# Sampling of Reactor Pressure Vessel and Core Internals

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**Keywords:** *sampling, lens sample, RPV, core internals, under water, dismantling, packaging, activity model, interim storage, final storage, accessibility, radiochemical analysis*

## 1 Introduction

Decommissioning and dismantling of nuclear power plants is a growing business, as a huge number of plants built in the 1970s have now reached their lifetime. It is well known that dismantling a nuclear power plant means an extraordinary expense for the owner respectively operator. Besides the dismantling works, the disposal of activated components and other nuclear waste is very expensive. Moreover, the fact that, in most countries, final disposal facilities are not available yet implies the need for interim storage on-site in specially built facilities. It can be concluded that a special attention is paid on producing a minimal radioactive waste volume. For this, optimized dismantling and packaging concepts have to be developed. The challenge is a fair balance between the obtainment of optimized packing and on the other side the fulfillment of stringent regulations set by the authorities and the storage requirements.
The basis of a well-founded, optimized dismantling and packaging concept must always be the detailed knowledge of the radiological condition of the component to be dismantled. In the best case a 3-dimensional activitiy model contributes to this basis.

AREVA has developed various dedicated studies and already carried out sampling activities in different countries for many years. This paper describes the approach and the main aspects of sampling activities.

## 2 Objective of Sampling

Under the above mentioned aspects of dismantling and minimization of radioactive waste a sampling of the reactor pressure vessel (RPV) and its internals is necessary to verify the theoretically calculated radiological data. For keeping the necessary sampling effort as small and efficient as possible, representative sampling positions are defined in advance by theoretical radiological examinations. For this, a detailed 3D-CAD-model of the components to be dismantled has proven very helpful and effective.

The obtained results of activation and contamination are taken into account for the optimized dismantling and packaging strategy. The precise 3-dimensional activity model will reduce the necessary number and types of final disposal containers significantly. The shielding effort is also optimized. Besides, components or even parts of components may be subject of release measurement. All these facts can cause a significant reduction of costs.

## 3 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
- Accessibility
- Handling effort
- Radiological conditions
- Occupational safety
- ALARA principles (As Low As Reasonably Achievable)
- Approval conditions
- Intermediate and/or final storage requirements
- Legal and commercial aspects

Taking into account the relevant protection goals, a detailed planning of the work execution on-site enables a trouble-free and time optimized project process. In the end, the customer gains a precise overview over the radiological condition of the RPV and its internals necessary to optimize the radioactive waste management.

## 4 Sampling Techniques

There are different sampling techniques available. Each has specific advantages and disadvantages, as shown in table 1.

| **Technique** | **Advantage** | **Disadvantage / Comment** |
|---|---|---|
| Scratch sample | Low device-related effort | Mixture of CRUD[1)], cladding and bulk material<br>Subjective factor with regard to removal depth |

| | | |
|---|---|---|
| Drill sample | Low device-related effort<br>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 (EDM)<br>Flush water influences CRUD[1)] results<br>Relatively high space requirement |
| Lens sample | Undamaged surface for CRUD[1)]-sampling in laboratory<br>Sample of cladding and bulk material from same position<br>Enough material for reserve sample | Cooling needed when used on atmosphere |

*Table 1: Comparison of sampling techniques* [1)] CRUD = Chalk River Unidentified Deposits

To decide on which technique is the most suitable the respective boundary conditions have to be specifically taken into consideration.

## 4.1 Lens Sampling

To sample spherical samples, i.e. lens samples, with a diameter from 20 mm to 70 mm, the sampling device designed by AREVA cuts these samples out of the surface of the component (picture 1). Thickness can be chosen from 3 mm to 12 mm. The well-proven, robust and adaptable sampling device is applicable for both under-water and on-atmosphere sampling.

