

## **TRU WASTE MINIMIZATION DURING HOT CELL DECOMMISSIONING**

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### **ABSTRACT**

A commercial closed-loop cleaning system based on the Sonatol™ process has been adapted to decontaminate a wide variety of TRU level contaminated materials for disposal as Low Level Waste (LLW). The computer-controlled, remotely operated system incorporates an ultrasonic bath cleaning with surfactant, heat, and recirculating fluid flow to transfer radioactively contaminated particles away from contaminated items and into a collection filter. The Sonatol system's re-circulating design optimizes the loading factor of the collection filter and continuously recycles the working fluid. The resulting TRU contaminated collection filters are designed to facilitate characterization according to the waste acceptance criteria of the Waste Isolation Pilot Plant (WIPP). This paper will discuss the design challenges faced in the development of the cleaning system and the solutions adopted by the design team.

### **INTRODUCTION**

The Battelle Columbus Laboratories Decommissioning Project (BCLDP) is currently utilizing a Sonatol SCS-300 Decontamination System to clean TRU Level contaminated items for disposal as Low Level Waste during the D&D of former research facilities. In the course of decontaminating these facilities, approximately 13,000 cubic feet of materials were initially identified to be TRU suspect materials. Much of this volume, approximately 10,000 cubic feet, was found to be only smearably contaminated with TRU level material. By utilizing the Sonatol SCS-300 Decontamination System, the remaining 3,000 cubic feet of waste can be processed so that the resulting TRU waste volume is minimized. Physically, the process involves transporting TRU waste in the transfer baskets in closed carts to the SCS-300 cleaning skid, removing the baskets from the carts remotely with the crane and indexing them onto the transfer table. The computerized system then takes over to load the baskets remotely into the cleaning chamber and perform the cleaning cycle.

### **FLUID TECHNOLOGY**

The Sonatol process uses perfluorinated liquids that are recycled in a closed-loop system. The Sonatol fluids are non-toxic, non-flammable, generally safe to use, and do not present a hazard to the stratospheric ozone layer. It is generally innocuous to all materials including paper, plastics, metals, wood and cloth. It not only does not harm the processed items; it will not react with the

radioactively contaminated particles either. Sonatol is not soluble with water, oils, salts, organics, etc. It has a density approximately 1.73 times that of water but has the viscosity of alcohol and readily evaporates with warm air. Because the heat of vaporization is low, the fluid creates more turbulence on wetted surfaces than fluids with higher vaporization energies.

The other medium used in the ultrasonic cleaning process is a solution of a high molecular weight fluorocarbon surfactant in the Sonatol carrier liquid, which is also recycled in the process. The surfactant is also nonflammable, generally safe to use, and does not present a hazard to the atmospheric ozone layer.

## **SYSTEM DESIGN ISSUES**

The major design issues centered on the fact that only 1% of the radioactive source term consists of Pu-239 equivalent radionuclides. The contamination consists of concentrated fission and activation products characteristic of low-burnup nuclear fuel. There is a significant gamma and high-energy beta radiation emitted from the fuel matrix residues. The challenges, therefore, center on contamination control and external dose rate reduction. The process system is outlined in Figure 1 and detailed in Figure 2.

The first step was to divide the system into modules according to dose rate potential, access requirements, and maintenance needs. Dividing the system into modules reduces the dose rate that operators experience during the various phases of cleaning and maintenance activities. The system consists of five major components: (i) a heated ultrasonic cleaning workstation, (ii) a distillation and storage system, (iii) a skid that contains the stainless steel filter specifically designed for TRU waste, (iv) a computer control console, and (v) support equipment required to provide chilled water, compressed air, and makeup fluids. The cleaning workstation is where baskets of contaminated materials are loaded and unloaded. Because people access this module frequently, the design locates the highest dose rate components, the collection filter and still, on different skids that can be shielded and remotely located. Once baskets of contaminated parts are loaded in the system, the operators retreat to a remote control console where the cleaning operations are initiated and monitored. Since the transfer tables, valves, pumps, heaters, and chilled water are controlled remotely from the computer, the operator has minimal radiological exposure while operating the system.

