ZÁPADOČESKÁ UNIVERZITA V PLZNI

FAKULTA ELEKTROTECHNICKÁ

Katerdra elektroenergetiky a ekologie

DIPLOMOVÁ PRÁCE

Demontáž jaderných zařízení v CEA Saclay

Bc. Ondřej Plojhar 2014

Abstrakt

Předkládaná diplomová práce řeší problém kompletní renovace horké komory pro třídění vysokoaktivního jaderného odpadu v CEA Saclay. V práci je navržen postup údržby horké komory a také je zde navržen nový proces pro třídění jaderných odpadů uvnitř horké komory. Je zde také vypracována bezpečnostní analýza, která bere v potaz jaderné i nejaderné risky.

Klíčová slova

Horká komora, jaderný odpad, bezpečnostní analýza, úroveň ozáření.

Abstrakt

This Diploma thesis deals with the problem of complete renovation of the hot cell which serves for the treatment of high activity level nuclear waste in CEA Saclay. In the thesis are designed steps for the maintenance of the hot cell and also for new process inside the hot cell. Also, the safety analysis is included, which deals with nuclear and non-nuclear risks.

Klíčová slova

Hot cell, nuclear waste, safety analysis, activity level.

Prohlášení

Prohlašuji, že jsem tuto diplomovou práci vypracoval samostatně, s použitím odborné literatury a pramenů uvedených v seznamu, který je součástí této diplomové práce.

Dále prohlašuji, že veškerý software, použitý při řešení této diplomové práce, je legální.

....

podpis

V Plzni dne 8.5.2014 Bc. Ondřej Plojhar

Poděkování

Tímto bych rád poděkoval vedoucímu diplomové práce Ing. Jane Jiřičkové, Ph.D. za cenné profesionální rady, připomínky a metodické vedení práce. Dále bych rád poděkoval panu Michel JEANJACQUES, který vedl můj projekt během mé stáže v CEA Saclay.

Poděkování také patří celé mé rodině za podporu během mého studia.

Outline

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Terminology:

CEA – Commissariat à l'énergie atomique et aux énergies alternatives
EP – Primary Package (Emballage Primaire)
HTM – Heavy telemanipulator
HLW – High Level Waste
MLW – Medium Level Waste
LLW – Low Level Waste
VLLW – Very Low Level Waste
HA – High Activity (Haute Activite)
INB – Basic Nuclear Installation (L'Installation Nucléaire de Base)
SACHA – System Automatisee de Compactage Haute Activite
ALARA – As Low As Reasonably Achievable

1. Introduction

The purpose of this thesis is made a study for the reusing of the hot cell HA in the building 120 of INB 72 for a case of legacy waste treatment. This cell was in past used for segregation of solid wastes, which were made in nuclear facilities in CEA Saclay Centre. But the rules for solid waste management were changed. The segregation of the waste is done directly in the facility, and the hot cell HA has not been used since 2003. But now, in building 114 of the INB 72 are presented drums with legacy waste, which is necessary segregate for future permanent storage. A part of these drums are outside of waste specifications.

The goal of this work is mainly to design the new process inside the cell HA. It includes proposing of pathways of the waste drums, design of new equipment of the cell HA and to design the changes and maintenances, which are needed to do on the cell HA. Also the computation of cost and delay of all works are one of the goals of this work.

I will have to take into account that the nuclear waste is paced in multiple coverage and will have to design the machines for the opening of these drums. Also I have to design the steps for the segregation of the waste and take into account all restrictions.

2. Presentation of the company

French atomic energy and alternative energies commission is a public entity established in 1945. Nuclear energy is one of the key areas of CEA's research since its inception. Now, it is obliged to manage decommissioning of its Basic Nuclear Installations (INB) and holds responsibility of legacy waste. Cleaning and dismantling operations of the facilities are the primary requirements of the CEA decommissioning policies. Nearly 400 million Euros is invested in decommissioning activities each year. Currently, dismantling activities are in progress in Cadarache, Fontenay-aux-roses, Saclay, Grenoble and Marcoule. Present work is under DEMSAC project in CEA SACLAY.

2.1 CEA

The "**Commissariat à l'énergie atomique et aux énergies alternatives**" (Atomic and Alternative Energies Commission) or CEA, is a public establishment related to industrial and commercial activities whose mission is to develop all applications of nuclear power, both civilian and military. CEA is headed by the general administrator currently Bernard Bigot, advised by the high-commissioner for atomic energy, Catherine Cesarsky. Its yearly budget amounts to 4.3 billion € and its permanent staff is over 16,000 persons.

It is divided into 5 operational divisions:

- The division of nuclear energy (DEN)
- The division of technological research (DRT)
- The division of life sciences (DSV)
- The division of sciences of matter (DSM)
- The division of military applications (DAM), which builds the nuclear weapons of the French military and designs the power plants of the nuclear submarines of the French Navy

Civilian Research Centers: Saclay, Grenoble, Cadarache, Marcoule, Fontenay-aux-roses

Military Application Research Centers: Bruyeres-le-Chatel, Cesta, Gramat, Le Ripault and Valduc

2.2 Centre d'Etudes Nucléaires de Saclay (CENS)

Frédéric Joliot-Curie, the then High commissioner of atomic energy and Raoul Dautry, the then general administrator of atomic energy have set up CEA, Saclay. The construction of Saclay started in August 1949. In 1952, the first French van de Graff type particle accelerator was put into operation. In 1953, Cyclotron was put into operation it was quickly followed by waste treatment plant in couple of years. EL3 (heavy water reactor) and PS1 (gas diffusion process) were started in 1957. Spent fuel testing laboratory (LECI) was soon established in 1959. Today, the work force is around 6000 persons and the research carried out in the center in the domains of chemistry, biology, metallurgy, electronics and Physics. Numerous laboratories and research reactors are built up until now in CEA, Saclay for fundamental and technological research, and a few to name are Osiris, Orphee, Tamaris, Neurospin and Saphir.

2.3 Departments

2.3.1 DRSN

Département des Réacteurs et des Services Nucléaires (DRSN) is a department in DEN and the objectives of this department are:

- Operation of OSIRIS (INB 40) reactor, High activity laboratories (INB 49), LABRA (INB 77), Orphée reactor (INB 101), STEL (INB 35) and DS (INB 72), ADEC
- Exploitation of decommissioning INB of FAR
- Sanitation and Waste management
- Maintenance, modifications and Operations of all installations

DRSN total workforce is around 300 persons with five divisions in it.

2.3.2 DPAD

« Département de Projets d'Assainissement et Démantèlement » (DPAD) is a department in « Département d'Energie Nucléaire » (DEN) in Marcoule and is established in 2007. Objectives of this department are:

- Preparing termination of exploitation (CDE) of operating facilities
- Operational management of sanitation and decommissioning of the nuclear installations
- Operational management of projects for recovery of materials and nuclear waste
- Operational management of cleaning the site

DPAD total workforce is around 120 with two sub departments. The mission of the first dub department is to manage the decommissioning projects; this department is divided into another 5 sub departments. The second sub department provides technical services for decommissioning projects; this department is also divided into 5 sub departments. Below given block diagram gives a brief description of DPAD department.

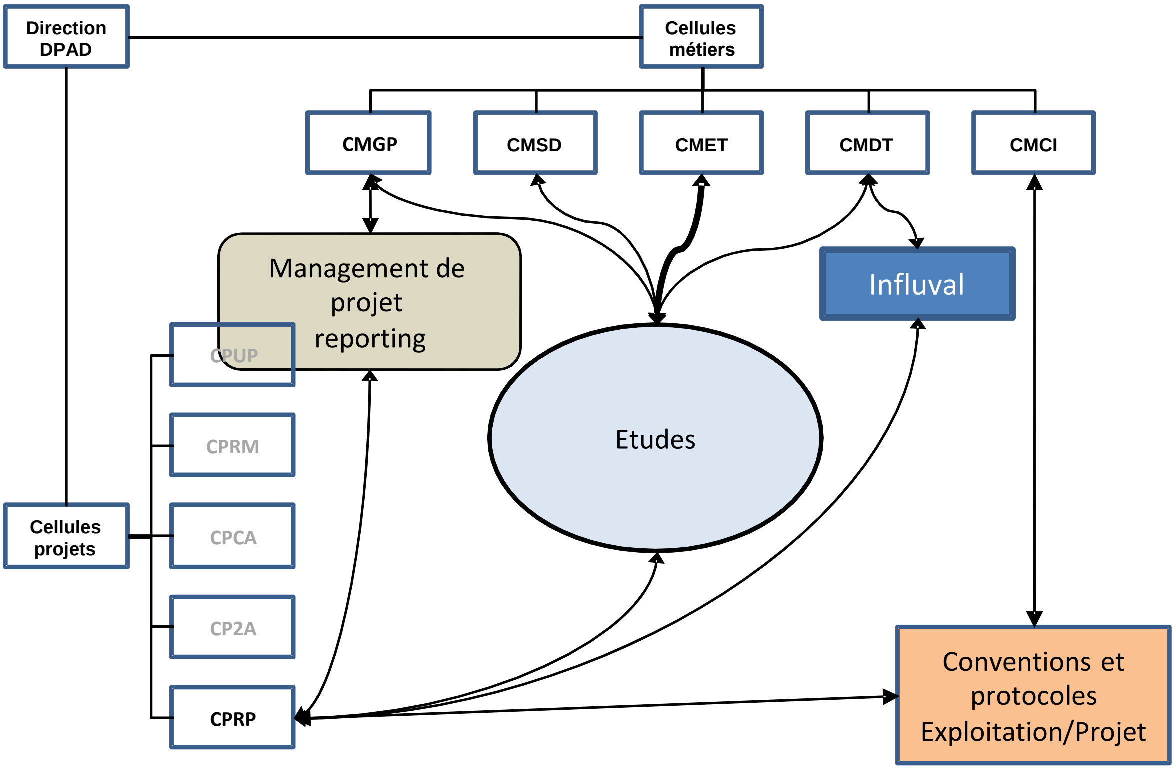


Figure 1 Structural scheme of DPAD

3. Description of the Installation

The Basic Nuclear Installation No. 72 (INB 72), the area of solid waste management, is located southwest of CEA Saclay Centre. INB 72 is involved in storage and treatment of waste produced mainly by the reactors, laboratories and workshops of CEA Saclay. Also, the facilities include the means of testing and characterization of the waste packages. The waste is treated, packaged and stored prior to the evacuation.

The hot cells HA and RCB 120 are placed in the building 120. The cell HA is divided to the six workstations without separation. The cell HA was intended to do the sorting and repackaging of the HLW in solid form, which was produced in the center of Saclay. The operation of HA cell was interrupted between February 1998 and July 1999 to improve the level of safety. Meanwhile, was decided to build a replacement cell (cell RCB 120). Following an internal review, the Directorate of Saclay decided to stop the operation of the cell HA in November 2003.

The cell RCB 120 is in operation. The main tasks of the cell are compaction of drums with nuclear waste and package them. The compacted drums are after compaction put to the laminate basket. The laminate basket is plugged when is full of compacted drums. Plugged laminate basket is put to 60 l drum made of stainless steel. This drum is transported to the building 114 placed in INB 72.

3.1 Description of building 114

There will be provided removing of the waste drums from pits in the building 114. There will be also provided counting of radiological parameters of new waste drums in SACHA system.

3.1.1 The pits

3.1.1.1 Drained pits

These pits are formed in two sets: first one is 60 tubes and the second one is 36 new tubes. The constituent materials are listed below:

- Bulk: sand containing 4% of cement
- Wall of pits: concrete (17 mm thick)

The set of 60 tubes

It consists of 10 rows with 6 pits (arranged in square grid with a pitch of 90 cm by axis) in Fibrocement 7 m in length and 0.40 m in diameter placed vertically in concrete pit 9m x 5.5m and 7.5 m in deep.

Ordinary concrete slab 1.25 m thick provides biological protection for the next level.

The openings of the pits are sealed by plugs with circular cross section of 0.65 m diameter and 0.8 m high. They are made by a concrete barite with density 3.6. A crane in the building 114 can manipulate with this lids.

A double bottom, which serves for supporting of the base on the tubes, provides flow of water into a sump potential control.

The double bottom is obtained in the following manner: on the axis of each of the six rows, there is provided a channel whose slope is facing north. These trenches, which are about 15 cm deep, are covered with concrete slabs 0.05 m. Some of these panels are perforated by a sleeve of 40 mm in diameter corresponding to the center of each tube. In the area of low points, six vertical tubes 40 mm in diameter embedded in the thickness of the veil, reserve access to a dike at the end of the channel for implementation of drawing devices.

These collection points for water are identified from east to west by the names X1, X2, X3, X4, X5, X6.

The set of 36 tubes

These new pits were drilled in 1995 in the pit hall. They have not yet been put into service. The pits are modified by follow procedure:

- It has been emptied of its equipment
- Its rigidity is enhanced by the introduction of a metal frame on its four sides. The space, which left between the metal frame and the edge of the groove, is filled with concrete
- The seal is achieved by the establishment of a horizontal yoke pulled on the bottom of the pit and a steel casing is installed, the casing is then embedded in the concrete filling
- Inserting of gutters under the tubes in the axis of each row, to collect effluent comprising water due to condensation in the pits
- Implementation of pits
- Implementation of concrete filling

The set consist of three rows of 12 pits arranged in a square grid with a pitch of 90 cm by axis.

Each pit is formed by a concrete core with steel tube. The tubes have following characteristics: inner diameter 402 mm, outer diameter 500 mm and length 6120 mm.

The floor of the pit is provided by the ordinary reinforced steel with 1.25 m thick, which provides biological protection at the highest level.

The openings of the pit are sealed by plugs with circular cross section of 0.60 m diameter and 0.80 m high. They consist of shell filled by a concrete. A crane, which is presented in the building 114, can manipulate with this lid.

3.1.1.2 Undrained pits

40 pits without water collection were built on the old storage pits location in reinforced concrete with dimensions 9m x 5.5m and 7.5m deep. They consist of Fibrocement tubes 7m length and 0.4 m in diameter, they are placed vertically. The space between the tubes is filled with sand.

A conventional concrete slab with a thickness of 1.25 m provides biological protection on the top. They are sealed by a plug with circular cross section of 0.65 m in diameter and 0.80 m in height. These plugs are made of barite caps with density 3.6. A crane can manipulate with these plugs.

These 40 pits will be gradually emptied and closed. Pending their closure, their use is restricted to drums with the least important activities. These pits will not be used during works on legacy waste.

3.1.2 SACHA system

All examinations, measurements and loading equipment are located in a sealed concrete pit (dimensions 10 x 3 x 7 m deep), covered by removable protective slabs made by reinforced concrete with concrete plugs for access or for introduction of equipment or troubleshooting.

The bottom of the pit is equipped by three low points with sleeves for passage of a tilt tube with potential liquid effluents.

The pit is surrounded by a network of drainage and water is collected in a well located outside the building.

The interior walls of the pit are covered with two layers of oil-based paint.

The pit includes the following subsets:

- Post introduction and review of waste drums
- Station and tunnel for measuring by gamma spectrometry
- Loading station of transport equipment
- Storage position (capacity of 18 drums, which are waiting for measurement and evacuation)
- Internal transfer devices: carriage and beam rolling
- Ancillary facilities

Protection against radiation

The whole installation is located under the ground level in concrete pit covered by protective slabs consist 1.1 m ordinary concrete and 0.5 m steel.

The walls between the operator access areas and areas where are the irradiating drums have a thickness of 1.3 m ordinary concrete or 0.55 m barite concrete + 100 mm of lead.

At the bottom of the pit, thickness and location of walls were determinate to reduce the direct or indirect radiation, which can disturb the probe spectrometry, and to account for any human intervention in the event of an accident.

3.2 Description of the building 120

The building 120 consists of:

- Zone Avant (ZA) – Forward area of the cell
- Zone Arriere (ZAR) – Backward area of the cell
- Cell for conditioning and treatment – cell HA
- Local ventilation
- Truck hall
- Cell RCB 120

This can be seen in the figure 2.

3.2.1 General equipment of the cell HA

a) There are six workstations without separation in the hot cell. The cell is made up of concrete walls. Each workstation has a lead window and a pair of telemanipulators with a force 100 kN. There are heavy telemanipulator with a force 100 daN and lifting unit with a force 500 daN inside the hot cell.

