EDF General Methodology to assess worker exposition and environmental impact caused by work during dismantling –

Lack of knowledge and tracks to improve it.

An operation type: the case of BUGEY 1

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Content

9 EDF units under decommissioning

1 pressurised water reactor (PWR)
Chooz A (300 MWe) - 1967-1991

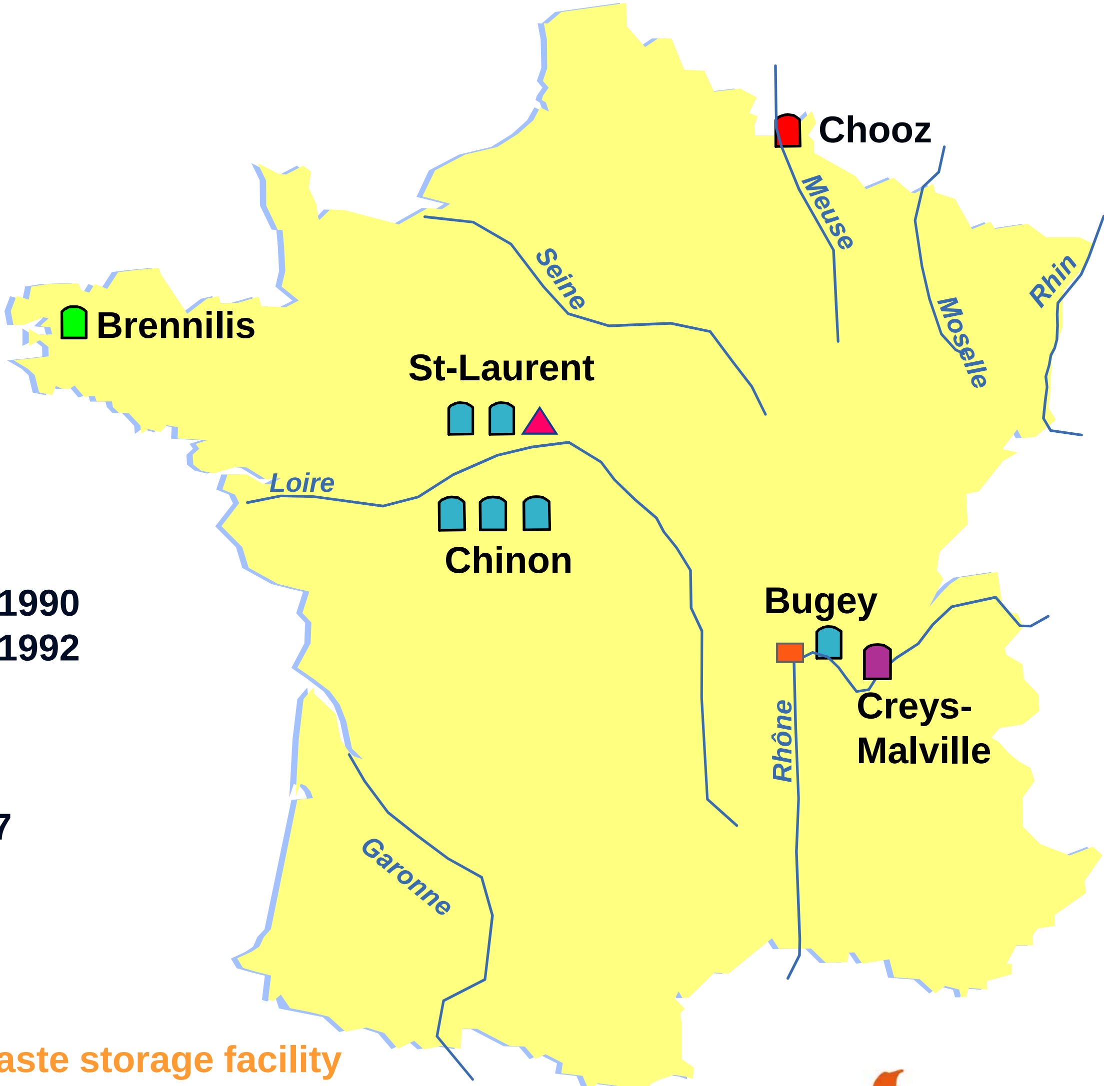
1 heavy water reactor (HWR)
Brennilis (70 MWe) - 1967-1985
(EDF - CEA)

