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

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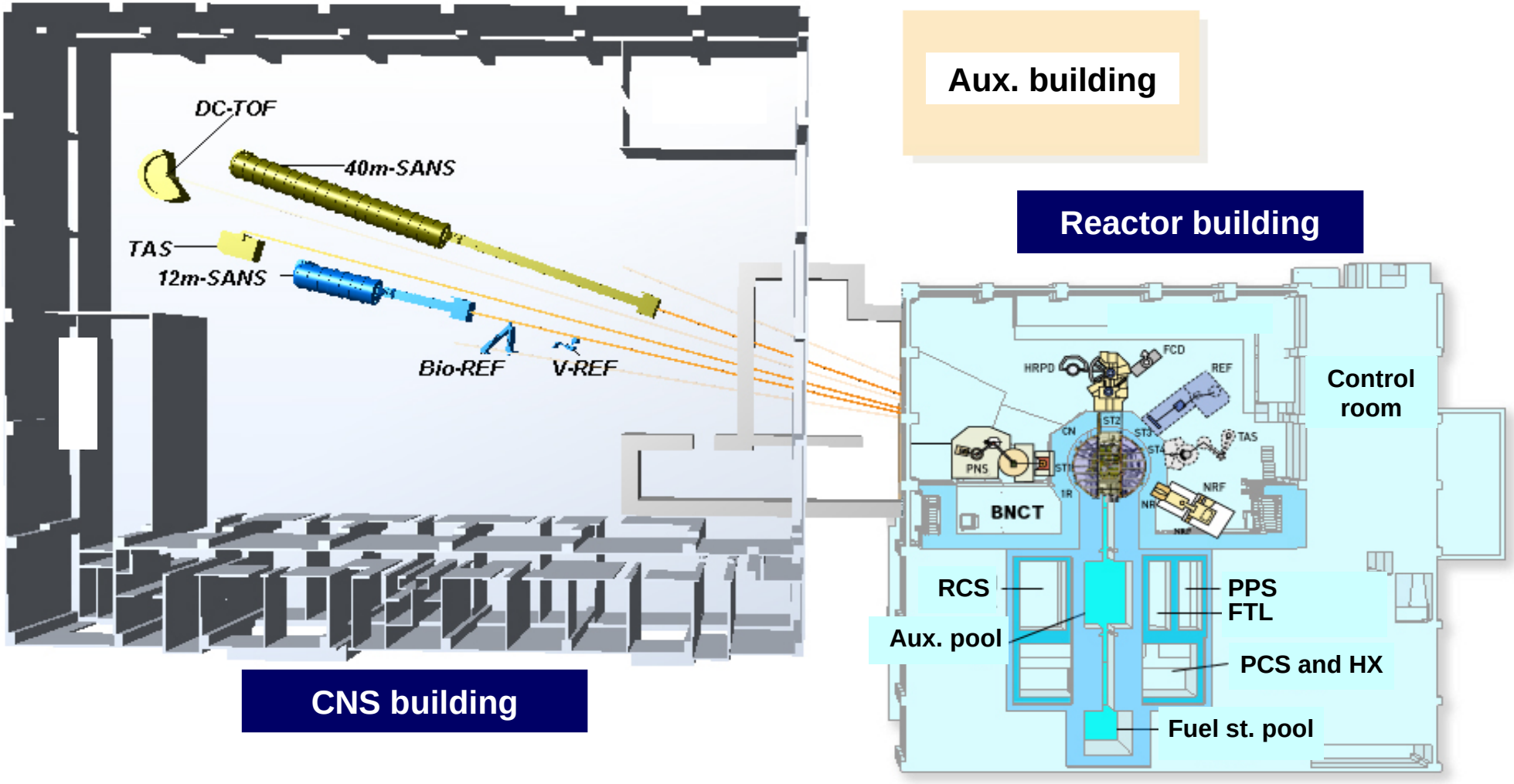
HANARO CNS facility (planned)



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

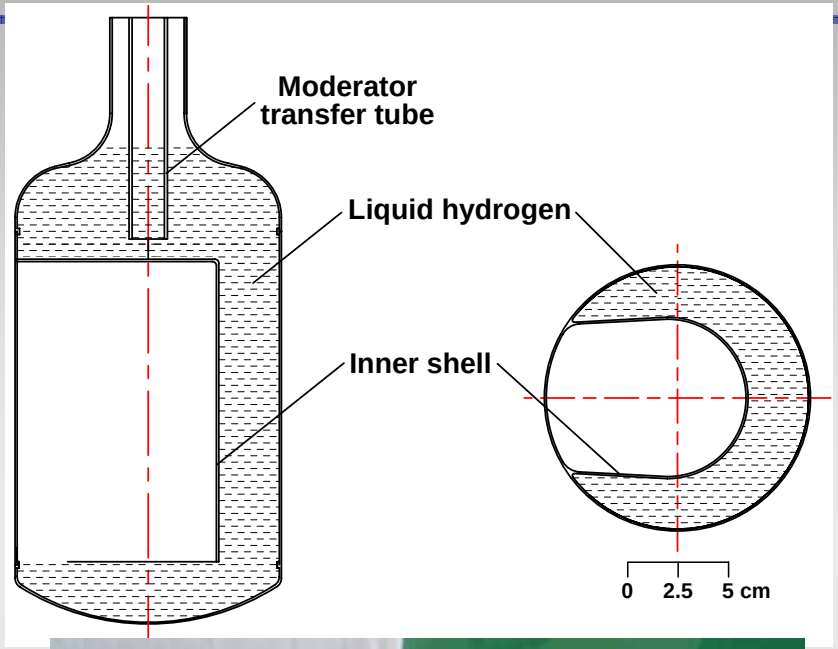
$$\alpha = \frac{\ln(I_\alpha / I_L)}{\ln(I_G / I_L)}$$

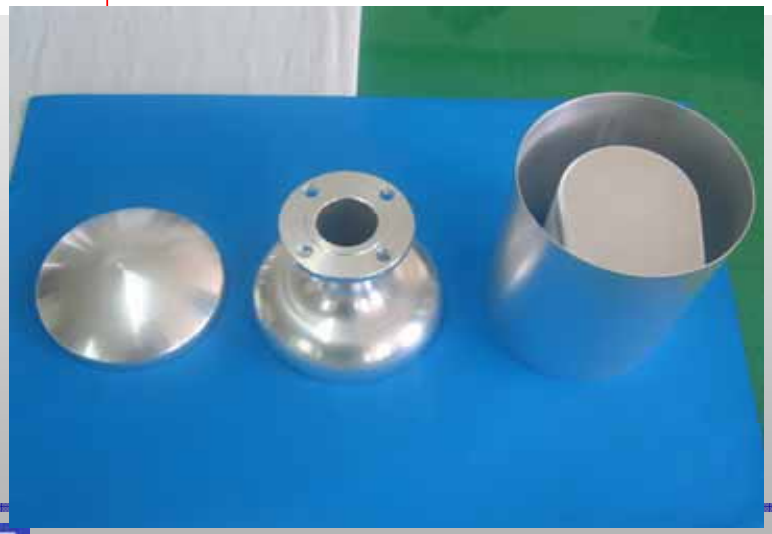
I_α : gamma-ray intensity measured for an arbitrary void fraction,

I_G : gamma-ray intensity measured for a single-phase vapour,

I_L : gamma-ray intensity measured for a single-phase liquid.

