The IPNS Program at Argonne National Laboratory

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Introduction

The eighteen-month period since ICANS-III has been a most exciting time for the IPNS Program. It has seen (a) the progress of IPNS-I construction from an empty building to the final stage of a major experimental facility, (b) the completion of the ZING-P' prototype operation with successful resolution of the key technical questions in the design of the IPNS-I facilities and instrumentation, and (c) the upgrade of the accelerator current to a level commensurate with the performance required for IPNS-I start-up. The simultaneous realization of these three goals in a situation of limited resources has called for dedication, ingenuity and excellent teamwork on the part of the people involved.

In the following sections of this paper, we shall briefly summarize the progress achieved in these three areas. Technical accomplishments in the areas of targetry and neutron scattering instrumentation will be covered in separate papers.

The principal components of the IPNS-I facilities are shown in Figs. 1 and 2. Fig. 1 gives a plan view of the accelerator systems and the 500 MeV beam transport line. The 500 MeV transport line and the relocation of the Rapid Cycling Synchrotron extraction into this line are part of the IPNS-I construction project; the other accelerator components were transferred from the DOE High Energy Physics Program. Fig. 2 gives a plan view of the neutron generation systems and research instrumentation, all of which are being built under the construction project, apart from the principal buildings housing these facilities which existed previously.

A. IPNS-I Construction

Progress in all areas of the design and construction indicates high confidence that the IPNS-I facilities will become operational in April 1981. With the shutdown of the ZING-P' program in August 1980 additional resources have been released to work on the transition from the prototype facility to IPNS-I where prototype operations did not allow construction work previously. Details of the progress for the three principal tasks of the IPNS-I projects are given below.

1. Proton Transport System (PTS)

The PTS tunnel was completed within the experiment hall (Building 375) and expanded to the limit of its support pad outside and north of the hall. Included has been the completion of the proton beam dump which will serve as a Faraday cup to accept the full output of the accelerator for operational optimization purposes.

The PTS magnets obtained from ZGS have been refurbished and mounted on newly-procured precision positioning platforms which will also serve as mobile transport dolleys for installation or removal from the PTS tunnel. Several magnets have been positioned in the completed tunnel and the alignment and vacuum system testing has been started.

With the completion of ZING-P' prototype operations, preparations for joining the PTS tunnel to the synchrotron cavity were begun. This work included removal of accelerator shielding blocks of the south side, excavation of the floor and earth at the cavity-tunnel junction area, placement of the extension of the high-load concrete support pad for the PTS shielding, and the relocation of accelerator power supplies and miscellaneous equipment previously located at the junction zone. Joining of the PTS tunnel to the accelerator cavity is planned for completion before the inclement winter weather arrives.

Progress is quite satisfactory for the ancillary systems to support the PTS. This work includes the subsystems for beam diagnostics, vacuum, beam control and safety shutdown. Accelerator modifications have been started to modify and relocate the extraction system. These activities are scheduled to be completed at the time when the PTS construction will be finished in February 1981.

2. Neutron Generation System (NGS)

The slow, tedious task of cutting and fitting of the shielding steel around the vessels and neutron beam tubes within the atmospheric control barrier has been completed. Design of the removable shielding to be used within the vessels and neutron beam tubes is complete and procurements have begun.

Fabrication of the components for the first target is progressing on schedule. Assembly of some of these components to form the first target will be performed in October with preoperational testing begun in November. Delivery of the target cooling systems is expected in early October with installation performed shortly thereafter. Mating of these systems to target assemblies is expected in November.

The beryllium reflector assembly and its contained moderator cans for the Neutron Scattering Facility is being fabricated. Delivery of this long lead item is not expected until late January and this work continues to comprise the critical path for the overall construction. The reflector assemblies for the Radiation Effects Facility are being fabricated with delivery expected in October.

Design of all electrical and mechanical facility systems for support of the NGS has been completed. All procurements are underway and installations were begun in September.

All designs for the NGS monitoring and control systems have been completed. All procurements have been placed and most have been received. Installation in the control room, now under construction, is expected to begin in late October.

