Session 9-1

Support System for Neutron Activation Analysis

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ABSTRACT

In the research reactor of JAERI, the Neutron Activation Analysis (NAA) has been utilized as a major part of an irradiation usage. To utilize NAA, research participants are always required to learn necessary technique. Therefore, we started to examine a support system that will enable to carry out INAA easily even by beginners. The system is composed of irradiation device, gamma-ray spectrometer and data analyzing instruments. The element concentration is calculated by using KAYZERO/SOLCOI[1] software with the k_0 standardization method[2][3]. In this paper, we review on a construction of this INAA support system in JRR-3M of JAERI.

INTRODUCTION

For joint use of JRR-3M, INAA support system is applied to the PN-3 facility. This system was automates the operating procedure of irradiation, measurements, analysis, etc. as much as possible, and it would enable to use INAA conveniently even by beginners. As an analysis method, the k_0 method which does not require individual standard reference material is applied in order to obtain the fixed quantity of the elements easily.

INAA SUPPORT SYSTEM

1. Irradiation facility

JRR-3M is a light water moderated and cooled swimming pool type reactor, operating with maximum thermal power of 20MW. The reactor is operated on 5weeks/1cycle, with about 26 continuous days at full power operation followed by 9 days for maintenance and refueling. There are a lot of experimental facilities in JRR-3M, as shown in Figure 1, involving 9 vertical holes installed for irradiation usage in the core and heavy water tank region and 9 horizontal tubes for neutron beam experiments. The PN-3 facility for the irradiation of INAA is installed in the D_2O tank region.

1.1 Irradiation hole

The PN-3 facility provides well-thermalized neutrons with $\Phi_{th}=2x10^{13}(n/cm^2 s)$, $\Phi_f=1x10^9(n/cm^2 s)$, $R_{cd}=300$. Homogeneity of the thermal flux in the facility is less than 1%. An irradiation rabbit for the PN-3 facility, which is made of polyethylene, has the dimension of 17mm diam. and 30mm long. The specifications of the irradiation hole are shown in Table 1.

1.2 Irradiation device

The irradiation device is composed of PN-3 irradiation tube, automatic rabbit loader, remover, solenoid valve and control equipment using sequencer, etc. The device has 3 operating modes; the automatic, semiautomatic and manual modes. The automatic operation can control a series of processes from irradiation to measurement at preset sample conditions. This mode suites to the process for a group of samples at the same conditions. The semiautomatic operation is used when conditions to be carried out for each sample are different individually. The manual mode is used only to operate by some skilled operators, particularly for the recovery when minor troubles occur in the device. The PN-3 facility allows the irradiation times of 3s up to 1200s. For short-lived nuclides, the sample in the rabbit must be off from the core within about 7s, followed by quickly measuring with the sample encapsulated. If necessary, it is also possible to repeatedly irradiate the same sample. On processing, necessary information can be collected, *e.g.* irradiation start date/time, irradiation finish time, exposure time, measurement start date/time, output of neutron detector, etc. PN-3 irradiation device is shown in Photo 1.

2. Measuring system

2.1 Gamma-ray spectroscopy system

The system has 2 Gamma-ray spectrometers; one for short-lived nuclide and the other for normal measurements. The former spectrometer for short-lived is for immediate measurement after irradiation. For the later case, samples are measured by replacing from the rabbit into polyethylene bag, subsequently setting them on the shelf. Especially, it has been composed of the Gamma-ray

spectrometer using DSP(digital signal processor) that is latest measurement equipment in proportion to the measurement of high count rate such as short-lived nuclide. The block diagram of the Gamma-ray spectroscopy system is shown in Figure 2.

2.2 Automatic sample changer

The automatic sample changer is composed of leads shield (10cm), 5 axis arm robot, controllers, sequencers, gravimeters for liquid nitrogen, etc. Up to 100 samples can be set into the changer. The changer has random sample accessibility and allows placing the sample at a measurement position. The sample-to-detector distance (0mm–300mm) is variable at 10mm intervals. Photograph of the automatic sample changer is shown in Photo 2.

2.3 Gamma-ray spectrum analysis software

Software GENIE-2000[4] for the spectrum analysis is a commercially available package running on personal computers under Microsoft Windows NT/95. Multi-user environment by ETHENET is available, enabling the data analysis and monitor through the network.

3. Data analysis system

The data analysis system is calculated for quantitative analysis by k_0 method or relative method, after the analysis sample is measured. Irradiation and measurement data necessary for the data analysis can be automatically received from INAA support system. As an analysis method of INAA, it is carried out based on the convenient and accurately procedure of the k_0 method. In this system, it is analyzed using evaluated marketing software SAMPO-90[5], KAYZERO/SOLCOI. Flowchart of INAA support system is shown in Figure 3.

3.1 Peak analysis

The peak analysis needs SAMPO-90 spectral format and analytical result used in the KAYZERO/SOLCOI. Therefore it is used after conversion of the gamma-ray spectrum into the type of data, which can be read in KAYZERO/SOLCOI. And, conversion software in proportion to several kinds binary file is prepared in order to convert the gamma-ray spectrum type.

3.2 Calibration of the Ge detector by SOLCOI

The SOLCOI determines effective solid angles and coincidence correction factors. Since accuracy of a detector is indispensable for k_0 method, a detector must be accurately calibrated beforehand for general users.

3.3 Calculation of the reactor parameter

The reactor parameter is a coefficient for correcting neutron spectrum of reactor, and it is shown in the thermal-to-epithermal neutron flux ratio, f and the slope of 1/E distribution, α. These parameters (f, α) must be also measured beforehand for general users.

3.4 Analysis

KAYZERO software, which performs qualitative/quantitative analysis based on the k0 method in this system, provides a list of concentrations and/or detection limits of all measurable elements. However, there are some difficulties in transporting analysis results automatically to KAYZERO from INAA support system, which runs under DOS. As a solution of this problem, original software, which will perform analysis automatically by k_0 method, will be prepared.

3.5 Analytical database

Analytical databases are that it accumulates data such as analysis condition, result of analysis, gamma-ray spectrum got by this system. And does the data base construction which faces every analysis sample. It will be improved in order to conjugate as a reference for deciding beginners or analysis conditions of the inexperience sample, etc.

FURTHER DEVELOPMENT

It is understood that the improvement of INAA support system based on the k_0 method is convenient instruments for the NAA users. An attempt to apply the support system to the PN-3 facility in JRR-3M of JAERI has been made at present, and its application for JRR-4 will be done in future. Further development and improvement of this system will be proceeded in order to utilize NAA more conveniently and accurately.

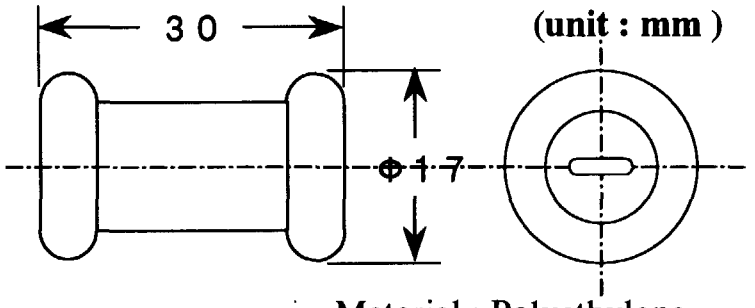
REFERENCES

(1) KAYZERO/SOLCOI User's Manual, DSM Research (1996)
(2) F. DE. CORTE and A. SIMONITS, VADE MECUM FOR k_0-USERS (1994)
(3) F. DE CORTE, "The k_0 Standardization Method", Rijksuniversiteit Gent (1987)
(4) Genie-2000 Spectroscopy System/Operations, Canberra Industries, (1997)
(5) SAMPO 90 User's Manual, Canberra Industries, (1991)

Table 1 Specification of PN-3 facility

Item \ Position	Bottom	Middle
Φ_{th}	1.9×10^{13}	1×10^{12}
Φ_f	6.0×10^{9}	10^{8}
R_{cd}	300	700 ~
Irradiation time	max. 20 min.	
Irradiation tube size	Φ 20 mm	

Irradiation rabbit



Material : Polyethylene

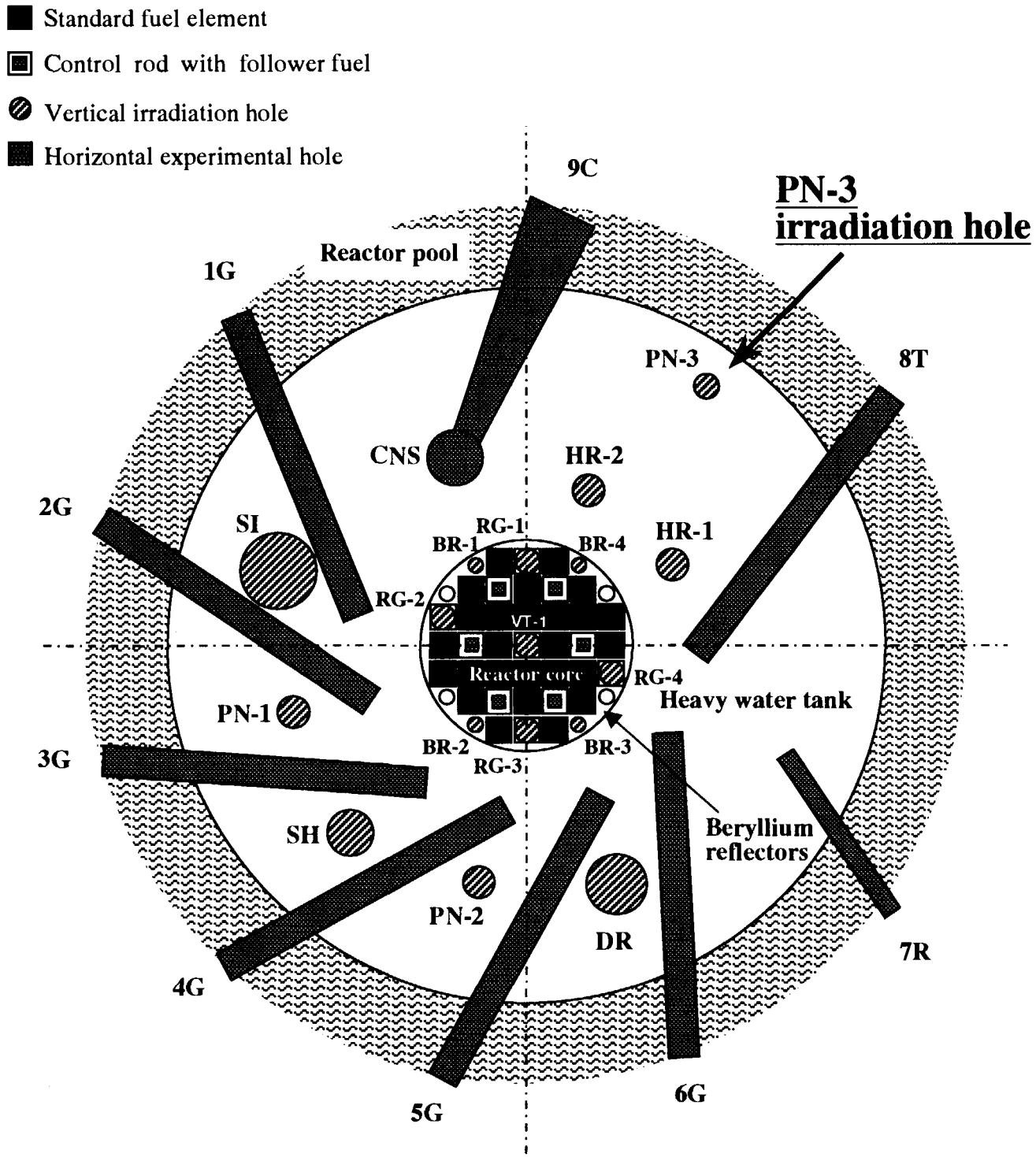


Fig.1 JRR-3M Reactor core and utilization facility

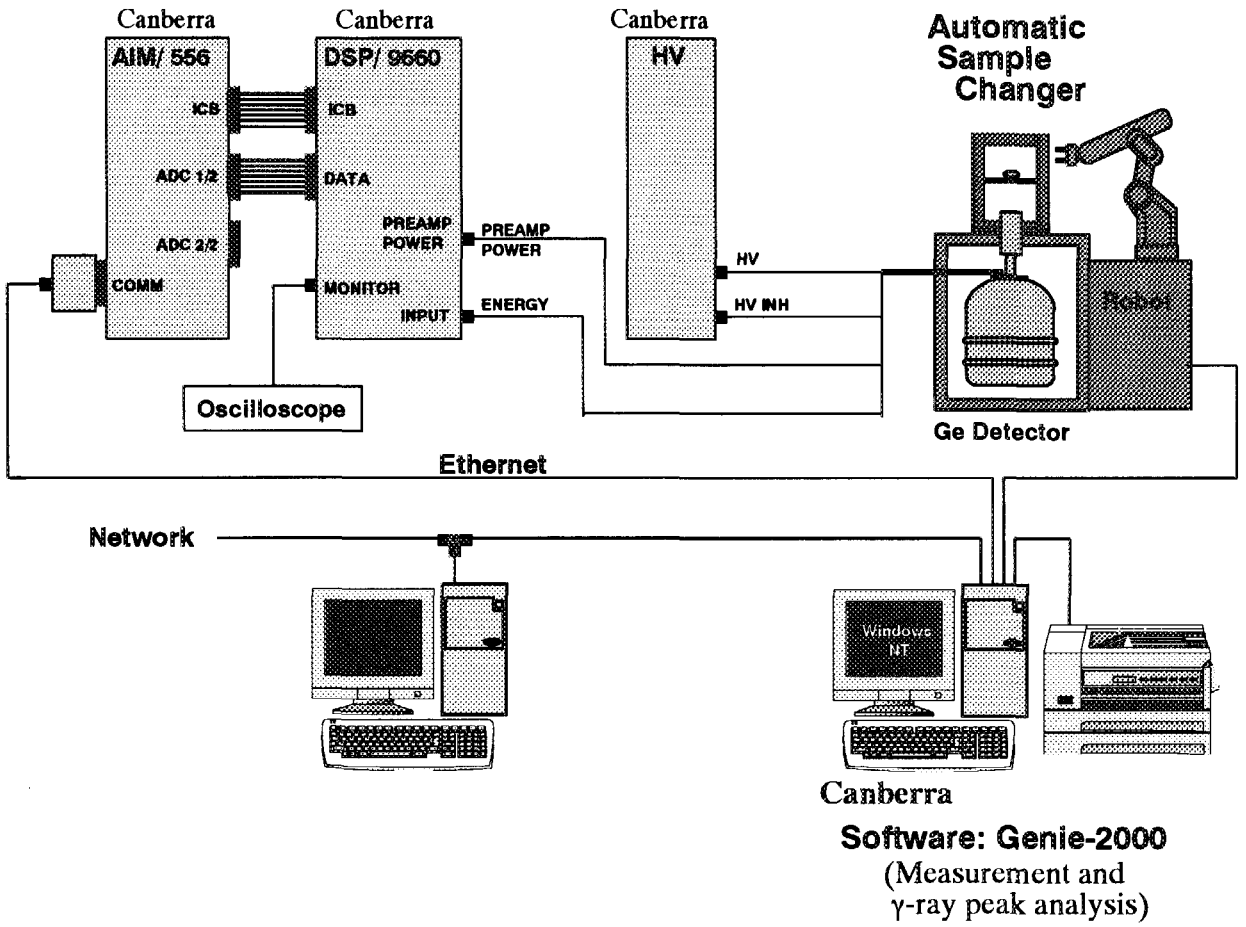
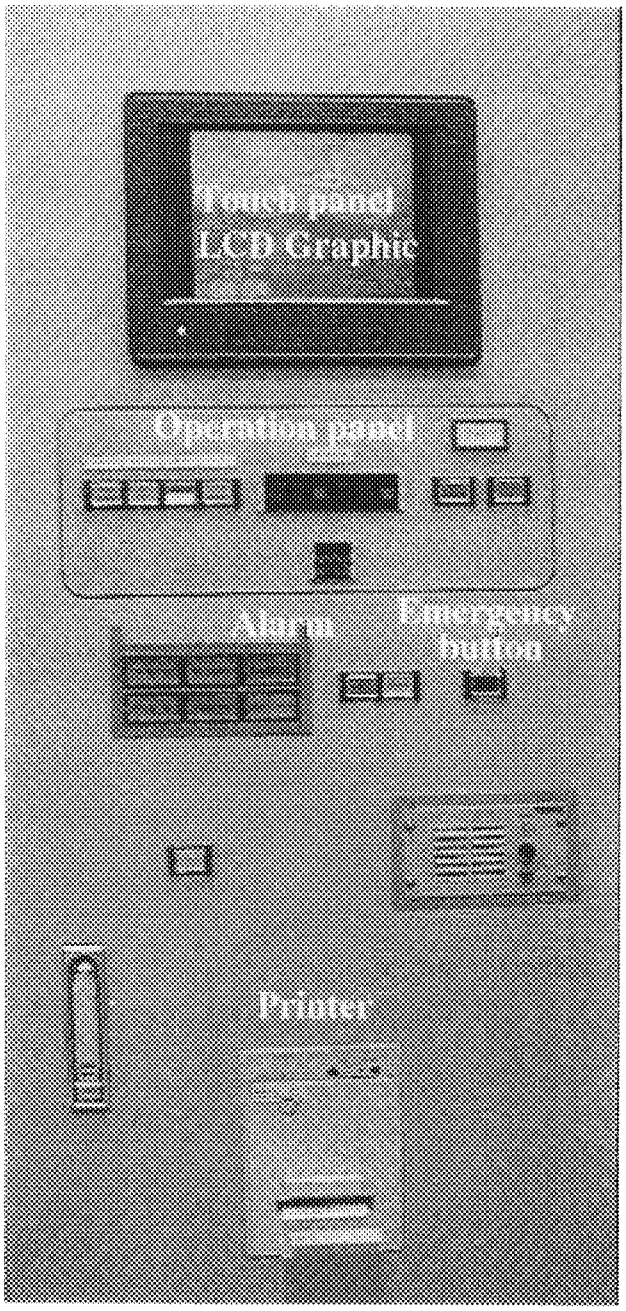


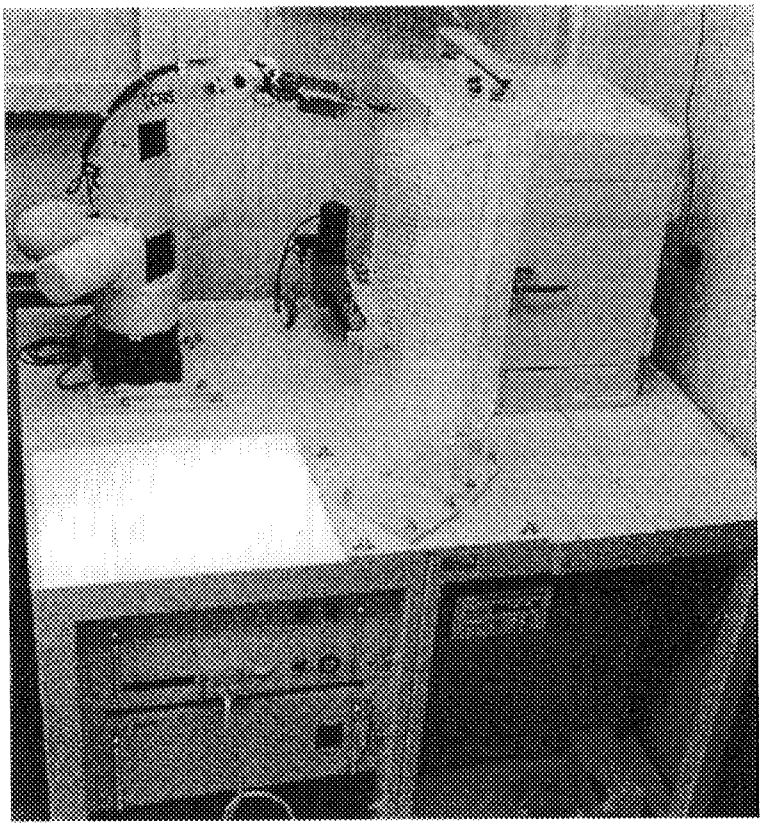
Fig.2 γ-ray Spectroscopy System



Specification

- Easy operation
- Operation by
  auto/semi-auto/manual mode
- Monitoring of operation condition
  and process data
- Repeatedly irradiation
- Interlock by dose rate
- Quick measurement
  for short-live nuclide
- etc.