The following openings are provided:

- In forward:
    - 6 leaded glass windows
    - 2 passes for slides
    - 12 passes for telemanipulators
    - 1 passage for air circuit

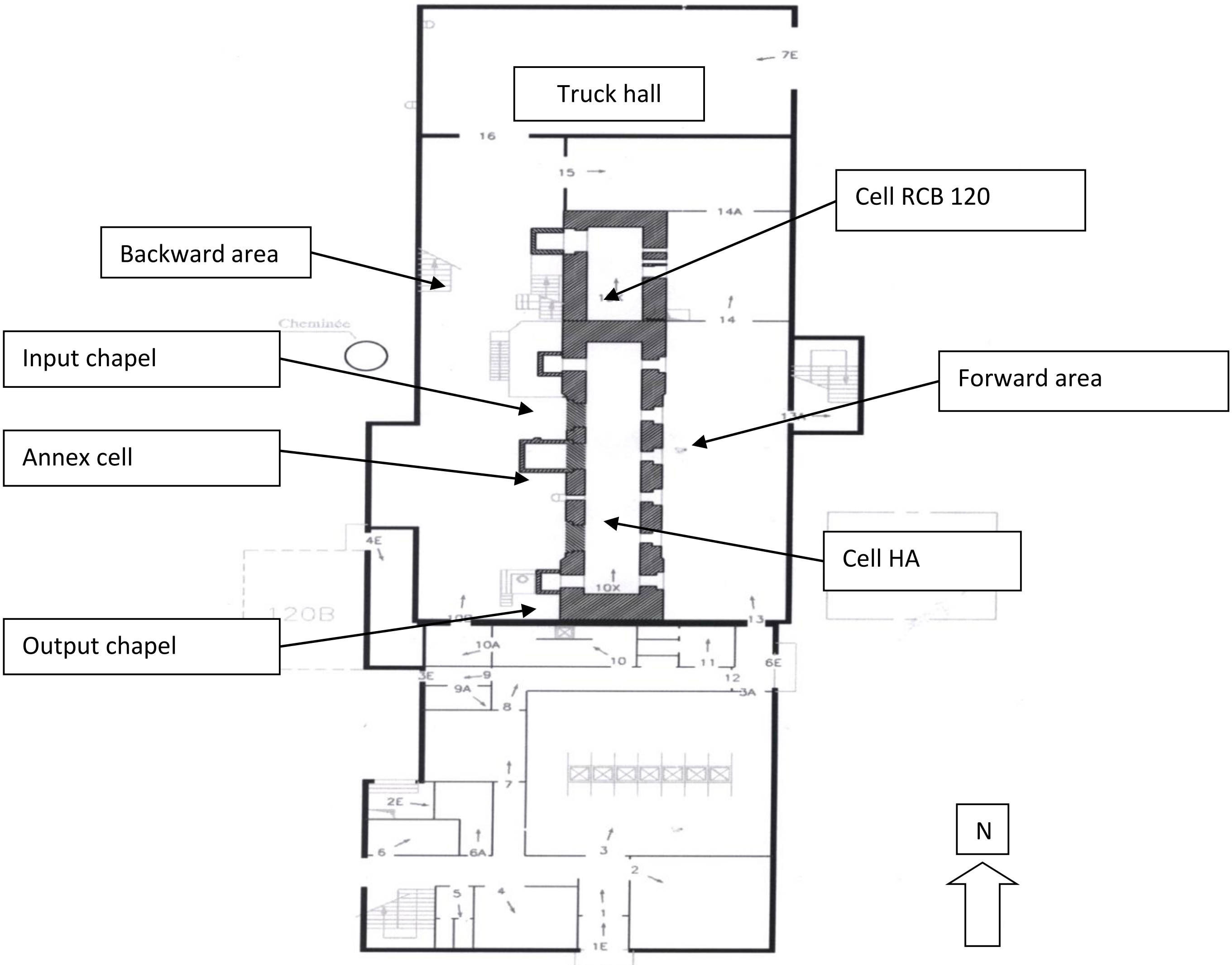


Figure 2 Building 120 [2]

- In backcourt:
  - 3 passes for concrete roller doors (position 2, 3, 5). The door in position 3 connects the cell with cell annex backcourt.
  - 2 passes, one for input chapel (position 1) and one for output chapel (position 6)
- On both sides:
  - 2 rows of steel sleeves for a fluid passes and for electrical circuits.

The celling of the hot cell is made of removable concrete slabs.

b) Work table:
There is a table inside the cell, which is placed in the central part of the cell (length 9.4 m, width 2.3 m).
On the work table is placed:
- 5 boxes with filters and fire detectors
- The compactor with force 40 tons and with cover plates
- Reciprocating saw

Both machines can be removed without complete disassembly.

c) Input chapel
It is located opposite the position 1 in the backward area.
It includes:
- hermetic sheet
- shield and support frame
- handling equipment and handling
- vision equipment
- devices for input of the waste

d) Output chapel
It is located opposite the position 6 in the backward area.
It includes:
- hermetic sheet
- shielding lead panels
- handling and vision equipment
- transferring devices of the pre-waste (polyester container charged with glass fibers compacted waste)
- transfer mechanism of the drums

e) Annex cell
This cell is in communication with the position 3 by a cylinder lock manually operable from the backward area. This cell consists of lead bricks and has a

completely removable surface, a pair of manipulators located on either side of a lead glass window and a working stainless steel.

3.2.2 General equipment of the cell RCB 120

a) Inside the cell RCB 120 is placed the compactor, the potting station, shielded lid of the reception, entrance door of the sealed enclosure, lift to the basket, handling crane, transfer carriage, reinforced door of the transfer zone, seamer and slide.

- The compactor
  It is operable to compress the primary package to obtain compacted cakes with a variable height depending on the resistance of the waste. The diameter of the primary packaging after compaction is compatible with the laminate basket. The compactor is shown in the figure 2. The hydraulic system of the compactor is located in the backcourt. It is placed on the floor in a specific compartment.

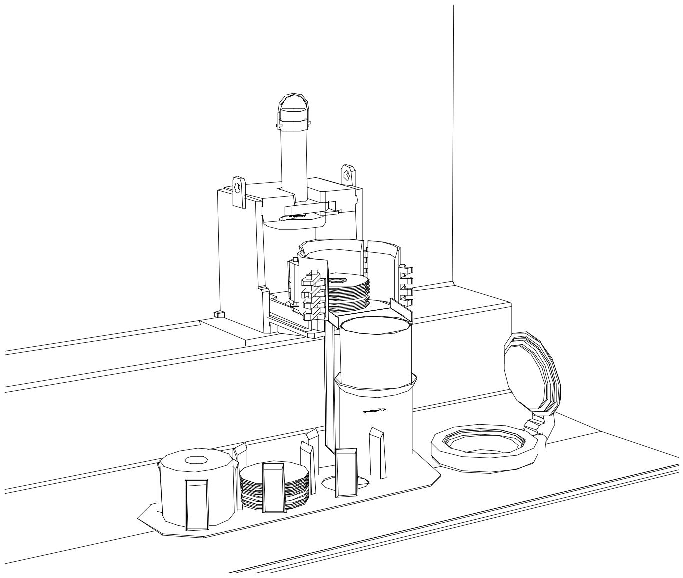


Figure 3 The drum compactor in the cell RCB 120 [4]

- The potting station
  The potting station allows the dosage and transfer of the epoxy resin, and curing of the laminated plug. The dosage of these two products is continuously monitored during injection by an electronic system.

- The shielded lid of the reception
  The lid of the cell RCB 120 is in the form of a shielded drawer to ensure the continuity of the radiological protection, which is equivalent to 200 mm of the lead. In the open position the slide releases a useful passage section with diameter 530 mm.

- The entrance door of the sealed enclosure
  Under the cap of the shielded cell, sliding doors controlled by a jack allows access even within the confines of the cell RCB 120.

– <u>The lift to the basket</u>
  The lift receives the drum from the transport container and allows the leveling of a cover with the handling bracket. Is rated load of 100 kg.
– <u>The handling crane</u>
  The handling bracket rated load 100 kg, can serve several plug points or removal:
  - the platform on the lift
  - the work plan and rack
  - the docking area
  - the baler

  When the crane is no in use, it is positioned along the storage wall.
– <u>Transfer carriage</u>
  The moving of the carriage in the transfer area on the rails is fixed to the ground. It is rated load of 100 kg. A system of vertical movement allows upgrading the metal drum 60 l to the berths and crimping.

– <u>Reinforced door of the transfer zone</u>
  The security door is provided between the transfer area and the output chapel if needed for and intervention on the seamer or the transfer carriage. The gate is made of 25 cm thick lead.

– <u>The seamer</u>
  It is located in output chapel and allows the crimping drum lids reconditioning.

– <u>The slide</u>
  The existing slide allows the passage if power and resin and hardener passage compressed air control of the casting head. This slide consists of a bent tube of 100 mm diameter.

b) Forward area
   In front are located:
   – a transparent glass panel with a thickness of 20 mm, installed in correspondence with a lead glass window with thickness 1 m
   – a passage, in the lower part, for the electrical cables, which are necessary for the operation of the cell
   – an intercom, for communication with the backward area and the top of the cell
   – a receiver station connected to the two mobile cameras, which are located on the bracket on the bottom of the cell

c) Backward area
On the rear panel are located:
   - a curved passage, which allows the passage of the flexible potting and power controlling the pneumatic nozzle resining
   - a passage of small diameter to the ground, which enables (though he transfer area) passing the hydraulic power of the press
   - the fire suppression system
   - an insertion hole in the enclosure (chapel entrance)

d) Transfer area
The tunnel belonging to the transfer area leads to the output chapel, which provides in all respect radiation protection as 25 cm of lead.
The transfer area is separated from the chamber by a sealed dicking. The transfer area is separated from the output chapel by an armored door and the end of the transfer area. A safety ladder enables access to the transfer area.

e) Output chapel
The output chapel is equipped with a lead glass window view with width 635 mm and with the manipulator gripper.
The roof of the chapel is made from a removable panel for the insertion ad removal of the equipment. The drawer closes the discharge orifice of the barrels to the transfer package.

3.2.3 Forward area (Zone avant)

This area with diameters 18 m x 5.2 m contains:

- every control workstations on the front panel of the cell
- the enclosure of all equipment inside the cell
- workstations for groups of hydraulic machines (press, milling machine, reciprocating saw)
- offices of operators
- the radiation beacon (atmospheric contamination, external exposure)
- monorails for changes of telemanipulators

3.2.4 Backward area (Zone arriere)

This room has diameters of 18 m x 10 m. The backward area gives access to the rear face of the cells and to the roof of the cells. There is also a lifting unit 15000 daN (hook height is 9.5 m), which cover the entire area, especially the input and output chapels, the roof of the cell and the area where the carriage moves.

Access to the backward area is through the air-lock which has a cloakroom, shower, sink and measuring equipment for radiation protection staff.

This area communicates with the truck hall via a sliding door which allows transfer of containers.

In the northern part of the backward area is possible operate the cell material. It includes a platform located at 6 m high reached by a staircase.

3.2.5 Truck hall (Sas camion)

The building 120 is extended on the north through a truck hall. This hall separates outside of the building and backward area of cells. There are two doors, for communication with the outside of the building 120 and for communication with the backward zone.

a) Construction
   The structure is made of reinforced concrete and masonry walls are made of hollow concrete blocks.
b) Dimensions
   - Width: 7.96 m
   - Length: 15.62 m
   - Height: 8.00 m
   - Floor area: 124.30 m^2
   - Volume: 995.00 m^3
   - Floor loading: 10/m^2
c) Coating
   The interior walls are covered by enamel paint. The floor of the room is covered by a screed mortar resin, epoxy finish.
d) Access
   - Exterior: for trucks, a metal door with double wings powered by a hydraulic cylinder (size 4 x 4.5 m high). The sealing closure is provided by a neoprene gasket adhered to the periphery of the leaves. A door emergency exit is incorporated into the one of the wings.
   - Interior: communication between the backward area and the truck hall is through the metal sliding door (3 x 4 m high). The translation is managed by an electromechanical group.

3.2.6 Local ventilation

The local dimensions are 30 m x 5.3 m on the 1st floor in the northern part of the building above the front area.

Access for persons is via the room 107. Access for the material is through a double meal doors. The monorail daN 250 allows entry and exit of the material.

In the north, a staircase gives access to local ventilation located above the truck hall in the building 120 (height 3.60 m, volume 448 m^3).

4. The safety analysis

Nuclear safety involves all action taken to avoid nuclear and radiation accidents or to diminish their consequences. All operational limits and conditions that applied for operating facility should be kept if possible. This involves, not only dose limits, actions levels etc.; but also all normal requirements for every industrial facility, like occupational safety and fire regulations.

In this part I made a detailed safety analysis of all works on the hot cell or during the manipulation with the waste drums. I used comparison table, where can be seen the risks (nuclear and non-nuclear) for each action. From this table I made analysis for each action which is in the table.

4.1 Identification of risks

The safety criteria to be applied to all nuclear activities, which provide the basis against which the safety assessment is to be evaluated, are identified. The criteria are based on:

- Dose to workers
- Dose to the public
- Discharges to the environment
- Exposure to chemical and other non-nuclear hazards

4.2 Risk evaluation

The analysis of the main operating phases allows identifying risks on which means have to be designed to either get the event probability lower or to prevent this risk occurrence. Detailed analysis of potential risks for each operating phases is necessary in order to design means for prevention or decreasing probability of events resulting from the risks.

- There are three main types of risks to be analyzed
- Nuclear risks
- Internal non-nuclear risks
- External non-nuclear risks

4.2.1 Nuclear risks

Main nuclear risks to be assessed are:

- External exposure
- Internal exposure
- Reactivity control
- Radioactive material dispersion
- Residual heat removal

4.2.2 Non-nuclear risks

The main non-nuclear risk, which should be considered are:

- Internal risks
  - Handling risk
  - Fire and explosion risk
  - Using of electricity risk
  - Human factor
  - Internal flooding risk
  - Risk of using chemical reagents

- External risks
  - External flooding risk
  - External fire risk
  - Earthquake
  - Extreme meteorological condition
  - Surrounding industrial activities
  - Plane crash

The most serious non-nuclear hazard is risk resulting from handling operations.

Manual handling is any task that requires to push, pull, lift, carry, move, hold or lower any object. Manual tasks include tasks that have repetitive actions, sustained postures and may involve exposure to vibration.

Not all manual handling is hazardous. A manual task becomes hazardous when it involves one or more of the following:

- Repetitive or sustained operations
- Repetitive or sustained application of force
- Application of high force
- Exposure to sustained vibration
- Tasks involving the handling of unstable or unbalanced loads
- Tasks involving the handling of heavy loads
- Works and tasks in high altitudes
- Reduced movement due to lack of space

4.3 General safety culture

General safety principles must be taken into account and are valid for all operations to be done the project. Such principles are listed below:

- Workers and stakeholders must be aware of the nature of the facility
- Workers must be trained according to nuclear safety/radiation protection
- Workers must be trained according to occupation and fire safety
- Workers must keep the workplace clean and safe

- Principles of occupational safety shall be adopted
- Principles of fire safety shall be adopted
- All means of communication and electricity shall be in operation
- Use of open fire is strictly forbidden (No smoking, only mechanical cutting tool can be used)
- Emergency plan must be established - emergency exists and pathways must be marked

4.4 Detailed safety analysis

The detailed safety analysis for each operation provides the table below.

Resulting from the table there are a few dominant nuclear risks:

- External exposure
- Internal exposure
- Dispersion of radioactive materials

The main risk of external exposure could results during manipulation with the drums with nuclear waste out of the pits in building 114 or out of the cell in the building 120. But this risk is in all operations covered by the transfer cask, which completely prevents workers against the external exposure.

Risk resulting from reactivity control and residual heat removal is not considered because there is no critical amount of radioactive material.

The most serious non-nuclear hazards are:

- Risk of injury resulting from handling works
- Risk of internal fire
- Risk resulting from using of electricity
- Human factor

External risks are mainly due to surrounding industrial activities, because the CEA Saclay Centre is indeed huge facility. Probability of earthquake is negligible low due to stable area where the facility is placed. All external risks are almost negligible.

Risk of fire shall be always taken into account. The facility already has fire protection system and all prevention means are already implemented.

Risk assessment table of the project		The manipulation with the waste drums in the building 114	Transportation of the drums	The manipulation with the waste drums in the building 120	Maintenance and changing works in building 120
Nuclear risks	External exposure	xx	-	x	xx
	Internal exposure	x	-	-	x
	Reactivity control	-	-	-	-
	Radioactive material dispersion	x	-	x	x
	Residual heat	-	-	-	-
Internal non-nuclear risks	Fire and explosion	-	-	-	-
	Handling	x	x	x	x
	Using of electricity	-	-	-	-
	Human factor	x	x	x	x
	Use of chemical reagents	-	-	-	-
External non-nuclear risks	Fire and explosion	x	x	x	x
	Flood	-	-	-	-
	Earthquake	-	-	-	
	Extreme meteorological conditions	-	-	-	-
	surrounding industrial activities	x	x	x	-
	Plane crash	-	-	-	-

xx - Potential risk x - Low risk (-) - Negligible

Table 1 The risk assessment table

4.4.1 The manipulation with the wasted drums in the building 114

4.4.1.1 Nuclear Risks

External exposure

Risk of external exposure results mainly from the opening of the pits. Between the opening of the pit and putting of the shielded cask on the pit, there is time where is the radioactivity released from the pit.

Possible consequences

- Exceeding of dose limits for workers
- Exceeding of the dose limits in case of uncontrolled access

Preventions

- Workers must be aware the pit during its opening
- Workers must stay far from the opening pit in order to keep the protection by distance
- The opening time of the pit must be as low as possible
- Controlled access
- During works, permanent radiological surveillance is provided
- Active and passive dosimeters

Internal exposure

During this operation, the risk of internal exposure is also only when is the pit open. However, the risk is very low.

Possible consequences

- The risk is very low. There is only risk of exceeding the dose limits

Preventions

- The workers must be aware the pit during its opening
- Workers must stay far from the opening pit in order to keep the protection by distance
- Workers must wear the mask, when is the pit open
- The opening time of the pit must be as low as possible

Radioactive material dispersion

The risk of radioactive material dispersion is very low. This risk can occur during the manipulation with the transfer cask with the waste drums, only in case of some accident when are all barriers destroyed.

