RESEARCH REACTOR'S ROLE IN KOREA

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ABSTRACT

Since TRIGA MARK-II was constructed in 1962, new research activity utilizing neutron had prevailed on the all science field in Korea.

Radioisotopes produced from the MARK-II played a good role in 1960s to educate people what the neutron is. As research reactor implanted the neutron science in the country, another TRIGA MARK-III had to be constructed within 10 years after importing the first reactor due to increased neutron demand from nuclear community. This kind of research environment utilizing research reactor however, came to be cooled down by means of abrupt nuclear power plant project. For a while research activities were almost oriented to nuclear power plant technology and its localization.

However, the localization of nuclear power plant technology caused to require more highly capable research reactor like HANARO 30MWt. HANARO will meet all the engineering tests and nuclear programs with high performance in the future.

1. INTRODUCTION

Since nuclear energy was introduced to the world through World War Two and the peaceful use of the nuclear energy was proposed at the 8th U.N. General Assembly in December 1953, the nuclear energy became a dream that Koreans had desired to realize as an ideal energy resource. So Korean government legislated the Atomic Eenergy Law in 1958 and started to review the import of research reactor in order to implant nuclear energy into the country. TRIGA MARK-II of 100kW thermal power, was first imported from General Atomic Co. U.S.A. in 1962. This reactor played a pioneering role in Korea in the division of reactor engineering, neutron physics, radioisotopes production, and other basic researches in various fields.

Many demands from various research fields for higher level of neutron caused to increase the capacity of TRIGA MARK-II from 100kWt to 250kWt in 1969. This power up-grade is the first application of our own technology which had been accumulated by then through the experience of reactor operation. As even the up-graded capacity of TRIGA MK-II couldn't meet the requirements of increasing neutron from various research fields, the construction of mega watt level of research reactor was demanded and came true.

The construction of TRIGA MARK-III of 2MW thermal power was launched in 1969. The construction work of this reactor was carried out under non turn-key-base with foreign company which was a different type of contract from that made at the time of construction of first reactor because some technologies in design and construction during the first reactor installation were transplanted into the country.

The second reactor, TRIGA MARK-III came in normal operation from 1972, which has 2MW thermal power and about 10 times higher neutron flux level(6.5×10^{13} $n/cm^2 \cdot sec$) than the first reactor, TRIGA MARK-II. The first reactor was mainly dedicated to student education, while the second one furnished the facilities primarily for training of personnel, radioisotopes production, neutron activation analysis, beam experiments and neutron radiography.

Korea Atomic Energy Research Institute(KAERI), established in 1959 as the master organization subsidized by government for nuclear technology development, made long-term national plan for the development of nuclear technology. According to the plan, nuclear technologies, even related to nuclear power plant, were planned to be developed by using research reactor.

However, the government had launched the 5-year national economic development plans since 1962. The national prosperity through successful performance of the each economic plan had resulted in the magnificent rate of energy increase every year. So government expedited the nuclear power program to meet the sharply increasing energy requirement. Heavy blow in oil price at 1973 became another cause for speeding up the nuclear power program.

As nuclear power plants(NPP) became reliable resources of electrical power supply in the country, safety analysis and the localization of important parts of NPP were stood out as the main research subject. This new blow of phenomenon consequently caused basic research activity to be reduced and engineering application study to be increased every year. Unfortunately the existing research reactors couldn't meet new requirements for engineering application study from nuclear community.

Under the realistic requirements of multi-functional and powerful reactor from nuclear community, KAERI started multi-purpose research reactor(KMRR) project of 30MWt in 1985. From the basic design phase of the multi-purpose reactor AECL cooperated with KAERI to complete the reactor successfully.

2. Nuclear technology development status

The brief outline is given here of the progress of nuclear technology development in Korea divided into 10-year term basis. 1960s is the period of implementation of nuclear basic technology, 1970s is the period of technology build-up, 1980s is the period of basic stage for technical self-reliance, and 1990s is the period of maturing stage for technical self-reliance.

2.1 1960s

When KAERI was established in 1959, lots of expectation and concerns for the new science subject across the nation became a kind of hard challenge to KAERI.

