Current Status of HANARO And Future Plan

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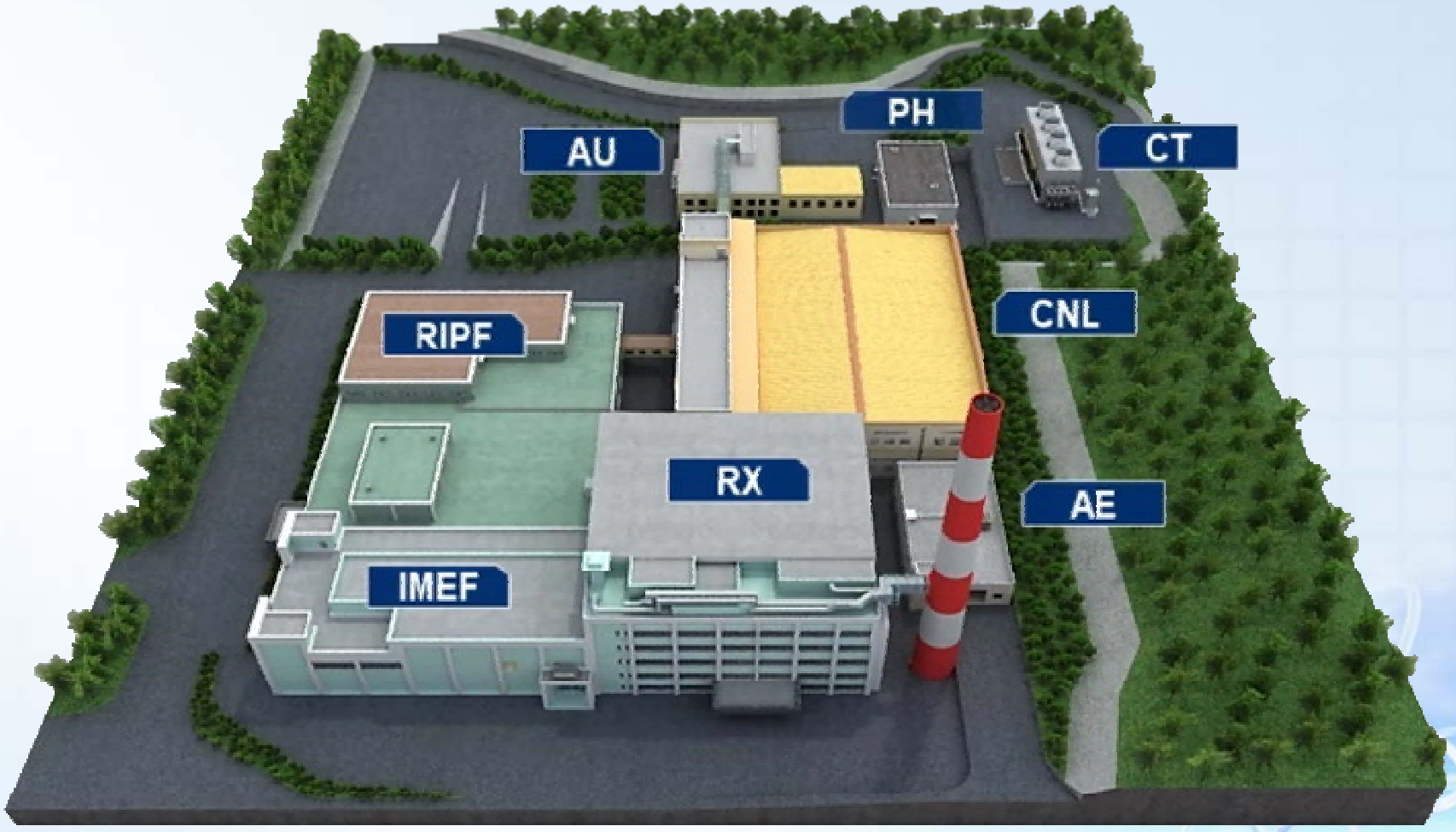
Introduction

Korea Atomic Energy Research Institute

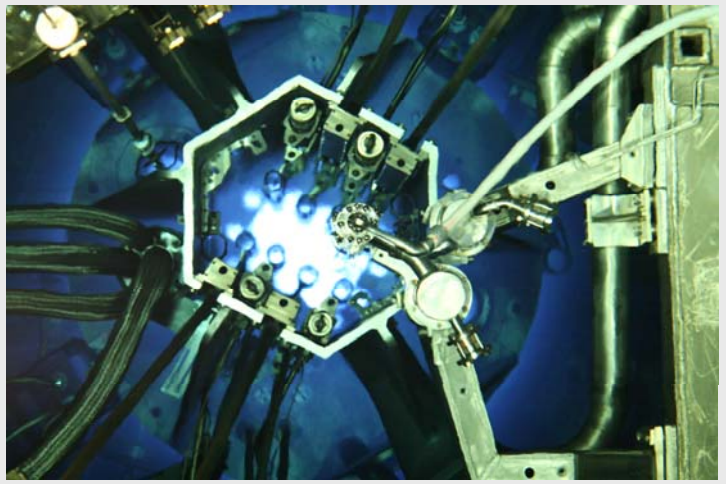
HANARO Complex in KAERI



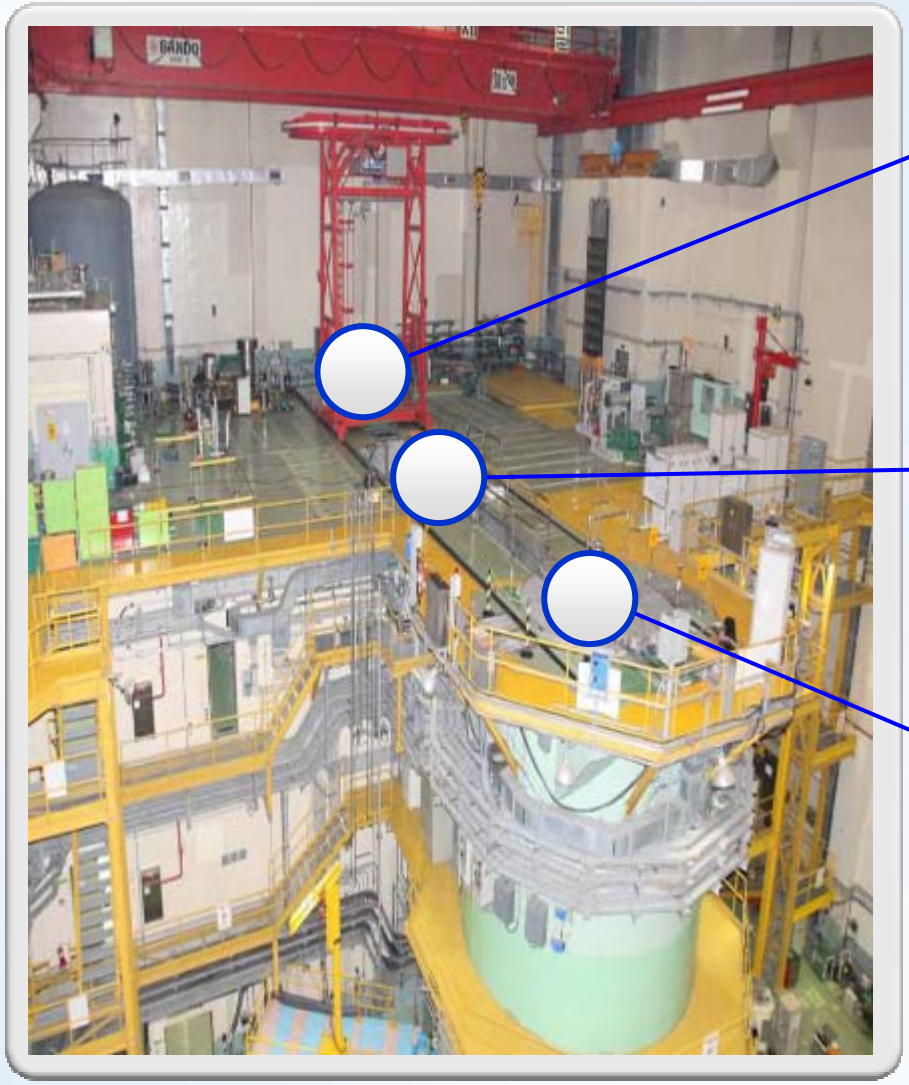
HANARO Reactor

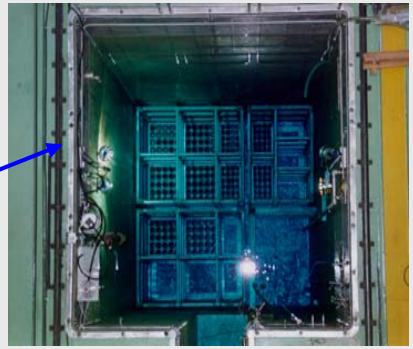
High-flux
Advanced
Neutron
Application
ReactOr