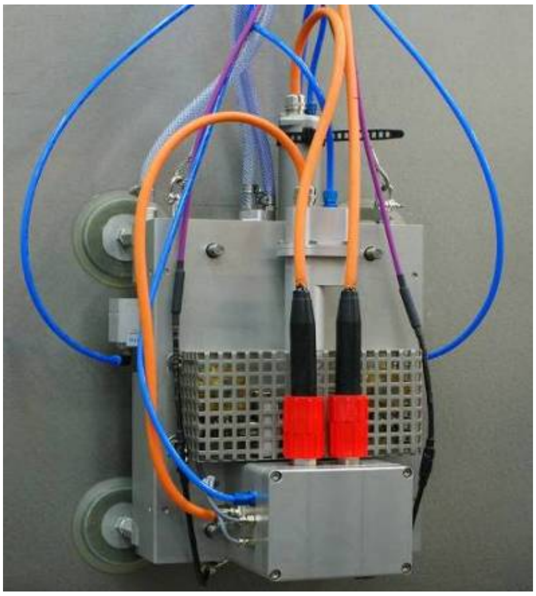
The sampling device consists of the following components:

- Control unit with integrated surveillance system
- Pneumatic unit
- Cutting device

For sampling the device with its hollow-ball-shaped cutter is placed at the defined position on the component and is fixed by vacuum or via tensioning or clamping. The drive of the cutting device is operated pneumatically.

The device offers the following advantages:

- Works in dose rate intensive areas
- Cuts out complete samples which are perfectly suitable for analyses (CRUD, cladding, wall)
- Dimension respectively mass of the sample can be influenced by cut-in depth (important for handling in the laboratory)



*Picture 1: Sampling device positioned on a wall*

*Picture 2: Lens sample*

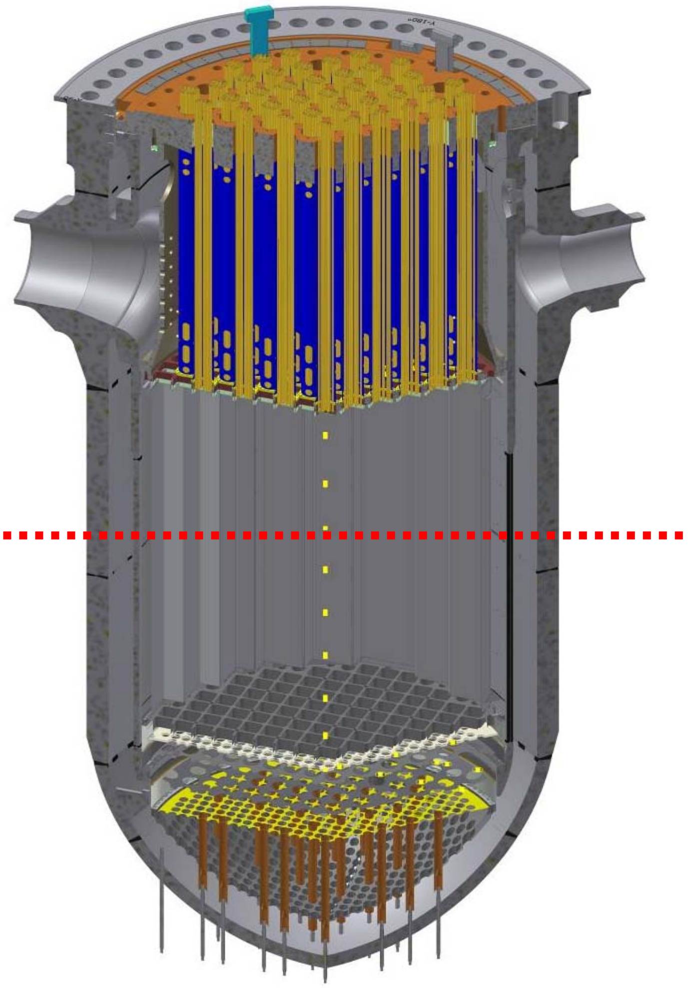
## 5 Sampling Positions

The challenge is to keep the number of samples and the handling effort as low as possible and, at the same time, as effective as possible.

An intensive sampling far away from the core center axis, above and below (picture 3), reduces the modeling uncertainties in areas that arise from the relative distance from the neutron flux, from rescattering effects and from different materials.

Characterization samples taken from low activated core internal components are then used to verify the calculated activity data. This prevents an overestimation of activities leading to higher effort regarding packing, shielding and container amount can be avoided.

If sampling at a specific position is not possible due to e.g. interfering edges, a new and equivalent position will be defined. Overall, it is very important to determine and consider the exact sampling positions in order to create a most realistic activity model.




