Two different methods for improving contamination confinement when refurbishing a hot cell

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Abstract

During the refurbishment of the LECA facility at Cadarache, it was necessary to both improve the confinement of contamination inside hot cells and comply with new safety rules, considering these cells were built in the sixties. Two different leak rates were established depending on the type of examinations performed on irradiated fuel rod elements. If the examination was considered to represent a low contamination hazard (e.g. non-destructive testing, or destructive testing with a dedicated containment system), the target rate was set at a maximum leak rate of 10^{-1} volume per hour. The leak rate for destructive testing had to be less than 10^{-2} volume per hour.

In the first case, after careful decontamination of the inner walls, a leak-proof stainless steel box was inserted inside each of the smallest cells to improve confinement and facilitate decontamination later on. In this case, the contamination hazard was separated from the radiobiological shielding provided by the concrete or lead walls.

In the second case, concerning the largest cells in the facility, work concentrated on detecting leaks, i.e. between the different parts of the cell roof and in all shielded plugs in the walls used for introducing cables or connection systems. New equipment (filters, manipulators or crane units) was designed for minimizing leakages and was placed inside the cells by remote manipulation.

This paper describes both methods and provides feedback on the refurbishment of both the largest and smallest cells. It shows how changes were made, the specific difficulties encountered in reaching the targeted maximum leak rates and how such leak rates were measured.

Keywords: ***Facility - hot cells - refurbishment - seismic strengthening - ventilation***

1. Introduction

The LECA or *Laboratoire d'Examen des Combustibles Actifs* (Irradiated Fuel Examination Laboratory in English) was designed and built in the sixties to examine irradiated fuels. This facility can be described as a standard laboratory equipped with a series of hot cells and was built in compliance with safety rules in force at the time. Commissioned in 1964, the LECA has thus far been operational without any major safety problems, providing considerable feedback in terms of operations and experimentation. However, its out-of-date design, combined with the continuous reinforcement of safety rules led the operator to consider refurbishing this building. Launched in 1997, the refurbishment project was submitted to the safety authority in 2000. A year later, approval was granted on the condition that refurbishment work was completed before August 2005 and operations continued until 2015. In parallel, substantial efforts were made to reduce the source term.

The project included:

- ✓ Civil engineering work on the building and cells to reinforce earthquake resistance so as to withstand a maximum historically probable earthquake;

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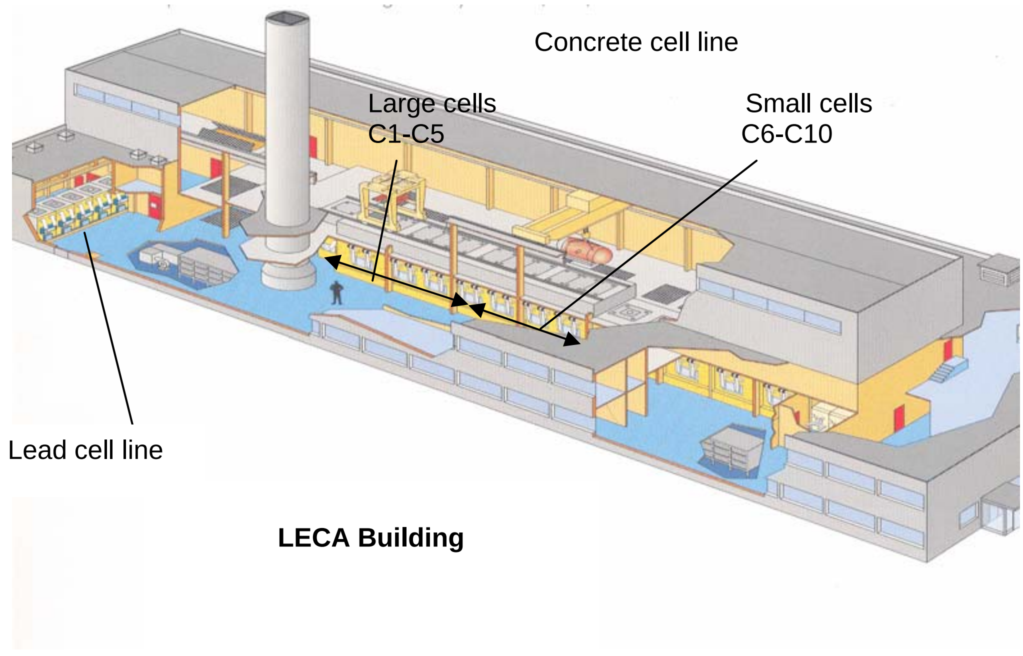
- ✓ Decontamination of the most irradiated cells and substantial reduction of the stored fissile mass;
- ✓ Improvement of static confinement by equipping the most irradiated cells with boxes, upgrading containment and using a mobile shielded air lock in the upper part of the cells;
- ✓ Improvement of dynamic confinement by upgrading the ventilation system;
- ✓ Replacement of electrical power supplies, remote manipulators and observation ports;
- ✓ Replacement of the main travelling crane and various other handling devices;
- ✓ Improvement of fire sectors, radiological zoning and radiological controls;
- ✓ Development of a cell designed to characterise waste produced by the facility.

