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3.3 CURRENT STATUS OF NEUTRON SCATTERING RESEARCH AND ACCELERATOR TECHNOLOGY IN INDONESIA

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ABSTRACT

The neutron beam generated from steady state reactor 30 MW RSG-GAS are used mainly for neutron scattering studies and isotope production. There are seven neutron scattering facilities under responsible and operated by Research and Development Center for Materials Science and Technology of National Nuclear Energy Agency (Batan) of Indonesia. In this report, current conditions of the facilities namely, DN1-M, HRPD, FCD/TD, SANS, HRSANS, TAS and NRF and research activities will be described. Also, a part of research activities by using accelerator technology at Batan-Yogyakarta will be reviewed.

REACTOR

The G. A. Siwabessy multipurpose reactor (RSG-GAS reactor) is the only one available neutron source used for neutron scattering activities in Indonesia. The reactor is a pool type reactor operated on 30 MW with average thermal neutron flux about 2 x 10^{14} n/cm^2/sec. This reactor is fueled with the MTR type fuel elements in the form of U_3O_8-Al, where it has operated formally since August 20, 1987. Before the economic crisis, the reactor had been operated with the power between 22-25 MW for 5000 hr/year. However, in the last two years the operation of RSG-GAS is reduced for only 3 cycles per year with the power around 15-20 MW, and the interval of operation and shutdown are 12 days and 9 days, respectively. The rescheduling of the reactor operation has been decided in order to economize the use of fuel as well as control elements. Decreasing of reactor power automatically reduce the neutron flux and to have an effect on the neutron scattering work, where the total beam time used in the measurement become almost twice more longer than before. On the other hand, twelve days operation of the reactor give an advantages to the neutron scattering group in planning the experiments in advance and improve the reliability of the neutron instruments.

The reactor has an L-shaped beryllium block reflector surround one half of the core. Six beam tubes-two tangential and four radials are available for experiments. One of the beam tube has a larger diameter (ϕ = 27 cm) than the others (ϕ = 24 cm) to accommodate two then neutron guides to supply neutron beam for spectrometers in the neutron guide hall. The neutron guide made from Boron glass coated with Ni^{58} in order to increase the critical angle.

The reactor has been completed by facilities as below :

- Five in core irradiation facilities for materials/ fuel testing and radioisotopes production
- Seven irradiation holes in reflector area
- Five rabid system
- One Power Ramp Test Facilities for PWR fuel testing
- One wet neutron radiography
- Six beam tubes for beam experiments , NDT and radioisotope.

The schematic lay out of the reactor can be seen in the figure 1.

THE ACCELERATOR

The current status of research and development by using accelerator technology in National Nuclear Energy Agency (Batan) can be divided in the two parts namely the R&D by using the existing accelerator, and future program with the new facility. In this occasion only the existing accelerator facility will be described.

Existing Accelerator

In the Research and Development Center for Advanced Technology of Batan at Yogyakarta there are two accelerator facilities have been installed i.e., accelerator for ion implantation and accelerator for neutron generator.

The accelerator for ion implantation. This facility can be used to accelerate many kind of ions weather from gas or solid targets with ion dosys about 10^{18} ion/ cm^2 and ion energy can be reach 150 KeV. The research activities carry out by using this facility are :

- **Surface Treatment**
  - Modification and enhancement of surface mechanic properties of the metallic materials including surface hardening, wear resistance and corrosion protection.
  - Modification and enhancement of optical properties of insulator materials
- **Synthesis of Semiconductor Materials**

- Research and development of electronic devices, diode and transistor materials based on silicon semiconductor.
- Research and development of cell photovoltaic.

The neutron generator is the one of ionic deuterons accelerator with low energy up to 150 KeV equipped with Tritium ^{3}H target. The deuteron ion beam resulted from the ion sources accelerated in the accelerator tube up to 150 KeV, then bombarded to the tritium target in order to get the fast neutron with energy 14 MeV through the nuclear reaction of $^{3}H(d,n)\ ^{4}He$. The neutrons flux resulted from this reaction are about 10^{7} n/ cm^{2} sec. These fast neutron have been used to analysis the elements of materials by FNAA(Fast Neutron Activation Analysis) method.

The research activities have been done as follow :

- Analysis on Environment Pollution
- Analysis of elements in mineral geology
- Analysis of elements on fertilizer and food nutrition

NEUTRON SCATTERING FACILITIES

The utilization of neutron beam research for neutron scattering technique has been started at National Nuclear Energy Agency since 1992. At present neutron scattering facilities consists of :

1. Powder Diffractometer which recently modified for Residual Stress Measurement (DN1-M).
2. High-Resolution Powder Diffractometer (HRPD).
3. Four-Circle Diffractometer (FCD/TD) for texture analysis and single crystal structure studies.
4. Small Angle Neutron Scattering (SANS) spectrometer.
5. High-Resolution Small Angle Neutron Scattering (HRSANS) spectrometer.
6. Triple Axis Spectrometer (TAS).
7. Neutron Radiography Facility (NRF) with real time experiment capability.

