TRANSPORT, INSTALLATION, AND TESTING OF A TRANSPORTABLE VOLUME REDUCTION AND BITUMEN SOLIDIFICATION SYSTEM

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ABSTRACT

Review of the Transportable Volume Reduction/Radioactive Waste Solidification System (TVR) shows that the fabrication of the system meets the Duke contract specifications and current regulatory requirements and that the system has successfully demonstrated its ability to solidify boric acid, EPRI chemical cleaning solvent, and demineralizer resin wastes in asphalt. Review of disassembly, transport and reassembly reveals the TVR System's flexibility to move in and out of a station without undue impact on station personnel. Modification of the plant for TVR installation is easily accomplished upon conducting a comprehensive review of design considerations; a discussion is given of the actual coordination, design, and construction applied in modifying Duke Power Company's Riverbend Steam Station. Initial results are presented from processing boric acid, chemical cleaning, and demineralizer resin wastes which show that this system is capable of volume reducing and solidifying the wastes.

INTRODUCTION

This paper presents an overview of the conceptual design of a Transportable Volume Reduction and Radioactive Waste Solidification System (TVR) as compared against its as-built condition; the disassembly, transport and reassembly of the system from the fabrication shop to the site; the design, coordination, and subsequent modification of the station for its installation; the site integrated functional test; an overview of process and production of wastes using bitumen as the solidification media; and the results of waste product testing.

HISTORY

This history section is provided as background information and summarizes TVR papers previously presented at Waste Management '83 and '84 (References 1 and 2).

In June 1982, Duke Power Company authorized Associated Technologies Inc. (ATI) to provide radwaste volume reduction and solidification services for Oconee Nuclear Station on a lease basis. The services were procured initially for the station's Unit 2 steam generator chemical cleaning originally scheduled for Fall 1983. Improved secondary side chemistry of this unit enabled it to continue operation and establish a world record for continuous operation. Realizing the necessity for future cleaning of the steam generators still existed, Duke Power Company decided to purchase the TVR System rather than lease services. The current state of waste disposal and station needs dictated the necessity for a radwaste system to have volume reduction capability, portability, simplicity of design and operation, and economic feasibility (Ref. 2). The TVR System utilizing the LUWA Thin-Film Evaporator was Duke Power Company's choice for processing the chemical cleaning wastes and meeting other station radwaste processing needs. The TVR System simultaneously feeds station liquid waste and molten bitumen into the vertical thin-film evaporator where they are mixed and the water evaporated to provide a homogeneous product with less than 0.5% free-standing liquid. Some additional features of the system are spill containment, fire protection, reagent feed system, ALARA design, and flush and decontamination capability (Ref. 2).

Duke Power Company's Design Engineering Department reviewed and advised on the design and inspected the manufacture of the TVR System to insure that all systems were "as designed" and that the quality of fabrication was as specified. Fabrication of the system occurred from February to October 1983. The fabrication process for the TVR System was comparable to that of prototypical modular processing systems. Following fabrication and while still in the shop, a start-up and functional test was performed. Start-up included hydrotesting of mechanical components, electrical diagnostic checkout of the computer, programmable logic controller and interlocks, spinning of the pumps, and opening and closing of valves. (See Ref. 2 for further details.) Shop testing was conducted by filling the waste tanks with simulated waste and processing it through actual TVR system operation. Problems incurred during system start-up and testing were relatively minor and easily repaired with the exception of the evaporator, which exhibited noise and binding at lower temperatures (see section on integrated functional testing for more information). Fluid flow in various piping systems checked out very well, as did the internal materials handling system. The shop functional tests were conducted during November and December 1983. Examination of the newly-developed 10CFR61 Branch Technical Position on Waste Form (BTP), the delay in cleaning Oconee Nuclear Station's steam generators, and the need for both additional functional testing and operator training indicated Duke Power Company could more easily and more economically continue non-radioactive testing at Riverbend Steam Station, one of Duke Power Company's fossil stations.

DISASSEMBLY

One of the principal concepts of the TVR System is ease of disassembly for transport. Disassembly at the fabricator's shop involved separation of the overall system into six individual transportable modules: the Process Module, Evaporator Module, Waste Batch Module, Control Module, Auxiliary Module, and the Reagent Module. This was accomplished in several steps, including system flushing and draining, disconnection of module interfacial wiring and piping, removal of module-to-module structural bolts, removal of rooftop components as required for transport clearance, and tagging of loose components. Each module was designed with a minimum of four lifting lugs which require two spreader bar assemblies for lifting. The entire disassembly process required a small crew of electrical and mechanical personnel approximately two weeks to complete.

