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Status of Argonne's Intense Pulsed Neutron Source IPNS-I

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Abstract

IPNS-I is approaching operational state. This report gives brief descriptions of the major components of IPNS-I, and describes the present status of each.

I. Introduction

Construction of IPNS-I is complete, and the final phases of checkout and tuneup of the accelerator, neutron generating systems and instruments are underway. This is the culmination of efforts begun with Argonne's first prototype pulsed spallation neutron source, ZING-P′ in 1974, and we are all excited.

Figures 1 and 2 show the overall layout of IPNS-I. Some small changes in instrument locations have been made since our last report. Figure 3 shows the facility at the end of May, 1981.

Since the time of the last ICANS meeting, we have seen and responded to the report of a well-publicized review of the U.S. neutron source program (the Brinkman Panel review), by which we felt threatened. The end result has been that IPNS-I will operate, although with a budget which seriously constrains operating time, and which will not allow us to pursue planned accelerator improvements to increase intensities to our original design goals. Thus our goal is now to produce 8 μA, 500 MeV proton beam on target, at 30 Hz. Operating time is envisioned to be 6 months per year, on a 24 hour per day, 12-day-on, 2-day-off schedule. We hope to improve performance of the accelerator eventually to give 12 μA, 500 MeV, 30 Hz, through experience, minor improvements and tuning.

II. Status of IPNS System Components

A. Rapid Cycling Synchrotron (RCS)

Beginning in August, 1980 after final shutdown of the ZING-P′ prototype, we have installed an extensive series of modifications of the RCS accelerator systems. (The paper of C. W. Potts, et al., in the accelerator sessions of this conference contains more details.) The table below summarizes the most important modifications:

RCS Modifications

- Move Extraction Point
- Install new kicker magnets and supplies
- Install programmable octupoles and supplies*
- Expand computer control systems
- Strenghten shielding
- Install new beam position diagnostics
- Double capacity of RCS driver and predriver power supplies
- Install new RF cavity bias system
- Modify injection bumper system
- Improve linac cavity cooling

* programmable sextupoles already were included.

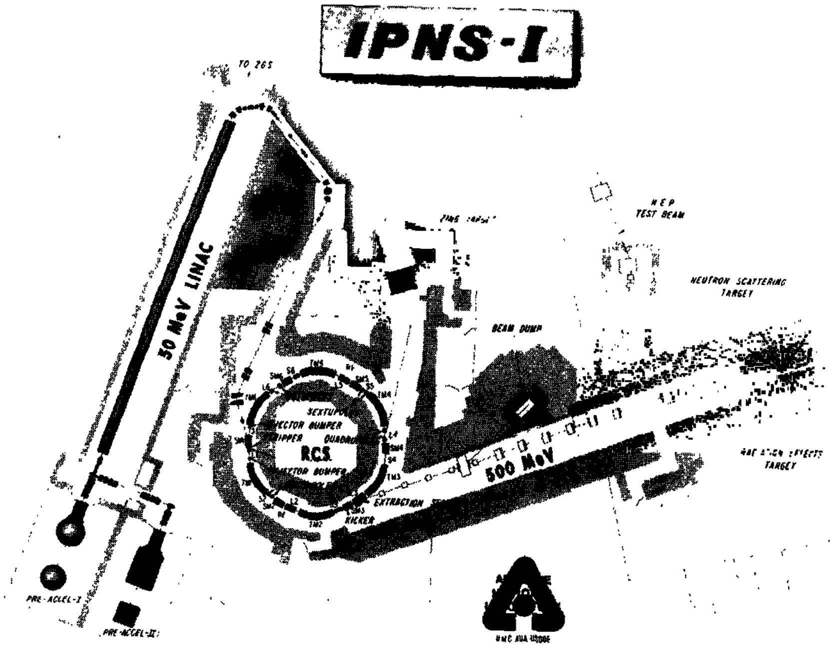
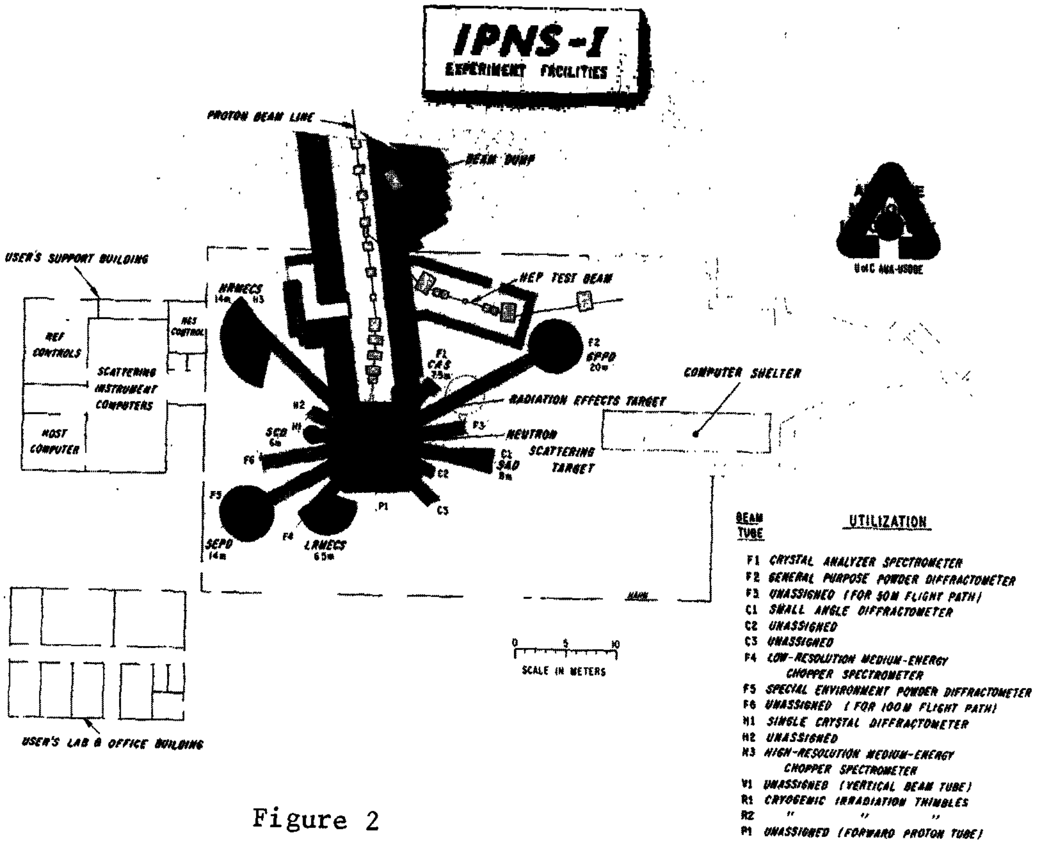


