A Survey of Magnetic Field Sample Environments for Neutron Scattering

M. B. Stone[1]

[1] *Quantum Condensed Matter Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA**

(Dated: July 1, 2015)

This is a brief survey of the design parameters of existing vertical field superconducting magnets in use at neutron scattering facilities.

Vertical field superconducting split coil magnets were assessed at several neutron scattering facilities with user programs. These include the NIST Center for Neutron Research (NCNR) reactor source in Gaithersburg, Maryland, the ISIS spallation source in Oxfordshire, England, the ILL reactor source in Grenoble, France, and the Helmholtz-Zentrum Berlin (HZB) reactor in Berlin, Germany.[1] Characteristics examined included the maximum magnetic field, the distance between the magnet poles or magnet split, the bore diameter of the magnet, the vertical angular opening of the magnet split, and the outer diameter of the magnet sample environment.[2] Figure 1 shows these characteristic dimensions for a generic magnet cross section. The magnets were also classified as either compensated or uncompensated. Compensated magnets include additional coils within the magnet body that serve to diminish the fringe fields of the magnet system. The potential for magnets to run in an asymmetric mode was not evaluated as part of these data. The split coils of large field superconducting magnets are mechanically supported by either several wedges and/or a series of annular aluminum rings. These two mechanical support techniques were not catalogued as part of this survey.

I. MAGNET OUTER DIAMETER

The outer diameter of magnetic field sample environments is shown as a function of maximum magnetic field in Fig. 2. There is a linear trend of increasing magnet diameter as the maximum magnetic field increases. Compensated magnets require larger magnet diameters to accommodate the additional coils.

II. MAGNET ANGULAR OPENING

Figure 3 shows the range of angular openings above and below the scattering plane for existing magnet systems. Above a 10 T maximum field the angular opening of the magnet systems begins to decrease. The angular opening of the scattered beam portion of a magnet should be chosen to complement the available detector geometry of the potential instruments at which the magnet will be used.

III. MAGNET BORE DIAMETER

The magnet bore diameter is the diameter of the vertical opening through the magnet coils available for placing a variable temperature insert (VTI) or dilution refrigerator (DR) or other insert within. The bore diameter should be matched to the beam widths available at the facility as well as the available sample environment inserts that are to be used with the magnet. The diameter of the space above the magnet can be wider than the bore diameter, but it should not be narrower. Figure 4 shows the magnet bore diameter as a function of maximum applied field for a series of magnets. In general the bore diameter decreases as the maximum magnetic field increases. When considering additional magnetic field capabilities, the bore diameter and location of heat exchangers above the sample position should be considered. This is so that inserts can be used across a facilities magnet suite with minimal configuration changes.

IV. MAGNET SPLIT

The magnet split is the vertical height available for the neutron beam between the mag-

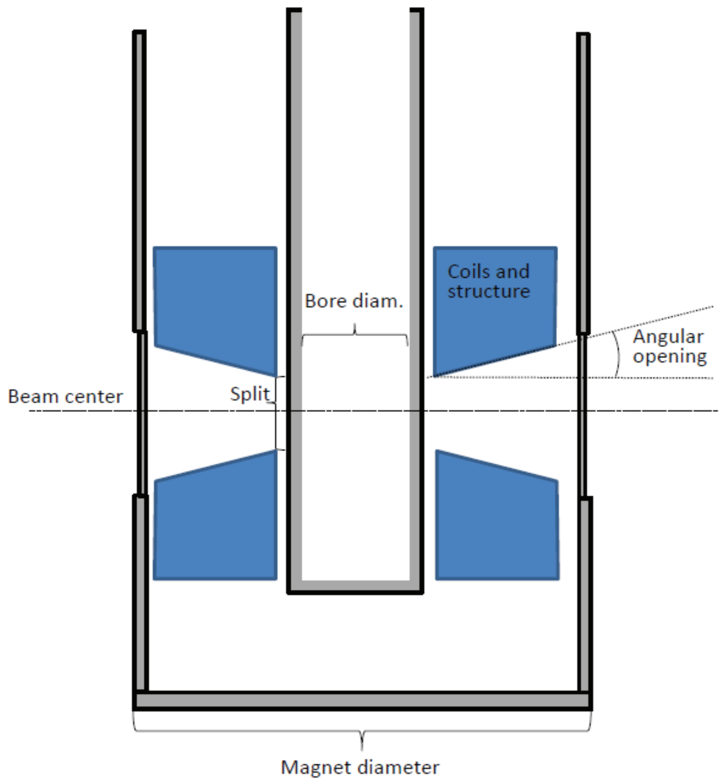

FIG. 1: Generic magnet cross section indicating characteristic distances and angles. The angular opening is measured with respect to the top and bottom of the magnet split. The outer portion of the magnet is shown with a thinned window in the vicinity of the neutron beam. The bore diameter refers to the diameter available within the coils of the magnet. The diameter of the variable temperature insert (VTI) above the magnet coils is typically larger than the bore diameter to accommodate sample environment inserts.

