XA04C1722

Current Status and Future Plan of Neutron Beam Facility at JRR-3M

F. Sakurai, A.Ohtomo, K. Kakefuda and K. Kaieda

Department of Research Reactor
Tokai Research Establishment
Japan Atomic Energy Research Institute
Tokai-mura, Naka-gun, Ibaraki-ken, 319-1195, JAPAN

ABSTRACT

JRR-3M (Japan Research Reactor No.3), which is equipped with a cold neutron source and five neutron guides, has provided researchers of fundamental and applied research with an intense and high quality neutron beam. The total number of instruments installed in a reactor hall and a guide hall is 25, and some instruments are being developed. The number of users increases drastically. Especially the total number of neutron beam users, who worked mainly in the field of neutron scattering has reached 17,000 person-day, and requested beam time has reached twice of available beam time in 1997. New instruments such as neutron Laue diffractometer are being developed for providing experimenters with various research opportunities. Replacement of a CNS moderator cell is planned this year in consideration of neutron exposure. Furthermore, in order to meet the demand for more intensity and beam time, replacement of existing nickel guide tubes with supermirrors is also planned for increase of the thermal neutron flux at least by a factor of five at the neutron guide end.

1. Introduction

JRR-3M, which is a pool type research reactor of 20MW, was constructed at just the same place where the old reactor was removed from, by a unique method named "one piece reactor removal method". Its first criticality was achieved on March 22, 1990. JRR-3M is operated with seven or eight operation cycles in each year. Its operation cycle is basically consist of four weeks of full power operation and one week of shut down for refueling, irradiation capsule handling and maintenance works. The integrated thermal power of 24700 MWday was attained at the end of fiscal year 1997.

Fuel conversion program from U-Alx dispersed MTR type fuels with a U-density 2.2 g/cm^3 to U_3Si_2-Al dispersed MTR type fuel with a U-density of 4.8 g/cm^3 and a burnable poison of Cd wire is progressing. By this conversion, the number of spent fuels can be reduced, and it will supply stable neutron beam to many users.

The JRR-3M is the first neutron source which is equipped with a large scaled cold neutron source and neutron guide tubes with a total length of more than two hundred meters in Japan. This remarkable feature makes it possible to open up new research fields such as soft material science, and also makes it possible to install many instruments along the guide tubes.

In this report, we describe a situation that the number of users of JRR-3M has been remarkably increasing in various advanced research fields, and the development of new scientific instruments and the replacement program of existing nickel guide tubes with supermirror guide to meet the demand for more intensity and beam time. Furthermore, replacement of a CNS moderator cell which is planned this year is reported.

2. Current Status of Utilization

Figure 1 shows the trend for the total number of users who worked in the field of beam experiment (man-day) categorized by affiliation. In 1997 the number of users inside JAERI was slightly bigger than that outside JAERI. The number of outside users was increasing year by year and increased by 55% in 1997 in comparison with 1994's. Users outside JAERI in 1997, most of whom are researchers from universities, occupied 61 %; users inside JAERI occupied 39% in 1997.

Status of utilization fields in 1997 is shown in Fig. 2. Neutron scattering experiments occupied 63% of the total use of JRR-3M. In neutron scattering experiment, solid state physics is a major field and soft material such as polymer and biology account for about a quarter, chemistry, neutron optics and fundamental physics are minor fields. As for the other neutron beam experiments, neutron radiography, prompt gamma ray analysis and development of supermirrors are listed with 12% occupation. The rest one third is occupied by the irradiations. Especially the total number of neutron beam users, who worked mainly in the field of neutron scattering has reached 17,000 person-day, and requested beam time has reached twice of available beam time in 1997.

All proposals are reviewed once a year by JAERI and University-Group independently, and are determined weather each should receive beam time and how much time is to be allocated

3. Current Status of Neutron Beam Facilities

Arrangement of the experimental holes and tubes at JRR-3M is shown in Fig. 3. Horizontal beam tubes are arranged in the heavy water tank for neutron beam experiments, nine horizontal beam tubes (lG through 6G, 7R, 8T and 9C) are arranged tangentially to the core, in order to reduce fast neutrons and gamma rays in the neutron beam. Seven out of the nine tubes, 1G through 6G and 7R, supply thermal neutron beam for experiments in the reactor room. The 8T beam tube transmits thermal neutrons into the beam hall through two thermal neutron guide tubes. The 9C beam tube transmits cold neutrons from CNS into the beam hall through three cold neutron guide tubes. It has become possible to install a lot of beam experimental instruments along these neutron guide tubes.

Five neutron guide tubes, T1 and T2 for thermal neutrons and Cl, C2 and C3 for cold neutrons, are installed to extract neutron beams efficiently from the heavy water reflector and the liquid hydrogen moderator in the heavy water tank through the horizontal beam tube 8T and 9C respectively to the beam hall. Seventeen neutron beam ports of which eight are set on the thermal neutron guide tubes and another nine on the cold neutron guide tubes, are available in the beam hall, 30m wide x 50m long, which is located next to the reactor building. The characteristic wavelength of Tl and T2 is 2Å and their radius of curvature is 3340m. The length is about 60m. Cl and C2 with a radius of curvature of 834m have a characteristic wavelength of 4Å. Their total length is about 31m and 51 m respectively. C3 with a radius of curvature of 370m has a characteristic wavelength of 6Å, and is 31 m long.

The CNS facility of JRR-3M is a vertical thermosyphone type using liquid hydrogen at 20K as a moderator. A schematic diagram of the CNS facility is shown in Fig. 4, and its design parameters and operational features are shown in Table 1. The CNS gain at wavelength of 5Å is 15. This facility is operated all during the reactor operation.

