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INTENSE PULSED NEUTRON SOURCE (IPNS) AT ARGONNE NATIONAL LABORATORY (ANL): A STATUS REPORT AS OF JUNE, 1982

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ABSTRACT

In this status report a general overview is given of the IPNS program. The facility has been operating since August 1981 and in a routine way for outside users since November 1981. The accelerator performance has been exceptional. Most instruments are now operational, or nearly so. For details of the individual instruments and experimental program the reader is referred to papers later in these Proceedings.

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1. INTRODUCTION

The Intense Pulsed Neutron Source (IPNS) has been operating since October 1981. The performance of the accelerator has been exceptional. From November 1 to May 5 it delivered protons for a total of 2175 hours at an average current of 8 μA and an operating efficiency of 88%. In this period of time some 80 experiments have been run at IPNS. Details of some of these will be found in the individual instrument papers. Figure 1 shows the layout of the experimental facilities. At this time three beams are unassigned, although two of them are being temporarily used for radiation damage experiments. As will be discussed in more detail, we now have 6 operational scattering instruments, 2 instruments in the testing stage, and 3 special experiments that are being set up on the neutron beams. Two cryogenic fast neutron irradiation facilities are operating.

2. IPNS-I ACCELERATOR SYSTEM

At the time of the ICANS-V meeting, the Rapid Cycling Synchrotron (RCS) was just in the process of turning back on after a lengthy shutdown for apparatus improvement and for relocation of the extraction components to deliver the proton beam to the IPNS-I targets. A report[1] at that conference detailed many improvements and gave preliminary assessments of their value. Reference to the 1982 operating records in Table I below indicates the overall success of the improvement program.

TABLE I
ACCELERATOR OPERATING SUMMARY

	1980	(Nov-June) 1981-82
Operating Energy	300 MeV	400 MeV
Average Beam Current	4.72 μA	7.98 μA
Operating Efficiency	85.2%	88.0%
Scheduled Operating Time	2569.2 hours	2471.0 hours
Available Operating Time	2187.8 hours	2175.3 hours
Total Pulses on Target	1.98×10^8	2.17×10^8
Total Protons on Target	2.25×10^{20}	3.60×10^{20}

The accelerator turned on in April of 1981 and made some brief tests with the proton beam to assure that no gross problems existed. RCS first delivered protons to the Radiation Effects Facility on May 5, 1981. First runs for neutron scattering instrument calibration began August 4. These runs were at a proton energy of 500 MeV. While average currents of 5 μA were achieved, reliability was poor and the continuity required for studies to increase the beam current was impaired by all too frequent operating interruptions.

The reliability problems were primarily in the charge storage cabling of the kicker magnet power supplies and in the rf system. The problems encountered were a type that took several million pulses to develop and the limited prior running had not revealed them.

400 MeV Operation

A decision was made at that time to operate temporarily at a proton energy of 400 MeV to allow the accelerator some time to sort out its problems. This was consistent with the experimenters needs also since lower electrical power costs allowed more running time for instrument development and the powder diffractometers, the workhorses of the early IPNS-I program, were quite effective with the neutrons available at 400 MeV.

The summer test running of the RCS had convinced the operators that the intensity dependent high energy beam instabilities that had previously plagued the RCS were not related to betatron tune and were not correctable with the new programmable optupoles.[2] Evidence indicated that the instability depended on rf voltage amplitude and at that time it was felt that enough additional protons could be accelerated at 400 MeV with better reliability to more than make up for the decrease in neutrons per proton at 400 MeV. The improvement in beam current and reliability shown in Figures 2 (a) & (b) during 400 MeV operation dramatically indicate the correctness of this assumption.

Reliable operation has allowed the accelerator crews the time to attack specific problems of the operation with gratifying results. The kicker cable problems were found to be the result of faulty cables and consultation with the manufacturer helped straighten these out. Modifications were also made in the terminating resistors to allow lower voltage operation. The rf problems were quite varied in nature but are now under control. Very early in the 400 MeV running period improvements were made in the beam phase feedback system which moved the beam intensity instability threshold from about 1.4 x 10^{12} protons per pulse to over 2 x 10^{12} protons per pulse (at 400 MeV). Machine studies have been done at 450 MeV with the accelerator easily achieving an extracted beam current of 8 μA.

Plans are to increase the energy to 450 MeV in September, evaluate the effectiveness of operation at this energy for 2-3 months, then begin operation at 500 MeV if no new problems develop at 450 MeV.

Chopper Controlled Operation

Almost all the RCS operation has been carried out with the entire accelerator timing system under control of a crystal oscillator. This oscillator also provides timing reference to one or more neutron choppers. Some of the accelerator modifications to permit this type of operation have previously been described.[3] Since all the accelerator power supplies have a voltage ripple which is synchronized to the power line, chopper controlled operation tends to be more unstable and lossy than power line synchronized operation. Accelerator personnel have continuously worked to decrease this instability so that chopper controlled operation is just as free of proton loss as line synchronized operation.

One of the approaches phase locked the chopper motor to the power line with a very slowly responding circuit. This provided significant improvement in accelerator performance and is acceptable to the chopper user as long as only one chopper is in use. This method is not acceptable for the more general case of several choppers in operation each with different moments of inertia, since only one can be in control of accelerator proton extraction timing. As of this writing, the accelerator runs quite cleanly under chopper control, but still requires a lot more operator attention than line synchronized operation.

