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CENTRE D'ÉTUDE SUR L'ÉVALUATION DE LA PROTECTION DANS LE DOMAINE NUCLÉAIRE

Radiation Protection at the Design Stage of Nuclear Installations

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OUTLINE OF PRESENTATION

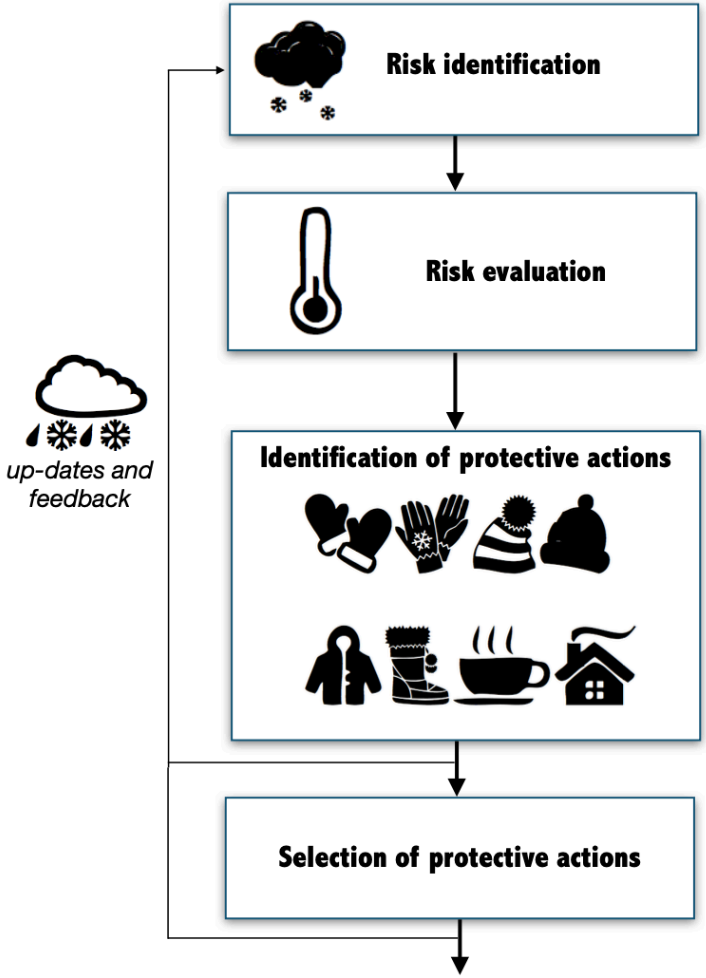
- Objectives and approach to taking account of radiation protection when designing facilities
- Identification and assessment of radiological risks
- Design provisions to take action on :
  - Source term / dose rates
  - Risk of contamination dispersion
  - Exposure time
- Elements of decision aiding methods for selecting actions
  - Criteria to be taken into account in the decisions
    - Example of biological protection
- Conclusion

Radiation protection at the design stage of nuclear facilities

- Objective to **define, as earlier as possible** at the design stage, the measures needed to limit worker exposure.

- **ALARA approach :**
  - Iterative process
  - Objectives refined as the design progresses

- **Qualitative and quantitative risk assessment**
  - Identification of the actions that will enable optimum risk levels to be achieved.
  - Selection of actions based on qualitative and quantitative criteria.



Identification of radiological risks/1

- **Inventory of radiation sources** during activities and for the various parts of the installation.
  - Based on feedback or modelling.

- **Characterisation of sources** (geometry, radionuclides, activity spectrum, physico-chemical form, dose rates, etc.), if necessary using a majority estimates to take account of uncertainties.

- **Identification of contamination levels**

- **Identification of changes in the radiological inventory during :**
  - Plant status (operation, shutdown, incident)
  - Installation/equipment configurations (open, closed, moved, etc.)
  - Life phases (activation, ageing, decay, etc.)
  - Identify active circuits (activated or contaminated) and potentially contaminable circuits.

