BACKFITTING AN ADVANCED RADWASTE VOLUME REDUCTION SYSTEM EMPLOYING MODELING TECHNIQUES

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ABSTRACT

Changes in regulations governing transportation and burial of low level radioactive waste and related economic factors have driven many utilities to implement plans for backfitting advanced volume reduction (VR) equipment into their existing plants. Because these projects typically involve interfaces with existing systems and structures, there are often areas in which unique problems can develop during the design and construction phases which would either not occur or can be eliminated when the VR equipment is part of a new plant design.

This paper discusses some of the unique problems encountered during the engineering design phase and early portions of the construction phase of a project to backfit an evaporator/crystallizer into the existing Auxiliary Building at the Zion Generating Station, a two unit PWR facility owned and operated by Commonwealth Edison Company of Chicago, Illinois.

In addition, the paper highlights the use of a scale model in both the design and construction phases of this type of project, including a discussion of how the model was incorporated into the project design and the effectiveness of the model in keeping costs and schedules on target.

INTRODUCTION

The Zion Generating Station is owned and operated by the Commonwealth Edison Company (CECo) and is located in Zion, Illinois. The station consists of an operating two-unit shared facility nuclear power plant with a total net capacity of 2080 MWe. The nuclear power plants are both pressurized water reactors with Westinghouse four-loop nuclear steam supply systems. Unit 1 was placed in commercial operation in 1973 and Unit 2 in 1974.

The original liquid radwaste system included a horizontal, submerged tube type evaporator for concentrating miscellaneous equipment leakage and floor drainage to 12 Wt percent solids (as boric acid). These concentrates were then solidified with cement in an automated drum filling/capping/tumbling operation. Finally, the drummed waste was remotely picked up by a small bridge crane and placed on a series of roller conveyors for storage. In 1975, a project was undertaken to install a backup unit of similar design. This second unit was installed in an unused area on Floor El. 592'-0" of the Auxiliary Building, directly below the original unit, which is located on Floor El. 617'-0".

In operation, both of the evaporators, as well as the solidification equipment and drum handling/storage equipment, experienced numerous problems, making the entire system very unreliable and man-rem intensive to operate and maintain. For these reasons, the decision was made to purchase disposable demineralizers for processing all liquid wastes and to hire a contractor to solidfy and dispose of the spent resins from these units using mobile equipment. This arrangement, which was put into operation several years ago as a "temporary fix", is still being used to process most of the wet wastes generated by the plant.

Because of the desire to provide a permanent system that would satisfy all ALARA criteria while achieving greater volume reduction (VR) factors, CECo funded several studies to determine the best course of action to take to improve the in-plant facilities. From the results of this work, it was concluded that a forced circulation evaporator/crystallizer should be installed. With this system, an average net VR factor (after solidification) of approximately 600 is achievable for typical liquid wastes produced at the site. In comparison, the portable demineralizer system yields an average net VR factor of approximately 300. The net savings in transportation and burial costs realized by this reduction in waste volume shipped was the determining factor in CECo's decision to procede with the current project.

DESCRIPTION OF MODIFICATIONS

As originally planned, the radwaste system modification design work awarded to Gilbert/

Commonwealth, Inc. (G/C) was to be limited to engineering: a) the replacement of one of the existing evaporators with a force circulation evaporator/crystallizer; b) the addition of a small concentrates storage tank to supplement the existing tank; and c) the replacement of the existing roller conveyor with a new, more reliable unit. Concurrently with this work, CECo was to independently procede with plans to upgrade and reactivate the in-plant solidification system and the other evaporator for use in conjunction with the new crystallizer. In addition, preliminary planning was underway for construction of a remote, long-term storage facility that would eventually handle all of the concentrates produced by either of the evaporators.

At the beginning of the project, G/C's first step was to review the plans for these other modifications with CECo. As a result of this review, it became apparent that some changes in the other projects were needed to arrive at an integrated plan for overall upgrading of the plant's radwaste processing facilities. The new plan created as a result of this review represented a significant departure from previous thinking. Key elements of this new approach were as follows:

- A pretreatment system would be added for chemical adjustment and sampling of the dilute waste feed streams.

  A larger, fully redundant concentrates storage system would be installed to completely replace the existing storage system, which was evaluated to be unreliable and inadequately sized for use with the new evaporator/crystallizer.

