BACKFIT OF A REDESIGNED RADWASTE

PROCESSING AND SOLIDIFICATION SYSTEM

R. J. Beaudry
The Detroit Edison Company

L. D. Kenworthy
NUS Corporation

ABSTRACT

The original design of the radwaste system for the Enrico Fermi Atomic Power Plant, Unit 2, had been overtaken by recent developments in processing and volume reduction/solidification technology as well as heightened awareness of ALARA concepts and experience with similar systems in operating plants. This paper describes the design and backfit of current technology liquid and solid radwaste processing systems, including an asphalt-based volume reduction and solidification system.

INTRODUCTION

By way of background, Fermi-2 is a BWR plant rated at 1056 MWe. Filter-demineralizers are used for condensate polishing, as well as for reactor water cleanup and spent fuel pool filtration. The original radwaste system, a standard BWR design for the period, also employed filter-demineralizers in separate processing trains for floor drains and equipment drains. Mixed bed ion exchangers were also provided in each of these subsystems. Radwaste evaporators were provided for use in processing high conductivity wastes. Centrifuges were installed for dewatering filter sludges and spent resin from the radwaste demineralizers. The solidification system utilized cement with in-drum mixing. Drum handling was by a transfer car which successively positioned the drum under the centrifuge hopper, cement fill station, cement mixing station, and capping station. The filled and capped drum was placed in storage on one of 13 reciprocating gravity conveyors which, together, had a capacity for 350 drums.

Separation of equipment drains and floor drains was and is maintained in the Fermi-2 design. The several floor and equipment drain sumps, located throughout the plant, are pumped to the radwaste floor drain collector and waste collector tanks, respectively. Oil removal capability in the original system consisted of a gravity separator for turbine building floor drains. A wet laundry was originally provided. The original system therefore had the capability to process detergent drains by collection, filtration, and discharge.

DESCRIPTION OF REDESIGNED SYSTEM

Liquid Radwaste System

The waste collector, or equipment drains, subsystem consists of a waste collector tank, redundant waste collector pumps, the original precoat filter, a new etched disc filter, a new oil coalescer, and the original waste demineralizer and floor drain demineralizer which will normally be aligned to operate in series. The processed liquid is collected in one of three waste sample tanks. These tanks can be discharged either to the plant's condensate storage tanks or to the environment, depending on the overall water balance. The contents of the waste sample tanks can also be pumped back to the front end of the system for reprocessing. A waste surge tank is also provided for accepting large, batch inputs.

A major goal in the redesign of the radwaste system was the minimization of internally generated suspended solids and improvement in the ability to handle suspended solids that would inevitably enter the system. This goal resulted in adoption of etched disc filters and design modifications to the waste collector and waste surge tanks. Sloped bottoms were installed in these tanks to improve the ability to remove settled solids. A fixed system of bottom washdown nozzles was provided to aid in moving settled solids to the bottom discharge nozzle. In addition to the bottom nozzle, the tanks were provided with a side, or decant, nozzle. This nozzle will be used in case of heavy accumulations of solids in the bottom of the tanks. Under this condition, use of the side nozzle ensures lower concentrations of suspended solids entering the filters, thus maximizing filter run times. The tank inventory below the side nozzle may be blown down directly to the condensate phase separators.

The new etched disc filter has an absolute rating of 5 microns. Its dirt holding capacity is one pound of iron oxide which, at a processing rate of 150 gallons per minute and suspended solids concentration of 13 ppm, results in a calculated run time of 62 minutes. The filter is backwashed automatically using 350 psig air. The backwash is directed to one of the condensate phase separators.

The new oil coalescer consists of a set of three pressure vessels in series, each of which contains three bundles of cartridge filter elements. Oil droplets coalesce in the filter elements and grow in size until they acquire bouyancy sufficient to cause them to float into the upper head regions of the vessels. An oil-water interface measuring system monitors the accumulation of oil and automatically opens the oil discharge valve for the particular vessel when the interface level reaches the set point. The accumulated oil is discharged to the new waste oil tank. The coalescer is designed for a processing rate of 150 gpm. Design basis oil concentrations are 5 ppm for the waste collector subsystem and 20 ppm for the floor drain subsystem. Effluent oil concentrations are expected to be below the limit of detectability of the measuring instrumentation and are guaranteed at 3 ppm, maximum.