Figure 1



BEAM TUBE	UTILIZATION
F1	CRYSTAL ANALYZER SPECTROMETER
F2	GENERAL PURPOSE POWDER DIFFRACTOMETER
F3	UNASSIGNED (FOR 50M FLIGHT PATH)
C1	SMALL ANGLE DIFFRACTOMETER
C2	UNASSIGNED
C3	UNASSIGNED
F4	LOW-RESOLUTION MEDIUM-ENERGY CHOPPER SPECTROMETER
F5	SPECIAL ENVIRONMENT POWDER DIFFRACTOMETER
F6	UNASSIGNED (FOR 100M FLIGHT PATH)
H1	SINGLE CRYSTAL DIFFRACTOMETER
H2	UNASSIGNED
H3	HIGH-RESOLUTION MEDIUM-ENERGY CHOPPER SPECTROMETER
V1	UNASSIGNED (VERTICAL BEAM TUBE)
R1	CRYOGENIC IRRADIATION THIMBLES
R2	" " "
P1	UNASSIGNED (FORWARD PROTON TUBE)

Figure 2

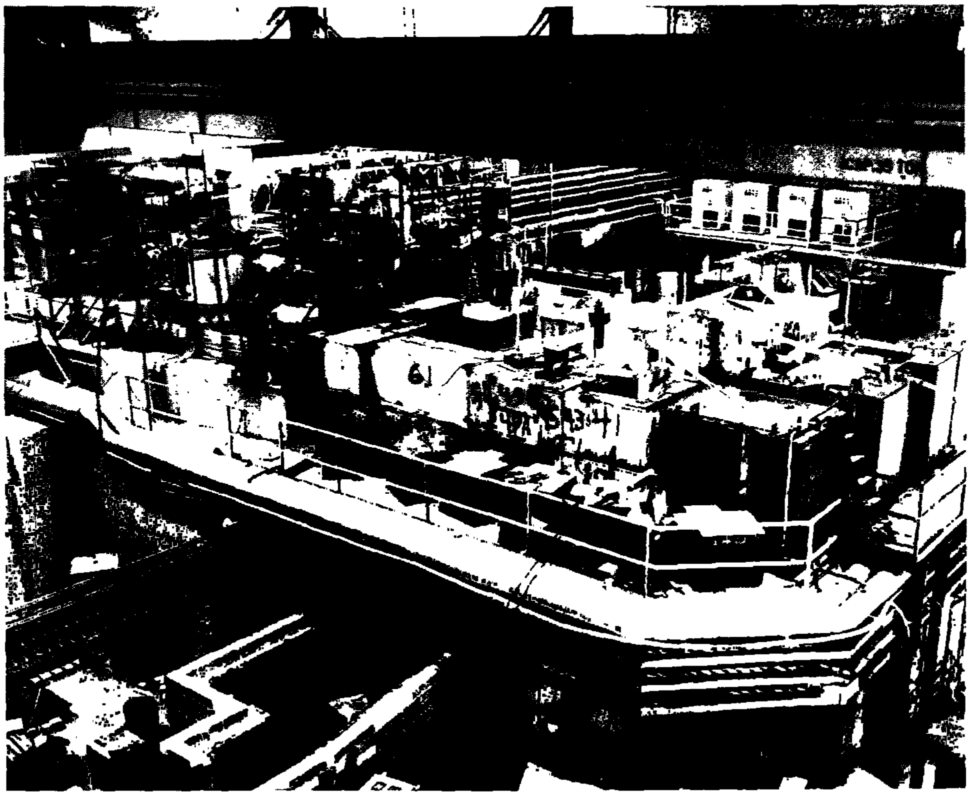


Figure 3

We completed these changes and resumed operations in a tuneup mode in April, 1981. Throughout, we found the usual large number of minor problems, and are curing them one by one. By early June 1981, we had accomplished a 18-hour run, with about 75% efficiency giving an average current of 4.5 μA of 500 MeV protons on the Radiation Effects Target of IPNS. During earlier 300 MeV operation, we delivered peak beam 20% higher than we were able prior to making these modifications.

Penning ion source development has been dropped, as have the once-intended modifications for 45 Hz operation.

B. Proton Transport System (PTS)

A new proton transport system connects the Rapid Cycling Synchrotron to the Neutron Generating System. The system includes a water-cooled graphite beam dump, which is designed as an efficient Faraday cup, and incorporates an upstream irradiation cavity. The system also provides a secondary (scattered) beam for use in testing high energy particle detectors. We adopted a very conservative design philosophy with the aim to minimize proton losses and maintain backgrounds in the experiment areas. All magnets and power supplies are second-hand components we obtained from Argonne's shutdown of ZGS as were most of the shielding steel and concrete. Ionization chamber loss monitors, beam-measuring toroids, and remotely movable segmented secondary emission monitors are distributed along the beam line to provide tuning and control information. The last magnet, a d.c. dipole, switches the beam alternatively between the two neutron generating targets.

The system is complete and, since debugging of instrumentation, has operated without any problems. We have noticed that the shield design contains a flaw in that groundshine beneath the shield walls may give personnel backgrounds greater than the design value, if proton losses are as great as 1% at any point. However, radiation surveys so far indicate no such problem.

