
AREVA

Sampling of Reactor Pressure Vessel and Core Internals

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Sampling of RPV and Core Internals Content

- Introduction and Motivation
- Main Aspects
- Sampling Techniques
- Sampling Positions
- Accessibility Studies
- Handling and Analysis
- Summary

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Sampling of RPV and Core Internals
Introduction and Motivation

- **Dismantling means an extraordinary expense:**
  - **Dismantling works and equipment**
  - **Costs for storage and disposal**
    - Containers
    - Facilities to be built on site
    - Fees

KONRAD Container


MOSAIK® Container

Examples:
- RPV Internals Stade NPP: 37 MOSAIK® containers saved
- RPV Würgassen NPP: Bonus for saved containers

Minimization of the radioactive waste volume as a key factor

- **Optimization / validation of the dismantling and packaging strategy**
  - **Sampling at relevant areas to calculate expected radiation exposure**
  - **Verification of the theoretically calculated radiological data**
  - **Most realistic evaluation of required technical & radiological measures (shielding, number & type of disposal containers, decontamination ability etc.)**

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Minimization of the radioactive waste volume as a key factor

All these facts can cause a significant reduction of costs.

Sampling of RPV and Core Internals
Background: Calculations

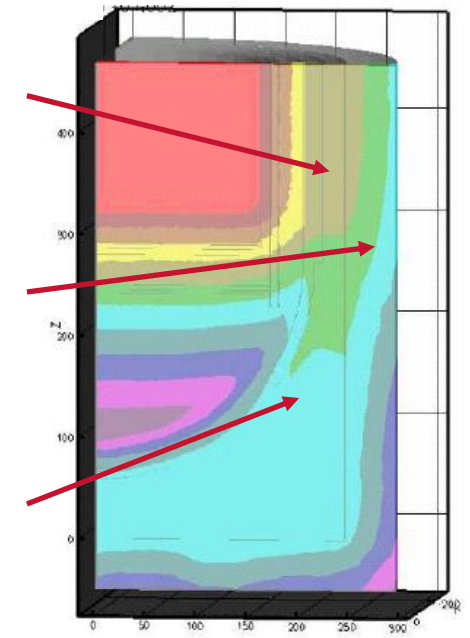
- **Objective goals of activation calculations**
  - **Depending from project phases**
    - Radiological planning
    - Planning on cutting and packing
    - Preparation of waste documentation
  - **Basis of calculations**
    - Neutron flux
    - Content of Co-60

Sampling of RPV and Core Internals
Background: Calculations

- **Objective goals of activation calculations**
  - **Depending from project phases**
  - **Radiological planning**
    - As a first and conservative approach: estimated maximum of activity
    - For planning of dismantling and packing strategies (remote handled required or manual work possible)
    - For planning of radiation protection measures (restrictions for retention and working time, shielding effort)
    - Nuclides Co-60 (for steel) and Co-60, EU-152, EU-154 (for concrete) represent the major sources of ionizing radiation which have to be considered for adhering to the dose rate limits
    - Caution: Be aware of the exact position and amount of stellite as a major source of gamma radiation!

Sampling of RPV and Core Internals Background: Calculations

- **Objective goals of activation calculations**
  - **Depending from project phases**
  - **Planning on cutting and packing**
    - Mandatory knowledge on
      - Activity inventory (nuclide vector)
      - Spatial distribution of activity inventory in RPV, internals and biological shield (especially outside the main axes)
    - Data help on
      - Cutting plan for components
      - Selection of suitable containers for intermediate and/or final storage
      - Decision on storage or free release
    - Co-60, Fe-55, Ni-63 (for steel) and Co-60, Eu-152, Eu-154, Ba-133 (for concrete) plus H-3 and C-14
    - Creation of spatial distribution by connection of results from 3D-calculation programs with measuring results (sampling)
    - Especially in areas where the share of activity is low compared to contamination, a detailed sampling is mandatory anyway to gain information on the contamination level
    - All calculations must be verified by measuring results as a principle