Other support equipment which were incorporated include: 1) The use of a dual hoist bridge crane system to load and unload the baskets around the cleaning skid. The baskets are limited to 200 pounds but could have high exposure material contained within them. The crane system allows for minimum exposure during transfer and processing of the baskets including "remote" capabilities. 2) A negative pressure, divided containment enclosure surrounding the cleaning skid. This enclosure provides radioactive containment and protection when the baskets are being loaded onto the transfer table from the closed carts.

To reduce doses incurred while conducting radiation surveys, the ultrasonic workstation is equipped with remote dose rate sensors on the cleaning chamber, collection filter, ultrasonic workstation, and inlet/outlet.

Next were issues related to getting the contaminated materials into the cleaning chamber. The ultrasonic cleaning tank will accept a basket 26" x 26" x 16" high. These baskets represent a considerable potential for radiation exposure and contamination because the contamination levels of the materials exceed 10 uCi/g. The basket can be loaded with contaminated items in a hot cell or glovebox and transported to the ultrasonic cleaning workstation. A specially designed basket was fabricated of stainless steel with solid sides and with solid top and bottom covers that slide out just as the basket is moved into the cleaning chamber. This arrangement allows the baskets to be loaded in a glovebox or hot cell and transported to the cleaning chamber in a closed cart for contamination control purposes. To reduce external radiation exposures, the baskets be remotely loaded into and unloaded out of the cleaning chamber by the computer through the use of a pneumatic transfer system. Thus, the operators are only required to remove the basket from the transfer cart and rig the basket onto the workstation prior to cleaning. The operation is reversed after cleaning.

The filters that collect the contamination may each accumulate up to 20 curies of beta-gamma radionuclides. These filters will be classified as TRU waste and eventually shipped to the Waste Isolation Pilot Plant (WIPP). To facilitate characterization under WIPP's waste acceptance criteria, the filters that receive the bulk of the TRU contamination are of specially designed 100% stainless steel construction. They are built to fit within a standard 55-gallon drum with four inches of shielding. The filters incorporate several features that enhance mass loading in order to minimize the number of drums of TRU waste that will result. These features include a 125 psi pressure rating, pleated filter construction for high filter surface area, a relatively coarse pore size (20 microns), and welded stainless steel wire construction to resist compaction of the filter medium. A clever arrangement of check valves on the inlet and outlet allows the filters to be air dried in a closed loop system prior to removal from the process. The check valves also make the filter self-venting while in storage. The waste characterization is simplified because the contents are solely the TRU contaminants removed by the Sonatol process and the stainless steel materials of fabrication. The potential for producing excessive VOC or combustible gases is minimized by the absence of hydrogenous or organic compounds in the cleaning fluid and the collection filter. The particular fluid used in this application does not dissolve organic residues.

In order to achieve high collection efficiency for small radioactive particles and high mass loading of the filter, the contaminated Sonatol fluid is repeatedly circulated through the cleaning chamber and the stainless steel filter to maximize the capture of TRU materials on the filter. Thus the effective efficiency of the filter is determined by the number of times the fluid is filtered, the filtration efficiency in each pass, and the ratio of fluid pumping rate to cleaning chamber volume. In this system, heating the fluid to reduce viscosity enhances the fluid-pumping rate. The size of the pump was limited by the desire to install a magnetically coupled pump to reduce maintenance related radiation exposures. The cleaning chamber was reduced to the minimum volume required to accept the basket of contaminated materials, approximately 300 liters. This leaves the number of fluid passes through the filter as a variable that can be adjusted to achieve the desired degree of decontamination. Initial plans are to process 3000 liters through the stainless steel collection filter (ten times the cleaning chamber volume) in each cleaning cycle. The computer can also monitor the cleaning process and continue the cleaning process for a preset time, a preset dose rate difference on the inlet/outlet lines, a preset cleaning chamber dose rate, or a preset rate of change in the cleaning chamber dose rate.