- The existing solidification system was judged to have too many serious deficiencies to realistically consider rehabilitating it. Therefore, provisions would be made for future addition of an entirely new solidification system designed to current standards for product quality and ALARA operation. In the interim, contract solidification services would continued to be used.

- The existing roller conveyors would be removed, but new units would not be installed, since this form of drum storage was deemed to be inefficient and too susceptible to mechanical breakdowns. The space gained by eliminating these conveyors would be used for some of the new pretreatment and concentrates storage equipment.

- Provisions would be made for future replacement of the existing bridge crane with a new unit designed to permit reliable remote handling of drums. The drum grapple would be designed to permit stacking of drums in the crane bay as a means of regaining the drum storage capability lost when the roller conveyors were removed. Long term storage would still be achieved using the remote storage facility as previously mentioned.

- The radwaste control area would be closed off from the remainder of the Auxiliary Building and fitted with air conditioning equipment to create a more suitable control room environment for the operators and for the new solid state microprocessing equipment being installed to control the new process equipment.

Boundaries of Work Area

Except for some of the piping changes, all of the modification work associated with this project is confined to the 579'-0" and 592'-0" Floor Elevations of the shared Auxiliary Building in an area bounded by Column Lines 26 and 30 on the north and south and Column Lines G and L on the east and west. The total floor area within these boundaries is approximately 630m^2. In block form, Fig. 1 illustrates the arrangement of processing equipment within this area prior to the start of the project. Figure 2 shows how the same area will be arranged after all of the modifications are completed.

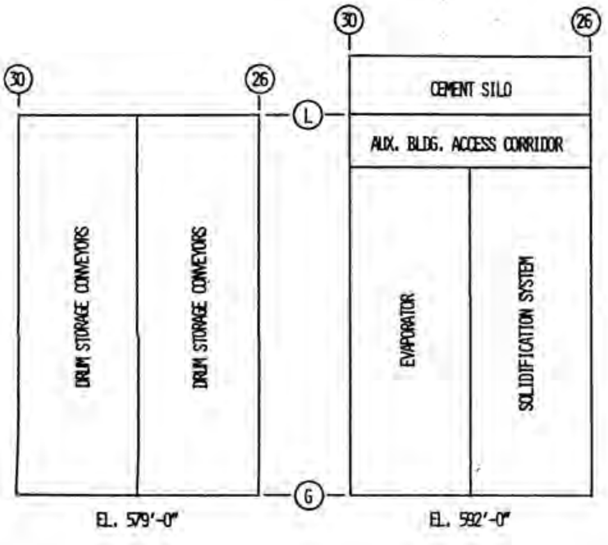

Fig. 1. Aux. Building layout before modifications.

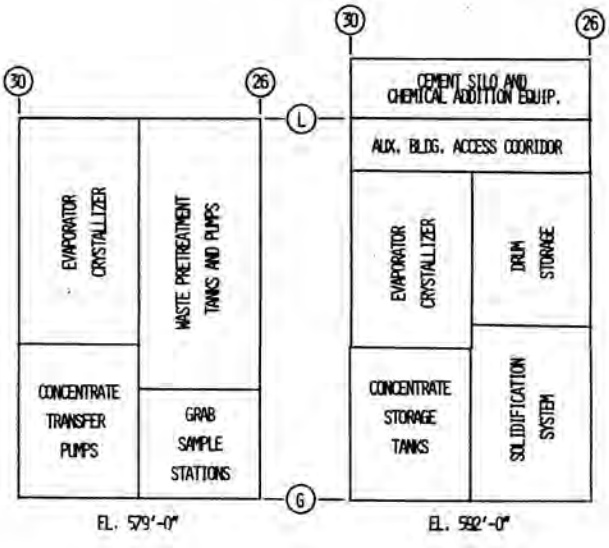

Fig. 2. Aux. Building layout after modifications.

DESCRIPTION OF DEMOLITION AND DECONTAMINATION WORK

To facilitate installation of the evaporator/crystallizer and associated systems, clean up and demolition activities were initiated. It was necessary to remove or demolish the failed systems, an accumulation of contaminated and radioactive materials, as well as portions of walls and floor slabs.

Equipment slated for removal and subsequent disposal consisted of the existing evaporator on Floor Elevation 592'-0", the existing in-plant solidification station, and miscellaneous tanks, pumps, piping, conduit and junction boxes. Since these items were to be disposed of, they were reduced to a suitable size for disposal using grinders and air arc or acetylene torches. A drum conveyor system also existed in the area; however, since it was to be salvaged, it was dismantled for future decontamination.