The closure heads of each coalescer vessel are fitted with electromechanical locking and lifting mechanisms operated remotely from a console in the radwaste control room. A bridge crane, also remotely operated from the console, removes and replaces coalescer filter bundles. The crane hook and filter bundle lifting attachment are designed for remote engagement and disengagement. The coalescer filter bundle is designed to fit into a standard 55 gallon drum. The design features of the coalescer installation thus provide for automated replacement of filter elements. Spent elements are expected to be encapsulated in asphalt utilizing the extruder/evaporator.

The new waste oil tank has a capacity of 1,000 gallons. It is located in a shielded cubicle and is equipped with a pump which will allow the contents to be discharged to drums for temporary storage and further dispostion.

Normal equipment alignment will place the etched disc filter first in line followed by the oil coalescer, and then the two mixed bed demineralizers, arranged for series flow. The existing precoat filter may be used in place of the etched disc filter and oil coalescer, or in a series arrangement consisting of the etched disc filter, coalescer, and precoat filter. The coalescer may also be bypassed.

The mixed bed demineralizers, originally dedicated one each to the floor drains subsystem and waste collector subsystem, were reconfigured to permit series operation and hence more efficient utilization of resin. Either bed may be used as the lead unit. A mode selector switch and automatic valving permit remote alignment of the units. Additional instrumentation and local control panels were added to permit automated resin removal.

The nominal processing rate for the waste collector subsystem is 150 gpm. The system can be cross-connected to the floor drain system, and vice versa, for additional flexibility

The floor drains subsystem is similar to the waste collector subsystem with respect to processing methods. The floor drain collector tank has been modified to provide a sloped bottom, bottom washdown headers, and side and bottom discharge nozzles. A new etched disc filter and oil coalescer have been added. The precoat filter has been retained, and will be used as a backup unit. Normal processing will utilize the etched disc filter followed by the coalescer. The precoat filter can be used alone, or in series with and downstream of the etched disc filter and coalescer. The coalescer can also be bypassed. The etched disc filter and coalescer are identical in design and capacity with those provided for the waste collector subsystem. They are thus capable of processing at 150 gpm in cross-over operation. At the nominal processing rate of 50 gpm for the floor drain subsystem, the etched disc filter has a calculated run time of 49 minutes with an inlet suspended solids concentration of 129 ppm.

Chemical wastes, primarily resulting from various plant decontamination operations, are collected in the chemical waste tank. After sampling and neutralization, these wastes are transferred to the floor drain collector tank for processing in the floor drain subsystem.

After filtration and oil removal, floor drain wastes are collected in the new evaporator feed/surge tank. High conductivity wastes collected in this tank will be processed by one of the two, original, 30 gpm radwaste evaporators. Evaporator distillate is combined with wastes from the waste collector subsystem and processed through the series demineralizer train. Evaporator concentrates are forwarded to the solid radwaste system for volume reduction and solidification.

Lower conductivity wastes can be processed directly through the demineralizer train to the sample tanks. It is also possible to bypass the demineralizers and pump directly to a sample tank with subsequent dilution and discharge.

Certain laboratory wastes will contain chlorides. These wastes are segregated from the floor drains subsystem and stainless steel evaporators by new drainage piping and a new storage tank. Chloride wastes are pumped directly to the solid radwaste system.

Solid Radwaste System

In keeping with the general goal of improvement in the management of suspended solids, an additional liquids/solids separation step has been added to the solid radwaste system. Primary separation continues to occur in the main solids receiving tanks and process equipment such as the RWCU phase separators, condensate phase separators, and radwaste centrifuge. However, decant flows from this equipment, which in most systems would be sent directly to the waste collector tank where entrained solids could settle or increase filter loadings, are instead directed to a secondary settling tank or waste clarifier tank. This tank provides a long residence time for additional settling. The waste clarifier tank overflows by gravity to the waste surge tank of the waste collector subsystem.

The waste clarifier tank was converted from the original waste sludge tank, a backwash receiving tank for the radwaste and spent fuel pool precoat filters. This required redirecting these sludges to the condensate phase separators. Internal modifications to the waste sludge tank included fitting a washdown sparger, sludge drawoff pipe, and a flow baffle. A new 50 gpm progressive cavity pump was provided for sludge drawoff.

Since the waste clarifier tank always operates full, it was possible to make use of its inventory as a source of slurry transport and dilution water. This reduces the amount of clean condensate that would have otherwise been required for this purpose and which would have added to the processing burden of the radwaste system.

Transfer of spent bead resin from the original spent resin tank was improved by replacing the eductor system. A new 50 gpm progressive cavity pump was provided. This pump and the new waste clarifier sludge pump previously mentioned can act as backups for each other. A new cone bottom was provided for the spent resin tank. A metered quantity of dilution water from the waste clarifier tank is blended with the bulk resin flowing from the spent resin tank, resulting in a uniform 25 weight percent resin slurry for transport to the new centrifuge feed tank or, in case of a centrifuge outage, to the new spent resin slurry feed tank.