The layout of neutron beam experimental instruments at JRR-3M is shown in Fig. 5. Their categories by instrumental type are listed in Table 2. The total number of instruments installed in a reactor hall and a guide hall is 25, and some instruments are being developed.

4. Replacement of a CNS Moderator Cell

The cold neutron source (CNS) facilities of the JRR-3M have been operating without exchanging a moderator cell for seven years since a start-up the reactor in 1990. The moderator cell of CNS is thin wall container of the 0.8mm thickness made of austenitic stainless steel. The fast neutron fluence of moderator cell is estimated to reach 2.0 x 10^{20} n/cm^2 by the latter half in this fiscal year, and the cell will be replaced by the new one (Fig. 6) with the same specification in consideration of embrittlement by neutron irradiation.

The replacement will be carried out from this October to January.

5. Upgrading of Thermal Neutron Guide Tubes

Use of a supermirror guide tube instead of a natural nickel guide can increase neuron flux and transmits shorter wavelength neutrons through the guide. This performance promise to open up new possibilities for the experimenters for neutron scattering and other absorption experiments. In recent years, the constructions of supermirror guide have progressed at ORPHEE reactor and so on. At JRR-3M, replacing program is progressing to obtain higher neutron flux and shorter wavelength neutrons. Replacing the thermal neutron guide tube (T-2) is the first project. Figure 5 shows a horizontal view of the guide hall. The total length of T-2 guide is 57 m including curved section with a length of 36 m. The radius of curvature is 3340 m, and its characteristic wavelength is 2 Å.

It is planned that all elements of the thermal guide tube (T-2) is replaced by a supermirror with an effective critical angle as same as twice of natural nickel ($2\theta_{Ni}$). Other design parameters of the guide tube such as the radius of curvature and the cross section of the guide tube are not changed not to change the layout of the existing instruments. Neutron transmission analyses have been conducted for design of the supermirror guide tube. Neutron trajectories were calculated using NEUGT code based on ray trace method which was developed to assess the design of the neutron guide tubes of JRR-3M. This code can not only calculate a neutron transmission and neutron spectra asumming the maxwellian spectra at a entrance of a guide tube, but also analysis the effect of abutment errors.

Figure 7 shows calculated spectrum at the exit of T-2 guide tube as a function of reflectivity assuming the maxwellian spectra with 293 K at the entrance of guide tube. Total intensity at the end exit in the case with a reflectivity of 0.95 is 5.6 times of the exiting nickel guide tube. Especially, intensity at 1.2 Å is 10 times of the exiting one.

6. Development of New Instruments

(1) Neutron Laue-Diffractometer for Crystallography in Biology

A diffractometer using nIP (neutron Imaging Plate) as a neutron detector has been designed and is now under constructing, as shown schematically in Fig. 8. An available neutrons are quasi-monochromated with a neutron velocity selector. The Laue diffraction patterns are recorded with nIPs. Combination technique of Laue method and nIP becomes possible to collect enough reflections to analyze structure of biological macromolecules precisely. Moreover the technique allows to reduce data recording times as against that of a conventional diffractometer with a gas-filled area detector.

(2) Reflectometer

Great interests have been given during recent years to the progress of neutron reflectivity experiments for the study of surface and interfacial phenomena. Because the neutron reflectivity profile at the glancing critical angle is sensitive to the depth profile of the neutron refractive index, the density profiles of surfaces and interfaces can be determined with a depth resolution of a few Angstrom. Neutron reflectivity has become a unique and strong tool for the study of surface and interfacial phenomena, and these scientific instruments have obtained great success.

A neutron reflectometer, which covers a wide Q-values ; up to 0.4 $Å^{-1}$ and has an intense neutron beam with an intensity of 2.1×10^4 n/s at a wavelength of 3.4 Å and an angular divergence of 0.04°, was installed at the cold neutron triple-axis spectrometer (LTAS) at the C2-1 beam station. The available wavelengths are 3 and 6 Å, which is close to the maximum intensity of the wavelength distribution in this guide tube. A reflectivity profile is obtained within several hours and reflectivities can be measured in the range of 10^{-6}.

The reflectometer has been arranged to correspond to state of the sample. Solid samples which are formed on a flat substrate, are measured in a vertical geometry. A liquid sample can be measured in a horizontal geometry. The angle of the incident beam is controlled by changing the height of the sample table, and changing the tilt of the PG monochromator which is set in the neutron guide tube.

(3) Four-Circle Diffractometer

A single crystal diffractometer is being installed at T2-2 beam port by university group. This instrument works in the wave length of about 1 Å to investigate the structure phase transition, structural disorder, hydrogen bonding in the field of condensed matter physics and so on.

(4) Multiple Extreme Conditions System

Elastic and inelastic neutron scattering have provided useful information for the investigation of the condensed matters. The parameters of temperature (especially low temperature), magnetic field and pressure has generally been used as a physical variables for samples in such studies. However, so far only single or double of these parameters have been controled in neutron scattering experiments because of various technological difficulties.

An unique system was developed for controlling sample circumstances during the neutron scattering experiments. The system is able to generate simultaneously triple-extreme conditions of low temperature, high magnetic field and high pressure. Figure 9 shows a cut-away view of the system : a conventional liquid-He cryostat with a superconducting magnet having an antisymmetric split-coils geometry for polarized-beam experiments and provides a vertical field up to 5T. The sample temperature range is about 1.7K to 200K. A high pressure cell was designed as a piston-cylinder type with the aim of generating pressure up to 2.5GPa. All the cell parts were made of nonmagnetic materials (Al alloy, sintered-Alumina, etc.) with sufficient mechanical properties at low temperature.

