Reference Instrument Complement for IPNS Upgrade*

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ABSTRACT

A feasibility study for a new 1 MW pulsed neutron source has recently been completed at Argonne. As part of this feasibility study, an instrument package to instrument 24 of the 36 beam ports has been considered. This complement of instruments is outlined, and details of some of the instruments are discussed. Developments required before some of these instruments can be built are also indicated.

I. Introduction

During the past year we at IPNS have been involved in analyzing the feasibility of the construction of a 1 MW pulsed neutron source, referred to as IPNS Upgrade, and in developing a workable design concept for such a source.[1] As the first part of this process, it was necessary to investigate the requirements imposed on such a source by the various types of neutron scattering instruments which are likely to be operated there. A list of 20-30 instruments was drawn up by the neutron scattering scientists at Argonne, including instruments which covered a broad spectrum of capabilities and which they would like to see at such a source. Realistic concepts for most of these instruments, based on currently available technologies, were developed to the point where the optimal source parameters (source pulse repetition rate, moderator type, angular separation between beamlines, etc.) could be assessed; this information was then used to fix the source parameters. Once the accelerator and target station concepts were more fully developed, it was possible to set up a fairly detailed Monte Carlo model of the target/moderator/reflector assembly and to use this model to calculate the expected intensities from each of the moderators. The instrument concepts were then re-evaluated to assess the instrument performance, and where necessary, the instrument parameters were adjusted to provide improved performance. The requirements imposed at these performance levels for various instrument components were then assessed to identify any problem areas and to provide realistic cost estimates. The various steps in this process are covered in some detail in the following sections.

II. Choice of Source Parameters

The preliminary analysis of a reference set of instruments showed that very few could be optimized for operation at source pulsing frequencies greater than 30 Hz. A number of the instruments were well suited to 30 Hz operation, and nearly all of the remainder could be optimized for operation with a 10 Hz source pulsing frequency. This analysis resulted in the requirement that the primary operation of the accelerator systems should be at 30 Hz, with the proton pulses from the synchrotron being multiplexed between two target stations. One of these

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target stations should receive every third pulse, and thus provide true 10 Hz operation. The other target station would receive two out of every three pulses, producing roughly twice the time-averaged neutron intensity as the 10-Hz station. However, the shortest interval between pulses governs frame-overlap conditions for the instruments, and for this high-intensity station the shortest interval would be that characteristic of 30 Hz operation, or 33 ms. This high-intensity station, referred to as the 30-Hz target station, is designed to be able to utilize the full 30 Hz accelerator output during periods when the 10-Hz station is not operating.

Analysis of the reference set of instruments also pointed out the need for a wide variety of moderator conditions; cryogenic and room-temperature moderators of different heights and volumes and with different types of poisoning and decoupling. Thus it was imperative that each target station provide positions for a number of different moderators, all having relatively high intensity, in order to permit optimal matching of the moderator performance to the requirements of each instrument. The horizontal-injection split-target geometry chosen, shown schematically in Fig. 1, allows the incorporation of six independent moderators in each target station (see the detailed discussion elsewhere in these proceedings). Two of these are tall moderators (20 cm x 10 cm) viewing the "flux trap" region between the two portions of the split target; these can provide greater intensity for those instruments which can utilize a large vertical divergence. The remaining four are wing moderators located above and below the front and back portions of the split target. The relatively high proton energy of 2.2 GeV distributes a considerable portion of the neutron production to the back target, so that the back wing moderators have good intensity (although not as high as that of the front wing moderators). Calculated time-averaged neutron beam currents at 1 eV from the moderators range from 2.4×10^{13} n/sr-sec-eV to 4.7×10^{13} n/sr-sec-eV, depending on the moderator position, geometry, and material, and on the degree of decoupling.

