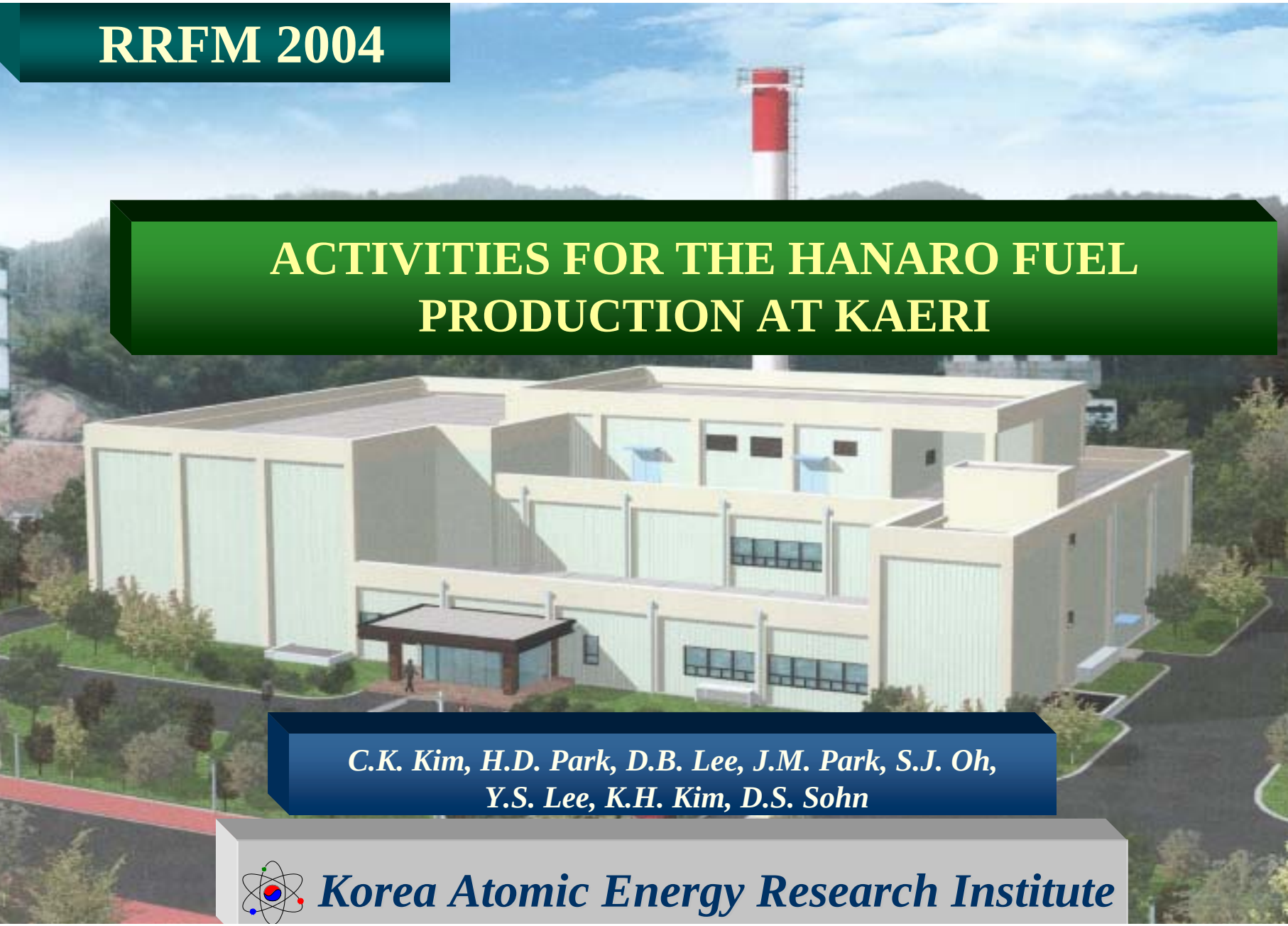
RRFM 2004

ACTIVITIES FOR THE HANARO FUEL PRODUCTION AT KAERI



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Introduction

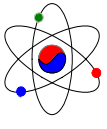
- In conjunction with the construction of HANARO a necessity for the fuel production for HANARO at KAERI was aroused around the middle of 1980s.
- A R&D project for HANARO fuel fabrication commenced in 1987.
- Fuel fabrication process for U_3Si dispersion rod type fuel had been developed. Atomization technology was applied to U_3Si powdering process. U_3Si powder having a spherical shape could be produced directly from U-Si alloy melt.
- The fabrication parameters were optimized and a Q/C system was established.
- Hydraulic tests were conducted for the preliminarily produced fuels.
- Irradiation tests the preliminarily produced fuels were performed in HANARO at a relatively lower power and a full power.
- The design and construction of the facility have been done from 1999. The fabrication license for the HANARO fuel was obtained

