DESIGN AND FIRST YEAR'S EXPERIENCE AT THE SURRY POWER STATION NEW RADWASTE FACILITY

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ABSTRACT

In 1991, Virginia Power placed a new state of the art integrated Radwaste Processing and Storage Facility in service. The facility is designed to process liquid waste, spent ion-exchange resin, laundry waste, radioactive filters, and dry active waste. It also provides Surry Power Station with a decontamination facility, a hot machine shop and a storage capacity of one year for all waste forms. This paper addresses the liquid waste processing capabilities of the radwaste facility.

The primary function of the Liquid Waste System is, through the process of evaporation, to segregate radioactive materials from liquid waste generated in the power plant and reduce chemicals and impurities in the effluent water to less than half of the National Pollutant Discharge Elimination System (NPDES) limits. The treated water is reused in the radwaste facility or discharged after monitoring. The concentrates from the evaporator are solidified by mixing with bitumen to produce a free-standing and liquid free monolithic form, in accordance with the requirements of 10CFR61.

INTRODUCTION

Virginia Power's Surry Power Station is a twin unit Westinghouse Pressurized Water Reactor facility. Surry Unit One was placed in service in 1971 with Unit Two following 16 months later. Within three years the installed Liquid Waste Evaporator failed, and portable vendor-supplied ion-exchangers were placed in service to process liquid waste. The vendor-supplied ion-exchanger systems processed liquid waste to meet regulatory requirements but resulted in high annual releases of radioactive materials to the environment. In 1985, Virginia Power implemented aggressive feasibility studies for the improvement of radwaste treatment systems. On-site visits and technical discussions were conducted with Radwaste Facility Operators from the U.S., Europe, and Japan. In these studies, Virginia Power focused on:

- Reducing the volume of radwaste shipped to disposal sites,
- Reducing the release of radioactivity to the environment,
- Reducing the radiation dose to operating and maintenance personnel,
- Reliable operation with proven state-of-the-art technologies, and
- Lessons learned by Virginia Power and other leading Radwaste Facility Operators.

As a result of studies and evaluations, Virginia Power completed the conceptual design for an integrated Radwaste Processing and Storage Facility. Several experienced American and International Engineering firms were invited to competitively bid a fixed priced turn key contract. JGC Corporation was selected based on their bid and excellent record as suppliers of radwaste facilities in Japan. The total engineering evaluation procedure, starting from the study phase, is visually presented in attachment (1). In accordance with attachment (1), each system was selected after performing technical and economic evaluations of competing alternative technologies. The selected systems were integrated for preliminary system design. They were then re-evaluated repeatedly until the optimum technical and economical conditions were obtained. A detailed scale model was utilized to determine optimum equipment layout. Surry Power Station operation and maintenance staff reviewed the model for operability and maintainability. The model was modified to satisfy all concerns addressed. JGC then utilized the model to develop the necessary drawings to support construction. The model was available to all crafts during construction. This allowed construction personnel the opportunity to see an actual 3-D layout of the final facility systems.

LIQUID WASTE SYSTEM

The Liquid Waste System is composed of several subsystems, each performing a specific purpose to support the processing of liquid waste. The subsystems include:

- Liquid Waste Collection and Surge Tank Subsystem,
- Oil/Suspended Solid Removal (SPI) Subsystem,
- Liquid Waste Evaporator Subsystem,
- Evaporator Distillate Subsystem,
- Liquid Waste Monitor Tank Subsystem,
- Evaporator Bottoms Tank Subsystem

Liquid Waste Collection and Surge Tank Subsystem

This subsystem consists of four 114 cubic meter tanks which receive liquid waste from Surry Power Station and the radwaste facility. A floating oil skimmer is installed in each tank to facilitate the removal of oil from the liquid waste stream. Oil is skimmed from the water surface prior to tank recirculation. Each tank is equipped with two diametrically opposed mixing eductors to ensure homogeneous mixing

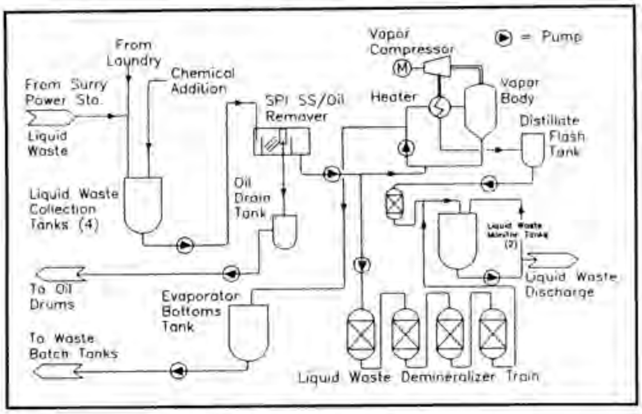

Fig. 1. Liquid waste system.

prior to sampling. Liquid waste is analyzed for pH, chromate, oil, boron and sodium.