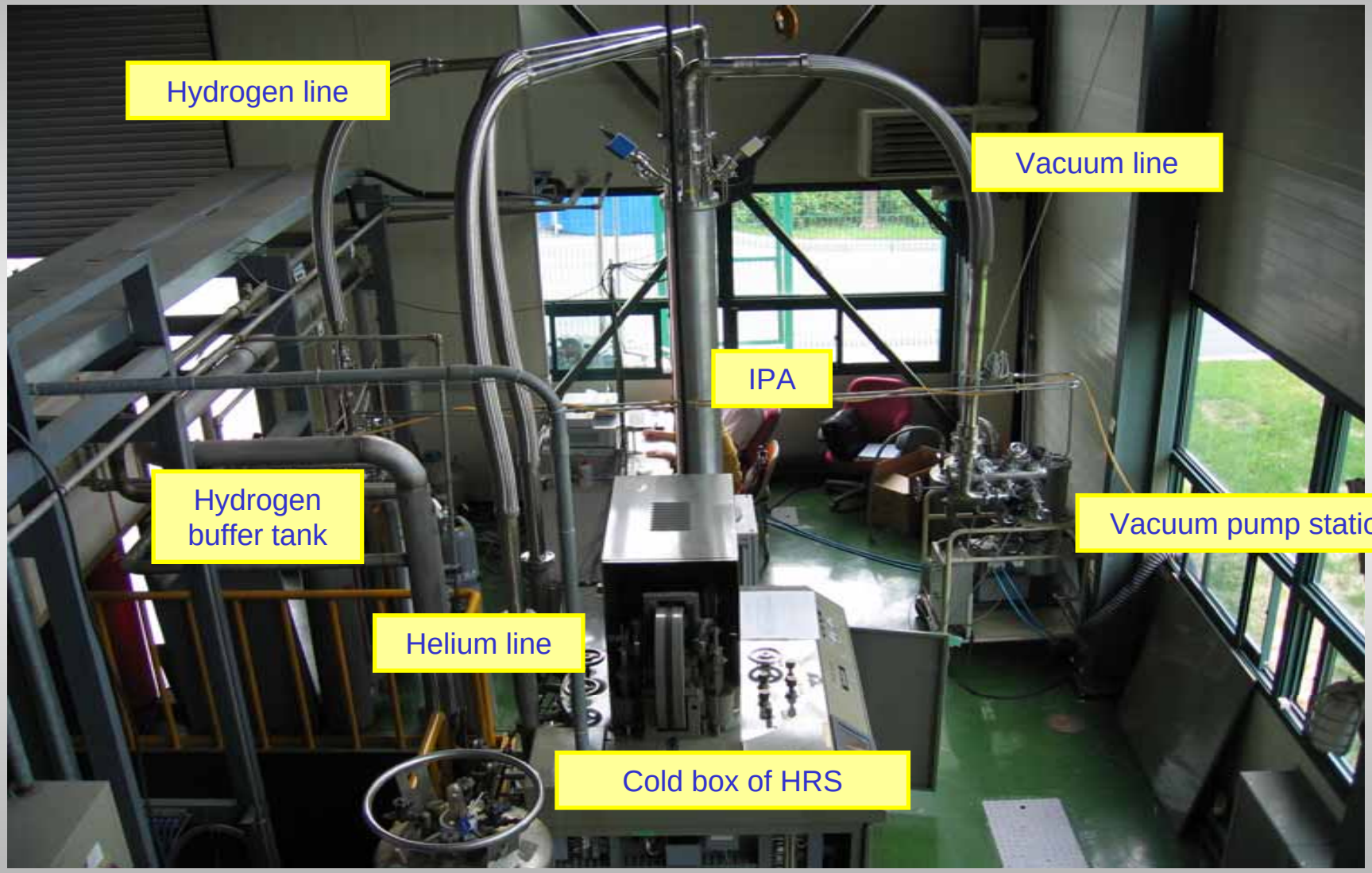
Moderator cell



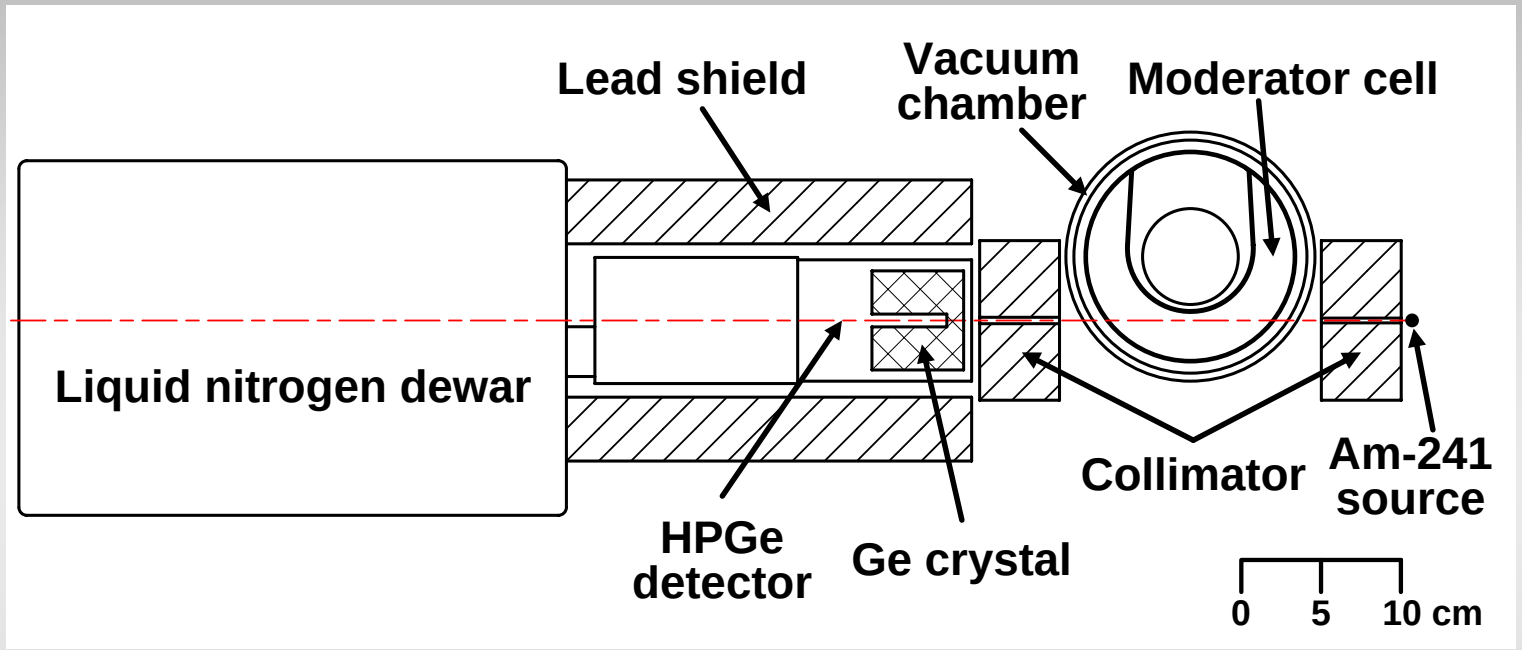


- Moderator cell
  - 6061 aluminium alloy,
  - Inner diameter : 130.0 mm,
  - Thickness : 1.0 mm,
  - The inner shell is open at the bottom.
- Cylindrical vacuum chamber
  - 6061 aluminium alloy,
  - Thickness : 5 mm.
- Simulation of nuclear heat load
  - Several line heaters and rod heaters

