ORNL's High Flux Isotope Reactor has been used for neutron-scattering studies since 1965. The reactor will have 15 new neutron-scattering instruments, and a cold neutron source will be added to slow neutrons, making them excellent probes for polymers and proteins.

NEUTRON SCATTERING

Instruments of Change

In 1994 Clifford Shull, who pioneered the use of neutron scattering for materials research at the Oak Ridge Graphite Reactor, shared the Nobel Prize for physics. Shull and his mentor, Ernest Wollan, used neutron scattering to determine where atoms are in a crystal. Neutron scattering has been used in reactors worldwide to probe the structure and dynamics of materials. The research has led to the development of high-strength plastics and the improved magnetic materials found in small motors, credit cards, computer disks, and compact discs.

In late 1945 Wollan, who had studied solids and gases using X-ray scattering, considered using neutrons from the Graphite Reactor for scattering studies. He produced a single-wavelength neutron beam by passing reactor neutrons through a crystal and used a spectrometer to measure the angles and energies at which neutrons are scattered by interacting with the nuclei of atoms in the target material. This information helped reveal material structure.

A year later, Shull and Wollan produced the first neutron diffraction pattern of a sodium chloride crystal and of polycrystalline manganese oxide (MnO). They also made the first neutron radiograph, determined how to correlate the intensities of scattered neutrons with the structure of the target material, and precisely located the positions of light atoms in sodium hydride and sodium deuteride.

In 1951 Shull showed the magnetic structure of the MnO crystal, which led to the discovery of antiferromagnetism (where some atoms of magnetic material point up and some point down). Because neutrons are tiny magnets, their interaction with atoms of magnetic material provides data important to the recording and computer industries.

In the late 1950s and early 1960s, neutron-scattering studies of magnetic structures and properties of rare earths were carried out by Ralph Moon, Wallace Koehler, Mike Wilkinson, and others at the Oak Ridge Research Reactor. Henri Levy, Selmer Peterson, Bill Busing, and George Brown pioneered single-crystal neutron-diffraction studies that revealed the structure of sugar and other crystals.

In 1965 the new High Flux Isotope Reactor (HFIR) began providing much higher intensities for neutron-scattering research, allowing studies of excited states of matter using triple-axis spectrometers. Wilkinson and Herb Mook used HFIR to scatter neutrons off helium-4 nuclei, to study the presence of Bose-Einstein condensation in the helium-4 when its atoms were chilled to near absolute zero.

Using a triple-axis spectrometer, Bob Nicklow and Harold Smith studied the superconducting crystal tantalum carbide and found evidence to support a theory of low-temperature superconductivity. In the 1970s Mook and his associates established the coexistence of superconductivity and magnetism in rare-earth rhodium borides.

Small-angle-neutron-scattering (SANS) studies began at HFIR, where Koehler established the National Center for Small-Angle Scattering Research. High-temperature superconducting oxides were discovered in 1986, so HFIR was used to help determine the structure of the new materials because neutrons could determine the position of light oxygen atoms better than X rays. Triple-axis measurements also elucidated the excited magnetic and lattice states, helping theorists explain high-temperature superconductivity.

Throughout the 1990s, SANS experiments led by George Wignall in collaboration with the University of North Carolina examined ways that polymers could be produced by using supercritical carbon dioxide as the organic solvent instead of traditionally used chlorofluorocarbons (believed to be depleting our protective ozone layer).

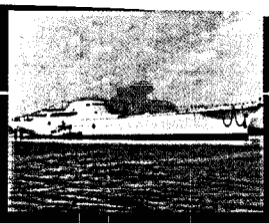
Measurements of residual stress also began at HFIR. One study focused on paper mill boilers clad with a steel alloy that can crack, leading to explosions. The measurements determined that use of a new steel alloy would prevent the problem.

In December 1999 ground was broken for the accelerator-based Spallation Neutron Source (SNS); among those present was Vice President Al Gore. The SNS, to be completed in 2006, will continue ORNL's tradition of world-class neutron-scattering studies.

1958
Startup of Oak Ridge Research Reactor

Project Salt Vault, the first national effort to site a high-level nuclear waste repository, started by ORNL

1959
Reactor shielding for the first U.S. nuclear-powered civilian ship evaluated by ORNL researchers



Maleness in mouse found to depend on presence of Y chromosome