C. Neutron Generating Systems

IPNS has two targets, one for fast-neutron irradiation experiments (the Radiation Effects Facility, REF) the other for slow-neutron beam experiments (the Neutron Scattering Facility, NSF) as shown in Figure 4. The targets shown in Figure 5 are nearly identical 25 mm x 96 mm ϕ depleted Uranium disks, clad with .5 mm thick Zircaloy-2, cooled by light water. Four of the eight disks contain thermocouples.

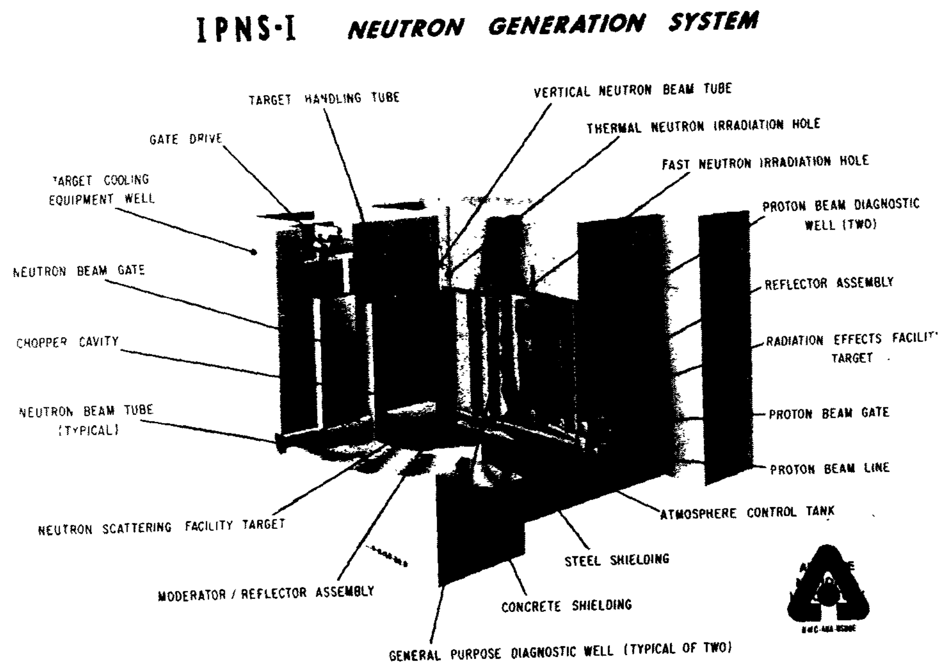


Figure 4

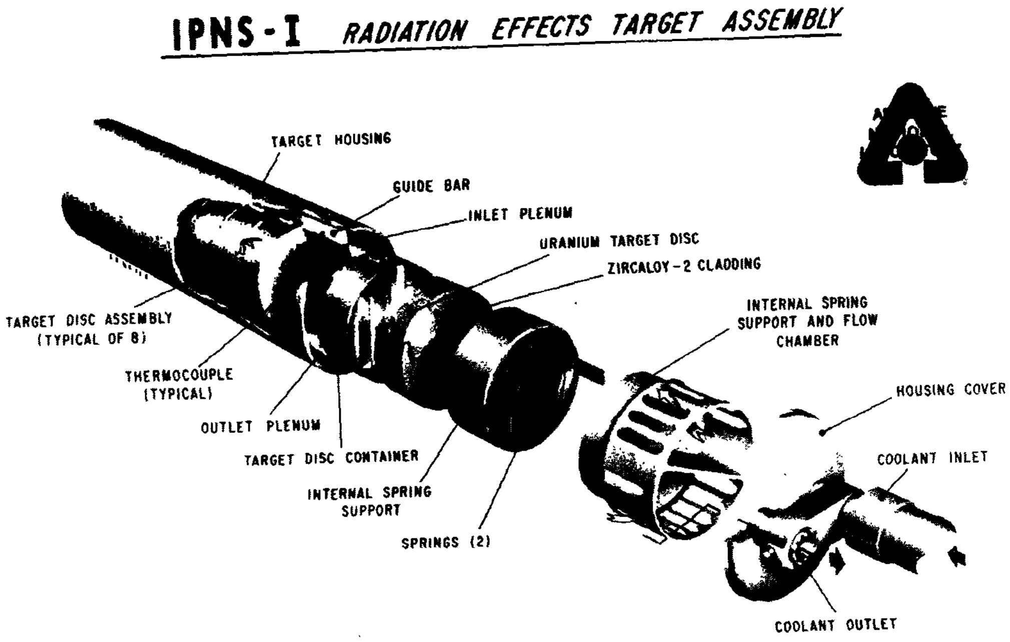


Figure 5

Aluminum-encased Pb reflectors surround the REF target, with two 50 mm ϕ vertical irradiation thimbles, and one 25 mm ϕ horizontal irradiation location. The reflectors are cooled by contact with a water cooled baseplate. Figure 6 shows the Radiation Effects Facility.

Proton beam delivered to the REF target produces the expected temperature rises in the disks; the thermal response consists of two main components, with e-folding times of about 7 sec, and 2 sec, which we have observed.

Four Beryllium-reflected moderators, two of Liquid H_2, two of Liquid CH_4, surround the Neutron Scattering Target illustrated in Figure 7. The inner Beryllium region is held at 100K to depress the thermal neutron spectrum and enable decoupling at lower energies. In the outer (300 K) Be region are two vertically-accessible thermal neutron irradiation thimbles. Pumps independently circulate cooled cryogens through the moderators. 14K He cools the hydrogen; 100K He cooled by liquid N_2 cools the methane. We have experienced a long series of problems with this complex system which are gradually being overcome. In early June, 1981, the system is not yet working and is delaying startup of the Neutron Scattering Facility. Figure 8 shows approximately the peak flux spectrum expected of the CH_4 moderator "H".

Primary shielding consists of about 4 meters of iron in an atmospheric control tank, and 2 meters of concrete. Twelve horizontal holes of approximately 30 x 45 cm^2 dimension provide neutron beams. Large iron plugs made in 4 pieces, contain 15 x 15 cm^2 channels into which collimating inserts can be placed. One-meter thick iron beam gates provide protection from direct radiation in the neutron beams when experimenters call for it. Each beam contains a vertically-accessible cavity in which to place a chopper, filter or other device. One of the gates has been modified to act as location for filters; one of the chopper cavities will contain a gate. The vertical beam contains a Ni guide tube.