7. Concluding Remarks

At JAERI, replacement of a CNS moderator cell will be carried out this year to keep safe operation. Upgrading of existing nickel guide tubes with supermirror guide is also planned to increase the neutron intensity and open up new experimental opportunities.

Furthermore, new instruments are being developed to meet the current demand for neutron beam experiments.

Table 1 JRR-3 CNS facility

(Design parameters)

Type	Vertical thermosyphne type
Moderator	Liquid hydrogen, 20K
Coolant	Helium gas
Moderator cell	Flask shape, 200mmH x 130mmW x 50mmT 0.8 litter, Stainless steel, 0.8 mmt
Vacuum chamber	ϕ154mm, 8mmt, Stainless steel

(Operational feature)

Pressure of hydrogen	1.2 ata
Volume of liquid hydrogen	1.5 litter
Nuclear heat	400 W
Thermal radiation heat	150 W
Cold neutron gain	10 (at the wave length of 0.5 nm)

Table 2 Neutron instruments at the JRR-3M

Type	Instrument	Name	Beam port	Affiliation*
Elastic scattering	Powder diffractometer	HRPD	1G	JAERI
		KPD	T1-3	Tohoku
	Double-axis diffractometer	KSD	T1-2	Tohoku
		RESA	T2-1	JAERI
	Small angle scattering	SANS-J	C3-2	JAERI
		SANS-U	C1-2	ISSP
		PNO	3G	JAERI
		ULS	C1-3	ISSP
	Diffraction camera	NDC	T1-4-2	ISSP
		PNO	3G	JAERI
	Interferometer	PNO	3G	JAERI
		ULS	C1-3	ISSP
		MINE	C3-1-2	Kyoto
	Diffractometer for biology	BIX-I	1G-A	JAERI
		BIX-II	T2-3	JAERI
In-elastic scattering	Triple-axis spectrometer	TAS-1	2G	JAERI
		GPTAS	4G	ISSP
		PONTA	5G	ISSP
		TOPAN	6G	Tohoku
		HER	C1-1	ISSP
		LTAS	C2-1	JAERI
		HQR	T1-1	ISSP
		TAS-2	T2-4	JAERI
	Special type spectrometer	NSE	C2-2	ISSP
		NSM	C2-2	ISSP
		AGNES	C3-1-1	ISSP
Others	Prompt γ-ray analysis	PGA	T1-4-1(C2-3-2)	JAERI
	Neutron radiography	TNRF	T1-4-1(C2-3-2)	JAERI
		CNRF	T1-4-1(C2-3-2)	JAERI

* Tohoku : Tohoku University
ISSP : Institute for Solid State Physics in Tokyo University
Kyoto : Kyoto University

