Current Status of HANARO and Future Plan

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Abstract

HANARO, a Korean multi-purpose research reactor, has been operating since Feb. 1995, and it reached 2000 days of operation in April 28 of 2008. It has been utilized for neutron science, material and fuel irradiation tests, radioisotope production, neutron transmutation doping(NTD), neutron activation analysis, and neutron radiography. After its initial criticality, various activities were conducted for the improvement of its system, its ageing management, and the installation of experimental facilities. The system upgrade activities included the improvements of reactor systems to resolve the issues found during power operation. Recent achievements are the installation of a fuel test loop(FTL) and the installation of a cold neutron research facility(CNRF). The fuel test loop in HANARO simulates the thermal-hydraulic condition of the power reactor, and the commissioning test including the test fuel irradiation, was successfully completed in Sept. 2009. On Sept. 3rd, the first cold neutron measurement was conducted at 30 MW, and the results satisfied the neutron scientists. These new facilities will help HANARO become a major neutron source existing in the Asian region.

1. Introduction

HANARO is a 30 MW open-pool type multi-purpose research reactor which is operated by the Korea Atomic Energy Research Institute. Its initial criticality was achieved in Feb. 1995 and has been utilized for various purposes. Fig. 1 shows the HANARO complex, which is composed of the HANARO building, the RIPF(Radio-Isotope Production Facility), the IMEF(Irradiated Material Examination Facility), and the CNL(Cold Neutron Laboratory). The construction of the former three facilities was completed in 1994, and the CNL was constructed in 2008. Fig.2 is a view of the inside of the HANARO reactor building, Fig. 3 is a view of the reactor core, and Fig. 4 is a plan view of the core showing the use of vertical and horizontal tubes together. HANARO has been utilized for neutron science, reactor material and fuel irradiation, radioisotope production, neutron transmutation doping, neutron activation analysis, and neutron radiography. To accommodate various applications, the installation of new utilization facilities has continued since its initial criticality. In addition, the upgrade of reactor systems and ageing management has been conducted to keep the reactor in good condition. Recently, the commissioning of the FTL and the CNS was successfully completed. This paper will give a brief description on the reactor system management, status of utilization, and the commissioning results for the FTL and CNS.

2. Major Facility Upgrades and Ageing Management

Fig. 5 shows the operation records of HANARO. When power operation started in 1996, the utilization facilities were very limited; RI production and some irradiation tests were the major applications. Following the increase of utilization, the operation-day increased by 2003. In Nov. 2004, the resolution of some conditional license issues made the reactor operate at 30 MW, which is the design power. Since 2005, large-scale upgrades of the reactor system and the installation projects for the FTL and CNS have limited the operation-day. Various activities have been conducted for the system upgrade and ageing management based on a program initially set in 2000, and to resolve the issues found during operation. The major activities for system upgrade were as follows:

- 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)
    i. Installation of a Window-based System in 2002
    ii. Upgrade in 2007 to integrate the FTL system
    iii. 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 limit the reactor trip due to a momentary interruption of electric power

The major ageing management activities were as follows:

- Measurement of reactor vessel inner-shell straightness and 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

3. Status of Utilization

Vertical holes are provided in the core region and in the reflector region. The vertical holes in the core region are used for irradiation tests and RI production. An FTL is installed in the IR1 hole. Fuel performance tests for the U-Mo research reactor fuel, high burn-up PWR fuel, and DUPIC(Direct Use of spent PWR fuel in CANDU reactor) fuel have been conducted. For the material tests, an instrumented material capsule, a fuel test capsule, a fatigue capsule, and a creep capsule have been developed[1]. The irradiation results of the pressure vessel material of Kori-1 power plant, which is the first Korean NPP built in 1978, are very important for the life extension of the Kori-1 NPP.

For isotope production, the irradiation holes in the core and reflector regions are used. The major isotopes from HANARO are I-131 and Ir-192. For I-131, about 60% of national consumptions are supplied from HANARO. For Ir-192, about 80% of national consumptions are supplied from HANARO.

Two vertical holes in the reflector regions, NTD1 and NTD2, were provided for the NTD service. The service started in 2003 and the doping for 5, 6, and 8” ingots are available.