*Picture 3: RPV (without head) and its internals*

## 6 Accessibility Studies

For shielding and dose rate minimization reasons sampling of the components will mostly be done under water and remote-controlled. In the initial state, as assumed, the RPV is in installed position and the internals are located inside the RPV. Therefore, accessibility studies need to take into account the following main aspects:

- Accessibility of the specific position with the chosen sampling technique
- Minimization of preparation and execution time (dose rate)
- Current licensing conditions
- Other boundary and site-specific conditions (e.g. influence from or on ancillary activities)
- Early consideration of future activities (dismantling of the components)

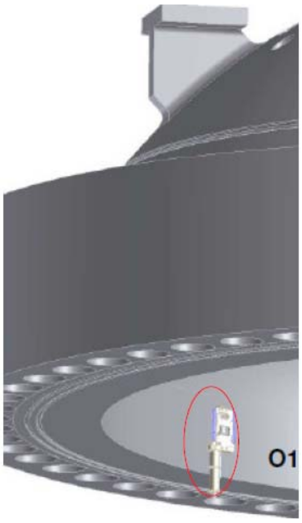
The easiest variant resulting in the lowest expense is the sampling of the RPV and its internals without dismounting the components. This means that samples are taken only from positions accessible in an installed position. Hence, this variant avoids time consuming disassembly activities. On the other hand it is clear that some sampling positions can only be reached with higher effort (which might lead to increased personal dose rate). Some positions are not accessible at all. To conclude, this variant does not provide comprehensive sampling, as important positions inside the RPV can not be reached.

The other extreme is the temporary dismounting of the entire core internals, causing a logistic and time consuming effort. Transporting the internals might cause additional personal dose rate. Space and tooling is needed in the ancient area, e.g. spent fuel pool, for parking the internals and for the sampling activities. Additionally a lot of water may be needed for radiation protection reasons. On the other hand, both the upper and lower core internals as well as the RPV inside is easily accessible allowing a comprehensive sampling and by this a detailed overview over the activation conditions can be gained.

As shown, there is no ideal solution which satisfies all technical, radiological and commercial aspects. Therefore, a compromise between different variants has to be entered. It has proven effective to develop a matrix of different intelligent variants comparing their characteristics. For this a detailed expert knowledge and specific experience as well as foresighted planning is indispensible. Finally, the most suitable variant can be chosen.

Attention must also be paid on samples to be taken from the RPV wall (outside). Accessibility has to be checked here, too, as space between RPV wall and biological shield, respectively RPV insolation, is often limited and hindered by interfering edges.

Pictures 4 and 5 show examples of the sampling device positioned at the RPV head and the RPV wall.




*Picture 4: Sampling device at RPV head*

*Picture 5: Sampling device at RPV wall close to the calotte*

# 7 Handling and Transportation

Dose rate measurements of the samples taken are necessary for their radioactive transport to the laboratory. Afterwards samples are transferred to an adequate primary packaging, e.g. a plastic box. Samples with estimated higher dose rate are handled with appropriate tooling (long-stemmed gripper etc.). For transporting the samples there are different boxes available that take into account the specific characteristics of the samples. Beside its shielding effect the box protects the samples from cross contaminating. Underwater samples require special boxes with holes for draining.

## 8 Radiological Analysis

Radiological analysis of the samples is employed in a suitably equipped and accredited laboratory. There the samples are analyzed with respect to their activation nuclides and other important element contents:

- Co-60 and other gamma-emitters
- Fe-55, Ni63 and C-14
- Other nuclides if necessary (site and country specific)
- Element content of cobalt (source for Co-60)

The goal is to get a correlation with the activity calculations.

The final report may contain 2 different examinations:

- Checking the acceptance conditions for an on-site interim storage facility at time X (current dose rate)
- Checking the ability for final disposal at time Y (decay correction of the relevant nuclides)

It is recommended to hold back spare material for possible necessary future examinations.

## 9 Summary

It has been shown that, in order to choose representative sampling positions and to verify their accessibility, different technical, radiological and commercial aspects have to be taken into account.

The results from the radiochemical analyses performed with the taken samples can be used for correlation with the activity calculations and to develop a 3-dimensional activity model.

A comprehensive sampling of the RPV and its internals is of decisive importance prior to dismantling. Only this provides for a detailed overview of the radiological condition of the components. Being aware of this condition is a prerequisite of being able to develop a dismantling and packaging concept optimized in work amount and, in the end, cost.