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The Weapons Neutron Research facility (WNR) is a pulsed spallation neutron source in operation at the Los Alamos National Laboratory. The WNR uses part of the 800-MeV proton beam from the Clinton P. Anderson Meson Physics Facility accelerator. By choosing different target and moderator configurations and varying the proton pulse structure, the WNR can provide a white neutron source spanning the energy range from a few meV to 800 MeV. The neutron spectrum from a bare target has been measured and is compared with predictions using an Intranuclear Cascade model coupled to a Monte Carlo transport code. Calculations and measurements of the neutronics of WNR target-moderator assemblies are presented.

[800-MeV protons, spallation, neutron spectra, 1 meV-800 MeV neutrons, Intranuclear Cascade Predictions]

Introduction

The Weapons Neutron Research facility[1,2] is an operational pulsed spallation neutron source at the Los Alamos National Laboratory. At the WNR, a portion of the intense 800-MeV proton beam produced by the Clinton P. Anderson Meson Physics Facility (LAMPF)[3] bombards a target to produce an intense white-neutron source. Variable proton pulse widths are available at the WNR giving time-of-flight (TOF) experimental capability for neutrons from a few meV to 800 MeV. The flexibility and capability of the WNR will be enhanced by the addition of a Proton Storage Ring (PSR)[4]. The PSR, presently under construction and scheduled for operation in 1986, will be able to alter the intensity, time structure, and repetition rate of the WNR proton pulse. We present here a description of the WNR, its operating characteristics, and some neutron spectra measurements and calculations.

Facility Description

The WNR is one of several experimental facilities located at LAMPF; the layout of the WNR is illustrated in Fig. 1. At present, the high-current area (target 1) is capable of accepting up to 20 μA of proton beam. Target 1 has a vertical target, is surrounded by a 2-m diam by 2-m high cylindrical void, and is shielded by a 3.7-m-thick laminated iron-concrete structure. Target 1 has a very flexible target-moderator—reflector handling scheme; all three configurations shown in Fig. 2 are employed. The orientation of the reflected 'T'-shape moderator in target 1 is illustrated in Fig. 3. For use with the PSR, the shielding and handling scheme for targets, moderators, and reflectors is being upgraded for operation with 100 μA of proton current. Neutron beams are extracted at 90° to the target axis; flight paths from 5 to several hundred meters are available. Basic research in nuclear physics and materials science research is done in the high-current target area.

The low-current target area (target 2) can accept up to 0.1 μA of proton beam or be used for measurements with neutrons from target 1. The horizontal proton beam in target 2 strikes targets which can be viewed at a variety of angles (from 7.5° to 165°) to the proton beam. We have implemented 30-m flight paths at 7.5°, 15°, and 30° to study (p,xn)- and (p,xp)-type reactions, and are considering longer flight paths and other angles. In target 2, we have also developed the capability to measure (for 800-MeV-proton spallation reactions). 1) spatial distributions of (absolute) 'thermal' neutron surface fluxes from moderators, 2) absolute neutron spectra for energies < 10 eV, and 3) neutron pulse shapes for energies < 0.172 eV. We use this unique experimental capability (combined with excellent computational support) to optimize the neutronics of the high-current production target system in terms of neutron beam fluxes and pulse widths, and minimizing high-energy neutron beam contamination and associated backgrounds[5,6,7].

Using targets placed in the WNR beam channel, we have constructed a 200-m flight path at 0° to the proton beam. This flight path combined with a unique WNR proton pulse structure* allows high resolution experiments to be performed at neutron energies up to 800 MeV[8].

Operating Characteristics

With or without the PSR proton beam, the WNR can operate in two modes. These modes are as follows:

- without PSR
  - micropulse mode
  - microsecond mode
- with PSR
  - short bunch high frequency mode
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A summary of the WNR proton pulse characteristics is given in Table 1. At present, the width of the WNR proton pulse can be varied from 200 ps to 8 μs. The PSR will provide additional pulse-width and repetition-rate combinations with higher instantaneous intensities, and more average proton currents.