After completion of shop functional testing of the TVR, performed at the fabricator's shop during November and December 1983, the TVR was disassembled portions at a time during completion of the final 10 percent of fabrication. In late January 1984, disassembly of the Evaporator Module (which was perhaps the most interesting phase of the disassembly process) was successfully performed. This procedure involved a four-point vertical lift of the Evaporator Module from its rooftop location on the Process Module, a midair transition of the module from its normally vertical position to a horizontal one via reattachment of one crane from top-mounted lifting lugs to side-mounted lugs, and setting the module on its side. Inspection of this disassembly revealed a successful lift which required four mechanics and two crane operators less than one hour.

Success and ease in disassembly of the modules were also demonstrated during other inspections, as the modules were separated and rejoined several times during the fabrication process. TVR fabrication and final disassembly were completed in early March 1984. Shop demonstrations verified that both mechanical and electrical disassembly of the TVR were in accordance with the preassembly-for-ease-of-disassembly concept designed into the TVR System.

TRANSPORT

During fabrication, the modules were transported several times within the shop by overhead crane. Due to the nature of these lifts (small heights and very slow crane speeds), transport preparation was not required. No problems were encountered with these relocations. Upon completion of fabrication, the modules were prepared for transport via truck to Riverbend. Preparation for TVR transport included bracing of those components within the modules requiring additional stability during shipment, bracing of certain piping ends at module interface points, packaging of loose or fragile components (CCTV monitors and cameras, etc.), and installing weather-protective coverings over module interface openings.

The six modules and miscellaneous components were loaded onto low flatbed trailers, tied down, and inspected prior to shipment. Six tractor-trailers were required in shipping the TVR modules and miscellaneous components to Riverbend (the majority of the material handling system was not shipped and would have required one additional trailer). The modules are approximately twelve feet high, giving a loaded clearance of approximately 15'6". In late March 1984, the system was shipped approximately 150 miles to Riverbend; no shipment problems or equipment damage occurred during the trip.

The 30-ton cranes were required for removing the modules from the trailers and locating them directly onto the concrete pad. The modules were transferred to the pad in the following typical sequence - Control, Process, Waste Batch, Auxiliary, Evaporator - to assure proper alignment and connection at module interfaces. Each module, which can be shimmed at leveling plates if required, was checked for centering and levelness. At Riverbend, unloading of the trailers, spotting of the modules onto the pad, and positioning of auxiliary rooftop equipment by crane was successful and required five mechanics and two crane operators less than eight hours.

ASSEMBLY AND CHECKOUT

The TVR System consists of six enclosed structural steel modules containing a variety of preassembled subsystems and components. These weatherproof modules are prewired and prepiped to the maximum extent possible to enable quick and easy assembly requiring a minimum number of field connections. During mechanical assembly of the TVR, the structures were bolted together and sealed water-tight at interfaces, piping was connected at the module-to-module interfaces, and rooftop and other internal or external components (not suitable for remaining attached to the modules during shipment) were installed. This included installation of auxiliary equipment such as the HVAC fan and filter skid, emergency generator, Waste Batch Tank agitators, ladders and stairs. Temporary bracing and supports were removed after the connection of piping was completed. Mechanical assembly at Riverbend was accomplished by four personnel within a two-week period.

Electrical assembly involved cable tray installation; connection of power, grounding, and control cables and instrumentation tubing between modules; and installation of any instrumentation requiring removal from the modules during shipment. Three personnel performed electrical assembly and complete electrical system checkout at Riverbend in approximately four weeks.

After assembly of the TVR, the entire system underwent a preoperational checkout to verify proper and complete mechanical and electrical operation prior to waste processing. This included hydrotesting of all radioactive service piping, inspection of piping and equipment alignment, dye penetrant testing on at least ten percent of module spill containment basin welds, electrical ringout of wiring, and a drum handling system trial run. Assembly of the TVR System at Riverbend was accomplished as designed with no significant problems or delays. This assembly and checkout was completed in May 1984, requiring an overall period of six weeks. The majority of the drum handling system was not completely installed at Riverbend due to space restrictions, and would have required approximately one week to install and test.