The new reference system is to be implemented on 1 December 2006 so corresponding work must be finished before this date.

2. Improving static confinement

The LECA laboratory includes alpha, beta and gamma hot cells dedicated to experiments on irradiated fuel. The laboratory is composed of two lines of cells with a total surface area of 120 m²: the lead cell line is currently being decommissioned, whereas the concrete cell line is being refurbished.

The concrete line is composed of 10 cells with 1.2 m thick walls made of heavy concrete. With a ground surface area ranging from 6 m² (C6 to C10 small cells) to 15 m² (maximum surface area of the C2 to C5 large cells), these cells are used for both non-destructive testing (eddy currents, X-ray radiography, gamma scanning, profilometry and fission gas measurements) and destructive testing (cutting, metallographs and microprobes), not to mention sample conditioning operations prior to irradiation.



LECA Building

Historically speaking, the most contaminating experiments on the most irradiated samples were always performed in the C6 to C10 small cells. The refurbishment project objectives therefore consolidate this tendency, with the final objective being to considerably improve confinement performance levels. The project submitted to the safety authority in 2001 included the decontamination of cells C2 to C10 and the insertion of stainless steel boxes inside cells C7 to C10.

During the first phase of decontamination on cells C7 to C10, it was observed that efforts required to render cells accessible for direct contact work had significant consequences on costs and deadlines. It was necessary to scrape several centimetres off the concrete walls using robotised means. Such operations were continued in cells C7 to C10 but the personnel involved in the project got together to find alternative solutions for cells C2 to C5.

3. Manual refurbishment work on the c7 to c10 small cells

3.1 Initial state

Before refurbishment, cells C7 to C10 were highly contaminated with ambient dose rates of about 1 Gy/h. A certain number of damaged equipment had been stored within, which made it very difficult to access these cells and impossible to carry out any experiments.

Fig. 1: Initial state of cell C9

3.2 Decontamination

This phase aimed at reducing the ambient dose rates in the cells to less than 0.25 mSv/h. A first phase of decontamination was performed in the most contaminated cell C9. This phase lasted 3 years and led to a change in methods.

During the first two years, the CEA attempted to decontaminate the cell using standard methods: operators protected by shielded decks working in direct contact. This first phase ended in failure for two reasons: the processes used (chemical decontamination of concrete) were inefficient and the accumulated dosimetry was much higher than set objectives (approximately 30 h.mSv with a residual dose rate higher than 2 mGy). Feedback logically led the CEA to employ remotely-operated means such as the STAUBLI RX-type arm equipped with concrete scabbling tools designed to implement decontamination tools capable of scraping concrete.