Neutronic Characteristics

The various designs of target, target-moderator, and target-moderator-reflector configurations for target 1 (see Fig. 2) are strongly influenced by the need for neutrons with energies ranging from a few meV to 800 MeV having pulse widths as narrow as practical. We use a bare target to produce neutrons with energies $\gtrsim$ 100 keV, an unreflected 'fast' moderator for neutrons with energies 1 eV $\lesssim E \lesssim$ 100 keV, and a reflected system for neutrons with energies $\lesssim$ 1 eV.

The high-resolution bare target presently used in target 1 consists of a Ta cylinder (2.5-cm diam by 15-cm long) placed in a water cooled Al canister. We measured the neutron spectrum (at 90° to the proton beam) from such a target; the results are shown in Fig. 4 and compared with calculated predictions. The bare-target data were measured

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at a 29.4-m flight path using TOF techniques and a scintillator of known efficiency. For these measurements, we used 200-ps-wide proton pulses spaced 11 μs apart at 12 Hz. Charged particle contamination of the neutron beam was observed to contribute significantly to the detector count rate at energies > 100 MeV and was eliminated using sweep magnets. The experimental data have been normalized to calculated results at 10 MeV.

In target 2, we measured the neutron beam flux from a reflected 'T'-shape moderator using a BF_3 detector, a 5.6-m flight path, and 35 ns proton pulses at 120 Hz[7]. The measured data are shown in Fig. 5 for a 100 cm^2 field-of-view at the moderator surface. The target was a 4.5-cm-diam by 25-cm-long W rod. The CH_2 moderator had a 0.0025-cm-thick Gd poison sheet located 1.91 cm from the viewed surface. The moderator was isolated from the Be reflector by 0.076 cm of Cd. The Be reflector was a cube with a 46-cm side. Measured neutron pulses from the Cd-decoupled, Gd-poisoned CH_2 moderator are illustrated in Fig. 6.

State-of-the-art Monte Carlo codes are operational on the Los Alamos computing system. These codes include the ORNL High Energy Nucleon Meson Transport Code (HETC)[10], and the sophisticated Los Alamos coupled neutron-photon transport code MCNP[11]. We used these codes in the calculation shown in Fig. 4. We have also computed the neutronics of moderated systems. In particular, we have calculated the outward neutron current at a moderator surface for the two configurations shown in Fig. 7; the results are given in Fig. 8. We used a 2.5-cm-diam by 15-cm-long Ta target in the unreflected slab-moderator computations. A 5-cm-diam by 25-cm-long W Target was used in the reflected wing-moderator calculations. The reflector was a Be cube (50 cm on a side), and the moderator was 3.5 cm from target center. The Cd-decoupler was 0.076-cm thick, and the Gd poison sheet was 0.0025-cm thick placed 1.5 cm from the viewed surface. Note in Fig. 8 the decrease in thermal neutron current when a reflected system is decoupled and poisoned; the thermal neutron pulse characteristics are, however, significantly better for the decoupled/poisoned system[7]. In Fig. 8, the neutron current from the unreflected slab-moderator is averaged over 400 cm^2 whereas the neutron current from the wing-moderators were averaged over 100 cm^2. The presence of a high-energy neutron component, beginning at ~1 MeV, in a center-looking field-of-view from a slab moderator (compared to the offset field-of-view in wing geometry) can be seen in Fig. 8. This high-energy neutron component can extend up to a few hundred MeV[9].

The characterization of the WNR neutronic capability will continue in an effort to intercompare calculations with experiments on an absolute basis.

