Idaho Closure Project Integrated Waste Treatment Project Construction and Startup Status and Lessons Learned - 10433

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ABSTRACT

The Idaho Closure Project (ICP) is a \$2.3B cleanup project at the Idaho National Laboratory (INL). The Integrated Waste Treatment Unit (IWTU) is being constructed as part of the ICP. This IWTU is a waste treatment facility designed to treat approximately 3,300,000 liters of highly radioactive liquid waste. The IWTU treatment process uses a form of fluidized-bed steam reforming technology to treat the highly radioactive liquid waste, producing a granular solid product suitable for packaging in waste containers. Having received approval to proceed with construction from DOE in August 2007, the project is now entering the final stages of construction and is in the process of initial turnover of systems from construction to startup. A number of factors have made the IWTU project a very complex undertaking. This paper will describe some of the more complex challenges that the project faced, the methods that did or didn't work to overcome these challenges, and recommendations for engineers and project managers embarking on or currently involved in construction projects of similar magnitude and complexity.

INTRODUCTION

The Idaho Closure Project (ICP) is a \$2.3B cleanup project at the Idaho National Laboratory (INL) contracted by the Department of Energy (DOE) to CH2M-Washington Group Idaho, LLC (CWI), a joint venture between CH2M Hill and URS. The Integrated Waste Treatment Unit (IWTU) facility is a \$570M line item construction project that is part of the ICP scope. The IWTU is a waste treatment facility designed to treat approximately 3,300,000 liters of highly radioactive liquid waste. The liquid waste, referred to as sodium-bearing waste (SBW), is from past INL operations related to deactivation of spent fuel reprocessing facilities, and is currently being stored in three underground tanks. Completion of the treatment of the SBW by December 2012 in order to allow for closure of the last of the underground storage tanks at the INL is a major milestone in the Settlement Agreement between the DOE and the State of Idaho.

The IWTU treatment process uses a form of fluidized-bed steam reforming technology to treat the highly radioactive liquid waste, producing a granular solid product suitable for packaging in waste containers. The technology provider for the SBW treatment process is Thor Treatment Technolgies (TTT). The process is designed to produce a product that is disposable at the Waste Isolation Pilot Plant (WIPP), pending the acceptance of this remote-handled waste form through the WIPP acceptance process.

Having received approval to proceed with construction from DOE in August 2007, the project is now entering the final stages of construction and is in the process of initial turnover of systems from construction to startup. Construction completion is currently scheduled for August 2010, and some equipment startup has begun. Start of operations is currently planned for summer of 2011.

A number of factors have made the IWTU project a very complex undertaking. Foremost, the facility is a first-of-a-kind design, adapted from previously demonstrated technology, but with significant technical advances that were needed for the demanding treatment campaign it is devoted to. The process vessels are operated at a very high temperature (nominally 640 ^{o}C in the primary process vessel) and will be processing a very chemically aggressive waste. As such, the process vessels and interconnecting piping are constructed from a myriad of exotic metal alloys, refractory materials, and insulation in a relatively complex process configuration. Adding to the complexity of the project, the facility structure and process confinement was designed to DOE Standard 1021 Performance Criteria-3 criteria, resulting in a very complex and difficult to construct design. Finally, the project is to be completed under a very aggressive schedule, with construction completion in less than 3 years, an approximate one year startup and commissioning phase, and finally, completion of operations in 15 months.

A number of significant technical challenges have been encountered along the path of the construction of the IWTU. Some of these include:

- design, analysis, and fabrication of the primary IWTU process equipment vessels in keeping with the requirements of Section VIII of the ASME boiler and pressure vessel code, and using alloys that include Haynes 556, AL6XN, Hastelloy C276, and several alloys of Inconel. Fabrication has involved weld sections of up to 5 cm on the Haynes alloy, presenting significant challenges for completion and certification of the vessel welds as adequate for service.
- completion of final design and engineering, equipment procurement, and vendor data incorporation in a manner that supports an aggressive construction schedule. Very little advance time is available, and some engineering and procurement activities are just-in-time with progress of construction, making a very difficult situation for communication and coordination between the engineers, the constructor, and the vendors.
- Contracting to and working with over 30 vendors for the procurement of engineered equipment that comprises the main process and balance of plant equipment. Certifying these vendors as compliant with NQA-1 standards or, where necessary, implementing a commercial grade dedication process to ensure compliance with quality requirements. Also, monitoring vendor performance and compliance, and managing the multitude of interfaces and technical challenges as the vendors produced and delivered the equipment. Many issues were encountered along the way, mostly in vendors meeting schedule requirements and delivering technically acceptable product.