Photo 1 PN-3 irradiation device



Specifications

- **Measurement method : Random Access**
- **Sample number : 100 sample (max.)**
- **Thickness of Shield : Pb 100mm (low B.G.)**
  Cu 5mm
- **Shielding door : Manual / Automatic door**
- **Measurable distance : 0 - 300 mm**
- **Sample plate size :**
  Manual : 200 mm x 200 mm x 3 mm
  Auto : 100 mm x 100 mm x 3 mm
- **Robot : 5 degrees of freedom**
  Repeatability : +/- 0.05 mm
- **Others**
  - **Balances for liquid N_2 level**
  - **Adjustable of Ge Det. height**
  - **Controls : Sequencer**
  - **Communication : RS-232C**

Photo 2 Automatic sample changer

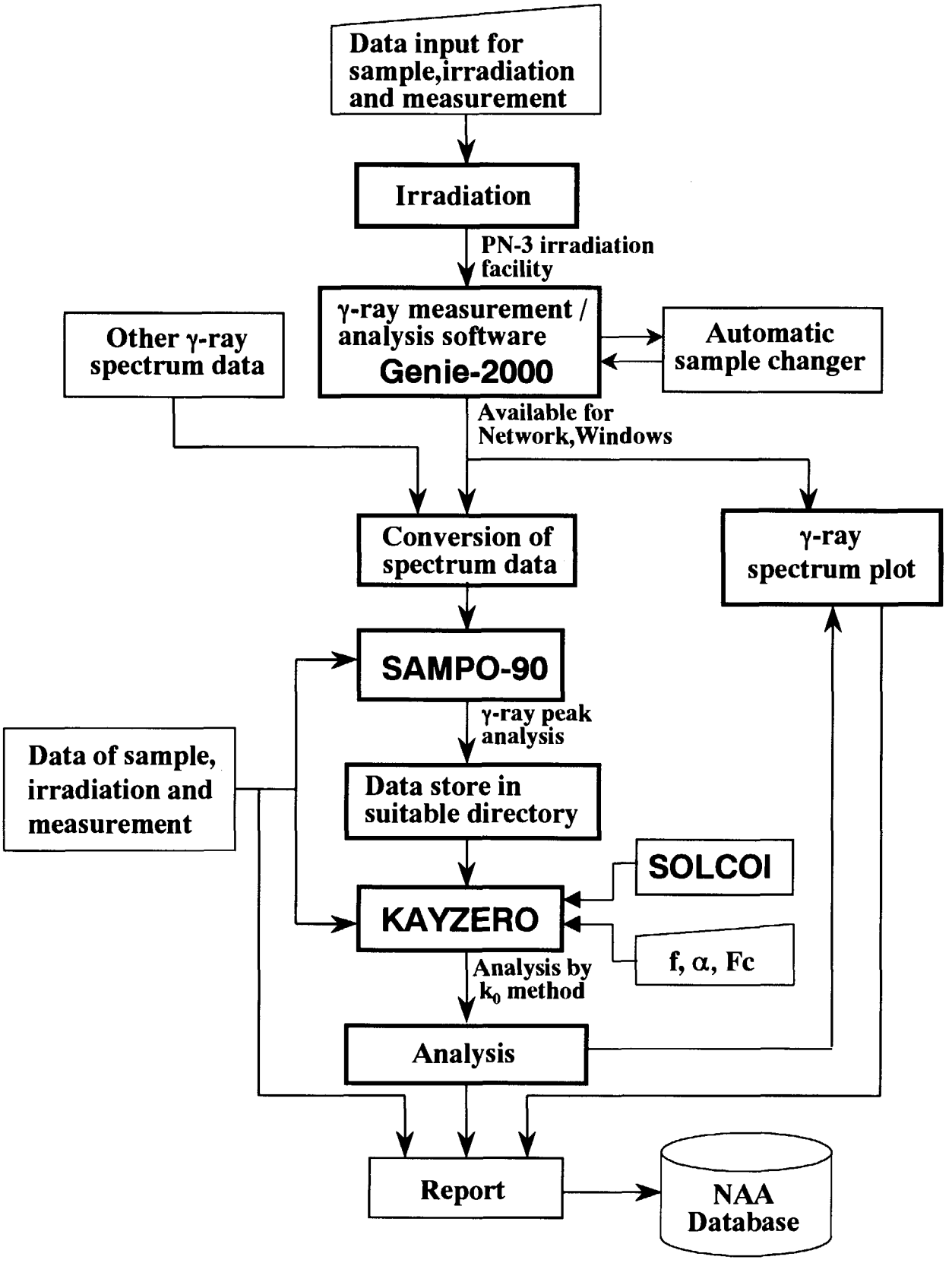


Fig.3 Flowchart of INAA support system