Acknowledgements

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TABLE I
LAMPF AND WNR PROTON BEAM CHARACTERISTICS

		PRE PSR		POST PSR			
		WNR		WNR		WNR PSR	
	LAMPF[a]	MICROPULSE MODE	MICROSECOND MODE	MICROPULSE MODE	MICROSECOND MODE	SBHF MODE[b]	LBLF MODE[c]
PROTONS/PULSE	5.2×10^{13}	$2.5\times10^{[illegible]}$	$5\times10^{[illegible]}$	$3.1\times10^{[illegible]}$	$5.2\times10^{[illegible]}$	1.04×10^{11}	5.2×10^{13}
PULSE WIDTH	833 µs	200 ps	8 [illegible]	200 ps	83 µs	1 ns	270 [illegible]
REPETITION RATE	120 Hz	1 Hz – 6 kHz	120 Hz	1 Hz – 166.6 kHz	120 Hz	720 Hz	12 Hz
PROTONS/s AVERAGE	6.25×10^{15}	$2.5\times10^{[illegible]}$ – $1.5\times10^{[illegible]}$	$6\times10^{[illegible]}$	$3.1\times10^{[illegible]}$ – $5.2\times10^{[illegible]}$	6.25×10^{14}	$7.5\times10^{[illegible]}$	6.25×10^{14}
AVERAGE PROTON CURRENT	1 mA	40 nA – 240 nA	9.6 µA	50 nA – 8.3 µA	100 µA	12 µA	100 µA

[a]The LAMPF beam structure consists of micropulses separated by 5 ns [illegible] grouped in 833 µs long macropulses at 120 Hz for [illegible] 10 [illegible] duty factor. Present LAMPF current is 200 µA at a 9 [illegible] duty factor.