Figure 1. IWTU treatment building and product storage building under construction in the fall of 2009.

The IWTU project overcame these challenges, and has done so while maintaining project schedule and budget within baseline performance targets, in spite of a limited project contingency of $52M. Along the way, many insights have been gained and many lessons have been learned. This paper will describe some of the more complex challenges that the project faced, the methods that did or didn't work to overcome these challenges, and recommendations for engineers and project managers embarking on or currently involved in construction projects of similar magnitude and complexity.

PROCESS DECRIPTION

The steam reforming process to be used for treatment of the SBW consists of two steam reformers that are integrated into a single process system. The system converts the SBW into a dry, solid, carbonate product. The steam reforming process includes a feed collection and transfer system through which waste from the Tank Farm is transferred into the first of two steam reformers, the Denitration and Mineralization Reformer (DMR). The DMR contains a moderate temperature (~640 ^{o}C) fluidized bed. The bed particles are fluidized by low-pressure, superheated steam. The superheated steam and a small amount of added oxygen react with carbon (a process additive) to produce process heat and a chemically reducing environment. The liquid waste is sprayed into the fluidized bed where it evaporates. As the waste evaporates in the DMR, the dissolved constituents form additional bed material that is removed as solid product.

The DMR destroys organics, nitrates, and nitrites in the feed, and converts the bulk of the dissolved chemicals into a solid, granular product. The DMR converts organics in the waste into

CO, CO_2, H_2, and short-chained organic molecules such as CH_4. The strong reducing environment inside the DMR transforms nitrates, nitrites, and nitric acid into elemental nitrogen. NOx formation is minimal. The DMR converts most of the dissolved constituents in the waste into a mineral form, comprised primarily of alkali metal-based carbonates, aluminates, and other oxides.

Process gas from the DMR goes through a cyclone separator, which removes small particles and returns them to the DMR. The process gas then goes through a set of sintered metal filters that remove almost all fine particles. The fine particles are periodically removed from the filter and combined with the solid granular product from the DMR for product packaging. The filtered process gas then flows to the second steam reformer.

The second reformer, the Carbon Reduction Reformer (CRR), operates at a higher temperature (900 to 1000°C) than the first and contains a semi-permanent fluidized bed of alumina particles. Oxygen is introduced into the second reformer, which changes the off-gas environment from reducing to oxidizing. The H_2, CO, and short-chained organics in the DMR process gas are oxidized to CO_2 and water vapor in the CRR.

Fig. 2. The DMR vessel being lowered into place in the IWTU facility.

Gases from the CRR (mainly oxygen, carbon dioxide, nitrogen, and water vapor) are cooled in a spray cooler, filtered through sintered metal filters and high-efficiency particulate air (HEPA) filters, processed through a mercury adsorber (mercury is volatilized in the DMR and is not retained in the DMR product), and vented to the atmosphere through a monitored, permitted stack.

The product from the DMR and sintered metal filters is pneumatically transferred to a solid-product packaging station. At the packaging station, the product is cooled and then loaded into remote-handled canisters.

VESSEL FABRICATION WELDING ISSUES

The IWTU main process vessel (DMR) and the main process filter (PGF) are fabricated from an alloy called Haynes 556. Upon completion of the first series of welds for the DMR head and PGF shell in early 2008, indications of surface cracking were found present. Investigation subsequent to the discovery of the initial surface cracking and the initial repair process showed that the weld process, even though performed as recommended by the material supplier and within the approved weld procedure, can produce the formation of very small cracks on and below the weld surface (See Fig. 3). The vessel fabricator was directed to perform an extensive set of weld coupon examinations using different weld techniques to explore the issue. In all examinations performed, the microfissures:

- Are not produced within 9.5 mm of the root of the weld (the typical weld preparation is a 30/70 double V configuration)
- Were randomly located and were no greater than 0.2.7 mm using the GMAW-P weld process
- Were isolated (i.e., not contiguous, or occurring in groups of several closely spaced flaws).

Upon further investigation of literature and contact with industry and academia experts, it was determined that this condition involving microfissures is not uncommon, especially in this type of alloy. However, given the high operating temperatures of the IWTU vessels, and the potential for these microfissures to grow into larger flaws, further evaluation was necessary to understand the soundness of the weld under the conditions that are expected.