Multi-purpose Research Reactor

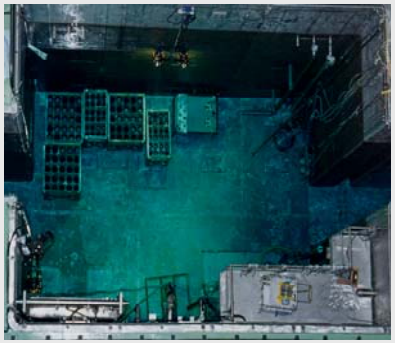


Reactor Pools

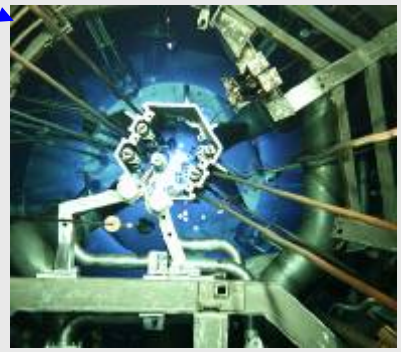




Spent Fuel Storage Pool



Service Pool



Reactor Pool

Mission of HANARO

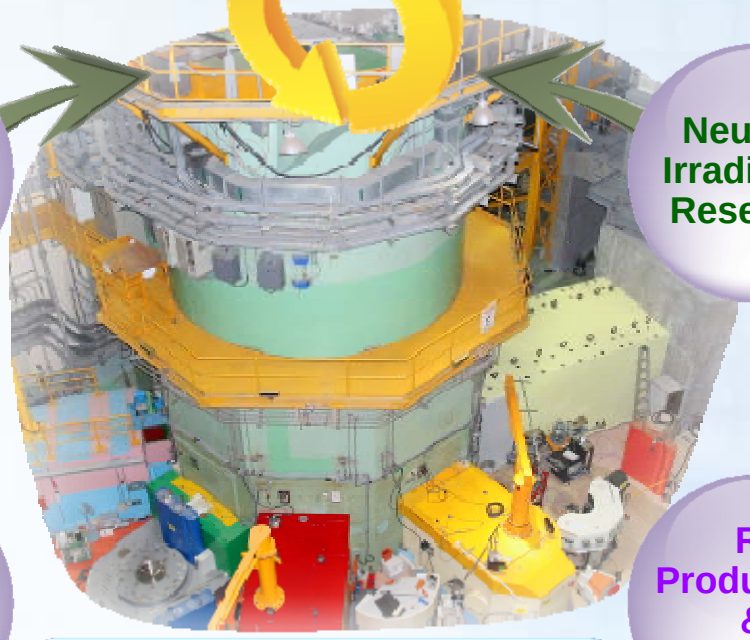
Platform for Nuclear Basic Research

User Community

- Industry
- University
- Institute
- International Cooperation

National Demand

- Basic R&D
- Competitiveness in Technology



Neutron Beam Research

- Cold Neutron Bea
- Radiography

Neutron Irradiation Research

- Fuel Test Loop
- Material Irradiation
- Neutron Activation Analysis
- NTD

Operation & Development

- Reactor Operation
- Experimental Facility Operation

RI Production & Utilization

- Public Welfare
- Industrial Application

SAFETY

Chronology

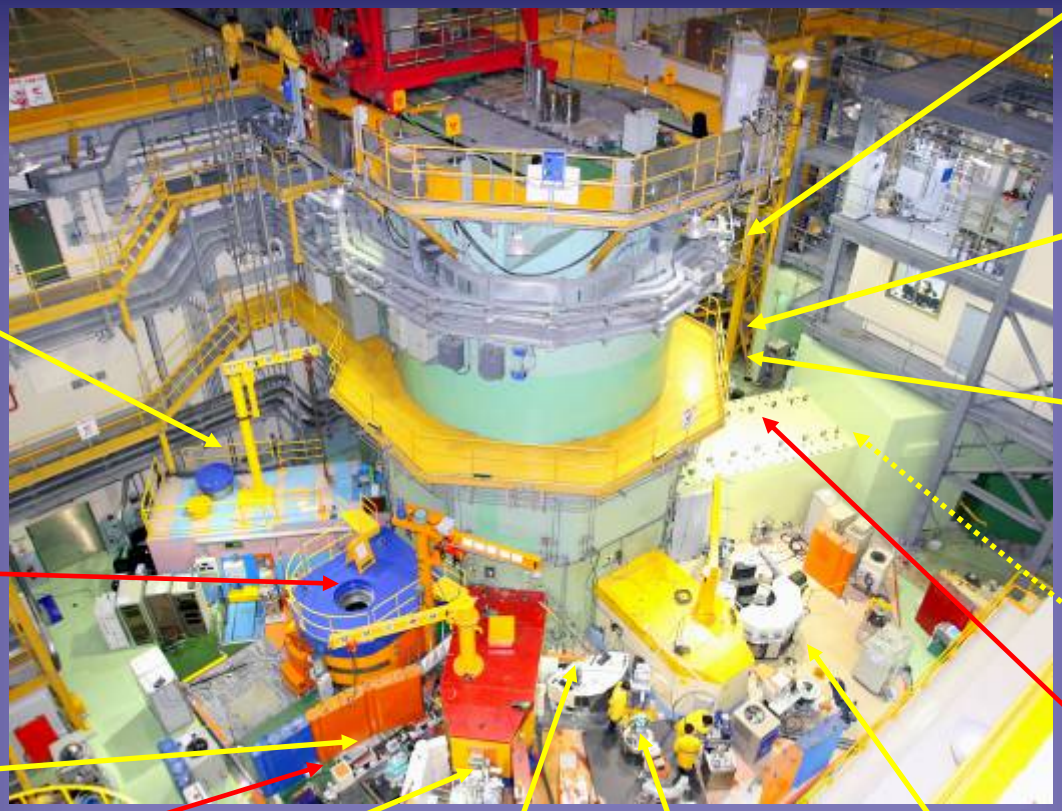
- 1985 JAN Start of HANARO Project
- 1989 JAN Start of HANARO Construction
- 1993 AUG Installation of HANARO Reactor Structure
- 1995 FEB Fuel Loading and Achievement of Initial Criticality
- 1996 JAN 15MW Power Operation
- 1999 DEC 22MW Power Operation
- 2004 NOV 30MW (Design Power) Power Operation started
- 2005 MAR First Loading of HANARO Fuel Made by KAERI
- 2006 APR Start of Cold Neutron Laboratory Construction (Completed in May 2008)
- 2006 JUL Start of Fuel Test Loop Installation (Completed in Feb. 2008)
- 2008 MAY Start of Cold Neutron Source System Installation
- 2009 SEP 3 First Generation of Cold Neutron
- 2009 SEP 28 Completion of FTL Commissioning Test