Each target has its own cooling system; these can serve either target. Gross gamma activity near the demineralizer columns is continuously monitored to detect changes which may indicate target failure. Primary system water and surge-tank cover gas are periodically sampled and counted to detect abnormal activities. The monitoring and control system processes temperature and pressure data from numerous transducers in the target cooling system. The radiation around the cooling boxes is primarily .5 MeV annihilation radiation, which reaches levels around 400 mR/hr during 5 μA, 500 MeV operation.

Radiation surveys around the shield so far indicate that there are no weak spots when the Radiation Effects Target receives protons. However, contrary to our design intent, we find nearly .1 R/hr (at 5 μA, 500 MeV on the REF target) neutron dose rates above the solid-iron central shield, which we have tentatively identified as 25 KeV "iron-window" neutrons.

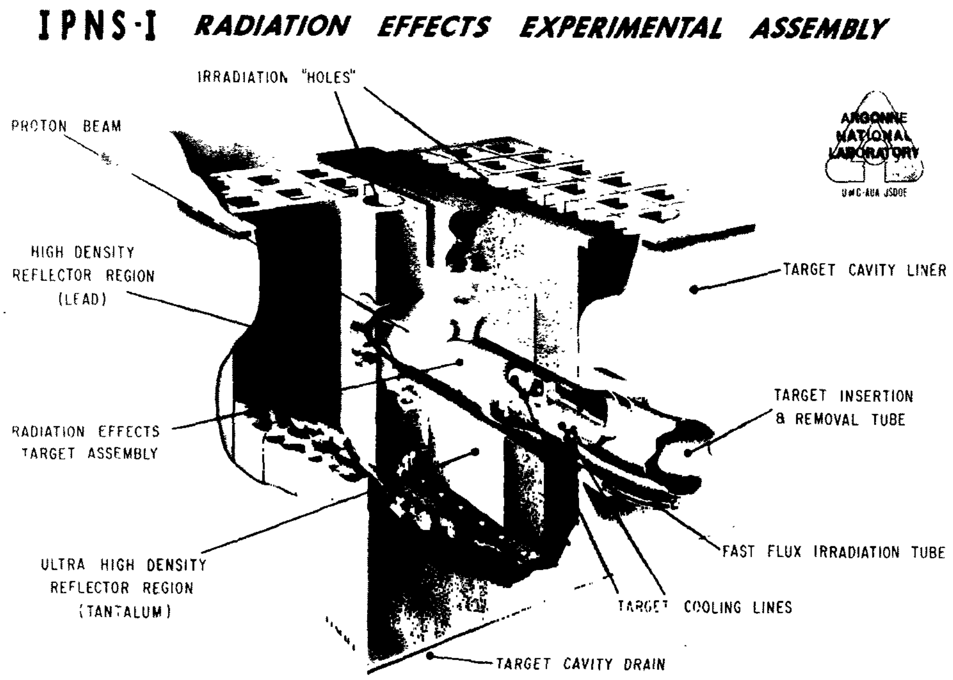


Figure 6

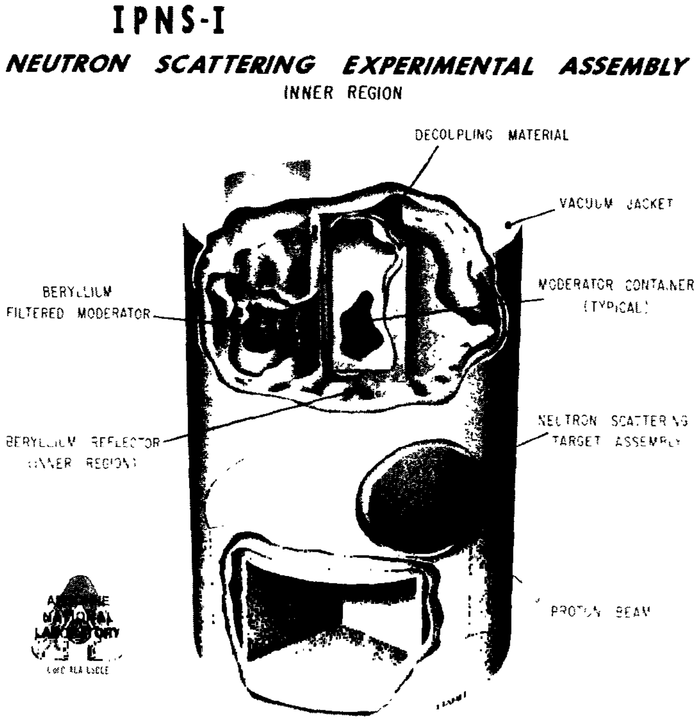


Figure 7

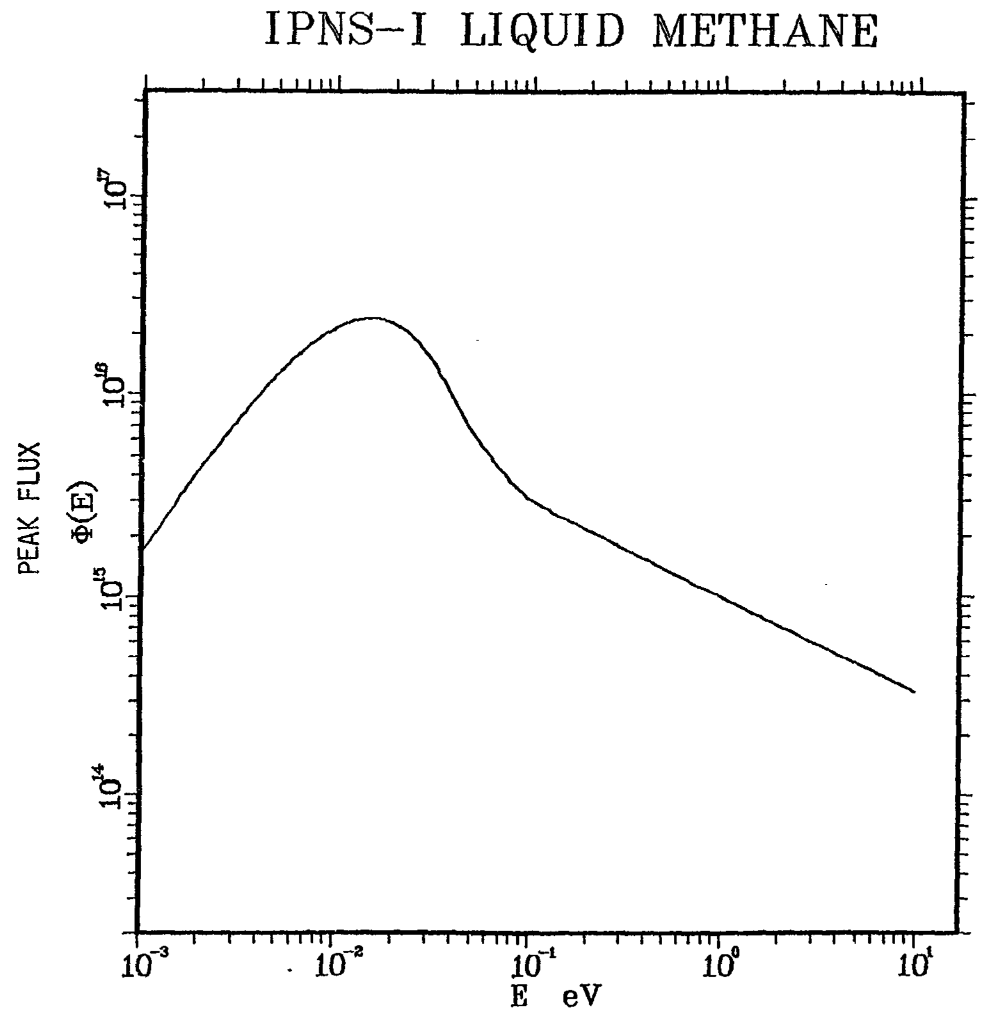
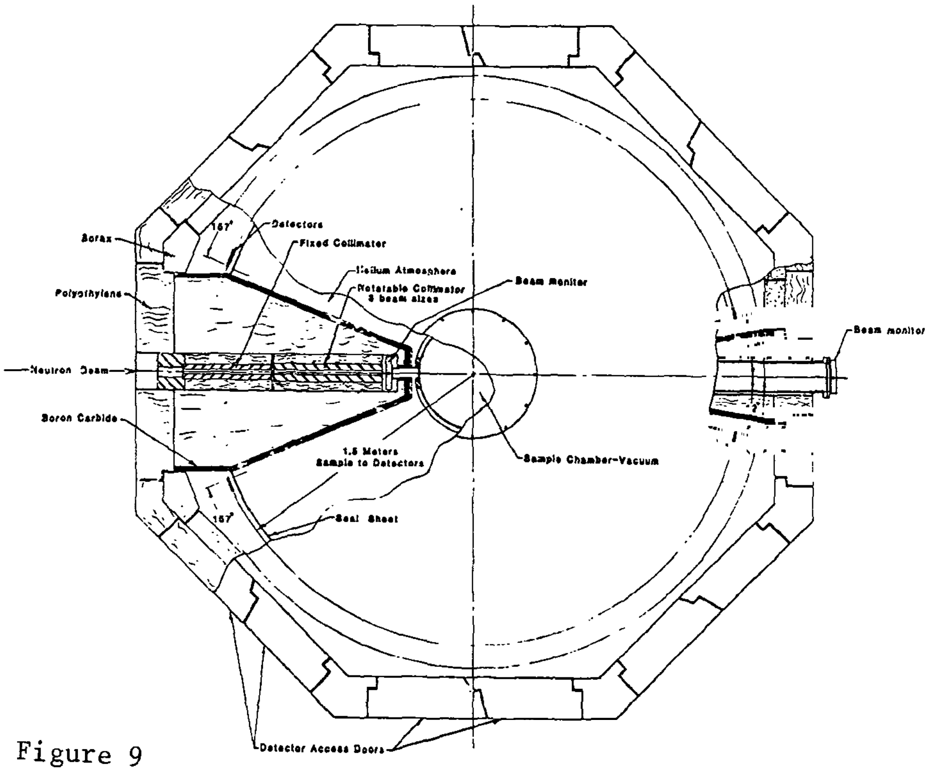


Figure 8 Spectral Temperature= 117.0
$Ith/[EI(E)]|1\ eV = 5.90$ $\tau(E) \cong 1.1\ \mu s/\sqrt{E_{eV}}$
$EI(E)|1eV = 3.25*10^{10}\ n/ster\text{-}sec\mu amp$
Frequency= 30.0
Proton Current= 8.00-μamp

D. Instruments

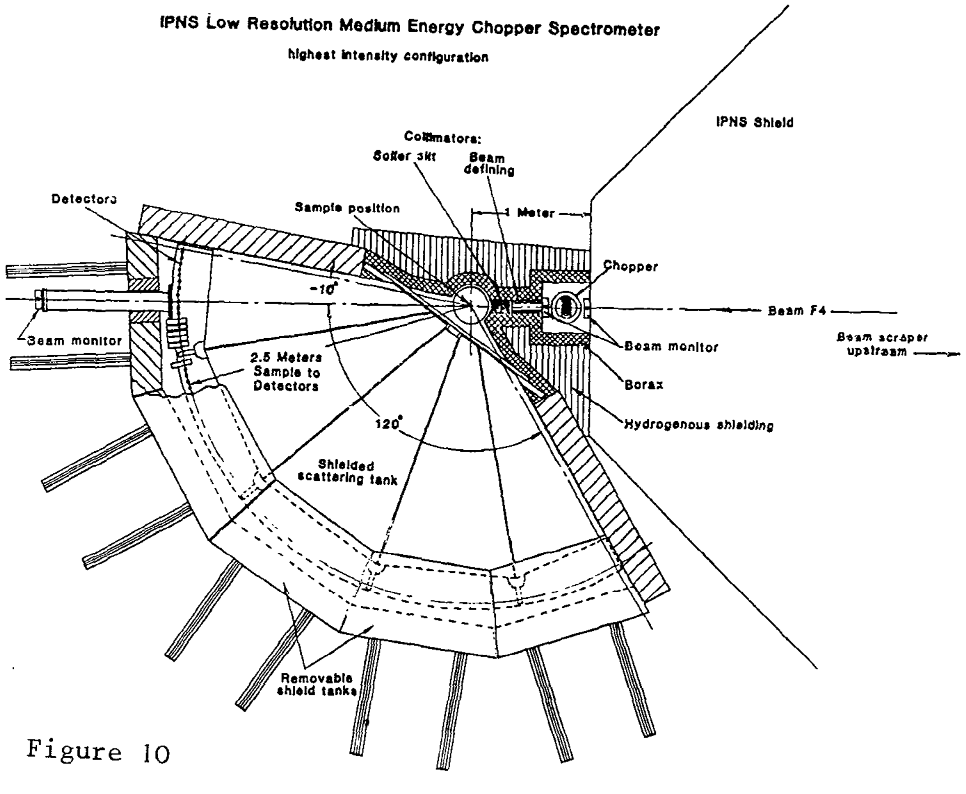
Two irradiation cryostats and associated equipment to maintain temperatures 4 K<T< 300 K are nearly complete. Table A summarizes features of the Radiation Effects Facilities.

Of the eventual total of seven scattering instruments, four (Special Environment Powder Diffractometer - SEPD, General Purpose Powder Diffractometer - GPPD, Single Crystal Diffractometer - SCD, and Low Resolution Medium Energy Chopper Spectrometer - LRMECS) are complete and ready for neutron beams. Figures 9, 10 and 11 show these four instruments. Tables B thru E summarizes the characteristics of the instruments.



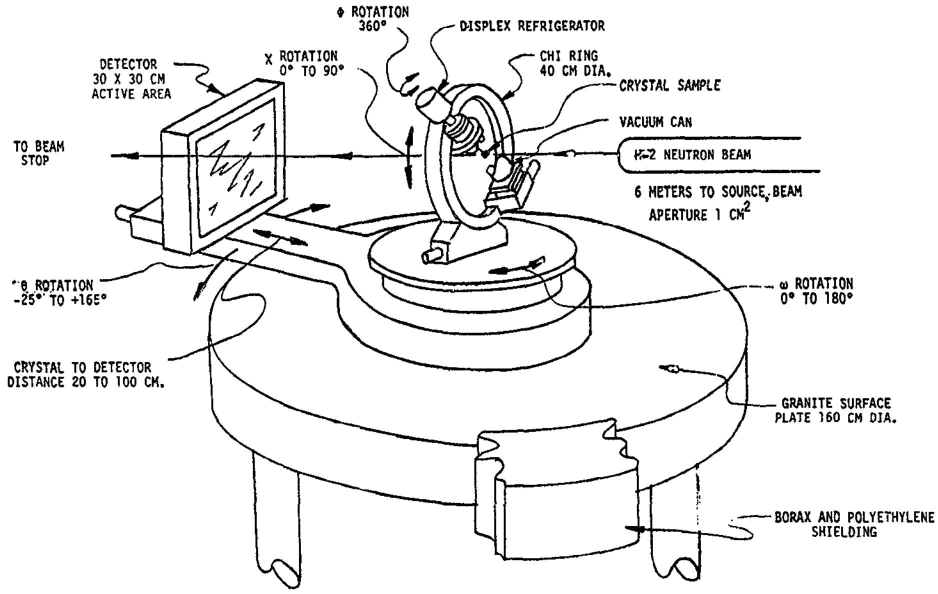
IPNS
Special Environment Powder Diffractometer
and
General Purpose Powder Diffractometer

Figure 9



IPNS Low Resolution Medium Energy Chopper Spectrometer
highest intensity configuration

Figure 10



IPNS SINGLE CRYSTAL DIFFRACTOMETER

Figure 11

TABLE A - REF PARAMETERS

Time-average fast flux (E_n > 0.1 MeV)	1.5 x 10^{12} n/cm^{2}sec
Fast neutron pulse width	100 ns
Low-temperature holes (vertical)	
Diameter	5 cm
Temperature	4 K $\leqq$ T $\leqq$ 300 K
Ambient-temperature hole (horizontal)	
Diameter	3.8 cm
Temperature	∿300 K
Other environmental controls available	
Data acquisition	

TABLE B - SEPD PARAMETERS

Beam-tube assignment	F5 (liq. CH_4)
Initial flight path	14 m
Final flight path	1.5 m
Beam size	1.25 cm x 5 cm
Detectors	1.25 cm x 37.5 cm (140)
Choppers	None
Scattering angles	± 12° - 157°
Time average flux at sample (0.5Å $\leq \lambda \leq$ 5.Å)	2.6 x 10^5n/cm^2-s
Wave-vector range	0.5 - 40 $Å^{-1}$
Wave-vector resolution	0.3 - 1.0%
Special capabilities	Sample chamber, 60 cm diam x 120 cm high, able to accommodate wide variety of environmental controls; can be pumped down to 10^{-5} torr in 1 h.
Environmental controls available	Displex refrigerator, 10-300K
Data acquisition	PDP 11/34
Analysis routines available	Rietveld profile refinement (VAX 11/80)

TABLE C - GPPD PARAMETERS

Beam tube assignment	F2 (liq. CH_4)
Initial flight path	10 m <u>or</u> 20 m
Final flight path	1.5 m
Beam size	1.0 cm diam x 3.8 cm
Detectors	1.25 cm x 37.5 cm (160)
Choppers	None
Scattering angles	±30°, 60°, 90° and 150°
Time-average flux at sample (n/cm^2-sec)	1.9×10^6(10 m), 4.7×10^5 (20 m)
Wave-vector range	0.6 - 24 $Å^{-1}$
Wave-vector resolution	0.26 - 2.2%
Special capabilities	Sample chamber, 60 cm diam x 120 cm high, able to accommodate wide variety of environmental controls; can be pumped down to 10^{-5} torr in 1 h.
Environmental controls available	Displex refrigerator (10-300K)
Data acquisition	PDP 11/34
Analysis routines available	Rietveld profile refinement (VAX 11/80)