STATION MODIFICATION

Duke Power Company's Design Engineering Department took on the task of designing, scheduling, and coordinating the plant modifications. The involvement of approximately fifteen working groups in the design of the station modifications called for a fairly extensive scheduling effort, although small in comparison to the effort required in designing for the addition of a permanent facility. The type of work performed ranged from the design of concrete foundations for the support of the TVR System to the design of various piping systems and electrical power system interconnections; thus, design working groups were called upon for piping system design, materials selection, equipment and instrumentation selection and procurement, heat-tracing and insulation design and procurement, power connection design, architectural layout, pipe support analysis, and structural design. An effort was made to minimize costs of installation which resulted in decisions such as using PVC piping materials instead of carbon or stainless steel for the temporary installation of this system. Assistance from Riverbend Steam Station personnel also proved invaluable; their personnel worked with the engineering staff to quickly locate station resources for piping and power connection and to provide grade work within the area. Once the designs were complete, along with the arrival of necessary materials, Duke's Construction Department erected the concrete foundation for supporting the system, piped up the station-to-TVR System interconnections and supplied the temporary power connections. Modification of the site and station-to-TVR System interconnection required ten men approximately four weeks to complete.

SITE INTEGRATED FUNCTIONAL TESTING

TVR testing performed at Riverbend can be divided into three phases: Phase I - Site Integrated Functional Testing, Phase II - Process Optimization Testing, and Phase III - 10CFR61 Waste Form Testing. Phase I initially involved completion of functional testing of the individual components and subsystems which were not tested at the fabricator's shop due to Duke's request for early shipment. This type of functional testing is normally performed at the point of manufacture to verify proper fabrication and a functionally sound system prior to operation. The remaining subsystems and components were functionally tested at Riverbend and included the reagent system, seal/flush water system, HVAC systems, radiation monitors, resin dewatering system, fire protection system, emergency generator, and sumps and drains system.

The intent of the Integrated Functional Test is to demonstrate successful operation of the complete TVR System as an integrated combination of subsystems functioning properly together. The majority of the problems incurred during integrated testing were relatively minor and are typically exhibited upon startup of systems of this type, with the exception of evaporator rotor binding during operation. When this problem occurred during shop testing, LUWA (manufacturer of the thin-film evaporator) performed a routine investigation as would be performed for any warranty-related problem. As a result, LUWA suggested a revision to evaporator operating procedures to be instituted at Riverbend, since shop testing was already completed.

After start-up at Riverbend, the binding problem reoccurred on a more frequent basis. LUWA was again consulted, at which time they conducted a more thorough investigation. The advice to revise operating procedures proved to somewhat alleviate the problem during operation at Riverbend. However, the thorough investigation led LUWA to suspect that the problem was not only operation-related, but also a mechanical problem as well, being one of thermal imbalance of the evaporator rotor and heated shell. At this time, the shell was inspected and found to be in an acceptable condition. Since Duke and ATI were still performing functional testing, LUWA provided temporary fixes to enable TVR operations to continue. LUWA suggested replacement of the rotor with one designed for higher operating temperatures as a permanent resolution to the problem. Upon review, Duke and ATI considered both the temporary and permanent modifications acceptable solutions to the problem. Testing has been allowed to successfully continue with the temporary modifications provided by LUWA. The replacement rotor is expected to arrive Spring 1985. (For a more complete description, see Ref. 3.)

During integrated testing, it was also found that the concentration of oils in the evaporator distillate stream was higher than expected. This problem is currently being investigated by Duke and ATI and resolution is expected in the near future.

Phase I testing also demonstrated success in the design of the fail-safe interlocks of the volume reduction system upon subjection to abnormal operating conditions and simulated component failures. The high degree of automatic and remote operation of the system was also successfully demonstrated.

WASTE FORM CHARACTERISTICS AND PROCESS RESULTS

Phase I testing also accomplished verification that the TVR System as a whole could perform its primary objective - volume reduction and solidification of liquid waste. This included verification that for each waste type (boric acid concentrates, spent resins, and chemical cleaning solvent), the process yielded a homogeneous, monolithic, free-standing solidified product containing no voids and less than 0.5 percent free-standing water, as guaranteed in the contract. 10CFR61 was still in draft form upon preparation of the contract; therefore, the more stringent waste form standards outlined in 10CFR61 and the subsequent BTP were not contractual requirements. Verification that the TVR waste product will also meet these standards will be performed under Phase III testing at a later date. Phase I verification was performed by visual inspection of the cross-sections of full-scale solidified product drums which were split in half lengthwise; these results are presented in this section, as well as preliminary results from compression tests used in planning for Phase III testing.