Fig. 2: RX arm equipped with booting

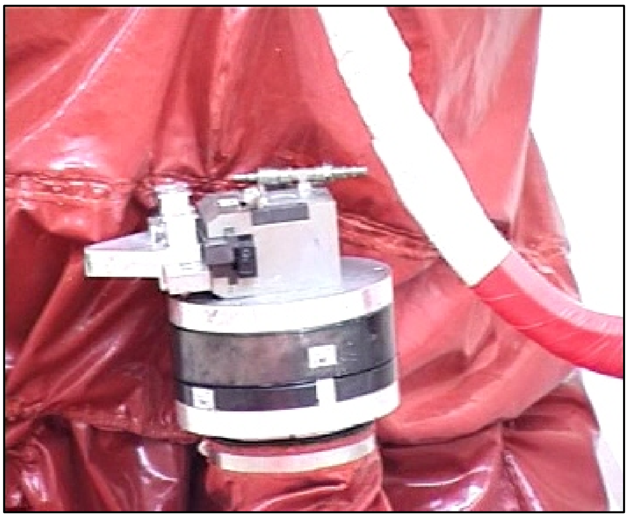


Fig. 3: Tool changer

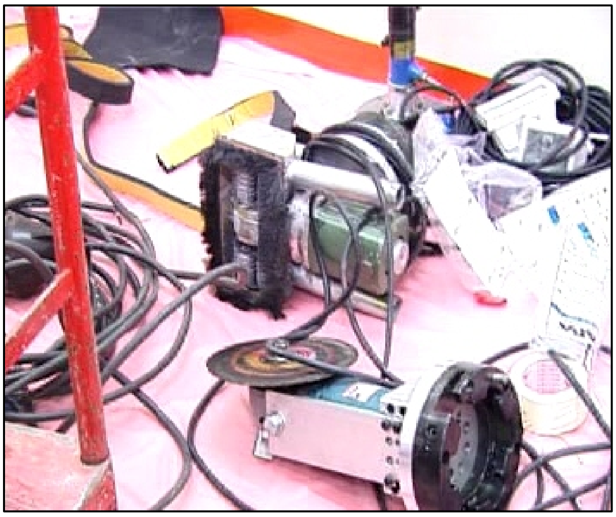


Fig. 4: Various tools – disk cutter and concrete scraper

Fig. 5: needle scaler for concrete scabbling

This change in method made it possible to finish decontaminating cells C7 to C10 by limiting the impact of frequent delays upon refurbishment operations. The decontamination of cell C10 was completed in July 2002, whereas C7 was finished in 2004.
The total cost of decontaminating cells C7 to C10 amounted to €2 million whereas the dosimetric total amounted to 50 h.mSv

3.3 Refurbishment of cells C7 to C10

This operation consisted in adding a stainless steel box in each cell and rebuilding all passages between the cell and its environment:

- Roof slab connecting with the upper room of the LECA building,
- Rotating cylinders connecting with adjacent cells,
- Remote manipulators, electric plugs and fluids, as well as observation ports connecting with the front zone,
- Air locks and cask connexions for equipment and samples entering and exiting the rear zone.

Other than being earthquake-proof, the boxes were originally designed to guarantee leaktightness with a leak rate less than 10^{-2} vol/h. It was therefore necessary to build:

- A removable leaktight roof,
- Slide valves on the plugs,
- Rings and bootings on remote manipulators, wall penetrations for electricity and fluids, and alpha-shielding glass in front of the observation port,
- Leaktight cask connexions with double doors for cell C9 and two equipment air locks for cells C10 and C8.

Fig. 6: Inserting a stainless steel box into a cell

This operation began in 2002 with in-cell measurements and preliminary studies and ended in 2005. The manufacturing of boxes C9 and C10 began 6 months before that of C7 and C8, but finished at the same time in December 2005 owing to technical difficulties.

The assembly phase itself lasted two years. Various problems were encountered due to the fact that the existing facility had not been taken into sufficient consideration. For example:

- The boxes were not very adjustable:
  - While positioning the box, the openings were adjusted to correspond with those in the walls and then the box was horizontally attached. When it came to adjusting the hatches and plugs of the main upper hatch, the accumulation of positioning uncertainties, manufacturing tolerances and measurement errors resulted in a difference of several centimetres. It was therefore necessary to modify the boxes.
  - The exhaust ducts that were pre-manufactured based on site measurements could not be assembled.
- Positioning operations resulted in the contamination of the box outer walls. Next, when the cell ventilation systems were switched back on, the inefficiency of certain temporary seals led to a low level of contamination inside the boxes. The operators thus had to decontaminate certain zones, and weari suitable work clothes (leaktight suits and protective masks) when setting up equipement.

The total cost of this operation amounted to €5 million and the dosimetric total amounted to 100 h.mSv. The four cells are now in the start-up phase and prove to be satisfactory.

4. remotely-operated refurbishment on C2 to C5 large cells

4.1 Object

The initial refurbishment strategy for cells C2 to C5 was identical to that of the C7 to C10 small cells. This strategy was modified to take into account feedback related to the problem of cleaning small cells and observations concerning the acceptable impact of remote operations on the difficulty of fitting out cells.