At the time of initial criticality of the reactor in 1995, no neutron scattering instruments were available. However, 9 neutron instruments has been developed since initial criticality, and they are: HRPD, 8M-SANS, RSI, NRF, REF-V, FCD, REF-H, HIPD, and ENF. 8M-SANS was moved to the CN hall, and 8 instruments are available in the reactor hall, as shown in Fig. 6. Researchers from about 60 Korean institutes or universities are using the instruments, and Japanese researchers frequently visit HANARO to use NRF or ENF. The major in-house research areas are the characterization of fuel cell, research on hydrogen storage material and research on the Li battery. Fig. 7 shows the CNRF(Cold Neutron Research Facility) with the arrangement of cold neutron instruments in the CN hall. REF-V and Bio-REF(REF-H) will be moved from the reactor hall. 12M-SANS is an expansion of 8m-SANS which was in the reactor hall. The installation will be finished by next May except for Cold-TAS, DC-TOF, and HRSANS.

4. Commissioning Tests for the Fuel Test Loop and Cold Neutron Source

The fuel test loop in HANARO can simulate the thermal hydraulic condition of PWR or CANDU and accommodates 3 fuel pins. Fig. 8 shows the schematic diagram of the loop, and Fig. 9 is a detailed view of the in-pile test section. The coolant temperature, fuel pellet temperature, and neutron flux levels are monitored during the irradiation. The commissioning test with real fuel was completed in Sept. 2009, and the approval of routine utilization from the regulator is expected.

The CNS system in HANARO uses two-phase H_2, and a cold source cell made of Al6061 was inserted in the CN hole in the reflector vessel. Fig. 10 shows the skeleton of the development activities and commissioning tests. On Sept. 3, the cold neutron flux and spectrum was measured, and the results showed that the performance of CNS in HANARO is very promising

5. Future Plans

If the installation of cold neutron scattering instruments is finished, all the utilization facilities that KAERI had in mind in the initialization period of HANARO will be completed. Also, the completion of heavy installation activities will make the reactor meet the design target operation-day per year, which is about 220 days. This will enable us to provide more beam time and more irradiation services. Thus, efforts will be given to settle down the neutron beam user support program and to provide better irradiation service. As for the ageing management of the reactor, emphasis will be given to the replacement of the reactor control computer and to enlarge the storage capacity of spent fuel storage within the reactor[2].

References

[1] C.S. Lee, G.H. Ahn and I.C. Lim, “Utilization of Irradiation Holes in HANARO”, presented at Int. Conf. on RR, 5-9 Nov. 2007, Sydney, Australia.

[2] M. Lee and et al., “Current Status of the Spent Fuel Management in HANARO”, to be presented at IGORR 2009.

