1. Background and Objectives of the research

In Fukushima daiichi nuclear power plant (1F) unit 1 and 3, Molten Core-Concrete Interaction (MCCI) would occur [1]. MCCI products in PCV will be sampled before sampling of fuel debris in RPV. Although MCCI products are complex materials because of mixture of fuel debris and concrete, MCCI research does not focus on MCCI products handling after accident, but it focuses on severe accident progression. Therefore, urgent and effective collection of information on MCCI products is needed for 1F decommissioning.

This research objective concerning MCCI products is to pick up needs of 1F decommissioning, to plan and to advance higher-priority research.

2. Picking up needs of 1F decommissioning

<table>
<thead>
<tr>
<th>Needs</th>
<th>Related On-site Task</th>
<th>/ R&amp;D Approach(s)</th>
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</thead>
<tbody>
<tr>
<td>a) Distribution in PCV</td>
<td>o Radiation protection, Defueling, Criticality management</td>
<td>Result</td>
</tr>
<tr>
<td>b) Inventory</td>
<td>o Radiation protection, Criticality management</td>
<td>Result</td>
</tr>
<tr>
<td>c) Characteristics</td>
<td>o Sampling, Defueling, Analysis, transportation and Conditioning of debris</td>
<td>Labo-scale experiments, thermodynamic calculation etc...</td>
</tr>
<tr>
<td>d) Analysis technique</td>
<td>o Sampling, analysis, conditioning, measuring control</td>
<td>Labo-scale experiments etc...</td>
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</table>

Results of severe accident analysis are used in characterization.
On the other hands, research of severe accident analysis and characterization is advanced in parallel, because results of characterization will be offered to on-site task such as sampling and defueling by the end of 2015 JPY.
Plan and advance of characterization research is discussed here.

3. Planning higher-priority research

Mechanical, thermal and chemical properties are necessary for sampling, defueling and analysis. These properties depend on their chemical form. Therefore chemical form of 1F MCCI products is evaluated at first. Research is advanced with CEA which has much MCCI test products and knowledge.

3.1. Research method

i. Chemical form estimation
a) Thermodynamic equilibrium calculation :
Chemical form of 1F MCCI products and VULCANO MCCI test products is estimated with the CALPHAD method and thermodynamic data on concrete and fuel debris.
b) SEM-EDS and XRD analysis of MCCI test samples :
Chemical form of VULCANO MCCI products is analysed and compared with calculation results.

ii. Properties evaluation
b) Characterization of mechanical and chemical properties of MCCI test samples :
The properties of VULCANO test samples are measured with chemical form.
e) Estimation of thermal property with thermodynamic data base

3.2. Schedule

<table>
<thead>
<tr>
<th>Year</th>
<th>Simulation &amp; desk study</th>
<th>Experiment</th>
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<tbody>
<tr>
<td>2013</td>
<td>a) Thermodynamic calculation</td>
<td>4.</td>
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<tr>
<td>2014 - 2015</td>
<td>b) Comparison of 1F and VULCANO condition</td>
<td>b.</td>
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<tr>
<td></td>
<td>c) Characterization of past VULCANO test samples</td>
<td>c.</td>
</tr>
<tr>
<td></td>
<td>d) Thermal property estimation</td>
<td>d.</td>
</tr>
<tr>
<td>2016~</td>
<td>b. c) Characterization of 1F simulating VULCANO test products (with CEA)</td>
<td>e.</td>
</tr>
</tbody>
</table>

4. Previous research results:
- Estimation of MCCI products by thermodynamic calculation
4.1. Calculation condition
Chemical form of 1F MCCI products was estimated with thermodynamic equilibrium calculation [2]. Calculation condition is shown as below:

- Software: FactSage 6.2
- Database: NUCLEA ver. 2005-01
- Corium composition (mass%):
  - UO₂ : Zr : Fe = 61 : 25 : 14
  - Concrete composition (mass%):
    - SiO₂ : CaO : Al₂O₃ : Fe₂O₃
    - 64 : 13 : 16 : 6

4.2. Results
- Chemical form of the bulk of 1F MCCI products was estimated on thermodynamic equilibrium condition. Typical components are (U,Zr)SiO₄, UO₂, and CaAl₂Si₃O₈. In the case of stratification, Fe₅Si₃ and Fe-Si alloy would be detected in non-oxide layer.
- Chemical form of the crust around molten pool was estimated on Scheil model. Typical components are (U,Zr)O₂ and CaAl₂Si₃O₈. The amount of (U,Zr)SiO₄ increases with oxidation.

5. Current and future research: ~Cooperation program with CEA~
5.1. Phase I: Characterization of previous VULCANO test samples
a. VULCANO test samples having similar conditions to 1F unit 1 are selected with MCCI simulation, experience and knowledge.

5.2. Phase II (tentative): VULCANO test simulated 1F unit 1
a. VULCANO test simulated 1F unit 1 is carried out.

5.3. Characterization of MCCI products has been advanced with CEA.
- JAEA estimated chemical form with thermodynamic calculation.
- CEA has been analyzing previous VULCANO test samples.

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Reference: