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TITLE: A LONG-PULSE SPALLATION SOURCE AT LOS ALAMOS: FACILITY DESCRIPTION AND PRELIMINARY NEUTRONIC PERFORMANCE FOR COLD NEUTRONS

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AUTHOR(S): G.J. Russell, Lansce-12
D.J. Weinacht, Lansce-DO
E.J. Pitcher, APT-TPO
P.D. Ferguson, Lansce-12

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A Long-Pulse Spallation Source at Los Alamos: Facility Description and Preliminary Neutronic Performance for Cold Neutrons

G. J. Russell, D. J. Weinacht, E. J. Pitcher, and P. D. Ferguson
Los Alamos National Laboratory
Los Alamos, NM 87545

Abstract

The Los Alamos National Laboratory has discussed installing a new 1-MW spallation neutron target station in an existing building at the end of its 800-MeV proton linear accelerator. Because the accelerator provides pulses of protons each about 1 msec in duration, the new source would be a Long-Pulse Spallation Source (LPSS). The facility would employ vertical extraction of moderators and reflectors, and horizontal extraction of the spallation target. An LPSS uses coupled moderators rather than decoupled ones. There are potential gains of about a factor of 6 to 7 in the time-averaged neutron brightness for cold-neutron production from a coupled liquid H_2 moderator compared to a decoupled one. However, these gains come at the expense of putting "tails" on the neutron pulses. The particulars of the neutron pulses from a moderator (e.g., energy-dependent rise times, peak intensities, pulse widths, and decay constant(s) of the tails) are crucial parameters for designing instruments and estimating their performance at an LPSS. Tungsten is our reference target material. Inconel-718 is the reference target canister and proton beam window material, with Al-6061 being the choice for the liquid H_2 moderator canister and vacuum container. A 1-MW LPSS would have world-class neutronic performance. We describe the proposed Los Alamos LPSS facility, and show that, for cold neutrons, the calculated time-averaged neutronic performance of a liquid H_2 moderator at the 1-MW LPSS is equivalent to about 1/4th the calculated neutronic performance of the best liquid D_2 moderator at the Institut Laue-Langevin reactor. We show that the time-averaged moderator neutronic brightness increases as the size of the moderator gets smaller.

Introduction

The Los Alamos National Laboratory has discussed (1) installing a new 1-MW spallation neutron target station in an existing building at the end of its 800-MeV proton linear accelerator (2). Because the accelerator provides pulses of protons each about 1 msec in duration, the new source would be a Long-Pulse Spallation Source (LPSS), as compared to a Short-Pulse Spallation Source (SPSS) which has proton pulse widths of around 1 µsec or less (3-8). The accelerator and the building in which the spallation source would be housed are located at the Los Alamos Neutron Science Center (LANSCE) (9). Because the spallation source would use existing LANSCE infrastructure and facilities, such an LPSS facility would be extremely cost effective. Since no new accelerator is to be built or commissioned, present estimates are that the LPSS could be designed and built in three years (1).

The target system (targets, moderators, poisons, decouplers, liners, and reflectors) is the part of a target station that contributes directly to the production of useful neutrons. (For most users of a pulsed spallation-neutron source, useful neutrons can be defined as those headed in the right direction with appropriate energy at the right time.) A target station consists of the target system, bulk shield, remote handling systems, and ancillary equipment. The particulars of a target station depend on whether it is designed for an SPSS or an LPSS.

Target stations are vital components of a spallation-neutron source, and target-station design plays a major role in determining the overall (neutronic and operational) performance of the facility. Several new concepts are being put forward to meet the challenge of designing a target station for the next generation spallation neutron source (1-5 MW of proton beam power). It is generally believed that a target station designed for 1 MW can employ existing target technology (e.g., solid targets cooled by either light or heavy water) (10-12); for higher proton beam powers such as 5 MW, liquid mercury targets are presently being studied (13,14).

The main advantage of an LPSS for neutron scattering will be for experiments requiring long-wavelength ("cold") neutrons or experiments for which good wavelength resolution is not needed. For many such experiments, the LPSS will perform as well as or better than the present world leader, the 60-MW nuclear reactor at the Institut Laue-Langevin (ILL) in Grenoble, France (15). Because the LPSS will produce a pulsed neutron beam rather than a continuous stream of neutrons like that provided by a nuclear reactor, the LPSS will use time-of-flight methods for many neutron scattering experiments and will open up new opportunities for advances in neutron scattering methods.

The basic neutronics of an LPSS and coupled moderators have been discussed in Refs. 16-19. We will now describe the physical concept of an LPSS at LANSCE, and compare the time-averaged neutronic performance of a reference target system to that of the ILL for cold neutron production.

The LPSS Facility

Figure 1 shows the experimental areas at the end of the LANSCE accelerator. These areas include the Manuel Lujan Jr. Neutron Scattering Center (MLNSC, which is now being referred to as the Lujan Center), the Weapons Neutron Research (WNR) facility, and the building housing the Proton Storage Ring (PSR), and Area A. The new LPSS will be located in Area A of the LANSCE complex. This new neutron source will provide complementary capabilities to those already available at the Lujan Center and the Weapons Neutron Research (WNR) facility. It will not affect operations at these facilities. The combination of the existing facilities and the 1-MW LPSS will provide uniquely powerful and versatile sources of neutrons in an energy range covering fifteen orders of magnitude: from hundreds of nanovolts to hundreds of megavolts. For many neutron scattering experiments using cold neutrons, the LPSS will provide capabilities comparable to those of the ILL 60-MW reactor.

