Research and Development of Gas and Aerosols Dispersion in the RB at EDF Nuclear Power Plants

ISOE European Symposium

M. LESTANG *(EDF UNIE GPRE)*

Participants of This studies

H. MOHAND KACI *(Post-Doctorat IRSN-EDF) -*
S. JAHAN *(EDF R&D)* **- :**
J. FAZILEABASSE ***(****EDF R&D)*
F. GAURIVAUD *(NPP GOLFECH)*
J.E. MAURER *(NPP TRICASTIN)*

And many others participants during the last 10 years

Research, Test & Development

2008-2010: **IRSN-DSU-SERAC-LECEV** *(C PREVOST – L BOUILLOUX – S ARTOUS)*
2008: **IRSN-DSU-SERAC-LPMA** *(S FAUVEL)*
2004: **ISRN-DPRH-SRBE-LRTOX** *(C CHAZEL – F PAQUET – E TOURLONIAS)*

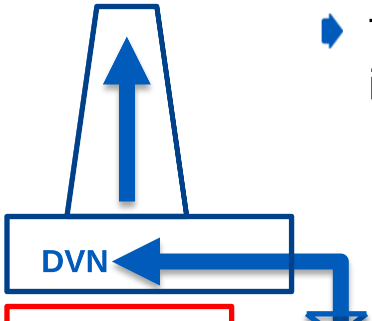
CHANGER L'ÉNERGIE ENSEMBLE

Context and issues

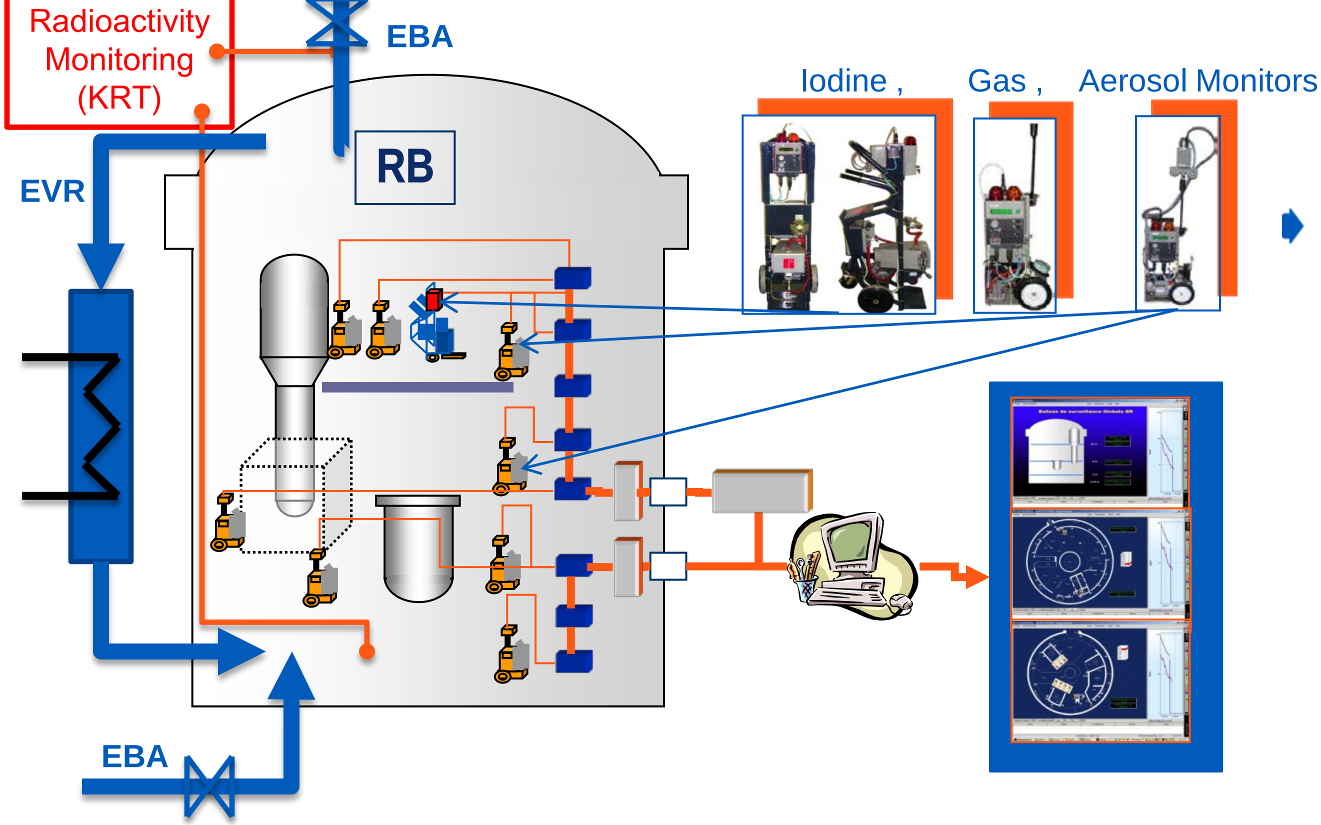
- Context
  - The Nuclear reactors requires periodic maintenance involving works on circuits carrying the contaminated fluid and may be causing internal and external workers exposure.
  - During outages in RB, many workplace at risk of dispersion of contamination (Steam Generator, Capacity, Pumps ...) involving a large number of workers.