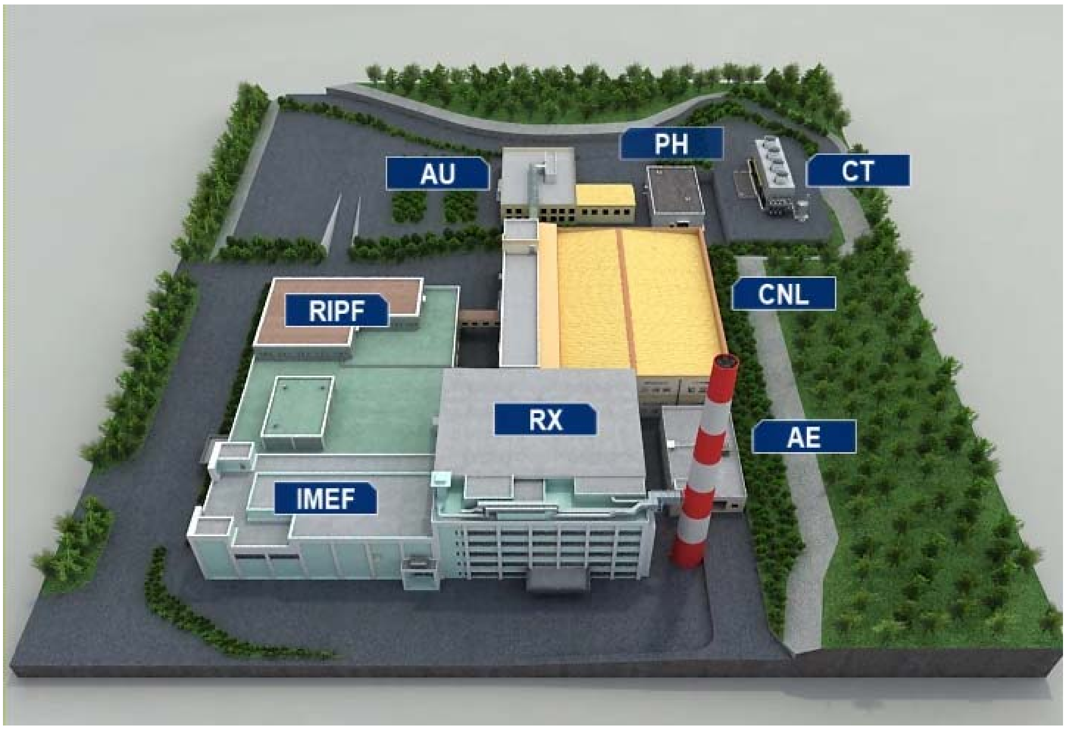

Fig. 1 View of the HANARO Complex in KAERI

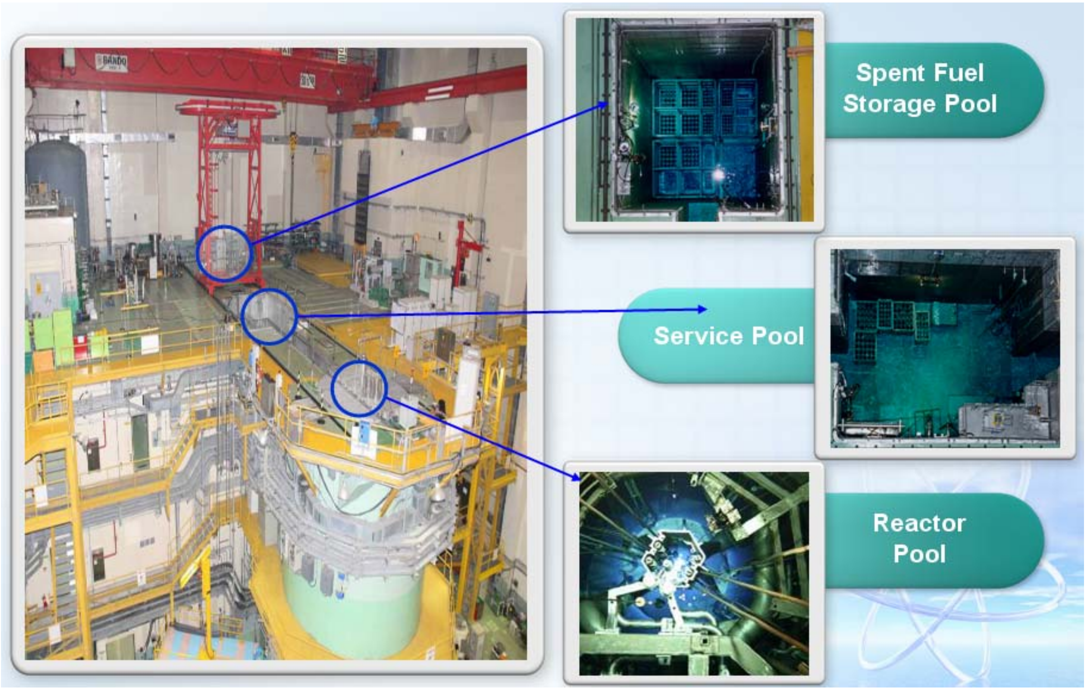

Fig. 2 Arrangement of Pools