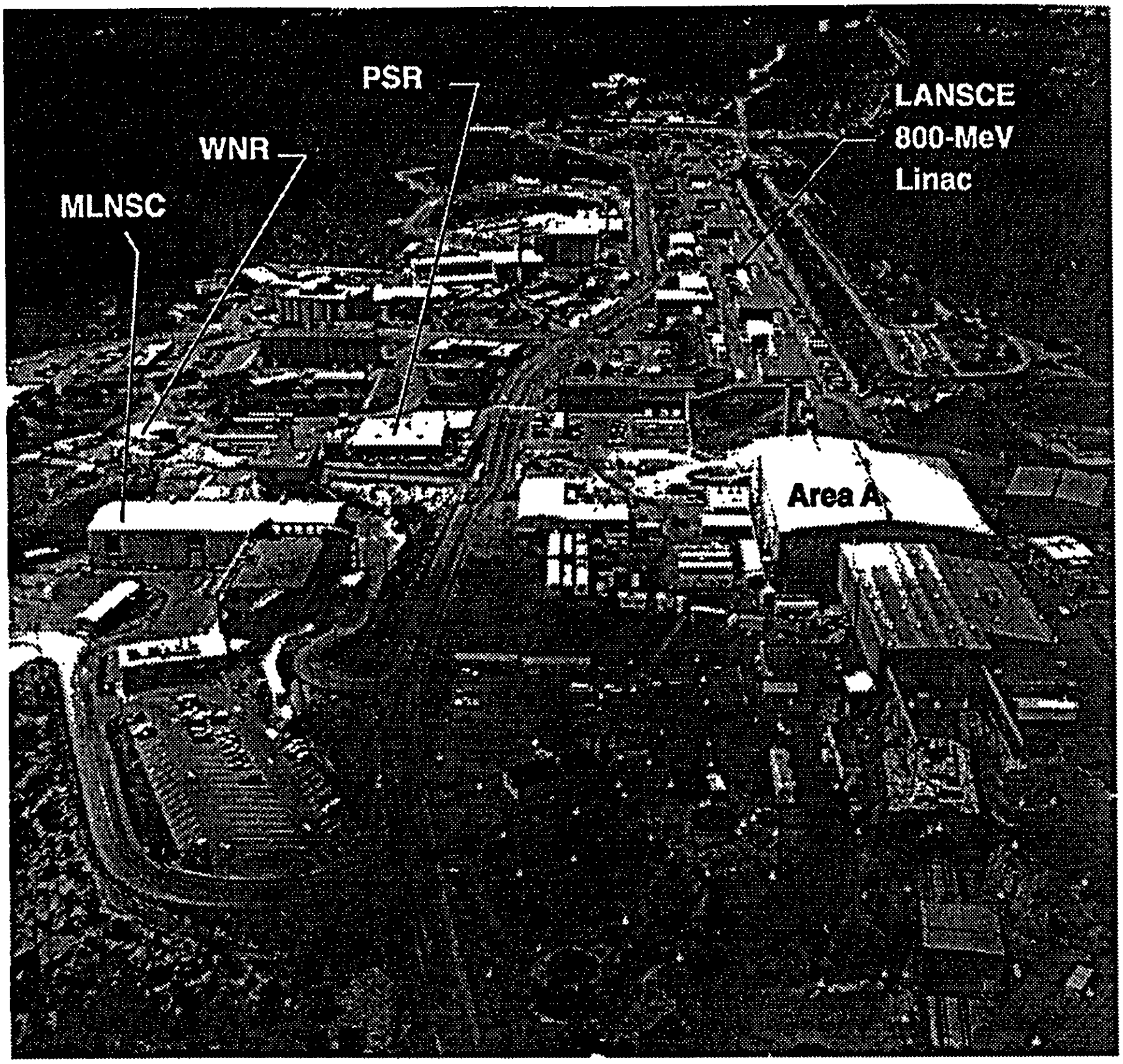

Figure 1: Aerial view of LANSCE accelerator and experimental areas. Area A is where the proposed LPSS will be built. This area and the accelerator were formerly known as the Los Alamos Meson Physics Facility (LAMPF).

Layout of the LPSS

As mentioned above, the LPSS neutron production target will be located in Area A (see Fig. 1) which originally housed nuclear physics instruments. Most of these instruments either have been moved or will be decommissioned in the future because the facility will not be funded as a nuclear physics facility in the future. The Area A building constructed of metal beams with a sheet metal skin, has approximately 3,000 m^2 of floor space and a usable height within the building of about 14 m. A 2.5-m-thick concrete floor would support the massive biological shielding in the center of the building. No modifications to the building or the floor will be required for the LPSS.

The facility is equipped with utilities and ancillary systems including:

- two 30-ton radio-controlled bridge cranes that can be coupled for 60-ton lifts;
- a 19,000-cfm capacity radioactive air handling system with a high efficiency particulate air (HEPA) filter bank and an approved stack emissions monitoring system;
- 20,000 tons of iron and concrete for biological shielding, some of which can be utilized for the LPSS;
- three 3-MW capacity cooling water systems that are adequate for LPSS;
- a 13.2-kV electrical substation with fifteen 1000-kVA distribution transformers (recently refurbished) that can provide power for experiments; and
- three remote handling manipulators and their control systems that will be used to handle targets and other radioactive components.

These systems, which constitute a considerable infrastructural investment (approximately $38M), will be used to the fullest extent possible to support the LPSS. Existing shielding will be reused where possible to reduce cost and minimize the volume of hazardous waste that must be transported away from the site.

Figure 2 shows the overall floor plan of the LPSS experimental area, including the flight paths. A monolithic steel and concrete biological shield consisting of about 4.5 m of steel and about 1.5 m of concrete will occupy the central part of Area A. The top of the shield will be about 7.0 m from the floor. A 1.5-m-thick poured concrete wall will comprise the outer wall of the shield. This wall will provide seismic stability, a barrier for low-energy neutrons, and containment for radioactive air produced by secondary particles from the target. The shield is designed to limit the radiation dose at the exterior boundary of the monolith to 0.1 mrem/h.

The neutron production target and moderators will be located at the center of the monolith with 15 beam tubes arranged radially. A hot cell will be adjacent to the shielding monolith directly downstream of the target system as shown in the cut-away drawing in Fig. 3. Moderators will be extracted vertically from the target chamber and drawn into a remotely operable shielded cask that can be moved on rails to a position above the hot cell. The moderators can be lowered into the hot cell for servicing. This same cask will service the beam diagnostics and materials test components located upstream of the spallation target. The spallation targets will be extracted horizontally from the target chamber and drawn into the hot cell for servicing. This approach ensures that the most highly activated component in the system (i.e., the spallation target) will always be shielded and contained. Handling of the spallation target will be conducted completely separate from neutron beam experiments, thus providing unimpeded user access to experiments and isolation of radioactive targets and moderators in a controllable manner. Operations in the hot cell will be performed with remote handling systems.