- Issues of internal exposure monitoring based on:
  - Compliance with regulations exposure limits,
  - Limitation and optimization of the internal contamination of workers,
    - By detecting with the best anticipation any drift of the radiological situation,
    - By performing a global collective monitoring for the entire RB volume
    - By performing a monitoring near the workplace.
  - Consistency technology devices used with the type of risks based on operating conditions.

Protection principles



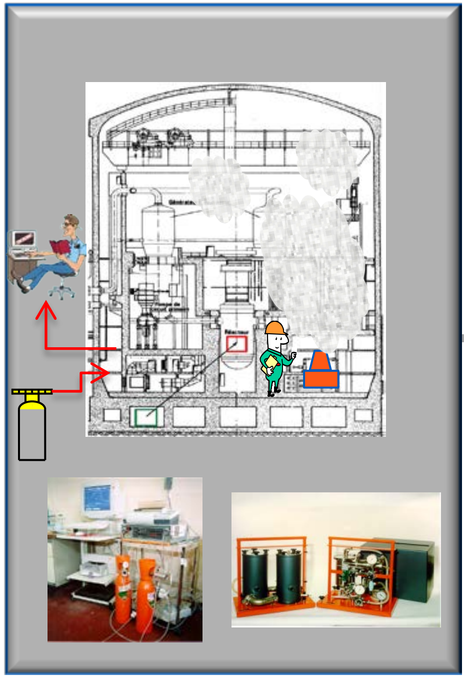
- The collective risk of internal exposure was assessed and taken into account in facilities design, with the concept of:
  - Dynamic confinements,
  - Ventilation system (Conditioning, Cleaning & Purification the RB air atmosphere),
  - Permanent Monitoring of the Radioactivity in the air via a sample extraction with aerosol, gas & Iodine monitors (KRT system) placed out of the RB.



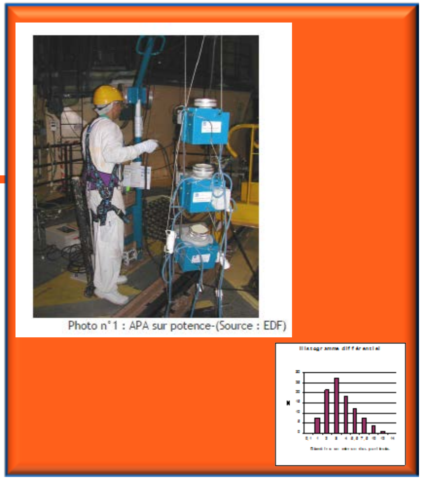
- In complement, EDF has set up a network of fixed and mobile Continuous Air Monitors (CAMs) which is giving a near-real-time monitoring of atmospheric contamination in RB.

Facility characterization

For 10 years, EDF has conducted fundamental studies and experiments to improve its knowledge of gases and aerosols dispersion in the RB

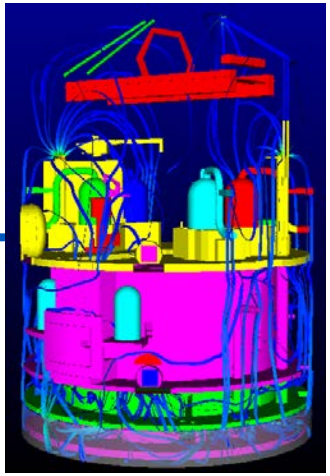


- Experimental characterization of the radionuclides and particle size distribution of aerosols emitted during outage,



- Experimental characterization of RB ventilations (EVR, EBA) & particularly the gas residence time and the aerosol transport,

- Model in 3D a RB and simulate the transport of aerosols in order to estimate the effectiveness of monitoring.



Experimental Characterization of radionuclides and aerosols particles sizes distribution in Nuclear Power Plants

-

TRICASTIN 2 - 900 MW
Pool Bottom areas

CONTEXT

Test Targets

- Qualify and quantify the risk of internal contamination of workers
- Make a space contamination map in according to the different phases of the outage, of:
  - volume and surface activities,
  - size particle distribution generated in workplace,
  - nature of the radionuclides
- Directed by EDF R & D with IRSN
- RB 2 TRICASTIN in October 2004.