Various concrete and block walls, floor slabs, structural steel and hangers had to be removed as part of the demolition. For walls and floors, this was a fairly simple (although time consuming) task accomplished with air hammers. This material was broken up using a 90 lb. hammer. Lighter 30 and 40 lb. hammers were used to clean reinforcing bar for splices and to smooth the edges of openings. All large openings to be made for future doorways and piping penetrations were formed by core drilling around the opening perimeters. The resultant block was then removed and broken for disposal. Structural steel and hangers designated for disposal were cut in the same manner as equipment.

The entire demolition process for the structure and equipment resulted in approximately 1,500 208 liter drums and about 50 3.6m^3 DAW boxes filled for disposal. This process expended roughly 21,000 manhours and resulted in a cumulative dose of about 18 man-rem.

To reduce labor costs and to minimize personnel exposure during subsequent constuction work, a commitment was made to clean the work area sufficiently upon completion of the demolition phase to permit construction worker access to the area in "street clothes". This required some form of decontamination program to be instituted.

Initially, a control area was selected for testing the effectiveness of the proposed decontamination techniques. This site was readily isolated to enable work to continue elsewhere. At the onset, over 250 smear samples were taken, with contamination levels in the range of 12,500 to 625,000 cpm.

To remove these levels of contamination, several decontamination techniques were identified and evaluated on the basis of previous experience at the site. The process eventually chosen consisted of scrubbing with abrasive pads and "Radwash", followed by a pressurized water rinse. Since some conduit, junction boxes and risers were to remain in the area, all scrubbing on the ceilings and walls was performed by hand. A power floor washer was used to provide the scrubbing action needed on the floors. The conduit, junction boxes and risers inthe area were decontaminated by manual scrubbing with a foam cleaner, followed by a clean water rinse.

Following decontamination, smears were again taken and indicated that an immediate "clean" level (defined in site procedures as less than 87 cpm) could be attained; however, within hours the level was observed to reach 300 to 400 cpm. This was attributed primarily to leaching and airborne contamination.

Subsequently, the conduit, junction boxes and risers were wiped down with oil impregnated cloths to remove contamination and then the entire area was sprayed with a liquid sealer. In this manner the contamination was able to be fixed, thereby permitting removal of the step off pads and access to the work area without protective clothing.

Additional decontamination work involved the conveyor system that was to be salvaged for future use. This equipment was decontaminated using the foam cleaner and manual scrubbing technique described above. An attempt was also made to salvage some of the removed structural steel using wire brushes and disc sanders. However, this procedure was found to be unsuccessful and these items were eventually cut up for disposal.

The entire decontamination process used approximately 2000 manhours and resulted in an accumulated personnel exposure of less than 1.5 man-rem. The total combined cost for decontamination and demolition was approximately $600,000.

Various problems were encountered during this portion of the project, resulting in appreciable time delays. Some of these were as follows:

- Demolition of the 5000 psi concrete proved to be more difficult than expected.
- Second and third shift operations personnel would deposit "hot" drums in the work area. This was rectified by making the decontamination test site a temporary storage area.
- Several weeks were lost because of personnel access limitations during unscheduled resin solidification operations.
- Initially, leaching and airborne activity in decontaminated areas caused erratic results that required additional work to correct.

SPECIAL DESIGN CONSIDERATIONS

Backfitting processing equipment into the radioactive environment of an operating nuclear power plant can present many unusual and challenging problems to the designer. Conditions at the Zion site imposed several difficult constraints on the engineering and construction planning for this project, which in turn resulted in the development of a number of special design features, including the following:

- Both reactors would be in operation during most of the construction work, and under no circumstances would the construction work be permitted to jeopardize the availability of either unit for power production. This resulted in considerable effort to locate acceptable tie-in points to systems that had to be available at all times for plant operation.
- The main access point for material flow in and out of the Auxiliary Building is a truck bay

adjoining the work area. Layout of the new equipment and construction work planning had to be done in a manner that would not block off this pathway. The truck bay is also used as the site for processing of spent resins with mobile solidification equipment. Since the flow of construction materials and personnel through this truck bay would not be permitted while the solidification process was in operation, construction planning had to take into account the periodic delays caused by this operation.