Reference LPSS Target-Moderator Geometry

The heart of the new LPSS is a system of spallation targets and moderators that generate neutrons for numerous research applications. Los Alamos National Laboratory has considerable experience with both the operation of spallation target systems and with the design and optimization of advanced target systems for a variety of applications including the Lujan Center (3,5), WNR (9), and the Accelerator Production of Tritium (APT) project (20). In our reference target-moderator design, the spallation target is split to produce the "flux-trap" geometry (21) used successfully at the Lujan Center. Figure 4 shows the LPSS reference target-moderator geometry which is composed of a split target, two liquid hydrogen moderators in wing geometry, and a liquid hydrogen moderator in flux-trap geometry (viewed both in transmission geometry from one side and in backscattering geometry from the opposite side). We report here only neutronic performance data for liquid H_2 moderators. Ambient-temperature moderators are also under study and may be of interest for an LPSS. The actual target-moderator configurations and moderator types used will be determined by future neutronic optimization studies and the suite of spectrometers to be installed at the LPSS facility.

A reflector (e.g., C, Be, D_2O, Pb, etc.) will surround the spallation targets and moderators to enhance the neutronic performance of the moderators. The reflector must be carefully designed to help produce neutron pulse shapes from the moderators that are suitable for scattering experiments. A composite neutron reflector (composed of beryllium and lead) is also being considered for the LPSS reflector (16-19, 21). Heavy water will be used to cool the reflector and the spallation targets.

The neutron production target and its associated moderators, reflectors, and iron shielding will occupy a 2-m-diameter stainless steel vacuum vessel at the center of the shielding monolith. Because the radiation and heat deposition levels in the vacuum chamber will be low, this component should serve throughout the lifetime of the facility

A moderator is being considered for Ultra-Cold Neutron (UCN) production. Ultra-Cold Neutrons (22) are neutrons with energies less than about 10^{-7} eV. As scoping studies of this specialized moderator are currently in progress, its integration into the LPSS will be part of the LPSS moderator system concepts going forward.

In the reference LPSS target-moderator geometry, neutron beams will be extracted from both sides of each wing moderator and the flux-trap moderator will be viewed in both transmission and backscattering geometry, providing six moderator viewed surfaces each with a 10 cm by 10 cm field-of-view. Since engineering detail is known to significantly influence target performance, a considerable amount of such detail has been included in the Monte Carlo simulations of the target system. For example, the present Monte Carlo model accounts for target/reflector dilution by an amount of heavy water coolant that is adequate for 1 MW of incident beam power on the target, a proton beam window, target enclosures, moderator canisters, moderator vacuum enclosures, and neutron flight path penetrations. The model does not account for target and moderator cooling lines and baffles or structural material in the reflector.

Neutron Flight Path Choppers

The LPSS flight paths will be equipped with chambers for neutron choppers that will also serve as guides for blade-type beam shutters. Most of the neutron scattering spectrometers at the LPSS will require what is called a T_0 chopper that will protect a spectrometer from the flash of fast neutrons and gamma rays that is generated when protons strike the tungsten neutron production target(s). Some LPSS spectrometers will also need lightweight disk choppers either to define the time-of-flight measurement frame or to shorten the neutron pulses produced by the target system. The location and design of these choppers will depend on the spectrometer served, so the chopper housing will be designed to permit positioning flexibility and to allow ready access to choppers for maintenance purposes. Additional research and development will be needed to ensure that the choppers function reliably and can be maintained without excessive impact on LPSS operations.

Poisons, Decouplers, and Liners

As mentioned previously, useful neutrons (at a pulsed spallation neutron source) are those neutrons headed in the right direction with the appropriate energy at the correct time. Unfortunately, spallation neutrons produced directly by the spallation target rarely have these desired characteristics. We must, therefore, add the necessary systems and devices to a bare neutron spallation target to tailor the neutron pulses so their characteristics are as close as possible to the user's requirements. As mentioned above, a complete spallation target system consists not only of spallation target(s), but also moderators, reflector(s), and, in the case of an SPSS, poisons, decouplers, and liners.

In addition to the choice of material, temperature, geometry (e.g., wing versus flux-trap moderators) (21), and the presence or absence of a reflector, moderator neutronic performance is also strongly tied to the presence or absence of poisons, decouplers, and liners. The choice of materials and thickness for these target system components is a crucial part of moderator design (10). The function of poisons, decouplers, and liners is to tailor the temporal and energy characteristics of the neutron pulses emitted by the moderator (17). Figure 5a shows the arrangement of poisons, decouplers and liners for a split-target, flux-trap moderator geometry (3,4). For thermal neutrons, the poison neutronically defines that part of the moderator "viewed" by an experiment. Decouplers surround a moderator and both geometrically and neutronically isolate it