PIE Results of the irradiation tests

	The 1st irradiation test (KOSI-1)	The 2nd irradiation test (KOSI-2)
U-density (weight fraction)	3.15 g-U/cc (Al-61 wt.%U_3Si)	3.15 g-U/cc (Al-61 wt.%U_3Si)
Test fuel bundle	18 rod type	36 rod type
Fuel meat size	ϕ6.35 mm x L 200 mm	ϕ6.35 mm x L 700 mm
Fuel rods	3 atomized U_3Si fuel rods 3 comminuted U_3Si fuel rods	3 atomized U_3Si fuel rods 3 comminuted U_3Si fuel rods
Irradiation hole	OR-4 (HANARO)	CT (HANARO)
Max. linear power	88.9 kW/m	121.6 kW/m
Center line temperature	262 °C	320 °C
Average burnup	~87 at.% U-235	~63 at.% U-235
Time	Dec. 16, 1997 to June 6, 1999	June 17, 1999 to July 25, 2000

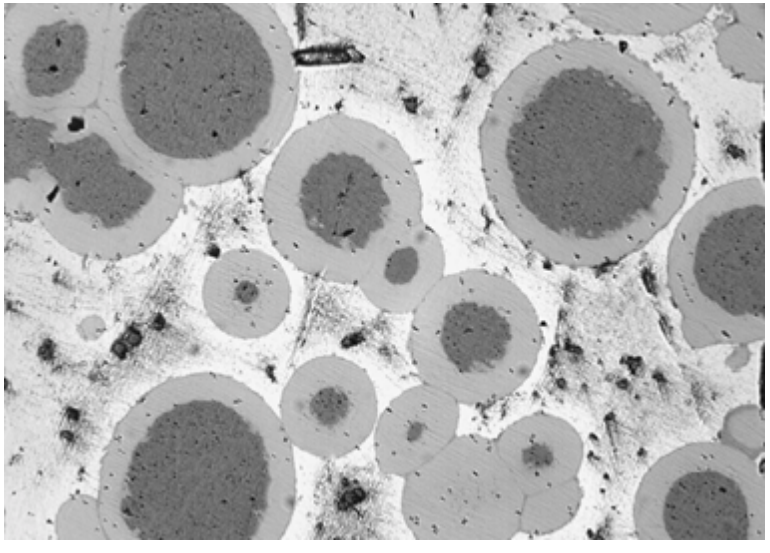
PIE Results of the irradiation tests

	The KOSI-1 test	The KOSI-2 test	
	Atomized fuel & Comminuted fuel	Atomized fuel	Comminuted fuel
Maximum Swelling	About 5 %	About 5.9 %	About 7.1 %
Interaction layer thickness	8~12 μm	5~15 μm	7~19 μm
Average bubble size	About 0.3 μm	About 0.36 μm	About 0.55 μm