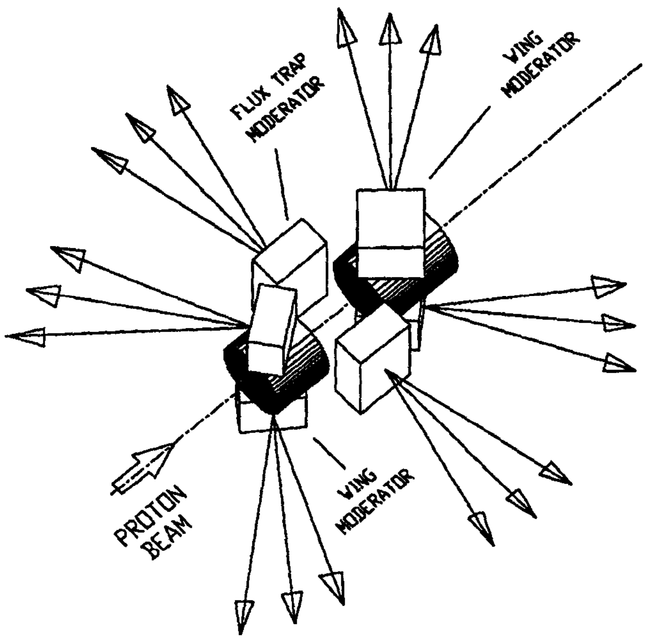

Figure 1. Schematic representation of the split-target geometry for IPNS Upgrade.

An analysis of heat deposition and radiolytic effects in the moderators has indicated that liquid H_2O, liquid CH_4, and liquid H_2 should all be viable moderator materials. Specific requirements regarding moderator material and configuration for the different instruments are addressed in the following section.

III. Instrument Parameters and Performance

A reference set of instruments was selected for detailed study. This set was chosen to represent a reasonable mix of the types of science which might be expected at a source of this magnitude. These instruments were analyzed and roughly optimized based on the specified source performance. There are 27 instruments in this reference set, including two partially-instrumented development beams, and they occupy 24 of the 36 beam ports on the two target stations. This reference set includes 10 of the present IPNS instruments, which would undergo varying degrees of modification before relocation to the new source. All but one of these 27 instruments operates in the time-of-flight mode. The remaining instrument, a cold-neutron triple-axis spectrometer, operates in a quasi-steady-state mode making use of the relatively high time-averaged flux of cold neutrons from a large coupled liquid H_2 moderator at this source (equivalent to a reactor cold source flux of $5x10^{13}$ n/cm^2-sec). The time structure of the source, while not used as the primary means of energy analysis in this instrument, provides discrimination against undesired orders from the monochromator and analyzer crystals as well as more general background reduction, resulting in an instrument with some unique capabilities.

Table 1 lists the 15 diffractometers and reflectometers in the reference set, and indicates their expected performance based on these source parameters. The five powder diffractometers are variously optimized for small samples (10-100 mg), high intensity, high resolution at 90° (0.2% in $\Delta d/d$), high resolution (0.08% in $\Delta d/d$), and for residual stress measurements on various types of samples. The general purpose small-angle diffractometer has an extremely broad dynamic range in Q, and it is complemented by a high-resolution instrument (Q_{min} = 0.0005 Å^{-1}) and by an instrument which can be reconfigured for various types of specialized small-angle scattering experiments (such as resonance small-angle scattering, measurements of inelastic effects, etc.). Additional diffractometers include a diffractometer for amorphous materials, and two single-crystal diffractometers, one of which is optimized for high real-space resolution (measurements made at Q values up to 30 Å^{-1}).

The suite of four reflectometers plus one reflectometer development beam is clustered on two beam ports, since the reflectometers are small and require only very narrow beams. This suite includes a polarized-neutron reflectometer, a general purpose reflectometer, a high-intensity reflectometer (reflectivities down to 10^{-4} in 1 min), and a reflectometer optimized for measurement of off-specular scattering. The latter three instruments have horizontal sample geometries, so that liquid samples can be accommodated.

Table 2 indicates the expected performance of the 10 remaining instruments, which are designed for inelastic scattering measurements. There are four chopper spectrometers including an instrument optimized for work with cold neutrons (better resolution but slightly lower intensity than IN5 at ILL) and one optimized for the study of excitations in single crystals, as well as traditional general-purpose instruments in both low and high resolution versions. Included among the five crystal analyzer spectrometers is the cold-neutron triple-axis spectrometer which operates in a quasi-steady-state mode as discussed above. The other four crystal analyzer spectrometers are time-of-flight instruments. Two of these are optimized for

Table 1 -- Reference Set of Diffractometers and Reflectometers

Powder Diffractometers			Range for d (Å)	Best Δd/d (%)	Measurement Time (min)
VSPD	very small samples (10-100 mg)		0.2 - 17	0.35	70
SEPD[a]	high intensity		0.2 - 17	0.35	3
GPPD[b]	medium resolution (excellent at 90°)		0.2 - 9	0.2	10 - 60
HRPD	high resolution		0.2 - 5	0.08	50
RSD	residual stress	(12-m position)	0.3 - 6	0.55	50
		(25-m position)	0.2 - 3	0.30	10