Identification of radiological risks/2

- **Identification of workplaces and activities**
  - Activities, dose rates at the workplace, exposed workload, contamination risks, etc.

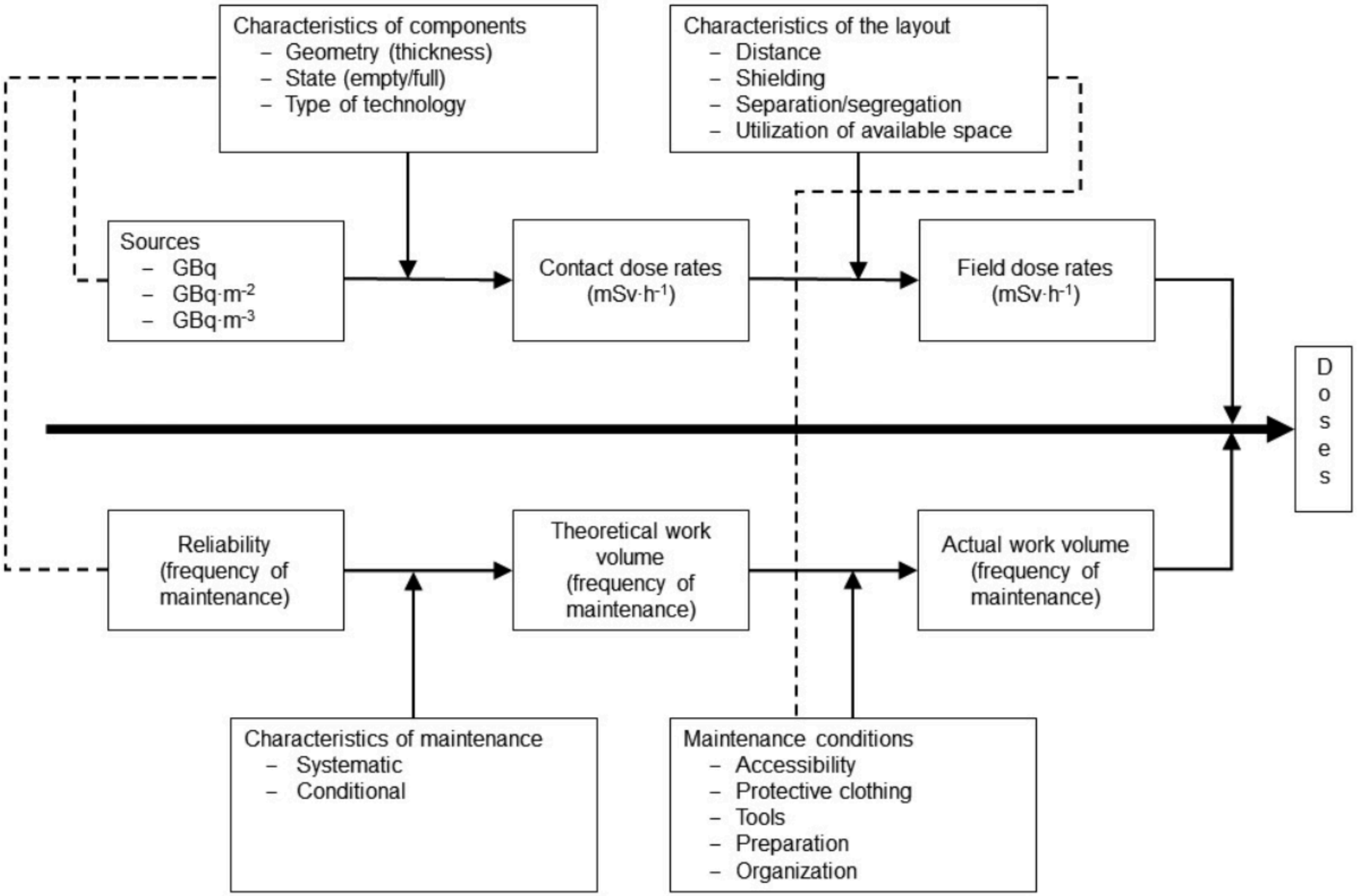
- **Initial estimate of doses at the workplace.**
  - External doses,
  - Internal contamination risks

- **Do any notable points emerge?**
  - Collective dose?
  - Activities giving rise to high individual doses?