The stainless steel filter is located on a skid to allow locating the filter in a shielded enclosure. The filter skid itself is designed to support up to four inches of lead brick or steel plate shielding or up to two inches of lead blanket shielding. The inlet and outlet lines are flexible hoses. The filter skid can be placed in a hot cell and operated using hot cell manipulators. A radiation detector on the filter skid remotely monitors the dose rate so that the filter can be changed while it still qualifies as contact-handled waste. During the changeout process, the fluid is remotely purged from the filter with compressed air. A remote quick-release coupling was designed to reduce radiation exposures during the removal of inlet and outlet hoses. The spent filter is moved by lifting the shielded lid of the filter enclosure. The filter is suspended from the lid by a steel cable and surrounded by lead blankets during the movement. After the filter is deposited in a shielded drum or storage cask, the steel cable can be remotely severed and a lid is placed over the filter.

The distillation system was designed with a pneumatically operated cleaning feature. Residues are transferred by gravity to a receiving chamber and then further transferred by compressed air to a shielded waste container. Because the contaminated fluids are filtered repeatedly before being pumped to the still, the preponderance of the radioactivity is expected to be deposited in the stainless steel filters and the distillation residuals consisting of surfactants, oils, and miscellaneous sludge are expected to be LLW. Nevertheless, the pneumatically operated transfer will reduce the operator's dose rate during transfers. Because the still is separated from the other modules, the dose rate from accumulated distillation residues is not a significant source of exposure during the loading and unloading of baskets at the ultrasonic workstation.

The system operation is controlled by a computer program through the use of spring-loaded, pneumatically operated valves. These air-operated valves revert to the closed position if there is a loss of compressed air. To further prevent loss of control, the SCS-300 can operate from the building air supply or a back-up air compressor.

Typically, it is estimated that less than four ounces of Sonatol will be lost when cleaning a basket of metallic waste material.

## **SYSTEM OPERATION**

The objective of the system is to decontaminate the materials sufficiently to change the waste classification of this heterogeneous debris from TRU to LLRW. The material that remains as TRU waste will be in a well-characterized form because it consists only of the filters used in the Sonatol process and the TRU contamination.

The items to be cleaned are first washed with a dilute solution of a high molecular weight fluorocarbon surfactant in an inert perfluorinated liquid (Sonatol). The combination of ultrasonic agitation and liquid flow promotes the detachment of the particles from the surface of the part being cleaned, their transfer from the boundary layer into the bulk liquid, and their removal from the cleaning environment, thereby reducing the probability of particle redeposition. After the cleaning steps, the parts are rinsed with pure Sonatol to remove residual surfactant, and dried.

The process is operated in a closed flow loop, thereby minimizing the consumption of the process liquids.

From a controls standpoint, the Sonatol SCS-300 components comprise a fully automated cleaning system. The control software runs on a PC computer. The control screen is shown in Figure 3. There are two modes of operation: (i) Manual and (ii) Automatic. The manual mode is used for system start-up, maintenance, and diagnosis. In the manual mode, operators can control the on/off status of following system components: air actuated valves, pump, wash tank heater, loading lift, cooling water air-operated valves, drying heater, and ultrasonic power. To ensure that the system is running properly, temperature and pressure are measured on-line in key locations and displayed on the screen. The system will shut down automatically in case of high temperature or high pressure. The system is incapable of automatically continuing the cleaning cycles until the contamination levels in the cleaning chamber have reached a preset value or until the removal efficiency of the filtration process reaches a preset value.