In this period, the government didn't have any long-term policy for the nuclear energy development, nor furnished ample funds to any research subject for nuclear study, as a matter of course all research works in the institute were inactive until TRIGA MARK-II had been in operation. Following the operation of TRIGA MARK-II, the government allowed KAERI to carry out its research program by supporting relatively enough research funds, so reactor characteristic experiment, neutron physics test, radioisotopes production and some studies using neutron in medicine and agriculture had been performed actively by utilizing the reactor.

Basic research, personnel training and production of small quantity of radioisotopes were main activities. KAERI was encouraged to set up long-term plan for the nuclear technology development in this period.

2.2 1970s

The normal operation of TRIGA MARK-III in 1972 had contributed to activate applied research as well as basic research. However, spike increase of electrical power demand due to nationwide prosperous industrialization enforced promptly nuclear power plant(NPP) to be in the power supply grid. Four units of pressurized water reactor(PWR) owned by Westing House Co. were to start construction in 1970, 1976, and 1978 respectively. Another type of NPP, CANDU reactor by AECL was to start construction in 1976. New era of energy supply by NPP was realistically opened at this period.

Research purposes for nuclear technology were naturally oriented to NPP related subject like nuclear safety and localization of some components. Study of design code verification and the inspection work at the NPP construction site prevailed on KAERI.

Fuel design and manufacturing technology was another het-up subject for studying. For technology transfer of nuclear design and engineering from foreign company, KAERI organized an independent architecture engineering(A/E) company inside the institute at 1975, and then for the purpose of nuclear fuel manufacturing, KAERI installed nuclear fuel development center.

2.3 1980s

A drastic measure was taken by the government to enforce nuclear technology localization. The government established the policy that every NPP should be designed and constructed by joint work with local company.

KAERI became a local counterpart to foreign company for the joint design of NSSS in NPP. This prime role of KAERI in NSSS design jointly with foreign partner caused the institute to be grown-up enough to design reactor by itself. CANDU fuel was localized and some technology for radiowaste treatment was developed. Further 6 units of PWR were to start construction in this period. As nuclear facilities including NPP were being built-up every year, nuclear safety and licensing matter were raised as significant issues.

Nuclear safety center was established at KAERI in order to systematically review nuclear safety for every nuclear facility and to strengthen licensing issue matter. Likewise nuclear business prevailed across the country, consequently almost all the technical papers and reports are related to NPP. Engineering test and performance test in the irradiation status were becoming thirst from nuclear community, in addition to this, radioisotopes demand in the country were being increased 40% every year.

In order to figure out national research program for the present and future, KAERI took the survey of research requirements and testing purposes from nuclear community around the nation. Based on the results from the survey, multi-purpose research reactor of 30MWt was designed conceptually from 1985, and 10 years were consumed for this 30MWt reactor to be completely constructed

2.4 1990s

Huge construction works for NPP were marched on even in this period. 3 units of CANDU reactor and 2 units of PWR were to start construction, and then more 2 units of NPP are presently under negotiation. All design, engineering, and construction of NPP are being conducted by full responsibility of local company, of course foreign companies joined as technical adviser or consultant. Korean standard type for PWR was developed in this period. In case of CANDU, review and study for the korean standard are still continued between KAERI and AECL.

The most significant event in this period was the successful completion of 30MWt research reactor. This reactor reached its initial criticality on February 8, 1995. The government president congratulated the inaugral ceremony of the research reactor and opened another ceremony for the new name of the reactor "HANARO".

HANARO which was developed jointly with AECL becomes a milestone for the nuclear technology localization in Korea.

Table 1 shows the status of utilization of research reactor from 1961 to 1993.

Nuclear technology development status is summarized in Fig. 1.

3.0 HANARO Reactor

HANARO, new name of the 30MWt research reactor means "Uniqueness & Togetherness" in Korean version. HANARO reached initial criticality on February 8, 1995 and is under nuclear testing. Detailed nuclear characteristic measurement and zero power measurement are scheduled as shown in Table 2.

When HANARO was started in 1985, three principles were set up to be kept through the whole course of the project;

- first, accommodation of state-of-the-art technologies and R&D programs.
- second, maximizing the involvement of local technology.
- third, performing the test of design verification and R&D programs in parallel.

