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WORKING GROUP SESSION REPORT

Neutron Beam Line Shielding

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Summary

Neutron beam lines at spallation neutron sources can present different (and challenging) shielding issues compared to neutron beam lines at fission reactors. Neutron beam line shielding is going to become even more important for pulsed spallation neutron sources in the 1-5 MW class that are presently either funded or proposed worldwide. Neutron beam line shielding includes shielding the following:

- beam shutters exterior to the bulk shield;
- collimators;
- neutron guides;
- T_0-Choppers, frame overlap choppers, etc.;
- experiment-caves; and
- beam stops.

Typically each of these neutron beam line components presents a different shielding challenge and requires a different shield composition and thickness.

Until recently, calculational capabilities have been "lacking" for computing ***absolute*** neutron and gamma-ray dose equivalent rates at the surface of neutron beam line shields at spallation neutron sources. ***What has now made this problem tractable is the computing power of modern workstations and the enhancements made to the Monte Carlo codes used in performing spallation calculations.***

As mentioned above, shielding at a spallation neutron source is much more difficult than shielding at a nuclear reactor. This is because at a spallation source you not only have to shield against "fast" neutrons (i.e., evaporation neutrons with a "fission-like" spectrum) but also against high-energy neutrons (i.e., neutrons with energies up to the energy of the incident protons). The former neutrons are more-or-less isotropic in angle, while the latter neutrons have a strong angular dependence. Neutron beam line shielding issues will become more difficult at the next-generation pulsed spallation neutron sources where proton energies in the

few GeV range are envisioned. *In addition to biological issues, we must start paying more attention to neutron beam line shielding issues because of instrument background considerations and neutron and gamma-ray cross talk between instruments.*

At Los Alamos, as part of the Accelerator Production of Tritium (APT) project, selected neutron cross section libraries have been extended to 150 MeV [1]. Also, the MCNPX [2] code, which is a merger of the widely used MCNP [3] and LAHET [4,5] codes, has been developed to use these libraries. The MCNPX code has the full complement of variance reduction techniques that can be utilized in shielding calculations. This code and the 150-MeV cross section libraries were used in three papers discussed in this Working Group Session.

Maekawa-san, et al. discussed shielding design studies of neutron beam line shutters for the JAERI/KEK spallation neutron source. **Russell-san**, et al. described the application of this computational technique to the design of neutron beam line shields for several new scientific instruments being built at the Lujan Center. These instruments have different beam line shielding requirements. The paper of **Muhrer-san**, et al. compared the calculated results of 2-D and 3-D neutron beam line shields.

Figure 1 depicts a cross section through the neutron beam line shielding for the Protein Crystallography Instrument on flight path number 15 (FP-15) at the Manuel Lujan Jr. Neutron Scattering Center at Los Alamos. This figure depicts the kinds of issues that can face the designers of neutron beam line shielding at spallation neutron sources such as:

- Minimizing the cost and weight of the shielding by contouring (stepping) the shielding. The shielding can be made more efficient by laminating it and/or choosing the most efficient shielding materials. Reducing the weight of the shielding can be important because of possible floor loading issues.
- Perturbations in the shielding caused by T_0-choppers, neutron beam shutter mechanism, etc. that weaken the beam line shielding must be properly addressed.
- In may be important to pay attention to crane capacities/requirements and hook heights of cranes.

The next generation pulsed spallation sources in the 1-5 MW range are expensive, costing around $1.5 to $2 billion U.S. dollars. Consequently, the designers and builders of these sources will want as many neutron beam lines and scientific instruments using the sources as possible. The proton energy of these sources is the few GeV range, which will make neutron beam line shielding problems more difficult compared to the existing pulsed spallation neutron sources where the proton energy is in the 500-800 MeV range. Also, the high-performance standards of these instruments will dictate low experiment backgrounds requirements and minimal cross talk between instruments. In addition, the design criteria for the biological total (neutron plus gamma-ray) dose equivalent rates at the surface of the neutron beam line shielding is being set at 0.25 mrem or less. All of these factors plus cost and the weight of beam line shielding will drive spallation neutron source designers to pay much more attention to neutron beam line shielding issues for these next generation pulsed spallation sources than heretofore has been done with the existing spallation sources.

In order to properly design neutron beam line shielding, the calculational tools and approaches in hand must be verified against experiments. Also, the cross section libraries should be extended to higher energies or the next-event estimators used in the Monte Carlo codes extended beyond the tabular region of the cross section libraries. In addition, the overall calculational efficiencies for doing neutron beam line shielding computations must be improve (e.g., enhancing the Monte Carlo codes to do parallel processing, faster computers, employing more efficient Monte Carlo models and variance reduction techniques, etc.).