Prevention

- Defense in depth - multiple barriers are provided in order to protect the waste drums

4.4.1.2 Non-nuclear risks

Handling risk

The handling operations are very important during the operations in the building 114. Indeed, these operations involve a high risk of weight falling or collision which could reach sensitive targets.

Main risks are:

- Falling of the shielded cask on the ground
- Falling of the shielded cask on the other equipment of the building 114
- Overload of the handling tools

Possible consequences

- Breaking of the shielded cask or equipment
- Breaking of the handling tools
- Injury due to falling of the shielded cask

Preventions

- It is strictly forbidden to stay under the crane, when is manipulated with the shielded cask
- Workers must keep a safe distance from the fork lift during the transportation

Fire risk

The fire shall be always taken into account. Especially, the risk of external fire must be taken into account due to the surrounding industrial activities. The facility has already fire protection system. It must be checked, if all fire protections are in operation.

Preventions

- No open fire is allowed to use
- Smoking is strictly forbidden

Human factor risk

Risk resulting from the human factor shall be always taken into account

During this operation, the main risks according the human factor are:

- Operating the fork lift
- Operating the crane

Possible consequences

- Improper handling with the fork lift or with the crane
- Accident during operation the fork lift or the crane

Preventions

- The fork lift and the crane can be operated only by trained person with relevant license

4.4.2 The transportation of the waste drums

4.4.2.1 Nuclear risks

External and internal exposure

The risk of external and internal exposure during the transportation of the waste drums between buildings 114 and 120 is almost negligible. The drums will be placed in the shielded cask, which protects people around.

Possible consequences

- Exceeding of the dose limits

Preventions

- Using of the shielded cask during the transportation
- Workers are not near to the shielded cask if it is not necessary

Radioactive materials dispersion

The risk of the radioactive materials dispersion is low. However, this risk must be taken into account, because the transportation of the drums will be outside the buildings.

Main risks:

- Incident of the forklift during the transportation

Possible consequences

- Spreading of the waste

Preventions

- Defense in depth – multiple barriers are provided in order to protect the integrity
- Not transport the waste drums during very bad weather conditions

4.4.2.2 Non-nuclear risks

Handling risk

The handling operations are very important during the transportation of the drums. Indeed, these operations involve a high risk of collision which could reach sensitive targets.

Main risks are:

- Collision of the fork lift during the outside transportation
- Overload of the fork lift

Possible consequences

- Breaking of the shielded cask or equipment of another buildings
- Breaking of the fork lift
- Injury due to the collision of the fork lift

Preventions

- Workers must keep a safe distance from the fork lift during the transportation
- Control the weight and dot to overload the fork lift

Fire risk

The fire shall be always taken into account. Especially the risk of external fire must be taken into account due to the surrounding industrial activities. The facility has already fire protection system. It must be checked, if all fire protections are in operation.

Preventions

- No open fire is allowed to use
- Smoking is strictly forbidden

Human factor risk

Risk resulting from the human factor shall be always taken into account. During this operation, the main risk according the human factor is the operating of the fork lift.

Possible consequences

- Improper handling with the fork lift
- Accident during operation the fork lift

Preventions

- The fork lift can be operated only by trained person with relevant license

4.4.3 The manipulation with the waste drums in the building 120

4.4.3.1 Nuclear Risks

External exposure

Risk of external exposure results mainly from the presence of workers in the backward are, this area is defined as a nuclear zone. The risk is low, but still the workers must be aware during the works in the backward area.

Possible consequences

- Exceeding of dose limits for workers
- Exceeding of the dose limits in case of uncontrolled access

Preventions

- The workers must be aware of the touching of unnecessary things
- Workers are allowed stay in backward area only during the manipulation with the waste drums
- Controlled access
- During works, permanent radiological surveillance is provided
- Active and passive dosimeters
- Only authorized people can enter the backward area

Internal exposure

During this operation, the risk of internal exposure is for workers in backward area where can be nuclear dust. This dust can be breath by the workers. However, the risk is very low.

Possible consequences

- The risk is very low. There is only risk of exceeding the dose limits

Preventions

- The workers must be aware of spreading of the dust
- During works, permanent radiological surveillance is provided
- Active and passive dosimeters
- Only authorized people can enter the backward area

Radioactive material dispersion

The risk of radioactive material dispersion is very low. This risk can occurs during the manipulation with the transfer cask with the waste drums, only in case of some accident when are all barriers destroyed.

Preventions

- Defense in depth - multiple barriers are provided in order to protect the waste drums.

4.4.3.2 Non-nuclear risks

Handling risk

The handling operations are very important during the operations in the building 120. Indeed, these operations involve a high risk of weight falling or collision which could reach sensitive targets.

Main risks are:

- Falling of the shielded cask on the ground
- Falling of the shielded cask on the other equipment of the building 120
- Overload of the handling tools

Possible consequences

- Breaking of the shielded cask or equipment
- Breaking of the handling tools
- Injury due to falling of the shielded cask

Preventions

- It is strictly forbidden to stay under the crane, when is manipulated with the shielded cask
- Workers must keep a safe distance from the fork lift during the transportation

Fire risk

The fire shall be always taken into account. Especially, the risk of external fire must be taken into account due to the surrounding industrial activities. The facility has already fire protection system. It must be checked, if all fire protections are in operation.

Preventions

- No open fire is allowed to use
- Smoking is strictly forbidden

Human factor risk

Risk resulting from the human factor shall be always taken into account

During this operation, the main risks according the human factor are:

- Operating the fork lift
- Operating the crane

Possible consequences

- Improper handling with the fork lift or with the crane
- Accident during operation the fork lift or the crane

Preventions

- The fork lift and the crane can be operated only by trained person with relevant license

4.4.4 The maintenance and changing works in the building 120

4.4.4.1 Nuclear Risks

External exposure

Risk of external exposure is the main risk during works on the cell, on chapels and annex cell in the backward area. Especially, during the works, when will be the initial equipment dismantled and the sources evacuated from the first position, the workers will be in contact with the open cell. Second possibility of higher risk of external exposure is in case, that workers will provide maintenance directly inside the chapels or inside the annex cell.

Possible consequences

- Exceeding of dose limits for workers
- Exceeding of the dose limits in case of uncontrolled access
- Exceeding of the dose limits due to time duration on workplace

Preventions

- The workers must be aware of the touching of unnecessary things inside the hot cell, chapels and annex cell
- Working time must be controlled and limited
- Workers wear universal suits and active suits
- Controlled access
- During works, permanent radiological surveillance is provided
- Active and passive dosimeters
- Only authorized people can enter the backward area

Internal exposure

During this operation, the risk of internal exposure is mainly for workers who work inside the Air-locks. During this works the hot cell, chapels and annex cell will be open, so works must be careful during maintenance or changing works.

Main risks:

- Dysfunction of active suits
- Unauthorized access

Possible consequences

- Exceeding of dose limits for workers
- Exceeding of the dose limits in case of uncontrolled access

Preventions

- Workers wear universal and active suits
- During works, permanent radiological surveillance is provided
- Active and passive dosimeters
- Only authorized people can enter the backward area

Radioactive material dispersion

The risk of radioactive material dispersion is very low. This risk can occur when the hot cell, chapels or annex cell are open. The airtightness of Air-lock must be perfect.

Preventions

- Using of Air-lock, when the hot cell, chapels or annex cell are open

4.4.4.2 Non-nuclear risks

Handling risk

The handling operations are very important during the operations in the building 120. Indeed, these operations involve a high risk of weight falling or collision which could reach sensitive targets.

Main risks are:

- Falling of slabs on the ground
- Falling of slabs on the other equipment of the building 120
- Falling of dismantled old or new equipment on the ground
- Falling of dismantled old or new equipment on the other equipment of the building 120
- Falling of the lead lid on the ground
- Falling of the lead lid on the other equipment of the building 120
- Overload of the handling tools

Possible consequences

- Breaking of the new equipment for the hot cell
- Breaking of air-lock on the hot cell or on the chapels
- Breaking of the new lead lid, breaking of a vinyl cover on the old lid or equipment
- Breaking of the handling tools
- Injury due to falling of the new equipment
- Injury due to falling of the lead lid

Preventions

- It is strictly forbidden to stay under the crane, when is manipulated with the lead lid or other equipment

Fire risk

The fire shall be always taken into account. Especially, the risk of external fire must be taken into account due to the surrounding industrial activities. The facility has already fire protection system. It must be checked, if all fire protections are in operation.

Preventions

- No open fire is allowed to use
- Smoking is strictly forbidden

Human factor risk

Risk resulting from the human factor shall be always taken into account

During this operation, the main risks according the human factor are:

- Using of equipment for maintenance
- Operating the crane

Possible consequences

- Improper handling with the equipment or with the crane
- Accident during operation the equipment or the crane

Preventions

- The equipment and the crane can be operated only by trained person with relevant license

5. The maintenance study

There is need to make some changes and maintenance of the equipment on the cell HA, because the cell is not in operation since year 2003. The maintenance, which I propose, will be focused on the input and output chapels and on the annex cell. Before the works is also necessary replace telemanipulators, change motors for the heavy telemanipulator and lifting unit. The old equipment of the cell is necessary remove, because for the process with the legacy waste is promoted new equipment of the cell.

On the input chapel must be change the lead lid. Present lid was designed for introduction of primary package. But during the treatment of legacy waste, the primary package is covered in another two packages. Due to, the diameter of introduced drums is larger and so the new lid with larger hole for introduction is necessary installed.

5.1 Functional steps for the removal of the equipment

- Revamping
- Investigation
- Accessing the sources
- Conditioning and treatment of the sources
- Pathway of the sources
- Decontamination of the cell
- Removal and dismantling of the material and equipment

5.1.1 Preparation

This is the first phase of the decommissioning operations, all unnecessary materials currently presented on the roof and in the backward area should be removed. An air-lock should be built with ventilation and filters. Two air-locks on the roof and in the backward area are built which should contain handheld radiological measuring devices inside them to control the dose and contamination. Building another small air-lock with minimum volume possible to reduce the contamination area, where the materials are introduced or extracted from the cell. All these air-locks should have moveable or sliding roof with vinyl tablecloth attached while opening the roof, in order to maintain the breach of containment and pressures should be maintained depending position of the air-locks. Air-lock on the roof top and in the backward area should be provided with additional room for dressing protective clothing against radiation and contamination. Two additional cells should be built for cutting, packaging and evacuation of waste. Radioprotection zones should be clearly mentioned everywhere. Finally, a report with information of each task that is to be performed by the personnel should be available.

Specific handling devices, tools, radio protection devices adapted to the nature of exposure, alarm device to communicate emergencies and fire accidents, dose and contamination measuring devices, sorting waste, emergency battery and other electrical equipment should be always at the disposal of the personnel working on the site for decommissioning of this hot cell.

5.1.2 Renovation

Revamping of the cell is inevitable, since the remote handling equipment and lifting unit are not working. I propose two scenarios and I include one scenario which was used in previous studies. I chose one scenario and this election is based on the ALARA principle. In any case, initial set up of confining the roof, setting up proper ventilation system and radio protection equipment and measurements devices are essential. These are established before any revamping is done inside the cell as explained in the above section. The scenarios proposed are discussed below.

a) Heavy manipulator is fixed under a slab

In this scenario, initially an air-lock is built over the roof followed by removal of slab getting access to the non-functioning heavy telemanipulator and lifting unit, these are removed from the cell eventually. It is proposed to fix the heavy telemanipulator (HTM) to one of the slab of the roof. It is easy to fabricate the slab with a provision to hold a HTM. This set up can be seen in the next figure. It has one disadvantage of limited accessibility in the workstation, slab with HTM should be replaced to each section as and when it is required. [11]

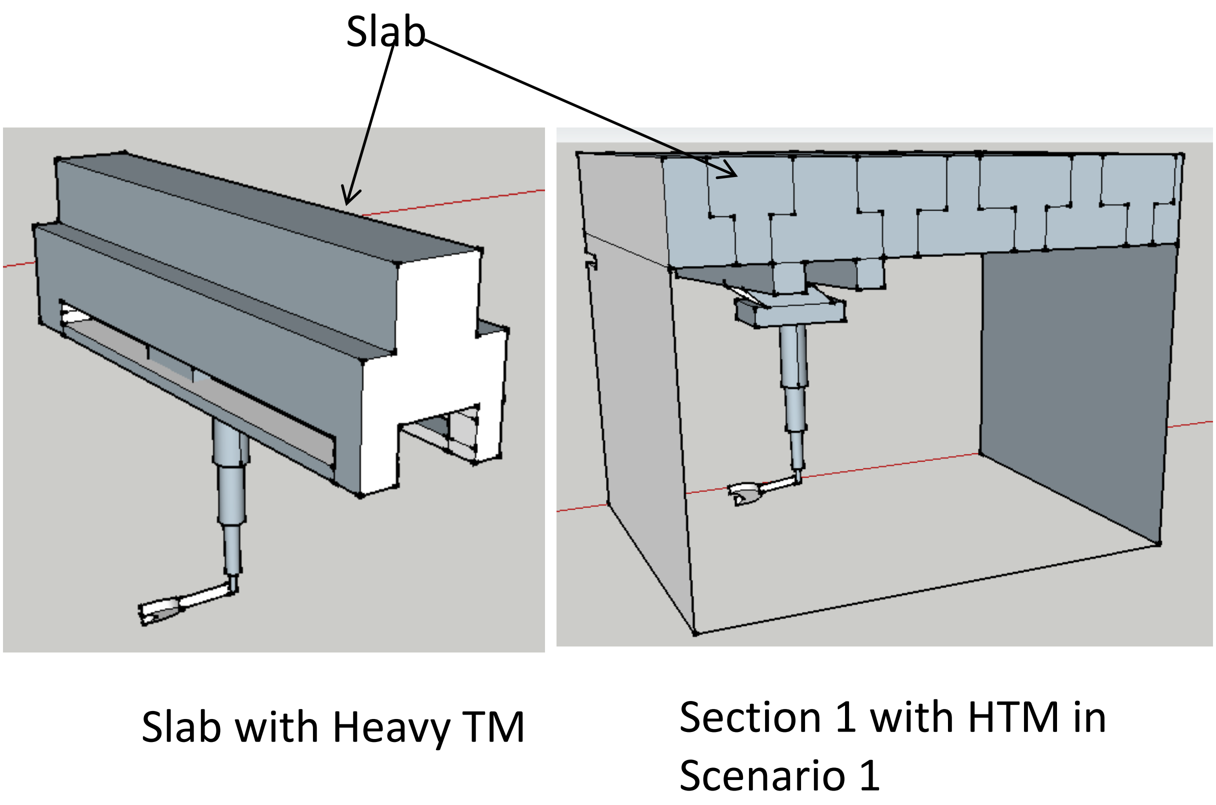


Figure 4 First scenario for revamping [11]

b) Replacement of slabs with a shielded sliding doors on ceiling

In this scenario I propose to build shielded sliding door on the top of the slab, this sliding door replaces two slabs from the roof of the cell. These shielding doors should be made of iron or lead, thickness should be equivalent to the thickness of the concrete which can stop same amount of radiation. Thickness of the concrete slabs is 1000 mm, between lead and steel, latter is less expensive than former. HTM and lifting unit are repaired and new equipment are fixed on the rail inside the cell. Setup of this scenario can be seen in figure 5. This scenario allows access to the cell with ease and gives more flexibility during dismantling operations.

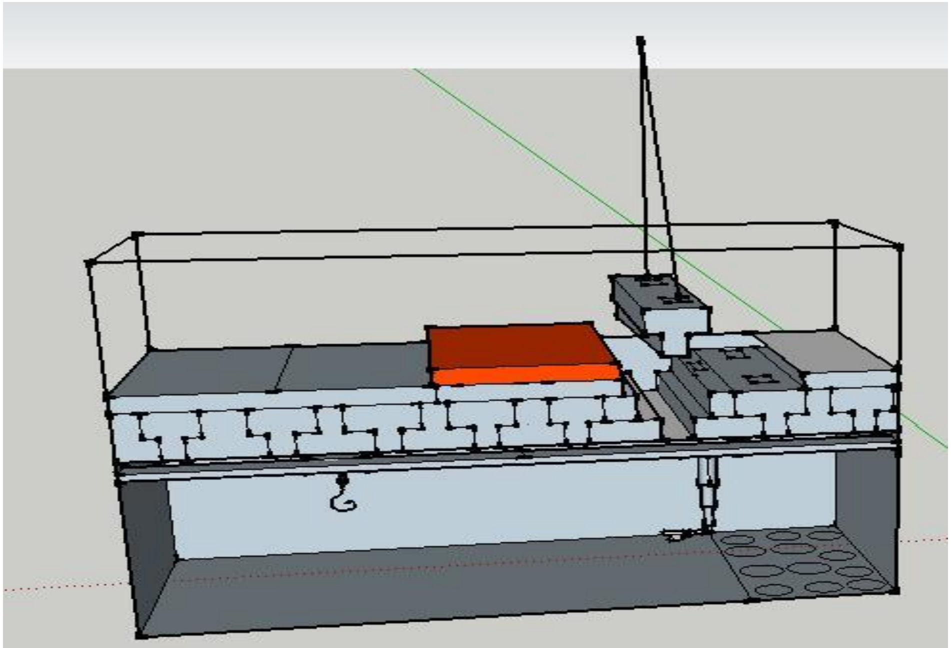


Figure 5 Second scenario – Removal of the slabs after shielding doors is established

c) Use a shielded lid on one slab

In the third scenario I propose to change one slab with a new slab with an operculum. The operculum is a special lid that is water proof sealing between the cell and the air-lock. This lid ensures no leak and breach of air-lock. It can be used for the introduction and removal of materials into and from the cell, as shown in the figure 6. This can be reused on another part of the cell roof for future use.