TABLE D - LRMECS PARAMETERS

Beam-tube assignment	F4 (liq. CH_4)
Initial flight path	7.5 m
Final flight path	2.5 m
Beam size	5 cm x 10 cm
Detectors	2.5 cm x 45 cm (100) 2.5 cm x 22.5 cm (36) 2.5 cm x 11.25 cm (24)
Choppers	
Scattering Angles	-10° to 120°
Time-average flux at sample ($E_o = 0.5$ eV)	2000 n/cm^{2}sec
Energy-transfer range	0 - 0.5 eV
Wave-vector range	1 - 20 Å^{-1}
Energy-transfer resolution	5%
Wave-vector resolution	2%
Special capabilities	Sample chamber, 30 cm diam, able to accommodate superconducting magnet and dilution refrigeration; can be pumped down to 10^{-4} tor in 2h.
Environmental controls available	Displex refrigerator
Analysis routines available	Reduction to S(Q,ω) (VAX 11/80)

TABLE E - SCD PARAMETERS

Beam-tube assignment	H2 (liq. CH_4)
Initial flight path	5.5 m
Final flight path	0.2 - 0.5 m
Beam size	1 cm diameter
Detectors	Anger scintillation detector 30 cm x 30 cm
Choppers	None
Scattering angles	-160° to 160°
Time-average flux on sample	
Wave-vector range	0.1 - 4 $Å^{-1}$
Wave-vector resolution	2% at 90° scattering angle
Special capabilities	Three-circle goniometer with auto-indexing procedure
Environmental controls available	Helium refrigerator
Data acquisition	PDP 11/34
Analysis routines available	Crystal structure refinement (VAX 11/80)

E. Data Acquisition System

The Data Acquisition System (DAS) is organized in a "star" configuration, with a minicomputer and data collection system for each instrument connected to a central "Host" computer through independent data lines. The Host computer is a 32-bit VAX 11/780 with a Floating Point Accelerator, 0.5 MB of memory, an RM03 67 MB Disk Drive and a TU77 125 ips dual density magnetic tape unit. It also has hard copy terminals, video terminals, graphics terminals, a Versatec Printer/Plotter and modems for remote communications. The star configuration has the advantage of independent data collection and centralized processing power and allows the more expensive peripherals to be concentrated on one machine. Most Host computer software is in FORTRAN and can be run under the VAX VMS operating system.

Each Minicomputer System has a 16 bit DEC PDP 11/34A minicomputer for experiment control and for communication with its Data Collection System and with the Host, as shown in Figure 12. The Minicomputer System software is mostly in FORTRAN and programs will execute under the RSX11M operating system. Programs and data can be stored on an RL02 10 MB capacity disk. Each Minicomputer System includes an LA120 180 character per second hard-copy terminal and a VS11 graphics terminal.

Each Data Collection System includes a CAMAC System containing a Time-Digitizer Module, a Master Clock Module, Polling Modules for the Time-Digitizers, a CAMAC Crate Controller, and optionally, a Clock Prescaler Module. The Time-Digitizer Modules have 125 nsec time resolution and have eight input channels per single-width CAMAC module. The single channel analyzers in these modules have a software controllable lower and upper discriminator levels.

Each Data Collection System also includes a Central Data Corporation Z8001 single board microcomputer and bulk memory dedicated to data collection, transformation and storage. The microcomputer accepts the digitized data from the CAMAC System and makes the real-time transformations necessary to determine which memory location in the bulk memory should be incremented for a given detected neutron.

Five front-end computers and the Host computer are installed and operating with their peripherals. We have now completed adequate software to enable experiments to be handled by the DAS and have compiled a Data Acquisition System Manual.