Small-Angle Diffractometers		Q_{min} (Å^{-1})	Q_{max} (Å^{-1})	Measurement Time (min)
SAND[a]	general purpose (wide Q range)	0.002	2	1 - 90
HRSAND	high resolution	0.0005	0.4	60 - 1800
SPSAND	reconfigurable for special purposes	-------------------	variable	------------------

Amorphous Materials Diffractometer		Range for Q (Å^{-1})	ΔQ/Q(%)	Measurement Time (min)
GLAD[a]	liquids and glasses	0.07 - 120	1.2 - 10	10 - 50

Single-Crystal Diffractometers		Range for Q (Å^{-1})	ΔQ/Q(%)	Measurement Time (min)
SCD[a]	general purpose	0.9 - 17	0.6 - 0.9	20 - 200
HQSCD	high real-space resolution	2 - 30	0.4	~200

Reflectometers		Sample	Minimum Reflectivity	Measurement Time (min)
POSY-I[b]	polarized neutrons	vertical	10^{-6}	60 - 120
POSY-II[b]	general purpose	horizontal	10^{-7}	60 - 120
HIREF	high intensity	horizontal	10^{-4}	< 1
GREF	grazing incidence	horizontal	10^{-7}	60 - 120

a Transferred from IPNS with little change.

b Transferred from IPNS with some modification medium resolution (70 μeV) and high resolution (1-5 μeV) measurements at low energies, one is optimized for relatively high resolution chemical spectroscopy at high energies, and one is a multi-angle spectrometer for the study of excitations in single crystals. The final instrument intended for inelastic scattering measurements is a spin-echo spectrometer. This instrument utilizes cylindrical field geometry, and is the time-of-flight counterpart to IN11 at ILL. Resolution is expected to be better than at IN11, while data rates are expected to be somewhat lower than at IN11.

Table 3 indicates the facility requirements (path lengths, moderator characteristics, source repetition rates) for this reference set of instruments. Based on these requirements, a reasonable assignment of the instruments to specific beam ports was found. This assignment, although not yet fully optimized, provided each instrument with its specified flight path lengths and grouped instruments sharing the same moderators in such a way as to require only small compromises from the optimum moderator characteristics. Figure 1 shows this arrangement of the reference set of instruments about the two target stations, and their possible locations within experimental halls which already exist at Argonne.

Table 2 -- Reference Set of Inelastic Scattering Instruments

Chopper Spectrometers		Range for E_{inc} (meV)	$\Delta E/E_i$(%)	Measurement Time (h)
HRMECS[b]	high-resolution general purpose	4 - 2000	2 - 4	2
LRMECS[a]	low-resolution general purpose	3 - 2000	4 - 7	<1
CNCS	high-resolution low energy	0.3 - 20	<1	12
SCCS	excitations in single crystals	50 - 2000	~1	~12

Crystal-Analyzer Spectrometers		Range for E (meV)	ΔE (meV)	Measurement Time (min)
TFCA	general purpose	0 - 1000	0.5 - 30	20 - 80
QENS[a]	quasielastic, medium resolution	0 - 150	0.05 - 3	20 - 80
HRBS	microvolt resolution	0 - 10	0.005 - 0.06	~80
MICAS	survey of single-crystal excitations	0 - 20	varies	
QSTAXC	cold-neutron triple axis (QSS)			

Spin-Echo Spectrometer		Spectral Resolution (meV)	ΔQ/Q (%)	Measurement Time (h)
TOFNSE	TOF spin-echo, cylindrical geometry	10^{-6} - 10^{-1}	1.5	2 - 48

a Transferred from IPNS with little change.
b Transferred from IPNS with some modification
QSS Quasi-steady-state

Table 3 -- Requirements for Instruments

30-Hz Target					10-Hz Target				
Instrument	L_i(m)	L_f(m)	Moderator Specs[a]		Instrument	L_i(m)	L_f(m)	Moderator Specs[a]	
SEPD	12	1.5	CH_4[b]	T	SAND	12	2	H_2	C,N
GPPD	25	1.5-4	CH_4[b]	T	HRSAND	20	5	H_2	C,N
HRPD	50	2	CH_4[b]	T	SPSAND	<40		H_2	C,N
RSD	25	1.5-3	CH_4[b]		POSY-I	18	<2	H_2	
VSPD	12	0.75	CH_4[b]		HIREF	18	<2	H_2	
GLAD	23.5[c]	1.5	CH_4	T	POSY-II	18	<2	H_2	
SCD	10	0.6	CH_4[b]		GREF	18	5	H_2	
HQSCD	30	0.7	CH_4[b]		REFD	18		H_2	
HRMECS	18	4	CH_4		CNCS	20	4	H_2	
LRMECS	12	2.5	CH_4		HRBS	30	3	H_2	T
SCCS	16	4	H_2O		TOFNSE	16	4	H_2	C
QENS	9	<1	CH_4[d]	T	DEVEL			H_2	
TFCA	16	<1.5	CH_4	T					
QSTAXC	17	<2	H_2	C,T,N					
MICAS	12	1.5	CH_4						