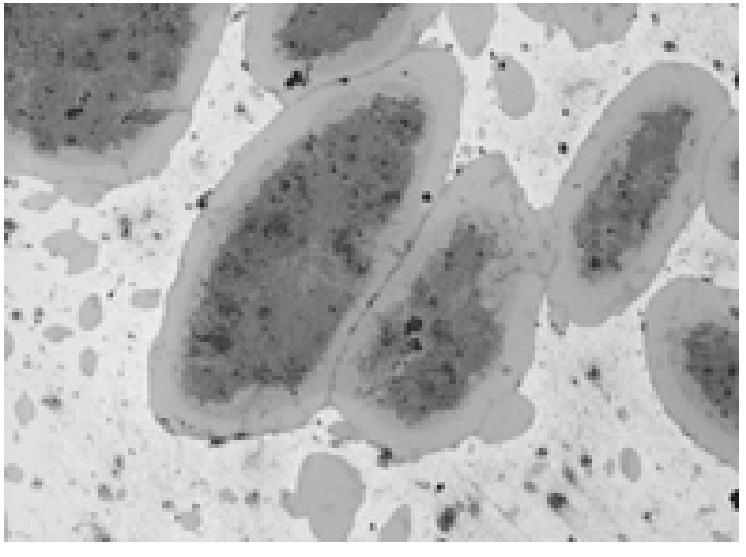


PIE Results of the irradiation tests

Observation on the cross sections of KOSI-2 fuel meats



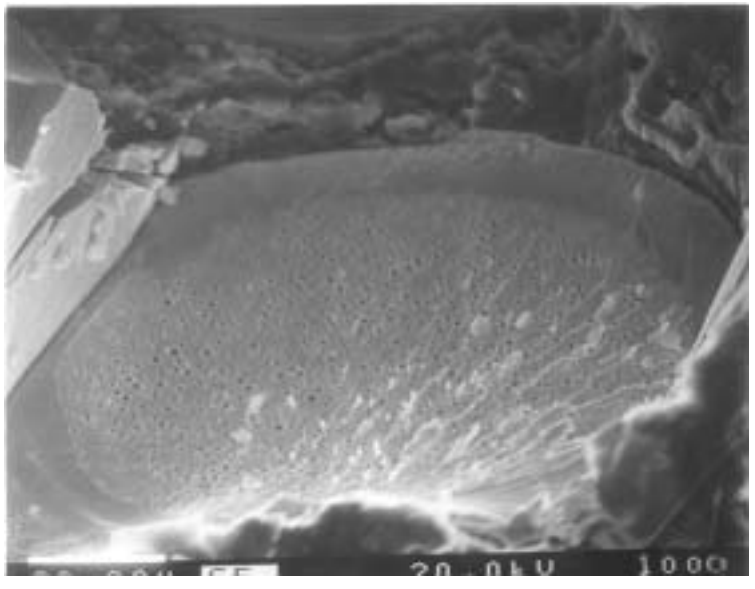
Atomized fuel meat



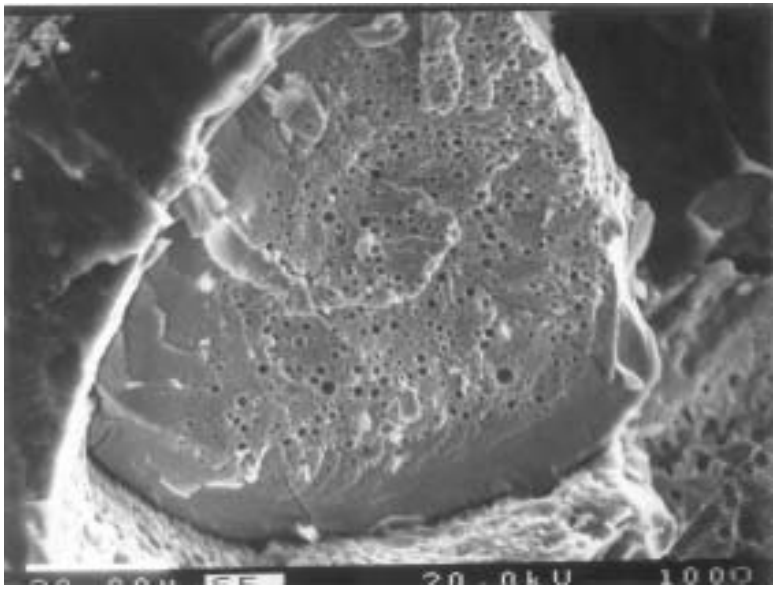
Comminuted fuel meat

PIE Results of the irradiation tests

SEM Observation on fractured surfaces of fuel particles in KOSI-2 fuel meats



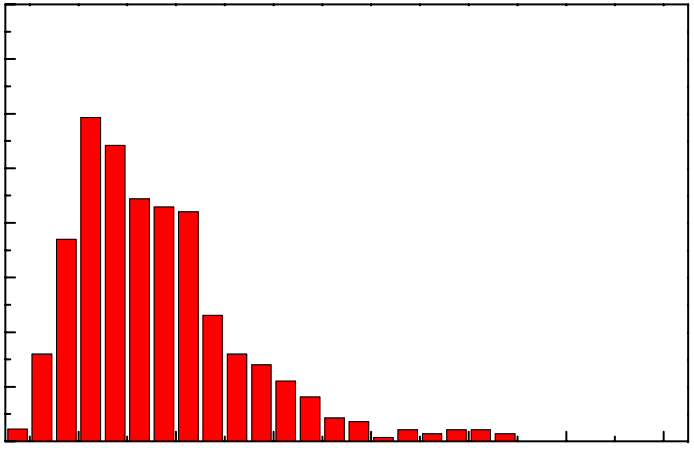
Atomized U_3Si fuel particle



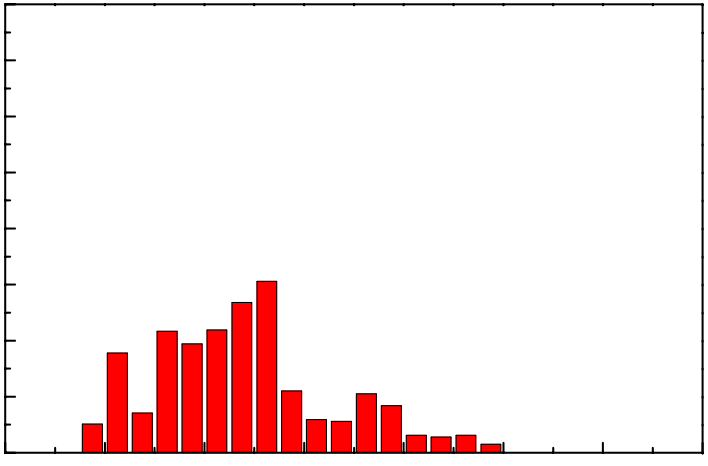
Comminuted U_3Si fuel particle

PIE Results of the irradiation tests

Bubble size distribution in the fuel particles



Atomized U_3Si fuel particle

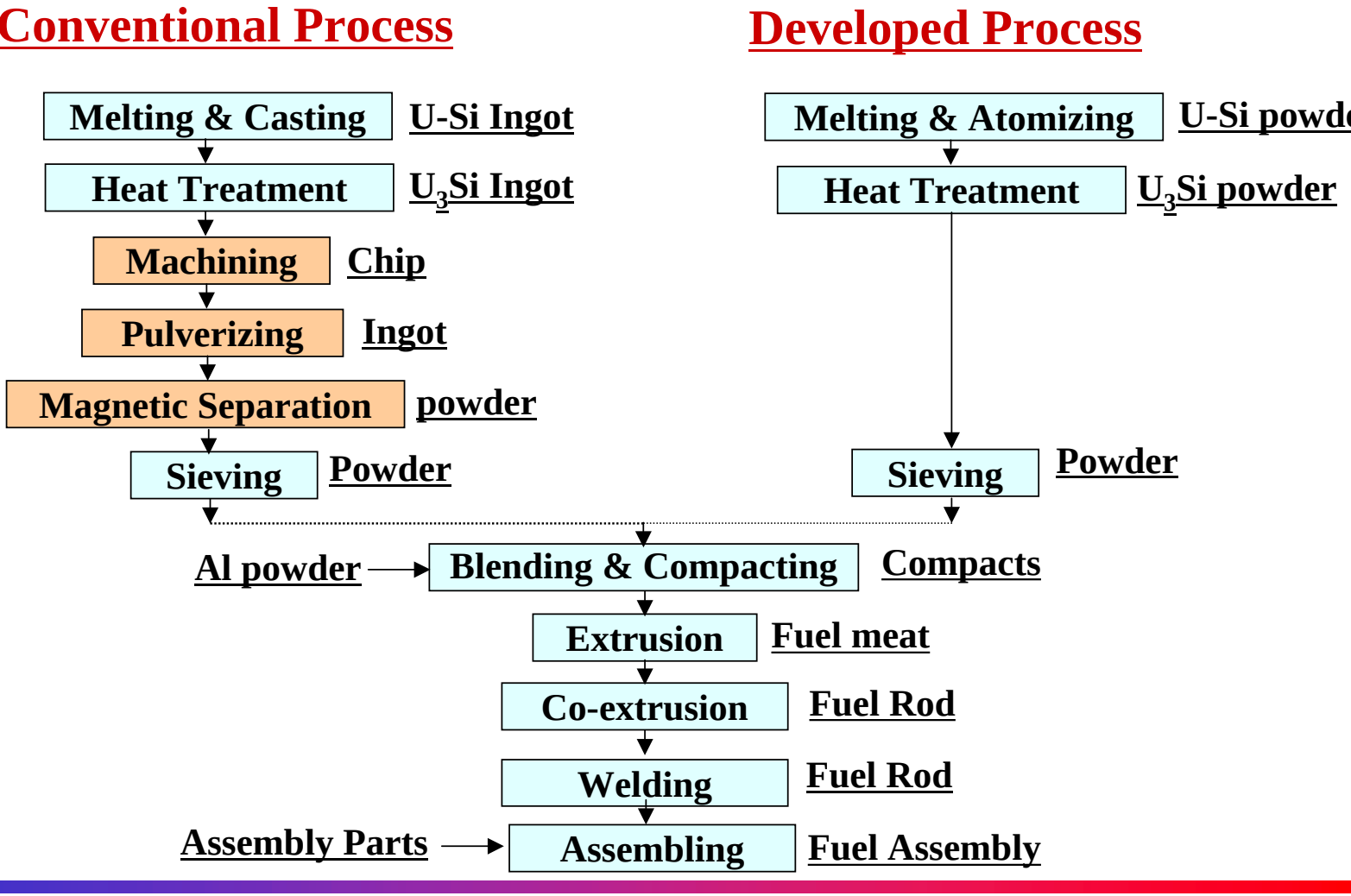


Comminuted U_3Si fuel particle

Design and Construction of the Facility

- **The annual production capacity of the fuel fabrication facility**
  - **HANARO Fuel**
    - **Hexagonal Fuel Assembly (36 rods): 27 set**
    - **Annular Fuel Assembly (18 rods): 18 set**
    - **Annual LEU metal consumption for HANARO fuel: about 100 kg**
  - **Annual production capacity of fuel powder: about 500 kg**
- **The facility design**
  - **Aseismatic design was applied.**
  - **Nuclear criticality safety was taken into consideration based on the double contingency principle by assuming the immersion condition in water with the computer code of SCALE4.4. The maximum effective multiplication factor was calculated to be 0.68955.**

The Fabrication Process



Process Equipments

Atomizer

Vacuum Heat Treatment Furnace

Process Equipments

Extruder

Process Equipments

Cladding Co-extruder

EB Welder

Quality Control