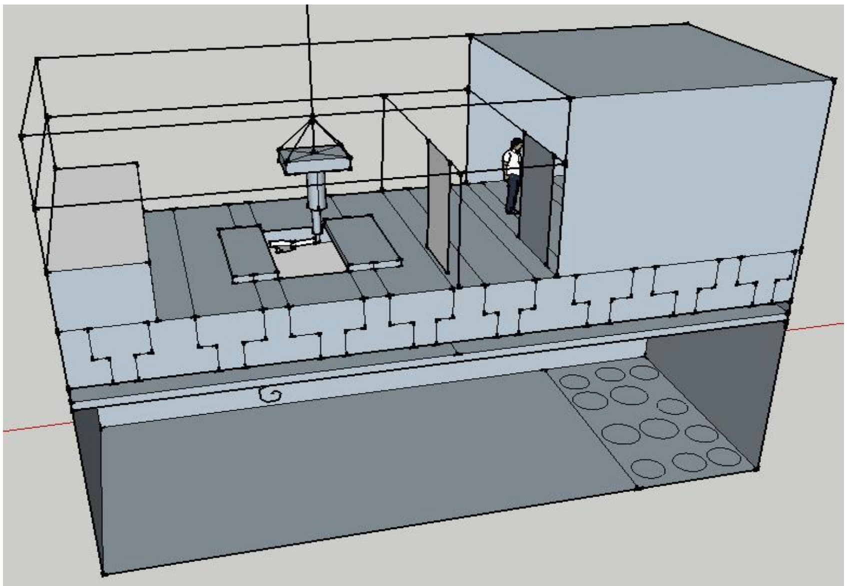


Figure 6 Third scenario - Removal of HTM and lifting unit from operculum

5.1.3 The ALARA principle

The ALARA principle is based on the calculations of costs, waste volume, delay of works and on the doses of workers. The ratios for the computation are shown in the next table. The scenario which receives the lowest number of points is the best scenario and will be chosen. In follow paragraphs is show the computation of the ALARA, there are used some coefficients which are only described. But the precise value of these coefficients isn't shown because they are internal values of CEA Saclay.

Criteria	Weighting coefficient
Complete cost (without waste) [€]	1 point / k€
Waste volume [m^3]	100 points /m^3
Delay [month]	100 points /month
Dose [H.mSv]	10 points / H.mSv

Table 2 The ALARA ratios

5.1.3.1 Computation of cost and the delay of works

Complete cost is sum of the cost of workers and the cost of material and equipment used during works. The price of materials and equipment is given from catalogs. I used the CEA catalog [12].

The computation of the cost of works is based on the computation of delay. The computation of delay for these scenarios is divided into the computation of building of the Air-lock and into the works inside the air-lock.

1) Building of the air-lock – this computation of delay depends only on the surface of the

$$d_1 = S \cdot c \tag{1}$$

d1 – the delay of building of the Air-lock [h]
S – Surface of the Air-lock [m^2]

c – The coefficient which respect the time which is needed for the building of 1 m^2 of the Air-lock and also there is included the time of construction of the Air-lock ventilation. [h/m^2]

2) Installation of the doors inside the air-lock – this computation is different for both scenarios. Because the computation is based on the ratio for each type of materials which will be worked with.

$$d_2 = \frac{m \cdot r}{n} \quad (2)$$

d1 – the delay of works inside the air-lock [h]
m – Weight of the material [kg]
r – Ratio for the material [h/kg]
n – Number of workers [-]

The computed delay in this step must be changed in the means that the limits for workers must be achieved, these limits are shown in the next table. That means, the delay is multiplied by the measured dose inside the cell and changed in Excel until it carry out all limits. The measured data of the state inside the cell are in the annex.

Duration	Maximum individual cumulated dose
1 day	0.2 mSv
1 week	0.5 mSv
1 month	2 mSv
3 months	5 mSv
1 year	20 mSv

Table 3 The dose constraints

3) The delay of works – the all delay is the sum of delays from previous steps

$$d = d_1 + d_2 \quad (3)$$

4) Computation of work costs – this costs depends on the type of clothes, which the workers are using. The workers can use follow type of suit:

a. Universal suit – this suit is without any restrictions, workers can work in this suit 8 hours per day.
b. Active suits – the workers have universal suit plus the mask, in this type of suit they can work only 4 hours per day, but they have to be paid for 8 hours.
c. Ventilated suit – the workers are inside the ventilated suit, the suit is filled by an air. They can work only 2 hours per day in this suit, but they have to be also paid for 8 hours.

In my case, the computation is divided into 3 different parts which depends on the type of the suit. Workers will be wearing the universal suit during the building of the air-lock. Active and ventilated suits will be used only inside the build air-lock.

The ventilated suit will be used only when will be the cell open. Due to, the time for wearing of ventilated suit is 50% of the time inside the cell.

$$C = d_1 \cdot c_1 + \frac{d_2}{2}(c_2 + c_3) \tag{4}$$

C – Total cost of works [Euro]
c_1 – The salary for workers in universal suits [Euro/h]
c_2 – The salary for workers in active suits [Euro/h]
c_3 – The salary for workers in ventilated suits [Euro/h]

5.1.3.2 The computation of the waste

For the second scenario the amount of waste include two concrete slabs and the lead doors, which will be placed instead of this slabs. The amount of waste for the third scenario is only one concrete slab.

5.1.3.3 The computation of doses

This computation is based on the measured data inside the cell and on the delay of works. As I described in the section for computation of delay, the doses for workers depend on the table 3. For my case the workers will receive the dose mainly when will be the cell open.

$$H = h \cdot \frac{d_2}{2} \tag{5}$$

H – Absorbed dose [mSv]
h – Dose rate [mSv/h]

5.1.3.4 Final comparison of scenarios

The first proposed scenario was designed by Praveen Sambu in his report and this scenario was designed for the total decommissioning of the hot cell. Due to, I do not include this scenario to the ALARA computation. The ALARA comparison table is in the next table. From this table can be seen, that the third scenario should be the recommended scenario.

The delay and doses for the second scenario are higher because after the works there can't stay the lead doors and the slabs must be placed back. Because of the need of lead doors change, the score of the second scenario is higher and can’t be chosen.

Criteria	Scenario 2		Scenario 3	
	Real values	Points	Real values	Points
Complete cost (without waste) [€]	336560	336,56	207400	207,4
Waste volume [m^3]	1,5	150	0,915	91,5
Delay [month]	9	900	5	500
Dose [H.mSv]	7,68	76,80	3,73	37,3
Total [points]		1463,36		836,2

Table 4 The ALARA comparsion table

5.1.4 Arrangements

Materials and equipment that will be sent inside the cell during revamping are remote handling systems, saws, shears, thermal cutting tools, spectrometer and calorimeter.

Air-lock is built on the top of the roof and in the backward area. Tools for handling the operations and maintenance should be placed inside the air-lock. To receive waste from the cell, a room or an air-lock must be built. Tools for cleaning and cutting should be placed in these air-locks, tools like band saw, circular saw, thermal cutting tools, vacuum cleaner. Control tools are also kept in these air-locks. Addition of necessary ventilation to these Air-locks is essential and the airflow should be 10 times the volume of the air-lock per hour, prefilter, filters and fans should also be added. Air-lock presented over the roof should have proper radiation shielding and static enclosure should be setup for manual intervention. A room is built for packaging of wastes and transport of these wastes is carried out from this room.

5.1.5 Investigation

Investigations should be carried to corroborate the values obtained from simulation software. This gives better understanding, whether to modify the existing planning and scenarios for the dismantling and also to verify if there is any unobserved radiating source which is disregarded in the earlier reports or past information. Investigation can be carried out by handheld detectors which held by remote handling machines to measure the dose rates and contamination inside the cell.

5.1.6 Recovery of the sources

5.1.6.1 Access the sources

Sources are present inside the drums in the pits in the position 1. These sources should be accessed using HTM and lifting unit, the lid of the pit is open and the drum is lifted using the lifting unit, drum can be opened using HTM and source pots can be accessed using remote handling arms. These sources and drums have denominations on them and they should be accessed accordingly to arrange them in basket. During the recovery of the sources, drums are again placed back in the pit at the end of the day while not working to avoid high doses in the cell and again they should be lifted up only in the morning when the work starts.

5.1.6.2 Container design

Cesium 137 and Strontium 90 sources are stored in two different types of cylindrical pots present in the drums inside the pits, namely type A & type B, baskets I designed according to the dimensions of pots. It is important that the source pots are put in basket and locked because they should be fixed inside the drum without any movement during transportation and further it is easier to handle the sources. As shown in the figure 7, basket consists of plates with openings, a central rod and a cap with threads (locker).

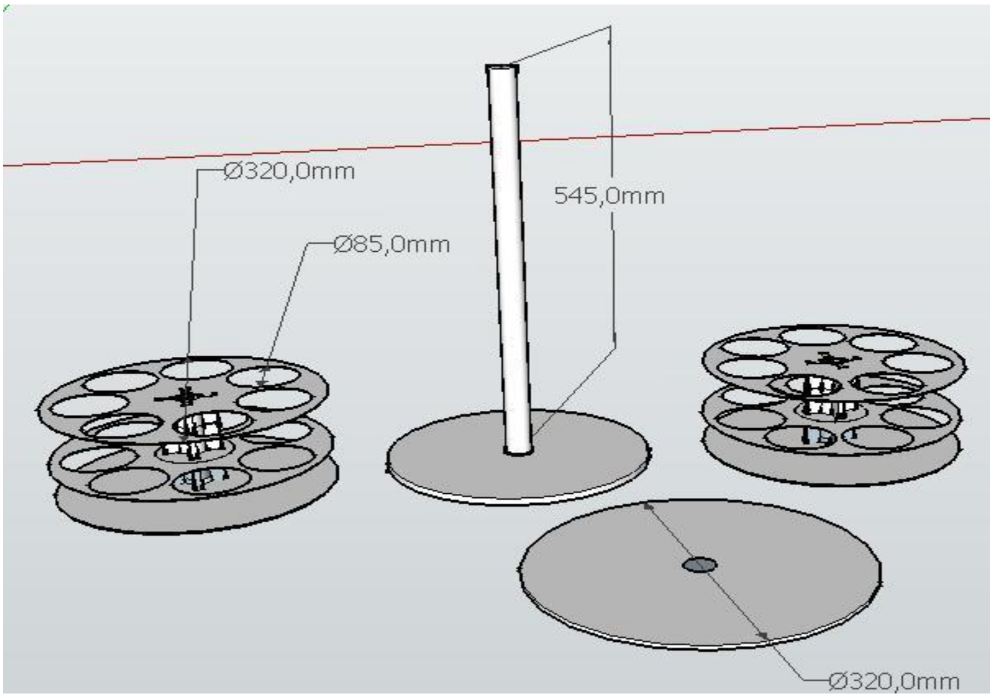


Figure 7 Basket design for Cesium 137 and strontium 90 sources

I designed two types of baskets with two different circular opening sizes. First type contains six circular openings on the plate and the other contains 5 openings per plate. Arrangement of pots is given in the next section. For Radium 226 sources, new pots are designed, since the existing pots data is unknown and it contains some plastic material which needs to be sorted before sending them out of the cell. Dimensions of the new pot are shown in the figure 8.

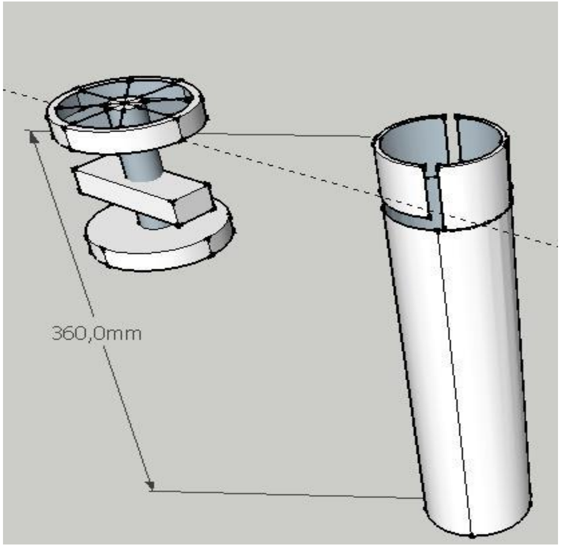


Figure 8 Design of the pot for Radium 226 sources

New basket is also designed in such a way that the pots can be placed inside it and this design can be seen in figure 9.

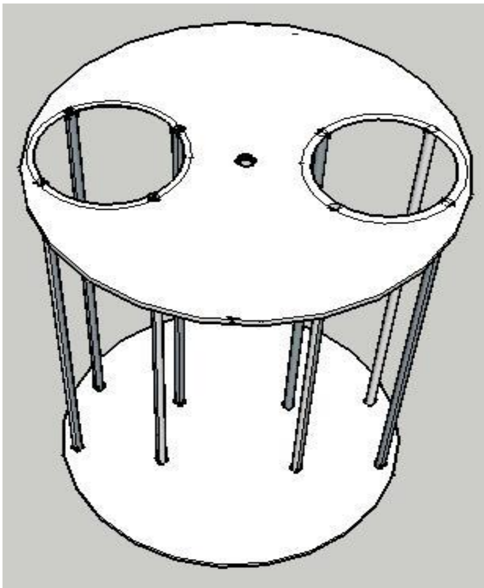


Figure 9 Basket design for Radium 226 sources

5.1.6.3 Arranging the sources

Cesium 137 and strontium 90 source pots are directly put in the basket. Their arrangement is given in Table 5. These pots should be arranged in a basket in such a way that they should meet all the requirements of the drum used for transportation.

	Pot Type	pot number	thermal power (w)	Activity (TBq) in 2016	weight (kg)
Basket 1	Type A (11 pots)	4, 5, 6, 7, 10, 11, 15, 16, 17, 21, 22	13.11	75.54	66
Basket 2	Type A (11 pots)	1, 2, 3, 8, 9, 12, 13, 14, 18, 19, 20	16.9	88.28	62
Basket 3	Type C (10 pots)	1, 2, 5, 9, 14, 15, 16, 17, 18,19	26.4	156.3	67.5
Basket 4	Type C (10 pots)	3, 6, 7, 8,10, 11, 12, 20, 21,22	15.76	96.02	48
Basket 5	Mixed (10 pots)	A-(23, 24, 25, 26, 27, 28) C- (4, 10, 13 21)	25.34	160	70

Table 5 Arrangement of Cs and Sr pots in Baskets

The specifications for a 60 liter drum are as follows, thermal power should be lesser than 30 watts, activity should be lesser than 185 TBq and weight should be lesser than 80 kg. Five baskets can be used to arrange all the pots follow these specifications. For radium 226 sources, old pots should be open and the sources should be sorted out. These are then put in the new pots, tightly closed and are placed in the basket.

5.1.6.4 Transportation and pathway for storage

For Cesium 137 and Strontium 90 sources, pots are put in baskets and these baskets are placed in 60 Liter drums. These drums are placed in shielded cask "A" and are sent to SACHA cell present in the INB 72. External surface of the drums are not allowed to counter any contamination, so to avoid this situation, drum is already placed in cask and opening of the cask with the drum is accessed in such a way that only internals are contaminated during the transfer of basket into the drum. The drum is stored in the SACHA cell until the arrival of TIRADE cask. This cask takes the drum to ISAI Marcoule, where the sources are removed from the drum and put in DIADEM container and these containers are sent to DIADEM center. This pathway is pictorially represented in the annex. Finally when the containers reach the specification of ANDRA, they are sent for final disposal. ANDRA is assumed to take the final responsibility of these sources in the near future since the repository for high level waste is underway.

For Radium 226, basket is placed CT270IX Container and this is placed in RD15IIB cask. This cask is directly attached to the Annex cell present behind the section 3 of the work station. Pots are lifted using remote handling machine and placed in the basket inside the drum. This cask is directly sent from the hot cell to Chicade center at Cadarache. Sources are removed from this cask and are then put in 870 Liter drum and filled with cement inside the drum. These drums are sent to CEDRA for temporary storage at Cadarache waiting for the final disposal at ANDRA. In this case, care should be taken since

CT270IX drum has limited allowance of 10 kg, the weight of the basket and the pots with the sources should not cross the allowable limit.

5.1.7 Removal of the material and old equipment

After the sources are recovered, dose rates can be calculated once again by Sonde type IF 104. Then is necessary to remove the material and old equipment, which is presented inside the cell. All of the equipment must be removed, because none of them can be used for the new process. Cleaning will be done by remote handling device to achieve low dose rates.

5.2 Maintenance of input and output chapel and annex cell

The chapels and annex cell should be capable of operation, but before their putting into operation, the maintenance is needed to do. The works on each of them are very similar. During this works will be checked motors, the state of transfer devices and other equipment of chapels or the annex cell.

On each of this cell are entrances for maintenance. Also, each cell has a widow with manipulators, so workers can do some works from outside of cells.

In case of direct maintenance by workers (they will use entrances of chapels or annex cell for maintenance), air-lock will be built around this entrances. For their protection, workers will wear inside the air-lock active suits with masks.

