Work continues on this project, with the focus of attention directed towards optimizing the design of the experiments that we will perform. Our principle activities have been studies of the configuration of the iron sample, investigations of the source reactions to be used for the experiment with the source located within the iron sample, and on improvements in detector efficiency for determining the neutron yield as a function of angle.

Iron sample configuration studies
Concerns were expressed within the collaboration on the high cost of fabricating spherical iron shells; also it is not clear if there is any advantage for using such a design compared to other less expensive shapes such as cylinders and cubes. This led to a study of the results obtained for several of different shapes.

The goal of the study is to evaluate neutronics of different target shapes (or models) including spheres, cylinders, and cubes. Each model consists of a 14 MeV point source placed at the origin, an iron shell of 5 cm thickness ("sample"), and a hollow tube of height 6 cm and thickness 1 cm (hereafter is referred to as "tunnel") placed at one side of the shell. To analyze the neutronic behavior of the three shapes, we utilize the continuous energy Monte Carlo MCNP code. For comparison, we determine, at the target location, the average flux and interaction rates of different types including "elastic scattering", "inelastic scattering," "capture", (n, α), (n, p), (n, 2n), and "total." We also tally and analyze the neutron flux within the "tunnel" to estimate the fraction of neutrons originating from scattering interactions within the sample.

The spherical shell sample has inner and outer radii of 16.0 cm and 21.0 cm, respectively, and a sample volume of ~21635.1 cm³. The cylindrical shell sample has the same inner and outer radii as the spherical sample with a height of 32.0 cm, and sample volume of
DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
DISCLAIMER

 Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.
Irrespective of the shape of the sample, elastic and inelastic scattering interactions dominate the reaction rates: ~70% for the elastic and ~20% for the inelastic scattering. Among the other interactions, (n, 2n) and radiative capture are noticeable (~8%). It is interesting to note that in spite of the fact that the cube model has the largest volume (factors of 1.14 and 1.91 larger than the cylinder’s volume and the sphere’s volume, respectively), it yields the lowest level of reaction rates, ~66% and 92% of the sphere and cylinder models, respectively. This can be attributed to the shape: a spherical surface reflects more particles inward, and these particles have more chance to interact within the sample. We have tallied the average neutron spectrum within the iron sample. For this, we have used a 26-group energy bin structure corresponding to the first 26 groups (0.1 to 14 MeV) of the BUGLE-96 multigroup library. All the models give very similar neutron spectra. Within the tunnel, we have tallied and analyzed the neutron fluence at ~5 cm from the sample surface. The cube model shows the highest fluence level, ~8% and ~21% more than the cylinder and sphere models, respectively. Analysis of these results indicate that the sphere model yields the highest percentage (~26%) of uncollided neutrons at this location, followed by 22% and 20% for the cylinder and cube models, respectively. This finding can be attributed to the fact that the sphere sample provides the shortest path length for particle transport. The presence of fewer uncollided particles for the cylinder and cube models indicates that more scattered particles get to the tunnel for these sample shapes; this is a preferred situation.

This study indicates that in fact cube and cylinder samples may yield higher fluences at the front of the tunnel. To finalize the sample design, we are currently extending our models, so that we can estimate the flux magnitude and spectrum at farther distances within the tunnel.

**Investigations of source reactions**

Further work has been done on the source reactions for the neutron source that will be positioned at the center of the iron sample. The focus of this activity has been to finalize the source reactions that will be used. We have performed studies for the following source reactions: D(d,n)^3He, T(p,n)^3He, T(d,n)^4He, 7Li(p,n)^7Be, 9Be(p,n)^9B, ^9Be(α,n)^12C, ^10Be(α,n)^13C, ^11B(p,n)^11C, ^12C(p,n)^12N, ^12C(d,n)^13N, ^13C(p,n)^13N, ^13C(α,n)^16O, ^15N(^3He,n)^17F, ^19F(p,n)^19Ne, ^19F(d,n)^20Ne, ^19F(α,n)^22Na, ^16O(d,n)^17F, ^15N(p,n)^15O and ^51V(p,n)^51Cr. Our work has involved investigating the neutron energy as a function of laboratory angle and the angular distribution of the neutrons, in the laboratory system, produced by these charged-particle reactions. Kinematic calculations of the neutron energies have been made for these reactions. We determined that more massive targets are preferred since the neutron energy range throughout the full angular range is less. Also it is better to use the lighter particle as the projectile for the same reason. For very massive targets, however, the first excited state of the residual nucleus (and possibly higher excited states, also) tends to be at a low energy. This limits the neutron energy that can be used since more than one energy group of neutrons will be produced.

Angular distribution data for the neutron source reactions listed above generally need
improvement. Our study has led us to conclude that the best reactions for the present experiment are the $^{15}\text{N}(p,n)^{15}\text{O}$ reaction at the lower neutron energies and the $\text{D}(d,n)^3\text{He}$ reaction at the higher energies.

**Improvements in detector efficiency for yield determination as a function of angle**

Neutron fluence measurements as a function of angle for the geometry of our experiment are planned to reduce our dependence on published angular distribution data. Such measurements have the advantage that corrections for effects such as the transmission through the materials in the gas target cell are included in the result. Work is being done to improve the efficiency determinations of detectors, including lithium glass detectors that will be used to measure these data. This investigation has shown large variations in calculated versus measured efficiency of lithium glass detectors.

For the experiment with the detector located in the center of the iron sample, there is concern about the cross section uncertainties that will be obtained using unfolding techniques. Instead, it may be better to use these data as benchmarks for which the measured reaction rate is compared with transport calculations. Comparison of measurements and calculations will provide information on the quality of the iron evaluations being used in the calculations.