Methodology

Study of pool bottom work areas in RB by:

- Sampling of aerosols on different levels.
- Measuring the activity of the sample

&

- Identifying the radionuclides by gamma spectrometric measurements.

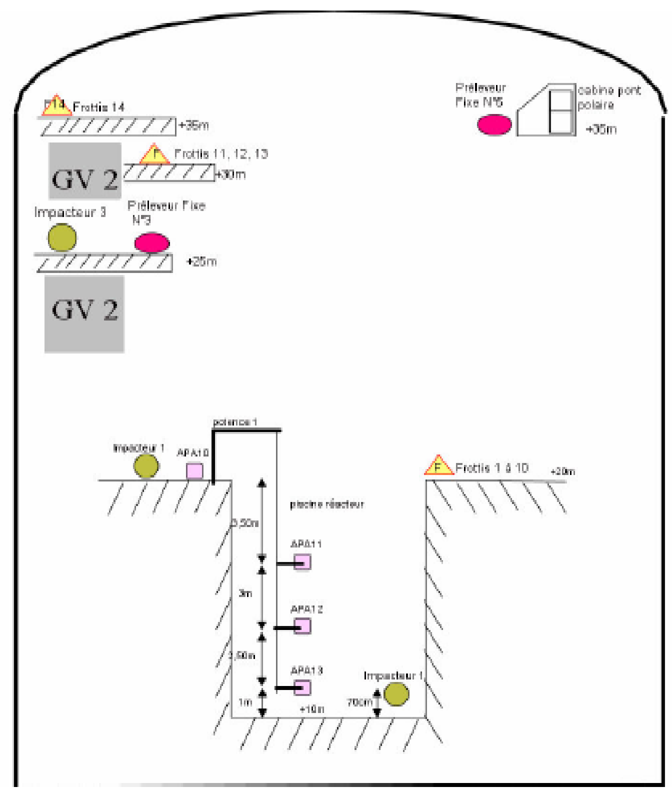
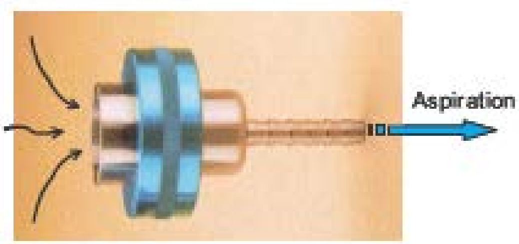


Schéma n°2 : Implantations des appareils de prélèvements dans le BR (vue en coupe). (Source : EDF)

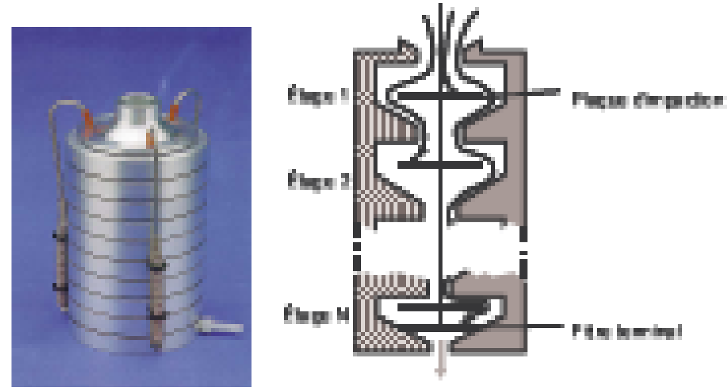
Sampling Devices

Photo n°1 : APA sur potence-(Source : EDF)



Débit de prélèvement	: ≈ 27 l/min
Diamètre d'entrée	: 47 mm
Vitesse d'aspiration	: ≈ 0,26 m/s

Photo n°2 : Porte-filtre Millipore 47 mm



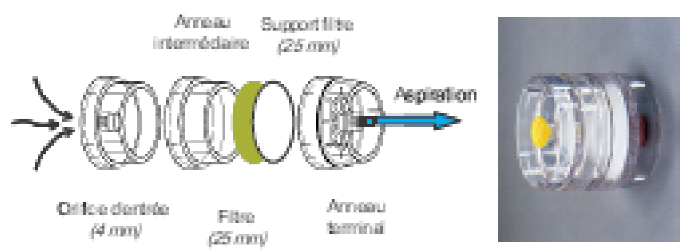
Air flow rate: 28,3 l/mn

Inlet Diameter: 25,4 mm

Vistesse d'aspiration: 0,8 m/s

Cutoff diameters(µm): 0,4-0,7- 1,1-2,1-3,3-4,7-5,8-10 µm

Photo n°3 : Impacteur Andersen à 8 étages



Débit de prélèvement	: 1 l/min
Diamètre d'entrée	: 4 mm
Vitesse d'aspiration	: 1,3 m/s