6 gas-graphite reactors (GCR)
Chinon A1 (70 MW) - 1963-1973
Chinon A2 (200 MW) - 1965-1985
Chinon A3 (480 MW) - 1966-1990
Saint-Laurent A1 (480 MW) - 1969-1990
Saint-Laurent A2 (515 MW) - 1971-1992
Bugey 1 (540 MW) - 1972-1994

1 fast breeder reactor (FBR)
Creys-Malville (1240MW) : 1986-1997

graphite silos

ICEDA - conditioning and activated waste storage facility (project)



Decommissioning Sites

Specific features of a decommissioning sites

- Dismantling activities present specificities in comparison with activities during reactor operation, which will have consequences on the radiation protection preparation of the task:

- **Lack of feedback experience:**
  - **Most of the time, new tasks and even sometimes unique tasks (i.e. most of dismantling activities of the Creys-Malville reactor),**
  - **Not yet enough feedback experience.**

- **Difficulties to accurately evaluate radiological conditions:**
- **Lack of knowledge about history of reactor operation,**
- **Impossibility to perform measurements or old radiological maps,**
- **Decrease of the source term following removal of equipments or due to radioactive decay,**
- **Changing dose rates in waste storage,**
- **Very dosant works when reaching equipment close to the core, little national Feedback, important international Feedback (notably from the US)**

Specific features of a decommissioning sites

- ↳ **Difficulties to accurately evaluate the exposed workload:**
  - ↳ **Difficult to evaluate the exact work duration for tasks, which last months or even years,**
  - ↳ **Because of the great sizes a significant portion of the input data is only estimated and calculated**
- ↳ **Waste management :**
  - ↳ **Many waste of different types (VLLW, LLW, ILW) to manage. Need to preserve the national repositories (notably VLLA**

- ↳ **Evolving configuration of installations during the works, important "worker safety" problem.**
- ↳ **Significant contamination problems linked to the airborne discount of radioactive materials following the use of aggressive cutting methods, in particular in case of using thermal cutting and/or presence of alphas.**
- ↳ **Problems of discharge are generally weak (cf. US Feedback) but an impact assessment is necessary, in particular for public enquiries.**
- ↳ **Partial/total release ('brown' or 'green' sites) of the sites.**
  - ↳ **What to do with VLLW from soil and concrete?**

Development of dismantling scenarios

- The choice of reference scenario is made in several steps (combination of ideas, pre design, detailed design) taking into account all the industrial actors involved in decommissioning activities

- Ultimately, leading to:
  - the files in order to obtain the dismantling authorization decree from public power
  - in support of that: a safety report and support studies

- A multi-industrial team (civil engineering, waste, decommissioning technology, radiation protection, safety, security, environment, etc.) supports the development of the scenario

Development of dismantling scenarios

- **ENVIRONMENT**: The choice can be oriented according to environmental requirements, notably filtration. In general, the constraints are proportional to those of the Radioprotection (for example in case of thermal cutting of activated structures) but are weaker.

- **WASTE**: The choice of cutting types is important but:
  - Absolute requirement to limit cutting:
    - Fewer releases,
    - Fewer doses,
    - Less waste generated,
    - Less road/rail transport,
    - Lower costs
  - *In all cases, prefer one piece removal (case of Vessel, Steam Generator, etc)*
  - Only envisage cutting if this is obligatory.

Development basis of dismantling scenarios

- **Radioprotection:**
  - **significant parameters which influence design choices**
  - **studies include, among others:**
    - **a detailed analysis of working conditions,**
    - **a detailed doses study reliable to the scenario.**

Development of dismantling scenarios

The need for a <u>lock-out period</u> between

- **The choice of scenarios and the reliable issues which are:**
  - **The doses at working places,**
  - **The environmental impact studies,**
  - **The waste studies.**
- **If one of these issues is unacceptable, the scenarios will need to be reconsidered.**

Environment: the impact study

Linked with:

- Source term released into the environment,
- Impact on water, on air.

This term is similar to the impact assessments issued for the operating units and will not be developed here (same methodology, same tools, same references)

In general, for EDF's operating units, the impact is low.

In the case of "mixed" sites (ie operating unit and dismantling unit):

Impact of the dismantling unit < Impact of the operating unit.

Source term released into the environment

It depends on:

- the planning of the operations,
- the radiological inventory:
  - coming from activation due to the neutron flow
  - coming from contamination by corrosion products
- The release into the “intra muros” (water and air) vectors is calculated by a cascade of factors correlated to the choice of cutting types (MDM, AWJ, mechanical cutting, plasma, etc.)
- The releases in the environment are made depending on the type of filtration in operation.