inside the Reactor Building

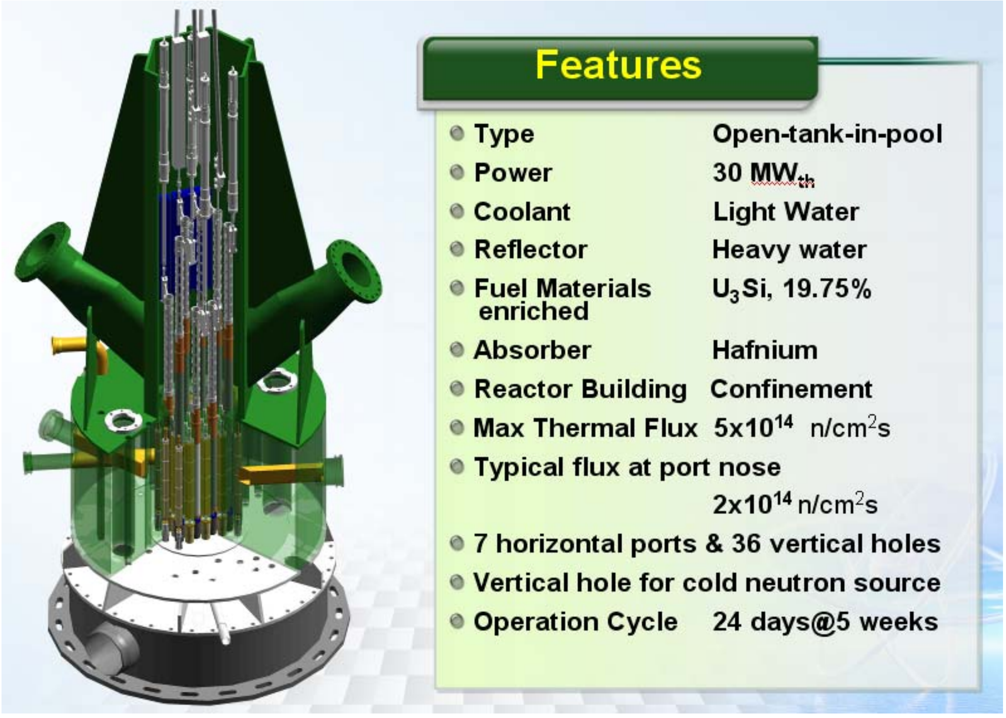

Fig. 3 Reactor Structure and Design Features of HANARO

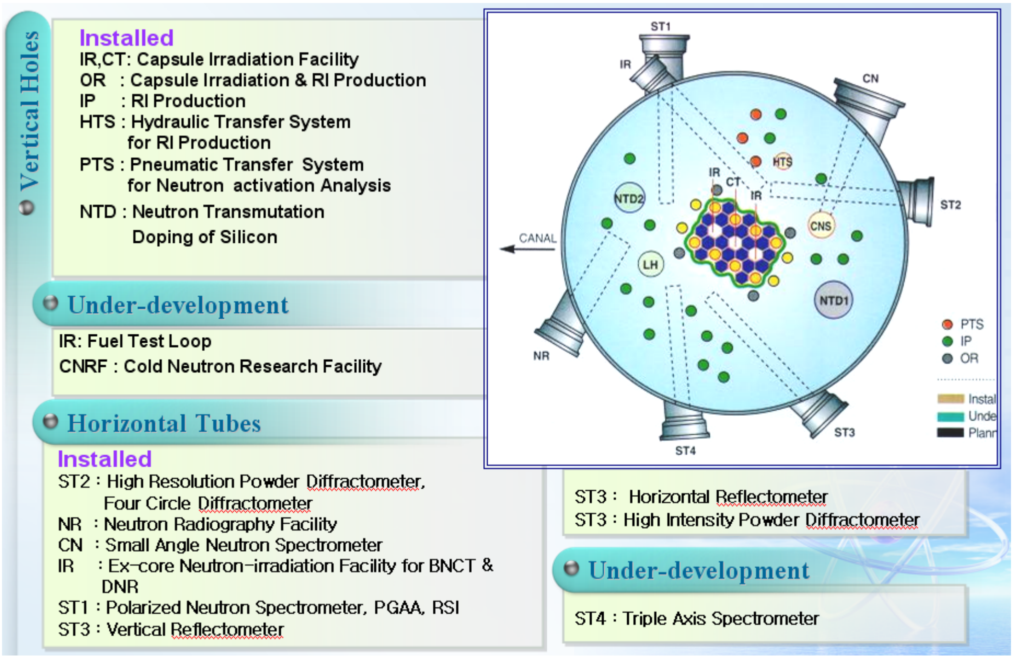

