# Securing Containers of Radioactive Materials

*A contractor details how to weld and inspect containers securing hazardous materials*

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*Fig. 1 — This designed and fabricated fixture supports and aligns the weld head during welding.*

The Department of Energy's (DOE) responsibility for the disposition of radioactive materials has given rise to several unique welding applications. Many of these materials require packaging into containers for either interim or long-term storage. It is not uncommon that final container fabrication, i.e., closure welding, is performed with these materials already placed into the container. Closure welding is typically performed remote to the container, and routine postweld testing and nondestructive examination (NDE) are oftentimes not feasible.

Fluor Hanford, prime contractor for DOE at the Hanford Site in Washington, has packaged many such materials in recent years as part of the site's cleanup mission. In lieu of postweld testing and NDE, Fluor's approach has been to establish weld quality through "upfront" development and qualification of welding parameters, and then ensure parameter compliance during production welding. This approach requires a rigor not usually afforded to typical welding development activities, and may involve statistical analysis and nonroutine weld testing, including burst, drop, sensitive leak testing, etc.

This article provides an instructive review of the development and qualification activities associated with the closure of radioactive materials containers, including a brief report on Fluor's welding activities for the closure of research reactor spent nuclear fuel (SNF) overpacks at the Hanford Site.

## Technical Approach

Welding development and qualification activities associated with the closure of radioactive materials containers typically require a greater level of effort than for most welding applications. As noted above, this is primarily due to the critical nature of the materials being packaged and the difficulty in performing routine postweld testing and NDE. In addition, this work is performed in a highly regulated environment that is subject to significant review and analysis. The technical basis for development and qualification activities must ensure that requirements are met and that container performance will meet the design service.

The following list of activities should be considered for welding development and qualification for the closure of radioactive materials containers.

- Clearly identify and understand weld requirements and criteria, including container service, performance, and regulatory.
- Based on weld requirements and criteria, select the best-suited welding


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*Fig. 2 — A pull test of 1.25 times the design lifting load took place on the overpack.*

process; this selection process may include performing a "down-select" or alternative selection review.
- Prepare a written development/qualification plan to include the following:
- Welding trials (including mockup assemblies) to establish suitable parameters. Parameter development should target values that produce desired (optimum) weld characteristics, such as bead penetration, bead shape, deposition rate, etc.
- Qualification testing to include that specified by the applicable code(s) and/or regulatory body(s) and any additional testing necessary to establish required confidence in the process and parameters. Test and examination may include NDE, mechanical testing (burst, drop, tensile, bend), metallography, etc.
- Demonstration or validation testing.
- Procure or design a suitable data-acquisition system (DAS) to be used to capture production weld data for weld parameter, compliance verification.

## Results/Discussion

*Fig. 3 — Shown are the thermocouple attachment locations and setup.*

Fluor has successfully completed several radioactive materials packaging campaigns, including those for plutonium-bearing special nuclear materials (SNM) (Ref. 1) and spent nuclear fuel (SNF) (Ref. 2). The following provides a brief review of the activities for the development and qualification of a gas tungsten arc welding (GTAW) process for closure of overpacks containing TRIGA®[1] research reactor SNF.

### Requirements and Criteria

The overpack was designed to provide confinement of the packaged materials against release to the environment during interim storage over a 40-year design life. The materials of construction, heads, shell, and miscellaneous pieces are Type 304L. Qualification of the welding process, procedure, and welding operators met requirements of ASME *Section IX — Welding and Brazing Qualifications*. In addition, storage-facility criteria required the welded overpack to be leaktight per ANSI N14.5 ($\leq 1 \times 10^{-7}$ atm cc/s air).

### Welding Process Selection and Description of Equipment

The GTAW process, machine-welding mode, was selected for this application. Equipment included a full-function, microprocessor-controlled system (Gold Track V) manufactured by Liburdi Dimetrics®[2]. Welding was performed remote to the overpack with the aid of a video console and cameras at the weld head. A fixture to support and align the weld head, with respect to the overpack closure, during welding was designed and fabricated — Fig. 1.

### Welding Trials

Design of the production weld joint called for a 3⁄16-in. (4.8-mm) fillet to be welded in the horizontal or 2G position. Initial welding trials were made on flat plate test coupons, representative of the overpack weld joint with regard to material type, thickness, weld joint design, and welding position. These were followed by trials on round sections, simulating the actual overpack.

One of the constraints considered during parameter development was weld joint fitup, i.e., the potential for a gap at the shell/head interface. Per the design drawing, the gap could range from 0 to 3⁄32 in. (2.4 mm). To ensure the welding parameters/process would accommodate fitup within this range, several test coupons were welded in which gaps varied from 0 to 5⁄32 in. (4 mm). It was determined that a 3⁄32-in. (2.4-mm) gap could be successfully welded.