- **The assessments will have to be repeated as the optimisation process progresses** (iteration) or if the design of the installation is modified (evolution).

Identification of protection actions

Analysis of elements contributing to individual and collective exposures



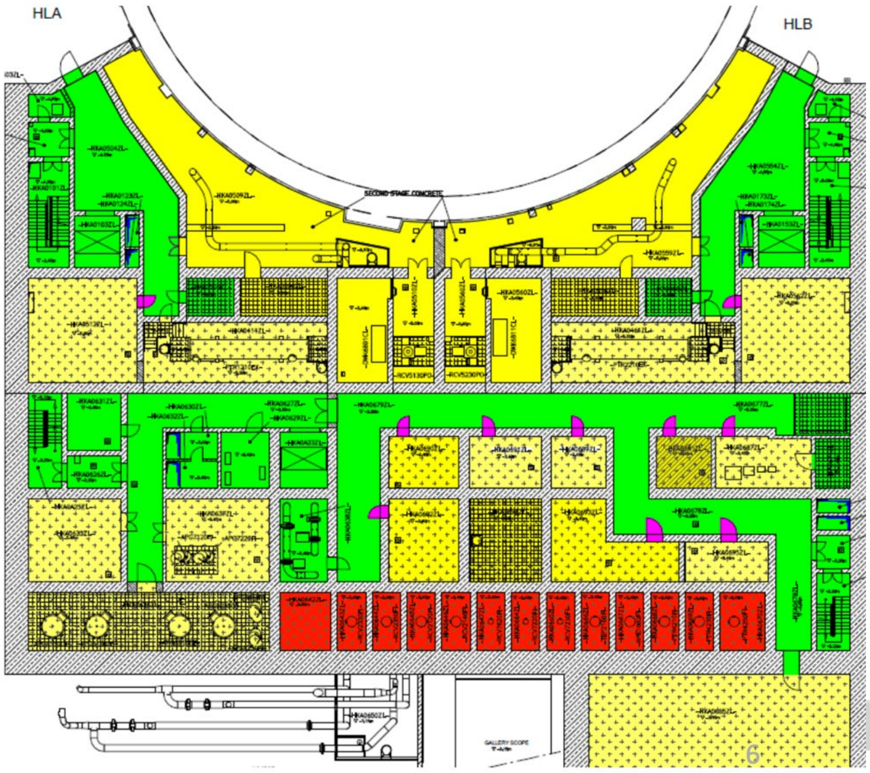
Radiological zoning

- Objective : To identify rooms, corridors and passageways that must remain in a low-dose-rate zone and a clean zone, separated from areas where there is a risk of contamination.

RADIATION PROTECTION ROOM CLASSIFICATION

SUBZONE		GREEN ZONE		CLEAR YELLOW ZONE		DARK YELLOW ZONE		ORANGE ZONE			RED ZONE	
DOSE RATE		10 µSv/h	25 µSv/h	0.1 mSv/h	0.2 mSv/h	1 mSv/h	2 mSv/h	10 mSv/h	30 mSv/h	0.1 Sv/h	0.3 Sv/h	
Rooms with no iodine risk	No aerosol risk or non-fixed contamination	A	2.5A	B1	2B1	C1	2C1	D1	3D1	E1	3E1	F1
	Aerosol risk	--		B2	2B2	C2	2C2	D2	3D2	E2	3E2	F2
Iodine risk		--		B3	2B3	C3	2C3	D3	3D3	E3	3E3	F3
Access		Regulated work area		Regulated stay area				Limited stay area				