HANARO, Past and Present

Feb., 1995

Oct., 2009

Reactor Hall, 2009



In-service
Under way

IR Port

Ex-Core Neutron Irradiation Facility (ENF), 2005

ST1 Port

Prompt Gamma Neutron Activation Analysis(PGAA), 2003

Residual Stress Instrument(RSI), 2003

NR Port

Neutron Radiography Facility (NRF),1997 Upgrade

ST4 Port

Triple Axis Spectrometer (TAS), 2010

Neutron Reflectometer (REF-V), 2006 To be moved 2010

Bio-Diffractometer (Bio-D), 2010

CN Port

Small Angle Neutron Scattering (SANS),2001 Currently dismantled

Cold Neutron Guide, 2009

ST3 Port

Neutron Reflectometer, (REF-H), 2008 To be moved 2010

High Intensity Powder Diff. (HIPD), 2008

ST2 Port

High Resolution Powder Diff. (HRPD),1998

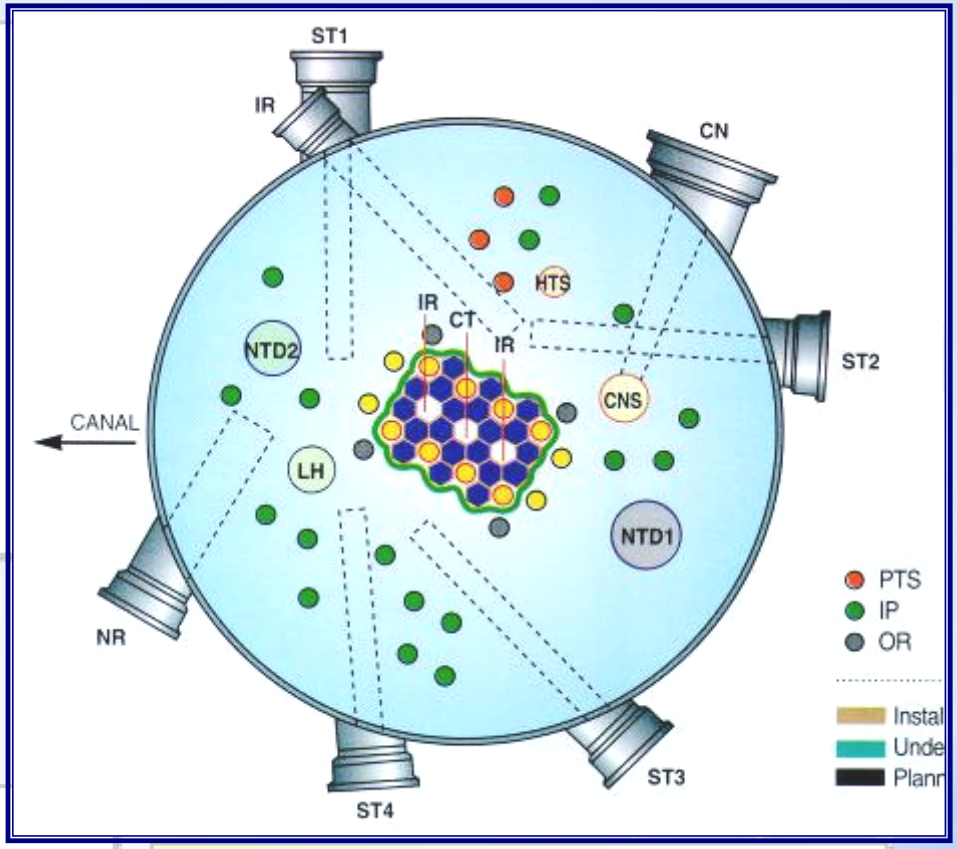
Four Circle Diffractometer (FCD),1999 Upgrade '05-'06

Status of Experimental Facilities

Vertical Holes

Installed

IR1: Fuel Test Loop
CT, IR2: Capsule Irradiation& RI Production
OR : Capsule Irradiation & RI Production
IP : RI Production
HTS : Hydraulic Transfer System for RI Production
PTS : Pneumatic Transfer System for Neutron activation Analysis
NTD : Neutron Transmutation Doping of Silicon
CNS : Cold Source Installation



Horizontal Tubes

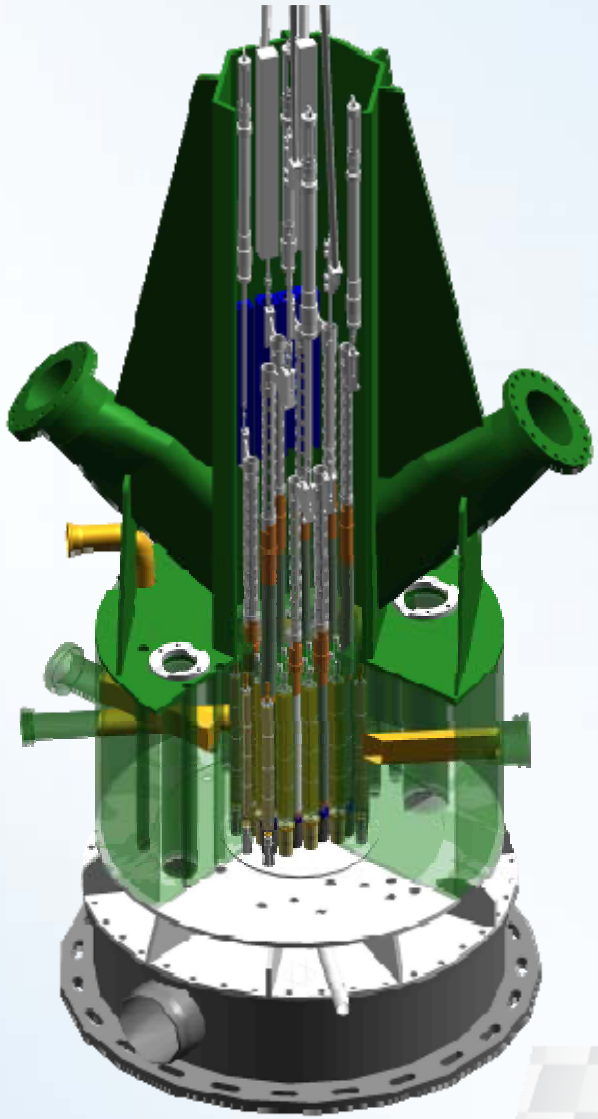
Installed

ST2 : High Resolution Powder Diffractometer, Four Circle Diffractometer
NR : Neutron Radiography Facility
CN : Cold Neutron Guide
IR : Ex-core Neutron-irradiation Facility for BNCT & DNR
ST1 : PGAA and RSI
ST3 : Vertical Reflectometer
ST3 : Horizontal Reflectometer
ST3 : High Intensity Powder Diffractometer