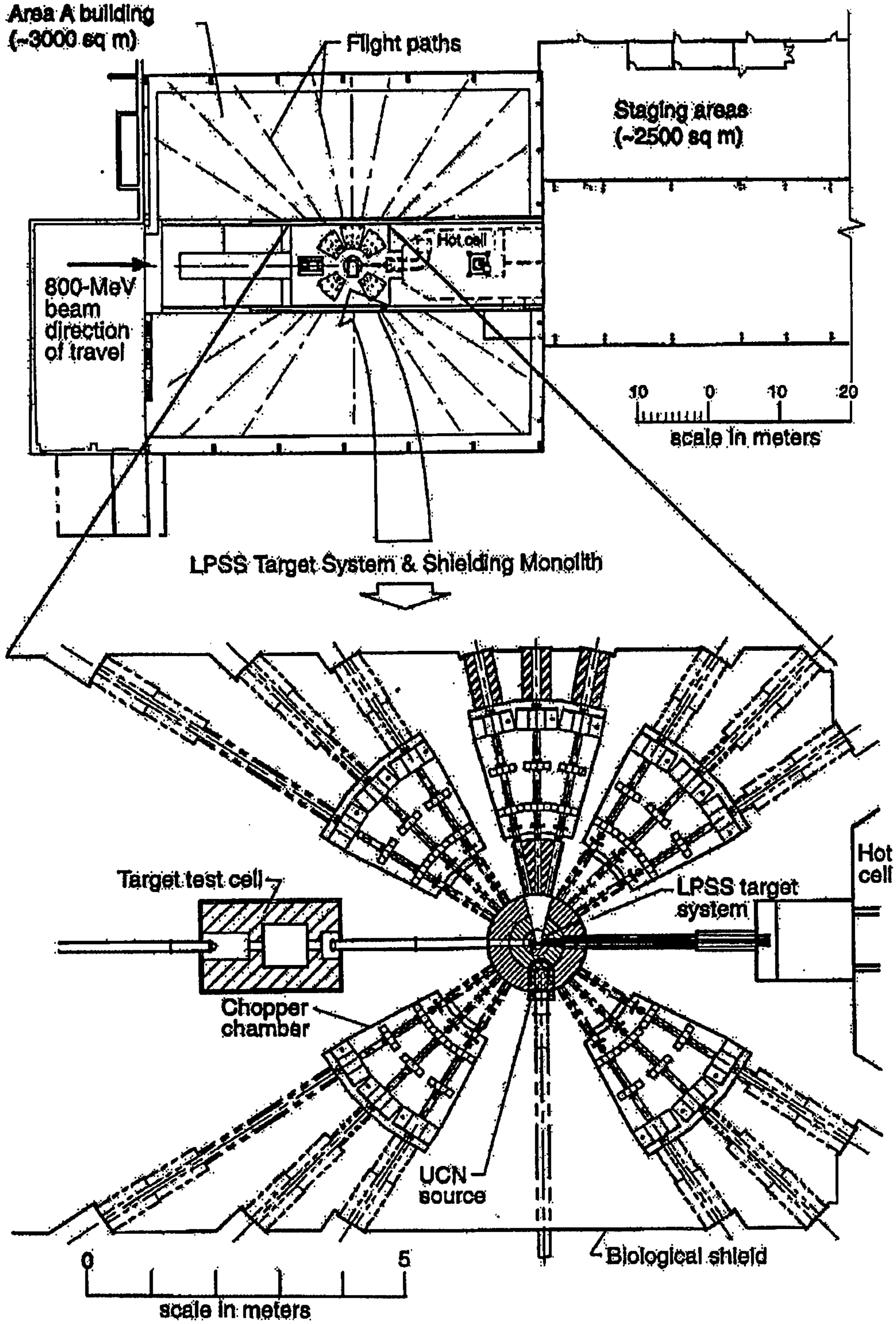

Figure 2: Overall layout of the LPSS facility. The target system and shielding monolith will be positioned in Area A as shown. The target test cell is no longer being considered for the LPSS.

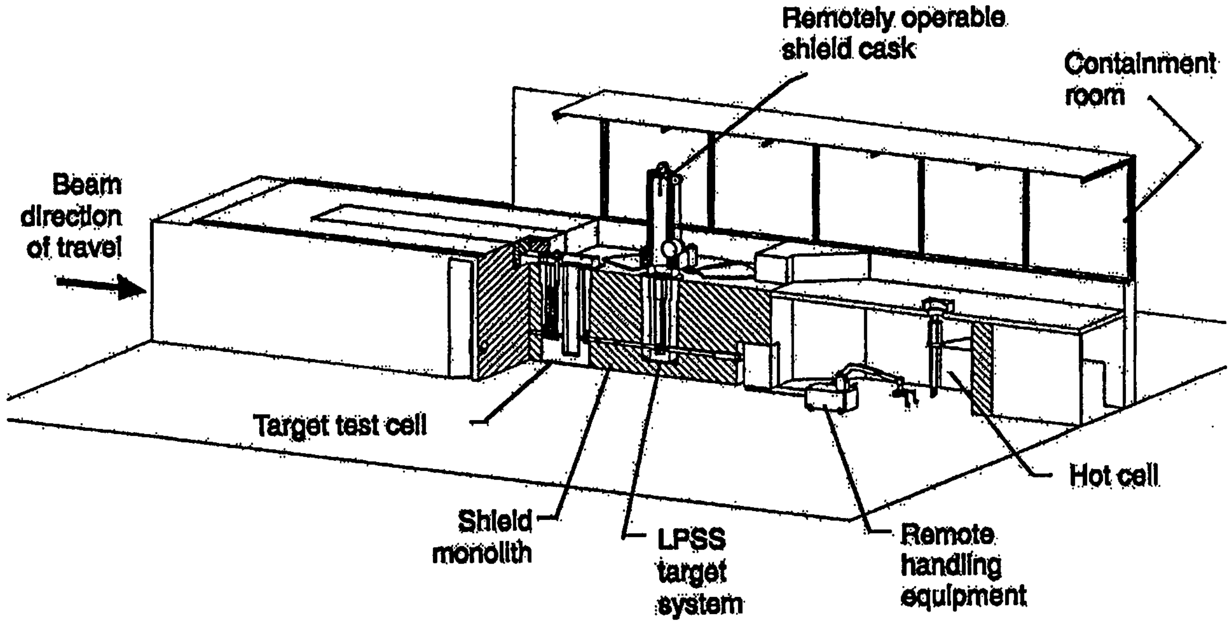

Figure 3: Cut-away view of the shielding monolith and hot cell.