Present Status

The accelerator has now operated in a production mode for 22 weeks and performance has exceeded expectations. A most vital ingredient required to make this a production facility has been control of the proton losses in the accelerator tunnel. This has been partially accomplished by added diagnostics, some of which automatically shutdown faulty operation. While Table I tells the success story of the IPNS-I accelerator, some other points are worth noting. The accelerator has reached peak currents of 11.2 μA for short periods under acceptable operating conditions and 24 hour averages of 10 μA. Accelerator study periods have produced 2.4 x 10^{12} protons per pulse at 5 Hz. The limiting component of the system is now clearly the H^- ion source. The synchrotron and linac can efficiently handle all the H^- current presently available, at least at 400 MeV. It may be possible to edge the average current up to 10 μA with the present source, but that will be about the limit.

Stripping foils have been something of a problem since they have to be replaced about every 5 million pulses. A new foil must be conditioned for about 4 hours at reduced current. This significantly reduces average current so that we are considering better foil materials.

Future Plans

Machine studies have revealed no serious injection space charge problems with 3 x 10^{12} protons injected. The operating ion source provides such beams at 5 Hz but at 30 Hz only about 2.2 x 10^{12} can be delivered regularly to the synchrotron. This source produces a current of 15 mA at an energy of 750 keV. Linac personnel have adapted a 15 Hz Fermilab magnetron H^- source to run at 30 Hz. This new source reliably produces 40-50 mA H^- beams at 32 Hz on the test stand. Plans are to install this source about March of 1983.

While we cannot fully evaluate the RCS capability with the present ion source, we believe it should be possible with the new ion source in operation to get the average current up to about 12 μA without any further significant changes in equipment. Added rf voltage will probably be required to increase the beam current above 12 μA. With some compromise in rf reliability, about 10% more voltage can be achieved with the present cavities. A third rf system is actively being considered as a major future improvement.

3. TARGETS AND MODERATORS

The IPNS Zircaloy-2-clad uranium targets have been in use in both the Neutron Scattering Facility (NSF) and the Radiation Effects Facility (REF) since startup time. Completely-assembled tantalum targets are available for both facilities, as are spare uranium target assemblies. We have not yet used either. The targets and (independent, interchangeable) cooling systems have operated completely trouble-free, and according to design expectations.

The uranium targets consist of eight, 25-mm-thick, 100-mm-diameter uranium-alloy disks, clad with 0.5-mm Zircaloy-2, (1.5 mm on circumference) cooled by light water flowing in 1-mm channels between disks. Disks 1,3,5, and 7 contain small, steel-sheathed thermocouples in Zircaloy wells at their centers.

The entirely-conventional cooling systems have two loops; the primary loop contains a helium-gas-covered surge tank with hydrogen recombiner, filters, ion-exchange column, the pump and heat exchanger. Radiation monitors near the exchange column detect gross changes in radiation levels, which are primarily due to positron-annihilation and nitrogen-16 gammas. Periodic sampling and gamma-ray spectral analysis of primary water and cover gas gives us the most sensitive, longer-term indication of trouble such as a breach of cladding. Normal gas and water samples contain isotopes identified as spallation and activation products of 300 series stainless steel, Zircaloy and water. No excess hydrogen is evolved, gratifyingly contrary to ZING-P′ experience.

The target temperatures behave according to design, with disk 1 centerline temperature rising approximately 14 degrees C above coolant temperature, per microamp of 400 MeV protons on the NSF. The temperature in the REF is somewhat higher, presumably due to sharper focussing of the proton beam.

We have measured the transient temperature response of the uranium disks: they respond to proton beam intensity variations in a fashion described by two time constants, 6.7 and 2.1 sec, in accordance with calculations. (Measured thermocouple response times are less than about .5 seconds.) Thus even beam power fluctuations on the times scale of 10 seconds give fully-reversed thermal stress cycles. (We identified cladding thermal stress cycling fatigue as the mechanism of failure of our targets at the original design current of 22 microamps, 500 MeV.) At 8 microamps proton current, we are operating at stresses just below the level of infinite fatigue cycle lifetime.

The shielding provides general background levels of .5 to 1. mrem/hr, at 8 microamps of proton current. We find exceptions up 3. to 10. mrem/hr in locations close to the neutron beam tubes at the shield face. At the shield top, where a corner of the central iron shield has no concrete shielding (an unoccupied area), we find several hundred mrem/hr, which we have attributed to 25 keV "iron-window" neutrons. Near the LRMECS chopper, shielded with only 30. cm of hydrogenous material, the dose rate is about 25 mrem/hr with 8 microamps of protons on the target. The beam stops are quite simple; we use second-hand shipping casks and reactor beam stops about which we admit we know little. Unmodified, these bring the dose rates down to levels of about 1 mrem/hr, except in the case of LRMECS, where we added 30. cm of iron in the beam direction to accomplish this level.

We have not yet installed the cryogenic moderator system, which originally was to consist of two liquid methane moderators at approximately about 100 Kelvin, and two liquid hydrogen moderators at approximately 25 Kelvin. This was due to problems of time dependent and static differential thermal contraction, material flaws, thermal shorts in the cryogenic heat exchangers, and some central instabilities. We have now repaired the moderator and reflector assembly, and will circulate liquid methane in all four moderators. We expect to be operating with the cryogenic moderator system beginning with the start-up this October.