[b]Short bunch high frequency

[c]Long bunch low frequency

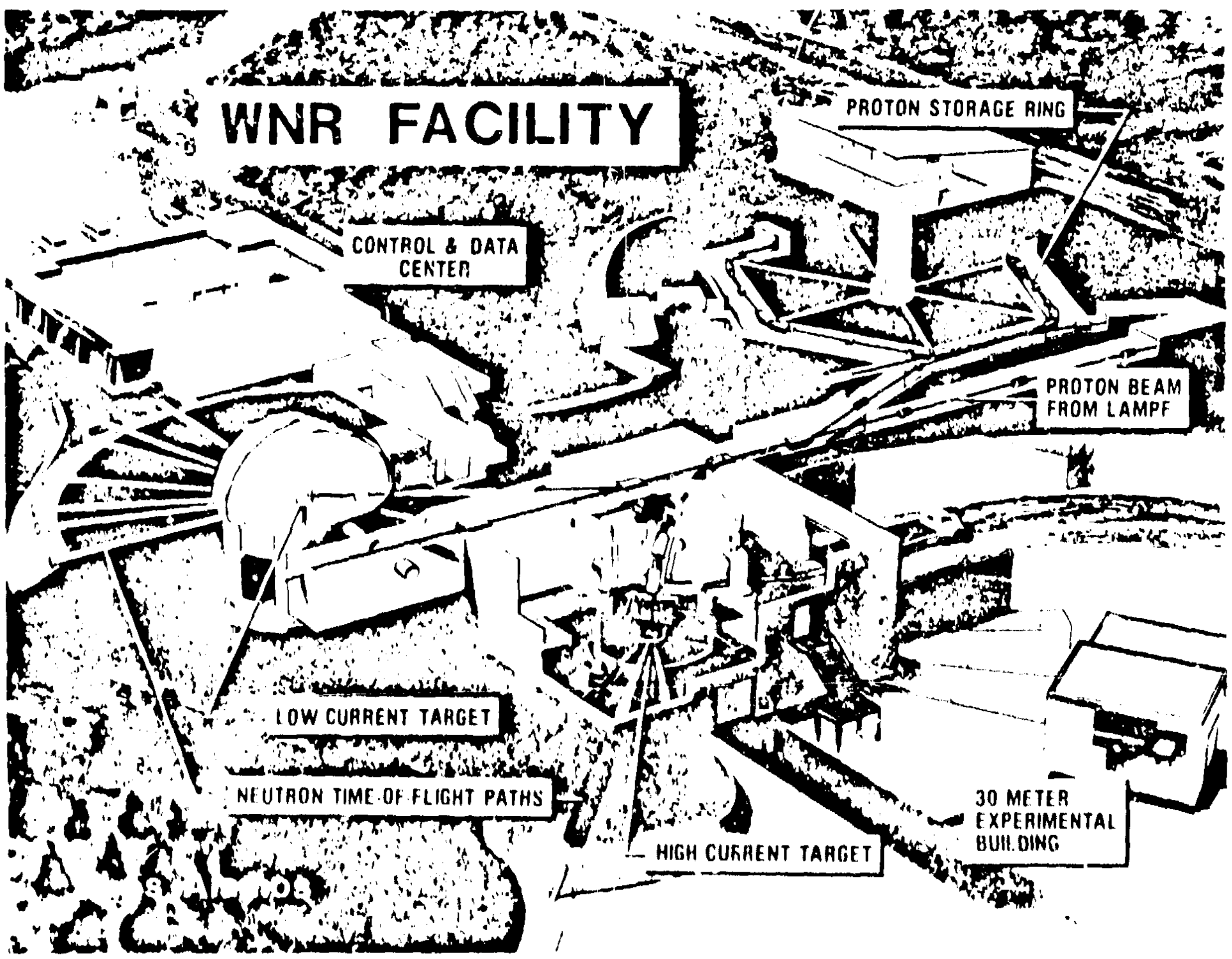

Fig. 1 This figure shows a layout of the WNR and the location of the proton storage ring. The high-current target is located in a vertical proton beam and is viewed by 11 horizontal flight paths. The low-current target is located in a horizontal proton beam and viewed by 11 horizontal flight paths and one vertical flight path. The 0° flight path extends out the end of the proton beam channel between the high- and low-current target areas.

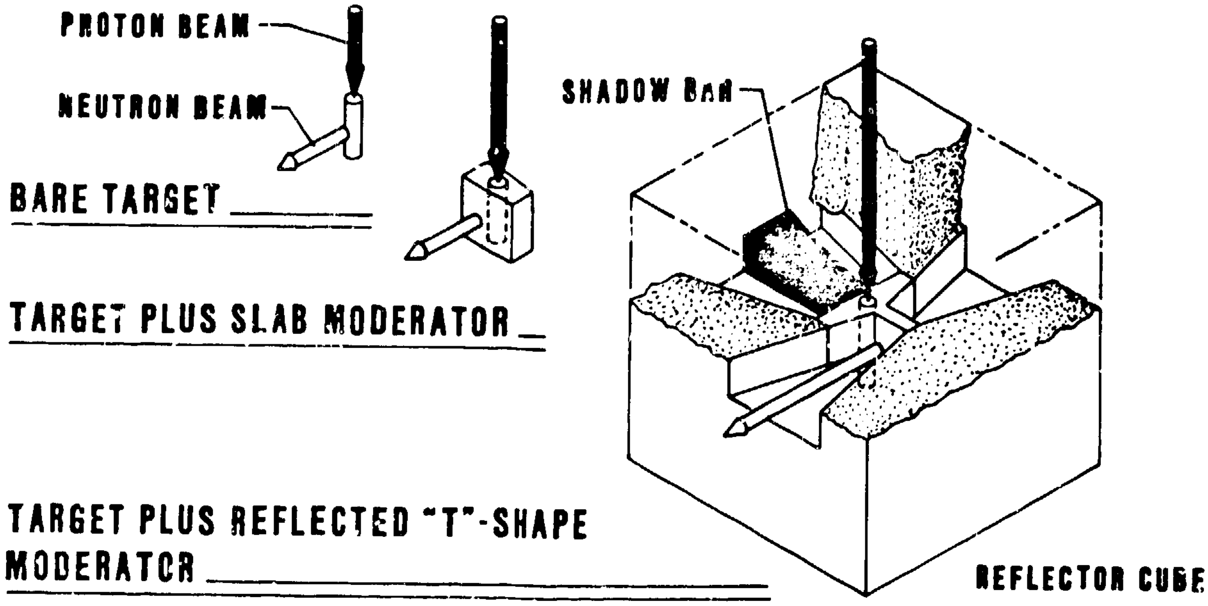

Fig. 2 Neutron production configurations presently in use in the high-current target area.