3. Instruments and Data Acquisition System (DAS)

It is planned that seven neutron scattering instruments will be operational during 1981. Designs were completed for the flight paths of the Special Environment Powder Diffractometer and General Purpose Powder Diffractometer. Bid solicitation for these components was completed and a fabricator selected. Work continues on developing layouts for the High Resolution Medium Energy Chopper Spectrometer scattered flight path housing. This assembly will be obtained by a design and build contract.

Conceptual designs for the Crystal Analyzer Spectrometer and Small Angle Diffractometer are continuing. Detail design work for the Low-Resolution Medium-Energy Spectrometer and Single Crystal Diffractometer will begin shortly.

Progress has been realized in the development for single-ended, linear position-sensitive detectors needed for the two powder diffractometers. Suitable detector systems are expected at the time when the housings are ready to accept them.

Work has begun on the rebuilding and refurbishment of vacuum systems required for the scattering instruments. Most of the vacuum equipment will derive from existing components obtained from completed HEP programs.

Designs for the five required choppers have been completed. A fabricator has begun the machining of the beryllium parts and ordering of other chopper components has been started.

For the DAS activities work continues on the detail design for detector electronics, computer software and computer hardware. A fifth front end computer has been delivered. One computer is being used for program development and detector electronics checkout.

The progress on developing encoding circuits for single-ended linear position-sensitive detectors has been excellent. Close coordination with the detector supplier continues in an effort to optimize the special detector needs for IPNS-I instruments.

4. General Items

At the beginning of August the contractor who began the IPNS-I construction work was dismissed and replaced by a new, inexperienced contractor. Since this action occurred with very short notice, all active subcontracts became invalid and required formalization with the new contractor. This caused some delays while new subcontracts were established. Also, some inefficiencies were encountered due to the changing of supervision. At present most problems have been remedied and harmonious and efficient construction activities appear to have been restored. High rainfall in August and early September caused some delays. However, exceptionally good weather in October has permitted acceleration of the construction activities.

The operations staff for IPNS-I, headed by Bruce Brown, has coordinated the development of the Safety Analysis Report (SAR). This report has been reviewed by committees with information participation by design personnel. The

reviews have resulted in some design improvements. The SAR has been approved by the Laboratory committees and submitted to the Department of Energy (DOE) for approval. With the DOE approval of the SAR on schedule, startup of the facility in April 1981 can be expected.

B. <u>Research and Development</u>

On August 4, we ended operation of ZING-P' to begin final preparation for IPNS-I. ZING-P' was the second prototype pulsed spallation neutron source operated at ANL, following the first experiments (anywhere, as we understand) in 1974 and 1975 on the ZGS Intense Neutron Generator Prototype, ZING-P. Foreseeing completion of the 500 MeV, 30 Hz Rapid Cycling Synchrotron, we conceived (with Motoharu Kimura, our visiting consultant from the Laboratory of Nuclear Science, Tohoku University, Japan) and decided to build this second prototype which was completed in time for startup with the new accelerator in December 1977.

The data acquisition system used for most of the scattering instruments was an ND6600 computer-based multichannel analyzer system with time-of-flight ADC's. George Ostrowski maintained the ND6600 and detectors for this system, and they fulfilled our needs well.

Our goals were to test further the applications of pulsed spallation neutron sources in scattering studies and to develop information needed for design of IPNS. We think we've been very successful in reaching these goals. Starting with low intensity operation with 0.5×10^{12} proton/pulse at 1 Hz, while sharing the injector linac with ZGS, we reached in the end 1.8×10^{12} proton/pulse at 30 Hz in a dedicated mode with reliability of about 90%.

Initially a target of tungsten was used with three Be-reflected room-temperature polyethylene moderators. Later we installed and operated a Zr-clad depleted uranium target and a natural-circulation liquid hydrogen moderator and also made a number of changes in moderator poisoning and decoupling. These developments not only provided a more effective neutron source, but enabled essential measurements relating to IPNS-I design.

Scientists of the Argonne scientific divisions developed and operated five scattering instruments and one general physics experiment. Several fast neutron radiation effects tests were done. An extensive series of measurements of target, moderator, reflector and cooling system tests were carried out, and the source was used as a test-bed for neutron detector tests by Argonne and Rutherford Lab groups.

The table summarizes scattering instrument developments, source measurements, and tests of applications of pulsed spallation neutron sources that we have carried out.