Meanwhile, since startup of the NSF, we have used a system consisting of three ambient-temperature polyethylene moderators, with inner graphite and outer beryllium reflectors, and cadmium decoupling and void liners throughout. (In this temporary assembly, we provide no vertical beam moderator.) The assembly is uncooled. Figure 3 illustrates the temporary assembly.)

We have measured epithermal beam currents from each of the temporary moderators. The table compares the results of these measurements with Monte Carlo calculations for the beryllium-reflected, cryogenic moderator system.

Epithermal Neutron Beam Current
EI_p (E) $_{1\ ev}$, n/s-μA-sec

Beam (Instrument)	Calculated	for	(Material)	Measured
H-1 (SCD)	$3.25 \pm .56 \times 10^{10}$		(CH_4)	$3.42 \pm .1 \times 10^{10}$
C-1 (SAD)	$2.09 \pm .38 \times 10^{10}$		(H_2)	$0.129 \pm 0.4 \times 10^{10}$ (a) $1.71 \pm .5 \times 10^{10}$ (b)
F-5 (SEPD)	$2.95 \pm .50 \times 10^{10}$		(CH_4)	$2.91 \pm .1 \times 10^{10}$
F-2 (GPPD)	$3.26 \pm .54 \times 10^{10}$		(CH_4)	----------------

(a) As measured, with effect of collimation.

(b) Corrected for collimation by ratio (Moderator area viewed through collimation/(Total moderator area).

The proton energy for the measurements was 401 MeV. That assumed in the calculation was 500 MeV. The results contain several surprises. First, that the measured and calculated intensities for most cases are in agreement, even though the proton energies are different. Measurements should be lower than calculation by a factor of about 1.36, the ratio of neutron yields, on this account. Second, we expect the present, temporary assembly, to be significantly inferior to the Be reflected CH_4 assembly, especially on account of degeneration of the polyethylene due to irradiation. The proton current normalization was from the toroid nearest the target.

4. NEUTRON SCIENCE

(a) Instruments

The instrumental parameters are specified in Table I. More complete descriptions of most of these instruments appear in later sections in this proceedings. What we shall do here is briefly outline the classes of instruments and their fields of study.

Powder Diffractometers

From the first prototype spallation source up to the present day it has been clear that these machines would open up new areas of research. There are two powder diffractometers at IPNS, as the table indicates, and both are fully operational. There are two primary reasons for this; first the abundance of epithermal neutrons has allowed measurements out to much higher Q values, possibly up to ~ 100 $\mathring{A}^{-1}$, and secondly, the short pulse width, together with long flight times has allowed new standards of resolution to be attained. For example, both instruments have a resolution of $\Delta Q/Q \simeq 0.003$, which is independent of Q. At the present time three main areas of study have been pursued: (i) Structural work. At present the heaviest demand is for this area, and since a data set can be collected from a reasonable (~5g) size sample in ~24 hrs the machines service a good number of users. In fact about half our present users fit into this category, although this may be misleading as not all our instruments are fully operational. What is of great importance is that the software package for handling this data is "on-line" at ANL. FORTRAN software for the display and analysis of time-of-flight (TOF) neutron powder data from the powder diffractometers is operational on our IPNS-dedicated VAX 11/780 computer. At the heart of this software package are the routines TOFPRP and TOFLS (written by R. B. von Dreele of Arizona State University and used extensively at Argonne over the past 2-½ years) which perform full-matrix least-squares refinement of crystal structure and peak shape parameters (Rietveld analysis) based on powder data. Programs to determine Bragg reflections for a given structure, to calculate Fourier syntheses, to calculate distances, angles and associated standard deviations from refined structures and to illustrate the atomic arrangement of a given structure have been adapted for use in this package. A user's guide to the Rietveld analysis of powder data at IPNS is in preparation. Users who have stayed an extra day or two after data collection have been able to leave with nearly complete Rietveld refinements. In addition, we are running a short course on Powder Diffraction and Rietveld Analysis at ANL from July 13-16, 1982.

(ii) Glasses, liquids and amorphous systems. For these studies the high Q capability is particularly important and this has already been exploited in a study of P_xSe_{1-x} glasses by Misawa, Price, and Susman. Another interesting application of the powder diffractometers was in determination of the magnetic scattering from an amorphous ferromagnet $Fe_{0.82}$ Y $B_{0.18}$ by Guttman, et al. Here the experimenters used banks of detectors placed symmetrically left and right of the incident beam, and applied a magnetic field $\vec{H}$ so that for one set of detectors $\vec{Q} \parallel \vec{H}$, and for another $\vec{Q} \perp \vec{H}$. Under these conditions the magnetic scattering appears in the $\vec{Q} \perp \vec{H}$ detectors only and can be separated out. Note that with the time-of-flight method this condition is true for all $\vec{Q}$.

(iii) Measurements of residual grain interaction stresses in deformed alloys. MacEwan et al have exploited the high resolution at all Q values to observe the shifts of individual peaks after materials have been permanently strained. They estimate that residual bulk strains of order 10^{-5} can be detected using the high resolution configuration.

Single-Crystal Diffractometer

This instrument, based on the wavelength-resolved Laue method, uses a 30 x 30 cm position sensitive ^{6}Li-glass scintillation detector developed by M. G. Strauss and others in the Electronics Division at ANL. The smaller-scale prototype built up at ZING-P′ was the first of its kind. As this technique is capable of viewing large portions of reciprocal space it has a wide variety of potential applications. The first experiments have concentrated on crystallography and the crystal structure of $Mn(CO)_3$ $(C_6H_8CH_3)$ at 25K was solved by a joint group from ANL and the University of North Carolina at Chapel Hill. The low-temperature structure was solved independently by direct methods - to our knowledge, the first such case with time-of-flight data.