In order to develop reactor core concept accommodating these principles, qualified top-class multi-purpose research reactors which were being operated or constructed in the world at that time were reviewed and analysed.

Even in the course of reactor type selection, lots of factor such as thermal power level, neutron flux, fuel type, safe operability, low cost in construction and operation, etc. had to be fully counted and evaluated.

Maple-X reactor concept being developed at that time by AECL was evaluated to be most suitable to the HANARO requirements, so AECL was invited to join from the conceptual design stage of HANARO.

3.1 Utilization program

Experimental facilities of HANARO consist of irradiation facilities and beam experimental facilities. A total of 32 irradiation holes and 7 beam tubes are positioned for easy access to the experimental facilities. The specific utilization programs of these facilities comprise;

- Fuel and material testing
- Production of key radioisotopes including ^{99m}Tc, ^{131}I, ^{192}Ir, and ^{14}C, ete.
- Production of neutron transmutation doped silicon
- Neutron activation analysis
- Neutron beam experiment
- Neutron radiography
- Cold neutron source

in order to cope with above multiple utilization programs, neutron flux of high quality and enough space are provided for the experimental facilities.

The irradiation holes and beam tubes are shown in Fig. 2 and the experimental facilities to be installed are shown in Table 3 and 4.

4.0 Conclusion

Two research reactors, TRIGA MARK-II,-III had contributed to enlighten Korean scientist upon what the neutron energy is and how the neutron can be applied. KAERI came to set up long-term plan for nuclear technology development by the utilization of research reactor. However, earlier landing of nuclear power plants into the country than the original schedule due to the prosperous nationwide industrialization didn't give any chances for the research reactors to perform their role.

When HANARO project was satarted in 1985, all the researched and developed data by that time in the country were to be evaluted and analysed in order that the reactor must be designed and engineered by the maximum utilization of local technologies. Consequently HANARO project had given a good chance for the local technologies to be examined. The high level of neutron flux, 5×10^{14} n/cm^2·sec from HANARO will support and activate lots of domestic dream for having advanced nuclear technology in the world.

Table 1 Papers and Reports utilizing Research Reactors

Division \ 5 yr interval	'61～'65	'66～'70	'71～'75	'76～'80	'81～'85	'86～'90	'91～'93	Total
Reactor Physics & Material	17	23	8				2	50
Neutron Beam Application	3	4	4	2	5	4	5	27
RI Production	5	20	2			5	3	35
Medical Application	3	11	3	8	11	12	11	59
Agricultural Application	3			2	6			11
Biological Application	7	10	6			1		24
Neutron Activation Analysis	6	13	4	1	1	4	3	32
Health & Physics	17	27	6	2	4		1	57
Mech. & I&C Design	10	8	5	2	1			26
Operation	4	15	5	6	5	6	7	48
T o t a l	75	131	43	23	33	32	32	369