Under-development

ST4 : Triple Axis Spectrometer

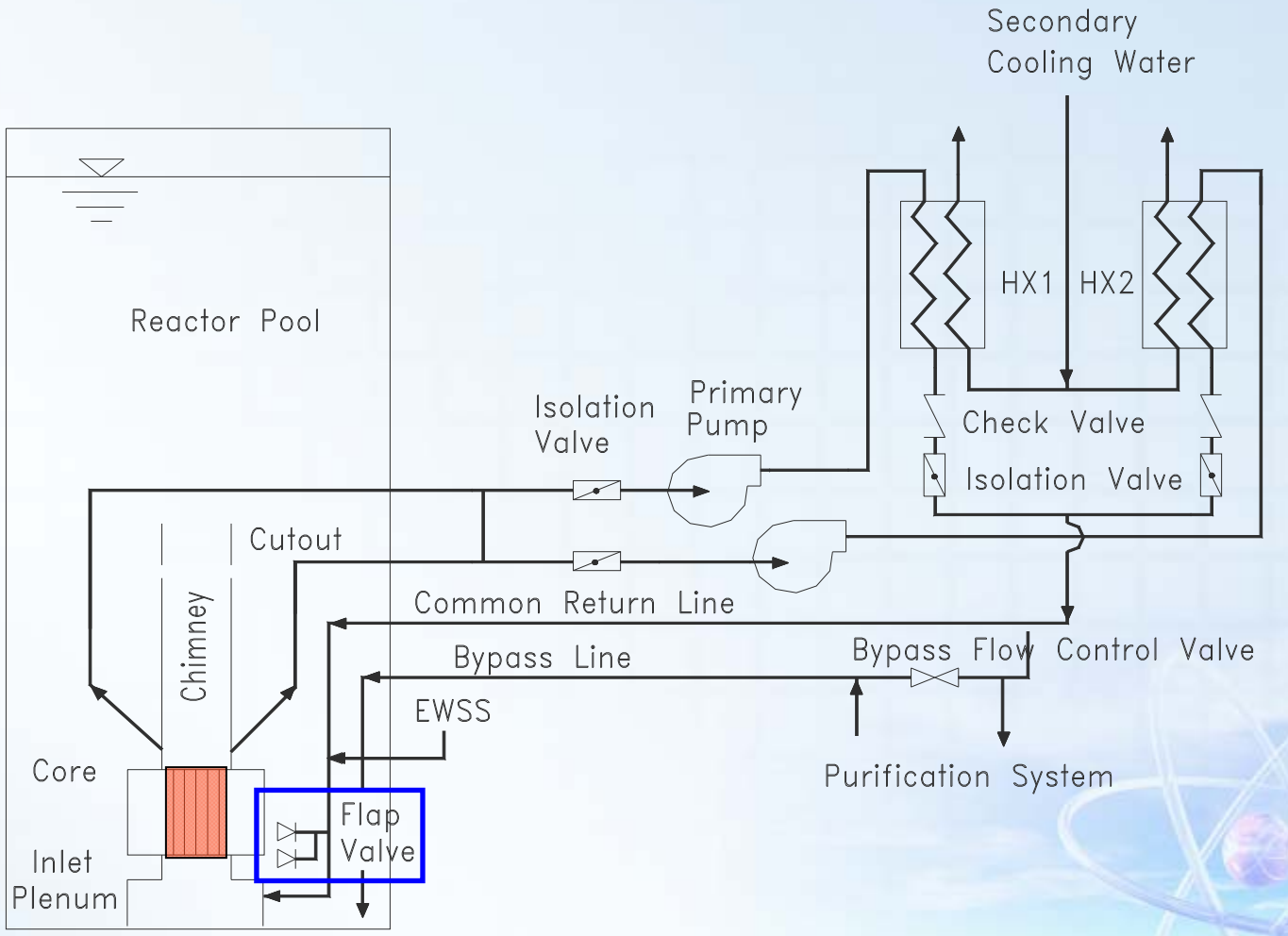
Reactor Structure and Characteristics



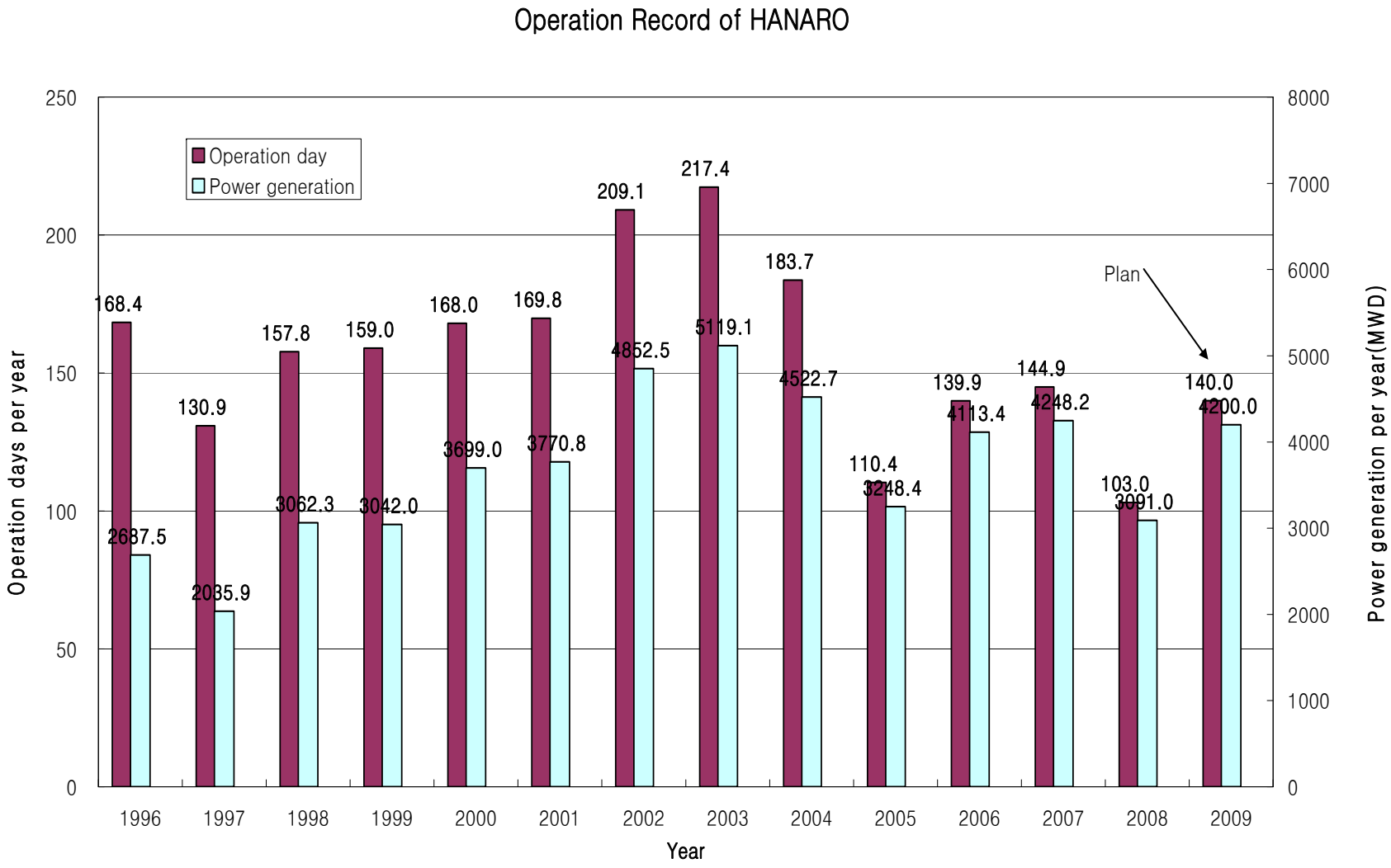
Features

- **Type** — **Open-tank-in-pool**
- **Power** — **30 MW_{th}**
- **Coolant** — **Light Water**
- **Reflector** — **Heavy water**
- **Fuel Materials enriched** — **U_3Si, 19.75%**
- **Absorber** — **Hafnium**
- **Reactor Building** — **Confinement**
- **Max Thermal Flux** — **$5x10^{14}$ n/cm^2s**
- **Typical flux at port nose** — **$2x10^{14}$ n/cm^2s**
- **7 horizontal ports & 36 vertical holes**
- **Vertical hole for cold neutron source**
- **Operation Cycle** — **24 days@5 weeks**

Primary Cooling System



Reactor Operation Record



International Communication

- **Mutual visits**
  (CARR, JRR3-M, JMTR, OPAL, HFIR, RRs in CEA, ….)
- **Invitation of experts**
- **Regional Cooperation (FNCA, RCA)**
- **Sabbatical stay in other RR Institute**
- **HANARO Symposium**
  - Official international symposium for 2005 and 2010

Major Facility Upgrades & Ageing Management

Major Reactor System Upgrades

- Installation of a hot water layer system in 1997
- Installation of a steel compartment in 2005 to confine D_2O reflector system components
- Replacement of entrance doors to the reactor hall in 2005 for physical protection
- Replacement of NaI detectors with delayed neutron detectors in 2006 for a failed fuel detection system
- Installation of gamma ion chambers for power measurement and a trip signal replacing the thermal power measurement system in 2006
- Upgrade of the OWS (Operator Work Station)
  - Installation of a Window-based System in 2002
  - Upgrade in 2007 to integrate the FTL system
  - Upgrade in 2009 to integrate the CNS system
- Installation of steel tanks in the reactor hall in 2007 for the temporary storage of pool water
- Re-structuring of the user rooms in the reactor hall in 2007 for the improvement of fire-resistance
- Installation of a voltage sag compensator in 2007 to prevent the reactor trip due to a momentary interruption of electric power

Major Reactor System Ageing Management

- Measurement of reactor vessel inner-shell straightness, visual inspection of SOR/CAR and fuel channels in 2004
- Extended endurance test of SOR for life extension
- Preventive maintenance of primary pumps
- Removal of scale in the secondary side of primary heat exchangers in 2004 and 2005
- Overhaul of reflector pumps in 2004 and 2005
- Replacement of the UPS system in 2005
- Overhaul of the compressed air system in 2006
- Overhaul of the electrical system in 2007
- Safety review and repair of the reactor building and cooling tower buildings in 2006
- Replacement of fission chambers (1 out of 6) in 2008

Status of Utilization

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Regional Cooperation for Neutron Science

The Asia-Oceania Neutron Scattering Association was officially formed on August 28th, 2008