5.3 Changing of lead lid on the input chapel

I designed follows steps for the changing of lead lid. I deal with the need to open the air-lock during the changing of lids.

Before the changing, it is necessary connect the crane with the lid and build an air-lock around the top of the input chapel. The air-lock is shown in next picture. When is the air-lock built, the radiological measurement on the lid will be provided. Especially, the measurement inside the lid is necessary to do. From these measurements will be then specified the absorbed doses of workers and time delay of the work on lead lid.

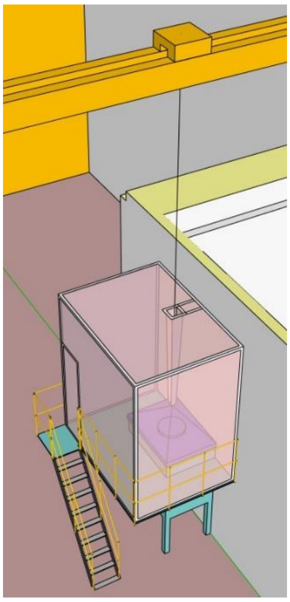


Figure 10 The Air-lock on the input chapel

The air-lock will be made with a movable piece of roof. It is from the reason that the lids will be transported by a crane, which is presented in backward area. This movable piece of roof is connected to the rope on the one side and on the other side it is connected with the air-lock. This part allows lifting of the lid and it still provides airtightness of the air-lock.

The rope from the crane is attached to the lid and it is lifted. Then is the lid placed on the pedestal which is installed inside the air-lock, it is wrapped in vinyl and prepared for the transportation. At the same time, when is the lid wrapped in the vinyl, the hole on the input chapel is sealed by a vinyl too. It is necessary to do, because through the hole, which was under the lid, can be released a radioactive materials from the input chapel or from the position 1. When the lid is wrapped in vinyl and the hole is sealed by a vinyl, the roof of the air-lock is dismantled for free way from the air-lock. Wrapped lid is then possible transport outside the air-lock. It will be transported on the cart, which made a communication between the backward area and truck hall.

New lid is transported by a cart to the backward area. Then it is again moved by a crane to the air-lock onto the pedestal. New roof with a movable part around the rope is made and the hole on the input chapel is unwrapped. After these operations the new lid can be placed on the input chapel. Before the dismantling of air-lock, the measurements around the new lid will be performed, just to prove the airtightness and protection against radiation from the input chapel.

All operation inside the air-lock will be performed by a works at least in suits with mask. After the measurement on the lid, this decision can be replaced to a work in ventilated suits (in case of higher dose from the input chapel).

6. The process inside the cell HA

6.1 Drums description

The waste is in three different drums or baskets. The example of the drum coverage is shown in the figure 11. The waste is in compacted metallic drums. These compacted drums are placed in the laminated basket. The lid of the laminated basket is not always in the same high (it depends on the amount of compacted drums). This laminated basket is placed in the metallic drum.

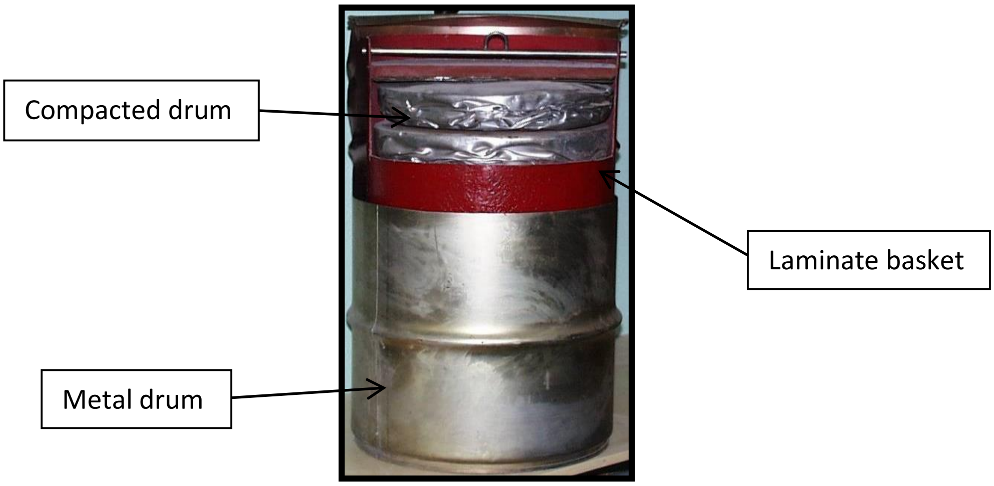


Figure 11 The drum with the waste [4]

6.2 Initial state of the waste

The drums with waste are placed in the building 114 of INB 72. These drums contain unsegregated legacy waste, which is necessary segregate.

6.3 Transport of the waste drums to the building 120

The waste drums in the building 114 are placed inside the pits. I designed the pathway from these pits because the drums must be removed and safely transported to the building 120 for the segregation of the waste.

6.3.1 The removing of the drums

The pits are covered by the lead lids, which are 0.8 m height. On the beginning of the works will be removed the lid from the pit. It will be done by the remote controlled crane. The worker, who controls the crane, must be far from the pit, because when the lid will put off, radioactivity is released from the pits. Immediately is placed on the pit the shielded cask, which serves for the transportation of the drum and its removing from the pit and also the cover made a protection against the release of the radioactivity from the pit.

The removing of the drum is made by the shielded cask. This cover has an attaching mechanism (each type of the cover has a different mechanism for the attaching of the drum, the specification are in Table 1), which attaches the drum and removes it inside the cover. Then is the shielded cask moved out of the pit and on the pit stays only transportable lid.

Before the transportation from the building, the shielded cask with waste drum must be measured. The worker provides two radiological measurements. The first one is on the surface of the shielded cask and the second one is in 1 m far from the shielded cask. There must be fulfilled follow conditions:

- On the surface must be maximum dose rate 2 mSv/h
- In the distance 1 m from the surface must be maximum dose rate 0,1 mSv/h

After the measurement, the shielded cask is attached to the fork lift, which provides the transportation between the buildings.

6.3.2 The shielded cask

For the transportation between buildings 114 and 120 serve three types of shielded cask. These casks also provide the removing of the drums from the pits with different mechanism:

- Shielded cask “A” is equipped by a grapple an its control system,
- Shielded cask “B” is equipped by the air suction mechanism,
- The “hood instrument” is equipped by the openings of different diameters or introduction of specific equipment.

Their technical characteristics are given in the table below.

The shielded cask “A” can be used for all operating activities (lifting and putting into the pits). The shielded cask “B” is used for drums whose integrity is guaranteed (the new barrels from the cell RCB 120 or verified drums by the SACHA visualization).

The hood instrument is used for operations which cannot be provided by shielded cask A and B (degradation of the envelope pit). All drums which are lifted by the hood required the establishment of containment air-lock and ventilation unit for the operation.

The hood instrument consists follow instrumentation:

- display system (camera, PC acquisition, control unit and display unit)
- handling tool
- recovery tool of drums or objects with control panel

Type	Technical Specifications	Use

Shielded cask LEMER C60-A "Shielded cask A"	• Biological protection 200 mm • Mass load of 7600 kg • Self-gripping grapple blocking • Control panel control • Automatic Tray Lock (clutch lever)	• Drum up to 60 liters • Maximum radioactivity was 185 TBq • Drums out of the cell RCB 120 was visualized in SACHA, or even integrates well from building 114
Shielded cask SDMS C60-B "Shielded cask B"	• Biological protection 150 mm • Mass load of 5 700 kg • Grip pneumatic suction • Pushbutton up / down and tap pneumatic supply • Air Reserve providing a range of 20 minutes in the event of loss of air supply • Manual Tray Lock	• Drum up to 60 liters • Maximum load was 80 kg (safety overload) • Maximum radioactivity was 185 TBq • Limit its use to drum whose integrity is checked (even out of the cell RCB 120 was visualized in SACHA)
The "hood instrument"	• Biological protection of 150 mm • Laden mass of 12 tons The upper part of the hood has openings with different diameters to include the introduction of a camera and a recovery tool.	• Barrel gradient with inability to use packaging Transfer A or B • Maximum radioactivity was 185 TBq

Table 6 The specification of the transfer casks

The shielded cask "A" can be used for all operating activities (lifting and putting into the pits). The shielded cask "B" is used for drums whose integrity is guaranteed (the new barrels from the cell RCB 120 or verified drums by the SACHA visualization).

The hood instrument is used for operations which cannot be provided by shielded cask A and B (degradation of the envelope pit). All drums which are lifted by the hood required the establishment of containment air-lock and ventilation unit for the operation.

The hood instrument consists follow instrumentation:

- display system (camera, PC acquisition, control unit and display unit)
- handling tool
- recovery tool of drums or objects with control panel

The shielded casks are shown in the annex.

6.3.3 The transport to the building 120

The shielded cask is placed on the fork-lift, which will transport the shielded cask from the building 114 to the building 120. These buildings are placed on the other side of the INB 72, so the transport will be realized outside the buildings. The next figure shows the pathway of the transport.

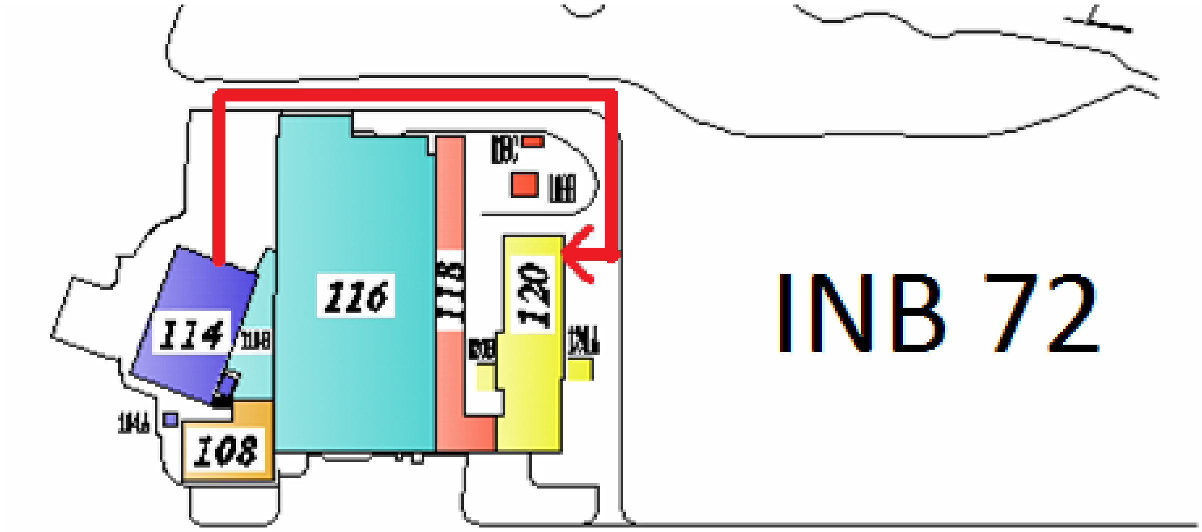


Figure 12 The transport pathway from the building 114 to the building 120 [4]

The fork-lift with the shielded cask will arrive to the truck hall in the building 120. The truck hall is connected with the backward area by an air-lock door. When will the fork-lift arrive to the truck hall, only the door to the outside the building are opened. The fork-lift will place the shielded cask on the cart, which makes the transportation between the truck hall and the backward area. When is the shielded cask on the cart and the fork-lift is out of the truck hall, the outside door are closed and the door between backward area and truck hall can be opened. The cart will transport the shielded cask to the backward area

6.3.4 Transportation in the backward area

The shielded cask with the drum is now inside the backward area. The crane is moved by the operator to the position, where is the shielded cask. The shielded cask is attached with the crane and from the cart is transported on the input chapel. These steps are shown on the next two figures.

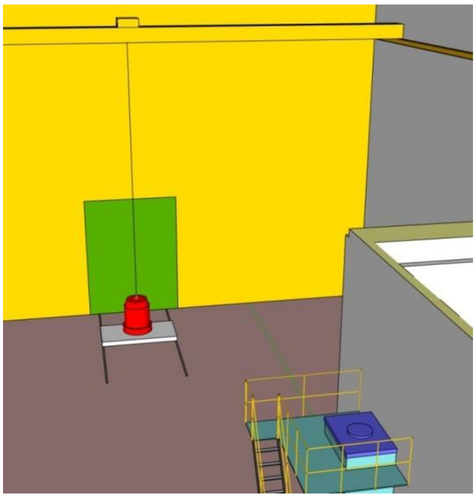


Figure 13 Receiving of the shielded cask

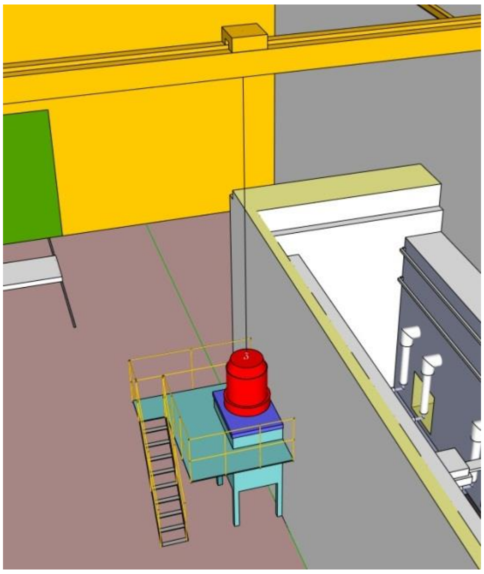


Figure 14 The shielded cask on the input chapel

6.4 Position 1 of the cell HA

In follow parts I describe all positions of the hot cell HA. I designed all steps inside the hot cell and new equipment for the hot cell. I also described the conditions for the treatment and for the segregation of the waste.

The position 1 of the cell HA is directly connected with the input chapel. The shielded cask is placed on the input chapel and the waste drum is released from this cask. The drum is then transported by the mechanism in the input chapel (inside are rails with moving platform, which provides the transport of the waste drum).

Inside the position 1 are 18 pits for waste storage. These pits are there from the previous usage and will not be use so much during the handling with waste from the building 114. But these pits can be used in future, when the waste drums will come directly from the facility to the INB 72. 3 drums can be placed to the every pit.

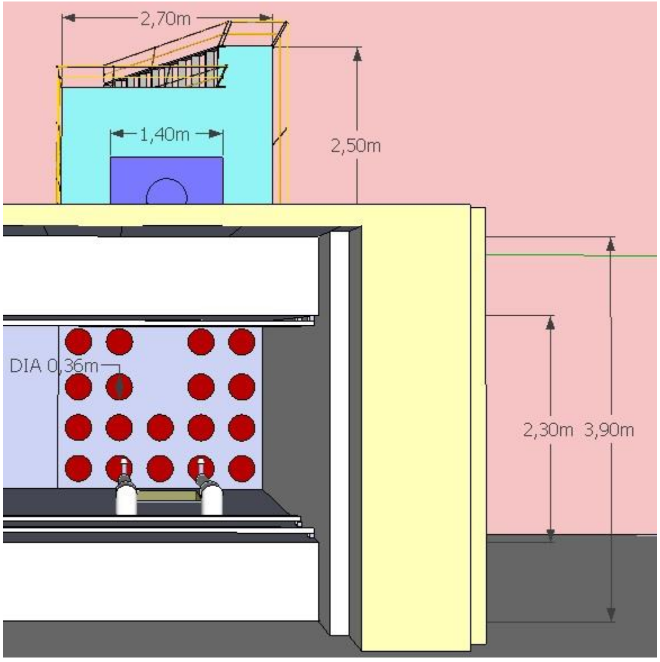


Figure 15 Position 1 and the input chapel

6.5 Position 2 of the cell HA

The drum coverage will be cut by the machine, which I designed. The model is shown in the next figure. This machine is constructed from these parts:

- Engine
- Rotating part
- Fixing parts
- Grinding machine
- Vacuum cleaner
- Height set part

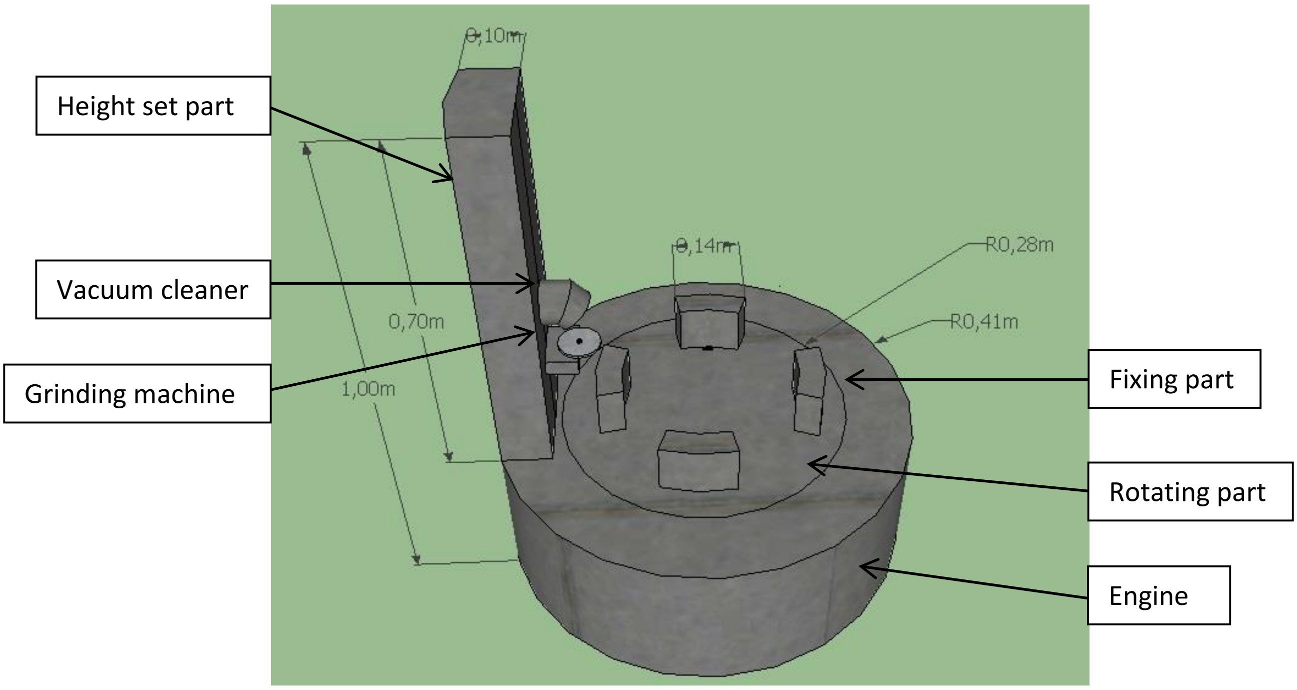


Figure 16 The drum cutting machine

The machine is remote controlled and the control panel of this machine is placed outside the position 2. By this control panel will be possible set the height of cutting tool, fix the drum, control the grinding tool (ejecting of the platform, where is grinding machine fixed, control the speed during grinding and turn on/off the vacuum cleaner) and control the engine of rotating part.

