CURRENT STATUS AND PROSPECT OF RESEARCH REACTOR UTILIZATION IN KOREA

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ABSTRACT

In Korea, two research reactors are in operation. HANARO, which is a 30 MW research reactor operated by KAERI is being used for neutron beam research, nuclear material research, RI production, NAA and NTD. Since the installation of a cold source in 2009, its role as a tool for basic science is increasing and it becomes a regional neutron source. AGN-201K, which is a 10 W educational reactor, is being operated by Kyung Hee University. With the benefits of zero power, it plays unique roles in training and education after refurbishment in 2007. In April 2012, the project to build a new research reactor, which is called KJRR, started and its design is being conducted. The major utilization of this reactor will be RI production and NTD. HANARO has a plan to expand its beam research capability by installing thermal beam guides, which is expected to be funded in 5 years. When these projects are completed, the role of three research reactors in Korea will expand for research, irradiation service, RI production and training and education.

1. Introduction

The foundation of KAERI in 1959 was a touchstone of nuclear R&D in Korea and the first mission of KAERI was to build a research reactor (KRR-1), which was a 100 kW TRIGA Mk-II reactor from USA and started operation in 1962. In 1968, the construction of KRR-2, which was a 2 MW TRIGA Mk-III reactor, started and it started operation in 1972. These two reactors were utilized for education, training, neutron beam utilization technology development, radio-isotope production technology development, and neutron activation analysis. Thus, these reactors had been doing important role as a large part of infra for the nuclear technology development in Korea until they were permanently shut-downed in 1995. The research reactor technologies and personnel grown-up at these facilities became the bases of other research reactors in Korea.

Now in Korea, two research reactors are in operation; HANARO and AGN-201K. HANARO is a 30 MW Multi-purpose research reactor operated by KAERI and it is one of the major national research facilities in Korea. Since its initial critical in Feb. 1995, the installation of new experimental facilities has continued to accommodate various applications and the installation of a cold neutron source and scattering instruments provide HANARO with a chance to become a regional neutron source[1,2]. A zero power reactor, AGN-201K has been operated in Kyung Hee University since 1982 for student education. It was a facility operated by Colorado State University from to 1967 to 1974 and was donated to Kyung Hee University in 1976. An extensive refurbishment was done during the period of 2004 through 2007. The Components for I&C and safety features were repaired and added in order to comply with standing safety regulations and rules[3].

Meanwhile, the worldwide Mo-99 shortage problem made Korea consider build a new research reactor whose main purpose is radio-isotope production. A project to build KJRR(Ki-Jang Research Reactor) started in April 2012 and its basic design is being conducted and its construction will be finished in 2017.

This paper is describing the status and future plans of Korean research reactors in operation or in construction.

2. Status and Future Plan

2.1 HANARO

Table 1 and Fig. 1 give the major characteristics and the plan view of core and reflector of HANARO, respectively. As shown in Table 1 and Fig. 1, high neutron fluxes of HANARO in inner core and reflector region enable HANARO utilized for neutron science, radio-isotope production, material/fuel test, neutron transmutation doping and neutron radiography. Neutron activation analysis and student education in the area of research reactor education are the part of HANARO utilization as well.

Fig. 2 shows the thermal and cold neutron scattering instruments of HANARO. Major research areas are the study on the characteristics of polymer material using SANS, Li-battery characterization using HRPD, the residual stress analysis for thick steel using RSI instrument, and visualization of fuel cell using NR. Fig. 3 shows the trend of neutron beam utilization. The completion of cold-TAS instrument commissioning in 2013 opens inelastic scattering experiments in HANARO. The commissioning of Bio-C and Bio-D will be completed in this year and this will make HANARO used for bio-research as well. Thermal-TAS and Bio reflecto-meter need more time for commissioning. From 2013, Hyundai Car Co. has started to export a fuel cell SUV to Europe and HANARO was used for its fuel cell characterization.

The major radio-isotopes produced in HANARO are Ir-192 and I-131. As for Ir-192, HANARO is supplying about 15% of world consumption and 70% of domestic use of I-131 is fulfilled by HANARO. From 2012, a study on fission Mo production technology development is being conducted. The developed technology and production facilities under development will be used in KJRR. A radio-immuno therapy study is also being conducted for the use of Lu-177.