The layout of the instruments and thermal neutron guides are shown in figure 2. The powder diffractometer that recently modified for residual stress measurement, the triple axis spectrometer and the neutron radiography are installed at the beam ports S6 (tangential), S4 (radial) and S2 (tangential), respectively. The neutron guides are installed starting from S5 radial beam port, penetrating the reactor confinement building wall and going through a 35 m

tunnel into the external Neutron Guide Hall. The neutron guide No. 2 has three beam ports labeled as NG2-1, NG2-2 and Ng2-3 at which the four-circle diffractometer, the high-resolution small angle neutron scattering spectrometer and the high-resolution powder diffractometer are installed respectively. The neutron guide No.1 is dedicated to the small angle neutron scattering spectrometer, which is installed at the end of the guide.

Among the neutron facilities have been mentioned above, the high-resolution powder diffractometer is the most intensively been used. In the last five years there are eight scientific papers have been published in the International Scientific Journals. The topics are mainly covering the magnetic structural studies of permanent magnets (R-Fe_{17}-X series). These research activities are apart of an intensive joint research on neutron scattering under Asia-Pacific collaboration in the field of magnetic materials, involving researcher from Materials Science Research Center (now Research and Development Center for Materials Science and Technology) of Batan, State Key Laboratory for Magnetism-Chinese Academy of Science, Chinese Institute of Atomic Energy and also Japan Atomic Energy Research Institute.

THE PRESENT STATUS OF NEUTRON SCATTERING FACILITIES AT BATAN

The slowed down of the reactor power due to the economic crisis in our country has also been effected to the performance of neutron scattering facilities. As a consequence of reducing the reactor power up to 15 MW the neutron flux also decreased, it was checked that the time needed for measuring the powder of TiO_2 standard sample by using HRPD was increased almost 20% more longer than when reactor was operated on 25 MW. In this present time the conditions of the neutron scattering facilities as follow :

1. Powder Diffractometer which recently modified for Residual Stress Measurement (DN1-M). This powder diffractometer was the first instrument installed in the reactor hall, in collaboration with Japan Atomic Energy Research Institute (JAERI) the diffractometer was modified for residual stress measurement. On the beginning it was used one-dimensional He^3 detector (PSD) system, but recently was changed to the point type detector. At the present, all the components of the system can be work properly, however small setting is still needed in order to get more realistic measured data. In this case, resetting the monochromator position and readjustment the first collimator on the proper condition, following recalibration of all the system by using standard sample from VAMAS are planned to be carry out.

2. High-Resolution Powder Diffractometer (HRPD). This facility is equipped with detector bank of 32 collimator backed by 32 He^3 detectors moves on the air cushions. In general this facility can be used properly, however small reparation is still needed especially in order to increase the efficiency of detectors. As the HRPD was installed since 1992, the most problem faced by this facility is decrease of laminar tension of solar collimator which gadolinium coated thin film that caused reducing the neutrons beam comes to the detector. Some of these collimators were readjusted, however in the case of the 3rd collimator although it was changed by a new one the neutron beam recorded by detector around this position is still inefficient. Up to now many afford have been done in order to solve these problems.

3. Four-Circle Diffractometer (FCD/TD) for texture analysis and single crystal structure studies. This facility on the mean time is not operated. The main problem faced by this facility is related to the computer system especially in the hardware components. Because the PC used in this facility is old enough, some of the spare parts are not available in the marked. Therefore, it was planned to change the computer system with a new one, parallel to this other alternative to control the facility was also studied.

4. Small Angle Neutron Scattering (SANS) spectrometer. This instrument is installed at the end of the 48 m long guide No. 1, situated in the neutron guide hall, to benefit from low background environment. The incident beam is monochromatized by a slot type mechanical velocity selector having a rotational speed of 700 rpm and a maximum rotational speed of 7000 rpm. The selector's tilt angle can be varied from – 3.9 ^{o} to + 3.9^{o}. By varying the rotational speed and tilt angle of selector, neutron wavelengths of 2 – 5 Å and a Q range of $(0.001 < Q < 0.6)Å^{-1}$ can be obtained. The collimator is placed in a 19 m long tube, comprises of four sections of movable guide tube, and one section of a fixed collimator (non-reflecting tube). Collimation is made by adjustable apertures (pin holes) at discrete distance of 1.5 m, 4 m, 8 m, 13 m and 18 m from the sample. The detector that can be moved continuously from 1.5 m to 18 m in 19 m tube, is a 128 x 128 He^3 to dimensional position sensitive detector (PSD) made by RisØ, with beam stoppers of 40, 80, 140 mm in diameter. This facility at the present time can be used fro the research activity. Some special care has been put to the components of velocity selector to maintain this part run properly. It was proposed

to use this facility through the CRP-IAEA programs in the field polymer science research.