Members

- Korean Neutron Beam Users Association
- Japanese Society of Neutron Science
- Australian Neutron Beam Users Group
- Indian Neutron Scattering Society
- Taiwan Neutron Science Society

Observers

- China
- India
- Indonesia
- Malaysia
- Singapore

Beam Research

Current major in-house researches

- **Research on fuel cell characterization**
- **Development of hydrogen storage material**
- **Characterization of Li battery**

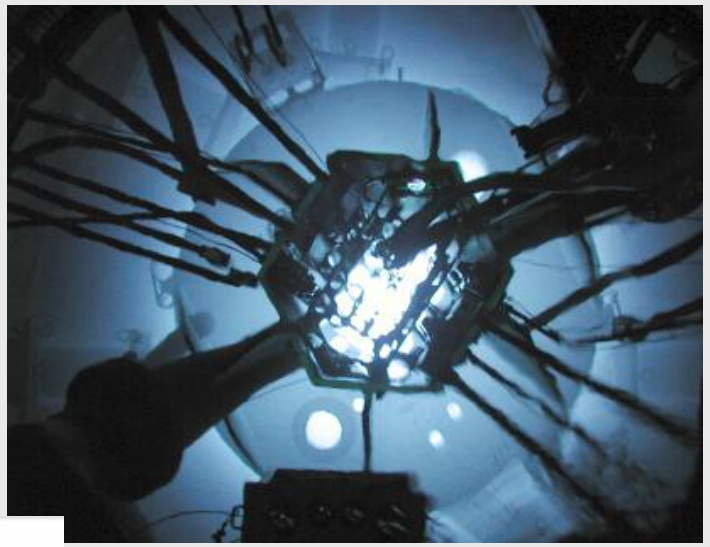
Visitors from Japan

- **Neutron Activation Analysis**
- **Neutron Radiography**

Material/Fuel Irradiation

Irradiation tests

- HANARO fuel irradiation test for the resolution of a licensing issue
- DUPIC (Direct Use of PWR Fuel in CANDU) fuel irradiation test
- High burn-up PWR fuel
- U-Mo fuel (7-UMo, 200 ºC of fuel temperature)
- Irradiation of Rx vessel material for Kori-1 (First Power Reactor in Korea)
- Calibration test for SPND



Irradiation capsules

- Un-instrumented and instrumented material irradiation capsule
- Fuel capsule
- Creep capsule
- Fatigue capsule

Radioisotope Production Facility

Bank II (11 Cells)

^{166}Ho,$^{32,33}P$, ^{99m}Tc,^{51}Cr, HDR ^{192}Ir

Bank III (6 Cells)

^{131}I, ^{125}I

Bank I [4 Cells]

^{60}Co, ^{192}Ir, ^{169}Yb

Bank IV (4 Cells)

$^{99}Mo/^{99m}Tc$ Generator

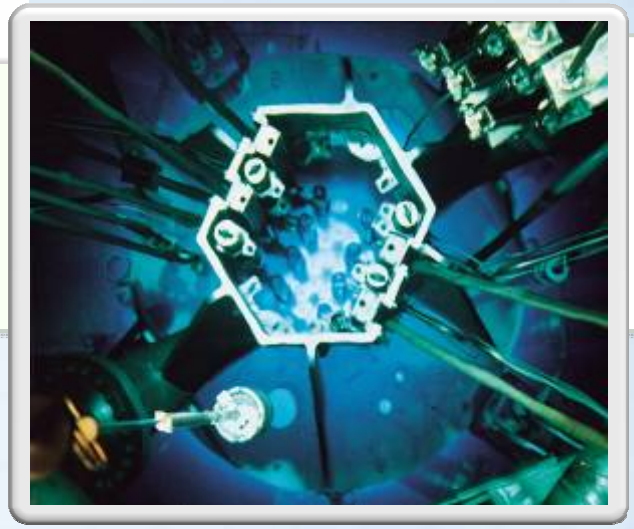
Preparation Room for Cold Kits

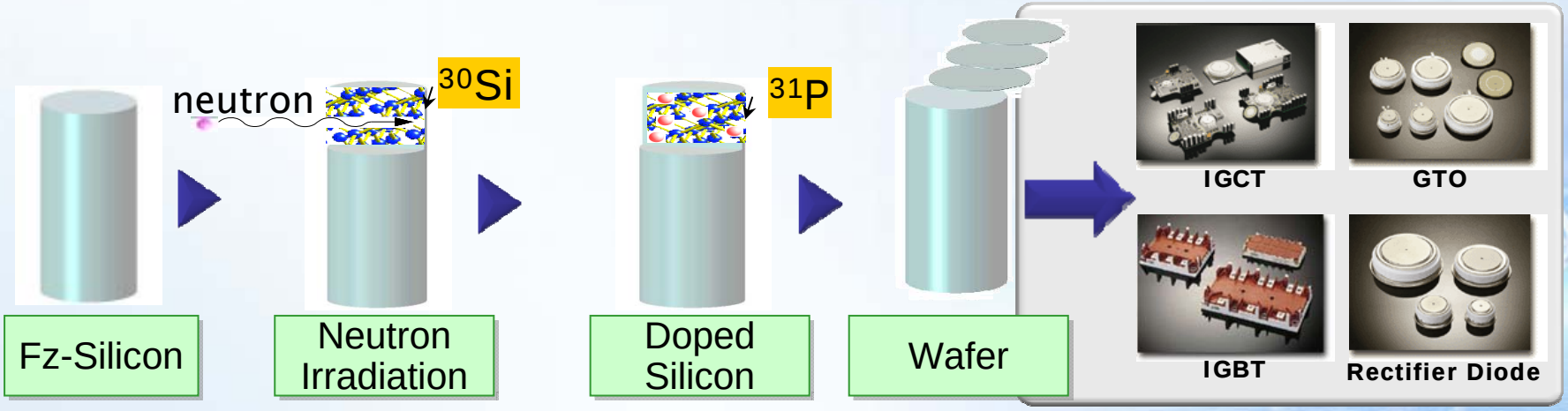
Neutron Transmutation Doping

Production of high quality Si Semiconductor

Services using NTD1 & NTD2 holes

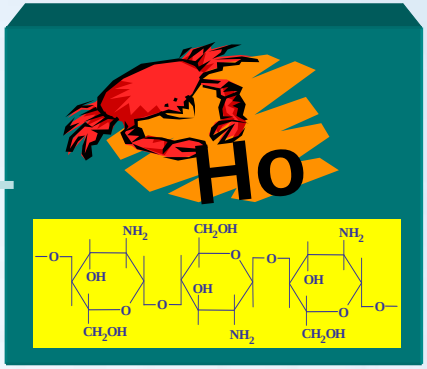
- **Irradiation of 5“, 6" and 8” Ingots**
- **High Uniformity & Accuracy**
- **Commercial Service from 2003**
- **10% of World Market Share**





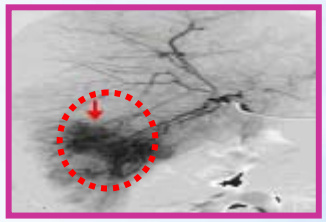
Milican® Injection for Liver Cancer Treatment

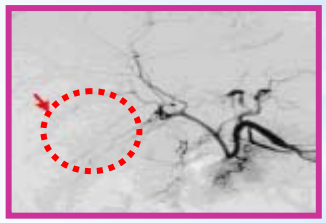
- ***Milican® injection : Radio-pharmaceutical for the treatment of liver cancer using ^{166}Ho***
- ***1,400 applications to patient***
- ***Applications are being extended to the malignant tumors; Cystic Glioma, Peritoneal Cancer, Colon Cancer & Rheumatism, etc.***



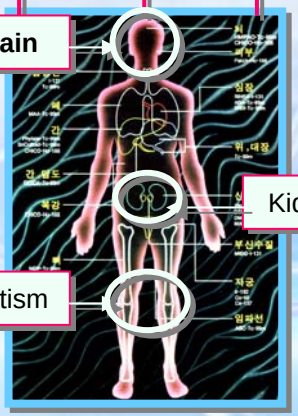
^{166}Ho-CHICO
(^{166}Ho-Chitosan Complex)