Radiological Zoning – *BD EPR2 Fuel Building level -3.4m*



Actions to reduce the source term / dose rates

- **Choice of materials:**
  - Limit impurities and stellites, i.e.: cobalt (Co), nickel (Ni), silver (Ag) and antimony (Sb)

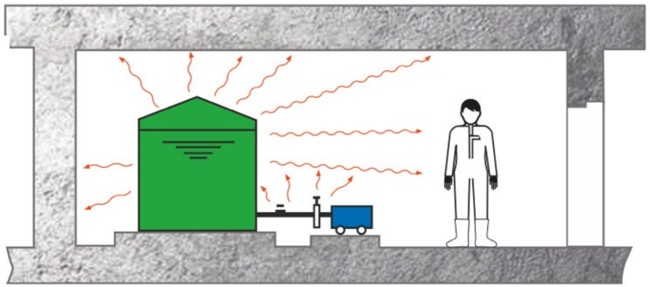
- **Actions on sources:**
  - Room layout
  - Wall thickness/position
  - Fixed shielding
  - Temporary shielding

- **Circuit layout**
  - Avoid high dose rate circuits in walking areas, in areas where there will be monitoring devices

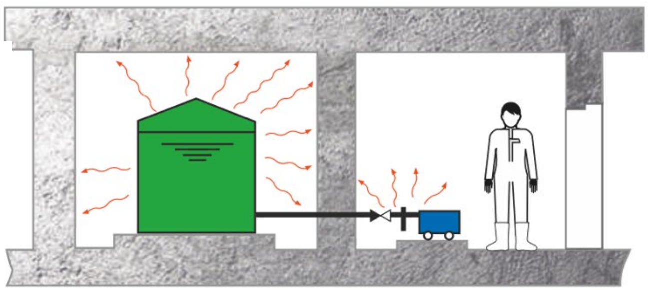
- Configuration of circuits to **limit deposits and hot spots**

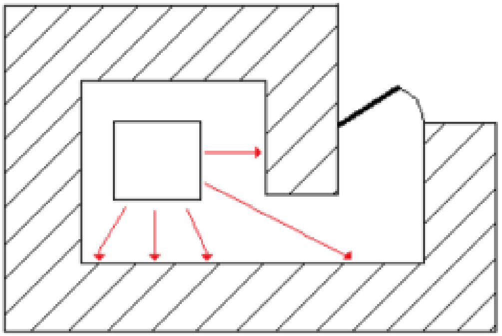
Actions to reduce the source term / dose rates
Rooms layout rules