5. High-Resolution Small Angle Neutron Scattering (HRSANS) spectrometer. This facility couldn't have utilized intensively. This due to the problem in performing the calibration every time to start the machine. Even in the middle of running it, the calibration should be done if there is an electric failure. However, at present this problem became adapted with to place one of the staff fully responsible to this machine, and research activities using this facility can be run as well.

6. Triple Axis Spectrometer (TAS). This spectrometer was not in operation since there is some problem with the computer system. Many afford have been done in order to bring this facility run properly, however not so much progress have been reached to solved the problems.

7. Neutron Radiography Facility (NRF) with real time experiment capability. This machine at present is ready to use, even though the high qualified researcher interested working in this field is really needed.

CURRENT RESEARCH TOPICS

At the present the activities under going in the neutron scattering group are related to the development of the system that can be used to control the machines (diffractometers or spectrometers) which more adaptable to a new generation of computer and instruments system. Continuing activities in calibrating the high-resolution small angle neutron spectrometer using SiO_2 standard sample.

Carry out neutron scattering studies on the temperature treatment effects to the mechanical properties of structural materials and residual stress measurement. The other research activity is related to the study of physical properties and phase transition on super ionic conductor glass by neutron scattering technique.

COLLABORATION RESEARCH ON THE NEUTRON SCATTERING

The reactor and all the neutron scattering facilities as mentioned above, are owned and operated by National Nuclear Energy Agency of Indonesia. These facilities are open to scientists from the universities and national institutions in Indonesia, as well as from foreign countries. Depending to the neutron scattering facilities condition as described above, the collaboration research topics can be realized as follows :

- Crystal structure analysis by using HRPD
- Research on the residual stress measurement by using DN1-M machine
- Micro structure analysis and instrumentation calibration by using SANS
- Technical development of control system for diffractometers (FCD/TD and TAS)

SUMMARY

The neutron beam research activities in Indonesia in general can be separated into two groups. For the neutron scattering activities the neutrons beam use are coming from the steady state research reactor (RSG-GAS reactor) situated at Batan-Serpong. Another one that use the neutrons generate using accelerator are mainly use for study irradiation effects on materials, where the activities are carry out at Batan-Yogyakarta about 600 km from Jakarta. The most problems faced by neutron scattering facilities are due to the their component's age, including the electronics and instrumentions parts that need to modify to accommodate the current available softwear as well as hardwear in the market. Some facilities such as HRPD, SANS, and DN1-M are in good condition and offer to the neutron scattering society in the world to collaborate the real experiments at Batan.

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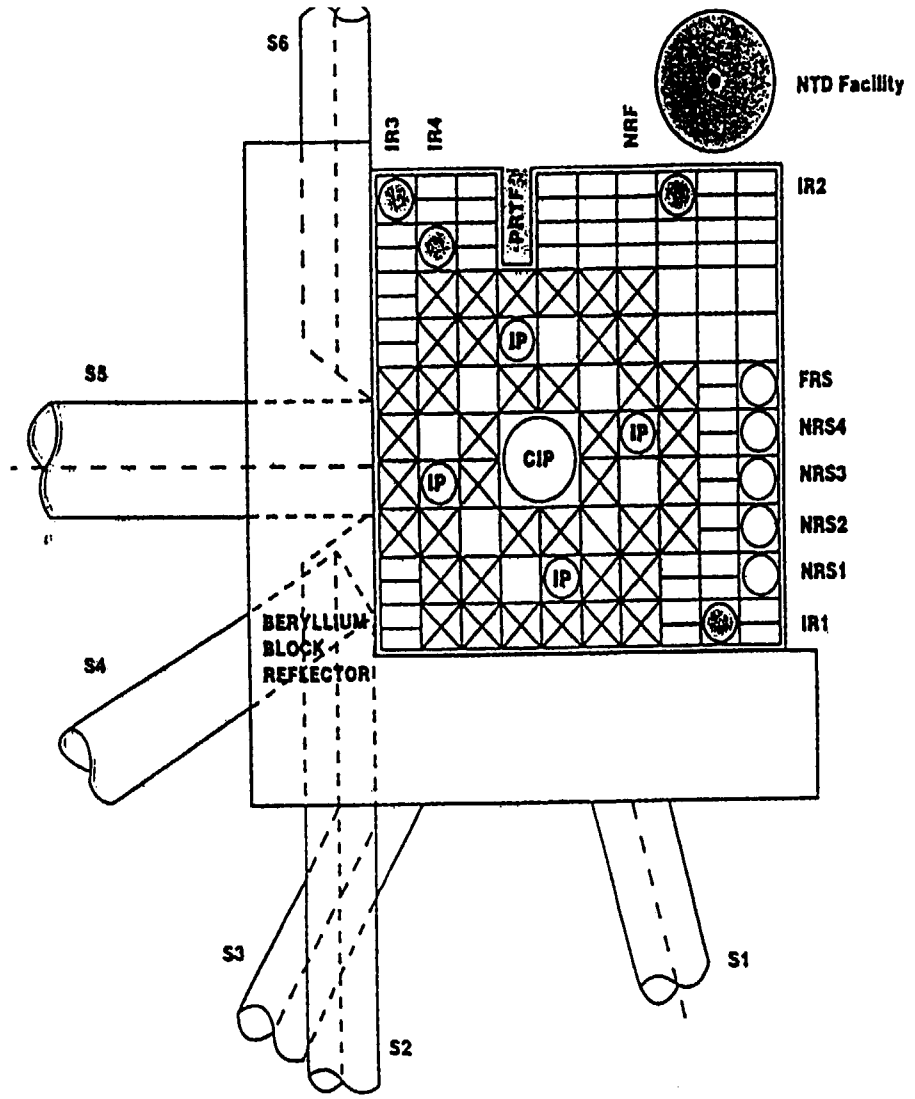


Fig.1. Reactor core and it's irradiation facilities

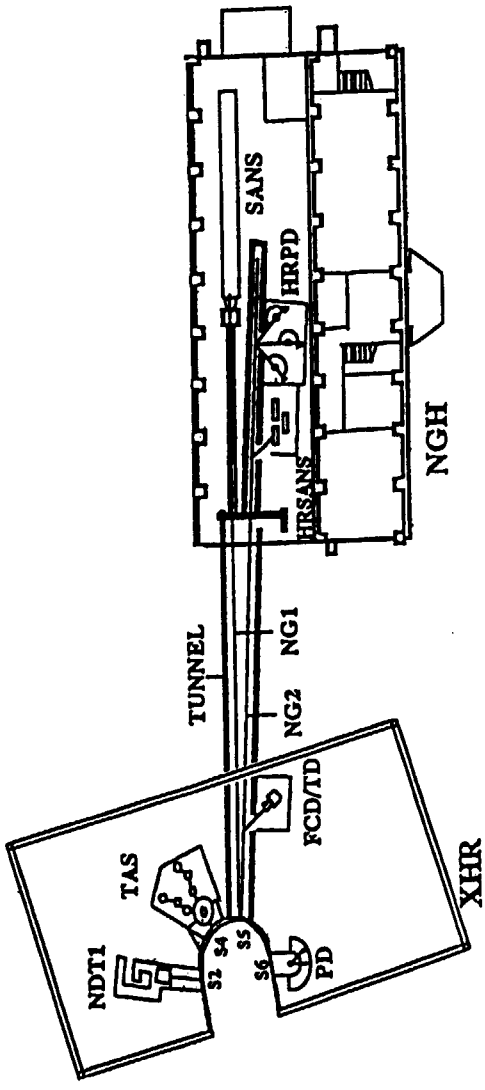
Berylium reflection element

Fuel assembly

Control assembly

CIP • Central Iradiation Pos
NRS • Normal Rabbit System
IP • Irradiation Position (Core)
S • Beam Tube

IR • Irradiation Position (reflector)
FRS • Fast Rabbit System
NRF • Neutron Radiography Facility (Out) of Core)
PRTF • Power Ramp Test Facility



XHR : Reactor Experimental Hall
NGH : Neutron Guide Hall
NG : Neutron Guide
NG 1 : First Neutron Guide
NG 2 : Second Neutron Guide
RN : Neutron Radiography Facility

DN-1M : Neutron Diffractometer for Residual Stress Measurement
DN-2 : Four Circle Diffractometer
DN-3 : High Resolution Powder Diffractometer
SN-1 : Triple Axis Spectrometer
SN-2 : Small Angle Neutron Scattering Spectrometer
SN-3 : High Resolution Small Angle Neutron Scatering Spectrometer

Fig.2. The layout of the neutron scattering instruments in the reactor experimental hall (XHR) and in the neutron guide hall (NGH)