Cold Neutron Source(CNS) Facility in HANARO Reactor

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Abstract

The princple subjects of this study are to analyze the technical characteristics of cold neutron source(CNS) and take measures to cope with the matters regarding the installation of CNS facility at HANARO. This report, thus, reviews the current status of the CNS facilities that are now in operation worldwide and classifies the system and equipments to select the appropriate type for HANARO and provides advice and guidance for the future basic and detail design. As we have none of CNS facility here and very few experienced persons yet, this report provides some information for domestic users through the investigation of the utilization fields and cost for the project based on JRR-3M. In addition, the work scope of the conceptual design, which will be performed in advance of the basic and detail design, and cooperative program with the countries having the advanced technology of CNS is presented in this report.

1. Introduction

The Korean multi-purpose research reactor, HANARO was inaugurated on February 8, 1995 by reaching to its initial criticality. Among various kinds of utility facilities, some are being tested before in-service and others are still being constructed or installed. Cold neutron source(CNS) facility and Boron neutron capture therapy(BNCT) are in the stage of a conceptual design.

For the installation of CNS at HANARO, some technical review and analysis has been taken to reveal physical interfaces and problems. Even though CNS installation has been considered from the beginning stage of HANARO design since 1985, only circular type vertical hole(16cm dia.) for the cold source and rectangular type horizontal beam tube(6 x 15cm) for neutron guide were secured in the reflector tank. Cryogenic system for cold source circulation and the divergence of cold neutron guides from the nozzle of reflector wall in need of more than one guide had not been considered technically when the reactor structures and embeded parts were being designed and constructed.

Consequently, HANARO, which refered the general concept to the CNS of Orphee reactor in France and of JRR-3M reactor in Japan, may take a drastic engineering modification due to physical interfaces and engineering shortfalls to accommodate the cold neutron facility. For example, thermosiphon route of hydrogen cold source from the moderator cell to hydrogen condenser could be submerged in the present pool without modification, but hydrogen condenser and buffer tank should be put in the separated pool from the reactor. However, there is no sub-pool or auxiliary water pool for these system to be submerged. So it must be designed as a triple layer system to prevent leaked hydrogen from contacting with air. Nitrogen or other inactive gas seal system have to be applied to the triple layer boundaries.

Apart from the engineering aspect of the CNS facility in HANARO, a fundamental matter for design of CNS is to select the suitable instruments for the neutron utilizing research purposes. Despite that we finalized a research target purpose, it still remains how we could develop detailed specifications of the instrument without having proper experiences for the instruments. For the resolution of these problems, we are going to categorize in two groups through a technical conceptual design. By surveying the utilization of existing instruments in foreign countries and technical papers related to neutron utilizing experiments, we will select first standard instruments for general purposes of a neutron research and second specific instruments of very high class for the advanced research purposes. Before finalizing each kind of specification of instrument, very experienced neutron physicists will be invited to give final comments so that the specification can be tuned up. Even engineering shortfalls and interfaces in the CNS of HANARO would be resolved through detailed conceptual and basic engineering works which will be carried out jointly with highly qualified foreign companies from 1996.

2. Analysis of Technical Characteristics of KAERI Cold Neutron Source(KCNS)

Since 1985 when the design of HANARO was started, CNS has been considered for basic research and development of applied technology such as material and polymer science. As there are none of CNS facility and very few experienced persons yet in Korea, it is important to analyze the technical characteristics of CNS and take measures to cope with the matters regarding the installation of CNS at HANARO.

The design of cold source, neutron guide tube, and other facilities for the CNS will be started in 1996, and completed in 1999. From 2000 to 2001, experimental facilities such as 30m SANS, TOF Spectrometer etc will be installed.