Structural Integrity Associates, an industry recognized expert in this field, was retained to perform calculations to estimate the acceptable flaw size for the Haynes 556 material under the expected operating conditions [1]. The report concluded that the crack propagation rates in the low-stress welds of the vessel shell are negligible and the seam and girth welds of the DMR vessel upper and lower cylinders can tolerate weld fabrication flaws with through-thickness depth that are roughly 50% of the shell wall thickness (approximately 1.5 cm). The results from the nozzle-to-shell connections that are the most highly stressed indicated higher expected crack-growth rates, and thus smaller allowable crack size. The maximum allowable flaw size for the worst-case nozzle weld was determined to be 0.70 cm, which is larger than any flaw size encountered in the test coupons examined, even using the less effective weld techniques. It also should be noted that the worst-case value of 0.70 cm is based on 32,760 hours of operation (nominally 5 years of operation with 75% in-service use). For the expected duration of the IWTU operational period for carbonate product of 17,500 hours (approximately 24 months of hot operations), the critical flaw size would be larger (approximately 1.0 cm).

Fig. 3. Magnified cross section of a Haynes 556 weld coupon showing microfissures.

Radiography and conventional ultrasonic testing (UT) technology are unable to measure crack sizes at the allowable value. Structural Integrity Associates also has extensive experience in a variety of ultrasonic testing techniques, including a more sensitive ultrasonic testing method known as linear-phased array ultrasonic testing (LPA UT). LPA UT was used to examine test coupons generated using welding techniques that were known to produce flaws [2]. Using this technique, workers were able to detect flaws in test coupons, as evidenced by destructive examination of the coupons following the ultrasonic testing examination, and by testing of an embedded flaw of known size.

Based on these findings, the project issued the following direction to ensure the DMR and PGF vessel welds will be assured of being sound throughout the project operation.

1. Use GTAW welding of root and initial cover passes followed by filling the weld out using GMAW-P within the operating parameters established during the weld process investigations.

2. Perform liquid penetrant testing on the welds along the internal diameter of the vessel of completed welds to examine the welds for flaws.

3. Use linear-phased array UT with settings that have been calibrated with a block containing a flaw with a depth of 0.5 cm. Criteria for action from these inspection techniques are summarized below.

    a. If no indications of flaws in excess of 0.5 cm are identified, the weld will be accepted.

b. For areas of high stress, the indication exceeding 0.5 cm will be repaired.

c. For welds in lower-stress areas (i.e., the vessel heads and shells), indications of flaws exceeding 0.95 cm will be repaired. As noted above, the critical flaw size for these lower-stress areas is much larger (1.5 cm or more) but flaws of this magnitude (or even 0.95 cm) have not been seen; therefore, it would be prudent to examine these areas to assess the performance of the welding process.

Using these techniques and criteria, no rejectable flaws have been identified for any of the Haynes welds. The vessel welding has been completed and the vessels are installed in the facility.

ENGINEERING, WORK PACKAGE PLANNING, AND CONSTRUCTABILITY

Because of the milestone with the State of Idaho to have the SBW treated by December 2012, the IWTU project was baselined on a fast track basis, but in accordance with criteria to approve DOE capital projects as defined in DOE Order 413.1C. The Order defines a series of four approvals, termed “critical decisions”. Critical Decision 3 (CD-3) is defined to be the point at which design and engineering are sufficiently complete to allow construction to proceed.

To make the baseline schedule, final CD-3 design engineering on the process and facility was completed in less than a year. Also, some of the construction was also approved to proceed in advance of CD-3 approval. CD-3 approval was granted in August of 2007 and construction was authorized to proceed in full. However, a substantial amount of engineering was not completed at the time of full construction authorization. Very little of the engineered equipment had been placed under procurement, and most of the vendor data was not available including dimensions, weights, mounting details, and other basic design input information. In addition, much of the detailed electrical and piping design information was incomplete.

This situation created a great strain on the project early and well into in the construction phase. The trickle down effect of this that work package planners sometimes didn’t have all the information necessary to complete the packages and often assumptions or work-arounds had to be implemented. On top of this, the planning function was understaffed as well, and many work packages were being put into the field without the benefit of full constructability reviews. As a result, many instances resulted in work stoppage while engineering issues were addressed to overcome a problem of constructability.