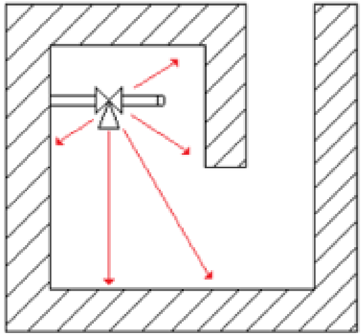
NO

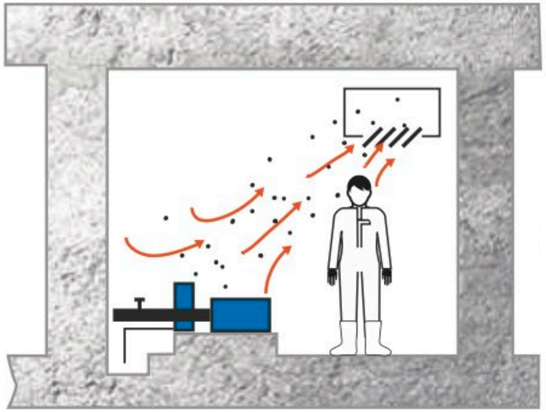


YES









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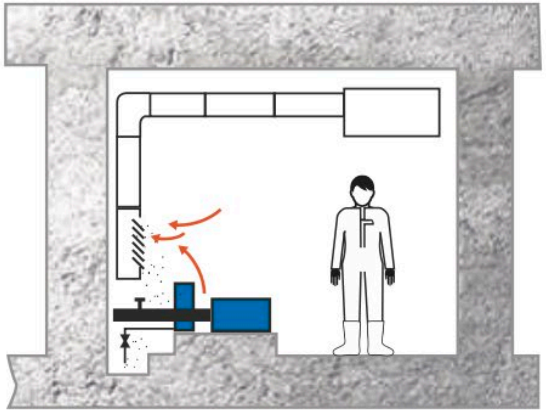


YES

Actions to reduce the source term / dose rates
Shielding


Fixed steel shielding


Fixed steel shielding

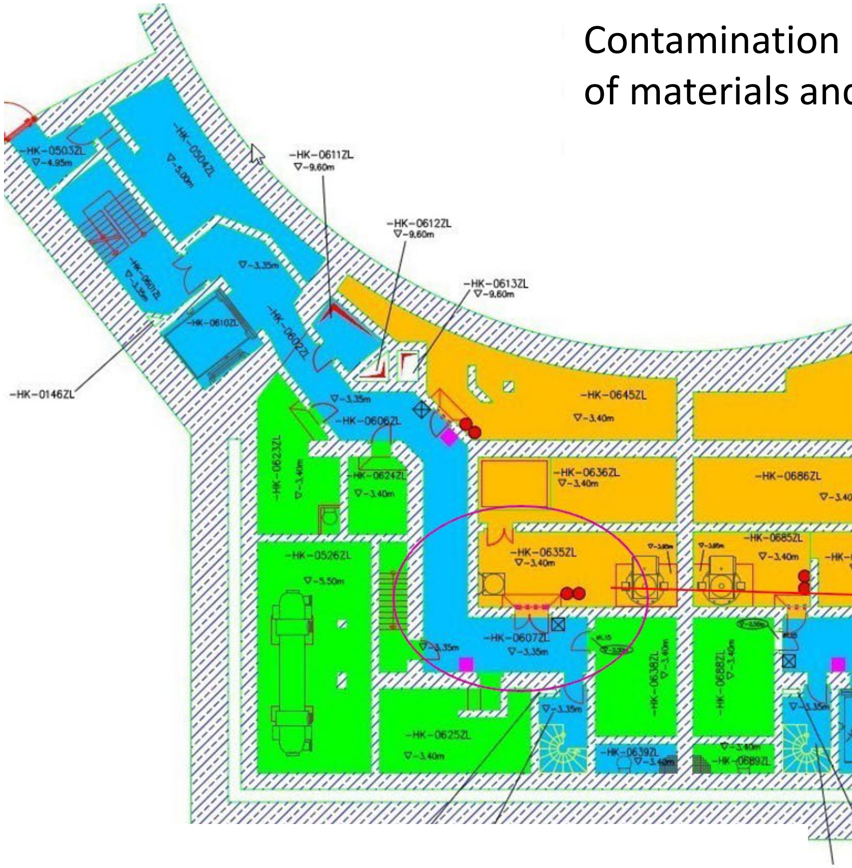

Lead Bricks


Fixed support


Fixed support

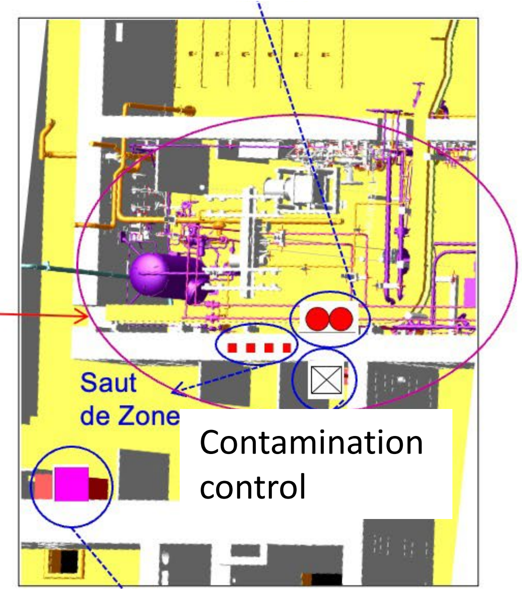
Managing the risk of contamination dispersion
Contamination control devices