1. Scattering Instrument Development

   Crystal analyzer spectrometer

   Single crystal diffractometer (Time-of-Flight Laue Camera)

   Small angle diffractometer

   High resolution powder diffractometer

2. Fundamental Physics Experiment

   Ultracold neutron generator (for neutron bottle and neutron EDM measurements)

3. Fast Neutron Irradiation

   S_iO_2, carbon

4. Radiation Effects Facility Mock-Up Measurements

   Pb reflector, Ta and U targets

5. Resonance Neutron Radiography

6. Source Measurements

   Total power in W and U targets

   Local power density in U target

   γ + n dose rates in neutron beams

   Total nuclear heating in liquid hydrogen moderator

   Nuclear heating power densities in polyethylene, Be and Pb

   Nuclear heating in boron and Cd-shielded boron decoupler materials

   Absolute neutron beam intensities for W and U targets

   Delayed-neutron fraction

   Neutron spectra for liquid hydrogen and polyethylene moderators

   Neutron pulse widths vs wavelength for liquid hydrogen and polyethylene moderators

   Radioactivity in H_2O cooling system

   H_2 production in cooling system

   Corrosion products in cooling system.

C. Accelerator Operation

The Rapid Cycling Synchrotron (RCS) and 50 MeV Linear Accelerator (linac) really came of age as a 30 Hz pulsed neutron source during the four-month run starting April 1. While all the system components had limited testing at 30 Hz prior to this run, it was very satisfying to see them perform reliably at this frequency over an extended period. The linac, run at 0.3 Hz for many years as part of the Zero Gradient Synchrotron (ZGS), had less than five hours of breakdown in 2500 hours of scheduled 30 Hz running. The rf, sextupole and extraction improvements installed during the previous shutdown all performed well. The new pulsed transformer septum magnet (the old septum magnet was the Achilles heel of the RCS) logged over 200 million pulses without a problem.

The summary at the end of this article details the RCS performance, but a few highlights should be noted. These include: at 15 Hz -- short-term average of 2.0 x 10^{12} protons per pulse and eight hour average of 1.9 x 10^{12} protons per pulse; at 30 Hz -- short-term average of 1.83 x 10^{12} protons per pulse (8.8 μA) and twenty-four hour average of 1.58 x 10^{12} protons per pulse (7.6 μA). All the good numbers in the summary were achieved under clean operating conditions such that beam losses during this run were on the average no greater than previous runs at 15 Hz. Some 280 hours of operating time were used in studies to improve the performance of the synchrotron system. A number of reliability problems were also sorted out and appropriate changes made during the machine study periods.

Average target current showed a steady improvement over this run. The temptation to get high beams regardless of beam loss was avoided. Problems of clean beam handling and radiation induced outgassing were faced and conquered gradually as the beam intensity increased. The machine physicists were as eager to see a "clean" operation as were the operators and repair personnel. In the long run, this is the only way a high-flux machine such as the RCS can function.

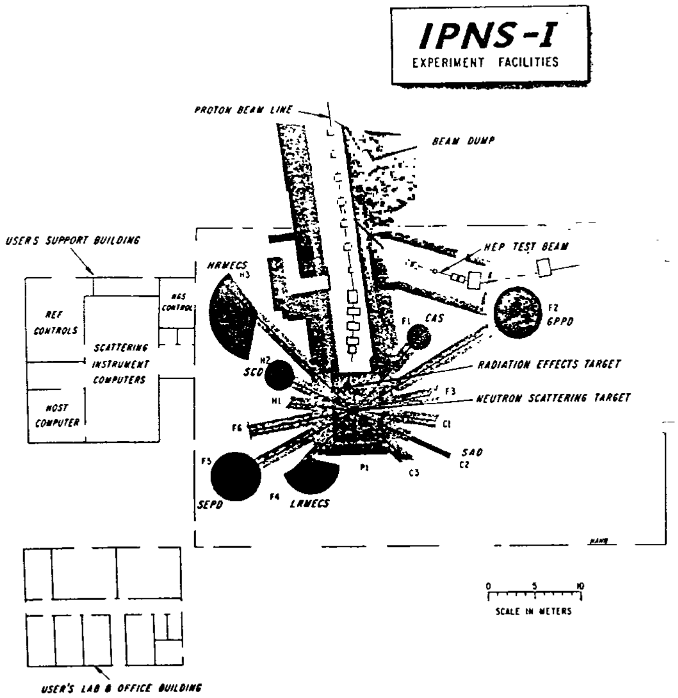
The upgrade activities (both long-term and short-term) progressed at a reasonable rate considering the attention required by operation and preparation for an assortment of review committees. Improvements planned during the next

six months are: tune control -- a programmable octupole magnet system; rf -- new cavity bias power amplifiers; kicker magnet system -- a new magnet and power supply capable of 50% more kick; and installation of the Penning ion source.