[a] Moderators are decoupled at 1 eV and poisoned unless otherwise indicated. C: coupled, T:can use a tall moderator, N:not poisoned.
[b] Could be H_2O.
[c] To low-resolution sample position.
[d] Could be poisoned H_2.

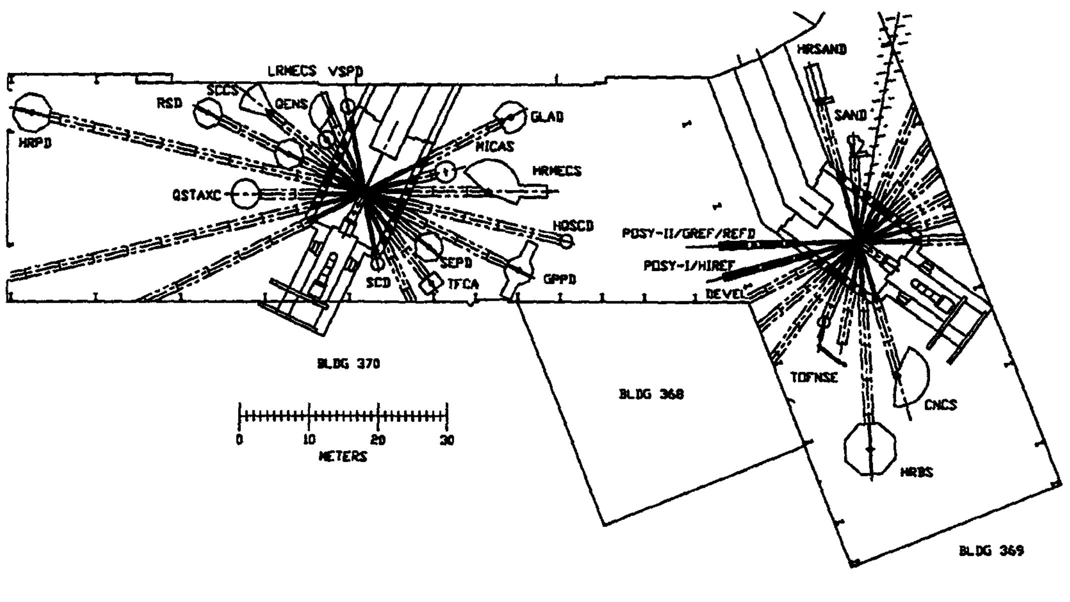

Figure 2. Location of the reference set of instruments on the neutron beamlines.

IV. Requirements for Specific Instrument Components

The requirements for instrument components such as choppers, guides, beamline shielding, detectors, data acquisition, etc., were assessed for all the instruments in the reference set. With the exception of the detectors, all other components required for these 27 instruments appear to fall within the capabilities of current technology, although a number of areas were identified in which development efforts could lead to significant cost savings and/or improvements in performance. For example, considerable development will be required to produce reliable and cost-effective designs for the data acquisition electronics to handle the high data rates expected. Also, since the beamline shielding is a significant portion of the instrument cost, a development program to optimize the geometry and composition of this shielding will be worthwhile.

As an example of such assessments, Tables 4 and 5 indicate the detector requirements determined in this process. For this exercise, all detectors were considered to be ^{3}He gas proportional counters, although other types of detectors such as scintillation detectors would work equally well in some (but not all) of these cases. Detector technology is currently available to meet all of the requirements for "standard" detectors indicated in Table 4. However, current

