Main achievements of the European R&D on the issue of air ingression during a LWR severe accident

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Context

A Severe Accident (SA) can occur if additionally happen:

1. Air can then penetrate in the reactor vessel evidenced by simulations with calculation codes (ASTEC, MAAP-SATURNE).

2. Remaining irradiation fuel is oxidised by air and may undergo large degradation.

3. Remaining fuel is also oxidised as well as fission products (FP) which form volatile species.

Consequence: core fusion and possible core vessel lower head failure.

Potential high release of volatile ruthenium oxides from the reactor vessel to the reactor containment, and possibly to the outside environment.

1. Air was in the range of 10% but far above the value that would be expected from the thermodynamic equilibrium (10^-7 bar).

2. Presence of steam, other fission products and UO2, influenced the concentration of RuO4, in the ambient temperature escaping gas, and caused a time delay in appearance of its maximum values.

Ruthenium transport in the RCS

All RuO4(g) inventory is not trapped by the RCS, leading to the presence of a significant fraction of gaseous tetroxide in the containment.

Ruthenium release from fuel

Ruthenium release kinetics depends on both fuel oxidation kinetics and ruthenium oxidation kinetics.

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<th>Reaction</th>
<th>Description</th>
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<tbody>
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<td>( \text{UO}_2 \rightarrow \text{UO}_2)</td>
<td>( \text{UO}_2 ) oxidation kinetics</td>
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<tr>
<td>( \text{RuO}_4 + y\text{O}_2 \rightarrow \text{RuO}_4(y\text{O}_2) )</td>
<td>( \text{RuO}_4 ) oxidation kinetics</td>
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Under air atmosphere, high ruthenium oxides releases were experimentally observed, and now are well estimated by calculations (ASTEC code).

Ruthenium behaviour in the reactor containment

Due to radiolytic reactions, RuO4(g) may be present in the containment atmosphere for several days.

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Preliminary evaluation of off-site radiological impact

Example for a LOCA scenario - filtered releases from reactor containment (beyond 24 h after core fusion).

- Partial pressure of RuO4 in the outlet air was in the range of 10% but far above the value that would be expected from the thermodynamic equilibrium (10^-7 bar).

- Presence of steam, other fission products and urania, influenced the concentration of RuO4, in the ambient temperature escaping gas, and caused a time delay in appearance of its maximum values.

Conclusions: main achievements in SARNET

- Air ingress scenarios have been simulated. Such scenarios have significant implications for the source term and specifically towards ruthenium 106, which is highly radiotoxic.

- Under very oxidising conditions, like those induced by air, ruthenium can form volatile oxide species from metallic ruthenium still present in the fuel.

- These ruthenium oxides can be transported through the RCS and are able to reach the containment building.

- Due to various radio-chemical reactions in the containment, the species RuO4 can persist in the gaseous phase during several days.

- Potential release of RuO4(g) in the environment may occur due to the French ultimate procedure of containment venting, leading to a probable increase of the total efficient dose in the environment.

- The assessment of RuO4(g) remaining in the reactor containment atmosphere before containment venting procedure is of primary importance.