Mock up test facility



Experimental setup

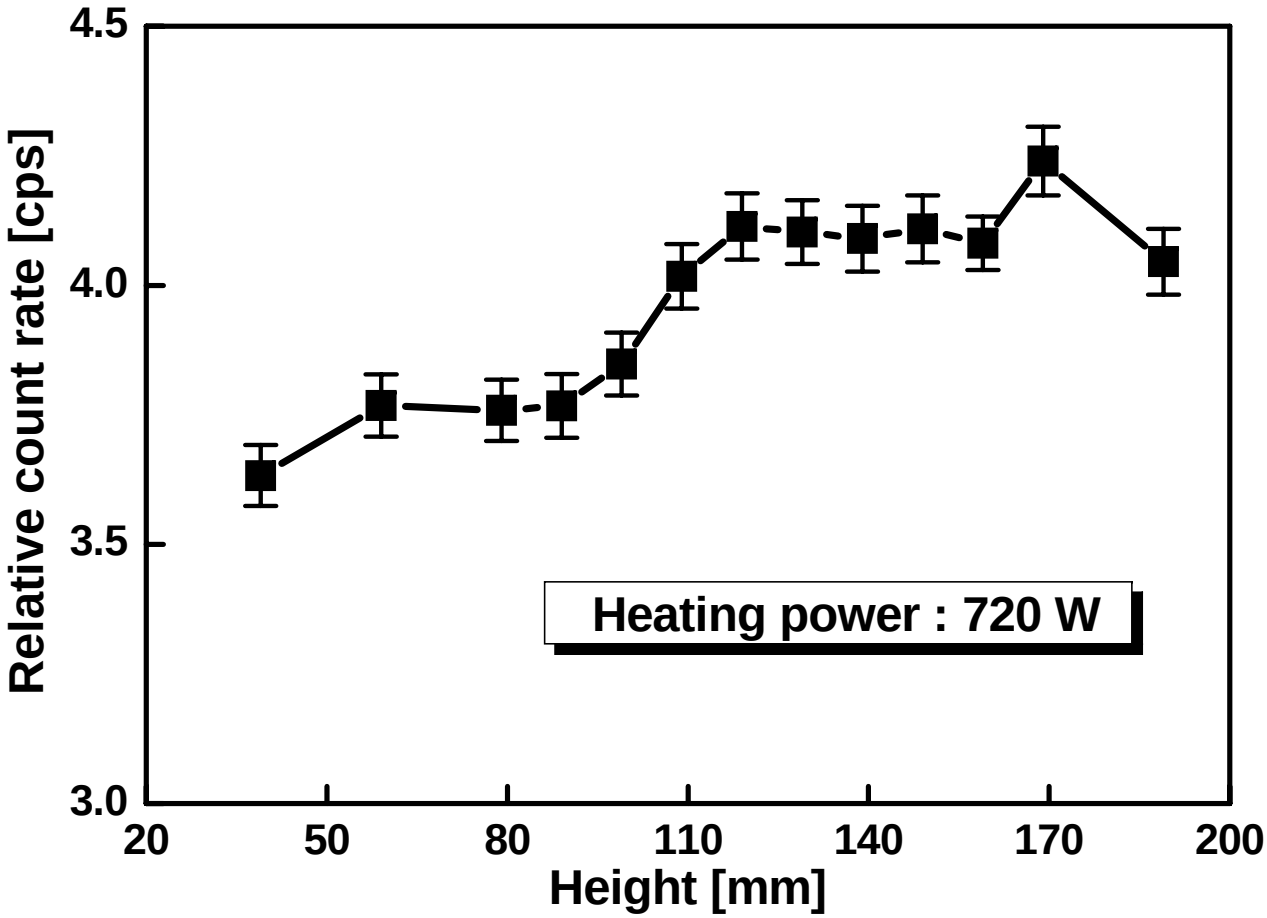


- 59.5 keV gamma-rays from the Am-241 isotope.
- Coaxial HPGe detector with a detection efficiency of 40%.
- Pathlength of the gamma-rays transmitted through the test section of the hydrogen medium : 102.5 mm.

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.