Radioprotection: estimation of doses at working places

- Forecasting the linking of dismantling operations
  - Data arising from planning of operations (number of participants, protective equipment, complexity of work, etc.)
- Knowledge of the source term and dose rates (conditions of work)
  - Source term: characterization by sampling, measurement, knowledge of the history of the installation, code simulations (neutrons and activation calculations)
  - Iterations of calculations (with samplings measurements results) are necessary to take into account impurities generating significant activities if they are unknown at the time of the supply.
  - Dose rates and zoning are defined on mapping completed with situ studies and <u>by simulation</u> thanks to the structures activation data.

Radioprotection: estimation of doses at working places

- **Internal contamination and exposure**
  - **Care must be taken in order to get internal doses which must be considered as negligible in EDF sites**

    ⇒ key factor ⇒ the internal doses are not taken into account in the working studies
  - **Levels of contamination measured on-site: they are estimated on future sites and based on coefficients of resuspension specific to the types of work undertaken.**

Use of PANTHERE type models

- The planned dose rates are estimated in the framework of the scenario studies with variable installation configurations that no longer correspond to the initial state

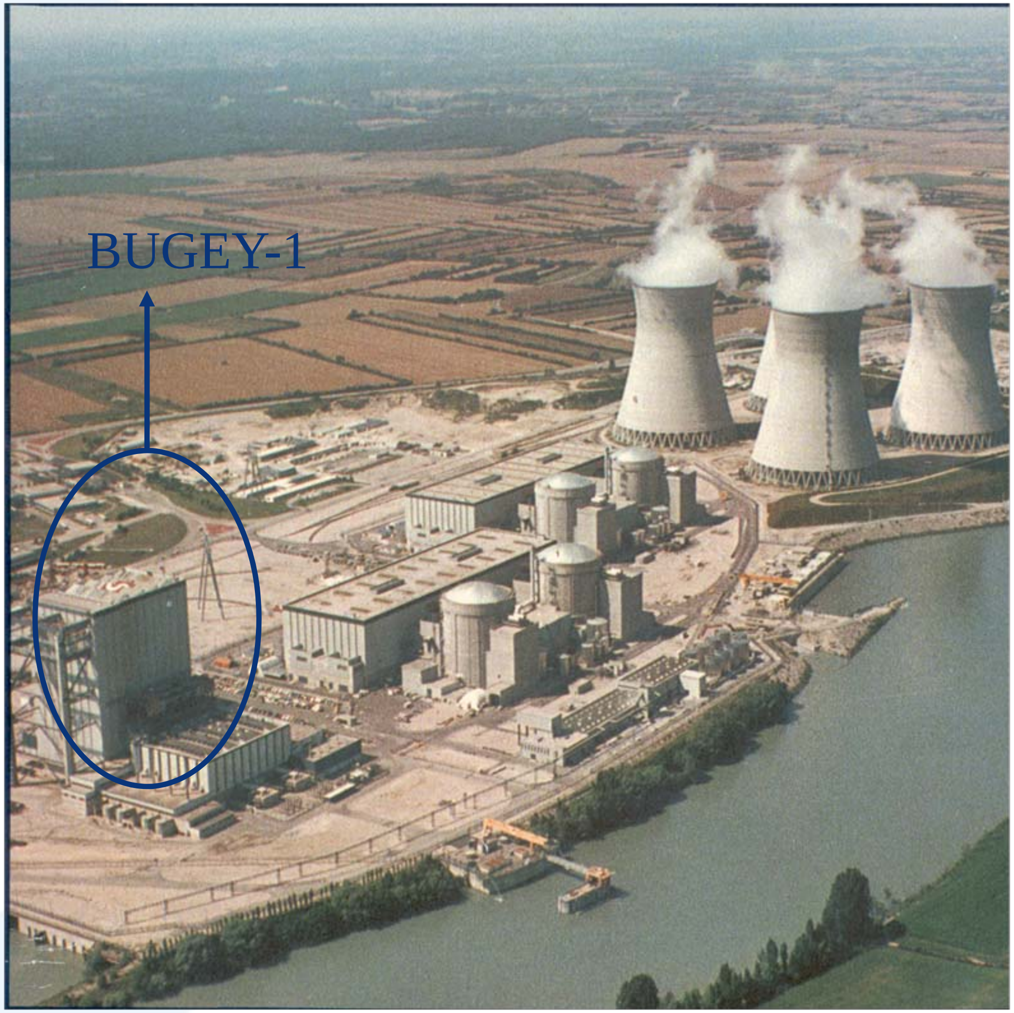
  ⇒ to support the technical choices

  ⇒ to define a reference scenario

  and evaluate the working dose rates.