Example: 3D activity model, source: DSR

Sampling of RPV and Core Internals
Background: Calculations

- **Objective goals of activation calculations**
  - **Depending from project phases**
  - **Preparation of waste documentation**
    - For declaration of the waste according to the relevant acceptance and storage specifications, the information on additional nuclides is necessary
    - Can be derived from either complementary calculations or feasible comparisons or any other procedure aligned with the authorities
    - It is highly recommended (and often mandatory) to confirm the „calculated“ activity proportions of nuclides to each other by respective sampling and radiological and chemical analysis

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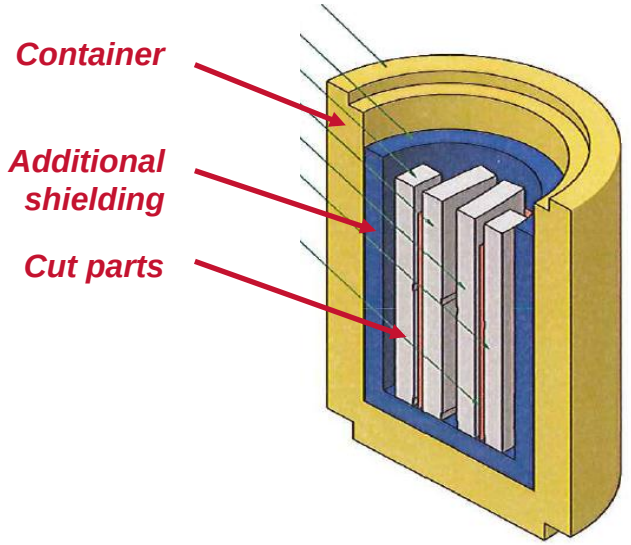
Sampling of RPV and Core Internals Main Aspects

- **The following main aspects have to be taken into consideration for sampling activities:**
  - **Site-specific conditions in general**
  - **History of the plant**
  - **Representativeness of sampling positions**
  - **Available time frame**
  - **Accessibility & handling effort**
  - **Radiological conditions**
  - **ALARA principles & occupational safety**
  - **Intermediate and/or final storage requirements**
  - **Approval conditions & legal and commercial aspects**



Example: Loaded MOSAIK® container

- **Detailed planning provides a trouble-free sampling process optimized in time**

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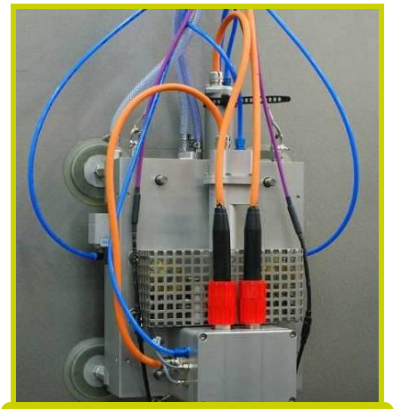
Sampling of RPV and Core Internals
Sampling Techniques

Technique	Advantage	Disadvantage / Comment
Scratch sample	Low device-related effort	Mixture of CRUD[1)], cladding and bulk material Subjective factor with regard to removal and depth
Drill sample	Low device-related effort Wall activation profile possible (samples from different depths)	Mixture of CRUD[1)], cladding and bulk material
Shuttle sample	Sample is suitable for materials testing	Relatively high device-related effort Flush water influences CRUD[1)] results Relatively high space requirement
Lens sample	Undamaged surface for CRUD[1)] -sampling in laboratory Sample of cladding and bulk material from same position Enough material for reserve samples	Cooling needed when used on atmosphere

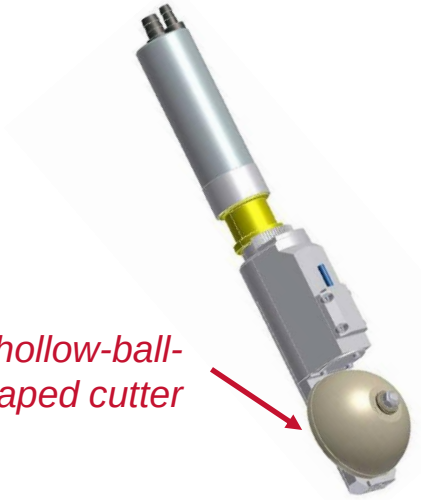
[1)] CRUD = Chalk River Unidentified Deposits