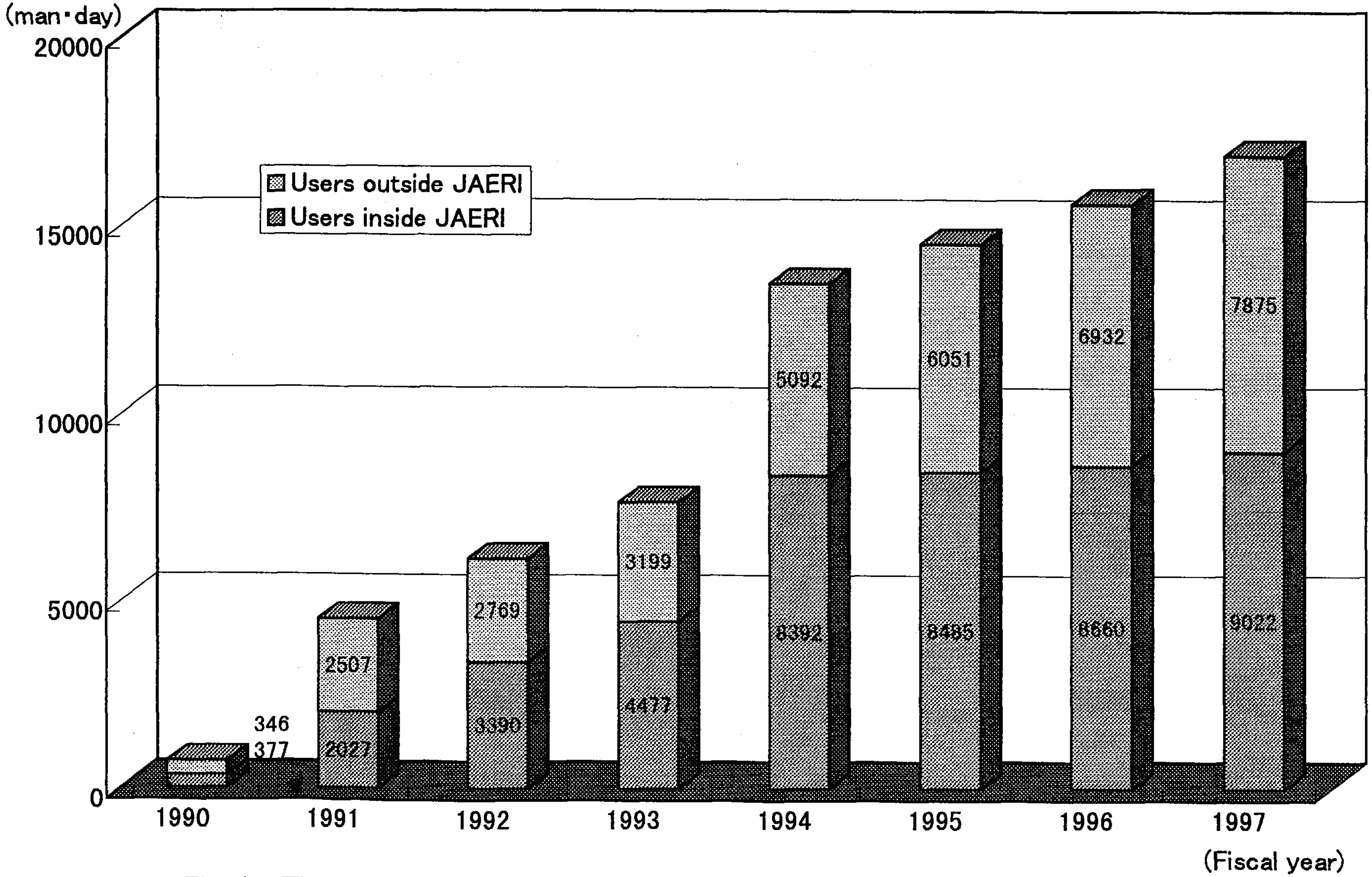

Fig. 1 The number of users who worked in the field of beam experiments (man-day) categolized by affiliation.