In the automatic mode, operators can select either "Full Cycle" or "Short Cycle" to meet different cleaning purposes. The Full Cycle or "Surfactant Cleaning Cycle" is the standard Sonatol process which includes four steps: (1) Pre-Rinse, (2) Wash, (3) Final Rinse and (4) Dry. During the Pre-Rinse step, rinse liquid is transferred from rinse tank 8 to the cleaning tank 6 through the magnetic pump and the rinse filter. When the ultrasonic cleaning tank is filled, the computer stops the liquid transfer and turns on the ultrasonic power and circulates the fluid through the stainless steel filter for a preset time or a preset performance value. The liquid is then pumped to the still. The next step is Wash, which is similar to the Pre-Rinse but a different liquid is used. In the Wash step, wash liquid is drawn from the wash tank 7. After the wash cycle, the liquid is pumped back to the wash tank 7 through the filter. The Final Rinse step then follows. The purpose of the Final Rinse step is to remove and recover any surfactant used in the Wash step that remains on the filter materials. The cleaning mechanism of the Final Rinse is exactly like the Pre-Rinse. After the cleaning process, the materials in the basket are dried for 20 minutes by heating coils in the cleaning tank. The vaporized liquid is then recovered by a water-cooled condenser in the cleaning tank.

The Short Cycle or "Non-Surfactant Cleaning Cycle" contains only the Pre-Rinse and Dry steps. The total cycle time for the Full Cycle is about 3 hours and 30 minutes and the Short Cycle is about 70 to 75 minutes. Tank levels and pump status can be remotely monitored.

### **LIMITATIONS TO THE SYSTEM**

There is really no barrier to deploying this technology in a multitude of radioactive applications. The system provides operational advantages in concentrating TRU Material into a small volume and reducing overall exposure to the workers. As with all technologies, however, the Sonatol process does have some limitations in its use. The perfluorinated liquid (Sonatol) is fairly expensive and does evaporate in open containers. Therefore, use of Sonatol is limited to a closed-loop system where it can be recycled. The use of this product as a wipe down agent out in the open is not recommended.

Also, the system will make RH TRU Level waste out of CH TRU level waste and LLW since the process essentially concentrates the loose particles on the collection filter. Therefore, LLW should not be allowed to go through the system and radiation levels on the collection filter must be limited to ensure that the dose rates on the exterior of the drum packages does not exceed 200 mrem/hr. We found that except in specific instances of re-use, changing LLW items into even small quantities of TRU waste is not economically feasible. Therefore, when cleaning LLW items with a significant Pu component in the source term, the concentration of TRU materials in the filters and distillation residues should be monitored to ensure that the Pu-239 equivalent concentration is below 100 nCi/g. Likewise, the burial cost savings of cleaning LLW into free releasable waste does not pay for the equipment, labor and processing costs involved.

For this system to work effectively, the material must be contaminated with (but not consist of) TRU Level waste. The TRU level contaminate must be accessible to the working fluid and the material must be heavy enough to allow the TRU Level contaminate to be removed from it (this process will not clean sweepings or soil). Other items not recommended for Sonatol processing include resins, very small items such as steel shot, and degenerated material that would clog the collection filter. The use of containers or screens could allow some flexibility in this area, however. The system is not highly aggressive and will not clean heavily oxidized materials.

The item size is limited with this system to the basket size of 26" wide by 26" long by 16" high. Larger items could be decontaminated by spraying or hand wiping using rags or towels. The rags and towels could then be processed through the Sonatol system. The only other means to use this process on these larger items is size reduction. If one were to build a significantly larger system, the cost of Sonatol, the required line sizes, the required pump and valve sizes, etc. would increase greatly because the capital cost of the system is roughly proportional to the volume of the cleaning chamber.

## RESULTS

After initial testing with non-radioactive materials, the system has been used to decontaminate radioactive material with progressively higher levels of contamination. To date the system has processed materials that can be characterized as having smearable TRU contamination and borderline TRU contamination. The bulk decontamination factor (DF) for these operations has been in the range from 2 to 8 for total contamination on heterogeneous equipment and solid materials in 4 cubic foot lots. Since the available characterization method does not distinguish between fixed and removable contamination, the DF for loose contamination is not known. However, the characterization data does indicate that the DF observed to date should suffice to reduce more than 90% of the identified TRU waste to LLW.