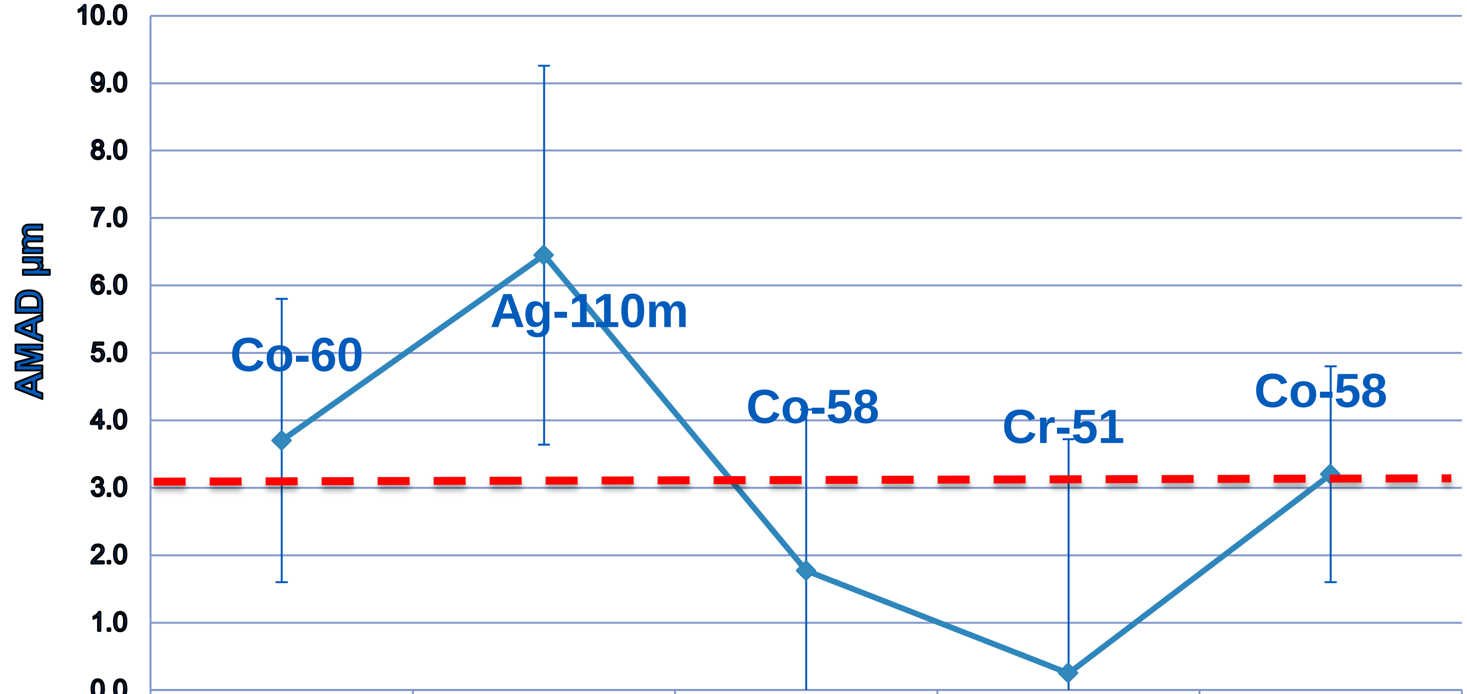
Photo n°4 : Cassette 25 mm

Results

Activity Median Aerodynamic Diameter of Particle-size distribution at the different phases of work during outage

- Concentration repartition of radionuclide depend to the phase of outage.

- Mean AMAD during outage: 3 +/- 2 µm (k=1)



	Point Zero	Openning Reactor Vessel	Pool Décontamination	Cleaning / Thread	Remove of Dummy Vessel cover
AMAD µm	3.7	6.5	1.8	0.3	3.2
Geometric Standard Déviation	2.1	2.8	2.4	3.5	1.6

➧ E.g.: Phase: Remove of dummy vessel cover

Remove of fake Vessel Cover	Ag-110m	Co-60	Co-58	Zr-95E	Mn-54	Co-57	Sb-124	Global Aerosol
AMAD (µm)	3,7	3,2	3,2	3,5	3,2	3,7	3,6	**3,2**
σg	1,4	1,6	1,6	1,6	1,6	1,4	1,3	**1,6**
Activity (Bq/m^3)	0,2	2,3	6,8	0,6	0,7	0,02	0,7	**11,4**