Considering the fact France has been leading CNS technology and cold neutron research outputs with an exellent performance, the CNS type of ORPHEE in France has been set up as a model for examining the technological characteristics and utilization scope in HANARO while making an extra investigation of and analysis for the status of that kind in NIST, U.S.A. NIST has been using D2O Ice Block as a cold neutron source, but recently has converted it into LH2. Consequently it was found out that the CNS characteristics of France, Japan and U.S.A. was the type using LH2 as a cold neutron source only with the dissimilarity in ways of conveying heating medium and the design of auxiliary system.

3. General Concept of KCNS

The KCNS will consist mainly of two parts as shown in Fig 1. One of them is the hydrogen system which will contain the condenser with cryopump and rupture disk, the cold transfer tubes, the vacuum chamber and the moderator cell. Another is the helium refrigerator system for supplying low temperature helium gas of 20K to the condenser, that consists of compressors, heat exchangers, control heaters etc. The building layout of KCNS is shown in Fig 2.

Based on the comparision with and analysis of the utilization fields and experimental facilities of CNS that are now in operation over the world, the CNS type suitable for HANARO is conceptualized as follows.

Type	:	Vertical
Cold moderator	:	Liquid H2 (Approx. 5 liters)
Moderator cell	:	Al or Sus 304L
		Double Cylindrical type
		Diameter $\leq$ 16cm
Heat removal	:	Thermosiphon type / Gravity flow
Hydrogen sealing	:	Submerging or Triple barrier
Refrigeration capacity	:	1200 ~ 1500W
Neutron guide tube	:	^{58}Ni or Super-mirror

Fig 3 shows the moderator cell of KCNS. The liquid hydrogen cold moderator is arranged in the form of a flat cylindrical vessel. In the vessel, the liquid fraction would be about 80% at 1.5bar so that the efficient thickness of liquid hydrogen be about 3cm. The volume of the vessel is approximately 1 liter, which implies 0.8 liters of liquid in the moderator cell during operation. Additional liquid will fill the supply line and part of the phase separator at the condenser. Fig 4 & 5 shows the dimensional size of CNS vertical hole for horizontal beam tube in the reflector vessel.

The characteristics of CNS being operated all over the world is shown in Table-1 and compared with KCNS to be installed at HANARO.

4. Test program and safety aspects

For successful moderation, hydrogen in the moderator cell must be kept at normal liquid density (70 kg/m³). As it is very difficult to predict the nature of the flow of boiling hydrogen in a cell, testing with full-scale model of the moderator chamber is necessary. This experiment will be focussed on observing the flow pattern of the working fluid, measuring the heat transfer limitation, the liquid level and void fraction in the moderator cell as a function of the charged liquid volume and thermal input by glass model.

In addition, mechanical strength test and radiation-proof test of moderation cell, explosion proof test through oxygen-hydrogen reaction will be performed.

Safety aspects with hydrogen are based on a double containment structure for hydrogen with a vacuum blanket and complete immersion of the hydrogen container both in the reactor pool and the sub pool. These aspects are focussed on preventing a contact between hydrogen and air in case of an accidental loss of leaktightness. The whole outer containment of hydrogen is strong enough to withstand the pressure of detonation that is the most severe phenomenon of oxygen-hydrogen reaction, that will be verified by qualification tests performed on the full scale models in the future. The sub-pool separated from the reactor pool will be considered whether it must be constructed or not so that the indepedent maintenance works can be carried out easily.

5. Review of Interferences When Installing CNS at HANARO

- Sealing vertical hole to make vacuum inside
- Installing sub-pool/Triple or quadruple layer of cryostat system
- Penetration of reactor pool wall
- Feasibility of the installation and maintenance of the CNS facility

6. Review of Technical Cooperation

The proposal for the conceptual design of KCNS submitted by some French company is on the review stage now. Technical informations are presently exchanged under the technical cooperative program between KAERI-JAERI. And also Technical cooperation with NIST, USA is being planned to select the suitable instruments and physicist training.

7. Installation schedule and Investment plan

Table-2 shows the installation schedule and investment plan for CNS work at HANARO.