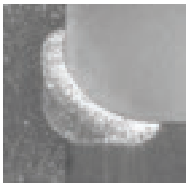
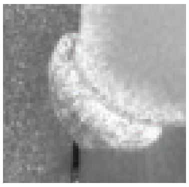
### Qualification Testing

With the nominal set of welding parameters selected, a simple statistical experiment was designed to evaluate bounding limits for two of the welding parameters — primary welding current and pri-

*1. TRIGA (Training, Research, Isotopes, General Atomics) is a registered trademark of General Atomics.*

*2. Liburdi Dimetrics is a registered trademark of Liburdi Dimetrics Corp.*

**Table 1 — Test Results and Photomicrographs from Three Weld Sections, Representing the Low, High, and Nominal Heat-Input Settings**

| Test ID | VT | PT | LT | Metallography | | |
|---|---|---|---|---|---|---|
| SW-1-1<br>SW-1-2<br>SW-1-3<br>SW-1-4<br>SW-1-5<br>SW-1-6<br>SW-1-7<br>SW-1-8 | Accept<br>No<br>Indications | Accept<br>No<br>Indications | Accept<br>Leak Rate:<br>$< 1 \times 10^{-7}$ atm-cc/s | Accept<br>SW-1-1 (Low Heat)<br>210 A/4 in./min<br> | Accept<br>SW-1-4 (High Heat)<br>270 A/3.2 in./min<br> | Accept<br>SW-1-6 (Nominal Heat)<br>240 A/3.6 in./min<br> |

mary travel speed. These parameters were judged to be of key importance in determining weld bead shape, weld pool control, and fusion at the root of the joint.

The purpose of the experiment was to identify a suitable/acceptable range for the critical parameters. Bounding values were set at the welding engineers' discretion to bracket anticipated variability of the welding and measuring equipment, and to accommodate potential upset conditions.

The experiment, a two-factor, two-level factorial with replication at high and low limit values, was performed on an actual production overpack. Welds were subjected to visual inspection (VT), liquid penetrant examination (PT), helium leak testing (LT), and metallographic evaluation. Table 1 provides test results and photomicrographs from three (of the eight) weld sections, representing the low, high, and nominal heat-input settings.

One additional production overpack closure was completed in which the entire weld was deposited using the nominal heat input parameters. Finally, ASME Section IX welding procedure testing was performed. All qualification testing met specified requirements.

## Additional Testing and Evaluation

### Integrated Proof Testing

A production overpack in which both heads were fitted with lifting lugs (in production only the top head receives these lugs) was welded using the qualified process. This overpack was subjected to a pull test of 1.25 times the design lifting load — Fig. 2. The tested overpack was visually examined and liquid penetrant tested for damage, and one of the head-to-shell welds was helium leak tested. All testing met specified requirements.

## Maximum Overpack Temperature

To understand the impact the heat of closure welding may have on the overpack contents, a temperature calculation, using the computer code FLUENT™[3], was performed. The maximum overpack temperature, at approximately three inches from the weld (on the shell), was calculated to be 153°C (307°F). Testing to measure actual maximum temperatures, via thermocouples attached to the final qualification overpack weld, was performed. Temperature values were recorded using a vendor-calibrated data logger; thermocouple attachment locations and setup are shown in Fig. 3. A comparison of the calculated value at three inches from the weld (on the shell) to the measured value at the same location confirmed the conservative nature of the calculation — that is, 153°C (307°F) and 80°C (176°F) for the calculated vs. the measured values, respectively.

## Discussion

In addition to the ASME Section IX certifications, the welding operators scheduled for production welding were those who performed the development work. This provided the opportunity to become thoroughly familiar with the process and the specific technique developed. The "machine-welding" mode relies, to a degree, on the skill of the welding operator. The overall strategy for providing high confidence in overpack closure welding includes both the development qualification activities and the skill of the qualified welding operators.

# Conclusion

Fluor has successfully closure welded many radioactive materials packages. As nuclear site cleanup activities continue, there will be an opportunity and need to develop and qualify additional closure-welding processes. The above-outlined approach provides a template to consider when preparing/planning for these activities.◆

*3. Fluent is a registered trademark of Fluent Inc.*



*References*

1. Cannell, G. R., Daugherty, W. L., and Stokes, M. W. 2002. Welds safeguard plutonium-bearing containers. *Welding Journal* 81(7): 42–46.

2. Cannell, G. R., and Ruth, R. P. 2003. Closing spent nuclear fuel canisters with GTAW. *Welding Journal* 82(12): 28–32.