VENTILATIONS

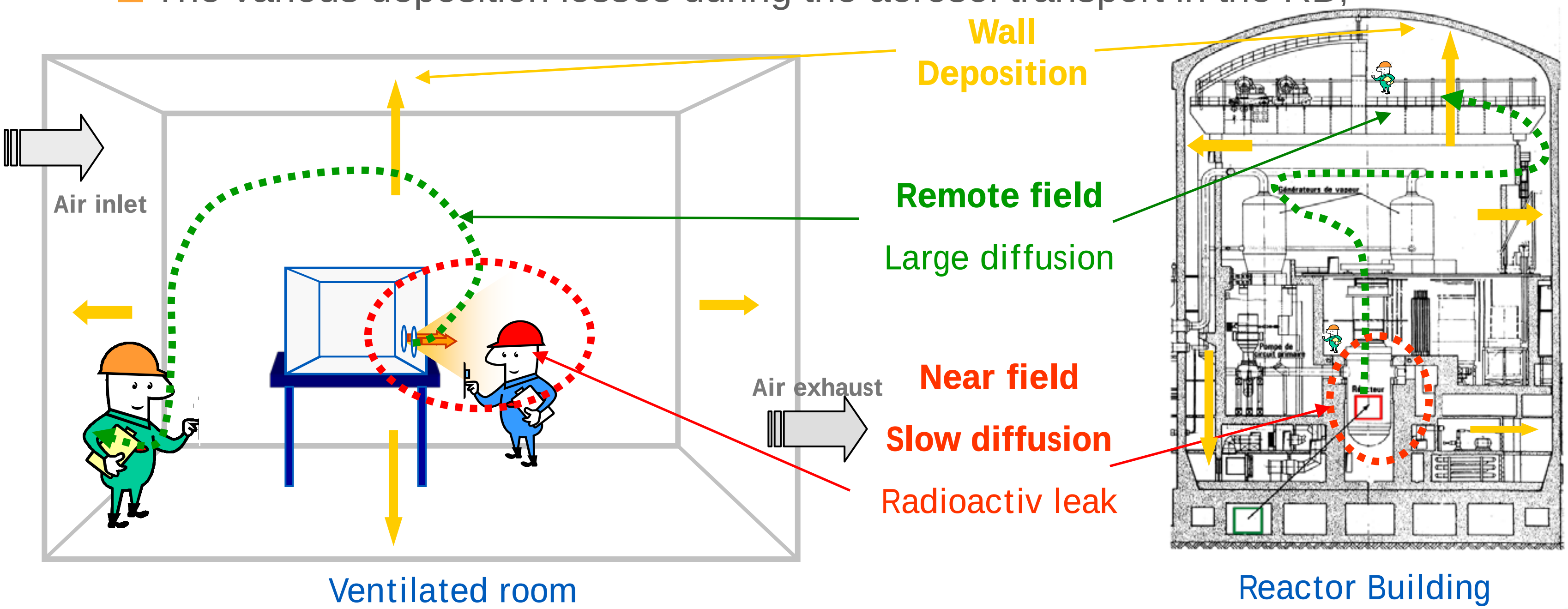
-

Experimental characterization of the RB homogeneity

Ventilations

The Ventilations Influence the evolutions of airborne radioactivity in the RB.

- The airflow conditions having an effect on:
  - The rate of air exchange in the containment building (exhaust air with fresh air inlet),
  - The effectiveness of ventilation in the containment building with possible presence of "dead zones",
  - Dissemination of aerosols and gases in the containment building,
  - The various deposition losses during the aerosol transport in the RB,



Test Description

Issue

- Characterization of the air homogeneity in the RB by measuring the gas time transfer and the gas and aerosols transfer coefficients.
- The particles are characterized by a monodisperse aerosol. MMAD of 1 µm and 5 µm.
- Directed by IRSN with EDF.
  - BR GOLFECH 2 (1300 MW) *March 2010.*
  - BR CRUAS 4 (900 MW) *April 2008.*