Fig. 4 Plan View of the Reactor Core with Vertical Holes and Horizontal Tubes

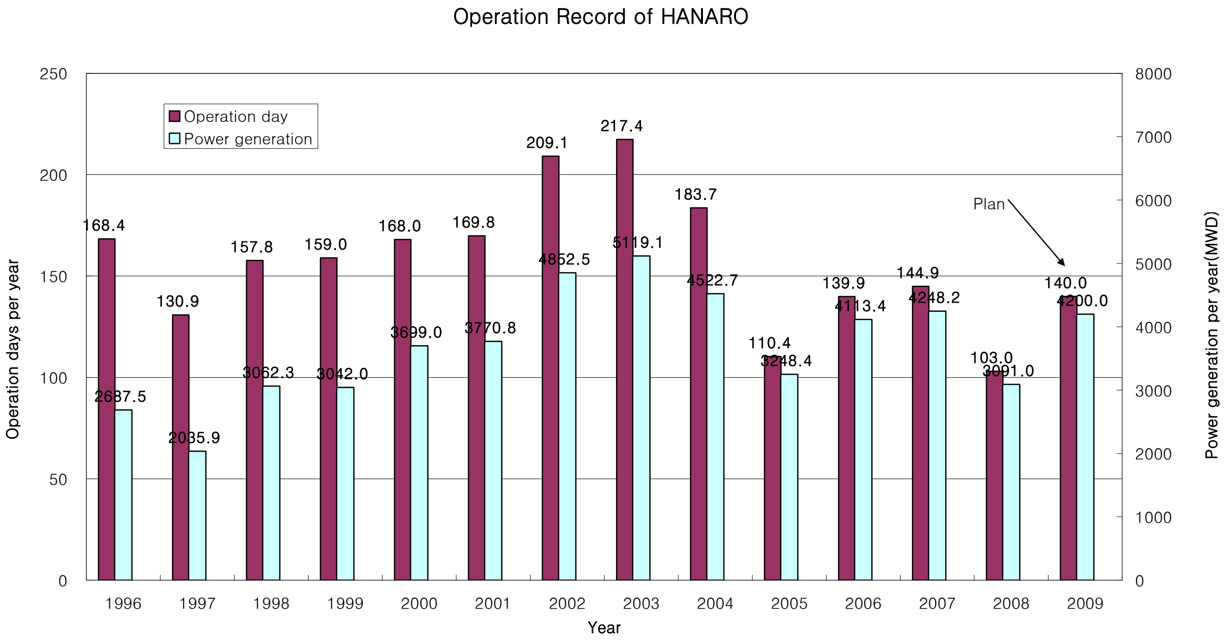

Fig. 5 Reactor Operation Record