- Need to plan the space required to manage workplaces with a risk of contamination dispersal and to keep the plant in a clean state



Contamination barriers: controlling contamination of materials and workers

Containers for contaminated waste or laundry



Contamination control

coveralls

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Managing the risk of contamination dispersion
Containment tent – Design constraints

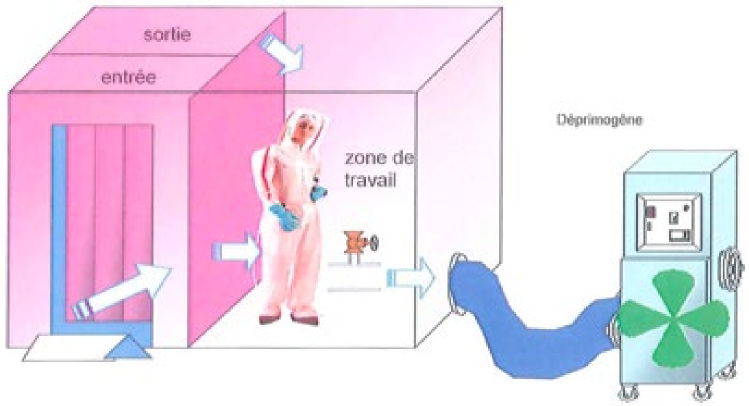
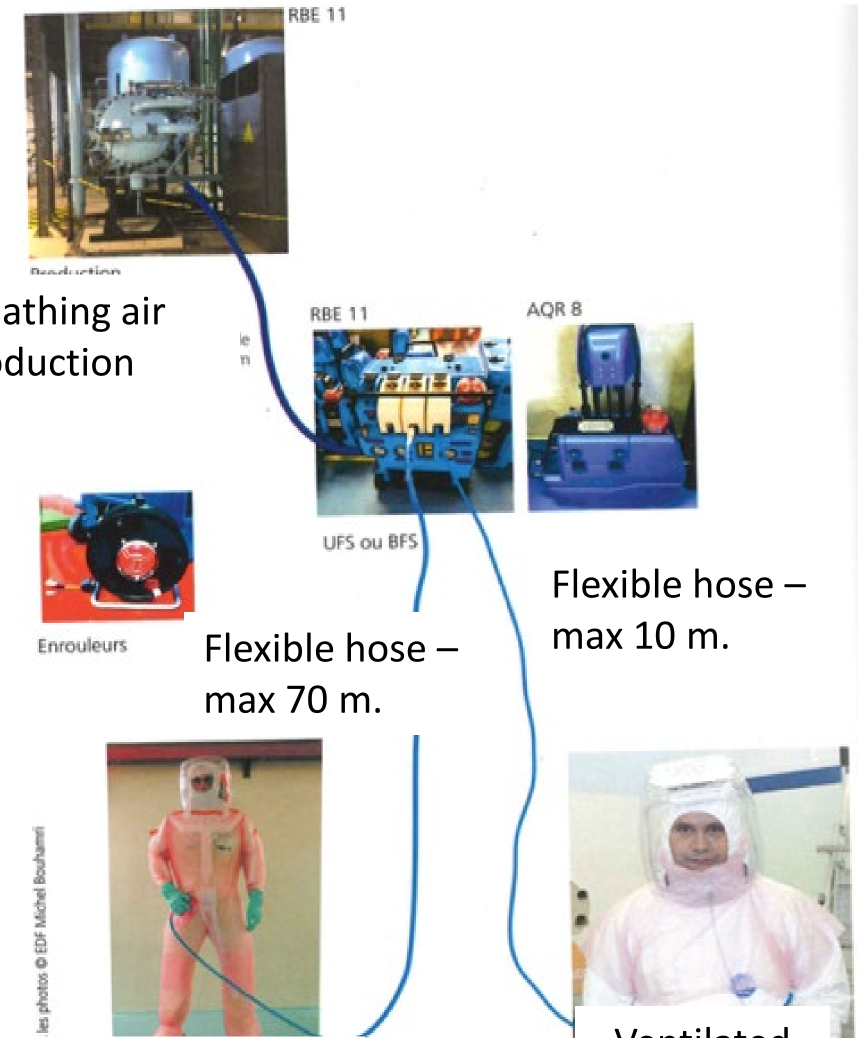