- pH

  pH is strictly controlled within the evaporator manufacturer's limits of 8.0 to 10.0. A Chemical Addition Subsystem utilizes sodium hydroxide or sulfuric acid to adjust pH. Surry has an industrial laundry facility for cleaning anti-contamination clothing. The sodium hydroxide based laundry detergent has a pH of 10.8 and is utilized to increase pH. This allows evaporation of laundry water as well as liquid waste and reduces addition of concentrated sodium hydroxide.

- Chromate

  Chromate is utilized at Surry Power Station as a corrosion inhibitor in the Intermediate Primary Cooling Water System. The Liquid Waste Evaporator is constructed of Inconel 625 material. Elevated levels of chromate will cause pitting in Inconel. If required, remedial filtration of chromate at levels greater than 20 ppm are performed prior to feeding the Evaporator.

- Oil

  Oil causes fouling and foaming in the Evaporator environment. The untreated liquid waste is transferred through an Oil/Suspended Solid Removal (SPI) Subsystem prior to Evaporator feed. Oil concentrations greater than 10 ppm are sampled downstream of the SPI Subsystem to ensure minimal oil feed to the Evaporator.

- Boron

  The limiting parameter for Evaporator operation is boron concentration. The Evaporator is operated to control boron concentration at 21,000 ppm. The boron concentration of the Evaporator feed is utilized to determine the concentration rate. A simple calculation utilizing concentration rate is performed by the facility operators to predict Evaporator concentration.

- Sodium

  The specific gravity of the Evaporator is continuously monitored. Sodium combines with the boron to form sodium borate, which affects the specific gravity of the concentrates. By determining the sodium-to-boron ratio, the approximate specific gravity for 21,000 ppm boron concentration can be determined. The Evaporator recirculation loop specific gravity is continuously monitored.

Once all chemical evaluations and procedural requirements are met, the tank is fed to the Oil/Suspended Solid Removal (SPI) Subsystem.

Oil/Suspended Solids Removal (SPI) Subsystem

The SPI is an inline gravimetrical oil and suspended solids remover. Pre-treated water from the Collection and Surge Tanks pass through the SPI Subsystem prior to feeding the Evaporator. Oil is skimmed from the water surface into an Oil Drain Tank. Oil removal tests indicate that a feed with 100 ppm industrial lubricating oil is reduced to less than 10 ppm at the SPI outlet. In the event of a very light viscosity oil, which does not gravimetrically separate easily, a carbon bed may be placed in service at the SPI outlet to remove oil from the Evaporator feed to less than 10 ppm. Suspended solids are collected in the bottom of the SPI and are periodically transferred to the Evaporator Bottoms Tank. Pumping the suspended solids directly to the Evaporator Bottoms Tank greatly reduces the amount of abrasive material in the Evaporator concentrates. Evaporator internal erosion, Recirculation Heater tube failure, and Recirculation Pump seal failures are significantly minimized as a result of SPI Subsystem operation.

Liquid Evaporator Subsystem

The Liquid Waste Evaporator uses forced circulation and mechanical vapor recompression to process up to 114 liters per minute. Liquid waste from the SPI is fed to the recirculation piping of the Evaporator. The liquid waste is recirculated through a regenerative type heater using the Evaporator Recirculation Pump. The heated concentrate flows into the Vapor Body where boiling takes place. The vapor released in the Vapor Body flows through the Entrainment Separator where water droplets and solid particles are separated from the vapor stream. The clean, dry vapor flows to the suction of the Vapor Compressor. The Vapor Compressor super heats the vapor upon compression. The superheated vapor is then returned to the heater shell where it is used to heat the liquid waste concentrate. Up to eighty-five percent of the thermal energy is recovered. A nine (9) kilogram per minute auxiliary boiler provides make-up steam for heat losses. The vapor condenses on the shell side and flows by gravity to the Evaporator Distillate Subsystem. As water leaves the Liquid Evaporator Subsystem in the vapor phase, the liquid waste concentration increases. When the concentration reaches 12.0 wt% boric acid (21,000 ppm) or 25% total solids by weight, a portion of the concentrate is removed by draining approximately one cubic meter of concentrates to the Evaporator Bottoms Tank.

Subsystem special features are:

- It is extremely important to monitor for surface foaming in the Vapor Body. Most Evaporator Vapor Bodies have portal windows to monitor for foaming conditions. They typically become fouled and useless. To alleviate this problem, a stream of approximately 60°C water from the discharge of the distillate pump can be sprayed on the inner windows to clean the viewing surface.