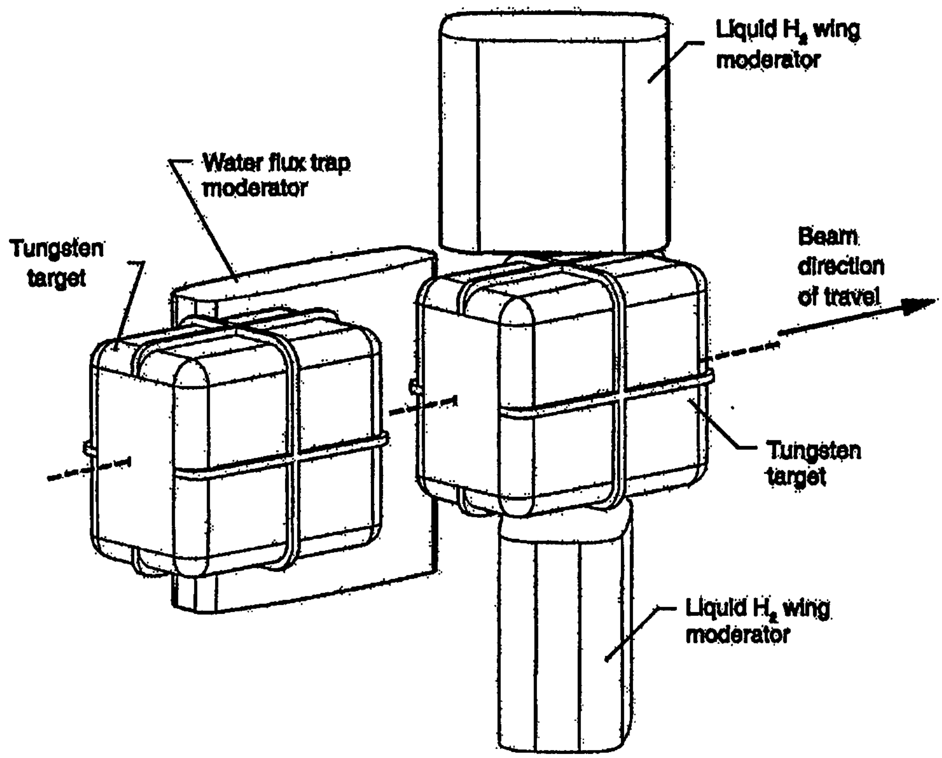

Figure 4: LPSS reference target system. This figure does not show the reflector, UCN moderator, or beam tubes.

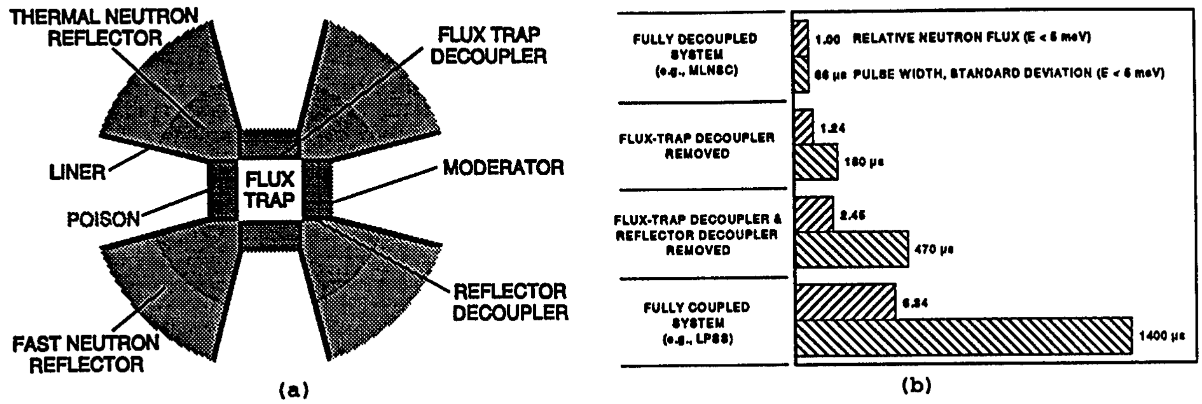

Figure 5: Arrangement of poisons, decouplers, and liners in a flux-trap moderator geometry. As shown in Fig. (a), poisons are typically oriented parallel to and positioned some distance (~1 to 3 cm) behind the moderator viewed surfaces. The flux-trap decouplers neutronically insulate moderators from one another, whereas the reflector decouplers neutronically isolate moderators from the adjoining reflector material. Liners neutronically insulate the reflector from the moderator viewed surface. Figure (b) shows the effect of poisons, decouplers and liners on neutron pulse intensity and pulse width for liquid H2 (ortho/para 50/50 v%) moderators. The labels on the left side of the bar graph indicate what items are present for the corresponding bars. The neutron pulse width is defined as the standard deviation of the time at which neutrons leak from the moderator viewed surface. The 22.5-cm-long, D2O-cooled W rod-target is singly split and the four 5x13x13 cm3 moderators are in flux-trap geometry. The poison is 0.00508-cm-thick Gd, and the decouplers and liners are 0.0813-cm-thick Cd. The reflector is D2O-cooled Be (D2O/Be 15/85 v%). The proton beam energy is 800 MeV. The target-moderator geometry is that described in Ref. 3.

from the reflector. Liners geometrically and neutronically isolate the "viewed" surface of the moderator from the reflector. We deliberately define decouplers and liners separately because they can be different materials each with distinct thickness, as in the Lujan Center target system design (3,4).

The goal of SPSS moderator design is to get as much useful neutron intensity from a moderator as possible with little or no attendant degradation in the neutron-pulse time distributions. For LPSS moderator design, poisons, decouplers, and liners will either be not used or used judiciously. The goal of LPSS moderator design is to get as much useful neutron intensity from a moderator as possible while matching the neutron-pulse time distributions to experimental requirements (16). We will now discuss the neutronic gains in going from and an SPSS to an LPSS (19).

<u>From an SPSS to an LPSS</u>

If we employ decouplers and liners in conjunction with a moderator surrounded by a reflector, we refer to those moderators as "decoupled" moderators. To date, only decoupled moderators have been used at the existing SPSS facilities (3-8). However, the Lujan Center will be using partially coupled moderators in its new SPSS target system, which is part of an upgrade project to the Lujan facility (23). The choice of material and thickness of the material for decouplers and liners is important in optimizing the neutronic performance of the next generation (1-5 MW) SPSS. Adequately cooling the decouplers and liners for the next generation SPSS's will be a design challenge.

If we do not employ decouplers and liners in conjunction with a moderator surrounded by a reflector, we refer to those moderators as "coupled" moderators. Coupled moderators are in use at the SINQ quasi-continuous spallation neutron source (24), and, as mentioned above, partially coupled moderators are being designed for an upgrade to the Lujan Center spallation target system. Coupled moderators can provide significantly higher neutron fluxes than decoupled ones. However, neutron pulse widths from a coupled moderator are much larger than that from a decoupled one. We illustrate this neutronic gain in Figure 5b for a liquid H_2 moderator as the decouplers and liners are removed in stages (i.e., in going from a decoupled moderator to a coupled moderator). For a liquid hydrogen moderator, a totally coupled moderator provides about 6 to 7 times greater neutron pulse intensity (for $E < 5$ meV) than a decoupled moderator. However, as indicated by the standard deviation, the neutron pulses are "broader" in time from a coupled moderator compared to a decoupled one, which is an issue that must be dealt with effectively. These gains in going from decoupled to coupled moderators depend on the target-moderator geometry.