The new radwaste extruder/evaporator has historically been designed to receive feeds in the form of solid/liquid slurries or concentrated liquid solutions. This feed method has also been retained in the redesigned Fermi-2 system as a secondary or backup feed method. However, the primary feed method will utilize the radwaste centrifuge. Use of the centrifuge to dewater the solids will greatly reduce the process time. To provide the centrifuge (and also the extruder/evaporator) with a constant and uniform feed, a new centrifuge feed system was designed. The major components in this system include a 6,000 gallon centrifuge feed tank with agitator and mixing eductor, centrifuge feed/recirculation pumps, and a centrifuge flow control valve. Slurry concentration can be adjusted in the centrifuge feed tank by settling and decanting or by dilution, as required, with water from the waste clarifier tank. The tank contents are agitated and recirculated at 300 gpm. The feed to the centrifuge is tapped off the recirculating loop and metered to the centrifuge through the flow control valve. Flow measurement instrumentation positions the flow control valve to maintain a preset flow rate. Centrifuge feed rates are expected to range from 10 to 20 gpm at 2.5 to 5.0 weight percent solids.

The backup slurry feed system allows powdered resin slurries to be fed from the centrifuge feed tank and bead resin slurries to be fed from the spent resin slurry feed tank. Evaporator concentrates solutions are fed from the new concentrates feed tank. Variable speed, progressive cavity metering pumps regulate the feed flow.

Feed flows to the extruder/evaporator are determined by matching the total water delivered with its evaporative capacity. Asphalt flow is provided on a nominal one-to-one weight basis with the dry solids content of the feed. A new sampling system was designed for remote collection of high radiation slurry and concentrates samples so that the necessary properties of feed - percent by weight solids, moisture content of the solids, and pH -can be determined. The sampling device consists of a reciprocating plunger, operated by a pneumatic cylinder, which withdraws a fixed volume of sample from the sample line with each stroke. A timer controls the number of strokes and volume of sample collected. The sample is collected in a shielded container.

The extruder/evaporator discharges the mixture of dry solid waste and asphalt into 55 gallon drums which are positioned by a six drum turntable. The turntable permits multiple fills of the drums to minimize the effects of shrinkage and maximize drum filling efficiency. The turntable is unloaded by a remotely operated monorail hoist and drum grab. The drum is closed by a seaming machine similar to those used in the manufacture of steel drums. After seaming, the drum is conveyed to the original transfer car which can discharge the drum for storage either in the new onsite storage facility or on one of the original, gravity storage conveyors. New drum handling equipment has been designed with redundant or manual backup drives, and critical original equipment has been upgraded to provide this feature also. A new drum weigh and swipe station has been added where drum surface contamination, weight, and radiation level can be remotely determined prior to shipment. CCTV has been added to monitor all drum transfer operations. Oil filled shield windows are also provided at the turntable, capper-seamer, and weigh and swipe station.

SUMMARY OF MAJOR FEATURES
OF REDESIGNED RADWASTE SYSTEM

- Etched disc filters*- added.
- Oil coalescers - added.
- Precoat filters - original.
- Demineralizers - original. Series operation - added
- Collector tanks sloped bottoms, washdown, decant -added.
- Evaporator feed/surge tank - added.
- Asphalt-based volume reduction and solidification -added.
- Centrifuge feed of extruder evaporator - added.
- Secondary settling of decant streams - added.
- Redundancy in pumping - added.
- Progressive cavity pumps for slurry transport - added.
- Segregation of chloride wastes - added.
- Radwaste evaporators for high conductivity wastes -original.
- ALARA system arrangement - added.
- Piping systems for high radiation slurries -redesigned to eliminate crud traps and ensure nonplugging operation.
- CCTV monitoring drum transfers - added.
- Local shield windows - added.
- Upgraded radwaste control room:

  Programmable controllers - added.
  Liquid system panel - replaced
  Evaporator panel - modified
  Solid system panel - modified
  Volume reduction system panel - added
  Sump panel - added
  Operator's coalescer crane and CCTV console - added.

- Drycleaning (replacement of wet laundry) - added.
- Automatic, remote collection of high-rad samples -added.
- High pressure dry waste compactor - added.

