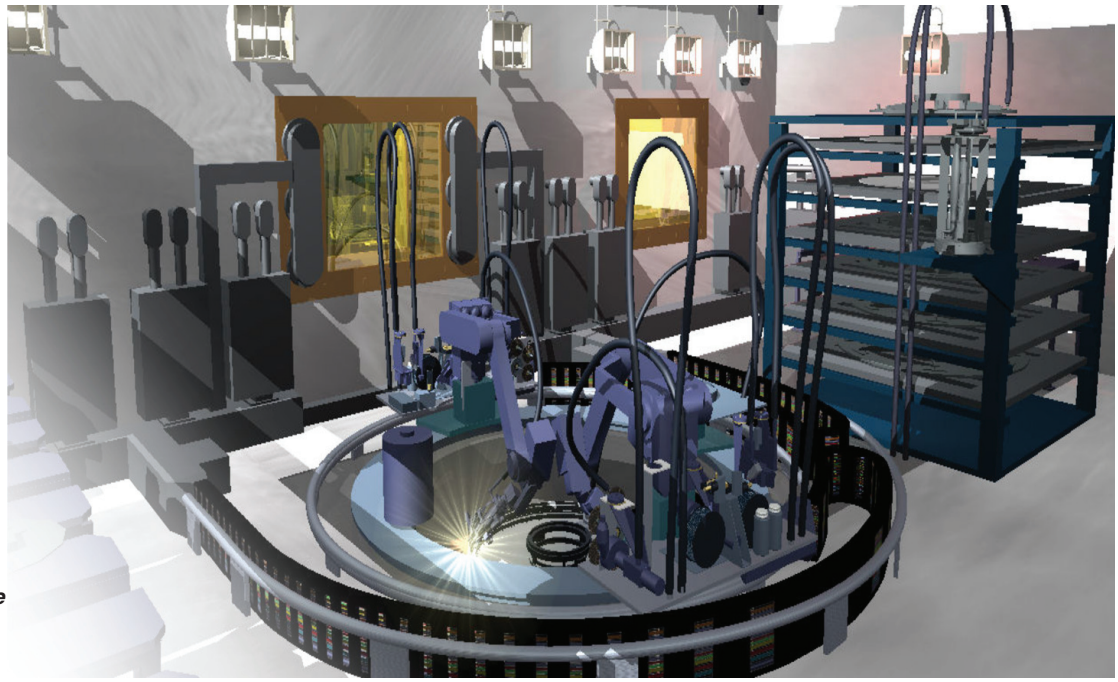

Illustration of the waste package closure system.

Waste Package Closure Project

Based on 50 years of engineering and operations excellence in nuclear applications, the Idaho National Laboratory was selected to design, develop and demonstrate a welding system to close and seal spent nuclear fuel and high level waste packages for the Department of Energy's Yucca Mountain project. A full-scale demonstration of the new system is scheduled for 2008.

Introduction

Spent nuclear fuel and high-level waste will be loaded into corrosion resistant waste packages prior to disposal in the underground repository at Yucca Mountain, Nevada. The waste packages come in multiple sizes but are nominally six foot in diameter and seventeen feet tall. Each waste package consists of two cylindrical containers, one nested inside the other. The inner vessel is made of stainless steel with 2-inch thick walls, and the outer corrosion barrier is made of alloy 22 with 1-inch thick walls.

The closure system will weld lids on both containers, evacuate and back fill the inner container with helium, nondestructively verify the integrity of the welds, and mitigate the tensile stresses in the outer lid weld to protect against stress induced corrosion. All the operations are automated to achieve high reliability, maximum throughput, and minimize radiation exposure.

Welding

Cold-wire gas tungsten arc welding is the method used for welding the lids in place and sealing the evacuation port. As illustrated above, the welding is performed by two robotic arms mounted 180 degrees apart on a circular bearing that surrounds the top of the waste package. Using two opposing robots cuts the welding time in half and helps minimize distortion. The arms conveniently fold back out of the way when placing a lid on the waste package or performing other operations.