Figure 6 depicts the energy-dependent gain in neutron beam intensity for a coupled liquid H_2 moderator compared to a decoupled one. As can be seen, the maximum gain in neutron intensity occurs below the decoupling energy (in the "useful" neutron regime). The time distributions of coupled and decoupled liquid H_2 moderators are depicted in Fig. 7. Coupled moderators have higher peak neutron leakage intensity than decoupled ones. However, coupled moderators have a longer "tail" on the neutron pulses.

In Fig. 8, we show the ratio of coupled/decoupled data for liquid H_2 moderators integrated over time; we call this *the time-dependent neutron leakage gain*. The results show that the neutron gain depends on the time over which the neutrons can be utilized in an experiment. The maximum gain for liquid H_2 is the factor of between 6 and 7 (as $t \to \infty$). In practice, the actual *time-dependent neutron leakage gain* will depend on the "engineering realities" of the specific target system being considered.

The data presented in Figures 5-8 are for the flux-trap moderator geometry of Ref. 3, and there are no premoderators in the calculations. Also, the 5x13x13 cm moderators are unpoisioned, and the Be/D_2O reflector is 85/50 v% Be/D_2O.

<u>Reference LPSS Target System Geometry</u>

The reference geometry for Monte Carlo simulations of neutronic performance is a singly-split tungsten target with a square cross section. This geometrical model was devised by Pitcher (17). The Monte Carlo model is based on horizontal proton beam insertion into the target system. The Monte Carlo geometry of the reference target system is depicted in Fig. 9. The upstream target is $10x10x8.5$ cm^3 and the downstream target is 10x10x19.5 cm^3, with homogenized material compositions equivalent to that of the tungsten plate target concept proposed by Carpenter (7). The material compositions of the two targets were originally set to handle 1 MW of proton beam power at 2 GeV. We increased the coolant gap to 0.2 cm and added 0.05 cm of tantalum cladding to each plate per a discussion with Broome (25). This gave the following homogenized volume fractions of 69.4 v% W, 9.4 v% Ta, and 21.2 v% D_2O for the upstream target and 85.1 v% W, 4.6 v% Ta, and 10.3 v% D_2O for the downstream target. Both target sections are enclosed in 0.2-cm-thick Inconel-718 target canisters. The flux-trap gap between the two target sections is 11.5 cm.

Located at the flux-trap gap is a 6x10x10 cm^3 liquid H_2 flux-trap moderator. The liquid hydrogen moderator is enclosed in an Al-6061 canister with 0.35 cm walls at 20 K. The moderator canister is separated from a 0.35-cm-thick Al-6061 vacuum canister by a vacuum gap of 0.5 cm. A similar canister arrangement exists for the two liquid-H_2 wing moderators on the top and bottom of the upstream target. The flux-trap moderator has wrapped around its perimeter, a 2-cm-thick layer of H_2O, at a temperature of 293 K. A similar H_2O layer is present around each wing moderator, except that the thickness is 1 cm. For the flux-trap moderator, the distance from the proton beam centerline to the inner surface of the liquid H_2 is 7.1 cm. This distance for a wing moderator is 8.4 cm. The reference ortho/para-hydrogen concentration was assumed to be 50/50 v% at 20 K. The anticipated ortho/para-hydrogen concentration in the LPSS moderator needs further study.

Before striking the spallation targets, the 800-MeV proton beam passes through a proton beam window, represented by two 0.108-cm-thick Inconel-718 plates separated by a 0.2-cm-thick gap filled with H_2O.

The overall reflector size is 150 cm diameter by 150 cm high. The reflector composition was assumed to be Be/D_2O with 85 v% Be and 15 v% D_2O. Pitcher (26) has shown that the neutronic performance of coupled moderators is not too sensitive to the D_2O coolant fraction in a tungsten target. A similar study needs to be performed for the coolant fraction in the reflector.

Results

We used the LAHET Code System (LCS) (27) to calculate the time-averaged performance of the LPSS reference target system. The magnitude of the energy-dependent, spatial-average moderator brightness is derived from point detector tallies placed 10 m from the moderator leakage surfaces. The four leakage surfaces from the wing moderators were averaged together to reduce the statistical error. The results of the calculation are shown in Fig. 10 for the reference target system. Also, we are studying ways to improve the LPSS moderator performance below about six angstroms. An example of this effort is depicted in Figure 11, where we change the moderator width and height (the moderator thicknesses are the same) from 10 cm by 10 cm to 9 cm by 9 cm. Figure12 shows data for 8 cm by 8 cm moderators. Based on these calculations, the overall source brightness of the LPSS reference target system (from 2-10 A) is comparable to about one quarter that of the ILL over the wavelength range two to ten angstroms.

It is important to note that all three moderators in our reference target system are high-intensity moderators (i.e., all three moderators perform essentially the same neutronically). Thus, for the target-moderator geometry of Figure 4, all eighteen neutron beam lines (e.g., three beam lines per moderator viewed surface) would be serviced with high-intensity cold neutron beams.

Reference Target Systems Materials

Tungsten is our reference material for the LPSS spallation target. It is a high temperature material with good characteristics for producing

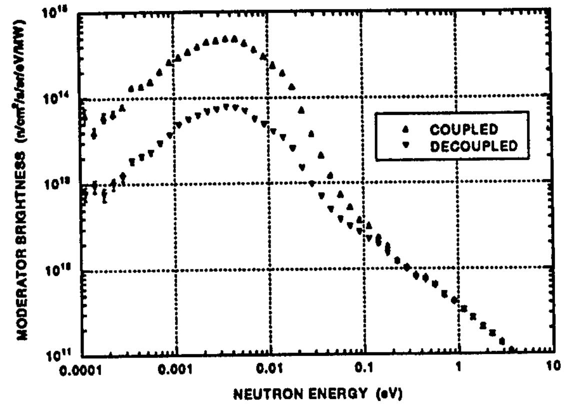

Figure 6: :Neutron flux spectrum for a decoupled liquid H2 (ortho/para 50/50 v%) moderator showing the energy-dependent differences of leakage neutrons.