Table 2 Nuclear testing schedule of HANARO

1. Fuel loading and Initial Criticality

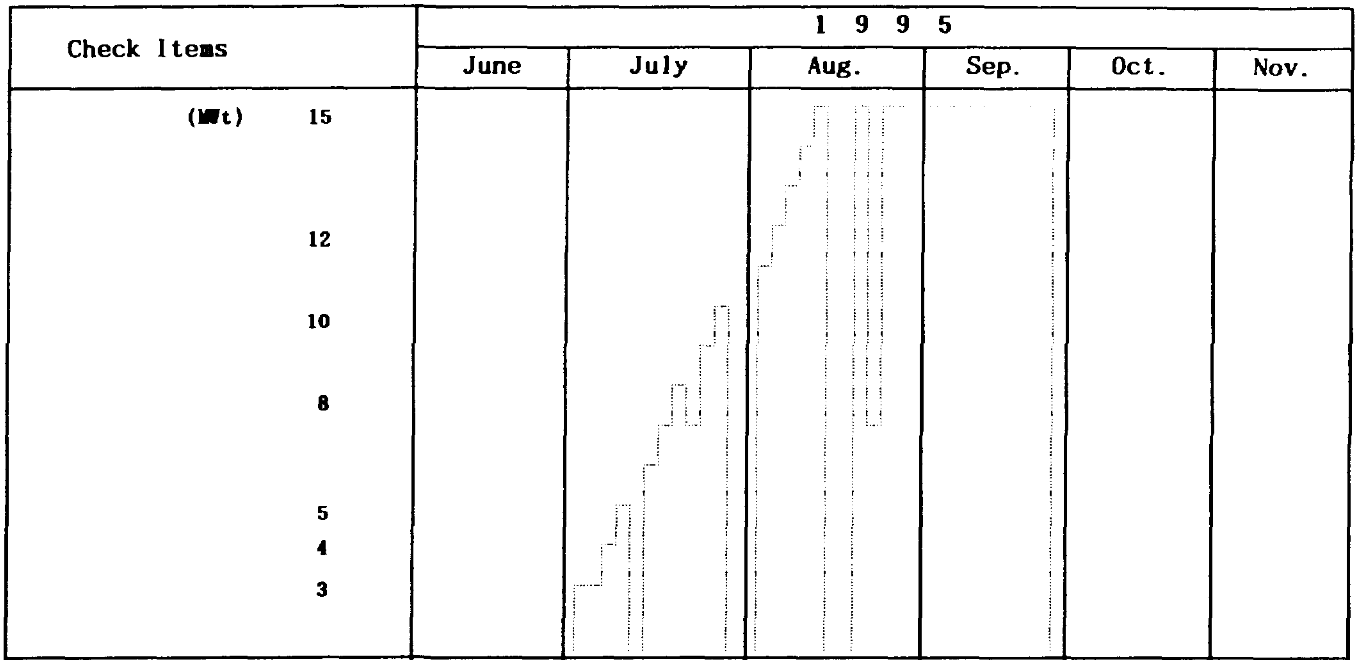
date / check items	January, 1995			February, 1995		
	1 ~ 10	11 ~ 20	21 ~ 31	1 ~ 10	11 ~ 20	21 ~ 28
Radiation monitor * cheeking every wednesday		O-O				
Fuel loading and initial criticality • Minimum core for initial criticality		O—	——	—O		
• Initial criticality				◎		

2. Operation core and zero power test

date / check items	1995					
	Feb	Mar	Apr	May	June	July
Operation core	O—	——	—O			
• measuring reactivity fuel			O-O			
Measuring reactivity of CAR/SOR	O-O					
drop time measuring	O-O					
neutron noise measuring	O-O					
void coefficient measuring			O—O			
thermal neutron flux mapping				O—O		
fast neutron flux measuring					O—O	
power distribation pes fuel bundle measuring					O—O	

Table 2 (continued)

3. Power ascention test



Check Items	June	July	Aug.	Sep.	Oct.	Nov.
Temp coeff. measuring	O-O					
Cooling cap. measuring		O—	—O			
Natural convection test	O—	-O				
Power defect measuriement		O—	—	—O		
Zenon characteristics test		O—	—	—O		
Normal power failure		O-O	O-O O-O			
OPOH test		O-O	O-O			
Primary coolant treatment * Check every week		O—	—	—O		
Radiation monitoring * Check every week		O—	—	—O		

Table 3 Utilization facilities installed at irradiation holes

IRRADIATION HOLES	LOCATION	FACILITIES	6INSTALLATION YEAR
IP1 ~ IP17	Reflector	Capsule for RI(^{99m}Tc, ^{131}I, ^{51}Cr etc.)	'95
NAA1 ~ NAA3	〃	Pneumatic Transfer System	'95
NTD1, NTD2	〃	NTD-Silicon Production Facility	'95
LH	〃	Fuel Test Loop (For Steady-State)	'96
HTS	〃	Hydraulic Transfer System for RI	'95
CNS	〃	Cold Neutron Bource Facility	'99
OR3 ~ OR6	Core	Capsule for RI (^{192}Ir, ^{60}Co. etc.)	'96
IR1, IR2, CT	〃	Fuel Test Loop Facility (For Transient State)	'99