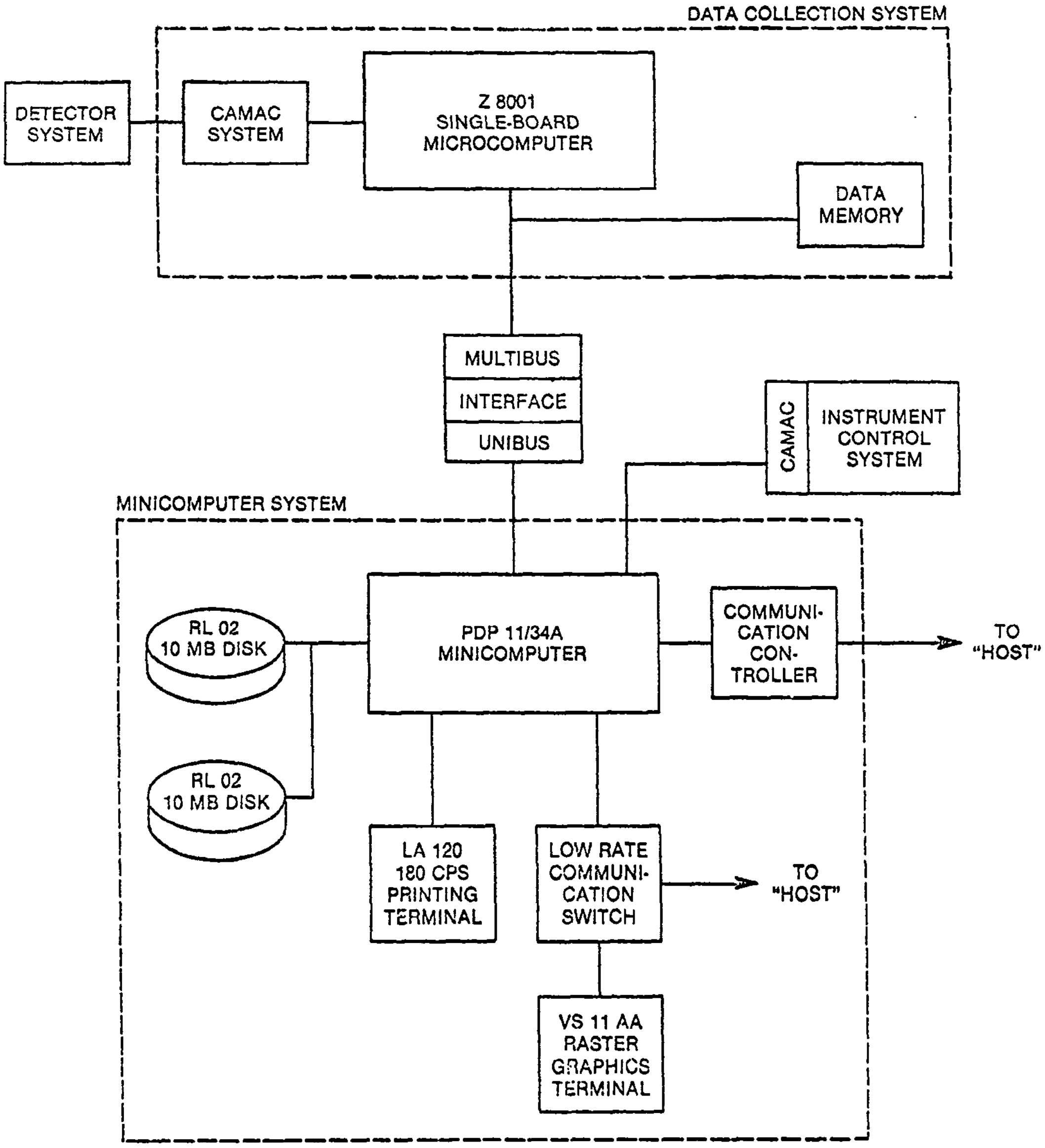

DATA COLLECTION SYSTEM
DETECTOR SYSTEM
CAMAC SYSTEM
Z 8001 SINGLE-BOARD MICROCOMPUTER
DATA MEMORY
MULTIBUS
INTERFACE
UNIBUS
CAMAC
INSTRUMENT CONTROL SYSTEM
MINICOMPUTER SYSTEM
RL 02 10 MB DISK
PDP 11/34A MINICOMPUTER
COMMUNI-CATION CON-TROLLER
TO "HOST"
RL 02 10 MB DISK
LA 120 180 CPS PRINTING TERMINAL
LOW RATE COMMUNI-CATION SWITCH
TO "HOST"
VS 11 AA RASTER GRAPHICS TERMINAL

Figure 12

III. General Items

Documents

In order to gain approval to operate IPNS-I, (not to mention, for our own purposes also) we have prepared a Safety Analysis Report (SAR). This has been reviewed and approved by all relevant Argonne and DOE bodies. (IPNS-I is designated a "non-reactor nuclear facility".) We have also generated from the SAR a working handbook of Operations Safety Requirements (OSR) which summarizes limit points, etc., for safe operation and which has also been reviewed and approved. On these bases we have full authorization to operate.

We have completed in draft form a Users' Handbook which summarizes the characteristics of the source and instruments and the available facilities. The Users' Handbook also provides information to help outside users new to Argonne Laboratory.

User Program

IPNS-I is operated as a user-oriented facility. This is not a new idea within the European neutron community, but is the first attempt in this field in the United States to provide a formal method of access to a major facility. Early this year we called for experiment proposals to be submitted for the Radiation Effects Facility, the first four scattering instruments and the uninstrumented beam tubes, for the period October, 1981 - March, 1982. We received 119 proposals, representing oversubscription of the instruments by factors between 5 and 10. The Program Committee, meeting on June 3 and 4, accepted all six special experiments, for otherwise-uninstrumented beams, and 34 neutron beam and irradiation experiments. The low rate of acceptance reflected the fact that operating time is very severely limited by funding constraints; proposals were almost all of high scientific quality. We will make another call for experiment proposals at the end of this year.

IV. Research and Development

A. Neutron Position-Sensitive Scintillation Detector(Anger Camera)

The Neutron Position-Sensitive Scintillation Detector (NPSD) is a two-dimensional neutron detector based on the principle of the highly-evolved medical gamma ray imaging device, the "Anger" camera. We have described the principles and results of prototype tests earlier. However, a larger version is nearing completion which is 30 x 30 cm overall, uses 2-mm-thick ^{6}Li-loaded, cerium-activated GA-20 (NE905) glass, and 49 2"/square RCA S83003E photomultipliers.

Resolution is 3.mm (measured on the 20 cm ϕ prototype). Pulse height resolution is 14%. The efficiency is expected to be 60% at λ = .5 Å, and over 95% at λ = 1.8 Å. Position stability with respect to temperature variation is less than 0.05 mm/°C. Pulse-pair resolution (includes digitizing ((9 bits))) time is less than 5 μsec.

The first model is to be used in the Single Crystal Diffractometer. We hope later to provide similar detectors for the Small Angle Diffractometer and for epithermal neutron radiography.

B. Compact Preamplifier

We have developed a compact, charge sensitive preamplifier for IPNS instruments which is housed in a 5 x 7.5 x 2 cm^3 brass box and costs $85.00 per unit to produce. The small physical size is attributable to the circuit layout and the low (2500 volt) operating voltage of the ^3He detectors being used in IPNS instruments. This allows small, 3 KV DC filter capacitors to be used. Two integrated circuits perform the work of the 5 or 6 discrete components found in more conventional preamps. Savings result from reduced assembly time. Gain varies among the preamps within approximate range ± 25%; we account for this in the single channel analyzer limits.

The small size and weight of this preamplifier allows it to be mounted directly to closely-packed detectors. This factor is further advantageous for reducing noise pickup in cabling between preamp and detector. We have built 600 of these preamplifiers.

Conclusion

IPNS-I will be the most powerful pulsed spallation neutron source for the next several years. We look forward enthusiastically to its imminent startup, confident that IPNS-I, together with the sources elsewhere, will provide significant advances in the scientific applications and technical development of pulsed spallation neutron sources.