DESIGN EVALUATIONS

Initial Studies

Detailed evaluations of the original radwaste system were started in January 1980. Because fuel load was then scheduled for as early as October 1981, initial emphasis was placed on recommendations which were of limited scope and which could be implemented quickly. The evaluation work was closely monitored by Detroit Edison's engineering, construction, and plant operations personnel. It soon became evident that limited fixes would not result in a radwaste system meeting Edison's needs or expectations. Thus, by summer of 1980 and the conclusion of the evaluation phase, a redesign effort was begun which eventually included a new volume reduction and solidification system. By this time, fuel load was projected for late 1982. The project was thus to be on a very tight schedule.

The economic studies demonstrated a benefit for volume reduction. In addition, there were practical considerations. The schedule did not permit contemplation of a new radwaste processing building. Thus, the selected volume reduction and solidification system had to be capable of being backfitted into the existing Radwaste Building and of interfacing with some of the original drum handling equipment

Process Development

A major engineering effort was required to develop a quantified and documented design basis for the radwaste modification. The original system design was not extensively documented, and supporting calculations, assumptions, and data were not available. Of course, the original system had not yet operated, so there was no specific experience available either.

Liquid waste volumes experienced at other, similar, operating BWRs formed the basis for projections for Fermi-2. ANSI Standards 55.1 and 55.6 were also utilized. The system process flow diagram was redrawn and process calculations were prepared to document the process design.

Procurement Phase

Portions of the original radwaste system were designed and marked in accordance with nuclear codes. The system had nevertheless been classified as Quality Group D. This classification conformed to current requirements and was continued for the redesign because of the cost and schedule benefits.

The major long lead procurements were the volume reduction and solidification system and the etched disc filters. Specifications for this equipment were released in the fall of 1980. The extruder/-evaporator was delivered in April 1982, and the etched disc filters in March 1982. In all, 15 major procurement specifications were prepared, and 32 suppliers furnished equipment for the project.

Ripout Phase

The backfit necessarily required the removal of equipment and structure from the Radwaste Building. Major equipment removals included the cement storage silo, day bin, and scale hopper; detergent drain tanks, pumps, and filters; centrifuge hoppers; drum mixer; drum washout sump and pumps; and miscellaneous process pumps including the original spent resin pump and waste sludge pump. Approximately 120 cubic yards of reinforced concrete were removed as well as 43,000 linear feet of cable, 9,000 linear feet of conduit, and 3,800 linear feet of piping.

To control this work, a general ripout specification was prepared. This specification addressed general ripout procedures, salvage, and protection of retained equipment. Included were data sheets for each piece of equipment to be removed which detailed points of disconnection, whether removal could be by destructive means, whether flammable coatings or linings were present, weight, materials of construction, and final disposition. Addenda to the general specification were issued periodically which consisted of drawings marked to show the boundaries of piping, tubing, cable tray, conduit, and structural removals. Actual ripout work in the field was completed during the first half of 1981.

Detailed Engineering

In addition to the normal design processes leading to issuance of construction drawings for piping, structural work, conduit, cable tray, wiring, and instrumentation tubing, special emphasis was placed on equipment arrangement. The arrangement of the original system imposed constraints on location of new equipment and piping as did the limitations on physical space within the building. Although some unoccupied space was available, it was, in general, not optimally located for logical integration of the new equipment. Innovative solutions had to be found for problems such as:

1. Location of coalescers and etched disc filters, considering requirements for shielding, interfacing with existing process piping, transport of backwash flows, and filter bundle replacement;

2. Location of extruder/evaporator, considering requirements for interface with the existing drum handling and storage equipment, direct vertical discharge of dry feed from the centrifuge, proximity of metering pumps, proximity of auxiliary boiler and utility manifold, routing of recirculating feed piping, and shielding of piping and equipment;

3. Location of new tankage and pumps in keeping with requirements for shielding, access for maintenance, and separation of redundant equipment; and

4. Routing of new, high radiation slurry piping.

New tanks and process pumps were located in the Radwaste Building basement, in keeping with the original design practice. The tanks and associated pumps were placed in separate, shielded cubicles. The tank cubicles were designed to contain the tank inventory in case of postulated rupture. In some cases this was accomplished by use of watertight doors; in others with curbs. A central aisleway forms the longitudinal axis of the Radwaste Building basement. This aisle is designed as a low radiation, unrestricted access area. All high radiation sources were shielded from the aisle. This required creation of roofed enclosures for pumps. Piping crossing the aisle was routed over a new, shielded pipe bridge.

The new etched disc filters and coalescers were located on the first, or grade floor of the Radwaste Building. The original baled waste storage room was converted to house this equipment. This location was selected for ease of interfacing with process piping serving the original precoat filters and mixed bed demineralizers. The pipe chase carrying this piping was lengthened to serve the new equipment.