Table 4 Beam utilization facilities

BEAM TUBES	BEAM UTILIZATION FACILITY	INSTALLATION YEAR
IR	Irradiation Facility	'98
ST1	Polarized Neutron Spectrometer (PNS)	'96
ST2	High Resolution Power Diffractometer (HRPD)	'96
ST3	Triple Axis Spectrometer (TAS)	'99
ST4	Four Circle Diffractometer/Double Monochrometer TAS (FCD/DM-TAS)	'98
CN (Cold Neutron)	Small Angle Neutron Spectrometer (SANS)	'99
NR	Neutron Radiography Facility (NRF)	'96

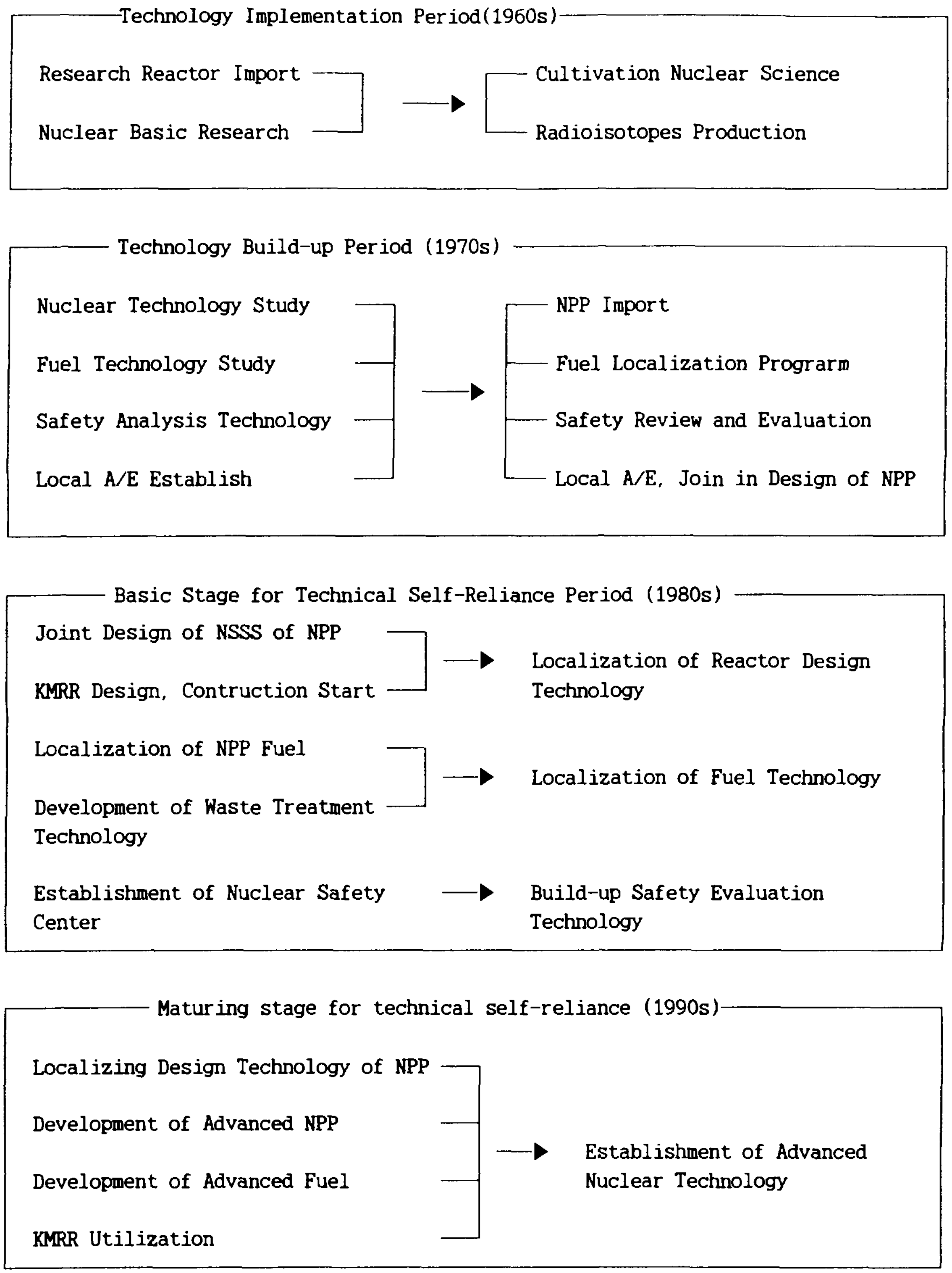


Fig.1 Summary of nuclear technology development in KOREA

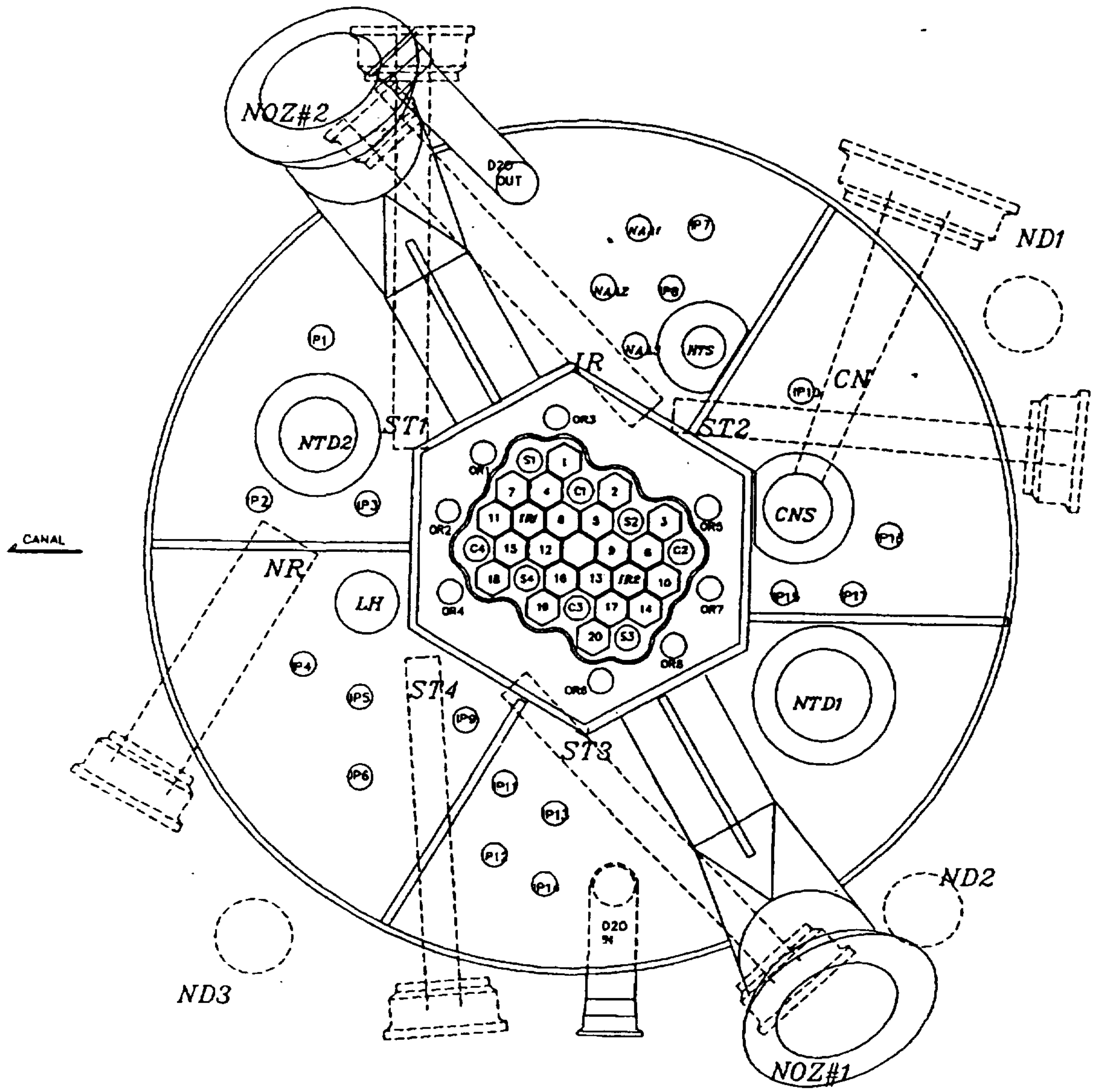


Fig. 2 Plane view of Irradiation Holes and Beam Tubes