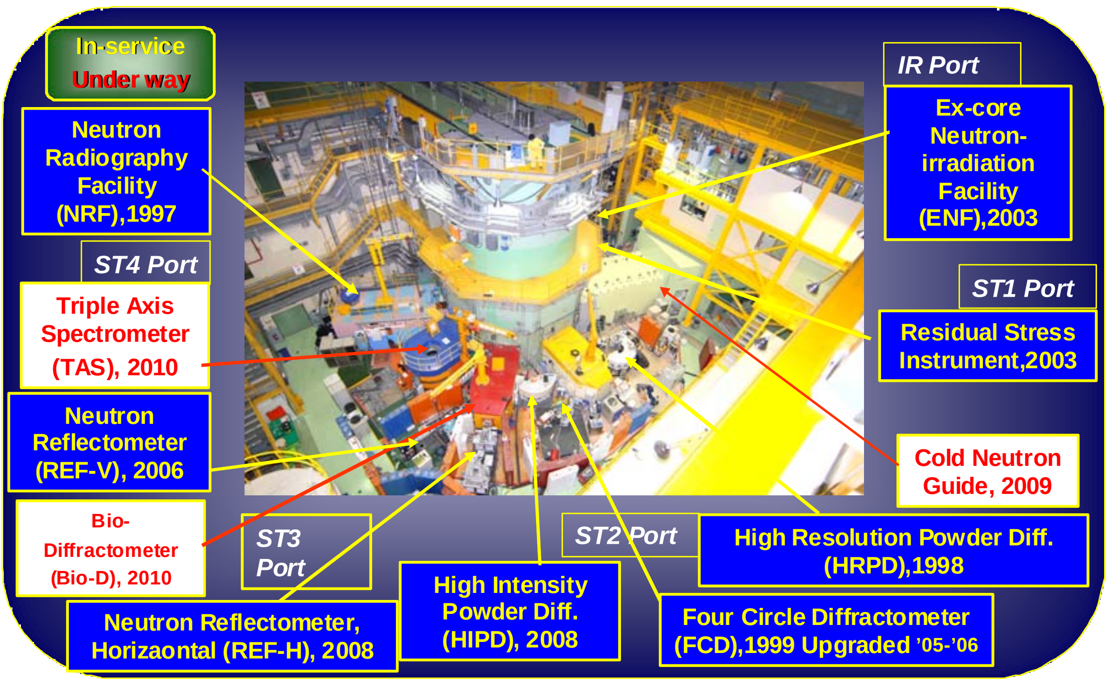

Fig. 6 Thermal Neutron Instruments in HANARO

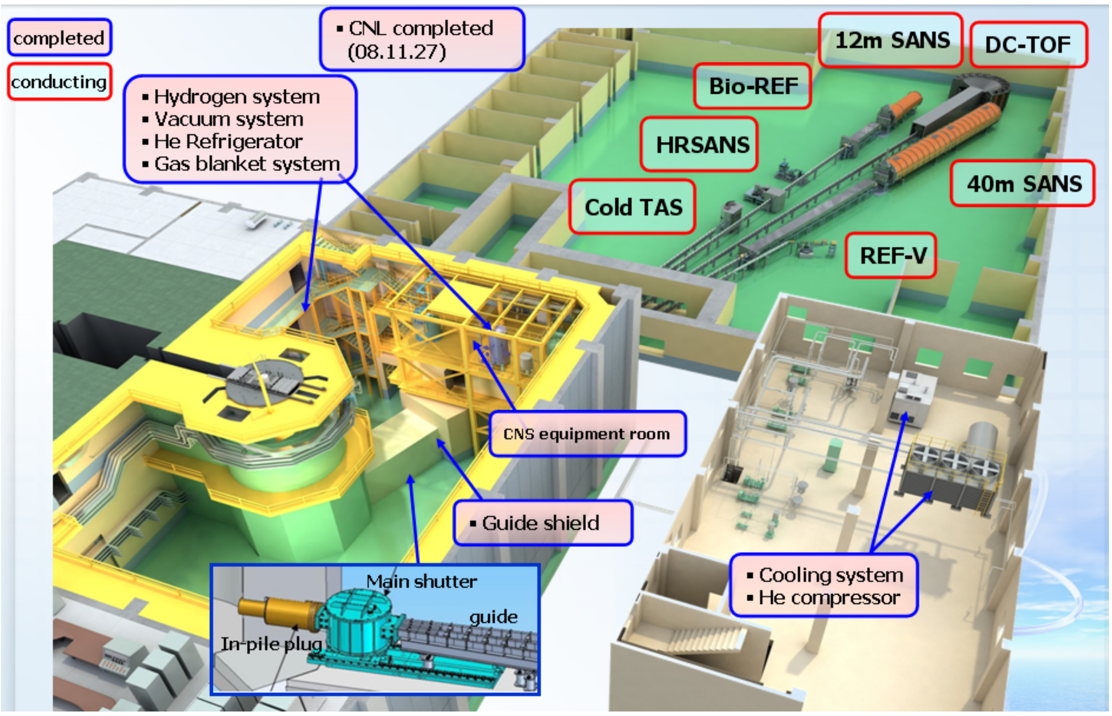