The handling with drums inside the cell HA will be provided by the heavy telemanipulator or by the lifting unit. The heavy telemanipulator will be used mainly for handling in each position and the lifting unit will provide transportation between the positions.

The waste drum is transported from the 1st position to the cutting machine, where will be cut the metallic drum and laminate drum. The last coverage, compacted metallic drum with waste, is then sent to the position 3, where is special cool cutting tool for opening of this drum.

6.5.1 The cutting of the metallic drum

The drum is placed on the machine and fixed by the fixing parts. The fixing parts serve also for setting of the proper position in the middle of the machine, because the operator is not able to place the drum to the middle. This position is necessary for successful opening of the drum. When is the drum fixed, the ejection of the platform with grinding tool will start. In the same time is turn on the grinding tool and vacuum cleaner. Vacuum cleaner is placed above the grinding tool and during cutting collects the dusts from the cutting. When will the grinding tool start cut the drum, the rotation of the drum is turn on. After one rotation, the drum is completely cut and the upper part is possible remove.

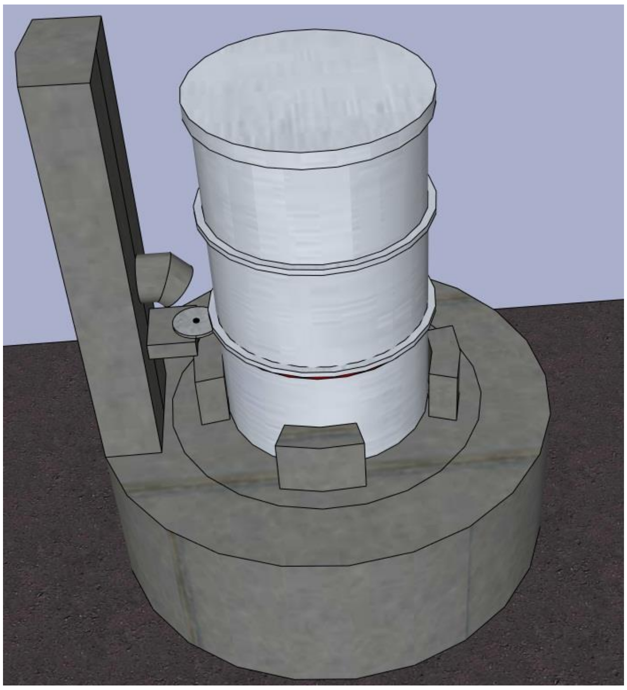


Figure 17 The cutting of the metallic drum

When is the cutting finished, the rotation of the drum, the grinding tool and vacuum cleaner are turn off. The grinding tool is retracted and the upper part of the metallic drum can be removed. The upper part is removed by the heavy telemanipulator and is placed near to the machine for future cutting to smaller pieces. After this has he operator an access to the laminate basket. The laminate basket is put out again by the heavy telemanipulator. On the drum cutting machine remains the bottom part of the metallic drum. The fixing parts release the bottom part, which is then send to the position 3, where is another reciprocating saw.

The upper part is then placed again to the machine and is cut to the smaller pieces. This cutting is provided from the top of the drum. These pieces are transported, as the bottom part, to the position 3 for future cutting.

6.5.2 The cutting of the laminate basket

When is the metallic drum completely cut, the cutting of the laminate basket will start. This basket is fixed on the cutting machine and all steps for cutting are similar with the cutting of the metallic drum. When is the upper part cut, it is put out by the heavy telemanipulator and the operator has an access to the compacted drums with nuclear waste.

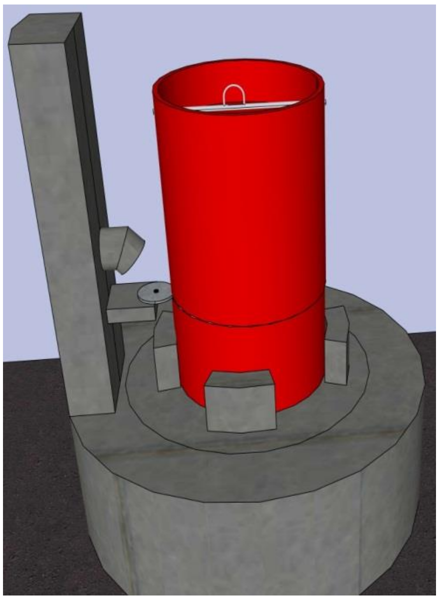


Figure 18 The cutting of the laminate basket

The compacted drums are then sent to the position 3, where will be opened by a different cutting tool. When are all compacted drums out of the laminate basket, then this basket is cut to smaller pieces as the metallic drum. The pieces of the laminate basket are also sent to the position 3 for future cutting.

6.6 Position 3 of the cell HA

To the position 3 is connected Annex cell, which serves for insertion of the waste, which is not in metallic drum (so called atypical waste, for example large pieces of metal etc.). During operations on the waste drums from the building 114, annex cell will be used for evacuation of drums with LLW.

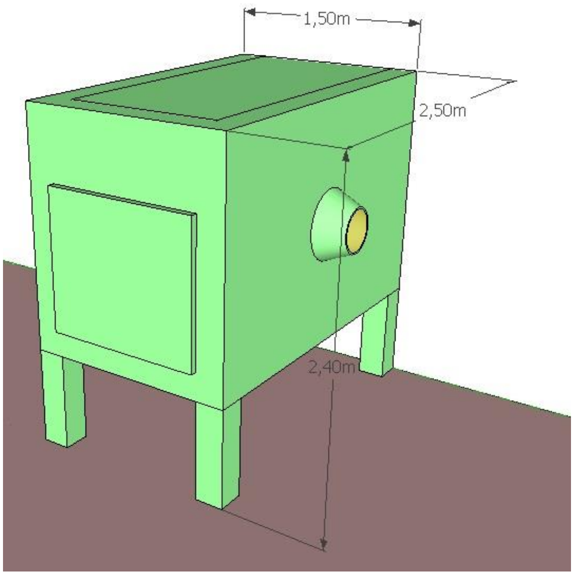


Figure 19 Annex cell

Inside the position 3 will be placed two machines. The first machine is reciprocating saw. This saw will serve for cutting of the metallic drums, laminate baskets and empty compacted drums. Next purpose is cutting of items, which will be inserted by the annex cell. The second machine is the opener of compacted drums.

6.6.1 The opening of the compacted drum

The machine which I designed for compacted drum opening is cool cutting tool due to the possibility of presence of flammable materials inside the compacted drum. The shape of this machine is shown in the next figure. The main parts of the machine are:

- Engine
- Rotating part
- Fixing parts
- Knife for the cutting
- Height set part

The principle of this machine is that the knife will pierce the drum on the beginning and during rotation will cut the top of the compacted drum. The machine is remote control and the control panel is placed outside the position 3. By this panel is possible change the high of the knife, fix the drum and turn on/off the rotation of the drum.

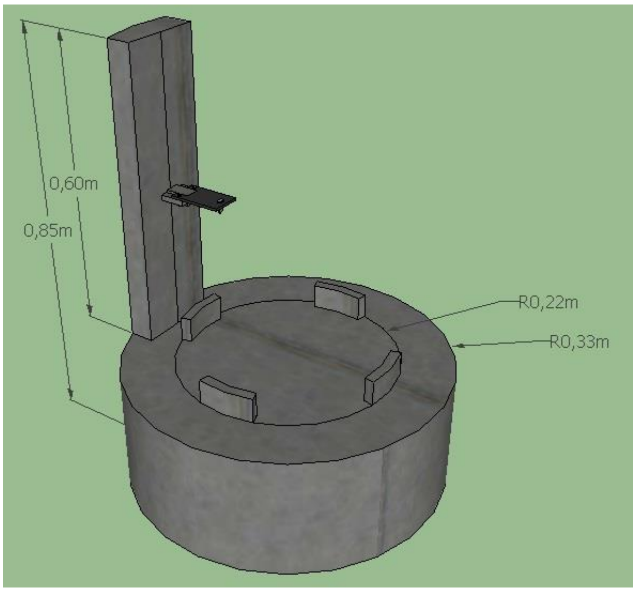


Figure 20 The machine for cutting of the compacted drums

The compacted drum is transported from the position 2 by the heavy telemanipulator to the position 3 to the machine. When is the drum placed on the machine, the drum is fixed by the fixing part in stable position. Then will start the knife move down and will pierce the drum. After that will be turn on the engine and the drum will start rotating and due to this move the knife will cut the top of the drum. After one rotation is the top completely cut and is possible remove it.

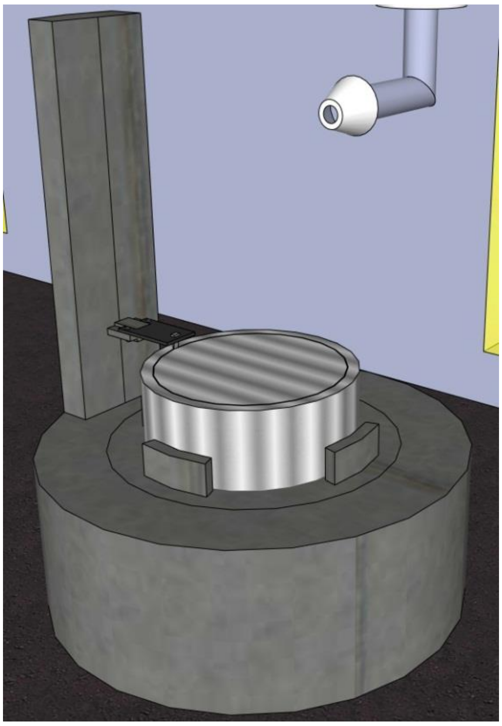


Figure 21 The compacted drum after cutting

The drum without the top is unfixed and sent to the position 4, where will be segregate the waste, which is inside.

6.7 Position 4 of the cell HA

In the position 4 is provided the segregation of the waste. On the begging the lid, which was cut in previous position, is put out. Now the worker has an access to the waste inside the compacted drum. From the drums is the waste ejected piece by piece, characterized and then put into the appropriate drum.

6.7.1 Characterization of the waste

The waste is segregate by physical conditions and by activity level. The segregation is provided into follow physical categories:

- Poly vinyl chloride (PVC) waste
- Plastic waste
- Aluminum waste
- Other meal waste
- Non-authorized waste

The waste is also segregated by activity level into:

- Low level waste
- Medium level waste
- High level waste

For each type from these categories and their combinations (for example HLW aluminum waste etc.) will be prepare new primary package. Accept the non-authorized waste, which is put into the special drum.

PVC waste

This waste comes mainly from the softened PVC as a contamination protection of slave parts of telemanipulators, which are inside the hot cells. The volume of the PVC waste is possible strongly reduce, because this waste is very good compactable.

Plastic waste

In this category are presented other materials than the PVC waste. Plastic wastes can be divided into two categories: compactable and non-compactable wastes. Each type is placed to the different drum, due to the future processing.

6.7.1.1 Restriction for radiolysable materials

The main restriction during filling of primary packages by radiolysable or organic waste is the production of hydrogen in this waste (specification of future underground storage). The conditions for hydrogen production depend on the place of final disposal of the waste and also on the type of final package for storage:

- Cadarache – in this waste treatment facility is presented a super-compactor for compaction of 60l drums. In this case is compacted ten 60l drums and they are inserted to the 500l drum. For whole 500l drum is maximum production of 10 l of hydrogen per year.
- DIADEM facility – in this future facility will be stored drums with waste, which is not possible to treat in Cadarache facility. In this case must be fulfilled the rule of maximum production of 10 l of hydrogen per year for DIADEM drum.

The accumulation of hydrogen is very dangerous. The hydrogen accumulation increases the pressure inside the drum. This overpressure leads to the big stress of the drum and possibility of its break and spread the hydrogen outside the drum. The hydrogen is strongly flammable in contact with air, which can lead to the explosion. This explosion can destroyed other drums and spread the waste, which is inside the drums.

Aluminum waste

The aluminum waste must be separated from the other metal. The amount of the aluminum waste depends on the total free surface of all pieces. From the table in annex 1 follow values must be keep:

- Radiolysable waste: <0,05 m^2/EP
- Non-radiolysable waste: <0.75 m^2/EP

Due to these restrictions must be known the volume of aluminum waste, which is in primary packaging. The computation of the surface can be very difficult on complicated shapes of wastes, so in this position will be placed small compactor. The purpose of this compactor is:

- Reducing of the total free surface
- Easy computation of the total free surface after the compaction

The easy computation of the total free surface after the compaction is based on known diameters of the compactor. The product of compaction is small cylinder and thanks to the diameter of the compactor and high of the cylinder, computation of the total free surface is very easy.

Other metal waste

Other metal is mainly non-compactable waste. It is necessary make a difference between the aluminum and other metal. It is not possible for the worker recognized the difference by a view. But the difference is in weight of the pieces. The same piece of metal weights more than aluminum piece. The second possibility, how to determine the metal waste, is by the sound exam. In the cell are placed microphones and in case, when a piece of metal hits another metal, it makes a noise. In comparison, when a metal piece hits aluminum piece, no sound is recorded by the microphone.

Non-authorized waste

Materials, which belong to the non-authorized, are described in annex 1. For these wastes is prepared a different drum. This type of drums is stored in pits in the position 1. Another possibility is, if is there a small amount of the non-authorized waste, because this waste can be put together with other metal waste. But in comparison with the other metal waste, there is allowed only 5% of non-authorized waste for whole primary packaging.

6.8 Position 5 of the cell HA

In the position 5 will be provided measurement of the drums with the waste before the final closure of the drum.

In this position will be controlled the weight and radioactivity conditions of the primary package:

- maximum weight is 25 kg,

- the radioactivity has to be below 185 TBq.

Due to these conditions will be in position 5 placed one device which provides both measurement.

6.9 Position 6 of the cell HA

The completion of the primary package is provided in the last position. The lid is placed on the drum and is attached and fastened. Next step depends on the type of waste. The drums with the compactable waste are only visually controlled by workers and then are send to the output chapel.

The drums with non-compactable waste are inserted to the laminate basket and wait for it fulfill by another primary package. The laminate basket is send to the output chapel in case when is full of primary package or in case when the weigh and radiological conditions are fulfilled.

In both cases the drums are sent to the chapel output, which made a transport between the position 6 and the shielded cask. The chapel output was designed for the 60l drums. But in this case, the primary packages or laminate baskets are sent through this chapel without complications, because their diameters are smaller than diameter of the 60l drum. The process in the output chapel is shown in the next figure.