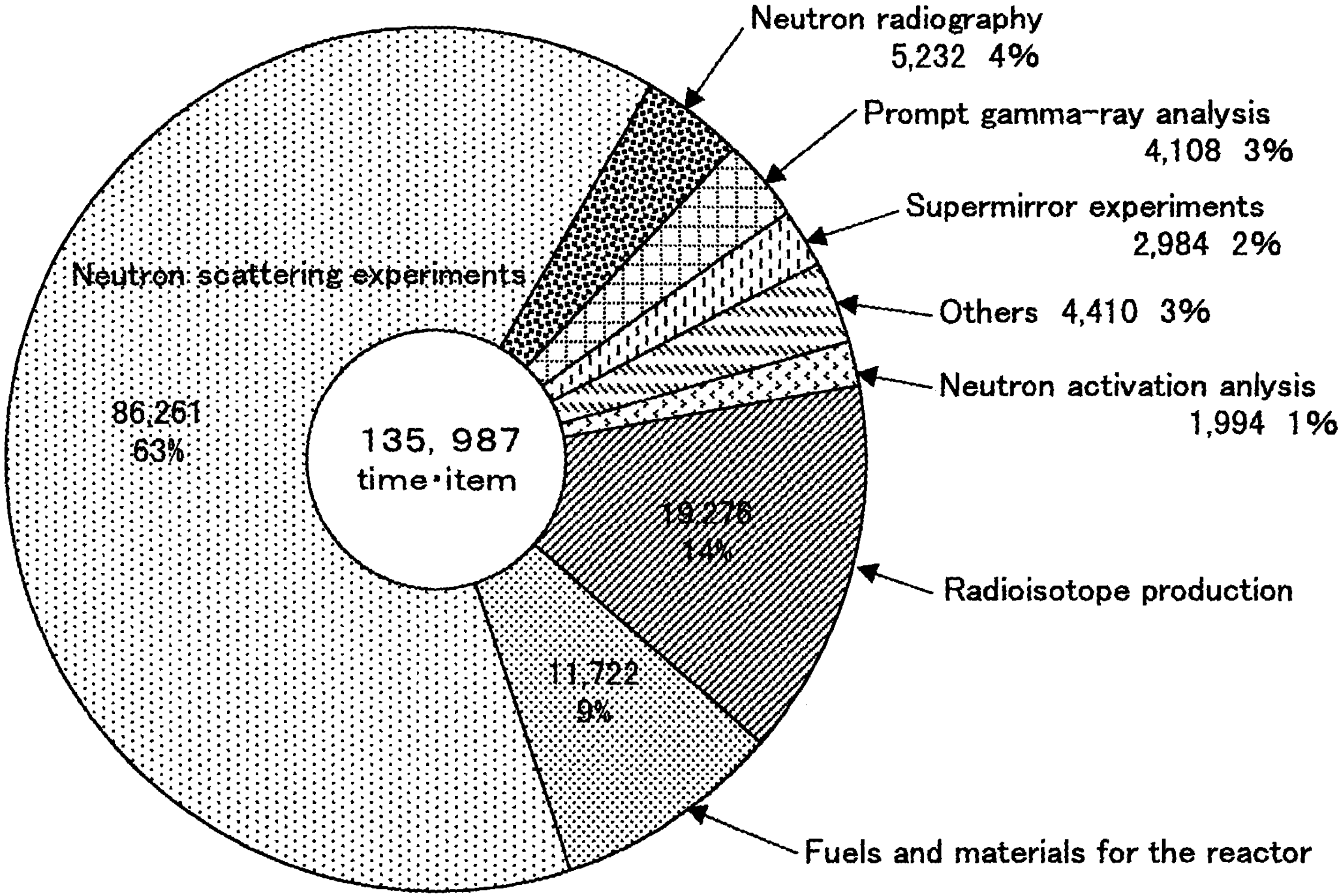

Fig. 2 Status of utilization in 1997

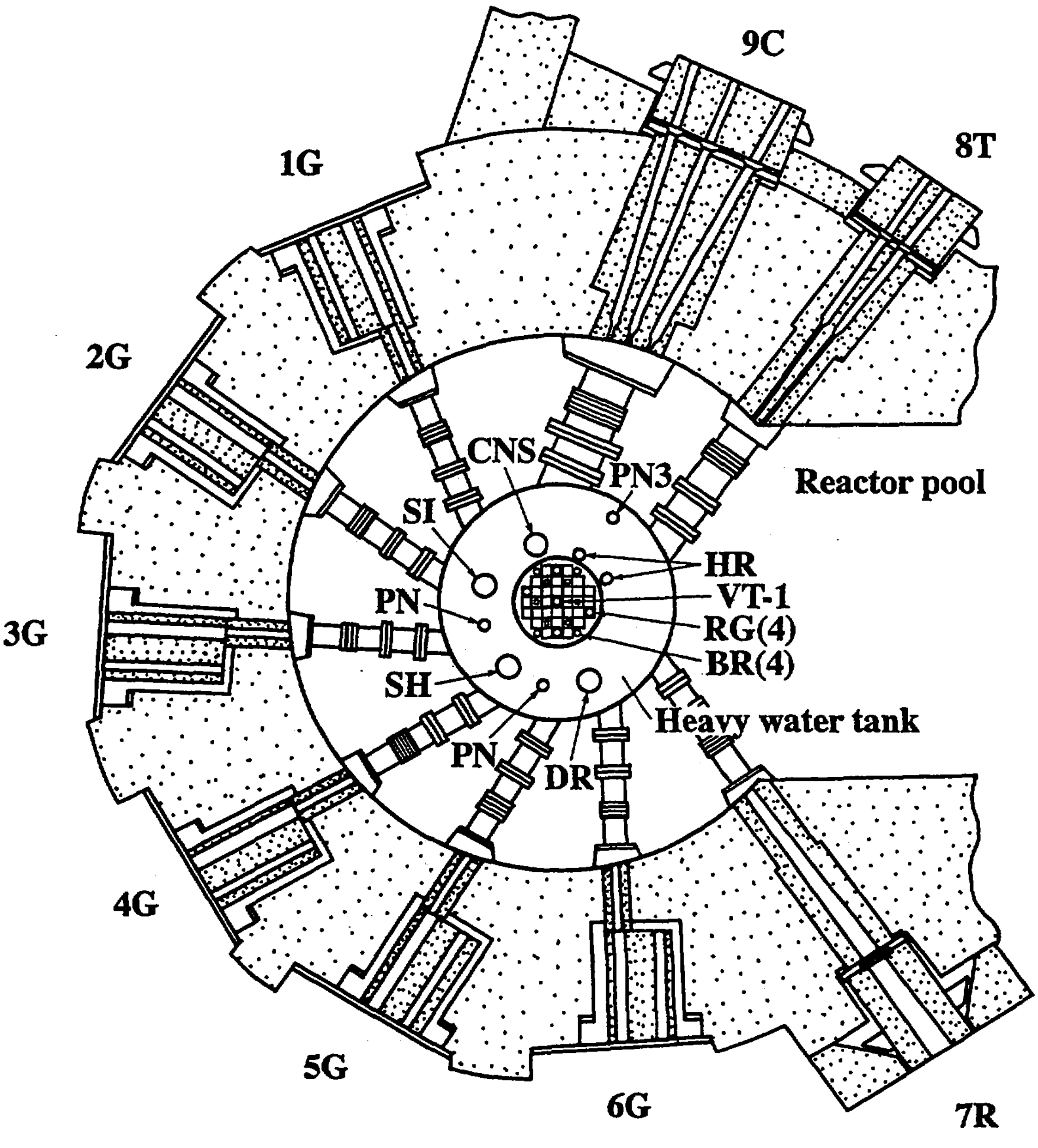

Fig. 3 Arrangement of the experimental holes and tubes, vertical irradiation holes: HR, PN, PN3, SI, DR, RG, VT-1, BR, SH; horizontal beam tubes: 1G - 6G, 7R, 8T, 9C.

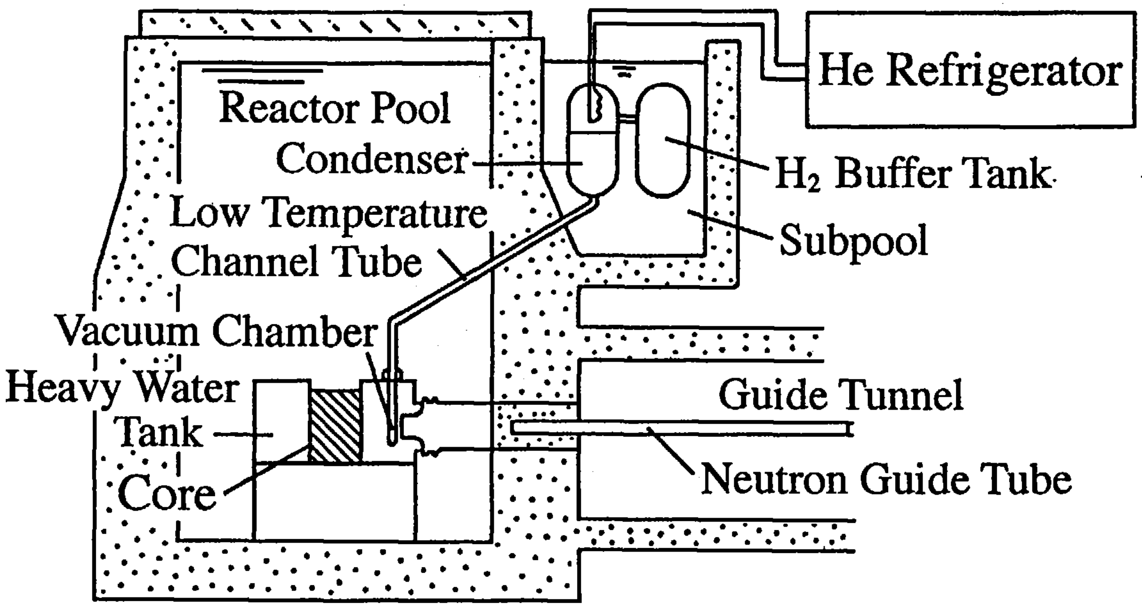

Fig. 4 Schematic diagram of CNS facility.