The end effector for welding, shown on back, has a custom designed 300 amp torch that uses air-cooling rather than conventional liquid-cooling to prevent accidental introduction of water into a waste package, which could pose criticality concerns. An on-board laser profile sensor guides the end effector along the weld joint, and two cameras provide the operator with a leading and a trailing view of the weld in progress.

Continued on back

Science

Idaho National Laboratory

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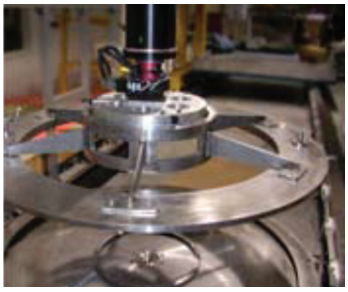
Welding end effector with torch, seam tracker, and leading and trailing cameras.



Leak detection tool being placed on a simulated waste package.

A weld dressing end effector is available to each robot for wire brushing the welds between passes. The dressing end effector has an automatic tool changer that allows it to exchange the wire brushing wheel for a grinding wheel if a weld needs to be ground out for repair.

Evacuation and Backfill

After the inner lid is welded in place, the inner vessel is evacuated and backfilled with helium. Displacing the air with helium reduces the risk of corrosion internally and aids in transferring the nuclear decay heat through the waste package. For minimizing process time, a single tool has been designed that evacuates and backfills the inner vessel, seals the evacuation port with a gasketed threaded plug, and leak tests the plug seal. After passing the leak test, the plug is seal welded to the inner lid.

Nondestructive Examination

The closure system uses four methods of nondestructive examination to verify integrity of the welds; visual examination, leak detection, eddy current examination, and ultrasonic examination. Visual examination is performed on all final weld passes by scanning them with the laser profile sensing seam tracker on-board the welding end effector. The seam tracker automatically flags any surface defects that exceed acceptance criteria.

Leak detection is used to verify integrity of the inner lid seal weld prior to welding the evacuation port. The tool shown below evacuates the inner lid weld region and monitors for any helium leaking through the weld.

The outer lid weld, which is a multi-pass weld, is ultrasonically examined between passes for early detection and repair of any flaws. Once the weld is completed it is examined three ways; with visual, eddy current, and ultrasonics. All three methods are performed before and after the weld surface undergoes compression by low plasticity burnishing to remove tensile stresses that may initiate stress corrosion cracking.

The eddy current and ultrasonic probes are integrated into end effectors for deployment with the robotic arms. The eddy current probe uses an array of elements to reduce inspection time. The ultrasonic probe uses phased array technology, which offers the flexibility of beam steering and variable depth of focus to achieve a thorough volumetric examination with a minimum number of probes.

An additional specially designed eddy current probe is attached to a separate end effector deployed by the robotic arms. It is used during weld repair to verify the flaw has been adequately removed by grinding prior to reweldng. All the end effectors are housed on a tool tray attached to the back of each robot.

Material Handling

The handling of tools and materials inside the closure cell is predominantly performed by a programmable, bridge-mounted, telescoping z-mast. On board the Z-mast is a machine vision system. This system has the ability to make precise measurements and recognize specific patterns. Machine vision guides the Z-mast in coupling precisely with tools without requiring special fixturing of the tools.

Control and Data Management

The closure system is controlled on three levels: supervisory control, process control, and component control. Supervisory control oversees all closure operations and interfaces with other operations in the facility. The process control level provides real time operator interface through workstations with the controllers driving the various systems. Component control is the low level communication with the individual components and the collection of operational data. Communications between all levels is via an Ethernet network that allows for easy expansion or reconfiguration of the control system.

All process closure data is accumulated at the process level. Data documenting the quality of the closure is forwarded to the supervisor level for permanent entry into the facility database. The remaining data is either retained temporarily at the process level for determining process trends or discarded.