8. Conclusion

Cold neutron has been used extensively for the study of the structure and dynamics of materials in some advanced countries during the last decades or so. According to the industrial progress in Korea, CNS facility becomes more indispensable to develop fundamental technology for industrial application such as polymer science, structural biology, colloidal chemistry, and metallurgy.

The research activity using cold neutron in Korea lags behind the other advanced countries. With the light of the PLS(Pohang Light Source, linac, 2 GeV) dedication to the science, physicists and industrial circles in Korea came to be enlightened for developing new materials and superconductors, and for studying the structure of bio-assembly, etc., and they are expected to perform fundamental experiment by using cold neutron.

As HANARO is producing high-flux neutron necessary for the study of advanced application of neutron, it is highly required to install CNS at HANARO as soon as possilble before its severe activation.

Reference

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Item	Orphee	HFR in Grenoble	JRR-3M JCNS	HANARO KCNS
1) Type	· Vertical · Thermosiphon	· Vertical · Thermosiphon	· Vertical · Thermosiphon	· Vertical · Thermosiphon
2) Cold moderator	liquid H_2	liquid D_2	liquid H_2	liquid H_2
3) Moderator cell capacity(ml)	~800	20×10^3	800	800~1000
4) Vacuum facility material	AG 3 NET	Zirc-2	Sus 304L	Sus 304L
5) Moderator cell material	A286(S.S)	99.5%Al	Sus 304L	Sus 304L
6) Refrigeration capacity(W)	700	10,000	1,200	1,500
7) For safety	H_2 system - in water - vacuum - adibatic	D2O system -in water -buffer tank sealed with N2 gas /double containment -vacuum -adiabatic	H_2 system - in water - vacuum - adibatic	D2O system -in water -buffer tank sealed with N2 gas /double containment -vacuum -adiabatic
8) Operation	1980	1972	1990	1999

Table-1 The Characteristics of CNS to be installed at HANARO

No	Work		1995	1996	1997	1998	1999	2000	2001
1	Investigation of Tech. Characteristics		—						
2	Design	Conceptual		—					
		Basic			—				
		Detail			—				
3	Order for Equip.					—			
	Bldg. Construction				—	—			
4	Equip. Installation						—		
	Safety Analysis					—			
5	Licensing/						—		
	Commissioning &						—		
	Operation							—	
6	Experimental Facility							—	—
	Investment(million $)		0.875	12.5	17.5	6.625	10	10	57.5