- The activities associated with the quality control in the fuel fabrication process
  - Dimension measurement,
  - Chemical analysis,
  - Phase analysis of the U_3Si fuel particle,
  - X-ray real time radiography inspection and the liquid penetration test for the defects in the welding parts
  - Soundness check for the cladding by the eddy current test
  - Homogeneity analysis for the fuel meat rod by the gamma scanner.
  - Go/No-go test is done using a Jig to check the reactor loading function.
- All the activities associated with the quality control are recorded in the Q/C computer system and the situation relating to the quality control can be monitored at every personal computer.

Licensing

- The nuclear fuel fabrication license was obtained from government. All the evaluation work was committed to the Korea Institute of Nuclear Safety.
- The submitted documents relating to the license
  - A report describing the facility design and construction plan
  - Environmental impact analysis report,
  - A document representing the processing capability of the fabricating fuel
  - Nuclear criticality safety analysis report
  - Quality assurance program and so on
- First an acceptable evaluation from KINS was obtained and an additional review was done by the National Atomic Energy Commission.
- the Ministry of Science and Technology issued the license.
- KINS audited the construction work.
- A report on the constructed facility and the process equipments was submitted to the Ministry.
- The license associated with the loading of the fabricated fuels into HANARO is under way on the base of the irradiation results.