A recent achievement in the area of material irradiation was the irradiation of heat exchanger tube material for SMART reactor, which is an SMR developed by KAERI. In SMART, heat exchangers are integrated with core in a reactor vessel, which brings the irradiation of heat exchanger tube. HANARO enabled this experiment in Korea. Recently, a study on the effect of irradiation on industrial materials such as superconductor material has started.

HANARO has the capacity to irradiate 5”, 6” and 8” silicon for transmutation doping. Currently, 5” and 6” silicon irradiation is available and HANARO is supplying about 10 to 15% of world NTD market.

Fig 4. shows the arrangement of CONAS (COld Neutron Activation System), which will be opened to user in next year. It is composed of NDP(Neutron Depth Profile) and CNPGAA(Cold Neutron Prompt Gamma Activation Analysis). They are believed to expand the horizon of neutron activation analysis.

HANARO is not proper to be used for university students to conduct the experiments on reactor characteristics. That mission is conducted by AGN-201K and HANARO is used for the educations on utilization such as neutron radiography, RI production and neutron activation analysis.

HANARO has capability to conduct fuel/material irradiation tests and has been utilized for many practical applications as shown in Fig. 5. One of recent achievements is the irradiation test of heat exchanger tube used for SMART(System-Integrated Modular Advanced ReacTor). SMART is an SMR designed by KAERI and all the primary cooling equipments are integrated into a reactor vessel and heat exchanger tubes are under neutron irradiation environment. HANARO enabled the completion of irradiation test in time. Currently, the irradiation test of materials to be used for JRTR is undergone. Recently, a program to study the effect of irradiation on industrial material such as super conductor or materials for electronic devices has started.

Even though HANARO is a multi-purpose research reactor, its strength is in neutron science. Considering this, there is a plan to install in the CNS hall, thermal guides and scattering instruments including a diffraction instrument, an instrument for energy storing material examination, and an instrument to analyze nano-bio structure of materials. In 2012, this plan was selected as an important national science facility upgrade plan by the National Science Committee of Korea.