- Establish the scheme zoning of the affected areas during the decommissioning.

Example of BNI N° 45: Bugey-1

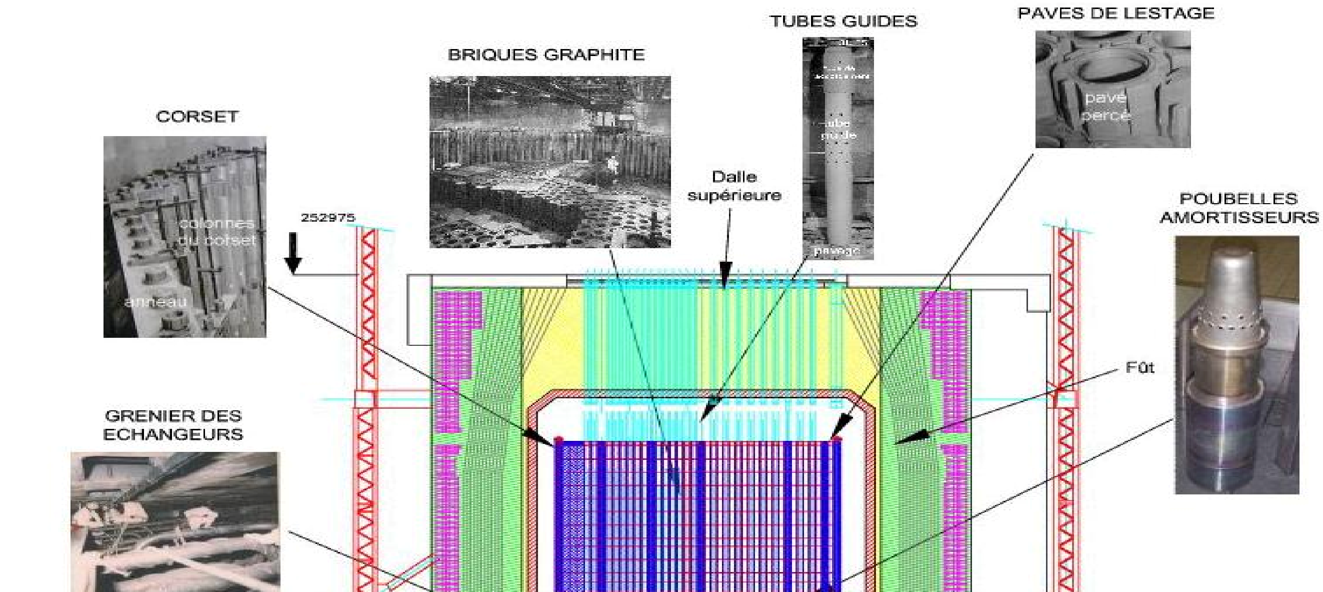
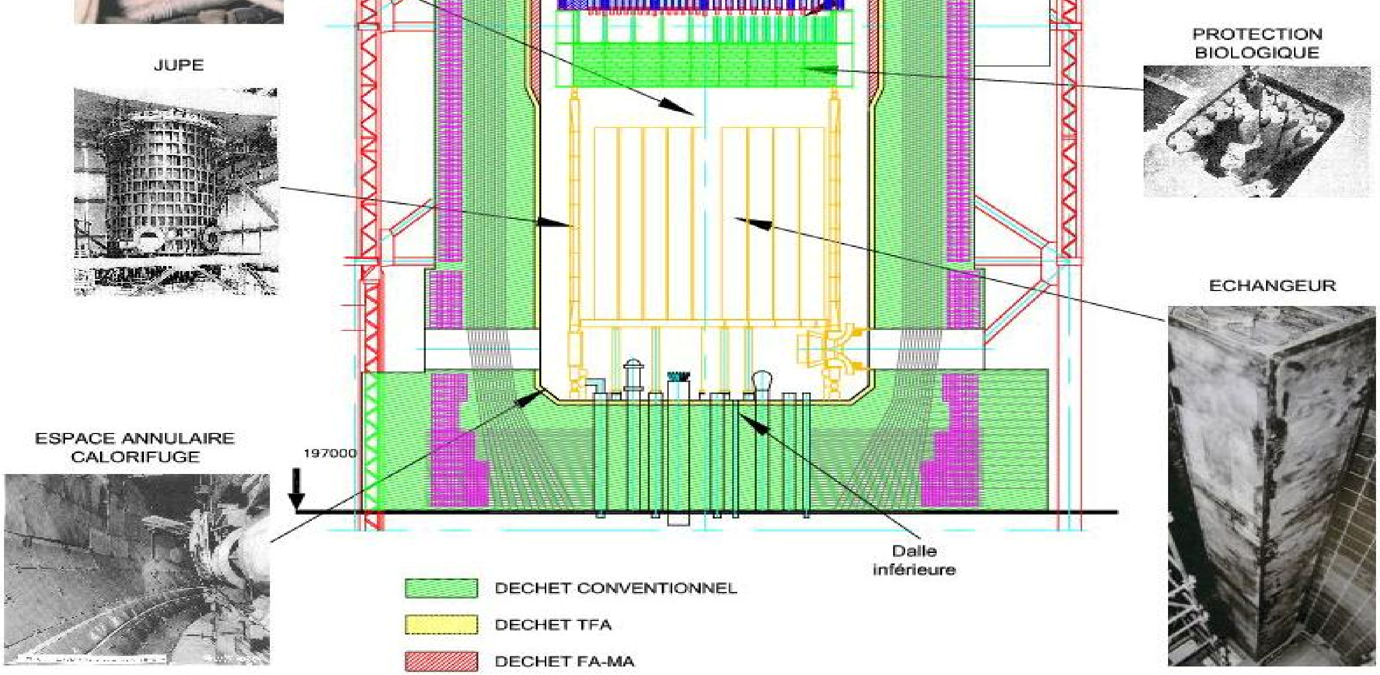