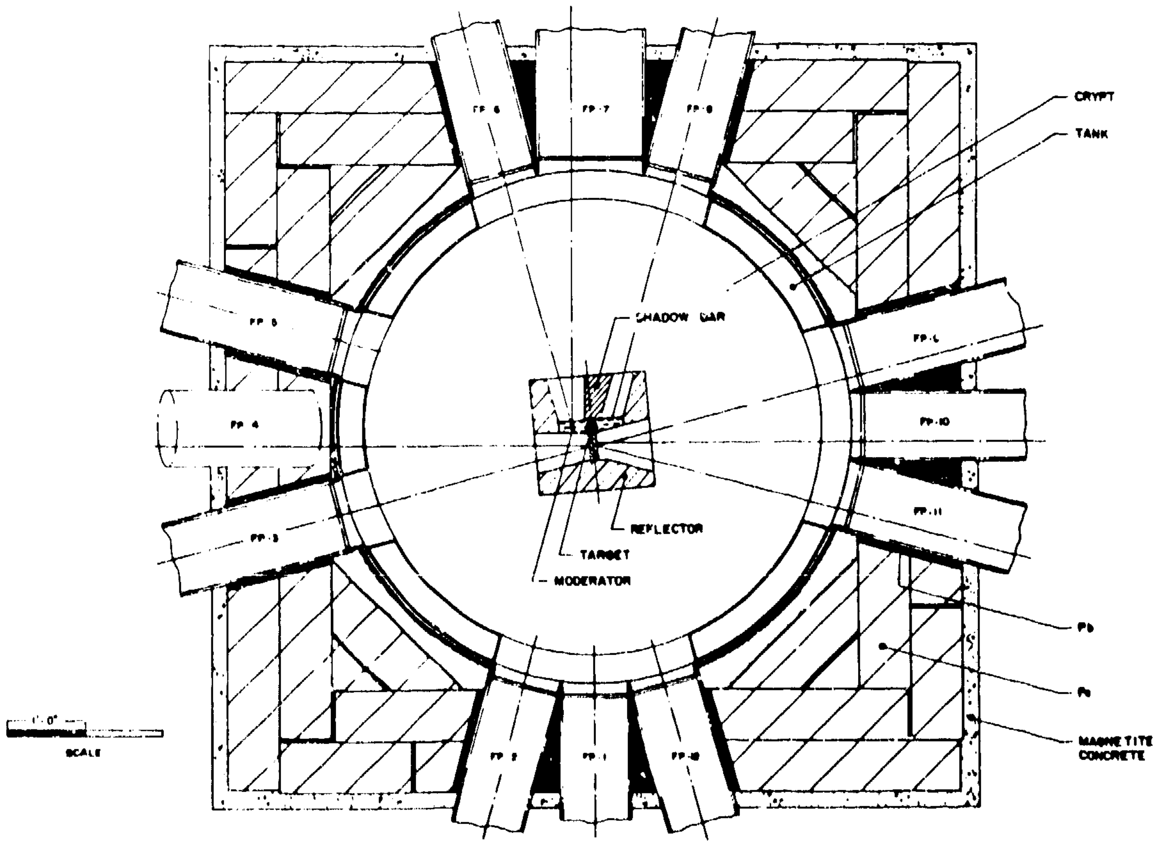

Fig. 3 Present orientation of the reflected 'T'-shape moderator in the high-current target area.

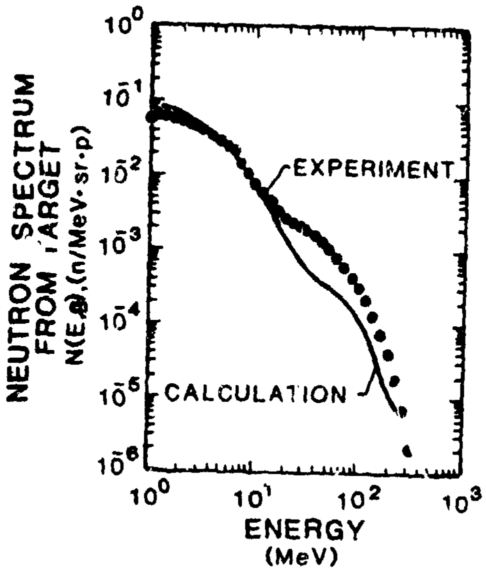

Fig. 4 Bare target spectrum (at 90° to the proton beam axis) emitted from the cylindrical surface of the WNR Ta target. The field-of-view at the target surface encompassed the full target diameter but limited the height seen to 4.4 cm centered 3.8 cm from the top of the target.