Characteristic





Applications



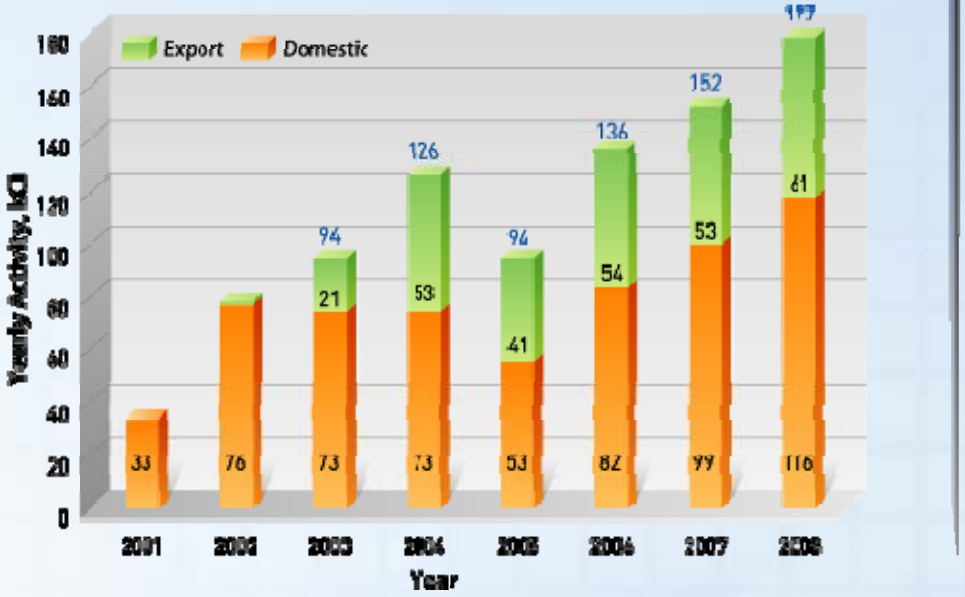
^{192}Ir Source for NDT

^{192}Ir & Production System

- *Activity : ~ 110 Ci/source*
- *Special Form Radioactive Material*
- *Production Capacity* : 400 kCi/yr

Year 2008

- *177 kCi of source produced*
- *~95% of domestic demand*
- *~35% of production for export*



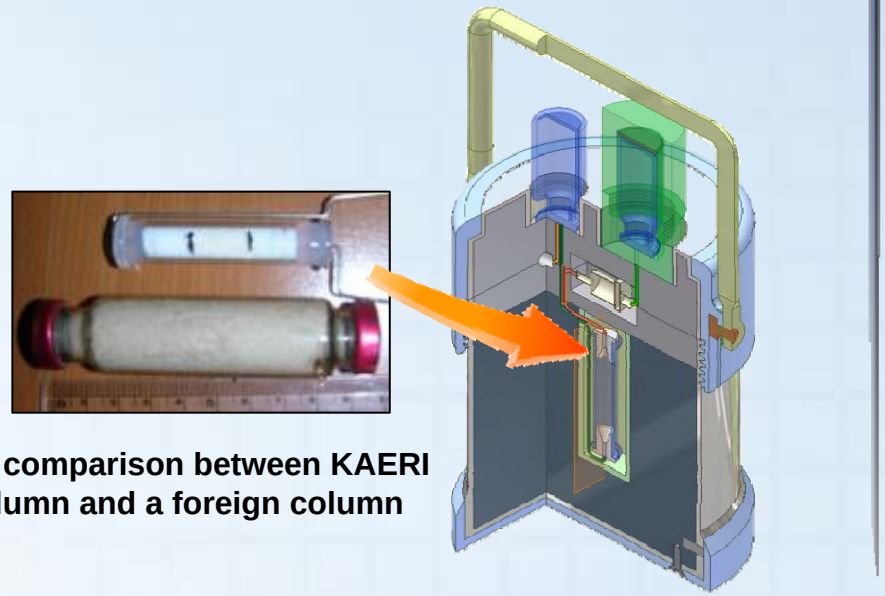
Ir-192 NDT Source

Production System

Development of $^{188}W/^{188}Re$ Generator for Radiotherapy

- ***High Performance Adsorbent by Sol-Gel Processing***
- ***Adsorption Capacity : ~500mg(W)/g(adsorbent)***
- ***General Specification***
  - *Capacity : 1000 mCi*
  - *Elution : ≥80 %*
  - *$^{188}W/^{188}Re$: 10^{-3}~10^{-4} %*
  - *$^{188}ReO_4^-$: 100 %*

The use for Mo/Tc using (n, gamma) with enriched Mo is under study.



Size comparison between KAERI column and a foreign column

KAERI's $^{188}W/^{188}Re$ Generator

Commissioning Test of FTL (Fuel Test Loop) & CNS (Cold Neutron Source)

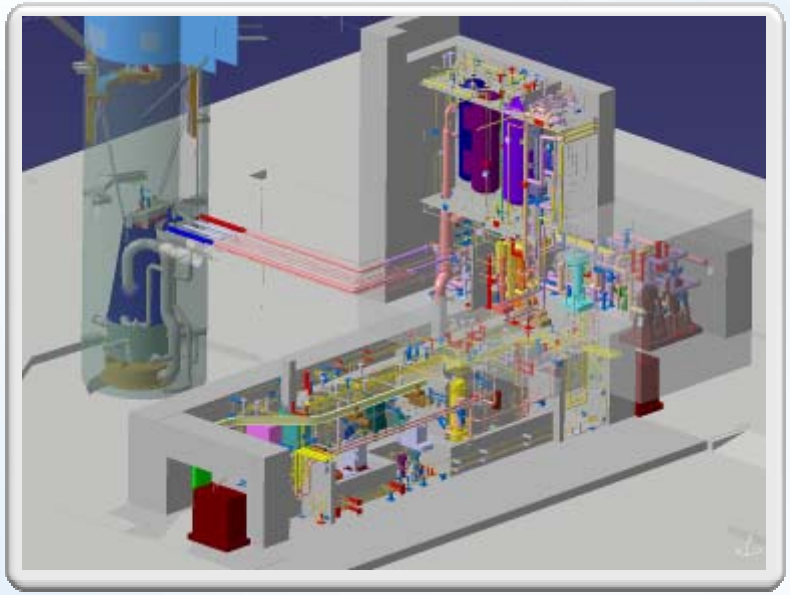
KAERI Korea Atomic Energy Research Institute

Fuel Test Loop Facility (1/2)

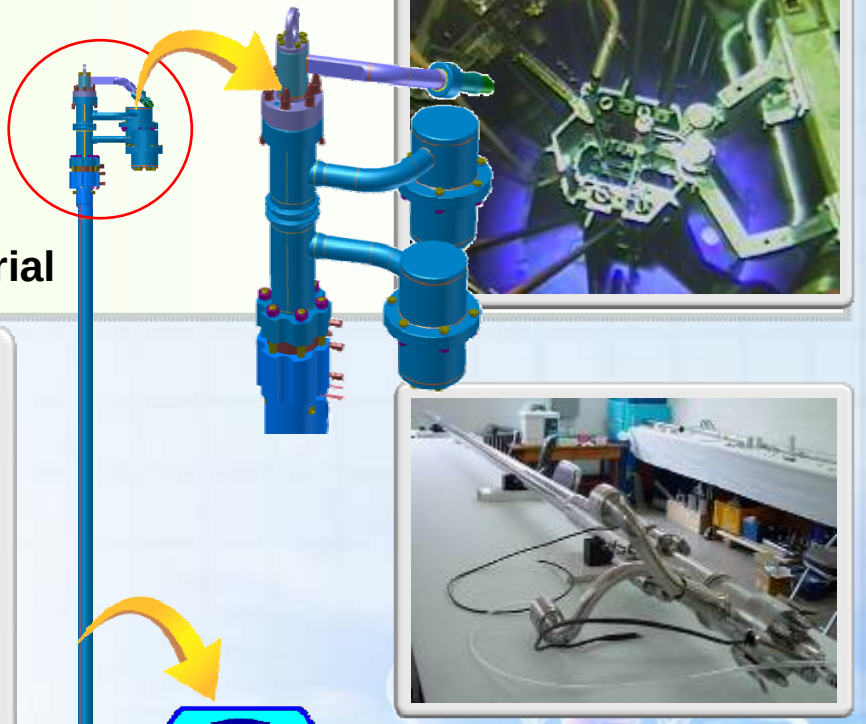
Commissioning test : ~ Sept. 2009

Applications

- **Integral Fuel Irradiation Tests**
- **Fuel Qualification Tests**
- **High Burn-up Fuel Tests**
- **Water Chemistry and Corrosion Tests**
- **Non-fissile Tests of Pressure Tube Material**