▪ **Characteristics of Plant 1:**

- **"INCA" UNGG reactor: caisson-based primary circuit, annular fuel element**
- **Thermal power: 1950 MW**
- **Electric power: 545 MWe**
- **Fuel: 320t of natural uranium slightly enriched in ^{235}U**
- **Moderator: graphite stacking (2080t) 9m in height and 12.20m in diameter**
- **Coolant: gaseous CO_2 under 41.5 bar pressure**

exchanger entry temperature: 402°C
exchanger exit temperature: 217°C

Bugey-1

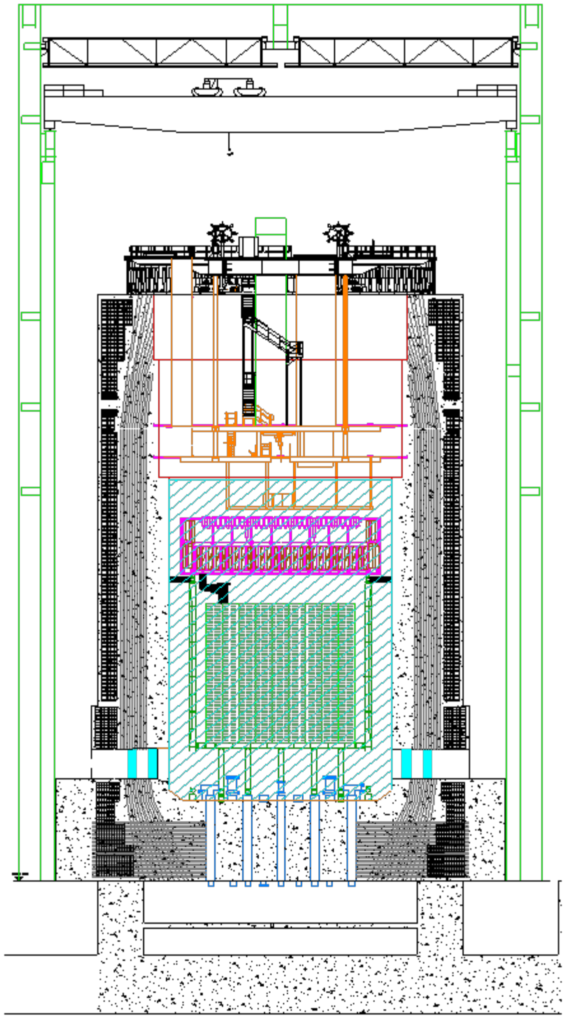
Characteristic dimensions:

External height : 55.98 m
External diameter : 28.10 m
Current thickness of the concrete wall : 5.50 m
Height of the interior cavity : 40.12 m
Internal diameter : 17.10 m

Dismantling scenario - principles **Bugey-1**

- **Underwater dismantling of internal equipment**
- **Opening of the upper slab**
- **Top-down dismantling**

  - **Biological protection of operators via a screen of water**
  - **Teleoperation close up**
  - **Technical flexibility (management of uncertainties)**
  - **Industrial feasibility (Fort St Vrain Feed Back)**
  - **Use of thermal tools and several workstations**



Dismantling scenario – steps Bugey-1

1. Dismantling structures outside the 'caisson'
2. Extraction of operational waste
3. Dismantling of the caisson
   - Preliminary operations
   - Opening of the BTS
   - Dismantling of upper internal equipment
   - Cutting of the activated civil structures
   - Lowering of the platform
   - Dismantling of the plates and support area
   - Total discharge of the caisson
   - Dismantling of lower internal equipment
   - Treatment of the lower part of the shaft
4. Decontamination
5. Remediation of the site

RP calculations – input data – source term

Bugey-1

- **Main characteristics of the sources:**
  - **Already discharged uranium fuel.**
  - **Most activated areas: stainless steel structures located close to the core**
  - **Main radio-element: ^{60}Co from the neutron activation by filiation of the ^{59}Co and ^{58}Fe present in the steel structures**
  - **Only the activated structures are modeled – the contamination is not taken into account (distribution is too heterogeneous)**

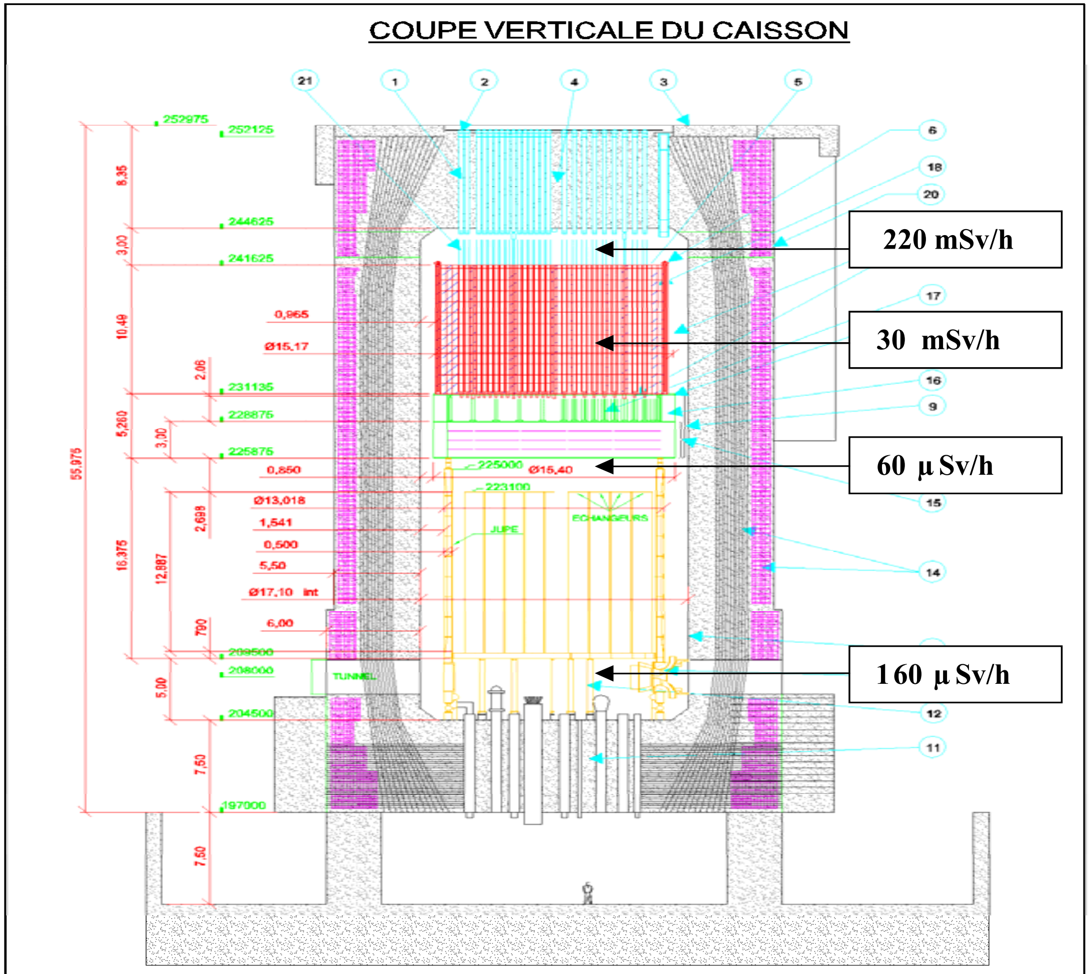
- **Reported sources for the calculations:**
  - **Complex and detailed spatial distribution of the sources**
  - **The majority of the source term is based on CEA/SERMA calculations:**
    - **Mapping of the flows in the reactor with the help of the TRIPOLI.3 code (future TRIPOLI.4)**
    - **Calculation of the activations with the help of the code system DARWIN/PEPIN.2**
  - **Certain sources have been recalculated analytically on the basis of base equations of the neutron activation:** $dN_B = [\Phi.\sigma_A.N_A - \lambda_B.N_B].dt$ **so as to adjust the impurity rates to the re-estimated values.**