- Some portions of existing mechanical equipment, piping, and electrical gear in the work area were not defined on existing drawings. This presented a difficult situation for the designers that was resolved by undertaking a considerable amount of field work early in the project to develop useable as-built drawing information.

- Available space for the new equipment was very limited. Since much of this equipment was relatively large, there was considerable concern about getting certain items into position while retaining sufficient access for future maintenance. Design features required to resolve this problem included:

    a) Flanged support legs on large vessels. These could be removed while the vessels were being moved into position and then re-attached while temporarily suspending the vessels with hoists or jacks.

    b) Pre-fabricated, removable access platforms for tanks that could be installed pre-attached to the tanks or installed later if required. Individual portions of these platforms were specially designed for quick removal and access to instruments and valves that had to be located close to tank connections.

    c) A special steel shield wall was designed to isolate the motor and gear box of the large evaporator recirculation pump from the radioactive process end of the pump so that access to the "cold" end, required on a routine basis, would not be hampered. A guillotine type door in this wall permits quick access to the stuffing box for seal replacement.

    d) Permanent, trolley-mounted hoists will be installed for removal and replacement of certain equipment items where available space would not permit portable, temporary lifting equipment to be set up easily.

    e) Future removal and replacement of the large horizontal heat exchanger in the main evaporator loop will hopefully never be required since the unit is fabricated from Inconel 625 material. However, based on past experience it was deemed advisable to have this capability as a backup. Again because of the limited space, removal of this heat exchanger would first require removal of a portion of a seismically qualified shield wall surrounding the heat exchanger. Block construction ofthis wall was desired; however, this required that a removable, external steel skeleton be specially designed to qualify the block construction for seismic conditions.

    f) The constructibility review process that is a standard part of all G/C design projects identified the need to develop a more detailed than usual preliminary construction work plan during the design phase to insure that the proposed arrangement of equipment and new walls could indeed be accomplished by the structural and mechanical contractors. The resultant plan identified the need for very close co-ordination between these contractors, as well as the need to have a mixed schedule of certain structural and mechanical activities in areas where the work could not be accomplished otherwise. For example, in many cases, portions of walls would have to be built before equipment was installed, but the equipment and piping would then have to be installed before the remaining portions of these walls could be completed.

- Existing walls and floor slabs in the building are seismic Category I design. Therefore, indiscriminant core drilling for anchor bolts and piping penetrations would not be permitted. This required development of special equipment foundations, each of which included an oversized steel plate bolted to anchor rods that will be grouted into core drilled holes positioned to miss existing rebar. The anchor bolts for the equipment will then be attached to these anchorage plates at the locations called for on the equipment arrangement drawings.

- Finally, the discovery that several cable trays running through the work area contained safety related wiring required relocation of high energy pipe lines and equipment wherever possible so that these cables would be protected from pipe whip, steam jet impingement and equipment collapse during a seismic event. Because the limited work space would not permit all of the offending piping and equipment to be kept a safe distance from these trays, special jet shields and pipe whip restraints had to be added. Equipment and walls that otherwise would not have to be seismically qualified also had to be upgraded to seismic Category I status.

USE AND BENEFITS OF A MODEL

Normally, usage of a scale engineering model on a project of this size would not merit serious consideration. However, because of the congested work area and the high levels of radiation that will be created in the area by operation of the new VR equipment, it was decided that a model could be beneficial in this case.

Two types of models are normally used by designers - design and design check models. A design model essentially replaces design drawings as the tool used to arrive at the desired equipment and piping arrangement. Once the model is completed, the design is documented on paper using standard drafting techniques or computer assisted, semi-automated drafting methods.

A design check model is built from design drawings which may or may not have already been checked. Depending on which approach is taken, the model then serves as either the primary means of checking the design or as a secondary verification tool.

On the Zion project, the initial plan was for the model to be used as a secondary verification method; however, as the project progressed and the benefits of the model became more apparent, the model took on more of the role of the principle means of checking, with review of the drawings becoming more of a secondary check.

A detailed scale model of a radioactive process facility such as the Zion liquid radwaste VR system is not only beneficial during design, but is also a vital tool for construction planning, system operation and outage maintenance. Potential benefits include:

- Reduced total plant cost by optimizing the physical design and eliminating costly field interferences.
- Shorter construction schedules through improved sequencing of work activities.
- Reduced operator training and maintenance costs by using the model for orientation and familiarization. Time saved in actual maintenance activities can also lead to significant reductions in personnel exposure to radiation.