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References

[1] M. B. Chadwick, et al., "Cross-Section Evaluations to 150 MeV for Accelerator-Driven Systems and Implementation in MCNPX, *NS&E* 131 (3), 1999.
[2] H. G. Hughes, et al., "Recent Developments in MCNPX," in the ANS Proceedings of the 2nd International Topical Meeting on Nuclear Applications of Accelerator Technology, September 20-23, 1998, Gatlinburg, TN, ISBN: 0-89448-633-0, pp. 281-286.
[3] J. F. Briesmeister, Ed., "MCNP — A General Monte Carlo N-Particle Transport Code," Los Alamos National Laboratory report LA–12625–M, Version 4B, (March 1997).
[4] R. E. Prael and H. Lichtenstein, "User Guide to LCS: The LAHET Code System," Los Alamos National Laboratory report LA-UR-89-3014 (September1989).
[5] R. E. Prael and D.G. Madland, "LAHET Code System Modifications for LAHET2.8," Los Alamos National Laboratory report LA-UR-95-3605 (September 1995).

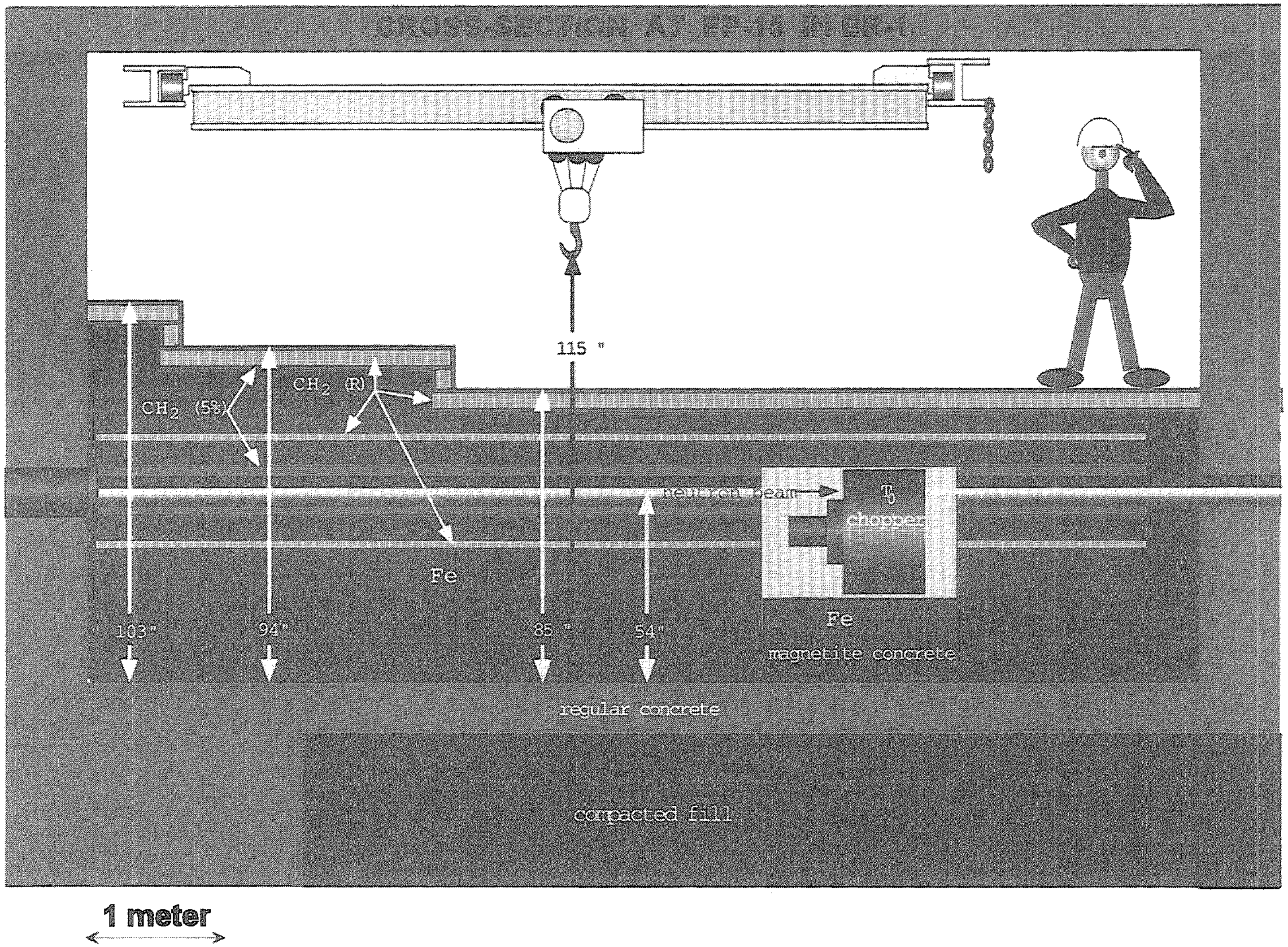

Figure 1. Illustration of a typical neutron beam line shielding problem showing the contouring (stepping) of a beam line shield, perturbations due to such beam line components as T_0-choppers, issues associated with crane hook height, potential floor loading problems, etc.