Bugey-1

Radiological state of the caisson in 2010

Calculated values (PANTHERE) in the upper part of the caisson,

Measured values in the lower part



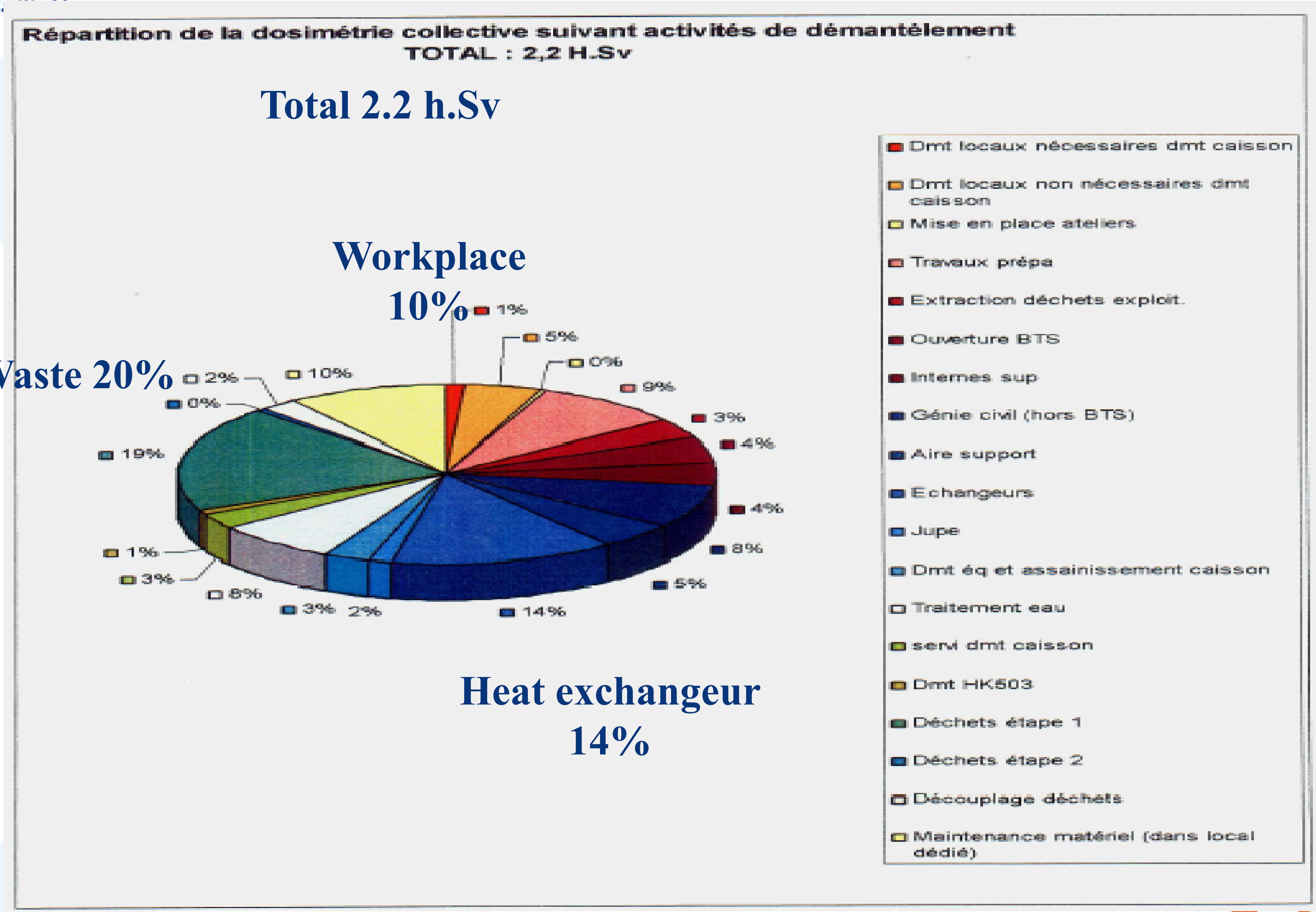
Surfacie Contamination :