Product acceptability for resins was demonstrated at the fabrication shop in November 1983. There, 20 cubic feet of dewatered anion resin were solidified to yield a final product containing 30-40 weight-percent solids. This corresponded to a volume reduction factor of approximately 1.2 (at 40-weight-percent solids). Two of the 55-gallon drums of solidified resin were frozen for 5 days, after which they were cut with a grinder and split in half with a wedge and hammer. The product was observed to be a homogeneous, monolithic solid containing no visible void spaces. All resin beads appeared to have an excellent bitumen coating (Ref. 2).

Following TVR installation at Riverbend, integrated testing of 12-weight-percent boric acid concentrates was performed. In October 1984, samples with waste-to-binder ratios of 35/65, 40/60, 45/55, 50/50, 55/45, 60/40 and 65/35 were produced. The maximum operating waste-to-binder ratio was found to be 65/35 for boric acid concentrates. A full drum with a boric acid-to-bitumen ratio of 45/55 was produced and frozen. The drum was then split in half and shown to fulfill the contract guaranteed parameters of being a homogeneous monolith containing no visible free-standing water. The maximum VR obtained with boric acid concentrates was found to be approximately 7.5.

In November 1984 after performing compression testing according to ASTM D-1074 on both solidified resin and boric acid samples and finding the results to be unsatisfactory, a decision was made to change the type of bitumen used in the TVR System. The straight distilled bitumen AC-20 was replaced with a stiffer bitumen known as Type 1 Roofing Asphalt (see Ref. 3 for further detail). A batch of boric acid concentrates solidified in Type 1 bitumen was produced in late November 1984. Compression testing performed on a 50/50 waste-to-bitumen sample yielded a compressive strength of 71 psi at 10% deflection, thus exceeding the BTP criteria of 50 psi.

In January 1985, EPRI chemical cleaning solvent processing and solidification with Type 1 bitumen was begun. The first samples produced without hydrazine at 45-weight-percent EDTA were porous and shrank upon cooling. After addition of hydrazine to the chemical cleaning solvent (see Ref. 3 for further detail), the waste product showed a decrease in off-gassing, resulting in a homogeneous solidified product with no voids.

Testing has also been performed at Riverbend in order to determine the evaporative capacities for various waste types. When processing only water at a heating fluid temperature of 430 degrees F, the distillate rate was found to be 951 lbm/hr. For water and AC-20 bitumen at a heating fluid temperature of 450 degrees F, a distillate rate of 875 lbm/hr was determined. For both of these cases, the water inlet temperature was 115 degrees F. When processing 12-weight-percent boric acid concentrates and AC-20 at a heating fluid temperature of 450 degrees F, the distillate rate was found to be 772 lbm/hr. For 12-weight percent-boric acid concentrates and Type 1 bitumen at a heating fluid temperature of 450 degrees F, a distillate rate of 569 lbm/hr was determined. For both of these cases, the waste inlet temperature was 180 degrees F. These results confirmed that the evaporative capacity of the system was as expected.

Following Site Integrated Functional Testing, Duke will begin Phase II - Process Optimization Testing to determine the maximum and minimum operating points achievable while producing a satisfactory solidified product. Items to be included in this optimization are:

a. maximum weight ratio for solidified product for each waste type
b. maximum transferable resin slurry concentration
c. minimum evaporative capacity for each waste type
d. minimum reagent and chemical feed concentrations required

As outlined in 10CFR61 and the BTP, the TVR must also undergo Phase III testing to verify product stability. This will be accomplished by performing the following series of tests:

a. ANS 16.1 Leachability
b. Compression
c. Compression after Thermal Cycling
d. Compression after Irradiation
e. 0.5% Free Water and Free-Standing Monolith
f. Compression after Biodegradation
g. Compression after Immersion

This testing will be performed on samples of solidified product for boric acid concentrates, spent resins, and chemical cleaning solvent. The data generated by this testing will supplement existing leaching data supplied by SGN (Societe Generale pour les Techniques Nouvelles - the licensor of the process to ATI in the United States) in order to demonstrate compliance with 10CFR61.

SUMMARY AND CONCLUSIONS

The TVR System has shown that it can easily be transported by truck or other means without adverse effects occurring during shipment, and that it can easily be assembled and disassembled without greatly impacting station personnel resources. Results of compression tests already demonstrate that boric acid wastes solidified in asphalt can meet the compressibility requirements of the 10CFR61 Branch Technical Position on Waste Form (BTP). We are confident that TVR System will produce a product that will meet the BTP requirements. In summary, observations to date tend to support the conclusion that the use of portable volume reduction systems can provide a viable and economical means of meeting station radwaste processing needs.

REFERENCES

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