Another issue hampering work in the field was the apparent lack of good interdisciplinary reviews between engineering disciplines during the design phase. The project was modeled using Plant Design System (PDS) software to create a 3D model. However, only the structure, major equipment, and piping designs were input to the model. In addition, at some point during the design phase, the decision was make that the model would not be kept current with respect to structural and major equipment design changes and design evolution. As a result, there have been numerous instances of interferences, with some of the most significant coming from conflict in foundation locations for major process equipment interfering with the main structure foundation. Many other interferences between ventilation ducts, process piping, and electrical runs have been encountered.

PROCUREMENTS

The procurement of the engineered equipment was a critical portion of the project. The budget for engineered equipment was approximately \$96M. A major portion of that budget was the fabrication of the main process vessel skids, which was contracted to a single fabricator. The remainder of the equipment was put out for bid in 68 individual procurements ranging in value from \$50K to \$4.2M.

Engineering specifications were developed for each of these engineered equipment procurements. When these specifications were initially sent out for bid, extremely high quotes were received in many of the early solicitations. As an example, the initial quote for the process waste feed pump, a 11.2 kW, 296 liter/min single stage centrifugal pump, was \$375K. Upon a scrub of the 100+ page specification, the project team discovered that the requirements laid out in the Specification were excessive and unnecessary. Subsequent revision produced a specification that, when rebid, yielded a final contracted cost of \$85K for essentially the same pump. Overall, the project was able to save over \$4M by critical review of the engineered equipment procurement specification requirements.

Other factors have hampered procurement and delivery of process equipment. One of the primary issues is locating qualified vendors that are actually willing to bid on DOE projects given the required flowdown of certain terms and conditions. One significant example was the process instrumentation for the project, which was designed around using Rosemount instruments. Rosemount had been the standard for many years at the INL. However, when it came time to place the procurements, CWI was informed that Emerson, the parent company of Rosemount, had issued a directive that no distributor was to sell equipment to any DOE project, siting issues with terms and conditions. This resulted in a complete rework of the instrumentation design, to include the 1,200+ instruments that were to be used for the project. More expensive components from Yokogawa had to be used instead.

It was never clear what the primary issue from Rosemount was, but other vendors who declined to provide quote often cited the Price Anderson requirements as the primary issue of most concern. It was CWI policy to generally require this clause on all contracts. In some cases, we were able to delete this requirement, which helped with some of the procurements, but continued to be a problem.

Another issue was determining quality level requirements for individual components and determining how to apply those determinations to the procurement process. CWI procedures define four quality levels (QL) that are used, with QL-1 for safety class, QL-2 for safety significant, QL-4 for commercial grade, and a QL-3 for components not safety basis related but considered to be “mission critical”. This of course created some confusion when determining quality requirements to be placed on procurements, as many QL-3 classified components could not be purchased at a reasonable cost unless they were procured as commercial grade (i.e. placing American Society of Mechanical Engineers (ASME) Quality Assurance Requirements for Nuclear Facility Applications (NQA-1) requirement would dilute the pool of qualified bidders and significantly increase the price). This affected dozens of procurement of components classified as QL-3.

One solution to this was to attempt to apply NQA-1 procedures for "commercial grade dedication" (CGD) to these procurements. This seemingly simple way around the issue was actually found to be far more complex than thought, and actually a misapplication of the intent of the CGD allowance that is part of NQA-1. As a result, the company developed a separate set of procedures that specifically address this issue to allow a properly graded approach to ensuring proper level of QA was applied to the subject procurements. As a result, the project only had four procurements regarding equipment that had to be purchased and dedicated into service through a CGD process.

CONCLUSION

At this stage of the project, construction on in the final stages, the majority of the complex issues described have been successfully remedied, and construction is scheduled to be complete in August of 2010. Plans are being put in place regarding turnover of equipment, systems and structures from construction to the commissioning organization. Test plans and procedures are under development to allow subsystem and integrated system testing, which is scheduled to complete by summer of 2011.

REFERENCES

1. SI, 2008a, *Crack Propagation Analysis for Selected Welds of the DMR Vessel for the Idaho Cleanup Project*, SI Report File No.: 0800474.301, Rev. 0, Structural Integrity Associates, September 3, 2008.

2. SI, 2008b, *Crack Detection Feasibility for Haynes Alloy Welds of the DMR Vessel for the Idaho Cleanup Project*, Report 80047.401.UT.R0, Structural Integrity Associates, September 4, 2008.