β/γ : 3020 Bq/cm²

α : 0,18 Bq/cm²

(Ratio β/α = 16500)

Collective dose for the dismantling Bugey 1 scenario



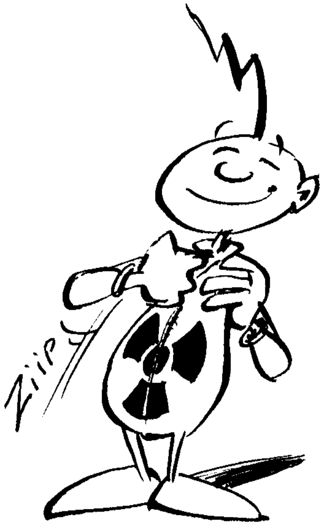
Radioactive releases

Annual activity releases for gaseous and liquid radioactive waste are required :

- **Tritium**
- **Carbon 14**
- **Other products of β/γ transmitter fission and activation**

Unit 900 operation (per year)	Regulations Gases	Actual Gases	Regulations Liquids	Actual Liquids
Tritium	2 TBq	0.23 TBq	185 TBq	11 TBq
C14	}111 GBq	0.15 TBq	} 2 TBq	11 GBq
PA/PF		0.003 GBq		0.3 GBq

Some lines of thought for the future



Radiological inventory
=> "Keystone" of the dismantling

1. **<u>Calculations</u>**

In particular:

- **Long-distance flow of neutrons ("biasing" method with cooperation of CEA)**
- **Quantification of uncertainties**
- **Quantification of radiation source by 'reverse calculation' from the mesurated doses .**
- **Development of "REMCO" software to quantify the radionuclides transfers on several substrates as steel, concrete, bore carbure (partnership with Ecole des Mines and CNRS)**

Radiological inventory => “Keystone” of the dismantling

2. **<u>Measures for consolidating the calculations</u>:**

- **Work closely with the calculator**
- **Definition of a range of equipment**

<u>From the more traditional</u>:

- **Gamma camera**
- **CZT spectroscopy**
- **ISOCS (soils, GC)**
- **Traditional core boring**

Radiological inventory
=> “Keystone” of the dismantling

<u>To the more recent</u>:

- **US “TRUPRO” core boring, (Feedback from US)**
- **Surface measurements in order to replace core boring (CEA, Kourtchatov, EDF/R&D)**
- **Tritium measures in the soil via vapor injection (EPRI/USA)**
- **Soil excavation ‘SGS system’ (issued from DOE studies)**

Lines of thought for the future

3. **Growth of Feedback US (10 sites, 10 commercial reactors dismantling)**

   Main lessons:

   - **Importance of monobloc discharge (Safety, Authority and ANDRA to be trained)**
   - **Choice of cutting techniques (importance of mechanical choice and choice of AWJ, MDM)**
   - **Importance of prototype tests at a good scale (not only tool tests)**
   - **Water treatment, purification rate of flow,**
   - **Management of soils and ground waters (4 sites have been or are in the process of being released as “green field” sites)**

Lines of thought for the future

4. <u>Some additional pieces of information</u>

➢ <u>Inhalation risk</u>:

Importance of optimized approach about inhalation

➢ <u>Definition of detailled studies of alpha on type working posts</u>:

E.g. at Saint-Laurent, drawing inspiration from what has been done for the operating units with EDF/R&D:

- Resuspension factors
- Size of aerosols
- Solubility…

Lines of thought for the future

<u>Decontamination of concrete:</u>

- **Technical alternatives in order to reduce of RP constraints (less trying work)**
- **Use of air sensors**
- **Alpha working places**

Thank you for your attention