After bulk decontamination, items are individually assayed and the decontamination processed is repeated if necessary to ensure that the item is not TRU level waste. To date, every item that has been decontaminated in the Sonatol system has been cleared for disposal as LLW.

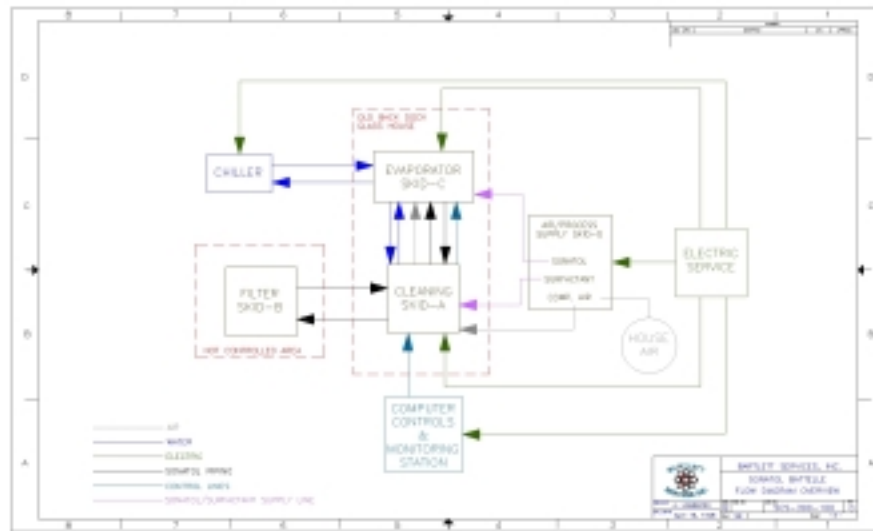
## **FUTURE PLANS**

For the next three to four years the system will operate to decontaminate suitable TRU level waste materials for the BCLDP. During that period of time, radioactive processing will eventually include the higher level wastes presently stored in the hot cells. Then the system will be used to clean equipment and materials that is presently located in the hot cells. This stepwise progression will reduce the amount of contamination in the SCS-300 as much as possible.

## **REFERENCES**

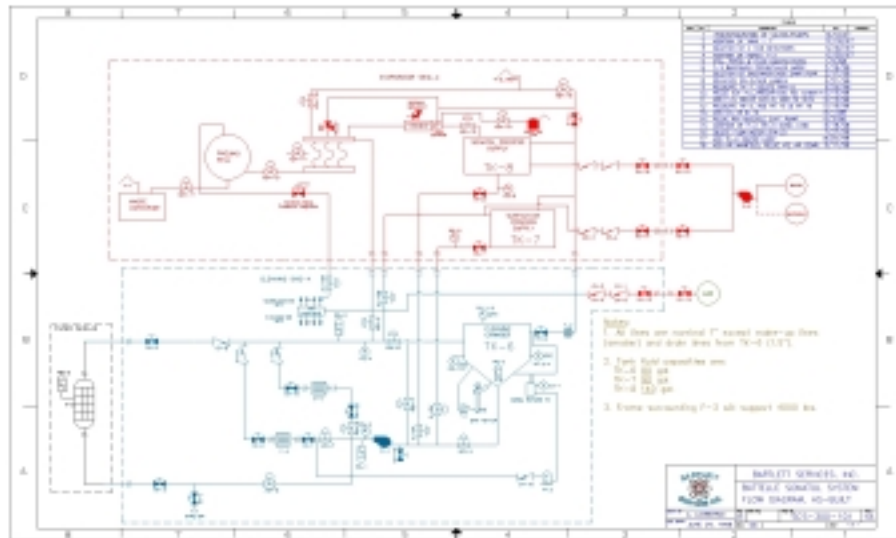
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Fig. 1



Sonatol SCS-300 Process System Outline

Fig. 2



Sonatol SCS-300 Process System Detail