Figure 2. Schéma de principe du confinement stato-dynamique

- Need to plan the space required for tents where entrance and exit are separated

Managing the risk of contamination dispersion
Individual Protective Equipments –Design constraints



breathing air production

Flexible hose – max 70 m.

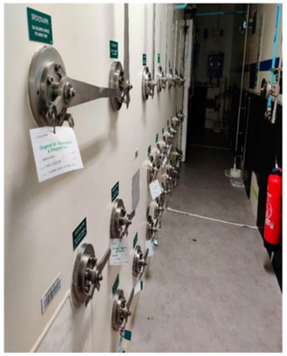
Flexible hose – max 10 m.

Ventilated – Pressurised suit

Ventilated hood

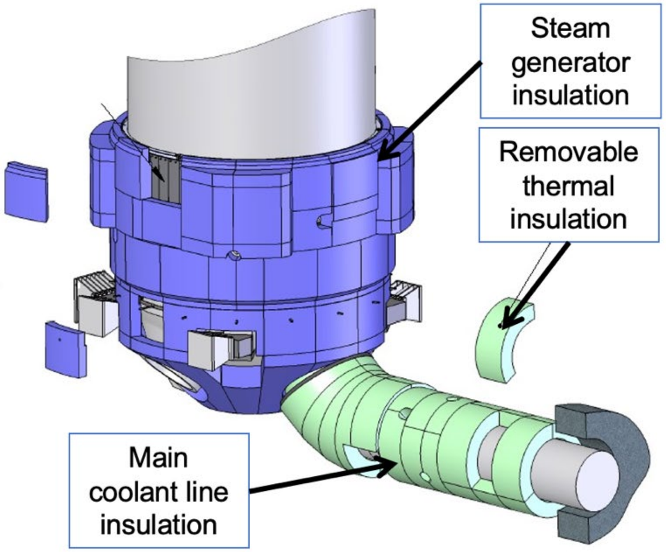
Actions to reduce exposure time

- **Organisation of work places**
  - Access to equipments
  - Light, Air and electricity spots
- **Equipment design**
  - to reduce maintenance needs
  - To perform pr of the job outside the radiation areas
  - To perform the job quickly