- In many Evaporators, the recirculating liquid waste is sprayed into the Vapor Body to increase the surface area for greater flashing, but this also increases the amount of contaminated water droplets and particulate carry over in the steam. The system at Surry recirculates the liquid below the Vapor Body surface. Only surface boiling generates the steam vapor, which reduces carry over.
- Removing the mesh pads from the upper Vapor Body and installing an Entrainment Separator allows the necessary space to double the number of mesh pads. Additionally, spray nozzles in the Entrainment Separator provide periodic spray for washing and reflux feed for scrubbing. Sight glasses with cleaning capability are provided for observation of all mesh pads.
- Major components are Inconel 625. Piping and minor components are 316L stainless steel to reduce chloride stress corrosion due to the periodic ocean water intrusion into the liquid waste stream.
- Specific gravity and pH instrumentation are provided to monitor waste concentration chemical parameters.

Evaporator Distillate Subsystem

Distillate, which gravity drains from the heater, is collected in the Distillate Flash Tank. After monitoring conductivity, the distillate is transferred to the Distillate Demineralizer through the Distillate Subcooler. The demineralized distillate is transferred to the Liquid Waste Monitor Tanks for sampling and radiological/chemical analysis. If distillate conductivity exceeds 7.5 microsiemens, the distillate is automatically transferred back to the Liquid Waste Collection Tank System for reprocessing. High conductivity could be an indication of a Recirculation Heater tube leak equipment failure in the Entrainment Separator or carry over.

Liquid Waste Monitor Tank Subsystem

The Liquid Waste Monitor Tank Subsystem is a redundant system. One tank receives treated water, while the other tank is in recirculation, sampling and/or being released. A liquid waste release flow control valve and a trip valve are provided to terminate a release in the event that an alarm annunciates on the Liquid Waste Release Radiation Monitor. Water is released at 681 liters per minute which correlates to one percent per minute decrease in tank level for human factor consideration.

Evaporator Bottoms Tank Subsystem

The Evaporator Bottoms Tank receives waste concentrates from the Evaporator through a ram seal valve and from the Oil/Suspended Solids Removal (SPI) System. This valve physically strokes into the recirculation piping to clear the transition piping before opening to allow flow. The waste concentrates flow by gravity through sloped piping with 5-D radius bends to the Evaporator Bottoms Tank. After each discharge a pre-programmed automatic flush occurs to ensure the piping to the Evaporator Bottoms Tank is clear of any concentrate. The Evaporator Bottoms Tank has sufficient volume to hold one and a half times the operating volume of the Evaporator. The tank has two eductors inside, which mix the concentrate when on Recirculation, Sampling, and Transfer Modes. The tank has two heaters, one on the bottom and one on the side, to maintain temperature. Concentrates from the Evaporator Bottoms Tank are transferred to the Bitumen Solidification System for solidification and storage. Hot water flushing is performed on all waste concentrate piping after transfer. This will be discussed at length later.

BITUMEN SOLIDIFICATION SYSTEM

The Bitumen Solidification System (VRSS) is composed of several subsystems, each performing a specific purpose to support the processing of concentrated liquid waste into a solidified waste product in accordance with 10CFR61 requirements. The subsystems include:

- Waste Feed Subsystem,
- Bitumen Storage and Feed Subsystem,
- Heating Fluid Subsystem,
- Thin Film Evaporator (LUWA) Subsystem,
- Distillate and Ventilation Subsystem, and
- Drum Handling Subsystem.

Waste Feed Subsystem

Concentrates from the Evaporator Bottoms Tank or spent resins from the Spent Resin System are transferred in batches to one of two identical Waste Batch Tanks (WBT). Excess water is removed (decanted) from spent resin batches. The WBT is provided with heaters and a mechanical agitator to maintain the waste in a homogeneously mixed state. Caustic, acid, and reagents are added as necessary to meet the Process Control Procedures (PCP) requirements. The Waste Feed Pump takes a suction from the recirculating WBT and feeds the waste to the Thin Film Evaporator at a calculated target feed rate.

Bitumen Storage and Feed Subsystem

Bitumen is stored in a heated 28 kiloliter storage tank. The Bitumen Feed Pump takes a suction from the Bitumen Storage Tank and feeds the bitumen to the Thin Film Evaporator at a calculated target feed rate. The bitumen piping and the Bitumen Feed Pump are heated with 190°C oil circulating through the outer jacket to ensure the bitumen is maintained fluid.