- A lead fuel bundle loading is requested.

Fuel Production Plan

- A rework for the unusable fuels imported from AECL in CANADA due to fuel design changes is under way.
- The number of fuel bundles to be reworked is estimated to be about 50 sets. It is assumed to take about 6 months to do the rework for all the fuel bundles.
- In the mean time some startup operation will be done in each process step. An effort will be made to produce one lead fuel bundle as soon as possible.
- It is expected that the production of the HANARO fuel can start from around June this year.
- The fuel bundles to be consumed in HANARO annually under normal operations are 45 sets, which consist of 27 sets of 36 rod type bundles and 18 sets of 18 rod type bundles.
- This facility will produce all the fuels needed for the operation of HANARO.

Summary

- **The HANARO fuel fabrication process has been developed in KAERI from 1987.**
- **In order to qualify the developed fuel process two irradiation tests were performed and showed acceptable results.**
- **The fabrication facility was designed and constructed by focusing on safety such as the nuclear criticality.**
- **A quality control was established to guarantee the product quality.**
- **Through the safety evaluation by the regulatory body and the review by the National Atomic Energy Commission, the fabrication license for the HANARO fuel was obtained from the Ministry of Science and Technology.**
- **The fabrication operation for the HANARO fuel commence this year and all fuels for HANARO are produced in KAERI from this year.**