Other types of experiments which are being performed with this instrument include searches for diffuse scattering, satellite peaks, and superlattice reflections. The versatility of the instrument is certain to make it particularly attractive for these latter studies. There are a few small difficulties still to be worked on, for example, involving dead time and minor aberrational effects and fast neutron background when the minimum wavelength is below ~0.6Å. However, the instrument is clearly operational and we expect these problems to be overcome and new uses to emerge.

Small-Angle Diffractometer

The SAD is another recently-developed instrument. As such, one expects to encounter new challenges, and the most difficult one is to diminish the background scattering from fast neutrons. The instrument has a 2-dimensional gas-filled proportional counter that sits directly in the incident beam, but the background is now a factor 10^6 lower than the direct beam flux. At present the minimum usable Q is limited to ~ 0.02 $\mathring{A}^{-1}$; however, once the cold moderator is installed, the Q range will be 7×10^{-3} to 0.35 $\mathring{A}^{-1}$. Experiments are being conducted on both metallurgical as well as biological samples, and we expect to receive proposals for this instrument for the first time in September.

Chopper Spectrometers

The inelastic scattering experiments at IPNS are of special interest because they attempt to exploit in a direct way the high epithermal flux, which is a unique capability of spallation sources. Both these machines run in the so-called 'direct' geometry, i.e. the incident energy E_0 is defined. So far runs have been made with E_0 = 160 and 500 meV.

The Medium-Energy Chopper Spectrometers at IPNS are designed for inelastic scattering experiments over a wide range of energy transfer (0-500 meV) and momentum transfer (0.1-20 $\mathring{A}^{-1}$). The high-intensity, low-resolution instrument (LRMECS) has been operating for several months and experiments approved by the Program Committee are underway. Measurements of the vibrational densities of states of amorphous SiO_2 and amorphous P have been completed. The electronics for the phasing of chopper and accelerator have been improved and the time in which the accelerator-chopper phase relationship is acceptable ($t_0 - t_c < \Delta T_c$, typically 2 μsec) is now essentially 100%.

The second chopper machine (High resolution medium energy chopper spectrometer, HRMECS) is now installed and initial tests have been run. Of particular importance is that we are able to run two choppers simultaneously, which presents a complex phasing problem since only one chopper can be used to trigger accelerator extraction. Tests have now shown that two (or more) choppers controlled by a fixed-frequency oscillator can be maintained in acceptable phase relationship with the accelerator.

As expected, the chopper spectrometers have been under great demand for experiments. At the last program committee meeting only 43% of the proposals on LRMECS could be accommodated. Although this situation may get better when HRMECS comes on line, the low percentage reflects both the long time required for these experiments and the high interest.

The reader is referred to the specific article on chopper spectrometers for further details of the experiments that have been performed and are planned.

Crystal Analyzer Spectrometer

This machine uses the 'inverse' geometry technique in which the final energy is defined by a cooled Be filter and focussed graphite crystals to be 3.6 meV. The time-of-flight technique is then used to determine the initial energy and thus the energy transfer is known. The CAS is being constructed primarily for studying vibrational modes at hydrogen in metals. The CAS can be used effectively for other studies such as vibrational densities of states and molecular spectroscopy.

(b) Radiation Effects Facility

The Radiation Effects Facility (REF) at IPNS has been in operation since January 1982. Two fast-neutron irradiation positions operate independently at controlled temperatures between 4.2K and about 500 C. Neutron fluxes, energy spectra, and flux gradiants have been accurately determined in these 2 temperature irradiation positions. Secondary proton and gamma fluxes have also been measured and found to be within acceptable limits. The fast-neutron flux is typically 1 x 10^{12} n/cm^2-sec ($E_n > 0.2$ MeV) and has an energy spectrum quite similar to a slightly degraded fission-neutron spectrum. Computer controlled data acquisition systems for in-situ experiments are in use for the 2 temperature controlled irradiation positions. The REF is available for user's experiments approximately 1/4 of the total IPNS running, or about 6 weeks through the year. More details can be found in the specific article on the REF.

(c) Special experiments at IPNS

In addition to the experimental facilities described above that are open to the entire user community on an experiment by experiment basis, three proposals were accepted by the Program Committee in June 1981 for long-term assignment of beams. These are described briefly below. In each case they represent a considerable effort, often collaborative with other institutions.

Nuclear magnetic ordering in ^{3}He at very low temperature

This experiment is designed to observe antiferromagnetic Bragg reflections from single crystals of solid ^{3}He below 0.001K. The facility is now in the final stages of assembly.

A vibration-free support structure to hold the cryostat has been completed and the dilution refrigerator has been installed at IPNS. In previous testing before this installation it cooled below 0.006K. The nuclear cooling stage is now being installed. The sample cell with a single-crystal silicon window is being leak tested.

Other necessary components such as filters, the chopper assembly, position-sensitive detectors, and shielding are now almost completed. Studies of solid ^{3}He crystal growth will begin soon, and the actual experiments later this summer.