Fig. 7 View of the HANARO CNRF

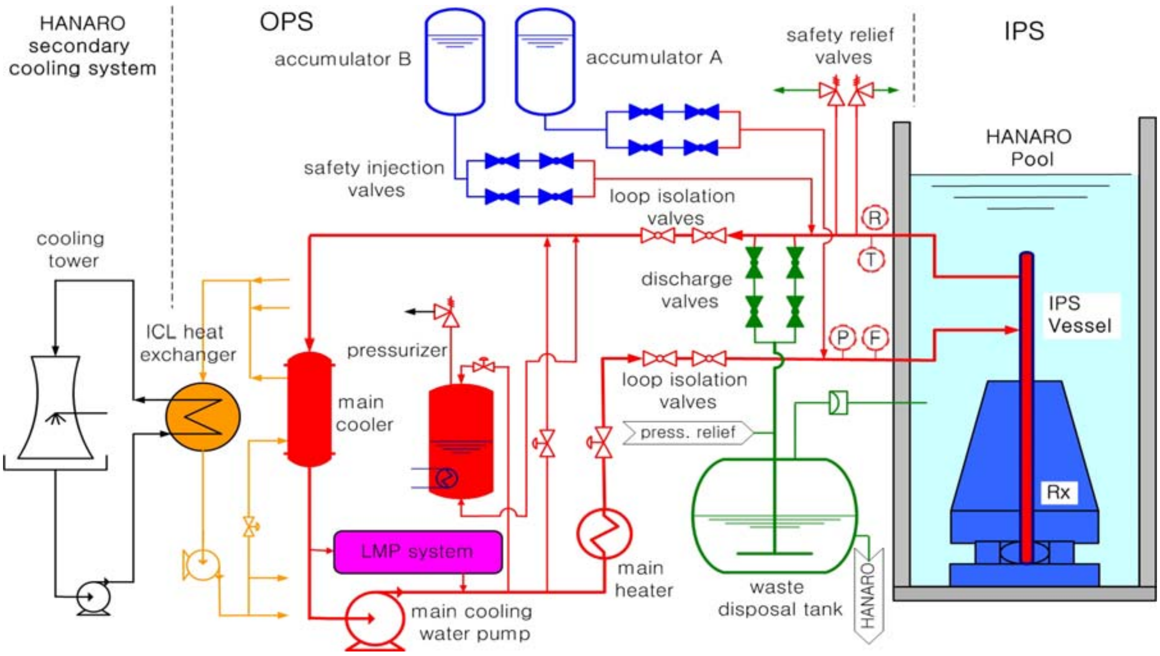

Fig. 8 Schematic Diagram of the Fuel Test Loop in HANARO

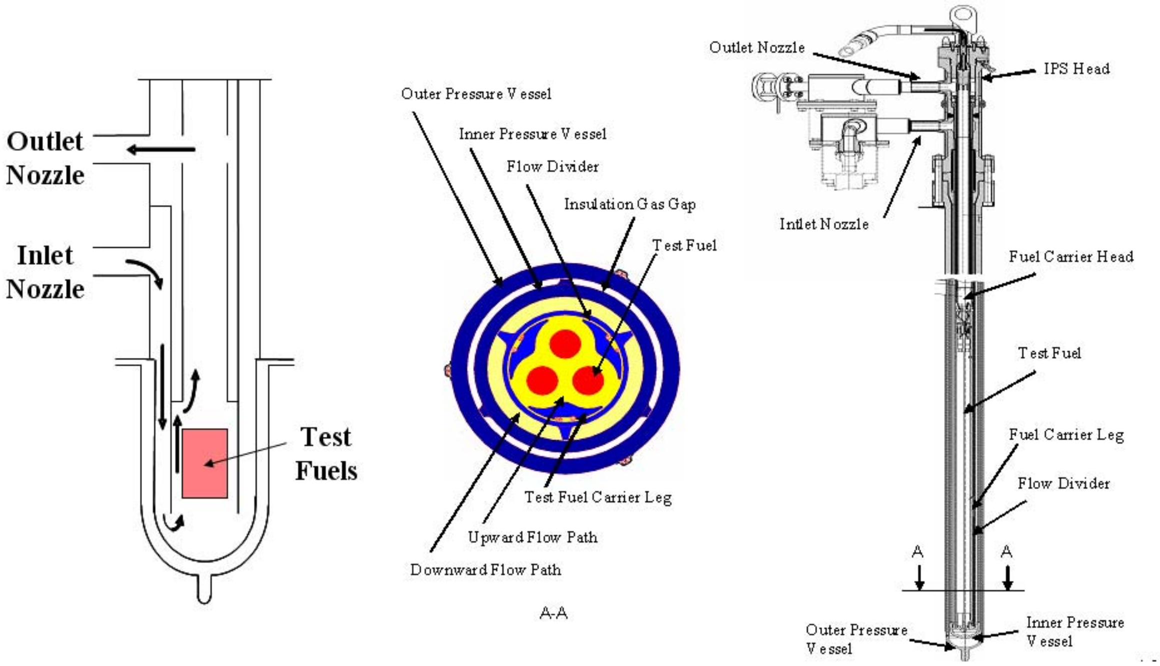

