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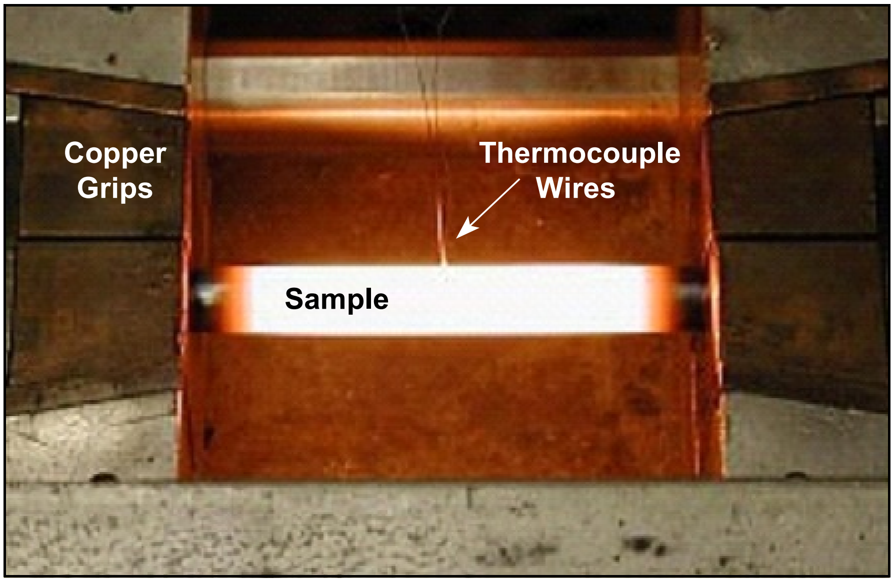
NEW ALLOY VERIFIED FOR SAFER DISPOSAL OF SPENT NUCLEAR FUEL

A new alloy developed and patented by researchers at Lehigh University and two U.S. Department of Energy National Laboratories could help the U.S. dispose of highly enriched spent nuclear fuel.

Dr. John DuPont, the principal Lehigh investigator on the project, said that a nickel-based alloy containing gadolinium (Gd) showed far greater ability than other alloys to maintain criticality controls by absorbing thermal neutrons over thousands of years. The researchers found that the nickel-gadolinium alloy passed an important test–it can be fabricated in small-scale quantities using conventional ingot metallurgy and has been welded by fusion welding techniques.

The research group included Drs. DuPont, David Williams, and Zhen Liu from Lehigh University; Drs. Charles Robino and Joseph Michael from Sandia National Laboratories; and Mr. Ronald Mizia from the Idaho National Laboratory. The project is supported by the National Spent Nuclear Fuel Program under the technical direction of Mr. William Hurt at the Idaho National Laboratory. The National Program had identified Gd as the preferred neutron absorber, and it was up to the research group to determine what structural alloy would best accommodate alloying with Gd.

Gadolinium, a silvery-white metal, is found in several different minerals. The research conducted by the group demonstrated that Gd could be added to specific nickel alloys that would retain their malleability and ductility as well as their ability to be heat-treated, shaped and fabricated into desired shapes.



Photograph of sample being tested in the Gleeble thermo-mechanical simulator. The sample is glowing white due to the high temperature. The sample is gripped at each end by copper jaws during the test and heated through resistive heating. After being heated to the desired test temperature, the sample is pulled in tension to failure by the copper grips in order to determine the high temperature ductility.

Mr. Hurt explains, “Safe disposition of Department of Energy (DOE) highly enriched spent nuclear fuel requires the availability of thermal neutron absorbing properties to be maintained for extended periods of time. Ideally, the Gd would be deployed in a structural material fabricated for use as the internal canister baskets. These baskets separate spent fuel assemblies providing structural support during storage, transportation and disposal. In the disposal setting, the Gd is an essential factor in maintaining nuclear criticality safety. Given the large quantity of material required for this application, the material must be producible using conventional large-scale production methods such as ingot casting and hot working. Because the material will be formed and welded into internal structures that will cradle the fuel to maintain a specified geometry, the material must also exhibit good weldability.”