Sampling of RPV and Core Internals
Sampling Techniques

- **Lens sampling device, designed by AREVA:**
  - **Diameter from 20 to 70 mm**
  - **Thickness from 3 to 12 mm**
  - **Well-proven, robust and adaptable**
  - **Applicable for under-water and on-atmosphere sampling**
  - **Works autarkic, no manual intervention necessary in dose rate intensive areas**



Lens sampling device



Lens sample

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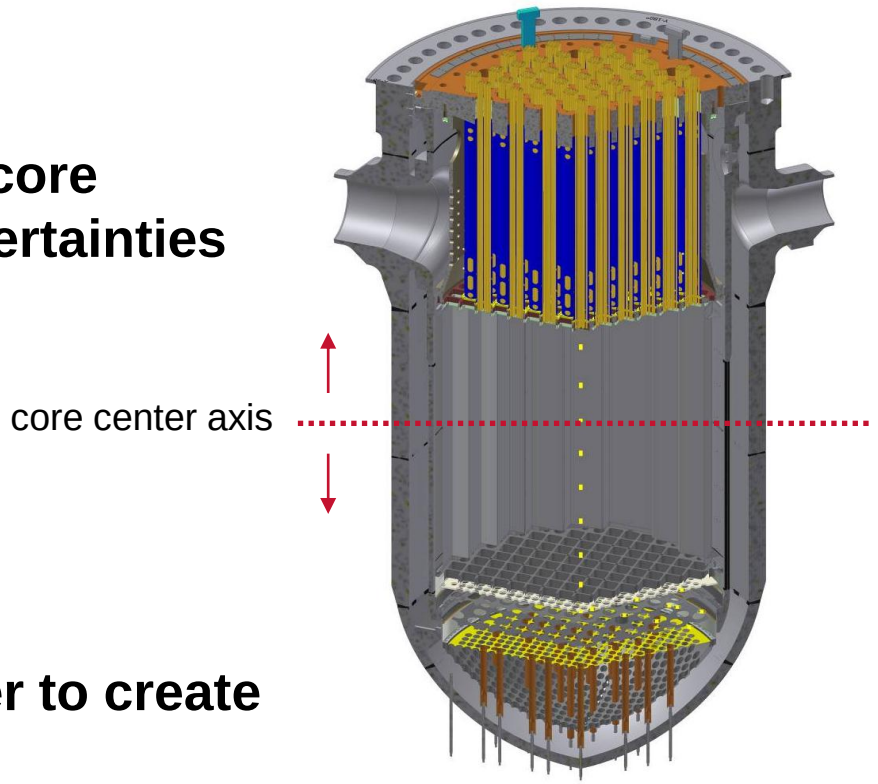
Sampling Positions

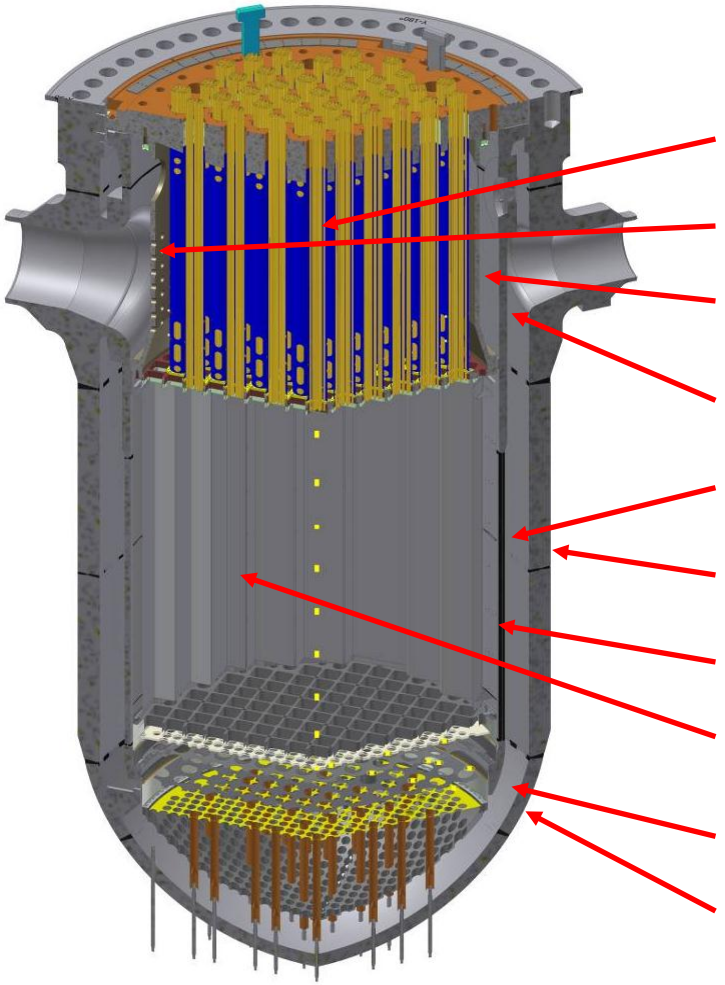
- **Challenge: Keep the number and effort as low as possible but simultaneously as effective as possible**