The extruder/evaporator was also located on the first floor to most easily interface with the existing drum transfer car. Considerable concrete work was required including removal of the original empty drum storage platform and creation of separate, shielded cubicles for the extruder/evaporator, turntable, and capper-seamer. Because of limited available space, a composite lead and steel shield wall was designed for the north side of the extruder/-evaporator cubicle.

The centrifuge was located directly above the extruder/evaporator on the first floor mezzanine. This placed the centrifuge in one of the original hopper rooms, allowing advantage to be taken of the heavy shield walls.

The original contaminated equipment room, located in the basement, was converted to house auxiliary equipment for the extruder/evaporator. Two new intermediate floor levels were created. The lower of these supports the electrically heated auxiliary boiler and the utility manifold. The upper level, a partial floor, supports the extruder/-evaporator metering pumps, placing them nearly directly below the extruder/evaporator which is located on the floor above. The space between the two levels is utilized as a pipe chase for centrifuge feed and metering pump supply piping. Also located in the converted contaminated equipment room are the new centrifuge feed tank, and, below the auxiliary boiler level, the centrifuge feed/recirculation pumps.

The detailed engineering phase occurred over a period of approximately 24 months, with production of drawings for construction taking place over the last 18 months of that period. The following is a tabulation of construction drawings and construction quantities for the project:

1. Mechanical Drawings

Piping	341
New and Modified Equipment	32
P&ID's/PFD/System Diagrams	32
General Arrangements	13
HVAC	6
Instrument Details	8
Ripout	83
Master Valve Lists	28
Fire Protection	4
TOTAL	547

2. Electrical/I&C Drawings

Logic Diagrams	132
Schematic Diagrams	254
Equipment Location Plans	29
Tray and Conduit Layouts	68
Connection Diagrams	164
Instrument Tubing	28
Panel Modification	67
MCC Modifications	8
Instrument Racks	23
Lighting	19
Communications	7
480V Load Center	9
4160V Switchgear	2
Heat Tracing	2
Ripout	75
TOTAL	887

3. Civil/Structural Drawings

Concrete Walls and Floors	144
Architectural	31
Structural Steel	14
Equipment Foundations	40
TOTAL	229

4. System Documentation

System Descriptions	4
Operating Procedures	10
Maintenance Procedures	63
Test Instructions	4
Design Instruction	1
TOTAL	82

5. Construction Quantities

Concrete	1,100 CY
Block Walls	4,000 CF
Structural Steel and Rebar	120 Tons
Large & Small Pipe	28,000 LF
Valves	400
Pumps	30
New/Modified Tanks	12
Wire & Cable	250,000 LF
Conduit	27,000 LF
Instrument Tubing	27,000 LF
New/Modified Panels	20
Field Instruments	700

SUGGESTIONS FOR SIMILAR PROJECTS

In any project of this magnitude, experience is gained which may possibly be beneficially applied on future, similar work. The following discussion highlights some of the more important of these areas.

1. If time permits, carry out radwaste system backfits before fuel load and before the system becomes radioactive. A less obvious benefit is the increase in productivity attributable to more relaxed security procedures.

2. The effort required to establish a firm engineering basis for the design of backfit systems should not be underestimated, especially in older systems where the original design may not be well documented. If the system has operated, experience with the operation can provide valuable input to the design.

3. In designing piping and equipment layouts, it should be kept in mind that conduit, cable tray, and tube track can take up considerable space, such space being a premium in a backfit. Whereas piping and equipment are typically located according to dimensioned drawings, the same is not the case for conduit and pull boxes. Physical drawings only give general, non-dimensional locations. Consequently, these materials may unwittingly be installed in areas where they may interfere with the movement of cranes, doors, personnel, and mobile equipment, and may obstruct access to equipment.

4. An attempt should be made to recognize the magnitude of the electrical and I&C effort during initial planning of the job. Nine, new major control panels were required, and significant modifications were made to two others. New, relocated, and deleted process equipment resulted in field instrumentation changes and associated additions and deletions of cable, conduit, and tubing. A new 480V load center and additions to two 480V MCC's were required.

5. Field engineering representatives of the Architect/Engineer proved a valuable liaison between the home office, construction craft, and the owner's site construction management organization. A staff of three field engineers was maintained through the construction phase. These engineers carried the experience gained beyond construction and into the startup phase.

6. A close and cooperative working relationship between the Architect/Engineer and supplier of the volume reduction and solidification system was indispensible in this schedule intensive project. Both parties performed design activities which required careful integration to assure that each party satisfied the other's, as well as his own, requirements.