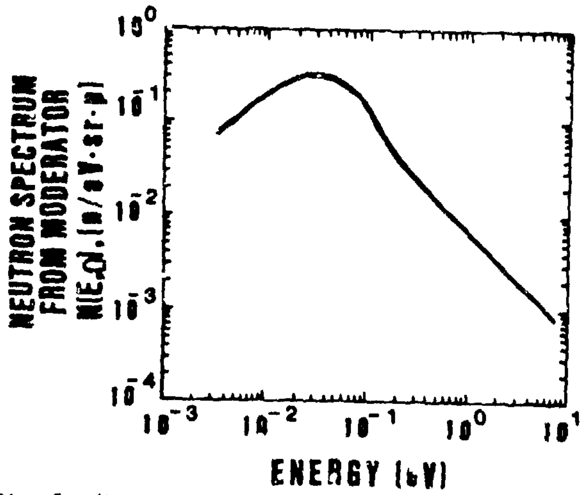

Fig. 5 Measured neutron spectrum emitted (at 90° to the moderator surface) from a reflected wing-moderator.

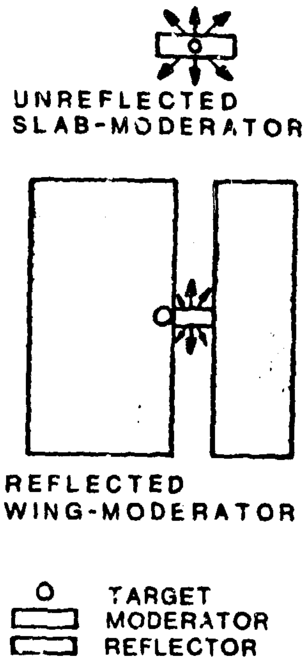

Fig. 7 Illustration of geometries used in calculating neutron leakage currents.

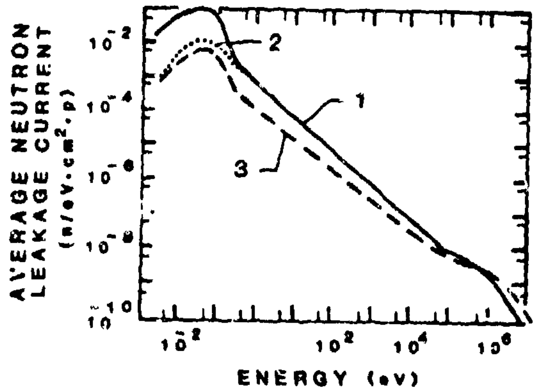

Fig. 8 Calculated neutron leakage currents averaged over the entire moderator surface for three configurations: 1) coupled reflected wing-moderator (5 cm by 10 cm by 10 cm H_2O), 2) Cd-decoupled Gd-poisoned reflected wing-moderator (5 cm by 10 cm by 10 cm H_2O), and 3) unreflected slab-moderator (5 cm by 20 cm by 20 cm H_2O).

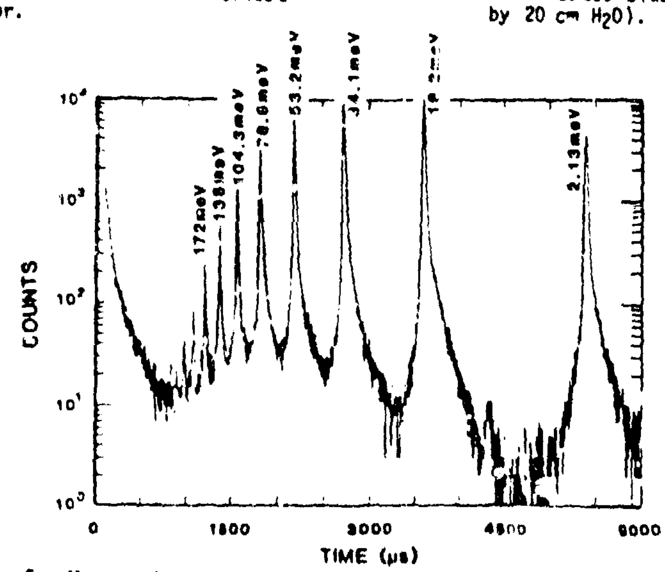

Fig. 6 Measured neutron time distributions from a Cd-decoupled Gd-poisoned reflected wing-moderator.

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