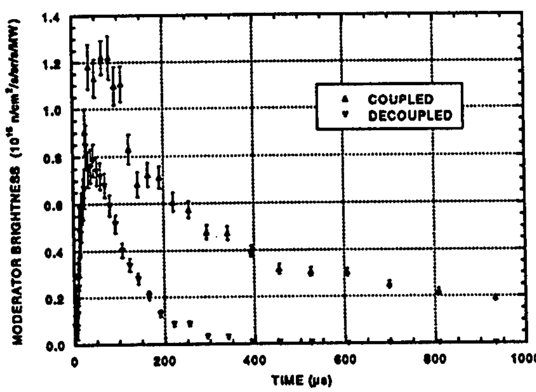

Figure 7: Time distributions for coupled and decoupled liquid H_2 (ortho/para 50/50 v%) moderators in flux-trap geometry, showing the time-dependent differences of leakage neutrons.

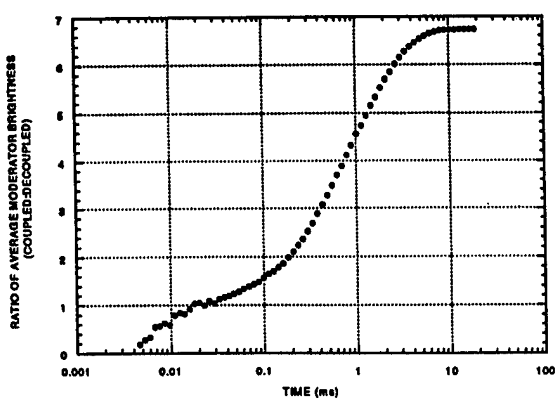

Figure 8: The time-dependent coupled/decoupled gain for an coupled and decoupled liquid H_2 (ortho/para 50/50 v%) moderators in flux-trap geometry, showing the time-dependent differences of leakage neutrons.

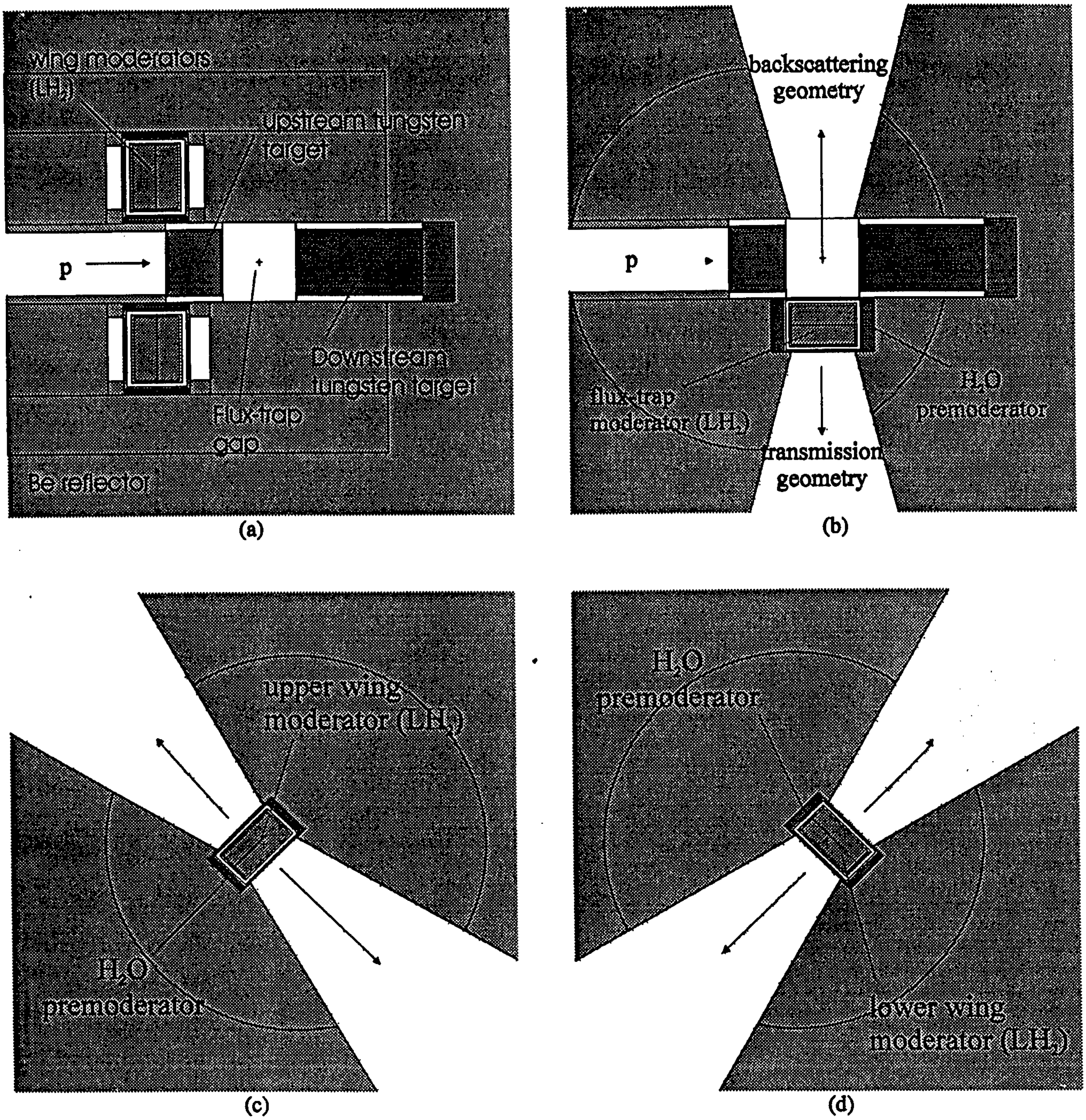

Figure 9: Cross sectional views of the LPSS target system Monte Carlo model: (a) elevation view showing the split target, flux-trap gap, and the two wing moderators; (b) plan view depicting the flux-trap moderator and neutron beam extraction in backscattering geometry and transmission geometry; (c) plan view of upper wing moderator showing neutron beam extraction; and (d) plan view of lower wing moderator depicting neutron beam extraction. A total of six moderator viewed-surfaces are possible with this target-moderator configuration.