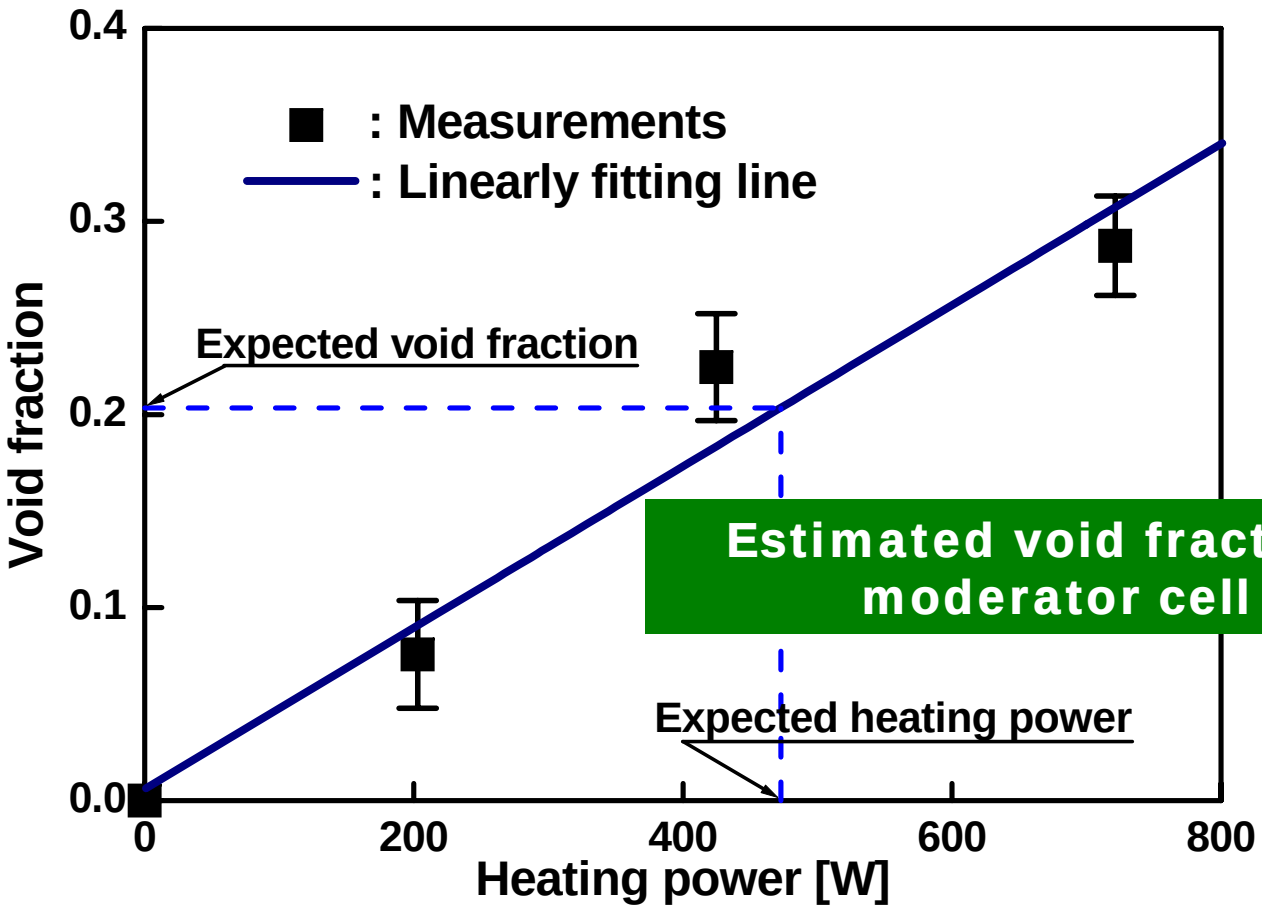
Longitudinal distribution of count rates



Measured void fraction

Heating power [W]	Void fraction		
	Lower region	Upper region	Volumetric weighted average
0	0.000±0.042	0.000±0.043	0.000±0.030
203	0.018±0.040	0.110±0.037	0.076±0.028
425	0.065±0.040	0.318±0.038	0.225±0.028
721.4	0.078±0.039	0.410±0.034	0.287±0.026
Gas	1.000±0.036	1.000±0.036	1.000±0.027

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.