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

Tab 1: Major Characteristics of HANARO

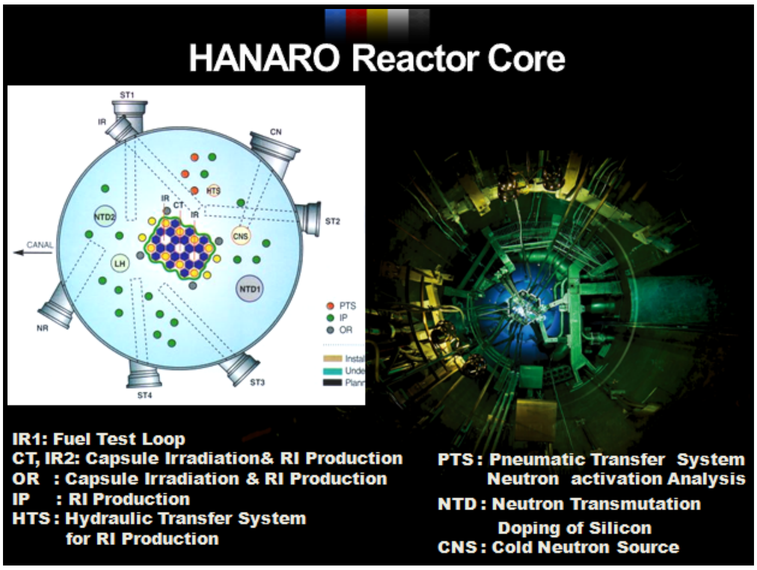

Fig 1. Plan View of HANARO Core

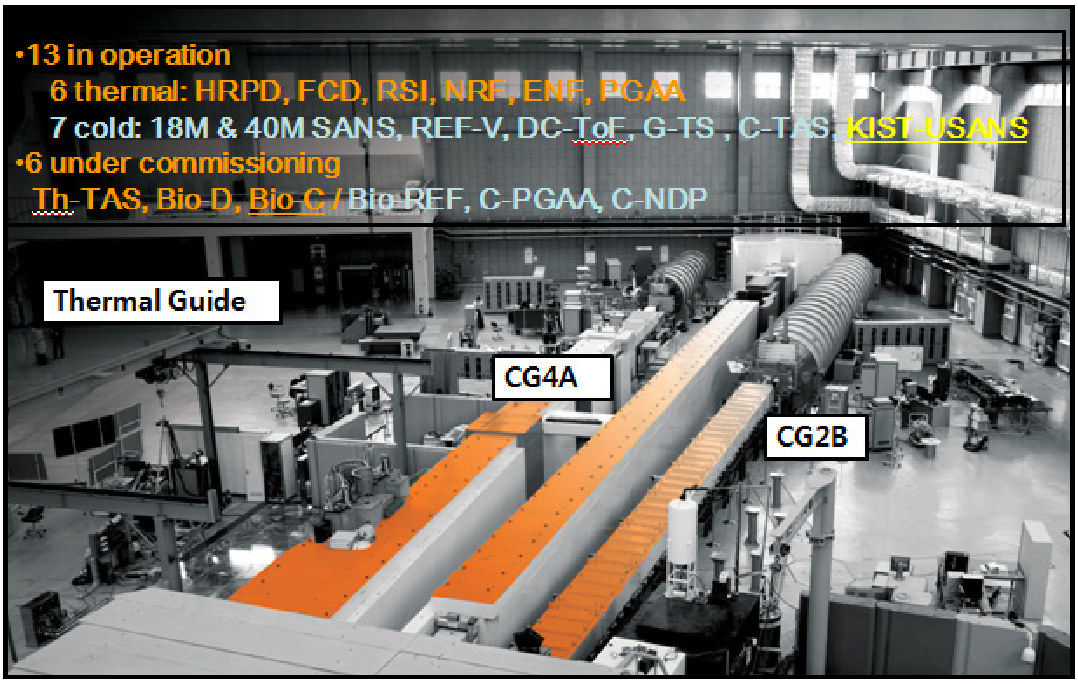

Fig 2. Thermal and Cold Neutron Beam Instruments in HANARO

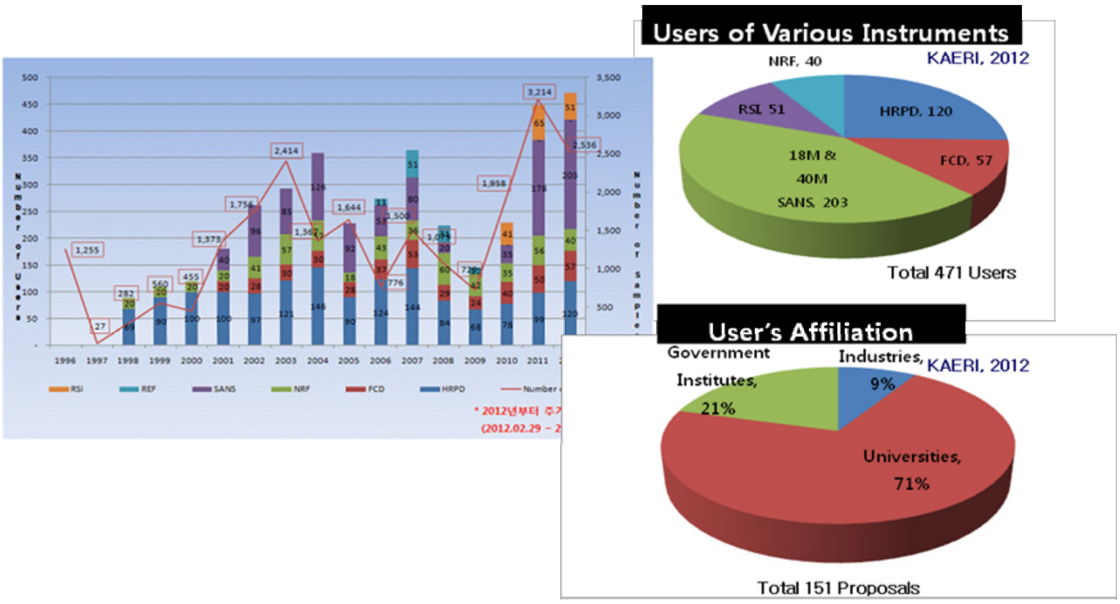

Fig 3. Annual Trend of Neutron Beam Users for HANARO

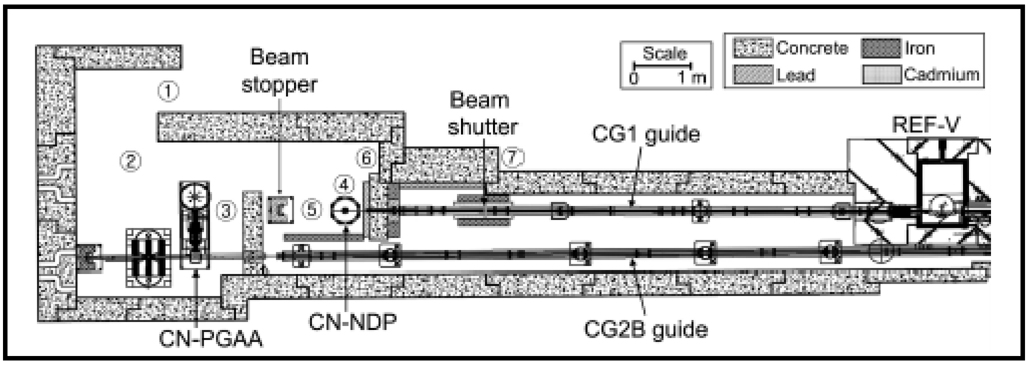

Fig 4. Arrangement of CONAS(NDP & CNPGAA) in HANARO

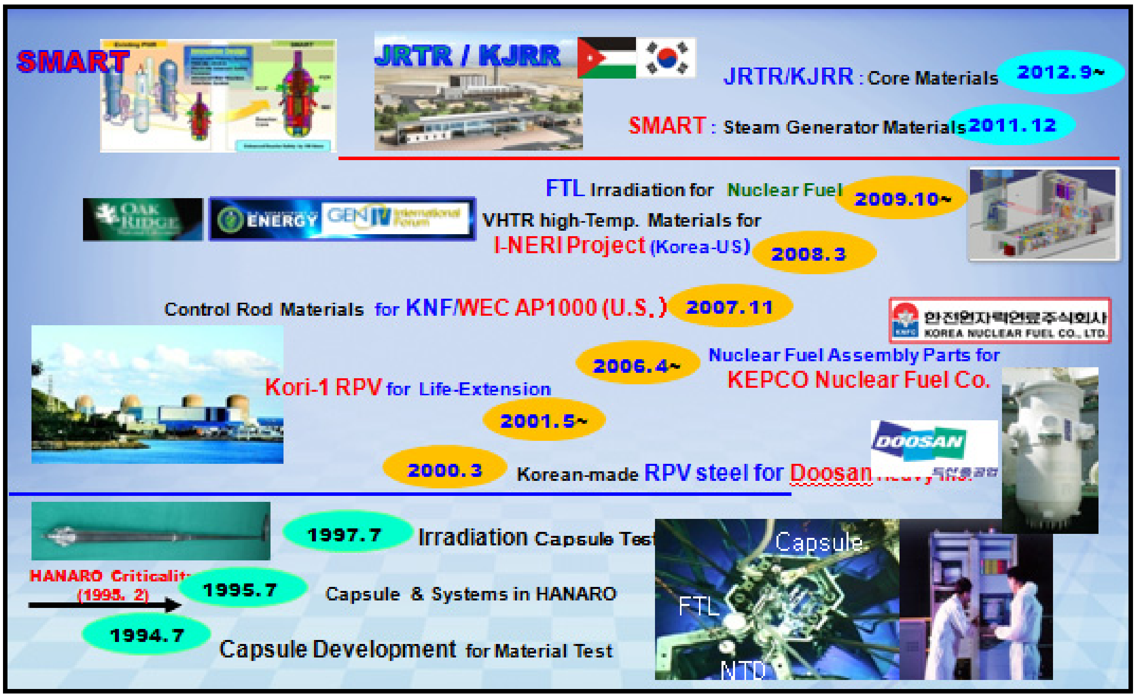

Fig 5. Application of Material/Fuel Irradiation in HANARO

2.2 KJRR

The KIJANG Research Reactor (KJRR) project was officially launched on the first of April 2012 with the three main goals. KJRR aims to self-sufficiently supply radioactive isotopes (RI) including Mo-99, to increase the capacity of the neutron transmutation doping (NTD) and to develop research reactor-related technologies. Kijang is in a suburb of Busan, the second largest city in Korea. The site is planned to be located in a radiation industrial complex. The Korea Atomic Energy Institute (KAERI) have progressed the project in cooperation with Kijang municipality. KAERI undertakes system design, licensing preparation and commissioning and Kijang municipality is to provide infra-structure such as water and electricity supply. The proposed design characteristics of KJRR and its bird eye view are given in Table 2 and Fig. 6, respectively. On 10th of April, 2013, Daewoo Engineering & Construction Co., Ltd. joined the project to carry out architect engineering (AE) works. KJRR is scheduled to be in operation for commercial production in March, 2017. We have dealt with many issues including siting, subcontract for AE, general arrangement and so on. After conceptual design was completed, we are now working on installation of a meteorological monitoring tower, probabilistic seismic hazard analysis (PSHA), contracts for components and facilities and etc. Among these, the agreement with the Idaho National Laboratory (INL) on a cooperative research for the performance test of U-Mo plate type fuel is one of our major achievements. After basic design is completed and construction permit is issued, we will move on the next stage that includes detail design, manufacturing major components and facilities, construction of reactor building and auxiliary buildings, grounding work and so on. In the last couple of years, we will start commissioning and then obtaining operating license, fuel loading, commissioning and pre-service inspection will follows.