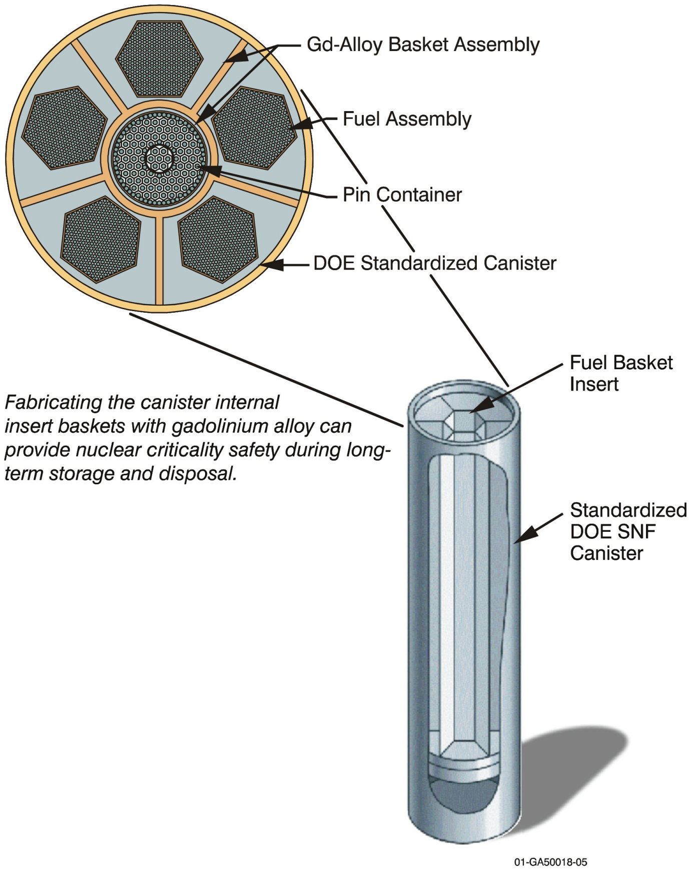
Mr. Mizia further explains, “Previous research on selection of candidate alloys, which could meet these requirements, focused on stainless steels containing boron. While alloys with boron are available as American Society of Mechanical Engineers (ASME) code-approved materials, Gd has received considerable attention in recent years. Gd has a much higher thermal neutron absorption cross section than boron, and thus, Gd additions could potentially provide a better means for safely storing highly enriched fuels in a disposal setting. The higher thermal neutron absorption capacity may also allow thinner sections of this material to be used, which would help ensure the total weight of the canister stays within prescribed limits. In addition, there are also long-term corrosion issues with nuclear fuel and Gd, containing constituents in the alloy that should not dissolve as quickly as chromium borides in the presence of water. Therefore, there is interest in the use of Gd-containing alloys for storage, transportation and disposal of DOE spent nuclear fuel. However, prior to our study, there had been very little research on production and welding of Gd-containing alloys.”

The research group conducted laboratory tests to determine the optimal chemical composition of the nickel-based alloy. The tests involved mixing the constituent elements of the alloy, heating and melting the mixture, and allowing it to cool and solidify. The alloy was then heated and rolled into half-inch-thick sheets and subjected to strength and ductility tests.

“We designed and developed various alloys to determine the quantity of gadolinium that could be added while still maintaining the desired properties,” says DuPont. “We needed to be able to heat-treat the final material, weld it and fabricate it.”

“Although we have demonstrated the ability of the alloy to achieve these goals,” Robino adds, “there is still a lot of development work to do to make the alloy feasible on a commercial scale.

Fast Flux Test Reactor Fuel Canister



Fabricating the canister internal insert baskets with gadolinium alloy can provide nuclear criticality safety during long-term storage and disposal.

Schematic illustration of standardized canister assembly for transportation and long term storage of spent nuclear fuel owned by Department of Energy.

A specification has been issued for the alloy by the ASTM (American Society of Testing Materials), which sets technical standards for materials, products, systems and services. The alloy is being reviewed by the ASME, which also sets design standards for the use of new products. Neutron-absorption tests on the alloy were performed at Los Alamos National Laboratory in New Mexico.

Prior to its work with the gadolinium-nickel alloy, the researchers spent a year investigating gadolinium-enriched stainless-steel alloys for spent nuclear fuel storage applications before coming up against major obstacles to the production of those alloys using conventional hot working techniques.

The group's research results, described in an article in the December 2004 issue of the *American Welding Society's Welding Journal*, cap a 4-year study funded by the U.S. Department of Energy's National Spent Nuclear Fuel Program. The article, titled “Physical and Welding Metallurgy of Gadolinium-enriched Austenitic Alloys for Spent Nuclear Fuel Applications - Part II,” won the welding society's Warren F. Savage Award for advancing the understanding of welding metallurgy. ■

RESEARCHERS' PROFILES

- Dr. Hugo Caram is a Professor of Chemical Engineering at Lehigh. His research is in the areas of mass transfer, chemical reactor design and chemical thermodynamics.
- Dr. Shivaji Sircar has a Ph.D. in Chemical Engineering, with expertise in separation processes and materials. He is presently a Professor of Practice at Lehigh University
- Dr. John DuPont is an Associate Professor of Materials Science and Engineering at Lehigh. His research interests include welding metallurgy and processes.
- Dr. David Williams, Professor of Materials Science and Engineering and Vice Provost for Research at Lehigh, is a specialist in electron microscopy.
- Mr. Ronald Mizia is an Engineering Fellow at the Idaho National Engineering and Environmental Laboratory.
- Dr. Charles Robino and Dr. Joseph Michael are Distinguished Members of the Technical Staff at Sandia National Laboratories.