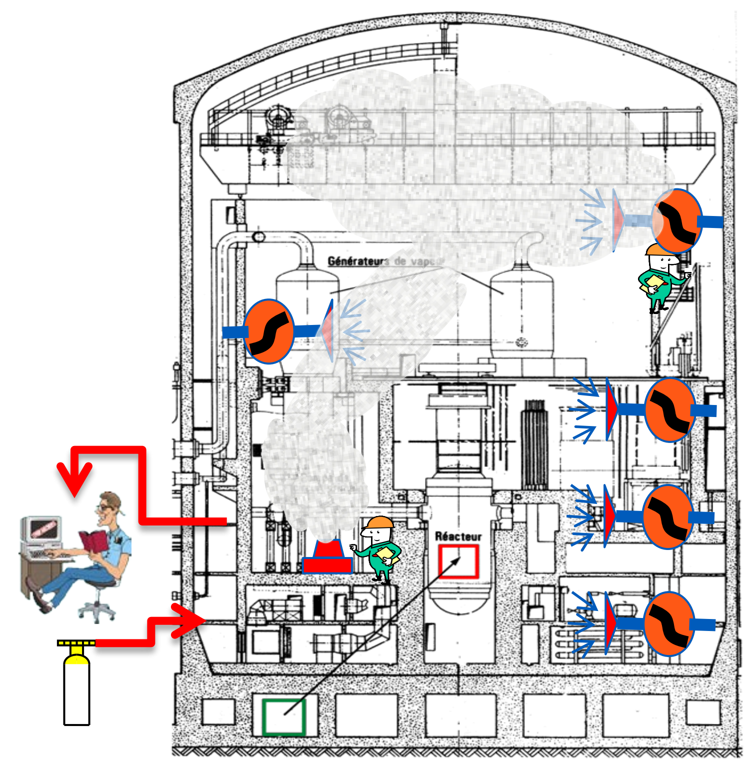
Methodology

- Two techniques were used:
  - Gaseous tracing with hexafluoride sulfur (SF6)

  ➔Simulation of Gases behavior
  - Particle tracing with sodium fluorescein

  ➔ Simulation of aerosol behavior
- Taking into account:
  - 6 emission points located at the different floors in the RB,

  and
  - 7 sampling points corresponding to the usual monitoring points in the RB..



Réacteur Buiding

Results

- **RB 900 MW – (CRUAS –Unit 4)**
  - **Homogeneous concentration**
  - **A less well-ventilated area to -3.50 m**

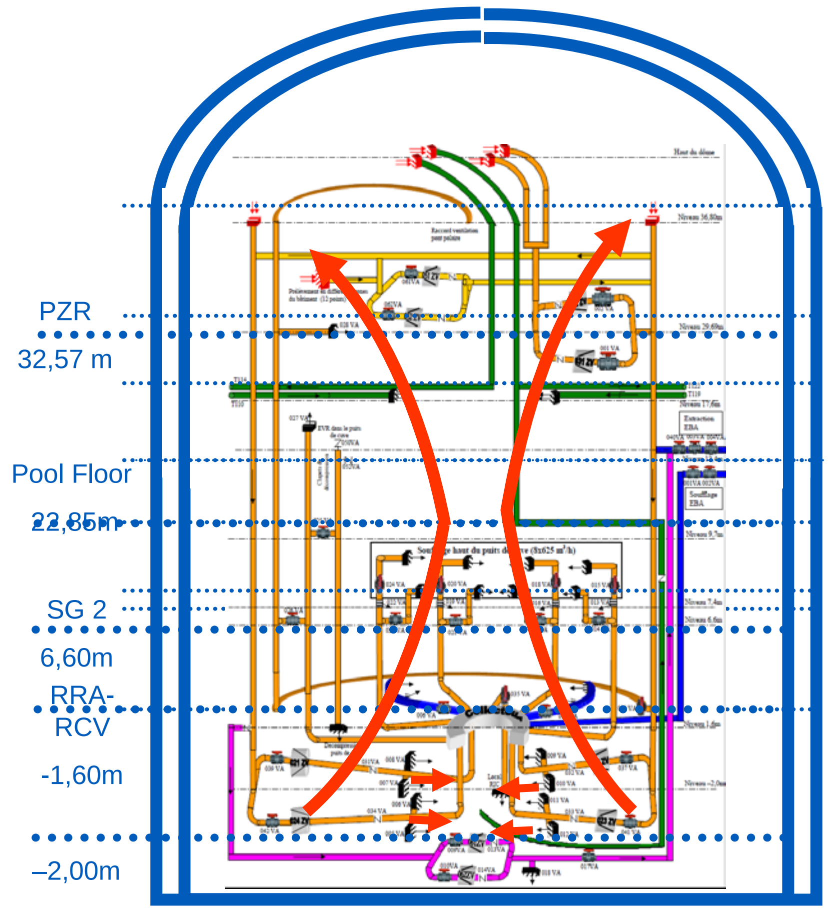
- **RB 1300 MW P'4 (GOLFECH UNIT 2)**
  - **Homogeneous concentration in operation with EVR**
  - **Concentration with an area less good mix with EVR stopped**