Polarized Neutron Mirror at IPNS

An optical instrument is being installed for neutron reflection studies. The object is to determine the magnetic induction $\vec{B}$ (z) close to the surface of materials. In many instances $\vec{B}$ varies as a function of the distance z from the surface until it reaches a value $\vec{B}_0$ for the bulk. The goal is attained by measuring the spin dependent reflectivity of the neutron beam by the surface, since this quantity is related by optical laws to $\vec{B}$ (z). The perturbation of the magnetic induction at the surface is detected if significantly different from the bulk over a region not smaller than 5 Å, nor larger than 1000 Å.

A filtered neutron beam is reflected by a magnetized cobalt mirror. This reflects only the neutrons whose spin is parallel to the magnetization of the cobalt. The polarized beam is brought on the sample, which has a well-polished surface and is kept in a magnetic field paralled to that of the cobalt mirror. The neutrons are partially reflected by the surface of the sample; the reflectivity as a function of the wavelength is measured by a time-of-flight detector. The insertion of a flipping coil in the space between the mirror and the sample allows the reversal of the neutron spins with respect to the laboratory magnetic fields; in this way the spin-dependent reflectivity of the sample is exactly identified.

The instrument is scheduled to start operating in June 1982. With an initial round of experiments devoted to the detection of the penetration length of an applied magnetic field in superconducting $ErRh_4B_4$, and the determination of the magnetic critical exponents at the surface of ferromagnetic nickel. The special environments for the samples are presently under construction.

Ultracold Neutron Experiments

The ultimate aim of this experiment is to measure the electric dipole moment (EDM) of the neutron as a test of time reversal invariance. A finite EDM would show failure of time reversal. We have demonstrated a practical system for producing ultracold neutrons (UCN) at high density from a pulsed neutron source using ZING-P′. We now need to show that we can hold these neutrons in a bottle for 100 seconds or so.

To do this we have (1) built a window that separates the bad vacuum of our source (a rapidly moving mica crystal which reflects 400 m/sec neutrons) (2) polished the surface of our bottle and (3) built pneumatically operated valves with minimum leakage to control the neutrons. We need a high flux of 400 m/sec neutrons to test the source and bottle and we hope to have this from the refrigerated moderator in IPNS.

To be competitive with other measurements of the EDM we need a density of about 10 UCN/cc stored in our bottle.

(d) Data Acquisition System

Ease of use, flexibility, and reliability were the primary goals in the design of the IPNS Data Acquisition System (DAS) and these goals have been met very well. Very little time has been lost through problems with the DAS and users have been able to begin using the system with a minimum of instruction. This is the first neutron scattering data acquisition system with the sophistication to do electronic time focussing on the fly, enabling the use of large detector banks in simple arrangements. The IPNS DAS includes a powerful and compatible host computer (a VAX 11/780) to permit rapid analysis of acquired data. This allows us to run an efficient user program despite the complex nature of the data. Outside users are usually able to complete most of their analysis before leaving the Laboratory if they are with respect to the laboratory magnetic fields; in this way the spin-dependent reflectivity of the sample is exactly identified.

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The DAS currently serves seven instruments: The SEPD, GPPD, LRMECS, SCD, CAS, HRMECS and the Solid He^3 Experiment (and on a temporary basis, the Polarized Neutron Experiment). The SAD instrument does not yet use the main IPNS DAS but instead uses an upgraded form of the data acquisition system which was used for this instrument at ZING-P′. All IPNS users analyze data on the IPNS VAX 11/780.

Many unique capabilities and a great deal of flexibility are provided by the IPNS DAS. The user can choose the range of times-of-flight over which data is collected, channel widths, grouping and/or time-focussing of detectors, and method of monitoring collection. Time-focussing corrections which can be made before recording each event include scaling of the time to correct for different flight paths, and/or scattering angles and corrections for time delays. This has permitted a simple symmetric design for the powder diffractometers with the detectors mounted on a circle surrounding the sample. Three types of time delay corrections are possible so corrections can be made for different types of instruments. Data from different detectors may be collected over the same or different ranges and a given event may be histogrammed more than once to allow collection with and without corrections such as time-focussing. Each powder instrument has, on occasion, collected data simultaneously into more than 220,000 channels. The Single Crystal Diffractometer can collect data into over one million channels at a time.

5. USER PROGRAM

IPNS is a national user facility. What this means is that we encourage and actively seek use of the various instruments by outside users. To achieve this effectively we have developed the following policy:

- o Program Committee (chaired by a non-Argonne scientist -- majority of members from outside Argonne) will review experiment proposals and allocate time to optimize the production of good science.

- Instrument Scientists will be allotted 25% of time on each instrument for checking, upgrading, calibration and their own experiments, remaining 75% will be allocated by Program Committee.

- Some beams will be left free for special experiments in which all experimental equipment will be provided by the users.

- Users will generally provide any non-standard equipment required (beyond conventional sample environment equipment).

- Users will provide their own travel support (Argonne Universities Association may be able to help university users in special cases).

- Neutrons will be provided free of charge for scientific experiments meeting criteria established by the Department of Energy.

- Proprietary experiments may be scheduled with appropriate cost recovery according to the Department of Energy guidelines.

The question is how well has this worked. On the whole extremely well. So far (Nov. 1981 - June 1982) we have run 80 experiments. About 60 outside users have been involved with these experiments, and of these about 30 have actually been at ANL to do their experiments. This is a promising start.