Table-2 Installation schedule and Investment plan

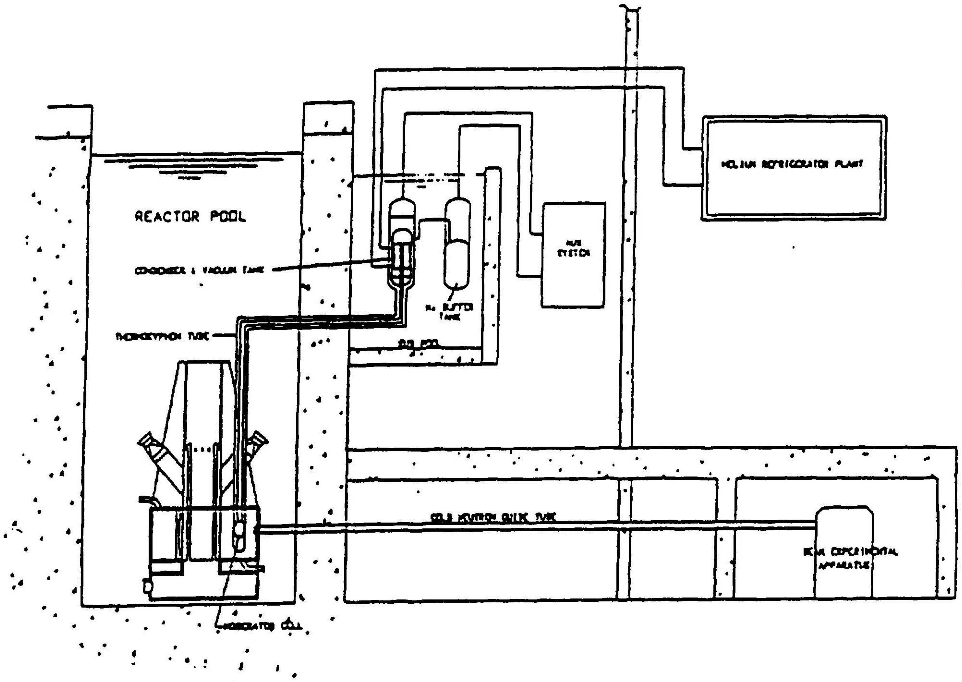

Fig 1 KCNS Block Diagram