Doubts anyone might have had about the usefulness of the model during the design stage were quickly dispelled. The model construction group set up shop in the middle of the Zion "project island" for maximum exposure to all project personnel. Once the basic modules were completed, showing the walls, floor slabs and equipment items, personnel from all disciplines gravitated to the model because of the ease it afforded in visualizing design intricacies and the actual condition of the congested work area.

One of the first benefits of the model came from the demonstration of the construction sequence. Before any piping was added, the model was designed so that certain critical equipment items could be removed and the sequence envisioned for installation of these items demonstrated on the model. Two items of particular concern were the pretreatment tanks and the evaporator heat exchanger. Figure 3 is a photograph taken during the actual demonstration of the installation sequence for the heat exchanger.

Fig. 3. Heat exchanger installation sequence.

This vessel, which measures 4.6 m long by 1.35 m in diameter, with 1.2m high pedestal supports, weighs approximately 8500 kg. In order to install the unit, it was determined from layout drawings that the flanged cover on each end of the vessel would have to be removed prior to moving the unit through the plant to its final location. As shown in Fig. 3, even with this step having been taken, the vessel would have to be tilted approximately 25° from the horizontal to fit through the hatch opening available in the floor slab at El. 592'-0" to reach the desired destination on El. 579'-0". Once on El. 579'-0", the unit would have to be put on rollers because of the low head room of 3.05 m and then rotated 90° before being slid into its final position. At the critical point in this rotation step, clearance between the walls and the vessel was calculated to be 7.5 cm. It was at this point that the model's benefit was graphically illustrated. In rotating the model, we found that the steel pedestals welded to the vessel hit against the 12.7 cm high concrete pads provided for anchoring the unit to the floor, necessitating the redesign of the pedestals to be flanged and bolted to the vessel so that they could be removed prior to reaching this position and then reconnected while the vessel was held above the foundation pads with jacks. Had it not been for the model, it is doubtful that this interference would have been realized before the heat exchanger was actually being moved into place, at which point the installers would have been faced with a very difficult series of manuevers to overcome this interference.

Other benefits of the engineering model to the design effort on Zion included the following:

- For support groups such as lighting and heat tracing specialists that were assigned to the project for relatively short durations, the time needed to become familiar with the arrangement of equipment and the inter-relationship between piping systems was greatly reduced. This permitted a greater percentage of the limited number of manhours allotted to these disciplines to be spent on the more important aspects of the work assigned to them.
- By visual inspection of the model, the project engineer (PE) could quickly verify that there were no interferences, that the designer had interconnected components correctly and that adequate maintenance access had been provided. As a result, as much as 40 percent of the time that the PE would normally have spent reviewing drawings was saved.
- G/C routinely performs an ALARA review of all system designs that involve the handling of radioactive fluids. Several aspects of this activity were aided by using a scale engineering model. First of all, the review was more comprehensive since all of the various electrical and mechanical systems were reviewed as a composite, so that the ALARA impact of one system on another was visually illustrated. Secondly, as new systems were designed and added to the model, feedback on the ALARA review reached the designer much sooner than if the review had been done using drawings. This was a benefit because undesirable conditions could often be corrected before design drawings were finalized, thereby minimizing the impact these corrective actions would have on manhours and project schedules.

Use of Model During Construction

As a scale replica, the engineering model can be a tremendous aid at the construction site. Construction planning and task coordination are achieved accurately and economically using the model as a construction focal point. The model of the evaporator/crystallizer was shipped to the Zion plant site a year ago in preparation for the construction phase of this project; however, this past year it has been used only sparingly because higher priority outage related work required several delays in the start of construction. Construction began in earnest only recently, and therefore, little can be reported here on the usefulness of the model during this phase. However, even at this early stage, one benefit of the model has been demonstrated in that the contractors bidding on the construction work were able to inspect the model thoroughly before submitting their proposals, which in turn gave them a better understanding of the scope of work and permitted responsive proposals to be submitted on a tight schedule.

Finally, perhaps the best guage of the value of an engineering scale model is the opinion of a contractor who has already been through the experience of backfitting a VR system into an existing facility. One such contractor was among those bidding on this project and has spoken very favorably to us about the potential benefits of this tool, declaring that many of the problems they had experienced on a previous project due to deficiencies in the design documents they were given probably could have been avoided if an engineering model had been used. Of course, by avoiding such problems, considerable savings can be achieved in terms of construction manhours and construction duration.