A summary of the research proposals submitted in February 1982 for the experimental period April 1982 - October 1982 is given below. The decisions on which proposals were accepted are those of the Program Committee which met at Argonne on March 1, 1982. The next proposal deadline is September 15. Proposal forms, experimental report forms, and a user handbook describing the instruments in detail are available by writing to the Scientific Secretary, IPNS-372, Argonne Natonal Laboratory, Argonne, Illinois 60439, telephone (312) 972-5518.

Instrument	Number Submitted			No. Accepted(3)	
	Outside Users	ANL	Total	Outside Users	Total
Special Environment Powder Diff.	10	10	20	6	13
General Purpose Powder Diff.	10	7	17	10	15
Low-Res. Medium-Energy Chopper Spectr.	6	5	11	2	4
Single Crystal Diff.	7(2)	1	8	6(1)	7(1)
Radiation Effects Fac.	7	8	15	7	13
Special Experiments	1	2	3	1	3
TOTAL NUMBER(2)	41	33	74	32	55

(1) Final experiments to be selected depending on results of screening measurements. One of these proposals includes 44 individual proposals from scientists representing 32 U.S. institutions.

(2) Counts proposals with multiple samples as one proposal.

(3) In most cases time allocated was less than requested.

Proposals were also received for the Small Angle Diffractometer.
and High-Resolution Medium-Energy Chopper Spectrometer.
These are not included here because these instruments are still in a testing stage.

6. FUTURE PLANS

For many years Argonne has been in the lead with thinking and developing spallation sources for neutron science. ZING-P in 1974 was the first source based on a proton accelerator in the world. The IPNS concept was developed and documented at ANL in 1978 (see ANL publication 78-88 compiled by J. M. Carpenter, D. L. Price, and N. J. Swanson, 291 pages) and included detailed specifications for both IPNS-I, which we now have operating, and IPNS-II, a more intense machine designed for 800 MeV energy and 500 μA current. Work on this latter machine is not at present continuing, since not only is funding unavailable but better ideas have also emerged in the intervening 4 years. The United States is looking to the WNR/PSR option at Los

Alamos as a high intensity source in the late 1980's. As a major center for pulsed neutron research, the staff at ANL are actively involved in collaborations with Los Alamos personnel on designing instruments and planning or continuing research programs at the WNR/PSR.

In addition some effort is being made at Argonne to think of new accelerator based systems. Since the research reactors in the U.S. were commissioned in 1966, and the LAMPF accelerator in 1972, this is a necessary step if we are to have a competitive source ten years from now. Dr. R. L. Kustom is in charge of these efforts and further details may be obtained by writing directly to him. Some of the ideas, particularly those involving the fixed field alternating gradient (FFAG) synchrotron, appear very promising from the viewpoint of neutron science.

7. CONCLUSION

IPNS-I is now working well. We are learning how to optimize the instruments to do the best science with pulsed neutrons. The accelerator is working well and we plan to increase the energy to 450 MeV in September. A new ion source will be installed next March, which will result in a large increase in current. Optimistically we hope a year from now that IPNS will have ∿ 2½ times the flux it now has. On the neutron science front we expect to have 13 instruments in operation and perhaps one or two new spectrometers in the early stages of design. Our efforts with pulsed neutrons has drawn worldwide attention and we expect a large number of visitors, both from the U.S. and outside, who are interested and wish to contribute to getting the best science from these sources. We urge you to submit proposals!

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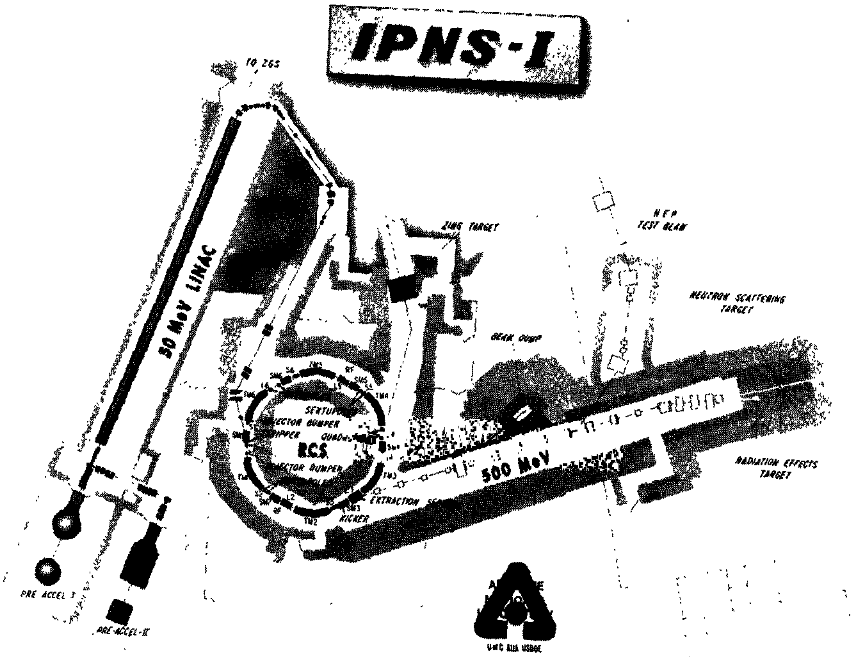

Fig. 1 Experimental Facilities at IPNS.

