Newly invented shielding for stopping neutrons cold

December 9 2013

Three new products developed at Jefferson Lab for shielding against neutrons consist of a boron-rich paneling for use in space-restricted areas (front), boron-rich concrete that absorbs neutrons using less material (left), and a lightweight concrete that is four times better at slowing down neutrons than ordinary concrete (right). Credit: DOE's Jefferson Lab

When faced with the challenge of protecting sensitive scientific equipment and computers from radiation, engineers at the U.S. Department of Energy's Thomas Jefferson National Accelerator Facility decided to take matters into their own hands. They came up with three innovative products that could soon find their way to nuclear power plants, particle accelerators and other radiation-generating devices around the world.

The three patented/patent-pending technologies form a system for shielding that is less expensive, lighter and less bulky than standard products and easily manufactured using existing techniques. They consist of recipes for a lightweight concrete that is four times better at slowing down neutrons than ordinary concrete, a boron-rich concrete that absorbs neutrons using less material, and a thin, boron-rich paneling for use in space-restricted areas. The ability of a system built using these technologies to block radiation, particularly neutrons, has applications in the storage of nuclear waste, in building compact nuclear reactors and in shielding radiation sources used in medical applications.

Neutrons are no strangers to Jefferson Lab scientists, who routinely probe these particles in hopes of learning how protons and neutrons come together to form the nucleus of the atom and all of the visible matter in our universe. To carry out these experiments, scientists rely on computers located nearby to operate the equipment and collect and transmit data. But the computers are at risk of being damaged by subatomic particles produced in these experiments.

Jefferson Lab Engineers Paul Brindza and Bert Metzger developed their new system of products to better protect these computers from the showers of particles, including protons, neutrons, electrons and other particles, which radiate away from Experimental Hall targets (there are currently four Jefferson Lab Experimental Halls – A, B, C and D).

"Getting rid of all the rest of the radiation is pretty easy, but the neutrons are very difficult, and they prove to be the thing that is dangerous not only to the electronics, but also to the software that runs the electronics," Brindza said. "We wanted to do a little better job shielding, so we came up with a series of new products."

Their system, while using clever new techniques to shield against neutrons, works on the same principles as systems currently in use. It consists of a concrete layer to slow down neutrons, a material to absorb them, and a thin lead layer to halt any residual radiation. In Hall C, where the system is now being installed, the lead layer is covered with an aluminum panel to prevent human contact with the lead and to allow easy attachment of room fixtures like lights and electrical outlets. (Note: In other applications, a thicker iron layer may be substituted for the lead layer.)

The first part is a lightweight concrete that weighs a third less than the same amount of ordinary concrete, but is four times more capable of slowing down, or thermalizing, neutrons. Ordinary concrete can thermalize neutrons, but requires a very thick layer of concrete to do so. In ordinary concrete, the neutrons are thermalized by hydrogen atoms in the water molecules that are trapped during the concrete mixing process.

The Super High Momentum Spectrometer is under construction in Jefferson Lab's Hall C. Bags of boron carbide for use in boron-rich concrete for shielding against neutrons sit on the floor in front of the partially complete concrete shield house. Credit: DOE's Jefferson Lab

"What you want to do is add something to the concrete that adds hydrogen. And you want it to be permanent. So, we used a recycled product - shredded plastic waste from certain molding products. This plastic is mostly hydrogen and carbon and a little bit of chlorine," Brindza explained. "This permanently adds hydrogen and increases the hydrogen density far beyond normal heavy structural concrete. The lightweight neutron thermalizing concrete is formulated to be just as strong as ordinary concrete."

The second part of the system is a concrete heavily loaded with a boron compound to absorb the neutrons. Boron has long been used in nuclear power plants and in particle accelerators to absorb neutrons that have been thermalized. One way to use boron to absorb neutrons is to add it to ordinary concrete. However, a foot-thick layer of regular boron-enriched concrete would have been required in Hall C, taking up valuable space and adding additional weight and cost.

Brindza and Metzger figured out a recipe for increasing the amount of boron in concrete per unit volume, without sacrificing strength. Using this new concrete heavily loaded with boron allows them to halve the amount of concrete that they need to use.

"What we worked out is a way that you can make concrete out of a boron compound and cement, and leave out everything else. It's basically only boron material, Portland cement and water, plus it is also as strong as ordinary concrete," Brindza explained.

For the third technology, he and Metzger then applied the same idea to making a thin panel of boron-impregnated shielding for areas in which a thick boron concrete layer was not needed. For this product, they turned to the process for making molded countertops. They replaced materials used in certain countertops with boron, resulting in a panel less than an inch thick and consisting of boron embedded in an epoxy resin.

"We pre-made the panels. And we had another contractor take a thin boron panel, a skin of lead and an aluminum cover and put it all together into something that can be installed and handled, so it is environmentally friendly," Brindza said.

In Hall C, the lightweight concrete is being used to form the shield house of a large, rotating particle spectrometer, called the Super High Momentum Spectrometer (SHMS). This device is one of the major new pieces of experimental equipment that are part of Jefferson Lab's 12 GeV upgrade. The shield house will protect the detector systems, as well as an electronics room. Each wall of the SHMS shield house will have lightweight thermalizing concrete, a boron layer and a lead layer that is designed for the particular experimental conditions in Hall C.

Brindza is excited to see the progress in installing the new shielding at Jefferson Lab, and he hopes that the builder-friendly recipes will soon benefit others.

"The stuff we made, any concrete company can pour it. We did a lot of work and engineering to make a product that anybody could dump into place and form up," he said.

The boron-rich concrete technology, "Thermal neutron shield and method of manufacture," has been granted patent #8,450,707 by the U.S. Patent and Trademark Office. The two other technologies, "Lightweight Concrete with Enhanced Neutron Shielding" and "Cost Effective Boron Shielding Panels," are patent pending.

According to Jefferson Lab's Chief Technology Officer, Roy Whitney, these three technologies are currently available for licensing.

"We're very interested in partnering with industry to get these technologies out in the market and put in use," he says. "This shielding technology will reduce the cost, size and weight for many applications both large and small. The Department of Energy's National Labs are all committed to making their technologies available, when appropriate, for the benefit of all Americans and American industry as part of participating in the global marketplace."

Provided by Thomas Jefferson National Accelerator Facility