A major activity of the group during the six-month shutdown will be the rearrangement of synchrotron components and shielding to deliver beams to the new IPNS-I target. This major activity along with several thousand man-hours of routine maintenance will make a busy time indeed for the RCS and linac groups.

The IPNS accelerator system operating summary for the period Arpil 1, 1980, through August 4, 1980, is as follows:

ZING-P' scheduled operating time	2465.0 hours
ZING-P' time available	2092.4 hours
Operating efficiency	84.9%
Total protons on target, pulses >10^{11} protons	2.19 x 10^{20}
Total extracted pulses >10^{11} protons per pulse	1.93 x 10^{8}
Average protons per pulse on target	1.13 x 10^{12}
Average current	4.81 μA
Average repetition rate	26.48 Hz
User requested downtime	68.1 hours
User requested operation <30 Hz	46.4 hours



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

Fig. 2 Plan View of IPNS-I Neutron Generation Systems and Research Instrumentation

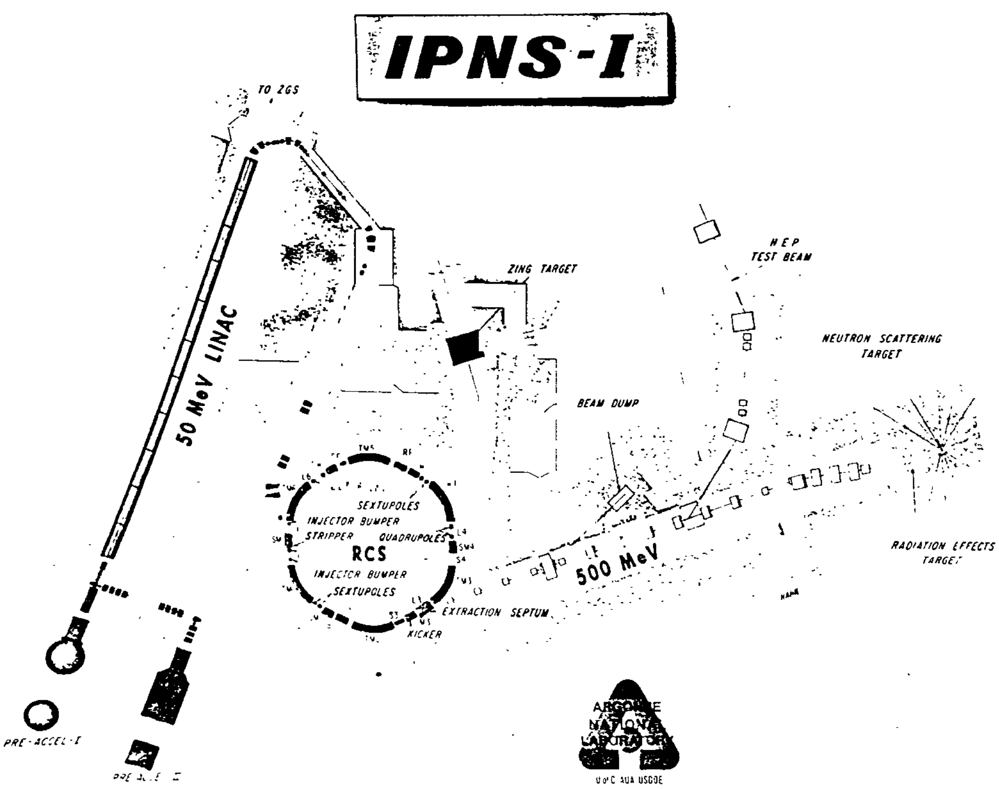


Fig. 1 Plan View of IPNS-I Accelerator Systems and Transport Line to Neutron Generation Systems