4.2 Objectives

The CEA had to deal with problems such as:

- Limiting the impact of work on the progress of experimental programmes,
- Removing unused fuel within the scope of limiting the source term,

- Reducing doses delivered to personnel carrying out refurbishment operations,
- Cutting costs by limiting cleaning operations (taking into account feedback from small cell cleaning) and related risks,
- Enabling front zone technicians to take part in remote cleaning operations,
- Having the possibility of keeping transfers between cells in the concrete cell line,
- Rapidly taking into account installed equipment,
- Controlling cell configurations as refurbishment operations progressed,
- Reducing the time needed to refurbish cells.

In return, it was necessary to take into account both the increased complexity and the risk of additional costs related to the feasibility of equipment and remotely-operated renovations.

4.3 Description of refurbishment operations

The following equipment was first removed from cells C3 and C4:
- Heavy remote manipulators and related beams,
- Lifting devices, related beams and travel tracks,
- Electrical cabinets,
- Internal shelves.

Following this phase, cell equipment was partially removed and the cell walls were briefly cleaned (suction, wiping and paint).
- Cell C2 was pre-cleaned by remote operation. Biological shielding was installed to block hot spots.
- In cell C3, all small equipment required removal, whereas the work bench and the VENDAUM bench (compact and only slightly irradiating) were left in the cell. However, the PLACID bench was removed (temporarily or permanently), being both fragile and bulky.
- All small equipment, tools and the work bench were removed from cell C4,
- No additional cleaning was performed in cell C5.

The following refurbishment operations were performed by remote operation:
- Dismantling and replacement of pre-filtering boxes,
- Replacement of remote manipulators and ring seals,
- Replacement of cabinets for electrical sockets,
- Upgrading of cask connexions for packagings and transfers in cells C4 and C5,
- Replacement of lifting devices and heavy remote-handling equipment,
- Creation of two equipment air locks.

The following refurbishment operations were performed outside the cells:
- Improvement of penetration leaktightness,
- Upgrading of roof, door and rear zone confinement systems.

The equipment air locks were inserted into their sheath from the inside of the cell, with fixtures being attached from the rear zone without any specific problems being encountered. The leaktight inner door of the C4 cask connexion was more problematic seeing that the fixtures were located inside the cell. Assembling by remote operation required decoupling the entire assembling process: a thick steel structure was used to establish a reference position and perform leaktight operations on the cell wall. This plate was assembled and adjusted using a template. Drilling operations required to fix the fastening bolts were then performed using tools mounted on supports designed to bear tool-related loads. Lastly, the door was mounted on its structure. This operation had been well-planned and did not come up against any difficulties.

The dismantling of old prefilters and the assembly of new ones required several weeks of remotely-operated work. The range of movement of the slave arms and their load capacities were limited for this application. The very unfavourable cutting position and the transitory loads owing to the cutting tools (disk cutter) resulted in numerous remote manipulator breakdowns. This problem had not been anticipated and therefore resulted in several delays. Feedback from these operations can be summarised as follows:
- Remotely-operated work required:
    - An adapted design of equipment and tools: the assembly of equipment required decoupling difficulties encountered (installation, adjustment and then fastening) and using templates. Tools

needed to be adapted to avoid overloading the remotely-operated arms and to establish the drilling sequence.

- In-depth preparatory work in uncontaminated conditions: full-scale tests on models, personnel training, validation of equipment and tools in the presence of CEA operators.

The total cost of refurbishing cells C2 to C5 amounted to about €3.5 million, including engineering and operation costs. The dosimetric total remained very low (less than 5 h.mSv). Costs were cut by an estimated €1 million thanks to remote operations.