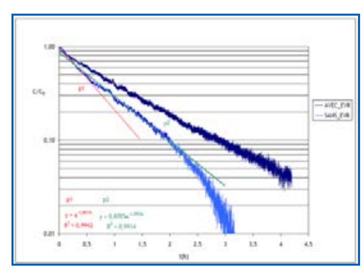
  - **Aerosols follow the direction of airflow through the containment structure, imposed by EVR (air is drawn on top of the dome and blow down of RB).**

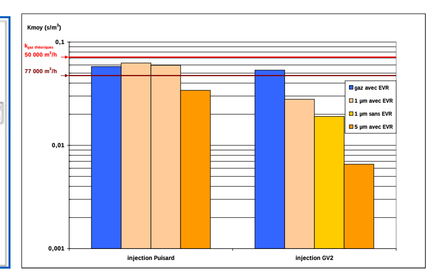
  - **Time to reach the position of the CAM, from the origin of the emission is about: a few seconds to 21 minutes.**

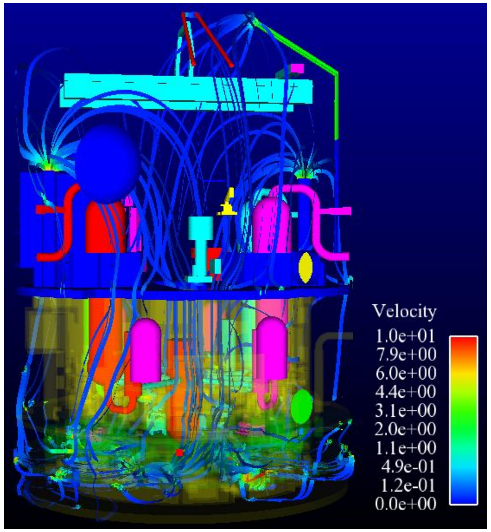
  - **The transfer coefficients of gases and aerosols 1 micron relatively homogeneous and close to the theoretical diffusion coefficients,**

  - **Characterization of coefficients and transfer time of aerosols (1 µm and 5 µm):**
    k 5 µm << k 1 µm (k = transfer coefficient)









VENTILATIONS

-

Development and validation of a multidimensional model of aerosol transfer in RB

Multidimensional model of aerosol transfer

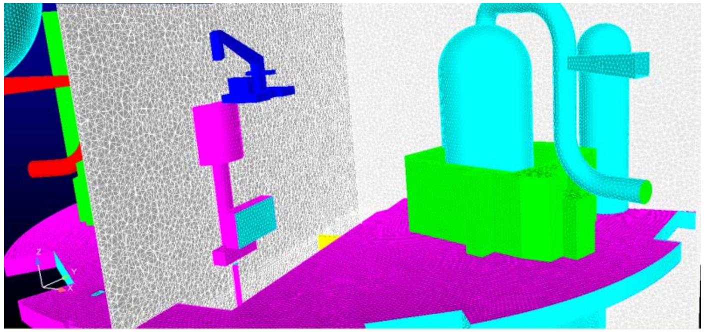
- Code _SATURNE is a free Computational Fluid Dynamics software developed by EDF R&D.

- A multidimensional model of aerosol transfer in a ventilated rooms was developed by EDF R&D and IRSN (Nerisson & al, 2011). The model was implemented on code_Saturne software.

- The model is composed of a concentration transport equation taking into account:
  - Sedimentation,
  - Turbulente and brownian diffusion,
  - Particles deviation,
  - Turbophorese: (for turbulent jet).

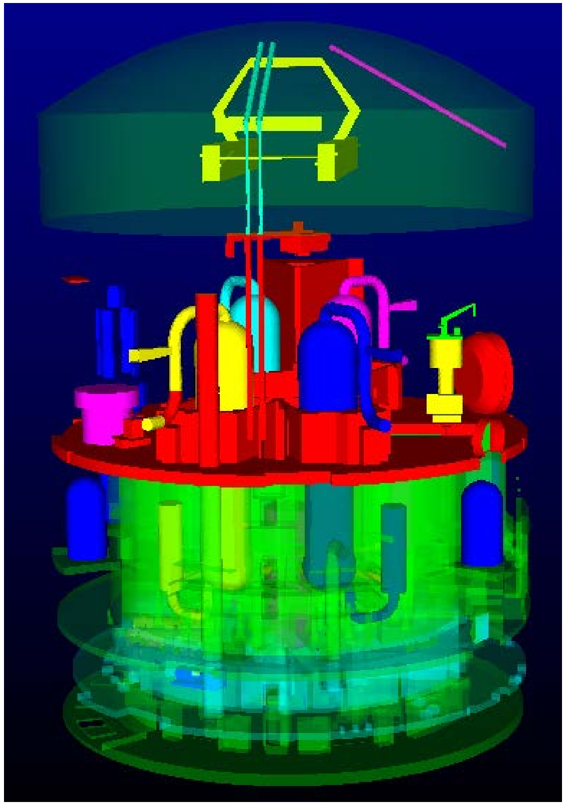
- The model was validated for simulation of local deposits in different rooms scales: 0,1- 1- 30 et 1500 m^3

