IPNS' success paved way to newest neutron source for materials research

Equipment installation inside the Spallation Neutron Source ring tunnel. Image courtesy of Oak Ridge National Laboratory.

When the Intense Pulsed Neutron Source at the U.S. Department of Energy's Argonne National Laboratory began operations in 1981, few could envision that it would lead to the $1.4 billion Spallation Neutron Source, beginning operations this spring on the grounds of Oak Ridge National Laboratory in Tennessee.

The Spallation Neutron Source, or SNS, is a unique collaboration of six Department of Energy laboratories, each bringing particular expertise to the design, construction and operation of the facility, which will provide the most intense pulsed neutron beams in the world for scientific research and industrial development. The SNS is about 10 times more powerful than existing neutron sources anywhere in the world, and will help sustain America's scientific leadership and economic competitiveness.

Neutron science helps develop new materials that are stronger, lighter, and cheaper yet perform well under severe conditions. More than ever, major research facilities, such as X-ray and neutron sources, are used to understand and engineer materials at the atomic level. Such materials have greatly improved properties offering both better performance and new applications.

Some examples include electronic devices, which require smaller and faster components. Commercial and military aircraft as well as space probes need new lighter alloys and stronger welds for higher speed and lower fuel consumption. Automobiles are using more high-temperature materials, lightweight alloys, and plastics to become more fuel efficient and less polluting. Computers require ever-increasing storage capacity using magnetic materials. New high-temperature superconducting materials promise more efficient motors and power transmission. And designer drugs and genetic engineering are revolutionizing medicine and health care. Neutron-scattering research plays an important role in all these areas and more.

Neutrons—uncharged particles found in the nuclear core of nearly all matter—are useful for materials research because of their penetrating power. X-rays and electrons, which are also used to study materials, typically penetrate only a few ten-thousandths of a centimeter inside materials. But neutrons can punch through several centimeters of steel, so experimenters can study materials inside pressure cells and furnaces. Neutrons are also uniquely useful for studying materials that contain atoms of the lighter elements, such as hydrogen and oxygen. Much of what is known about the atomic motion and structure of high-temperature superconductors—metal oxides that can carry electricity without energy loss—was discovered at neutron sources like the IPNS.

Neutron-scattering research has been an important scientific tool worldwide for many years, most of it carried out at research reactors, whose neutron intensities have reached their engineering limits. In the early 1970s, Argonne scientists, led by Jack Carpenter, now IPNS technical director, built up a series of first-of-a-kind experiments, pioneering the development of accelerator-based pulsed spallation neutron sources. The experiments eventually led to Argonne's Intense Pulsed Neutron Source, or IPNS, one of the earliest examples of a neutron source with full research capability. Over its 25 years of operation, the facility has provided the nation's most reliable source of neutrons for the study of atomic arrangements and motions in liquids and solids—information key to developing new materials—and has hosted thousand of users from around the globe.

The IPNS's popularity and the elegance of its instrument designs belie its humble beginnings. At the outset, it was built with equipment cannibalized from earlier projects and given only bare-bones funding in the beginning. Yet over the years it grew to become one of the country's leading facilities for research in condensed-matter physics. The instrumentation designed and developed at IPNS forms the core for the design of the neutron-scattering instrumentation for the SNS. Meanwhile, pulsed spallation sources in other laboratories worldwide have also provided important contributions to science and to the development of the new technology.

Argonne researchers, working closely with Oak Ridge National Laboratory scientists, have been primarily responsible for developing the neutron-scattering instrumentation and experiment facilities for SNS. SNS will initially have one target station operating at a frequency of 60 Hertz (Hz). Two "thermal" moderators and two "cold" moderators will serve 18 beam lines, and a variety of instruments will be constructed on these beam lines.

“The world-class instruments that are being built for SNS are the most efficient in the world, and will allow users to take full advantage of the high intensity of the SNS,” Carpenter said. Three of the Argonne-developed instruments will be installed and functioning in the SNS when it becomes operative later this year, and a fourth, still in development, will be available about a year later. An additional four instruments will be added at intervals as they are tested and ready for deployment as the power of the SNS increases.

In addition, other instruments are being proposed for funding and later development, Carpenter said. The SNS offers space for a total of 24 instruments, several of which will be constructed as the need for them arises.

For the experiment facilities, SNS expects 1,000 to 2,000 users each year from all walks of science and industry. Because not all these users will be experts in neutron scattering, SNS will provide scientists and technicians to maintain and operate the instruments and work closely with the user community.

The six-laboratory partnership in designing and building the SNS is an unusual one, Carpenter said, but has worked “amazingly well. A partnership on this scale has never been done before, and it's a remarkable success. It's a tribute to the management of SNS, but also to the good spirit of the partner labs, who have developed a conscious, consistent collaboration.”

The $1.4 billion facility has been under construction since 1999 and is being completed both on time and on budget with more than 7.5 million work-hours with only two lost work-days from injury, a remarkable accomplishment. The energy of the SNS proton beam is 1 billion electron volts, equal to 666,000,000 D-cell batteries joined end-to-end. The beam accelerates through the linear accelerator from a standstill to approximately 90 percent of the speed of light in two microseconds, and the energy striking the target is similar to a 200-pound block of steel hitting the target at 50 miles per hour. The placement of that beam to the target requires such precision that the Earth's curvature was factored into the construction of the linear accelerator—a tiny but critical difference of 7 millimeters from one end of the 1,000-foot accelerator to the other.

Source: Argonne National Laboratory, by Catherine Foster