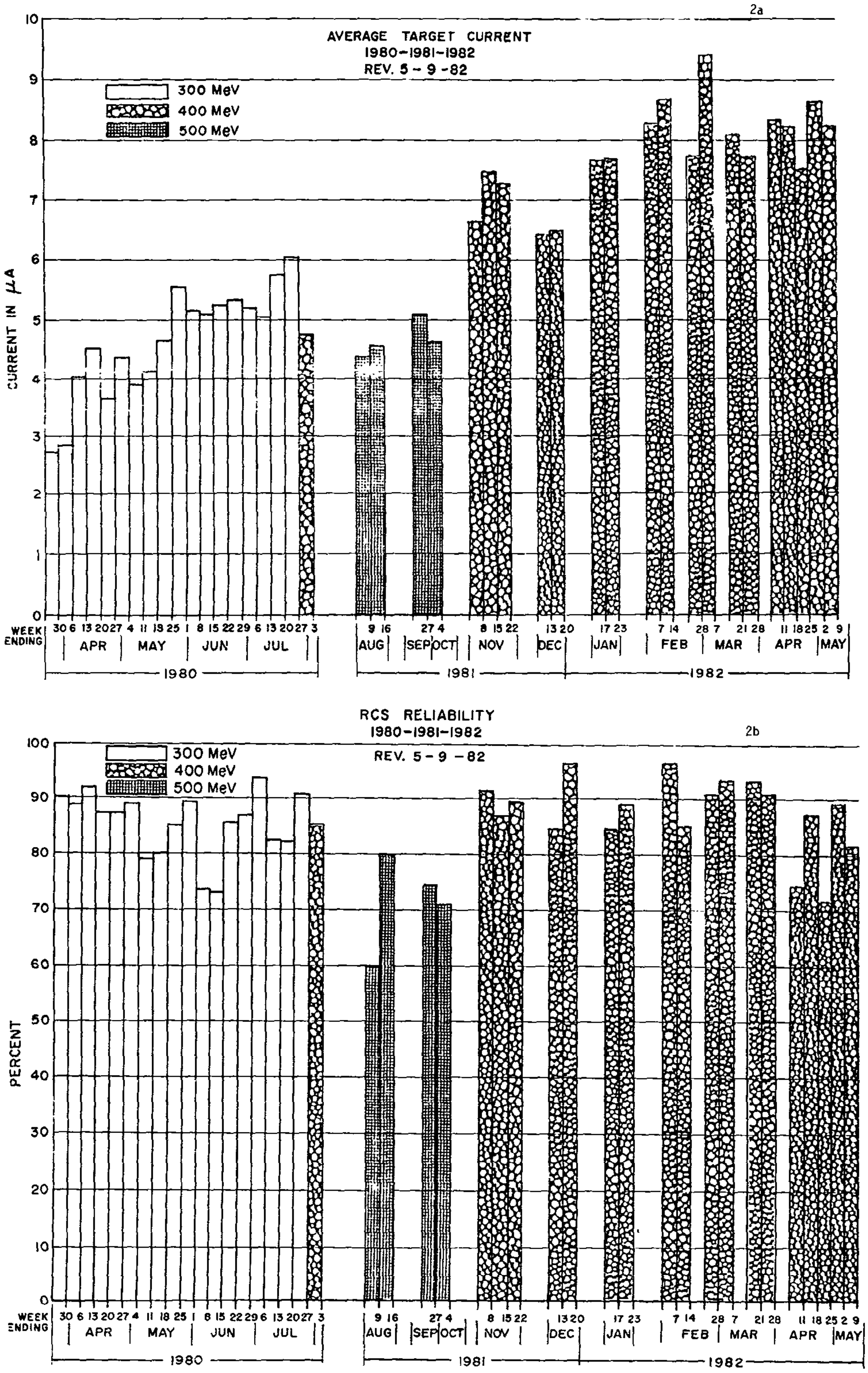

Fig. 2 (a) Average target current and (b) reliability since 1980 of the IPNS Accelerator system.