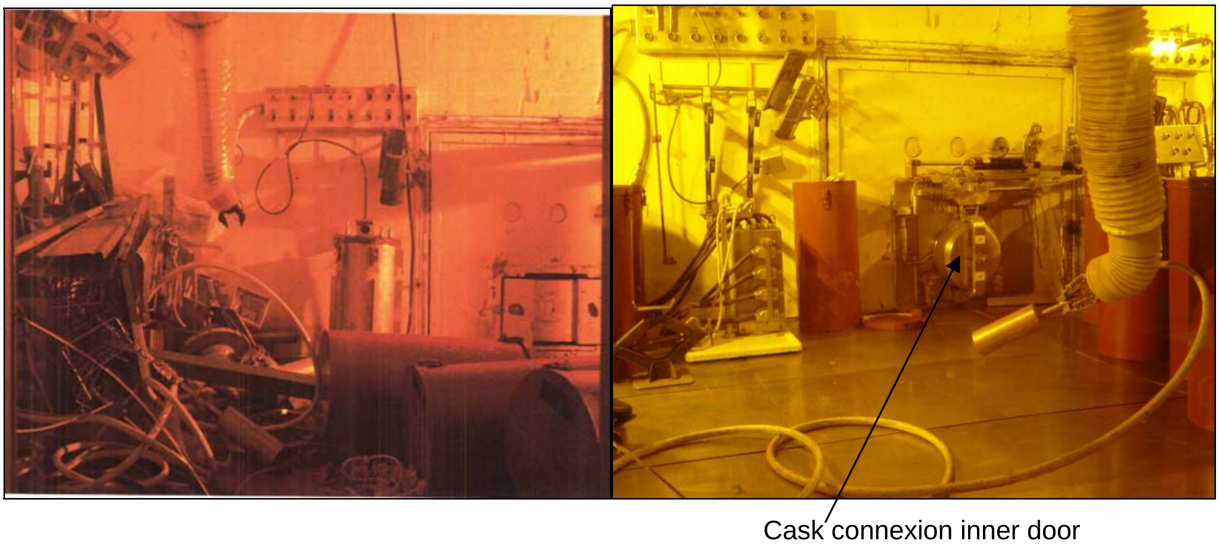


Fig. 7: Cell C4 before and after refurbishment

5. Review

The refurbishment cost for 4 small cells reached a total of €7 million, with the dosimetric total adding up to 150 h.mSv. The refurbishment cost for 4 large cells reached a total of €3.5 million, with the dosimetric total being insignificant. Described in such terms, analysis is clearly in favour of the remote operation option, so why wasn't such reasoning applied to the refurbishment of the small cells. In reality, the situation was much more complex and could not be evaluated by simply comparing costs. Remote operations were not feasible on the small cells.

- The nature of the experiments conducted in the small cells required reinforced confinement corresponding to a leak rate less than 10^{-2} volume per hour. This restriction itself justified the use of stainless steel boxes.
- The boxes could not be adjusted by remote operation: welding and precise adjustments required human presence in inaccessible areas. The level of skill required for such operations was incompatible with the remote manipulator technology.
- The small cells needed to be cleaned so the operators could install the boxes.

Feedback shows that techniques used in contaminated cells for major refurbishment operations must be chosen without disregarding any parameter. Among such parameters, the following must at least be taken into account:

- Initial level of contamination,
- The nature of operations to be performed,
- The complexity related to the installation of new equipment,
- The radiological level that must be compatible with implementation methods (direct contact or remote operation).

It was not possible to refurbish the small cells without prior major cleaning. The choice was however possible for large cells, and the nature of the operations was compatible with remote operations. The CEA was able to cut costs and follow the schedule.

This said, the cells will one day require cleaning in order to decommission the facility. In this case, the cleaning operations carried out in the small cells will have been a good investment: the walls are now relatively clean and the stainless steel boxes are easily decontaminated. However, major cleaning in the large cells remains to be done.

6. Obtaining and controlling expected levels of confinement

As previously mentioned, the expected levels of confinement correspond to a leak rate less than 10^{-2} volume/h for small cells equipped with boxes and a leak rate of 10^{-1} volume/h for large cells.

6.1 C7 to C10 small cells

The expected level of confinement was reached and subsequently controlled in the small cells. The main problems involved detecting leaks and depressurising the boxes.

Leak detection: this consisted in measuring the pressure at which the stainless steel box stabilised, before using a smoke generator to detect leaks. During the refurbishment operations, the operators were able to work in leaktight suits. Next, tests from the front zone of the boxes were performed. This is why a remotely-operated device had to be built in order to connect a tube to a penetration so smoke could be injected into the cell. This device was equipped with a camera used to detect leaks.

Depressurising: this method for measuring leaks consisted in depressurising (500 Pa) the boxes and timing the pressure drop. Seeing that the LECA ventilation system had been upgraded, the driving pressure in the exhaust manifold was improved. It was therefore necessary to limit the vacuum level and foresee a test procedure making it possible to protect equipment. The stainless steel boxes have now been tested and proven to be leaktight.

6.2 C2 to C5 large cells

The refurbishment strategy for the large cells greatly impacted on the foreseen confinement controls. Initially, each cell was to be controlled separately following refurbishment so as to check that its leak rate was less than 10^{-1} volume/h. This control was made possible by major cleaning and rendering cells accessible to operators. Such accessibility made it possible to isolate each cell using leaktight devices.