- **Intensive sampling far away from core center axis reduces modeling uncertainties arising from**
  - **distance from neutron flux**
  - **rescattering effects**
  - **different materials**

- **Define intelligent positions in order to create a most realistic activation model**



Sampling of RPV and Core Internals
Sampling Positions – PWR

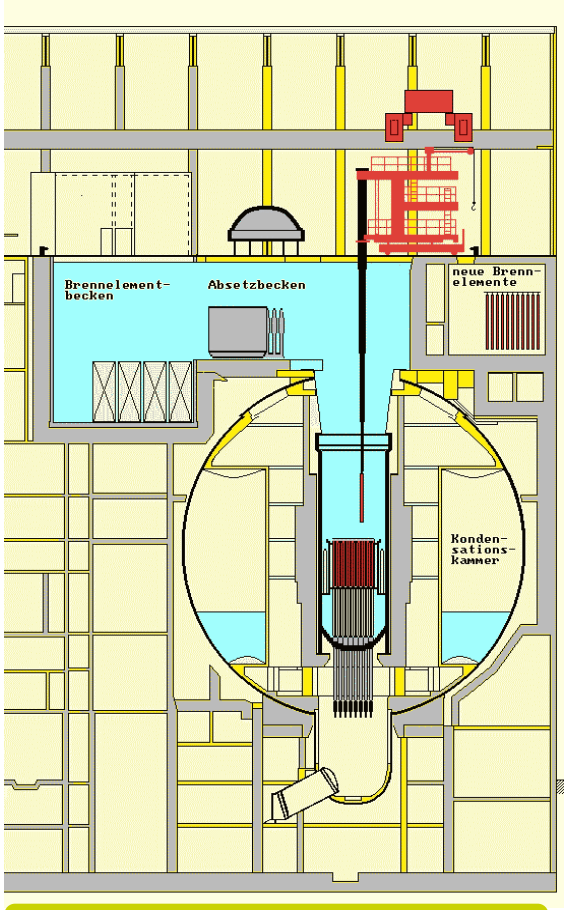


Control rod guide tube	Above core center axis
Upper core internals, outside	
Core barrel, inside	
RPV, inside	
RPV, inside	On core center axis
RPV, outside	
Core barrel, outside	
Core shroud	
RPV, inside	Below core center axis
RPV, outside	

Example

If specific position is not accessible due to e.g. interfering edges, a new and equivalent position will be defined.

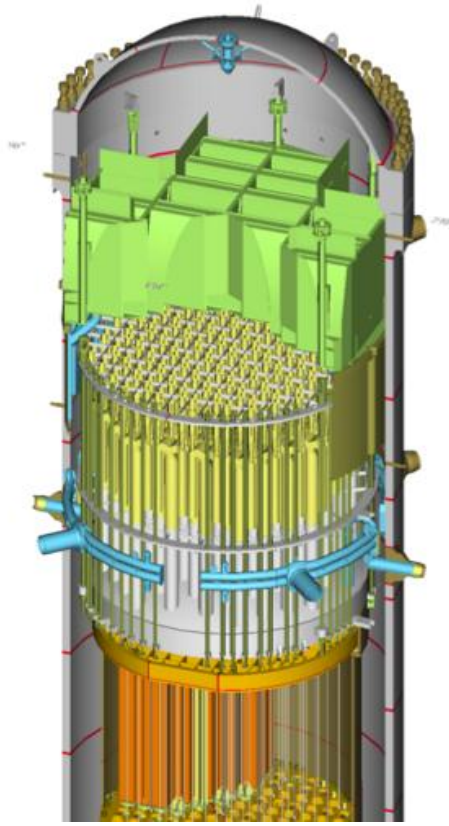
Sampling of RPV and Core Internals
Sampling Positions – BWR