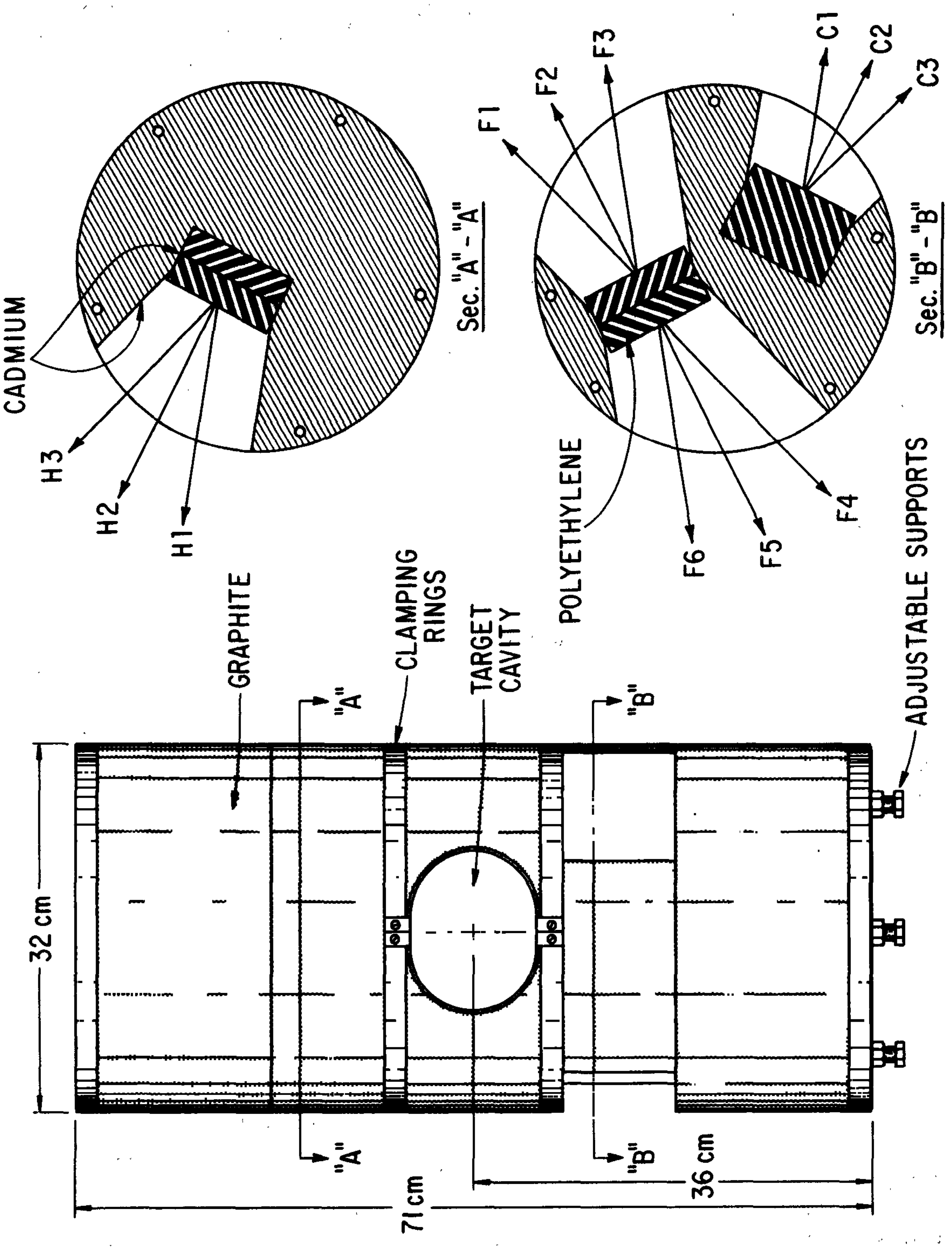

Fig. 3 The temporary moderator-reflector assembly. The three moderators are of polyethylene, reflected by graphite decoupled and heterogeneously poisoned by .5mm thick cadmium.

TABLE I IPNS-I EXPERIMENTAL FACILITIES

NEUTRON SCATTERING

Facility (Instrument Scientist)	Assignment	Range		Resolution	
		†Wave-vector	Energy	Wave-vector	Energy
Special Environment Powder Diffractometer (J. D. Jorgensen)	F5	0.5-40 Å^{-1}	*	0.35%	*
General Purpose Powder Diffractometer (J. Faber, Jr.)	F2	0.5-100 Å^{-1}	*	0.25%	*
Single Crystal Diffractometer (A. J. Schultz)	H1	2-20 Å^{-1}	*	2%	*
Low-Resolution Medium-Energy Chopper Spectrometer (J. M. Carpenter)	F4	0.1-30 Å^{-1}	0-0.6 eV	0.02 K_o	0.05 E_o
High-Resolution Medium-Energy Chopper Spectrometer (D. L. Price)	H3	0.3-9 Å^{-1}	0-0.4 eV	0.01 K_o	0.02 E_o
Small-Angle Scattering Diffractometer (J. E. Epperson (a), C. Borso (b))	C1	0.001-0.3 Å^{-1}	*	0.004 Å^{-1}	*
Crystal Analyzer Spectrometer (T. O. Brun)	F1	3-16 Å^{-1}	0.02-0.5 eV	3%	2%

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* No energy analysis

† Wave-vector, $K = 4\pi \sin \theta/\lambda$

(a) Materials Science -- 3 Meter Flight Path

(b) Biology -- 8 Meter Flight Path

NEUTRON BEAMS FOR SPECIAL EXPERIMENTS

Beam Tube	Current Use	Flight Path Length (m)
F3	Vacant	6-70
C2	Polarized Neutron Exp.	6-40
C3	Solid He^3 Project	7.5-25
F6	Irradiations	6-20
H2	Irradiations	6-20
V1	Ultra-Cold Neutron Exp.	2.7-6.7

RADIATION EFFECTS

Facility (Instrument Scientist)	Description
Radiation Effects Facility (R. C. Birtcher)	Two vertical (5 cm ID) tubes with flux 1 x 10^{12} n/cm^2 sec and one horizontal (3.8 cm ID) tube with flux 3 x 10^{11} for energy greater than 0.1 MeV at 8μA; capabilities for maintaining two samples at liquid helium temperature (4°K) and above

IPNS - G. H. Lander

H. Wroe	Comment -	I noticed that in scheduling you allowed 25% of the beam time for in-house use. On SNS we have allowed a commissioning period for a new instrument but once it's scheduled in-house scientists have to compete for time through the same procedure as the university user.
G. Lander	Response -	In practice the 25% rule is not applied across the board. The scientists often use the instrument time to finish off collaborative experiments. Even at the ILL quite a lot of beam time is reserved for internal use, and most people think this appropriate.
A. Carne	Q	How much beam time does the HEP test beam get?
J. Carpenter	A	It uses 1% of the beam which is scattered out continuously.
C. Potts	Comment -	We expect 500 MeV operation to be just as reliable as 450 MeV.