Out-Pile System

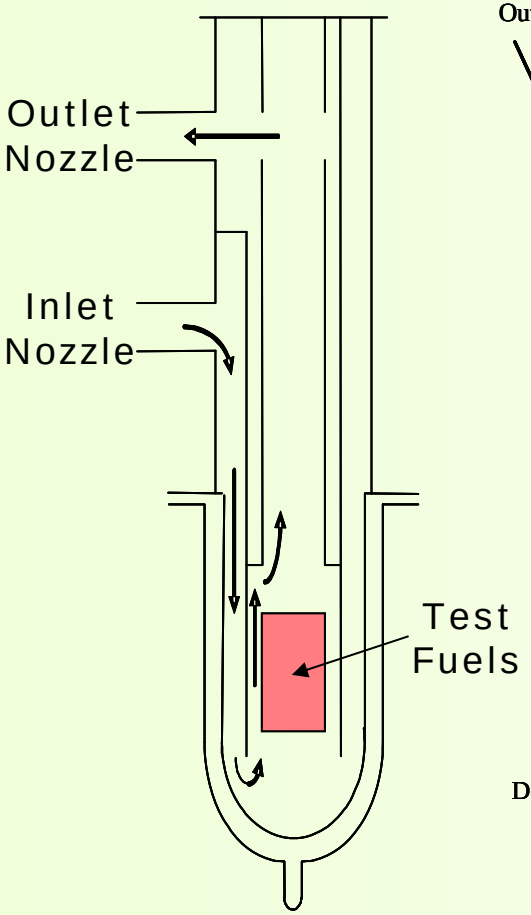


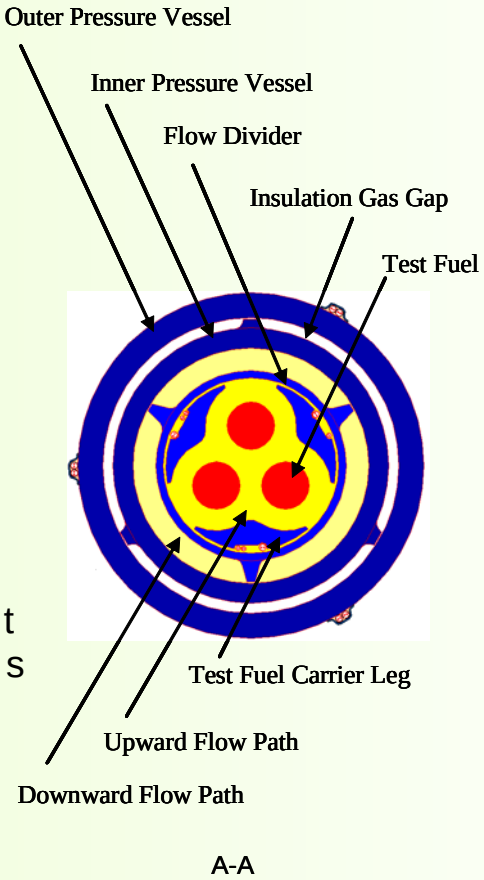
In-Pile Section

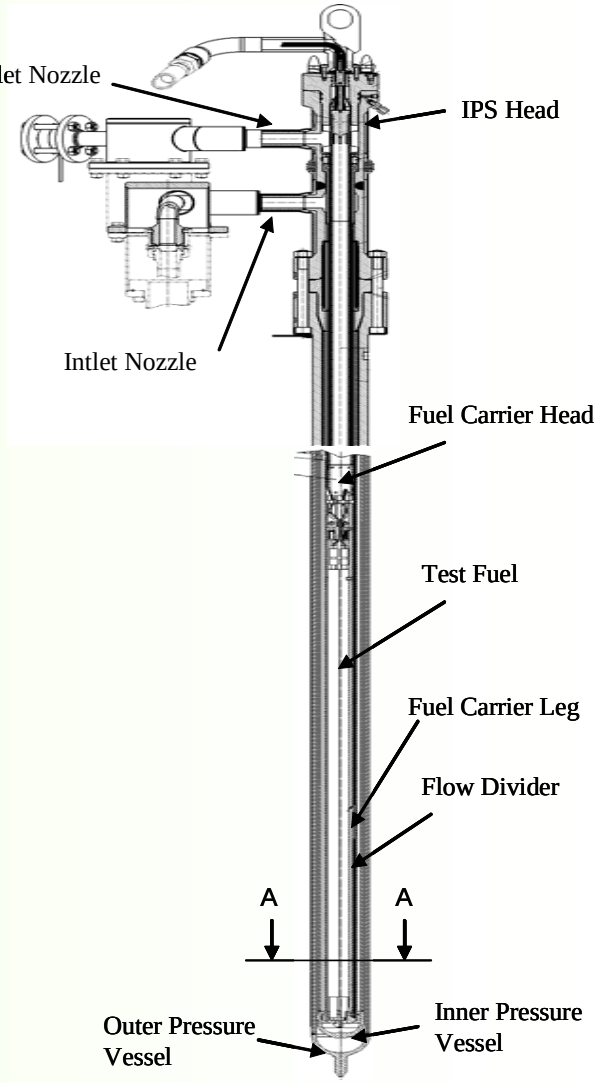
- **Design Pressure : 17.5 MPa**
- **Design Temperature : 350 ℃**

Fuel Test Loop Facility (2/2)

Thermal flux : 1.2x10^{14} n/cm^{2}s
Fast flux : 1.1x10^{14} n/cm^{2}s







Cold Neutron Research Facility

Project

Development of the Cold Neutron Research Facility and Utilization Technology

Project Period

2003. 7 – 2010. 4

Major Parts

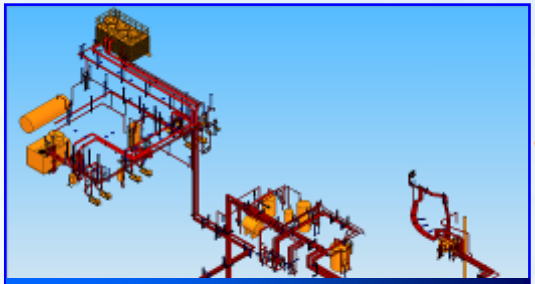
- Cold Neutron Source and System Utilities (CNS)
- Neutron Guides (NG)
- Neutron Spectrometers (NS)
- Users program and international collaboration
- Cold Neutron Laboratory (CNL) finished in May 2008