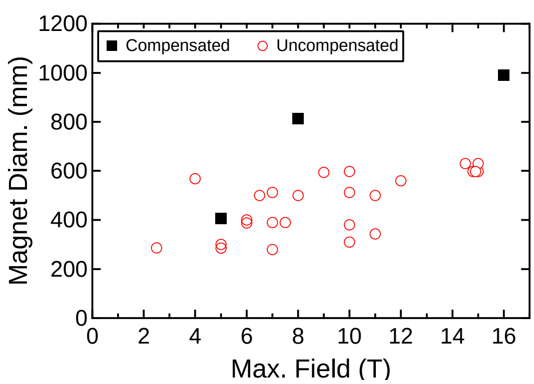

FIG. 2: Magnet sample environment outer diameter as a function of maximum magnetic field.

net poles without intersecting any portion of the magnet or shielding. The magnet split as a function of maximum available magnetic field is shown in Fig. 5 for a series of vertical field split coil magnets. In general, the trend is that larger fields require smaller magnet splits.

Figures 3 and 5 illustrate the angular opening and vertical split of available magnets as a function of the maximum magnetic field of the magnet. A large angular opening allows for measurements out of the scattering plane and relaxed sample alignment constraints for single crystals. However a large angular opening also decreases the effective beam height. Portions of samples which extend outside of the effective beam height will still be illuminated by the neutron beam, but these portions of the sample will not scatter neutrons with a greater cross-section at smaller out of plane scattering angles. This may skew the measured cross-section depending upon the distribution of the sample within the

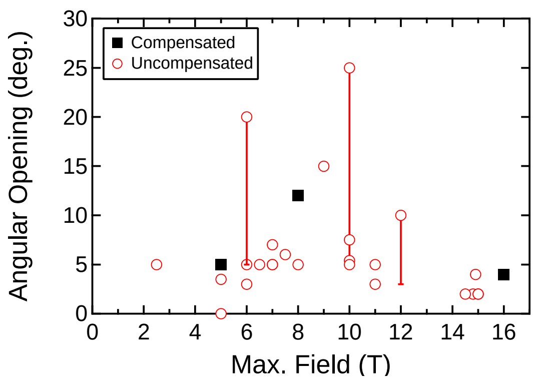

FIG. 3: Magnet sample environment angular opening out of the scattering plane as a function of maximum magnetic field. Points with vertical error bars correspond to asymmetric magnet openings. For example the red point at 12 T corresponds to a magnet which has an opening of 3 degrees below the scattering plane and 10 degrees above the scattering plane.

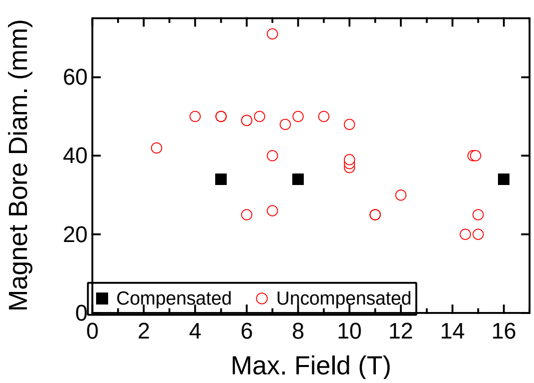

FIG. 4: Magnet bore diameter as a function of maximum magnetic field.

magnet. For a magnet with an angular opening, the effective beam height is decreased by $2S\tan(\alpha)$ where S is the magnet split and α is the angular opening. More of the incident beam can be effectively used if the magnet split is increased. The relationship between angular opening of a magnet, the out-of-plane detector coverage and the dimensions of the incident neutron beam need to be considered for sample environment magnets.

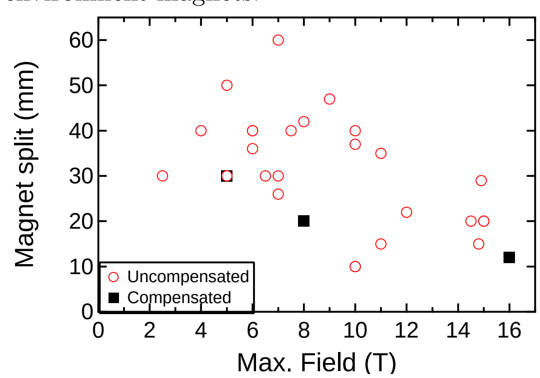

FIG. 5: Magnet split as a function of maximum magnetic field. Horizontal lines correspond to maximum beam heights for several instruments at the SNS as indicated. The sOI14 magnet is also shown on the figure as a blue square with a cross within it. Plotted proposed magnet point corresponds to Revision 1 of design parameters.

V. ACKNOWLEDGEMENTS

This research at ORNL's High Flux Isotope Reactor and Spallation Neutron Source, was sponsored by the Scientific User Facilities Division, Office of Basic Energy Sciences, U.S. Department of Energy. Thanks to Gary Lynn and Todd Sherline for providing details concerning the magnets at the ORNL facilities.

---

* stonemb@ornl.gov

[1] We gratefully acknowledge the assistence of Sergiy Gladchenko, Ye Qiang, and Yamali Hernandez from the NCNR, Richard Down of ISIS, and the sample environment web-pages at the ILL and HZB facilities.

[2] The values of magnet parameters presented were obtained from sample environment web-pages and emails to group leaders. Original manufacturer drawings were not referenced.