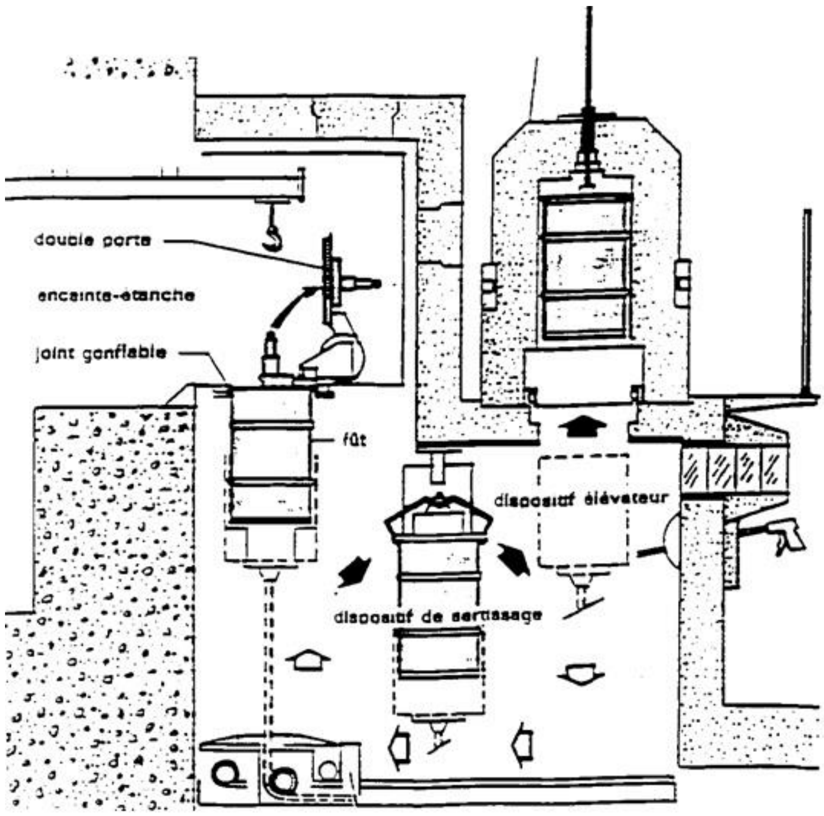


Figure 22 The output chapel [1]

6.10 The transport to the cell RCB 120

Primary packages or laminate baskets are placed on the output chapel to the standard shielded cask. By the crane manipulation is the shielded cask transported from the output chapel of the cell HA on the input chapel of the cell RCB 120.

6.11 The process in the cell RCB 120

The drum with the waste is now on the roof of the cell RCB 120. The sealed door of the cell is opened and the primary package is removed from the shielded cask. The primary package is placed on the platform, which made a transport from the door to the compactor. Then is the primary package compacted and final cake is put into the laminate basket.

When the basket is full of compacted drums, the metal lid is placed inside the basket. After that is introduced the resins casting manipulator and the lid is sealed in the resin plug. The casting manipulator is removed and the drying of the plug will begin.

The laminate basket with the compacted drums is then placed into the 60 l metal drum, which is located on the bottom of the cell. The trapdoor is placed on the metallic drum and fixed. The metallic drum is then transferred to the output chapel, where is provided visual examination and of the dose rate. Finally is the metallic drum placed to the shielded cask and is ready for the transportation.

A little different situation is with the drums with the non-compactable waste. These drums are transported directly in the laminate basket and in the cell RCB 120 is this basket placed to the position for the sealing of the basket. Next steps with resin plug and insertion to the 60l drum are the same as in previous case.

In the next figure is typified the process in the cell RCB 120.

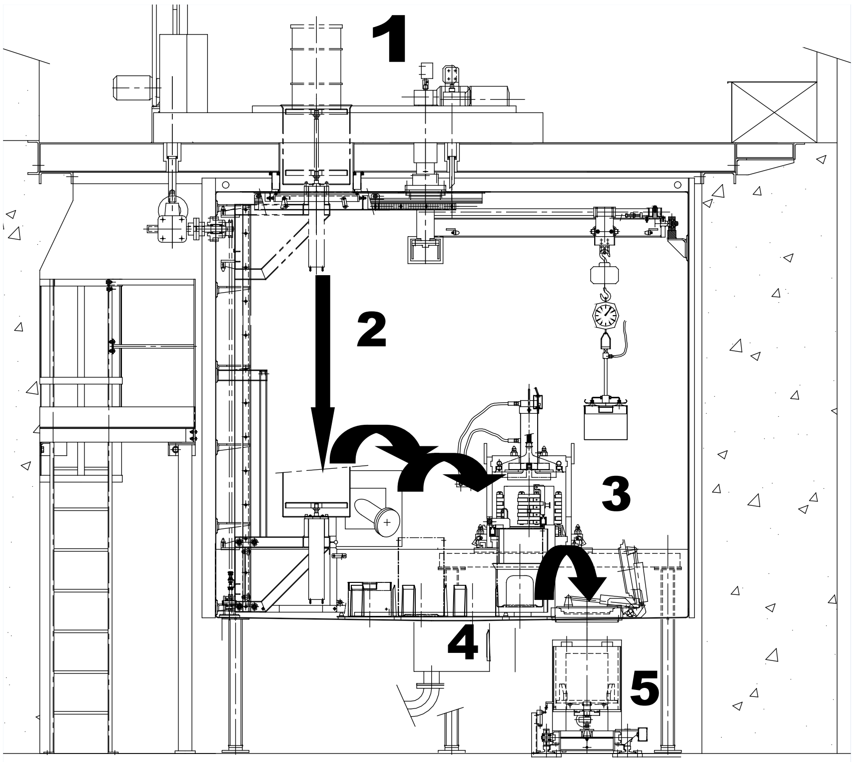


Figure 23 The process inside the cell RCB 120 [4]

1. The shielded cask on the input chapel
2. The transfer of the primary package to the cell
3. Compaction of the primary package in the press
4. The removal of the layered packaging
5. Transfer of the laminated basket (with the resin lid) to the 60 liter metallic drum

6.12 The transport to the building 114

The 60l drum with the waste is now placed in the shielded cask on the top of the cell RCB 120. Before the sending from the backward area is again necessary provide the radiological measurement. The limits of dose rates are the same as for the transportation to the building 120.

The process is similar with the transportation from the building 114. The shielded cask is placed on the cart, which made a change between the backward area and the truck hall. From there is the transportation by the fork lift (outside the building) to the building 114. In the building 114 is the drum inserted into the SACHA system. This system makes an automated counting of high activity. From the SACHA is the drum placed into the pit. In the pit the drums are waiting for transportation to the permanent storages in Marcoule or in Cadarache.

7. Transportation to the permanent storages

The final disposal of the waste will be provided in the permanent storages in Marcoule or in Cadarache. The destination depends on the type of the waste. The DIADEM storage in Marcoule is mainly for non-acceptable waste (this storage will be built in 2015, until that time the drums will stay in the pits in building 114).

Transportation of the drums is not allowed without the coverage – there is no surface contamination but the dose rate is high. Due to, the drums will be transported inside the containers, which I designed based on the ½ DIADEM container. For the container must be accomplished several criteria:

a) Containment material – closure

The closure is made by screwing. The lid on the container should, if it is possible, be preserved to ensure the containment area during handling and transportation. For handling, containers may need to be flipped horizontally. The filling of the containers with a metal drums is done vertically. The transportation may be done horizontally.

The final containment must be provided by welding. This containment of the metal drums must persist for the duration of 50 years. Welding conditions defined for the AISI cell must be preserver if possible. This welding is performed on the head of the container by an orbital welding. The seating of the container to the welding head is enabled thanks a groove on the inner diameter of the lid. This interface also allows the establishment of a ring seal control.

b) Handling

The handling is performed by a gripper. The container has a stud for this "Phoenix" type of gripping. This must be retained.

c) Filling

The container must ensure the optimum filling by waste. This is provided that, each container has precise dimensions for the containing of 60 l metal drum.

d) Permeability

The container ensures permeability of dihydrogen.

The waste is sealed in the metal drums, so the radiolysis of materials is capture by this drum. However, the container is able to evacuate the gases which could go outside the drum. This function is performed by four filters, which are welded in the lid of the container.

e) Mechanical strange

The configuration of the container should allow stacking of 15 levels and support the weight of the other containers without penalizing present deformations that may affect their recovery.

7.1 The container for transport

My designed containers must fulfill the dimensional constraints and geometry established to fulfill follow constraints:

- non-retention of contamination,
- structures, which will be transported or stored,
- their stacking one n another.

The container with diameters is shown in the next picture.

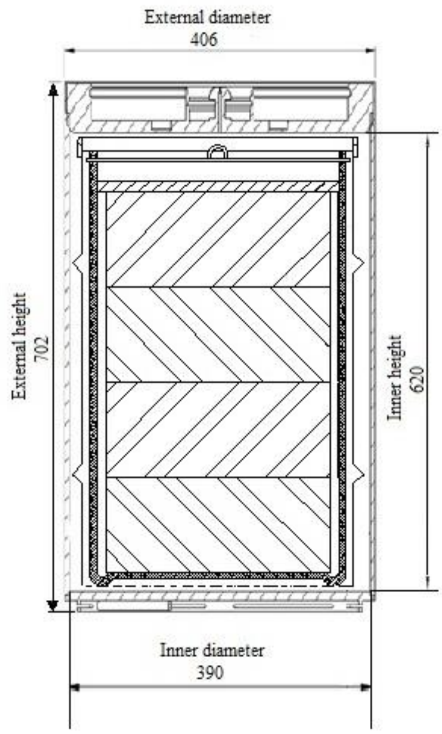


Figure 24 The container for transport with the waste drum [9]

7.2 The shipping process

Follow steps describes the shipping process of the drums from the pits in the building 114 to the permanent storage:

- Removing of the drum from the pit
- Insertion of the drum to the container for the transport
- Welding of head of the container
- Exam for airtightness of the welded container
- Radiological measurement of the container
- Loading of the containers to the transport vehicle
- Transport of the containers to the permanent storage

8. Finances

The computation of total cost is divided into the five main categories: studies, inventory, work, waste and new equipment. I computed these values or took over from documents.

8.1.1 Studies

I took over this value form the CEA documents. This cost is based on the delay of the studies. The delay of studies for similar projects are mostly 4 years. During studies is worked on the project as the planning of woks, the designing of new equipment for the hot cell etc.

8.1.2 Inventory

This cost I took over form the CEA document, which deals with the price of material and equipment [12]. I had to consider all equipment, which can be used during all process on the hot cell.

8.1.3 Work

The computation of work is shown in the part which deals with the ALARA principle. There is one difference, during the computation, and this is the computation of works during dismantling operations. These computations are more complicated because some operations are made in teleoperations.

$$d_D = \frac{m \cdot r \cdot (p_T \cdot c_1 + p_W \cdot c_2)}{n} \qquad (6)$$

d_D – The duration of dismantling operations [h]
m – The weight of the material [kg]
r – The ratio for the type of material [h/kg]
p_T – Percentage of works doing by telemanipulators
p_W – Percentage of works doing by workers
c_1, c_2 – The coefficients which deals with the speed of works made by teleoperators or by workers
n – Number of operators

This duration must be modified, because there is needed add some time for arrangement and demobilization works, and also the time for packaging and transportation of waste is necessary include.

$$d = (d_D + d_A) \cdot c_3 \qquad (7)$$

d – Pay hours for dismantling operations [h]
d_A – The time for arrangement and demobilization works [h]
c_3 – The transport, treatment and packaging coefficient

This computation I made for all works and for all types of materials which will be worked with during the dismantling woks

8.1.4 Waste

The price of the waste depends on the type of the waste and on the amount of drums. The waste is placed to the 60l drums and in the each drum can be maximum 300 kg of steal or 500 kg of concrete. For each type of waste is given fixed price for one 60l drum. The table with the characterization and the amount of waste is shown in the table below.

Items	Material	Weight [kg]	HLW	MLW	LLW	VLLW
12 telemanipulators	steel	1720		400	500	820
Milling machine	steel	400		50	350	
Saw	steel	750		100	650	
Shearing machine	steel	2500		250	1250	100
Pressing machine	steel	3600		1000	1000	1600
Concrete slab	concrete	7500				7500
Lead lid	lead	8650				8650
Miscellaneous items	steel	600		600		

Table 7 Charecterization of the waste

8.1.5 New equipment

Because the equipment for this hot cell is not made yet, the price is based on the similar application in the CEA Fontenay-aux-Roses research centre.

8.1.6 Final costs

The estimated cost for this project is around 12.03 million of Euros, with the uncertainties is the price 14.98 million of Euros. The biggest uncertainty is the price of new equipment, this price is estimated from previous similar operations in CEA. The costs are given in the table below.

Operations	Cost	Uncertainties
Studies	500k	10%
Inventory	1370k	20%
Work	3183k	30%
Waste	2193k	20%
New equipment	2785k	30%
Total	12.03Million	14.98 Million Euros

Table 8 Total cost of the project

An overall approximate duration of all works is given below. Detailed planning of this project can be seen in the Gant diagram below.

Steps	Number of hours	Number of operators	weeks
Preparatory operations	9940	2	142
Recovery of sources	2100	2	30
Dismantling and decontamination operations	9240	4	66
Installation of new equipment	2100	2	30
Final Cleanup	4200	4	30
Total			298

Table 9 Duration of the project

The below given chart gives cost of work excluding inventory, waste transportation and storage cost.

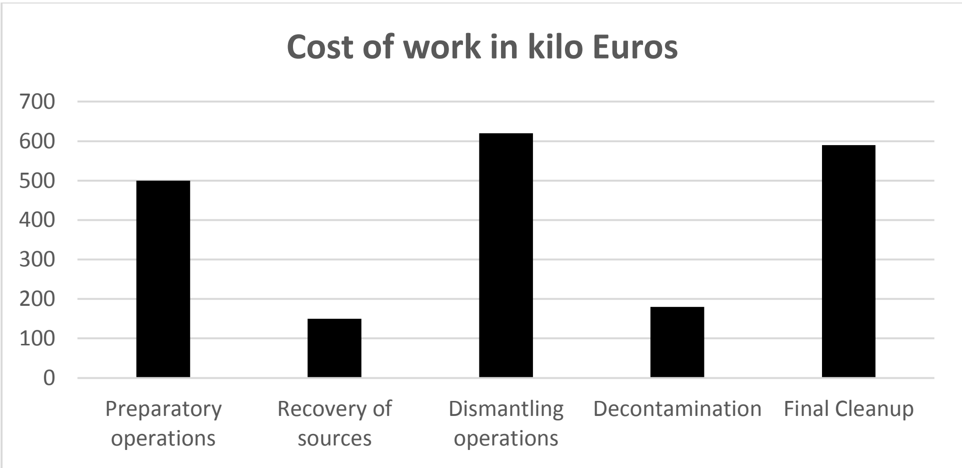


Figure 25 The chart of cost of work

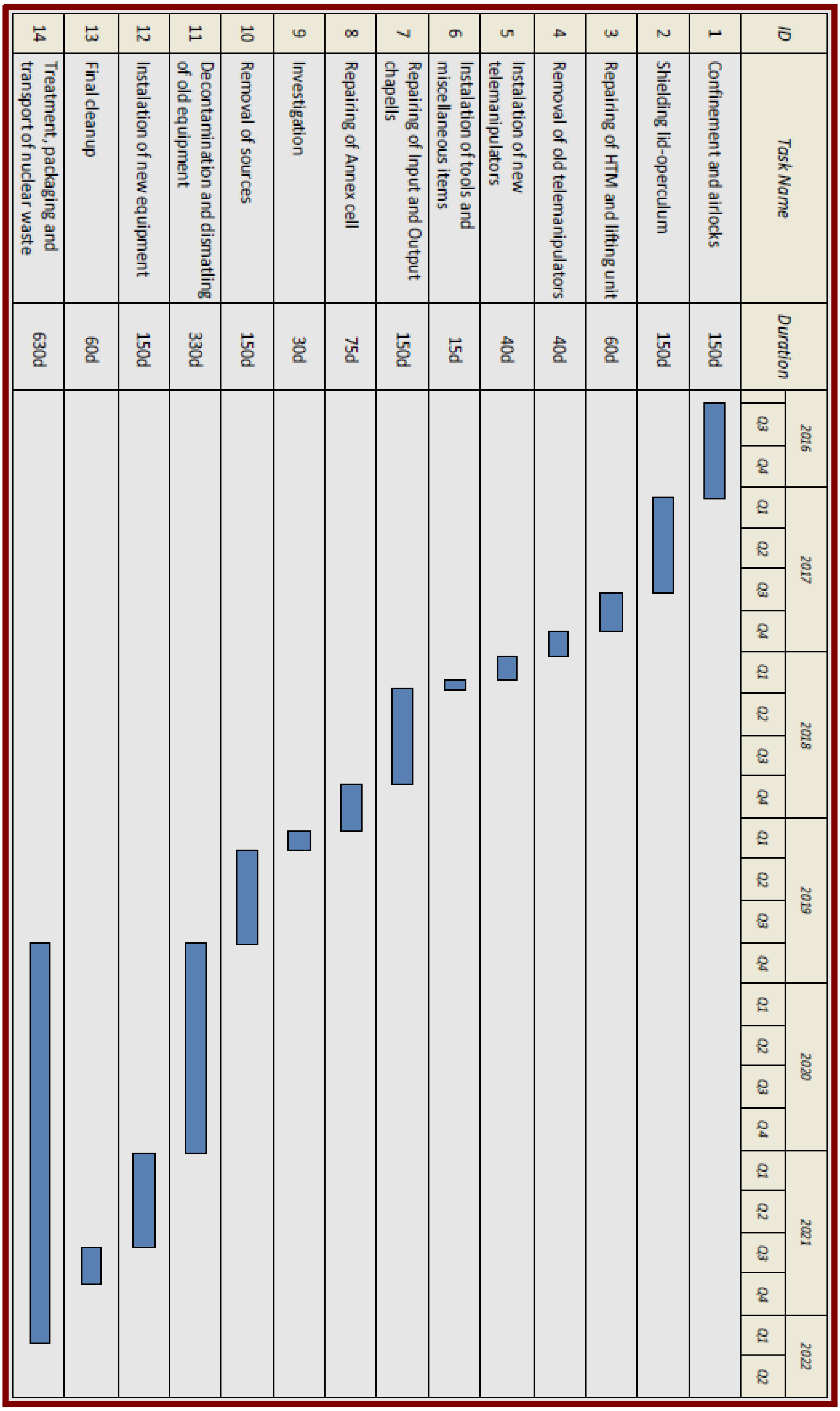


Figure 26 The Gant diagram of all works on the hot cell

9. Conclusion

This diploma thesis describes the segregation of legacy waste in the call HA and all steps which I designed for the reusing of this cell.