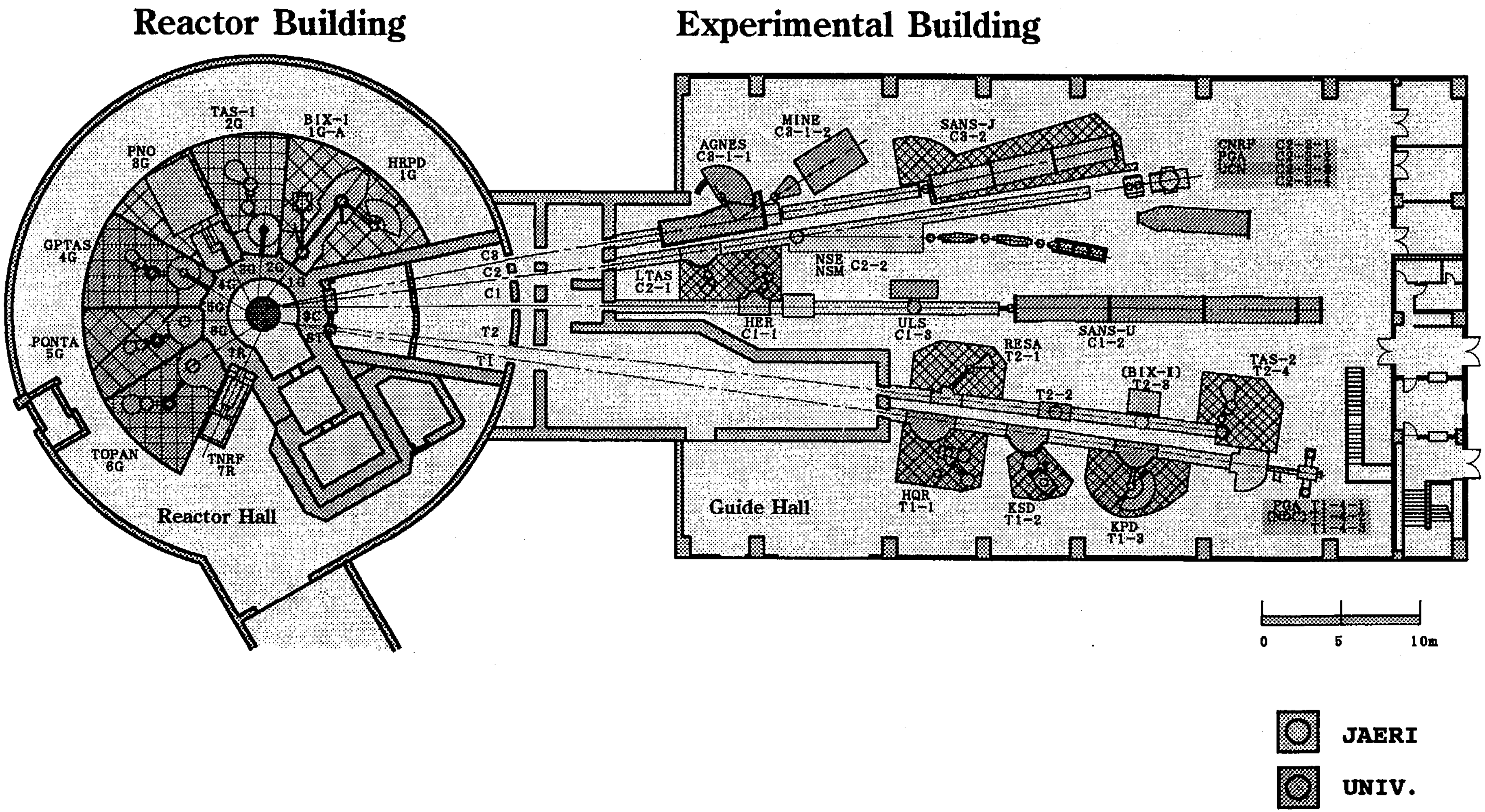

Fig. 5 Layout of neutron beam experimental instrument at JRR-3M

Fig. 6 CNS moderator cell

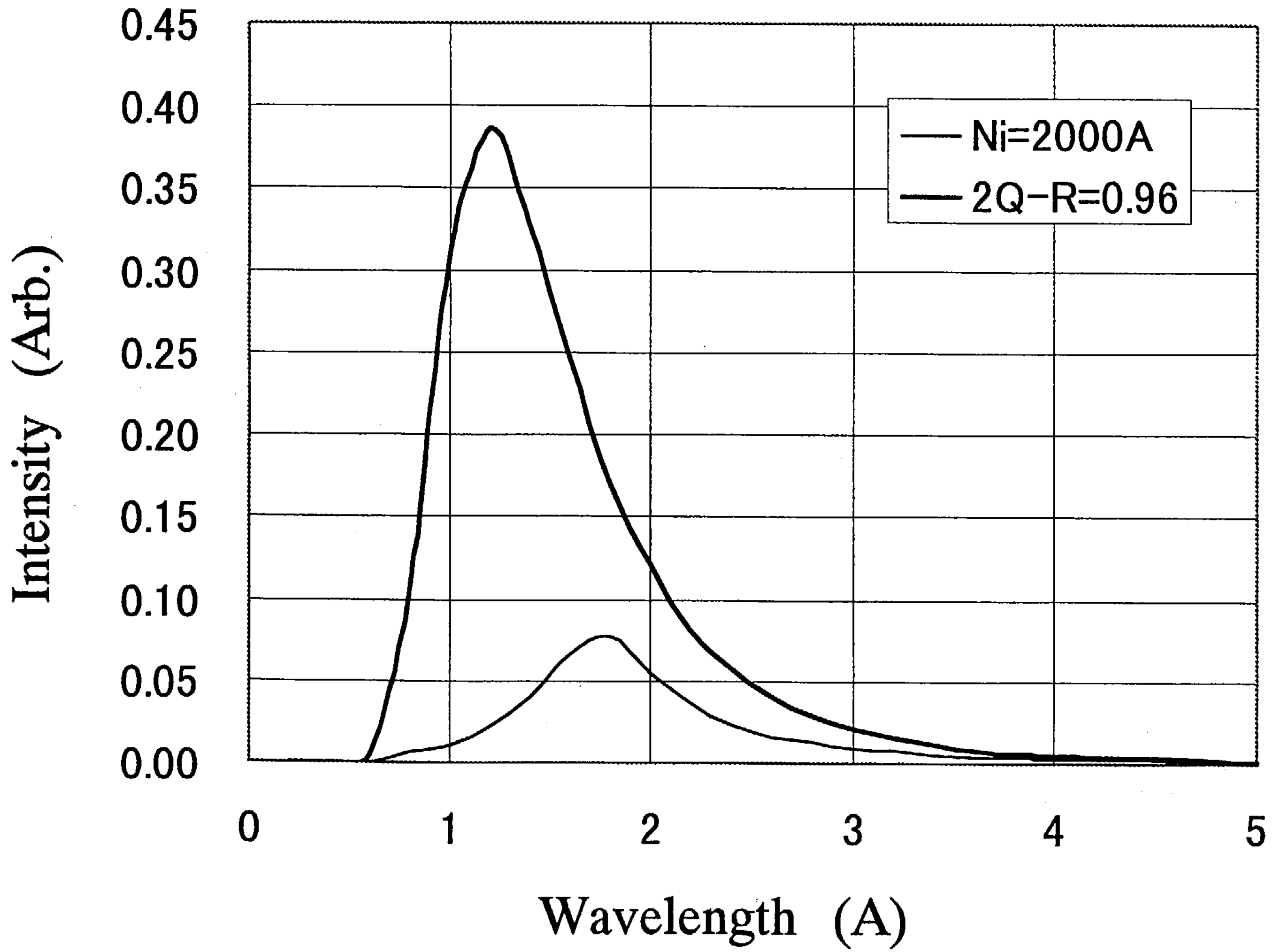