Table 4 -- Standard[a] Detector Requirements

Instrument[b]	Number	Diameter (cm)	Length (cm)	Max rate per det (cts/sec)[c] Instantaneous	Time-avg.
SEPD	~280	1.2	38	~5x10^{4}	~5x10^{3}
GPPD	~520	1.2	38	~5x10^{3}	~1x10^{3}
HRPD	~410	1.2	38	~9x10^{2}	~2x10^{2}
RSD	~250	1.2	38	~4x10^{3}	~7x10^{2}
VSPD	~560	0.6	19	~2x10^{3}	~3x10^{2}
HRMECS	~800	2.5	46	~2x10^{5} [d]	~3x10^{4} [d]
LRMECS	~160	2.5	46	~7x10^{5} [d]	~5x10^{4} [d]
CNCS	~1000	2.5 [e]	25	~4x10^{4} [d]	~3x10^{3} [d]
QENS	~100	0.6	10	~2x10^{3}	~9x10^{1}
HRBS	~150	0.6	10	~9x10^{1}	~9x10^{0}
TFCA	~300	0.6	25	~2x10^{3}	~9x10^{1}
QSTAXC	~12	0.6	10	~5x10^{4}	~7x10^{2}
MICAS	~20	0.6	10	~5x10^{4}	~9x10^{3}
TOFNSE	~10	0.6	10	~2x10^{2}	~2x10^{1}

a Detectors are specified as cylindrical ^{3}He gas proportional counters, but in some cases scintillation detectors such as those used on some instruments at ISIS can be substituted.

b Instruments not listed do not use any "standard" detectors.

c Scaled from IPNS rates where possible; otherwise estimated assuming the sample scatters 20% of the beam isotropically into a 4π solid angle.

d Maximum rates are for diffractometer mode (choppers removed). Rates in normal operation are much lower.

e This instrument uses "squashed" detectors with thickness ~1 cm and width ~3.5 cm.

Table 5 -- Position-Sensitive Detector Requirements

Instrument[a]	Dimension	Number	Width (cm)	Length (cm)	Resolution (mm)	Max rate per det (cts/sec)[b] Instantaneous	Time-avg.
RSD	2D	4	30	30	2	~1x10^5	~2x10^4
SAND	2D	1	40	40	4	~2x10^5	~7x10^4
	1D	65	1.2	60	10	~9x10^3	~3x10^3
HRSAND	2D	1	60	60	2	~5x10^3	~2x10^3
	1D	~20	1.2	60	10	~5x10^2	~2x10^2
SPSAND	2D	1	40	40	4	~5x10^4	~2x10^4
GLAD	1D	~410	1.2	60	10	~7x10^3	~3x10^3
SCD	2D	3	30	30	3	~1x10^6	~1x10^5
HQSCD	2D	1	30	30	1.5	~1x10^5	~1x10^4
POSY-I	1D	1	5	10	2	~1x10^3	~4x10^2
POSY-II	1D	1	5	20	2	~6x10^3	~2x10^3
HIREF	1D	1	5	10	2	~1x10^5	~3x10^4
GREF	2D	1	60	60	2	~1x10^4	~3x10^3
REFD	2D	1	3	3	0.5	~1x10^3	~4x10^2
HRMECS	1D	~40	2.5	100	20	~1x10^5 [c]	~2x10^4 [c]
LRMECS	1D	~30	2.5	46	20	~8x10^5 [c]	~6x10^4 [c]
CNCS	1D	~30	2.0 [d]	60	20	~4x10^4 [c]	~3x10^3 [c]
SCCS	1D	~256	2.5	100	20	~4x10^4 [c]	~8x10^3 [c]

a Instruments not listed do not use any position-sensitive detectors.

b Scaled from IPNS rates where possible; otherwise estimated assuming the sample scatters 20 % of the beam isotropically into a 4π solid angle.

c Maximum rates are for diffractometer mode (choppers removed). Rates in normal operation are much lower than this.

d This instrument uses "squashed" cylindrical linear-position-sensitive detectors with thickness ~0.8 cm and width ~2 cm.

technology cannot provide all of the required position-sensitive detectors indicated in Table 5. In particular, the 2D detectors for HRSAND, SCD, HQSCD, and GREF all have either counting-rate requirements or resolution requirements which exceed the capabilities now available. Thus some improvements in detector technology will be required if these four instruments are to perform at their full potential at this 1 MW source. Fortunately, developments which are in progress[2] show promise of providing detector performance at these levels by the time these detectors would be needed.

References

1. Full details of this feasibility study will be published as an Argonne Report.
2. A. Oed. *Nucl. Instrum. Meth.* **A263**, 351-359 (1988); P. Geltenbort and A. Oed. Proceedings of SPIE's 1992 International Symposium on Optical Applied Science and Engineering, San Diego, Calif., July 19-23, 1992, Vol. 1737, pp. 289-293.