The new refurbishment strategy – including minor cleaning – did not make it possible to isolate the cells between themselves, which thus required conducting an overall test on the concrete cell line (10 cells). This offered the advantage of being able to disregard passages between cells but made it harder to detect leaks.

Launched in June 2006, the tests have yet to be completed and leaktight operations are still underway. Problems exist on the same level as that for the stainless steel boxes.

Leak detection: detecting leaks is a complicated task owing to the size of the concrete cell line. During depressurisation, the front and rear zones have to be check to detect any smoke leakage. The main problem is related to the facility's history, which is not always known as a number of wall penetrations were not recorded on plans. This means that each zone needs exploring to evaluate the risk of unreported changes and leaks owing to such changes. The smoke test is then conducted and any leaks are sealed. The upper spacer block of cells C6 to C10 is a specific area containing various holes for the passage of cables and pipes, which are poorly visible from the outside.

Depressurising: as for the boxes, seeing that the cells were much more leaktight in the past, closure of the transfer dampers can lead to a pressure increase capable of damaging equipment. A device enabling the progressive rise in pressure is therefore required during the test. However, this device makes the test much longer because the volume to be depressurised is about 350 m^3 in comparison with 15 m^3 for a box. The complete sealing of the concrete cell line has been programmed for the end of September 2006.

Thanks to brief feedback on leaktight tests, it can be seen that the boxes used in the small cells made it easier to obtain the expected confinement level. However, the inaccessibility of the large cells – owing to simplified cleaning operations – made leaktight operations much longer.

7. Conclusion

During the refurbishment operations on the LECA facility, different strategies were used to upgrade two groups of cells. These strategies were chosen taking into account the initial contamination levels in these cells, the complexity of the required refurbishment work, the expected level of confinement following refurbishment and the type of experiments to be performed in such cells.

Refurbishment of the C7 to C10 small cells cost more than the large cells, seeing that they required major cleaning and the addition of stainless steel boxes. However, these cells have since been tested leaktight and are now ready to house contaminating experiments.

The refurbishment strategy for the C2 to C5 large cells changed during the project, taking into account feedback and including remote operations. This strategy made it possible to both cut costs by €1 million and shorten the deadline for refurbishment operations by about a year. However, this choice would have been unsuitable had it been necessary to install more complex equipment; furthermore, this choice required changing the leaktight testing method, which delayed performance tests on the entire cell line.

In terms of the experimentation devices, it seems that a third approach is being developed. More and more frequently, the devices themselves ensure the confinement of the fuel on which the experiment is being conducted. The devices are equipped with a leaktight confinement or suction system making it possible – during normal and incidental operation – to confine contamination. The Crocodile leaktight test oven and the Coralie test bench with integrated suction meet such requirements.

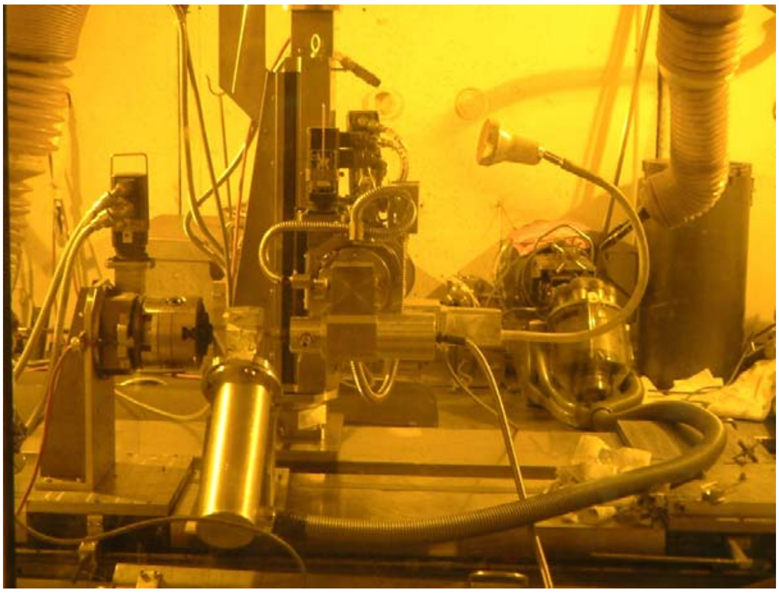


Fig. 8: Coralie device equipped with integrated suction