Source: Würgassen NPP, e.on

Component	Metal Samples	CRUD Samples
RPV Head	4	1
Steam Dryer	1	1
Separator	3	3
Feedwater sparger	1	1
Upper Grid Plate		0
Core Shroud	1	
Jet Pump	1	0
Control Rod Guide Tube, Shut down position	2	1
Control Rod Guid Tube, Control position	2	1
RPV Calotte	3	0
Total	**20**	**8**

Example



Number, position and type of samples are results of a dedicated study. Experience: the number of 28 samples were sufficient, but according to customer an even higher number would have been helpful.

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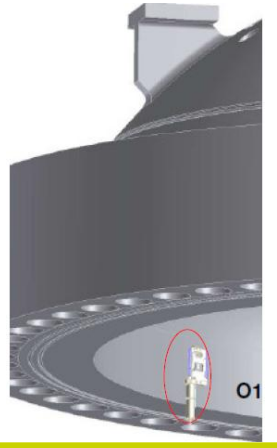
Sampling of RPV and Core Internals Accessibility Studies

- **Most likely sampling will be done under water (dose rate minimization)**
- **Assumed as initial state: RPV and internals in installed position**

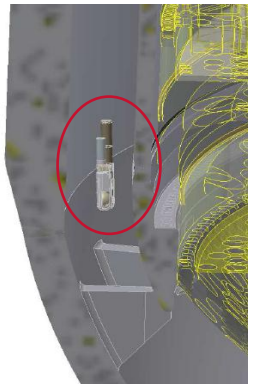
- **Accessibility studies need to take into account**
  - **Chosen sampling technique**
  - **Minimization of preparation and execution time (dose rate)**
  - **Current licensing conditions**
  - **Other boundary and site-specific conditions**
  - **Early consideration of future activities**



Sampling device located on RPV head

Sampling of RPV and Core Internals Accessibility Studies

- **Different variants are possible**
  - **1: Sampling without any dismounting activities**
    + time consuming dismounting is avoided
    - some positions may not be reachable at all -> no comprehensive sampling
  - **2: Something between**
  - **3: Temporary dismounting of the entire core internals**
    - logistic and time consuming
    - space and tooling needed
    + easily reachable position on all components
    + detailed overview over activation conditions can be gained
- **Compromise which satisfies all technical, radiological and commercial aspects**
- **Detailed expert knowledge and specific experience as well as foresighted planning is indispensible**



Sampling device located on RPV wall close to the calotte

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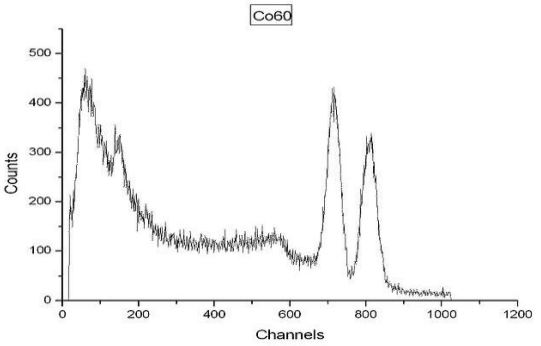
Sampling of RPV and Core Internals Handling and Analysis

- Dose rate measurements on the taken samples
- Transfer to adequate primary packaging
- Appropriate tooling might be needed
- Beside the shielding effect the box secures samples from cross contamination
- Transport to a suitably equipped laboratory
- Radiological analysis:
  - Co-60 and other gamma-emitters
  - Fe-55, Ni-63 and C-14
  - Other nuclides if necessary
  - Element content of cobalt (source for Co-60)



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Sampling of RPV and Core Internals Summary

- Representative sampling positions have to be determined
- Accessibility under the respective boundary conditions has to be verified
- Correlation with the activation calculations and development of a 3-dimensional activity model
- Comprehensive sampling of RPV and its internals is of decisive importance prior to dismantling
- Only a detailed knowledge of the radiological conditions offers the possibility to develop a dismantling and packaging concept optimized in amount and costs