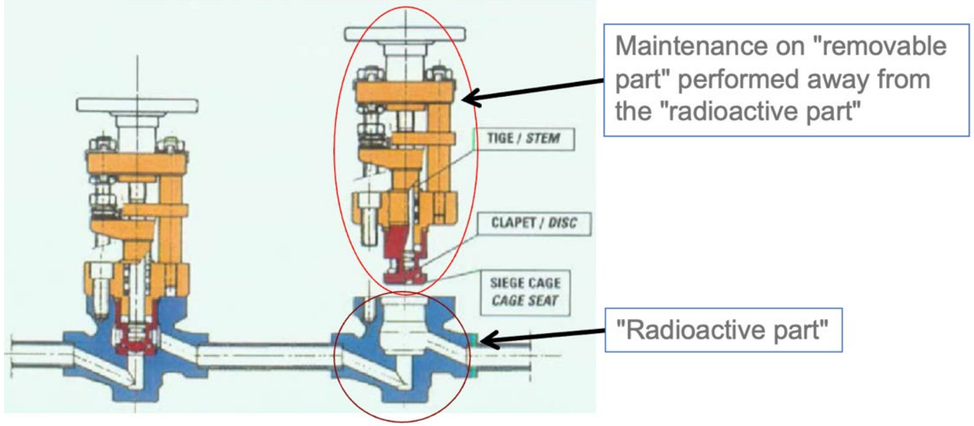


Valve remote controls

Thermal insulation fast mounting (exposure time limitation)



Valves with modular maintenance (exposure time limitation)



30% dose reduction in the activities related to “valve maintenance”

Decision aiding methods

- During the process of design, choices have to be made to optimise radiation protection and adopt the best design
- Cost/Benefit Analysis, main criteria:
  - Dose savings : individual dose, collective dose, estimated for whole plant life
  - Costs : investment costs – operating costs - potential costs savings
- Many other criteria need to enter into consideration such as:
  - Impact on contamination levels,
  - Worker safety
  - Job duration
  - Outage duration
  - Material constraints
  - Technical feasibility
  - ...
- Need to assess the positive or negative impact of the actions on these criteria

Example of criteria for deciding whether to install shielding /1

Criteria	Examples
Design and installation	• Specific geometries, Design complexity • Length of the surface to be protected, ...
Installation for the operator	• Handling means necessary to install/remove the shielding • Impact on job duration / outage schedule ↑ Fixed shielding need to be removed ↑ Fixed shielding increases the lack of space in the room ↓ Fixed support already installed decrease time to install temporary shielding
Duration of use	• How long is the shielding used • Taking into account the durability of shielding materials with time
Accessibility	• Fixed shielding can decrease accessibility to materials and rooms
Radiation protection	• Estimation of optimised thickness to reach the objectives of dose rate reduction • Level of dose rates behind the shielding • Specificity of radiation source : energy, various type of radiations (neutron, beta, alpha,...) • Evolution of dose rate with time (activation of circuits)

Example of criteria for deciding whether to install shielding /2

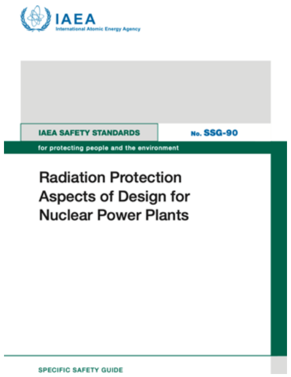
Criteria	Examples
Maintenance	• Is there materials behind fixed shielding?
Worker safety	• Does the installation create new safety risk for the workers?
Temperature	• What is the temperature in the circuits behind the shielding • Is it a cold, hot or humid atmosphere
Electric risk	• Is there any electrical cable or device behind the structure ?
Physical	• Shape of protection surface • Waterproff
Chemical	• Resistance to chemical products • Consider the potential need to decontaminate the shielding
Seismic and mechanical resistance	• Specific calculation to be performed to estimate the impact on seismic situations • It can be forbidden to increase the weight on some equipment
Economics	• Cost of materials, of design, of implementation,... • Waste cost

Conclusion

- This presentation gives a brief overview of the main principles to have in mind when designing a nuclear facility. The consideration of all RP issue is complex, and it impact the layout, the composition of materials, the processes, ...
- Radiation protection need thus to be considered and analysed at the earliest possible stage of design and a specific organisation needs to be set up.
- **A topic to be considered by all the design engineers, not only RP specialists**
- Specific programme and rules need to be laid down for the development of the generic layout, as well as the specific materials, equipment, systems, processes,...

Many aspects can be found in:

IAEA Specific Safety Guide SSG 90 (2024)
RP aspects of design for nuclear power plants




THANK
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