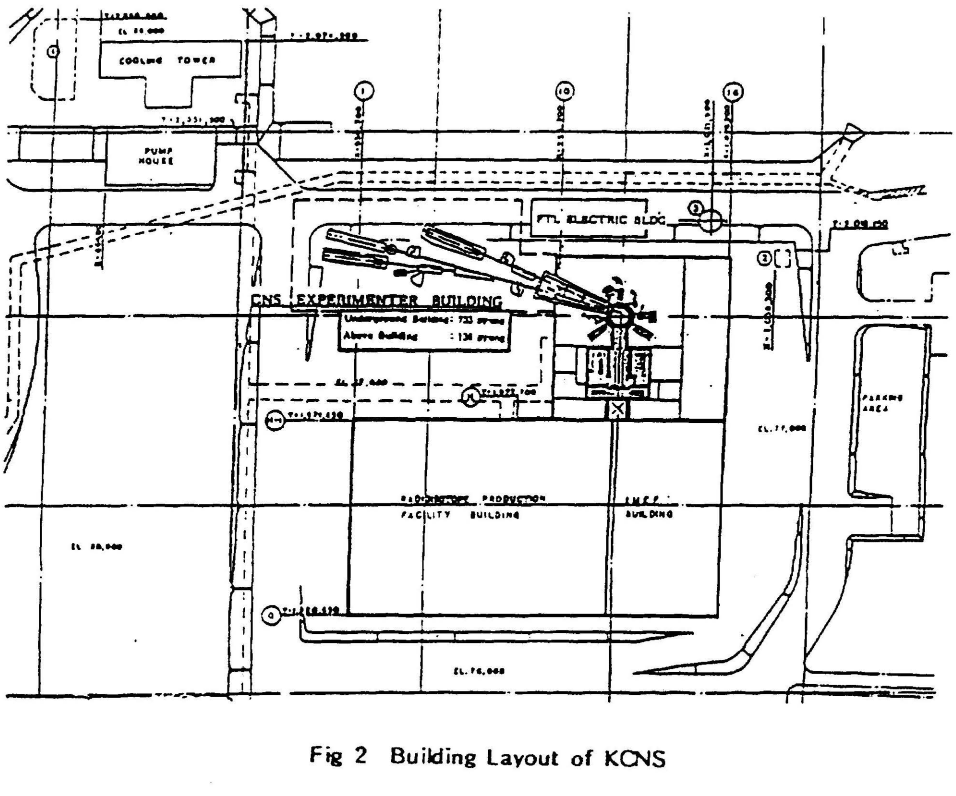

Fig 2 Building Layout of KCNS

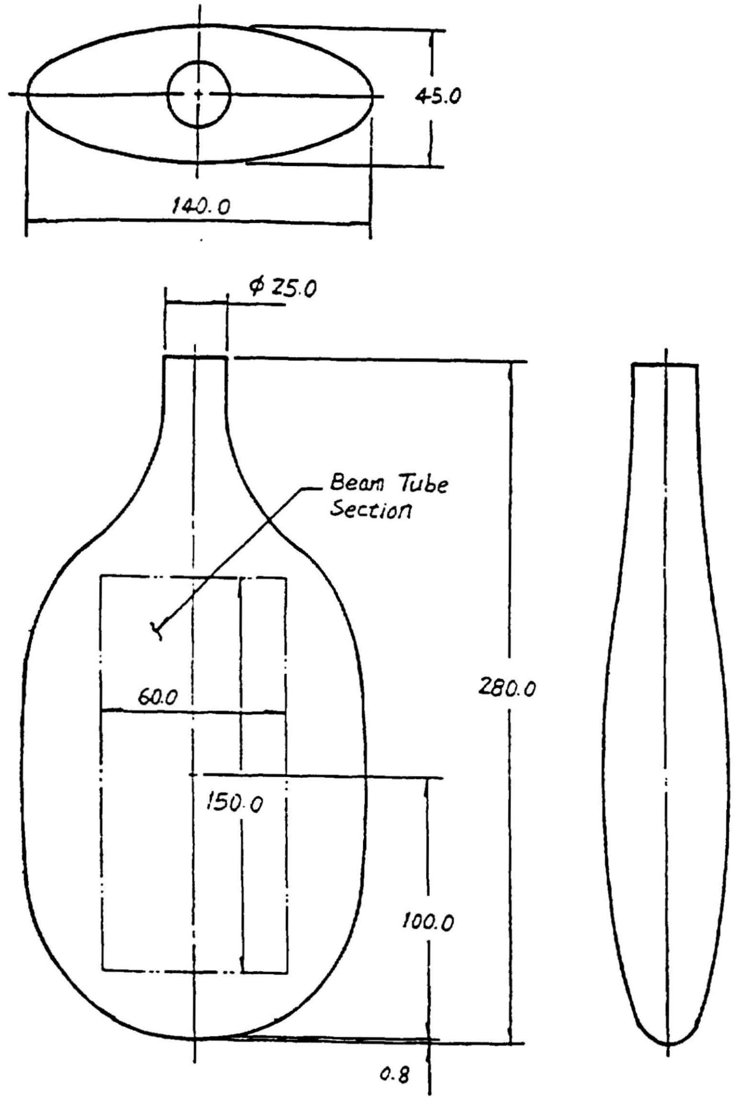

Fig 3 Moderator Cell of KCNS

