiography
<u>Cell 10 (α β γ)</u> - X-ray diffraction - Density - Pneumatic tube conveyor via C3	<u>Cell 10 (α β γ)</u> - X-ray diffraction - Density - Pneumatic tube conveyor via C3
<u>Cell 11 (α β γ)</u> - Reichert microscope - 1 polishing lathe - 2 ionic bombardments	<u>Cell 11 (α β γ)</u> - Reichert microscope - 1 polishing lathe - 2 ionic bombardments - α autoradiographic device - β autoradiographic device
<u>Hot laboratory</u> 01 - Transfer box via C7 02 - α autoradiograph developing box 03 - α box for processing microprobe replicas 04 - Nothing 05 - Cobalt monitor 06 - Nothing 07 - Sorbonne 08 - Sorbonne 09 - Nothing 10 - Nothing	<u>Hot laboratory (Fig. 10)</u> 01 - Transfer box via C7 02 - α autoradiograph developing box 03 - α box for processing replicas 04 - Evaporator 05 - Cobalt monitor 06 - α box - X-ray diffraction 07 - Sorbonne 08 - Sorbonne 09 - Tensile and compressive testing device 10 - Testing of vapour tension of fission products.

4. CONCLUSIONS

It should be noted that future modifications had been allowed for when the radiometallurgy laboratory was being constructed. The changes made were planned, or rather, had not been totally discarded. As from 1964, during the construction of the front wall of the cells, the wall was equipped with ducts enabling direct telemanipulators and various equipment (periscope, glove-box, etc.) to be inserted.

These various modifications were carried out during the normal operating periods necessary for re-equipment after cell decontamination. No supplementary funds were allocated for this work. Had it not been carried out, the budget necessary for operating cells with magnetic transmission telemanipulators would have been doubled as regards the items relating to Cells 1, 4, 5, 6 and 7a. Moreover, the work rates for these cells could only be increased by installing sophisticated "robot" type equipment, which was completely at variance with the normal approach and was bound to result in a new rise in the equipment budget.

Now, with its 117 m^2 of hot surface area, the Radiometallurgy Laboratory is able to maintain a steady working rate and carry out a wider range of various tests.

In line with the several lines of the specific tests (sodium, NaK, fission products, etc.), cell equipment specially adapted for this work is to be installed. Cells 5 and 8 will be the first cells to be equipped. However, we can already study fuel elements 2 m long and, if we have enough personnel, we shall be able to maintain an average working rate making it possible to test one pin a day.

5. FIGURES