MEASUREMENT OF VOID FRACTION IN HYDROGEN MODERATOR USED FOR MODERATOR CELL OF HANARO COLD NEUTRON SOURCE

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HANARO CNS facility (planned)

- CNS building
  - DC-TOF
  - TAS 12m-SANS
  - Bio-REF
  - 40m-SANS

- Reactor building
  - Control room
  - BNCT
  - RCS
  - Aux. pool
  - PPS
  - FTL

- Aux. building

- PCS and HX
- Fuel st. pool
Introduction

- Design and installation of cold neutron source facility in HANARO: now in progress.
- In-pool assembly: two phase hydrogen thermo-siphon loop and a vacuum chamber.
- Determination of void fraction in the hydrogen moderator: Characterization of moderation capability and stability of CNS.
- Thermo-siphon mock-up test with electrical heating as heat source instead of radiations.
- In this research,
  - Designing and installation of gamma densitometer with an HPGe detector and an Am-241 gamma-ray source,
  - Measuring the void fraction and its distribution in the moderator cell.
Void fraction measurement by gamma densitometer

Void fraction measured for two-phase flow by gamma-ray attenuation technique

\[ \alpha = \frac{\ln(I_\alpha / I_L)}{\ln(I_G / I_L)} \]

- \( I_\alpha \): gamma-ray intensity measured for an arbitrary void fraction,
- \( I_G \): gamma-ray intensity measured for a single-phase vapour,
- \( I_L \): gamma-ray intensity measured for a single-phase liquid.
Moderator cell

- Moderator cell
  - 6061 aluminium alloy,
  - Inner diameter : 130.0 mm,
  - Thickness : 1.0 mm,
  - The inner shell is open at the bottom.

- Cylindrical vacuum chamber
  - 6061 aluminium alloy,
  - Thickness : 5 mm.

- Simulation of nuclear heat load
  - Several line heaters and rod heaters
Mock up test facility

- Hydrogen line
- Vacuum line
- IPA
- Hydrogen buffer tank
- Vacuum pump station
- Helium line
- Cold box of HRS
- Vacuum pump station
Experimental setup

- 59.5 keV gamma-rays from the Am-241 isotope.
- Coaxial HPGe detector with a detection efficiency of 40%.
- Pathlength of the gamma-rays transmitted through the test section of the hydrogen medium: 102.5 mm.
Gamma-ray count rate for single-phase hydrogen

- Determination of gamma-ray count rate for single-phase liquid: measurements without an electrical heating power.
  - Estimation of the non-nuclear heating rate for this moderator cell using thermodynamic calculation: 3 W,
  - Negligible in comparison with the nuclear heating power,
  - No heat load intrusion from the outside of the moderator cell,
  - If no electrical heating power is applied, hydrogen in the moderator cell would be maintained as a single-phase liquid.

- Determination of gamma-ray count rate for single-phase vapour: measurements without refrigerator operation.
Longitudinal distribution of count rates

Heating power: 720 W

Relative count rate [cps]

Height [mm]
## Measured void fraction

<table>
<thead>
<tr>
<th>Heating power [W]</th>
<th>Void fraction</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower region</td>
<td>Upper region</td>
<td>Volumetric weighted average</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.000±0.042</td>
<td>0.000±0.043</td>
<td>0.000±0.030</td>
<td></td>
</tr>
<tr>
<td>203</td>
<td>0.018±0.040</td>
<td>0.110±0.037</td>
<td>0.076±0.028</td>
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<tr>
<td>425</td>
<td>0.065±0.040</td>
<td>0.318±0.038</td>
<td>0.225±0.028</td>
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<tr>
<td>721.4</td>
<td>0.078±0.039</td>
<td>0.410±0.034</td>
<td>0.287±0.026</td>
<td></td>
</tr>
<tr>
<td>Gas</td>
<td>1.000±0.036</td>
<td>1.000±0.036</td>
<td>1.000±0.027</td>
<td></td>
</tr>
</tbody>
</table>
Estimated void fraction for this moderator cell

Estimated void fraction for this moderator cell: 20%
Uncertainty

- Uncertainty in the void fraction determination by using a gamma densitometer for a hydrogen medium of about 10 cm: 2~3% in terms of the void fraction unit.
  - Quite big for the case of a small void fraction less than 10%.

- Uncertainty of the determined void fraction:
  - Closely dependent on the uncertainty in the determination of the count rates of the transmitted gamma-rays through the test section i.e. gamma-ray peak area.

- Reduction of uncertainty
  - Use of gamma-ray detector with higher efficiency,
  - Increase of the detection time,
  - Use of a gamma-ray source with a bigger activity.