Fig.7 Calculated neutron spectrum at the end of thermal guide (T-2) at JRR-3M

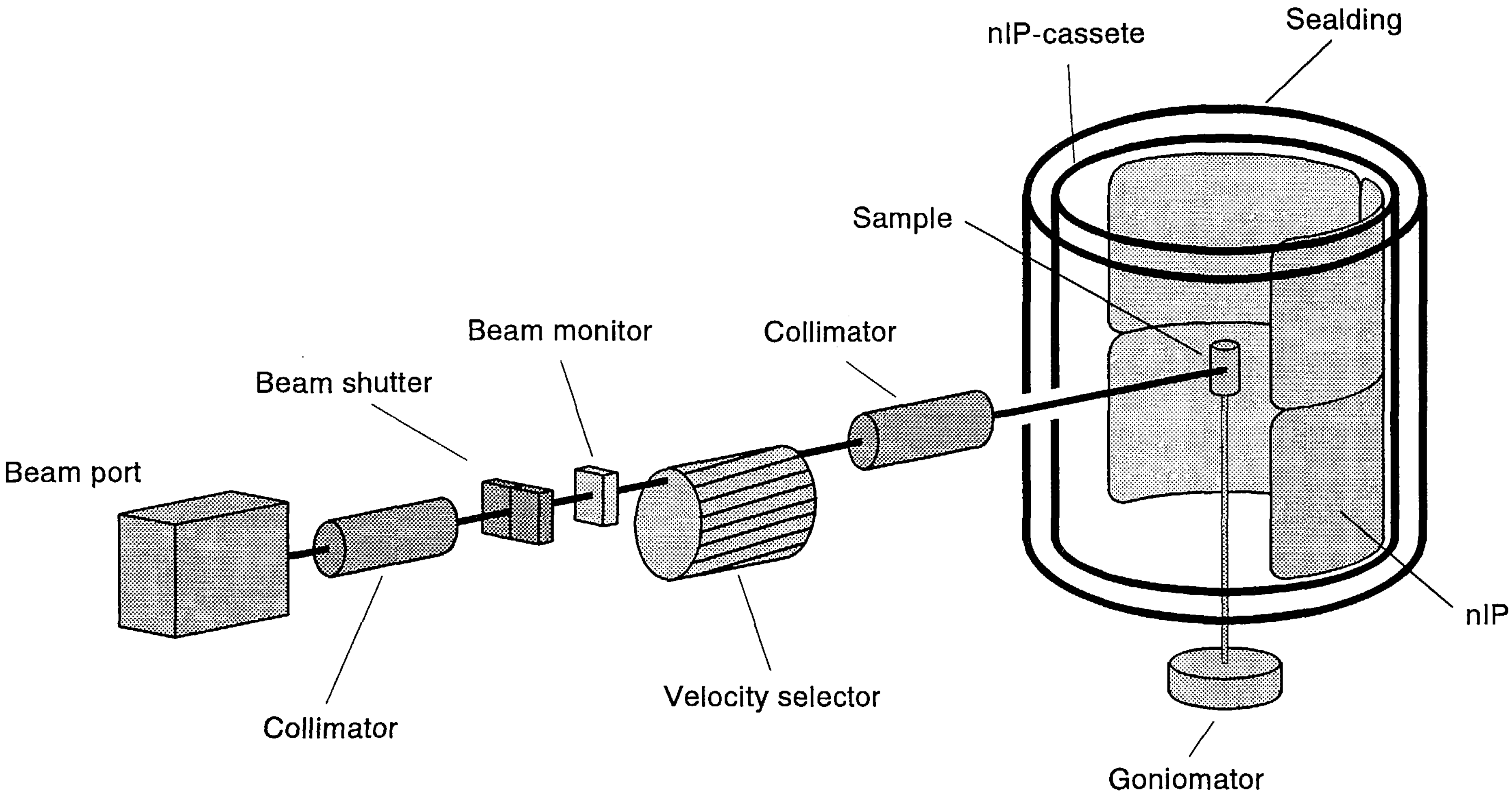

Fig. 8 Schematic view of a neutron