spallation neutrons. However, tungsten is a moderate neutron absorber requiring special attention to design details, including target geometry and the choice of coolant. Cladding tungsten appears to be required for high-power spallation target applications because of potential corrosion issues. Tungsten has been used successfully at the Lujan Center as a spallation target material. Because of its successful use at the LANSCE 800-MeV proton accelerator, Inconel-718 is the choice for the reference target canister and proton beam window material. Aluminum-6061 is the reference material for the liquid H_2 moderator canister and vacuum container; this material has been used for this purpose at the Lujan Center and at other spallation neutron sources. More work needs to be done on the choice of these materials for the LPSS application. As experience from operating spallation sources accumulates, as appropriate data from the APT materials irradiation and corrosion programs become available (29,30), and as our basic understanding of radiation damage to materials in a spallation source environment improves, we need to reevaluate our choices of materials for the LPSS application.

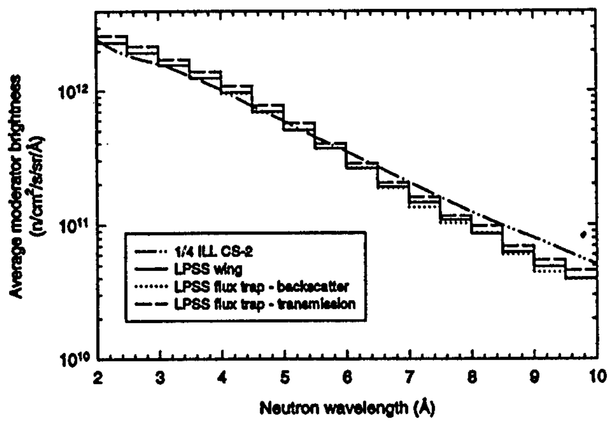

Figure 10: Average moderator brightness for the reference target system as a function of neutron wavelength. The 10 cm by 10 cm wing moderators and the 10 cm by 10 cm flux-trap moderator (viewed in both backscattering geometry and transmission geometry) all provide high-intensity neutron beams for experiments.

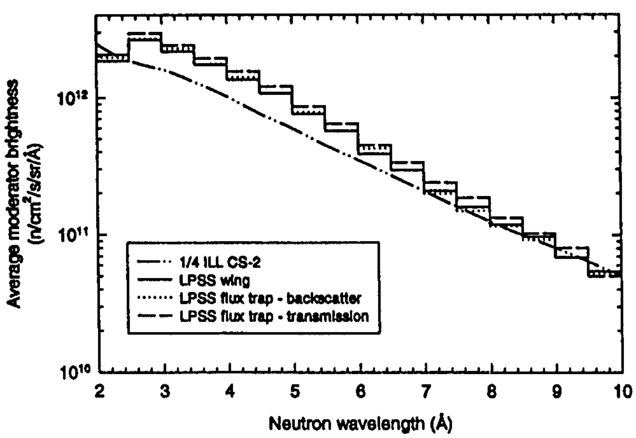

Figure 11: Average moderator brightness for 9 cm by 9 cm wing moderators and 9 cm by 9 cm flux-trap moderator (viewed in both backscattering geometry and transmission geometry). The moderator brightness increase as the moderator size gets smaller.

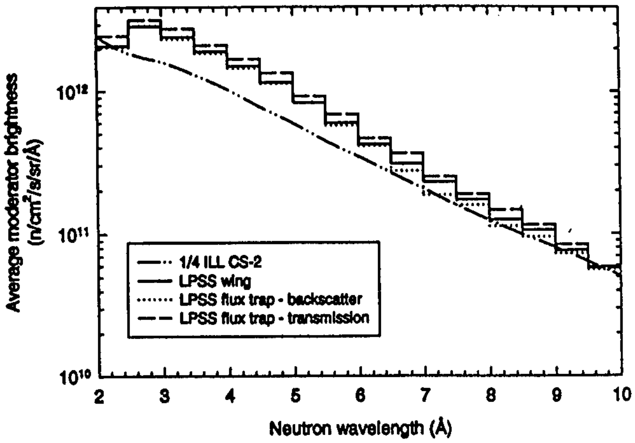

Figure 12: Average moderator brightness for 8 cm by 8 cm wing moderators and 8 cm by 8 cm flux-trap moderator (viewed in both backscattering geometry and transmission geometry). The moderator brightness increase as the moderator size gets smaller.

Conclusions

The performance of a reference target system for the LPSS has been established using the LCS. While ongoing research and development is likely to lead to even better performance, the reference LPSS target system demonstrates that adequate neutronic performance for cold neutrons can be obtained. Work is continuing on the neutronic optimization of an LPSS target system, including calculating time-dependent neutron beam fluxes. The coolant fractions in the various components of the target system need further study.

The performance of an LPSS for neutron scattering depends on both the time-integrated neutron flux generated by the target system and on the shape of the neutron pulses. These two quantities may be traded against one another by altering the relative amounts of reflector materials surrounding the target-moderator system. A research and development program that accounts for spectrometer performance will be needed before final decisions are made regarding the optimum configuration and materials for the LPSS target system.

Radiation damage to materials and corrosion issues will likely determine the lifetime of critical components in the LPSS spallation target system, including the proton beam window. We must continue to evaluate the choice of materials for the LPSS application as: a) data from radiation damage and corrosion experiments become available; b) our basic theoretical understanding of radiation damage and corrosion effects increase; and c) experience is gained from operating existing SPSS's.

A 1-MW LPSS has world-class neutronic performance. For cold neutrons, the calculated time-averaged neutron performance of a liquid H_2 moderator at the 1-MW LPSS is equivalent to about 1/4th the calculated performance of the best liquid D_2 moderator at the ILL reactor. The LPSS moderator brightness increases with decreasing moderator size. All the neutron beams from the reference LPSS target system are high-intensity neutron beams.

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