Power	~15 MWth
Type	Open Tank in Pool type
Max. thermal neutron flux (n/cm^{2}s)	> 3.0x10^{14} n/cm^{2}s
Operation day	~300/year
Life time	50 year
Fuel	LEU U-Mo plate type (U loading : 4.8~8.0 g/cc)
Reflector	Beryllium
Coolant and flow direction in operation	H_2O, downward forced convection
Reactor building	Confinement
Decay heat cooling system	Passive system
Robust Design, Aircraft Crash, 0.3g SSE, Digital I&C, Cyber Security, PSA of Internal & External Events (Earthquake, Fire, Flooding)	

Tab 2. Proposed Design Characteristics of KJRR

Fig 6. Bird Eye View of KJRR Site

2.3 AGN-201K

After the upgrade of facility, Reactor Research & Education Center(RREC) was established in 2008 at Kyung Hee University as a national-wide student training center using AGN-201K shown in Fig. 7[4]. The first role of RREC is to provide AGN-201K for the education of domestic student in nuclear engineering departments, whose number is 12 compared to 7 in 2007. The National Research Foundation (NRF) program for human resource development in university supports several university proposals every year and makes expensive university facilities to be shared by all students in Korea. Most of university nuclear engineering programs now get this financial support to send students for a short experimental one-week training courses using AGN-201K.