Extension of the model



- The model was extended by EDF R&D and IRSN (Hakim MOHAND–KACI & al,2012)

- Extension of the model by taking into account other mechanisms of deposits:
  - Polydispersion of particles ,
  - Consideration of additional deposits phenomena (Thermophoresis and electrophoresis).



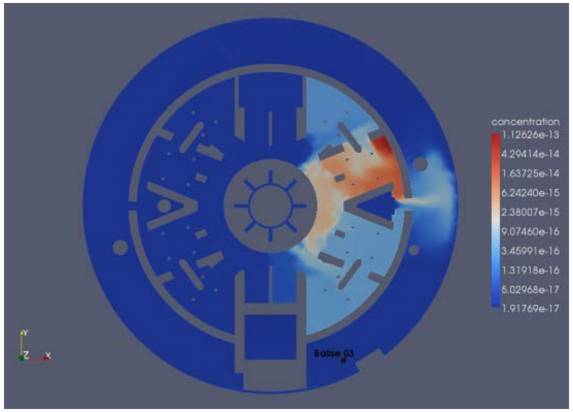
- This new model was validated at a reactor building scale (75 000 m^3) based on the gaseous and particles tracing experiments conducted in GOLFECH

Optimization of the CAM

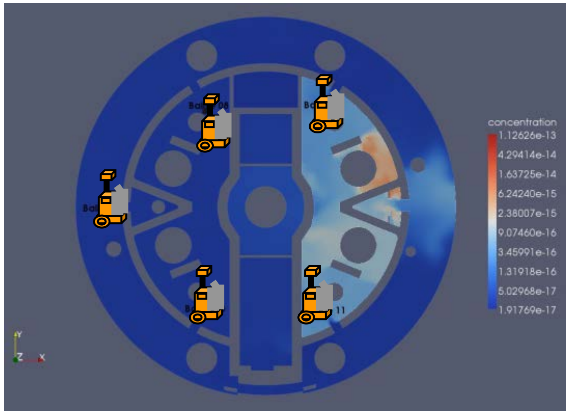
- In final step a optimization studies of aerosol position monitors, based on definition of different source emission scenarii was performed.

In this example:

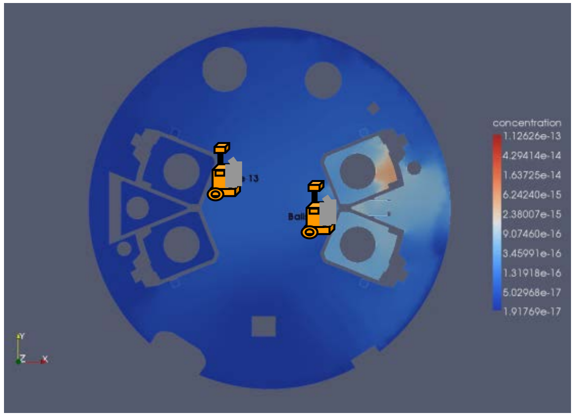
- A typical probable accident emission of contamination from Steam Generator.
- Knowledge of the spatiotemporal evolution of the concentration inside the whole RB domain provides the time response and the detection efficiency of all portable monitors.
- After this studies, EDF know the best configuration of the monitoring for more probable events contamination in RB type 1300 MW.



Floor: 6,60 m
SG radioactive leak



Floor: 12,85 m
Contamination diffusion



Floor: 22,85 m
Homogeneous
Contamination diffusion

CONCLUSION

The experiments enabled EDF

- to have greater control over monitoring of atmospheric contamination and associated parameters,

and

- significantly improve knowledge of risks and optimize the monitoring of workers in the RB.

Simulation

- allowed to find an optimal positioning of Continuous Air Monitor for a good efficiency to detect an event in RB 1300 MW, and to optimize the exposure of workers,

and

- In the coming years other types of RB will be modeled in order to ensure an ideal monitoring.

Hvala

Děkuji

ありがとう

Merci

Mulţumesc

Dank u

Muchas gracias

Danke

Kiitos

дзякуй

спасибо

Tack

Particular thanks for Hakim MOHAND KACI for the quality of his Work