Fig. 9 In-Pile Section of the Fuel Test Loop in HANARO

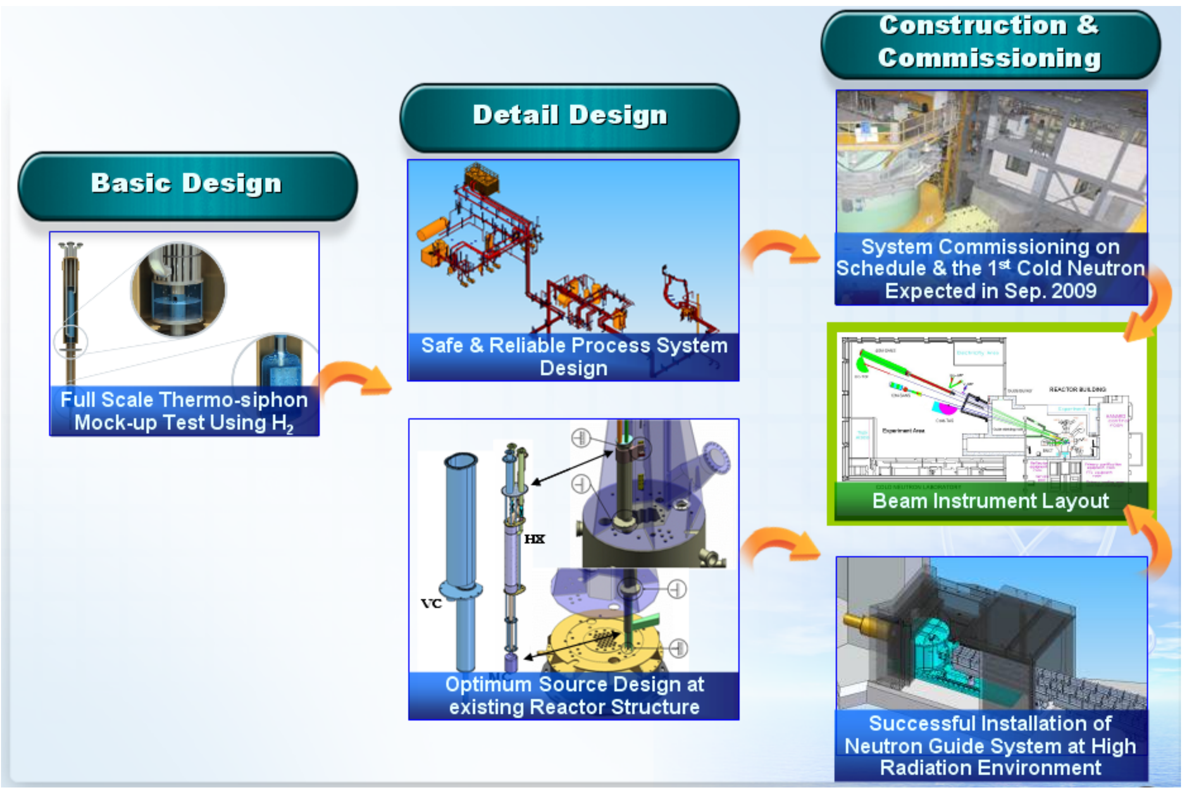

Fig. 10 Skeleton of the HANARO CNS System Development