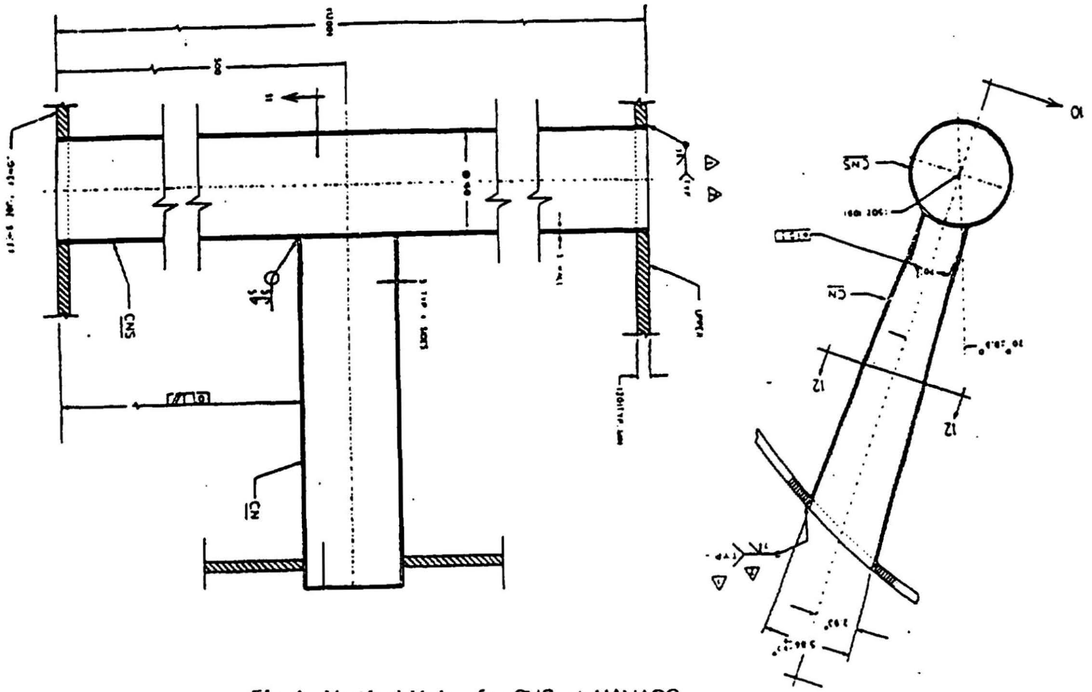

Fig 4 Vertical Hole for CNS at HANARO

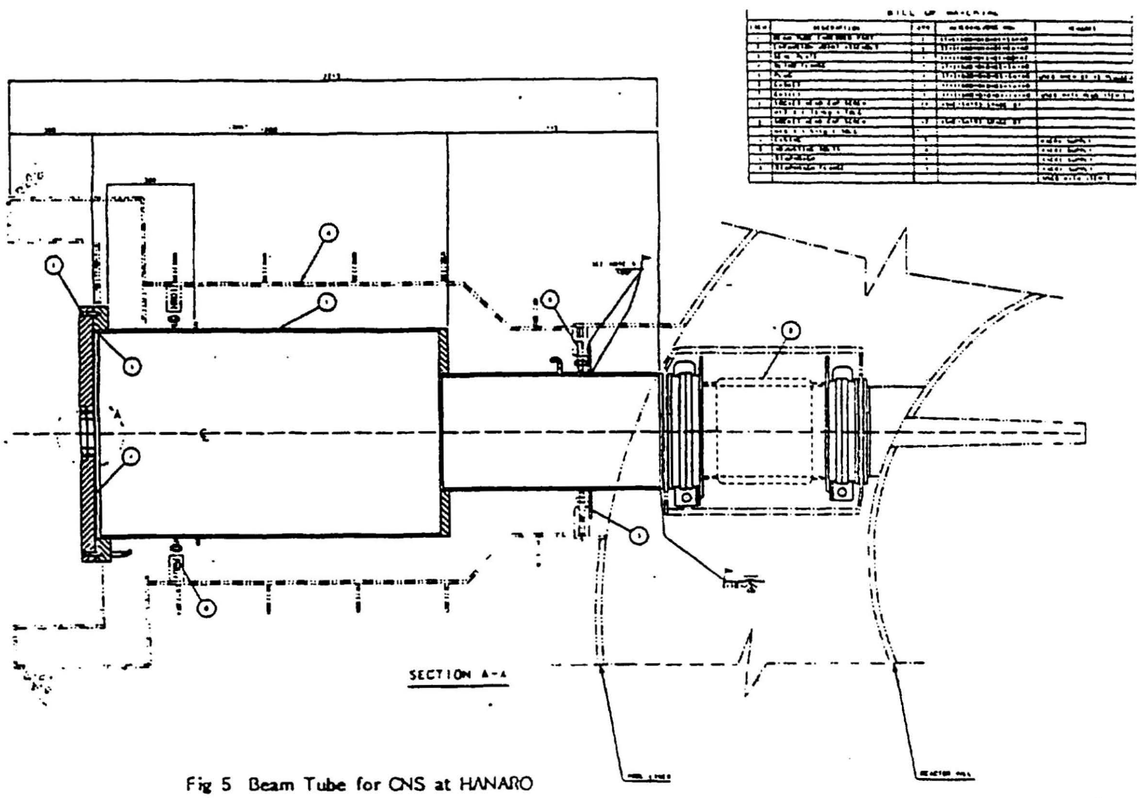

Fig 5 Beam Tube for CNS at HANARO