Heating Fluid Subsystem

The Heating Fluid Subsystem consists of both Primary and Secondary Heating Fluid Systems. The Primary Heating Fluid System supplies Therminol 66 at 232°C to the LUWA heating jacket to evaporate water and maintain the bitumen

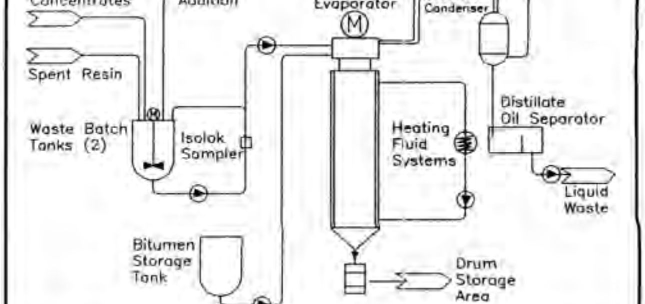

Fig. 2. Bitumen solidification.

fluid. The Secondary Heating Fluid System supplies Therminol 66 at 190°C to bitumen jacketed piping, the Bitumen Metering Pump, the LUWA mixing nozzle area, and the outlet nozzle.

Thin Film Evaporator (LUWA) Subsystem

Concentrates and bitumen are slowly fed by metered feed rates into the LUWA. The concentrates and bitumen are distributed evenly over the heated inner body wall. The wiping blades spread the waste and bitumen evenly, generating highly turbulent flow conditions. Bow waves, developed by the blades, generate optimum heat flux and cause water to evaporate rapidly. The mixture of solids and bitumen becomes homogeneously mixed as it flows downward and out to a 210 liter drum on a conveyor. Exit temperatures average 180°C which ensures greater than 99% of the free water in the concentrates is evaporated.

Distillate and Ventilation Subsystem

The evaporated vapor is condensed in a vertical shell and tube condenser. The condensate is transferred through an oil separator, cooler, and back to the Liquid Waste System for reprocessing. Noncondensable gases and ventilation air are exhausted from the condensor to monitored plant ventilation. Oils that are also distilled in the LUWA are removed by the oil separator and placed in a waste oil drum.

Drum Handling Subsystem

Drums are indexed on remotely operated hydraulic conveyors to allow processing to continue without interruption. An initial and a top off fill are used to fill the drums to at least 90% full. Filled drums are packaged on the conveyors using remotely operated shuttle conveyors, a capper and a swipe manipulator arm. The packaged drums are stored in the drum storage area to await off-site shipment. The drum storage area has space to store 693 drums stacked three high. Steel checker plates are used between layers of drums for stability. The drums are stored in a grid arrangement from a remote Crane Control Room utilizing video camera indexing.

HOT FLUSHING WATER SYSTEM

Waste concentrates, that require elevated temperatures to remain in solution, frequently solidify in piping that is used intermittently. Plugging continues to occur even though the piping is volumetrically flushed with demineralized water and is heat traced. Research has shown that when piping is flushed with room temperature water at less than the normal flow velocity a coating of concentrated waste accumulates on the inner pipe wall. This coating resembles a frost layer. After repetitive flushes the coating builds up until it insulates the heat tracing from the actual fluid, and line plugging occurs. Surry's radwaste facility has a closed loop Hot Water Flush System that is maintained at 70°C and provides one and a half times normal flow velocities to all concentrated waste lines and components when flushed.

OPERATIONS AND MAINTENANCE ENHANCEMENTS

- Components that would be lifted for maintenance that weigh greater than 22.7 Kg have installed lift beams and/or lift eyes.
- Utilizing the model, maintenance work areas and equipment removal paths were incorporated into the facility design.
- Piping has been configured to allow equipment removal for maintenance.
- System and equipment drains and vent lines are hard piped to installed drain funnels.
- Instrument Air System root valves are located in hallways to reduce exposure.
- The use of elbows was prohibited in radioactive lines. Only radius bends are utilized to prevent crud build-up.
- Untreated water lines are butt welded to reduce the potential for crud build-up in weld areas.
- Utilizing the model, the construction team ensured that all valves, instrumentation, and sight glasses were accessible to the average operator. Steps, platforms, and reach rods where installed to support operations.
- Kansui pumps were selected for their ease of maintenance. One maintenance technician can replace an impeller, pump bearing, double mechanical seal package, and oil seals and return the pump to service in less than one hour.
- Kansui pumps have been uniquely designed to prevent the emulsification of oil in the water being pumped.
- Kansui pumps reduce the noise in the work area to enhance operator sensitivity.

CONCLUSION

The water quality in the Liquid Waste Monitor Tank averages:

- pH - 7.3
- Conductivity - 1.7 μS
- TSS - 0.0 mg/L
- Oil and grease - < 5mg/L

Greater than 23,469 cubic meters of ~ $8x10^{-3}$ μci/ml water has been processed in the facility since September 26, 1991. With a lower level of detection (LLD) which averages ~ 1 x 10^{-8} μci/ml, there has been no detectable activity, excluding tritium, measured after the Evaporator process. The Bitumen Solidification System has solidified concentrated Evaporator bottoms into 530 drums of 60/40 bitumen/waste mix. There have been 486 drums buried at Barnwell, South Carolina to date. The NRC has given final approval for the Topical Report "High Strength Asphalt Solidification Process for Low-Level Radioactive Waste."