Laue-diffractometer for crystallography in biology.

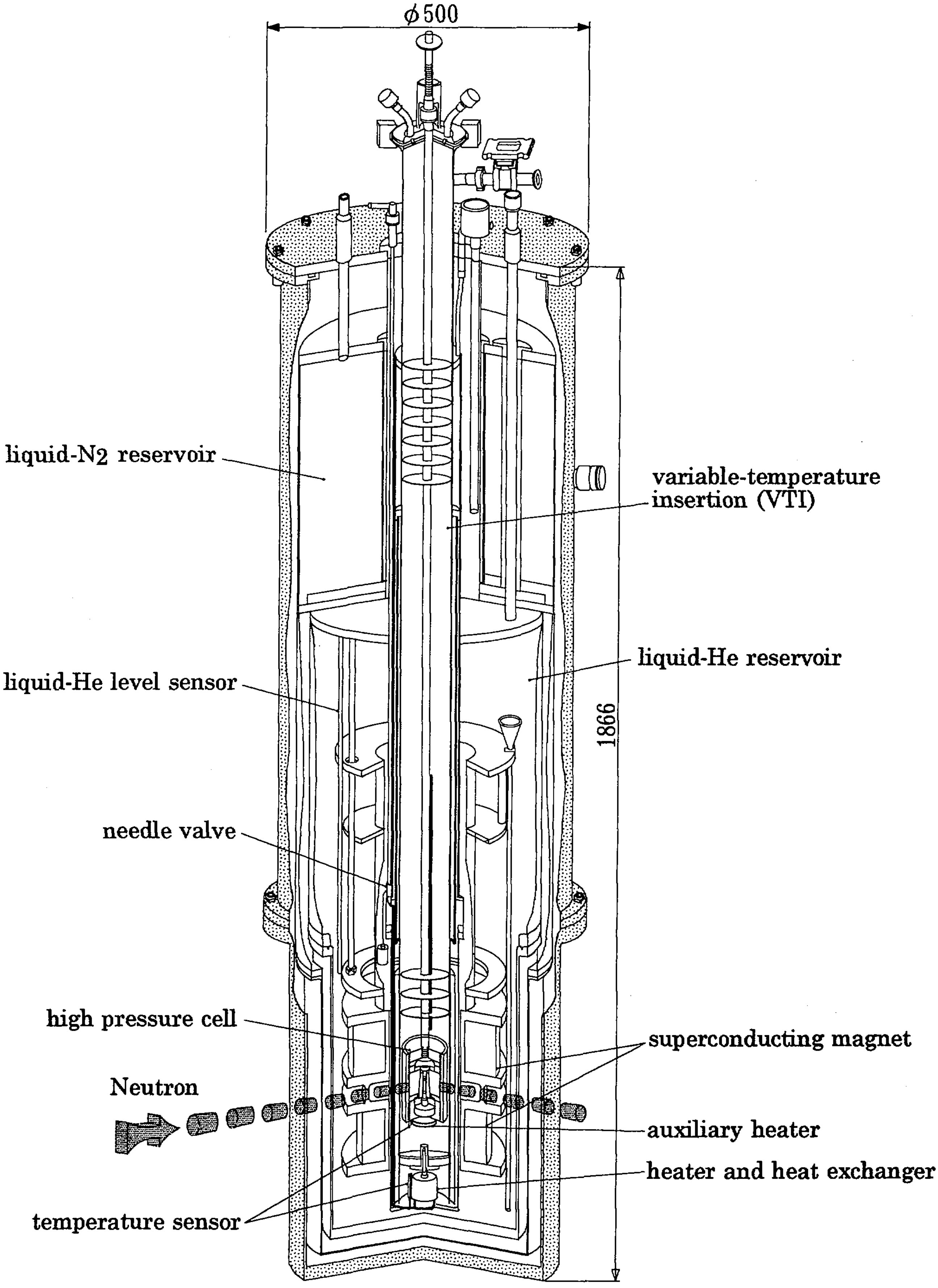

Fig. 9 Cut-away view of multiple extreme conditions system for neutron scattering