Development of CNRF for the Operating HANARO

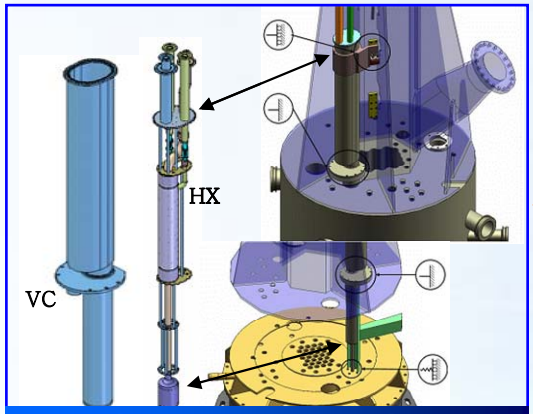
Basic Design

Full Scale Thermo-siphon Mock-up Test Using H_2

Detail Design



Safe & Reliable Process System Design

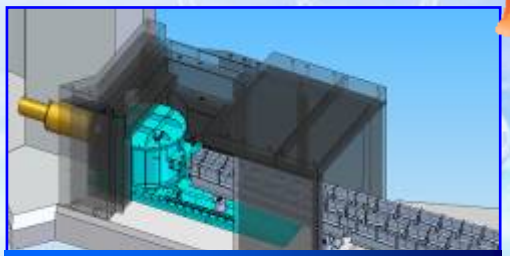


Optimum Source Design at existing Reactor Structure

Construction & Commissioning

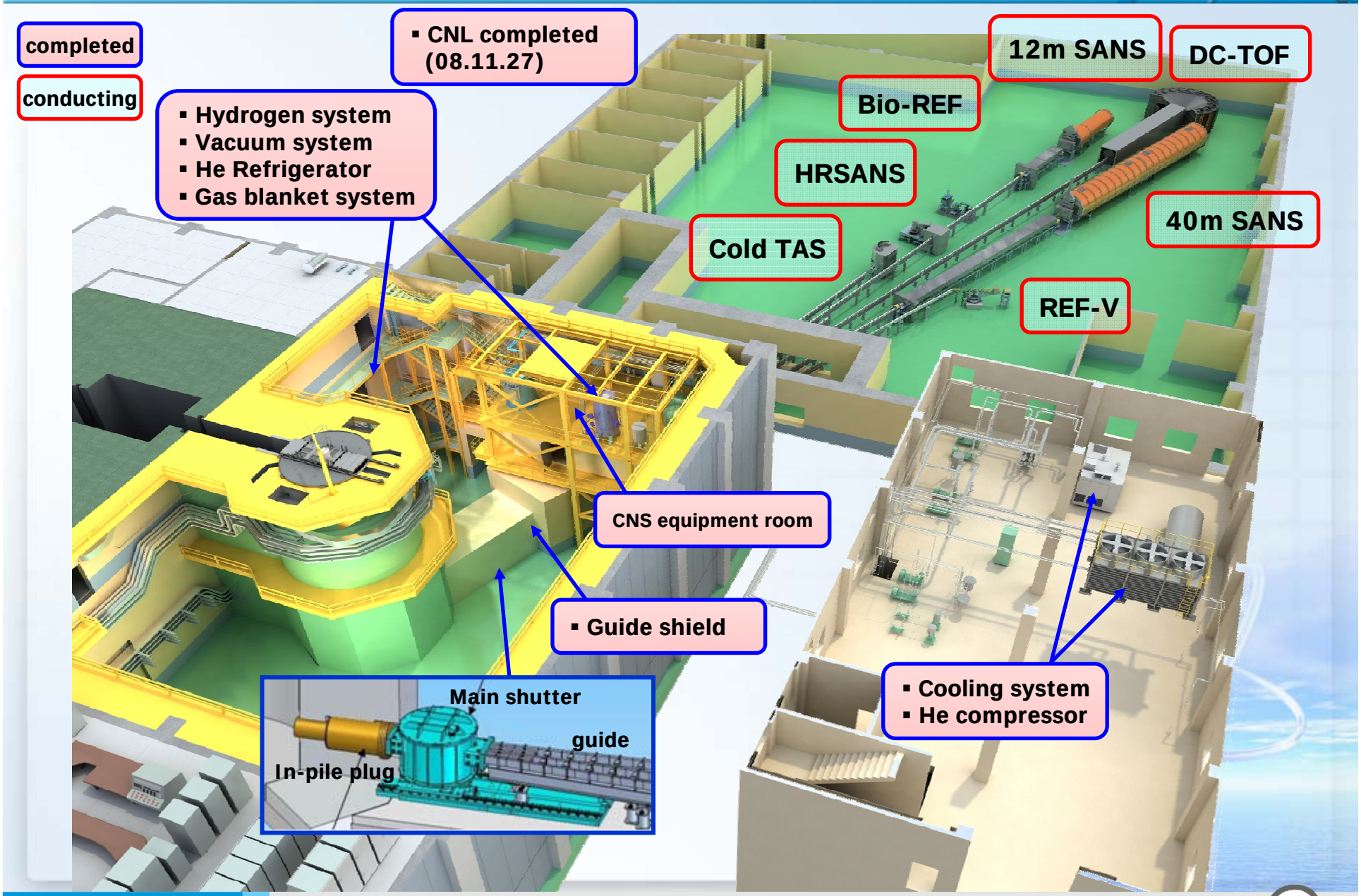
System Commissioning on Schedule & the 1st Cold Neutron in Sep. 2009

Beam Instrument Layout

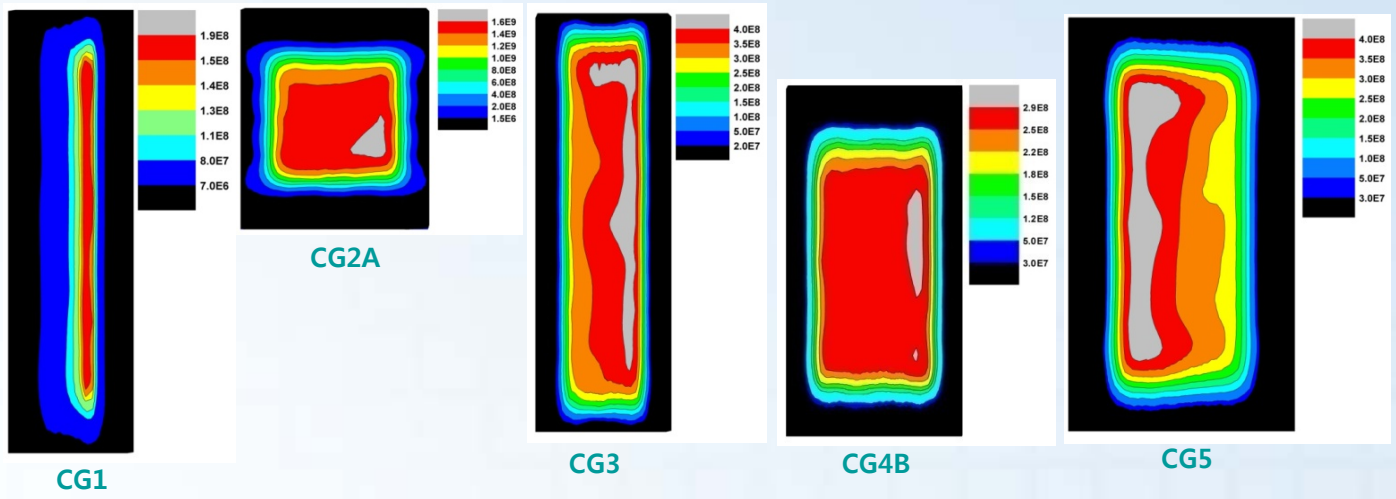


Successful Installation of Neutron Guide System at High Radiation Environment

Progress of Cold Neutron Facility

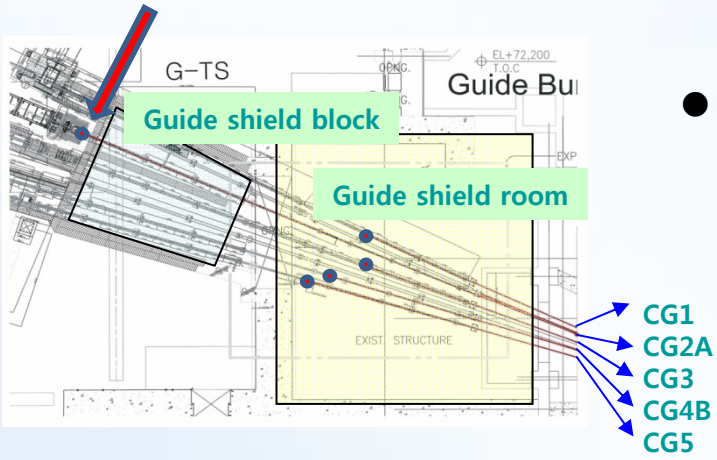


First Measurement of Cold Neutron in HANARO



Neutron Distribution in the Guide Section at the Secondary shutter

Measurement point: CG2A 40M-SANS NVS location



- **Neutron flux measurement results**
  - ✓ **Flux level: Higher than the expectation**
  - ✓ **Flux distribution : Very close to the expectation**

Future Plan

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Reactor Operation

- 220-day operation per year with reliability greater than 95%

Utilization

- Settlement of neutron beam user support program
- Expansion of Irradiation test using capsules and FTL

Reactor upgrade and safety management

- Replacement of reactor control computer
- Enlargement of spent fuel storage capacity
- PSR which is under a discussion

Knowledge management

- Baby-boomers (born between 1955-1963) will start to retire soon.
- Adoption of electronic procedures, research on expert system


Thank You!
KAERI
Korea Atomic Energy
Research Institute