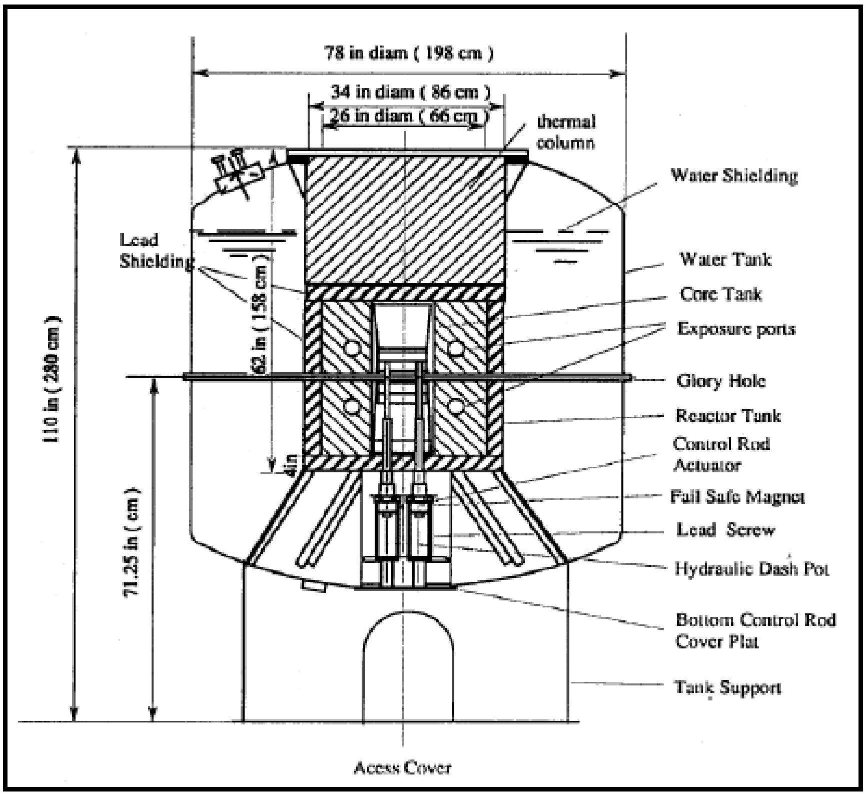

Fig 7. Structure of AGN-201K Core

The second role is the utilization for university academic research. The use of AGN-201K for research is limited for many reasons. The maximum flux at the center of core at the licensed maximum power is less than $4.5X10^8$ n/cm^2-sec. There is no coolant channel because of low heat deposition. Core is made of 9 homogeneous disks of polyethylene moderator mixed with uranium powder. There are only 2 control rods to be moved freely except 2 shutdown rods. However, this limited condition is good for experiments for special cases. This reactor eliminates thermal feedback effects and has an ideal geometry to be analyzed with computation. Therefore, three activities have been tried for computational research purposes. Although neutron radiography facility(NRF) is generally installed only at high-flux research reactors, the feasibility to use thermal column in AGN-201K for neutron radiography was evaluated by using MCNP code. With enough confirmation on feasibility, a neutron-sensitive image plate and a collimator was installed last year. Right now, experimental shot has been tried for the better image. The following Fig. 8 shows examples of neutron radiographic images[4,5].

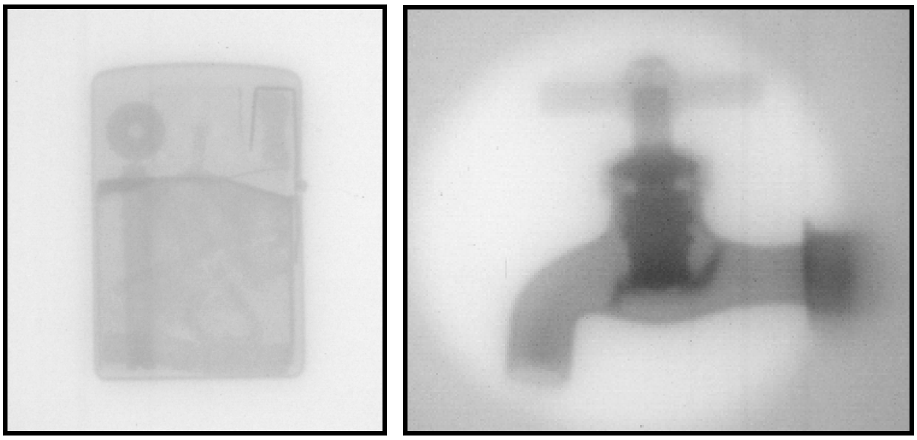

Fig 8. Images from Neutron Radiography in AGN-201K

Neutron detector for ex-core detector system and self-powered neutron detector(SPND) for in-core detector system are now manufactured in Korea. Thus, there is a demand for detector test and calibration with nuclear reactors. AGN-201K has a high feasibility in this application and there have been a few test studies on requests from domestic companies and showed good stability. Measurement of sub-criticality is a demanding issue in ADS research and spent fuel storage facilities and the Modified Neutron Source Multiplication method (MNSM) was proposed many years ago for this purpose. This subject was done for student research including experimental measurement, theoretical research and numerical simulation on AGN-201K[4].

The third role has been tried from this year. Facility was opened for high school students and teachers for their summer science camp. An "Experience Class for Understanding the Nuclear Power and Radiation" was held 4 times at last summer as an interactive public acceptance program. Even though number of attendee may be limited and small compared to all students and teachers, the feedback from participants was hot and positive enough to make professors be ready to sacrifice their personal time.

3. Concluding Remarks

The two operating research reactors in Korea are sharing roles; HANARO is serving for national research and irradiation service and, AGN-201K is for training and education. However, HANARO is also used for the education of students for utilization technique and AGN-201K is expanding its capability as a research tool.

The introduction of KJRR in 2017 will make a change in role definition. After that time, the services activities for RI production and NTD service will be mainly conducted by KJRR and the R&D on neutron beam utilization and fuel/material irradiation will be the main responsibility of HANARO. The installation of thermal guides and relevant scattering instruments is believed to start in 2019. Considering that the use of scattering instruments by industries is increasing, the beam instruments dedicated for private companies could be pursued at that time. IAEA is considering the introduction of ICERR(Int. Center based on Research Reactor) to facilitate the access of new comer countries to research reactor facilities and to improve the utilization of existing research reactors which have potential to become a regional or international center for research reactor utilization. In eastern Asia, HANARO is providing stable cold neutrons to the scientists of neighboring countries and KAERI has a lot of experience in development, operation and utilization of research reactors. Thus, it will be a chance for HANARO to share research reactor technologies with foreign institutes in deeper manner if HANARO becomes to to serve as an ICERR in future.

4. References

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