The safety analysis detailed deals with all the ways to prevent any accident on site, especially regarding the handling issues since that during operations will be lifted several heavy pieces, mainly by forklifts or cranes.

The part about maintenance of the hot cell mainly deals with the problem of evacuation of nuclear waste from the first position of the cell and evacuation of the old equipment. I proposed three scenarios for the opening of the cell and for computation of the best scenario I used the ALARA principle. The baskets for the evacuation of the sources from the first position are shown and proposed in this part of the thesis.

For the whole process inside the cell HA must be used new equipment. Due to, I designed new machines for the process in the document. Two of them are focused on the opening of waste drum, which have multiple coverage. Next equipment deals with nuclear wastes as a reciprocating saw and small compactor for nuclear waste. Each position of the cell HA and works which will be inside are precisely described. Also the rules and restrictions for the segregation are described in this document.

For the all designing works I used the Google Sketchup, which is sufficient for the designing of similar activities. Through this program is easy to show all works on the hot cell HA.

My propositions carried out in this diploma thesis will be developed by engineering studies in CEA Salclay and will be used during the renovation of the hot cell HA. Future work, which I didn’t worked on, should be focused on the technical project of cutting devices of drums.

10. References

[1] *CEA Saclay* : Rapport de sureté INB 72. *Corporate material of company CEA, Paris 1994*
[2] *CEA Saclay :* Dossier de sureté – projet d'assainissement de la cellule HA*. Corporate material of company CEA, Paris 2006*
[3] *CEA Saclay :* Rapport de sureté INB 72*. Corporate material of company CEA, Paris 2005*
[4] *CEA Saclay :* Règles générales d'exploitation de l'INB 72*. Corporate material of company CEA, Paris 2006*
[5] *CEA Saclay :* Dossier de sureté – Assainissement de la cellule HA de bâtiment 120*. Corporate material of company CEA, Paris 1998*
[6] *CEA Saclay :* Plans cellules HA. *Corporate material of company CEA, Paris 1993*
[7] *CEA Saclay :* Inventaires physique et radiologiques CEA, ETE-EVAL INB 72*. Corporate material of company CEA, Paris 2004*
[8] *CEA Saclay :* Prise en charge de déchets solides Faiblement Actifs (FA), Moyennement Actifs (MA) et Déchets Irradiants (DI). *Corporate material of company CEA, Paris 2012*
[9] *CEA Saclay :* Fiche d'identification de déchets – Déchets solides irradiants en emballage primaire. *Corporate material of company CEA, Paris 2012*
[10] *CEA Saclay :* Fiche reflexe – Déchets solides radioactifs de faible activité α, moyenne et haute activité β, γ en emballage primaire*. Corporate material of company CEA, Paris 2012*
[11] *Praveen Sambu :* Recovery of Sources from hot cell present in Building 120 of Basic Nuclear Installation 72*. Paris 2010*
[12] *CEA Saclay :* Catalogue de matériaux et équipements. *Corporate material of company CEA, Paris 20012*
[13] *CEA Saclay :* Description des sources au puits. *Corporate material of company CEA, Paris 2005*

11. Annex

11.1 Classification of solid nuclear wastes

Forbidden wastes

- Products or mixtures with the risk of fire or explosion or with risk of sudden exothermic reaction with the various components of the package
- Potentially infectious waste as defined in Decree No. 97-1048 of 06/11/1997, which is relating to the disposal of infectious medical operations and related risk of these operations
- Free liquid aqueous or organic (even the retained on absorbent)
- Saprogenous materials (dead animals)
- Self-igniting or strongly reactive metal waste (divided magnesium, sodium and sodium alloys)
- Containers with aqueous or organic liquids
- Waste recovered by blowing water (other than wood and wood-based products)
- Radioactive sources
- Fats and waxes

Wastes allowed without restriction

Physical nature	Code
Cellulosic materials (cotton, paper, cardboard, cloth)	A
Plastics and rubber	B
Ferrous metal waste whole, fragmented or reactive chips	C
Non-ferrous metal scrap (Al, Cu,…) whole, fragmented or chips except reagents	D
Rubble	E
Glassware and laboratory containers	F
Alumina, silica, glass wool	H
Filters from water dry circuits	L
Vacuum mobile filters	M
Ventilation filters	N
Iodine traps	P

Wastes allowed with restriction

Physical nature	Restriction to respect
Compactable heterogeneous waste (cloths, ...)	No dripping by simple manual pressure - Detailed identification and qualification - The systematic use of absorbent materials in manufacturing process, related to the achievement of the package is prohibited
Wood and products of wood	<u>Prior agreement by STED</u> <u>ANDRA package:</u> Quantity limited to 10% - Package in vinyl envelope - Disposed next to easily compressible wastes - Activity concentration < costing threshold (taking into account a uniform mass of 200 kg compared to the SE) - Amounts added - Identification of specific activities <u>Cadarache package:</u> These waste are prohibited support of the CEA Cadarache centre.
Paint residues	Demonstration that the residues are completely cured and the solvents are completely evaporated - Residues of the paint and photo(s)
Painted parts	Residues must be fully cured and solvent completely evaporated - Painted surfaces
Aerosol cans	- Emptied and drilled - Quantity + photo(s) of pictograms and risk phrases
Batteries and accumulators	- Packaged in vinyl packaging and completely drained from electrolyte content - Limited to 10% of the useful volume of the concreted drums or of the primary package - Mercury associated, demonstration of absence of highly reactive metals
Neon	Limited to 1 neon per EP • Packaged in vinyl packaging • Mercury associated
Aluminum metal	**Prior approval by STED**: Limited quantity for a primary package (emballage primaire - EP) • **Radiolysable waste: <0,05m^2/EP** • **Non-radiolysable waste: <0,75m^2/EP**

	- Indication of the total free surface
Reactive metals with hydraulic binders other than aluminum	Allowed due to the lack of contact with the mortar • Surface
Potentially reactive materials with hydraulic binders	Allowed due to the lack of contact with the mortar • Nature • Quantities
Waste containing chemical species which may interact with hydraulic binders	Allowed due to the lack of contact with the mortar • Nature • Quantities
Waste containing non-friable asbestos	**Prior approval by STED**: Quantity limited to 25 kg • Demonstration of non-friable nature • Amount by weight and percentages by weight • Crystallographic structure (amosite, chrysolite)
Homogenous wastes: Chemical co-precipitation sludge, evaporated concentrates, incinerated waste and Earth, sand	**Prior approval by STED**: • Maximum 10% of useful volume • Demonstration of the absence of water - Indication of the chemical composition of 95% of the mass of the dry extract - Identification and quantification of potential complexing substances - Indicate the average content (in relation to the weight of the waste contained in the EP) of binders with reactive substances
Wastes with a rate of spreading in case of very high fall: Powders, dusts	**Prior approval by STED**: The packaging of this type of waste in the free state is prohibited in the primary package
Wastes containing beryllium or graphite	**Prior approval by STED**: These types of waste are prohibited in support of the CEA Cadarache. They are subjects to approval by the STED depending on the final disposal of primary package

Toxic chemical waste

Toxic chemicals (including information contained in the Waste Electrical and Electronic Equipment called "WEEE") must be identified as soon as the content exceeds the thresholds defined in the tables below:

Contained in heterogeneous waste:

Toxic chemical species	Threshold identification in waste (in mass ppm)
Lead	100
Boron	20
Nickel	20
Total chromium	100
Chromium VI(*)	10 (*)
Arsenic	10
Antimony	10
Selenium	10
Cadmium	10
Mercury	10
Beryllium	10
Cyanides	10

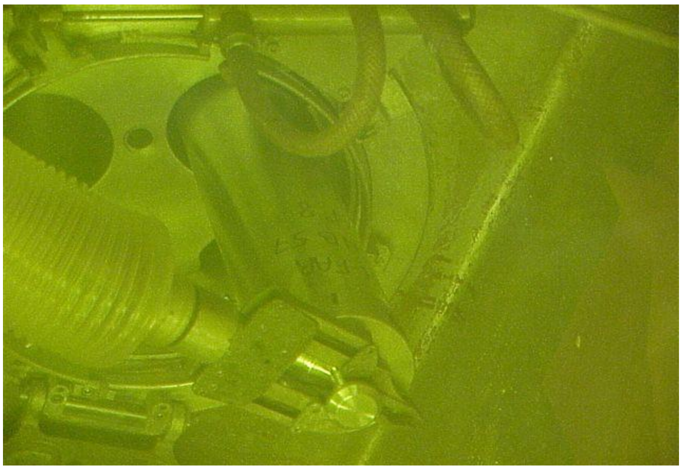
(*) Only in exceptional presence in heterogeneous waste (type filters).

Contained in the homogeneous waste:

Toxic chemical species	Threshold identification in waste (in mass ppm)
Lead	100
Boron	20
Nickel	20
Total chromium	100
Chromium VI(*)	1
Arsenic	10
Antimony	2
Selenium	1
Cadmium	1
Mercury	1
Beryllium	6
Cyanides	1

11.2 First position of the hot cell

Opening of the lid of the 60l drum with source pots inside



Placing of the pot directly into the basket held in drum which is present in cask

11.3 Packages used during operations

Primary package

Primary package in the laminate basket

60 l metal drum

The shielded cask type A

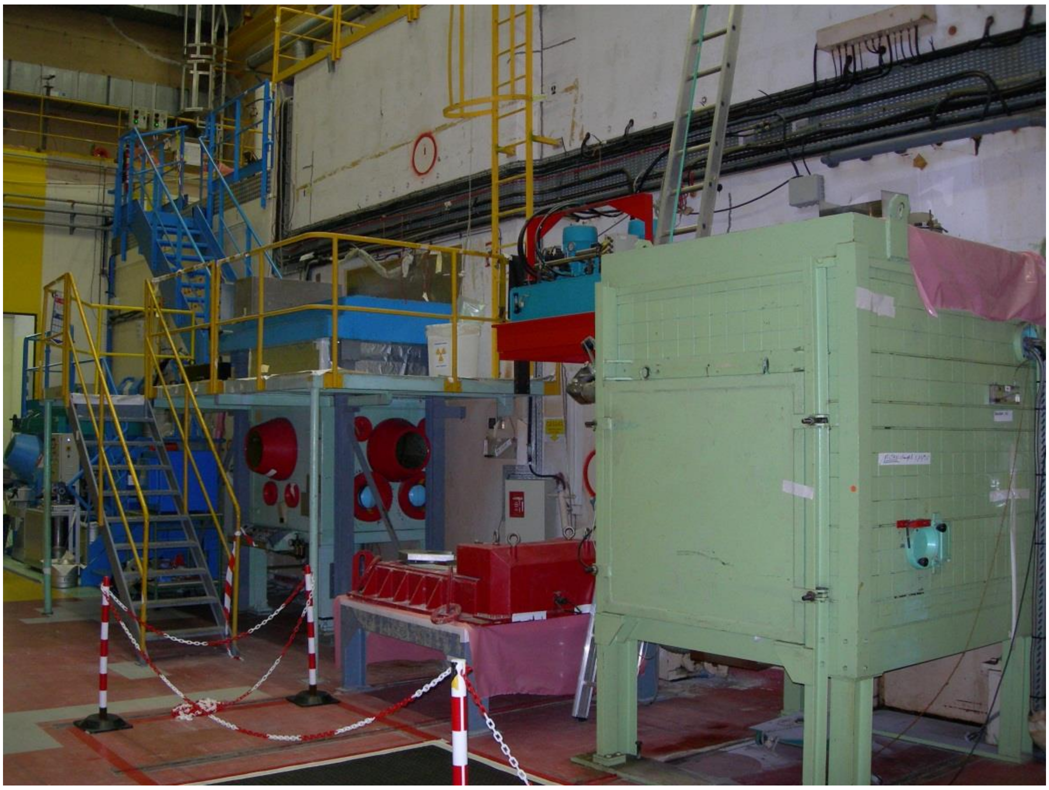
The shielded cask type B

11.4 INB 72

Building 114 - The hall with pits

Building 114 - The open pit

Building 120 - Cell RCB 120

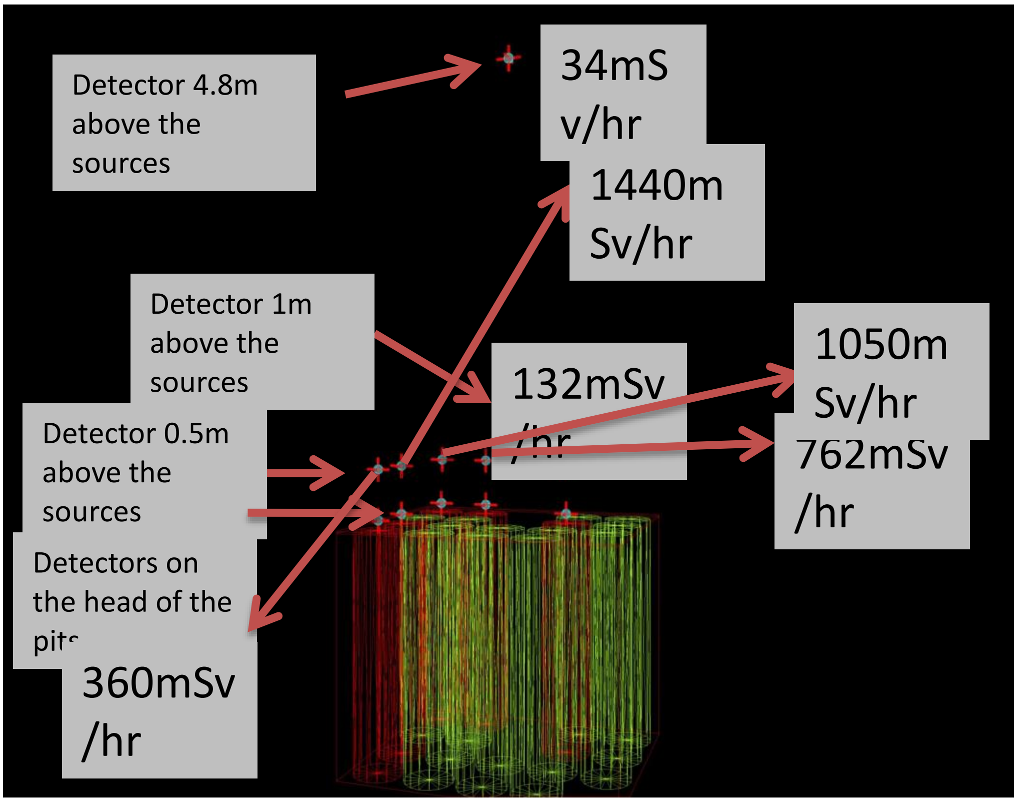


Building 120 - Backward area

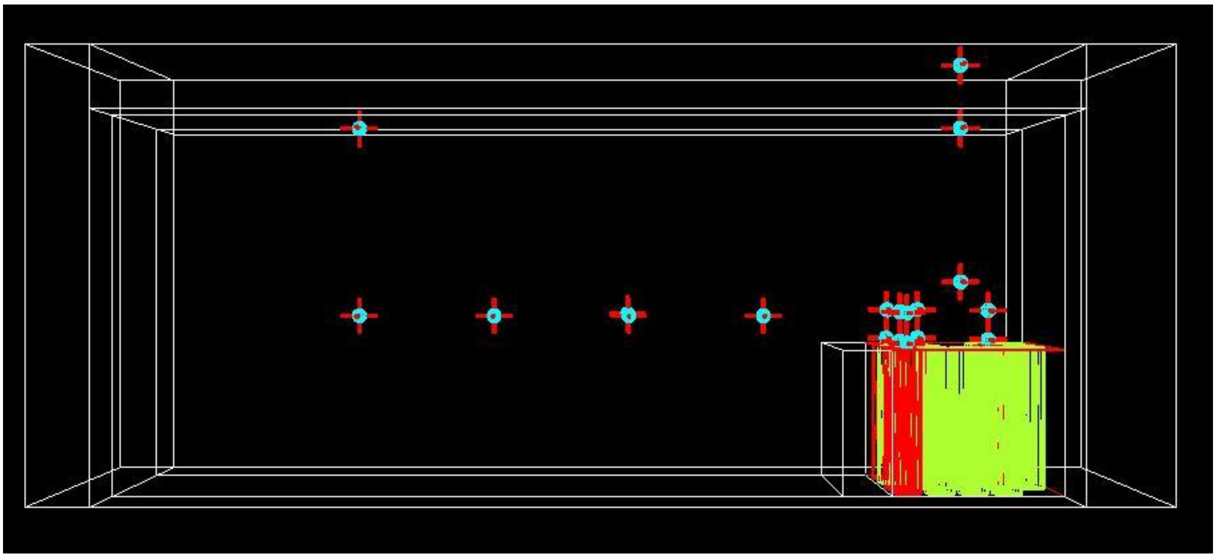
Building 120 - Forward area

11.5 The measuring inside the hot cell HA

The dose rates above the first position:



The dose rates above the first position



The radiological characterization of the cell

mSv/h	Section 1	Section 2	Section 3	Section 4	Section 5
300cm above the ground	223	18.68	2.1	0.5	0.2