PILOT SCALE TEST OF THE SONATOL DRY CLEANING PROCESS

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Abstract

Bartlett Services, Inc. installed a dry cleaning decontamination system for PPE at the Oak Ridge facility of US Ecology (USE). The dry cleaning system incorporated our patented Sonatol process. The process has no air or liquid effluents. Cleaning fluids are recycled in a closed system. No environmental permits are required.

The operation demonstrated:

1. Recovery of contaminated personal protective equipment (PPE) and materials that had previously been rejected for reuse after laundering and would otherwise be disposed as radioactive waste (LLRW). Approximately 92% of the PPE processed through the Sonatol system had residual contamination below the reuse criteria, as measured with a 100 square centimeter hand-held survey meter;

2. Reduction in the expense of procuring replacement PPE; and

3. Safe operation in compliance with DOE Orders and applicable regulations.

Introduction

The scope of work for the demonstration included shipping approximately 3841 pounds of PPE to USE in Oak Ridge, TN. The PPE were individually marked for identification and surveyed. Hot spots were also marked on the PPE. Survey work was conducted inside a tent with HEPA ventilation. The PPE were then processed in a dry cleaning machine with Sonatol cleaning fluids. After cleaning and drying in the machine, the PPE were returned to the survey tent. The entire surface of the PPE were surveyed and the marked hot spots were also measured.

Initial results indicated 60% to 70% of garments were cleaned sufficiently to satisfy the reuse criteria. The decontamination factors (DFs) for hot spots were variable, but were often <2. In an effort to improve cleaning efficiency, over twenty different cleaning cycles were developed and tested. A variety of prespotting surfactants, detergents, and enzymes were also tested. In the last week of the demonstration, the effectiveness was improved: approximately 85% to 95% of PPE passed the reuse frisking test, the DF for hot spots was approximately 30, and the volume

reduction factor for secondary waste was ~400 due to reduced use of detergents. In the last week, the volume of reclaimed PPE was 400 times greater than the volume of the secondary waste. The time required to clean one batch of PPE was reduced from nearly 100 minutes to 76 minutes by the end of the demonstration.

Because the PPE were previously laundered and rejected for reuse due to high residual contamination, a relatively long cleaning cycle was used at the start. Also tight schedule constraints mandated that the process should be successful "right out of the box" so that the entire 3841 pounds could be processed in the allotted time. In retrospect, we estimate that freshly contaminated PPE could probably be decontaminated with a 30 minute cleaning cycle and the longer 76 minute cycle and prespotting protocol could be reserved for clothing that exhibits excessive residual contamination.

The economics of this process can produce significant savings for SRS. A rejected set of PPE represents at least $30 in replacement costs and $30 in disposal costs. Cleaning the PPE for reuse at a cost of $10 per set produces a 6:1 cost advantage for SRS. The cost of the demonstration was higher than $10 per set of PPE because the detailed frisking and surveying added costs and because the dry cleaning machine was limited in capacity. A commercial scale activity with normal frisking requirements would cost significantly less.

In the long run, the Sonatol process can also reduce the life cycle cost of PPE use at SRS because the number of times that a garment can be reused is increased greatly. Taking the example of a $30 procurement cost and a $30 disposal cost for a set of PPE, it is evident that if the normal reject rate is 20%, then the average set of PPE is used 5 times. If the normal laundry cost is $4 per set of PPE, the average lifecycle cost to wear one set of PPE one time is ($60/5 + $4) = $16. If Sonatol reclaims 90% of the rejected clothing, then the estimated reject rate if Sonatol were used for all of the clothing is 2%. If the cost of cleaning with Sonatol were $10 per set of PPE, the average lifecycle cost to wear one set of PPE one time is now ($60/50 + $10) = $11.20.

This is a 36% savings on the total lifecycle cost of wearing one set of PCs.

Of course, these are example cost figures. However, actual costs are not significantly different. It is not unreasonable to expect 50 (or more) uses from one set of PPE. Our experience with nuclear garment cleaning indicates that PPE can be reused up to 140 times using a cold cleaning fluid and aggressive decontamination protocols.

In addition, a laundry process that extends the service life of the garments makes the use of advanced cotton or synthetic fabrics cost effective. Advanced fabrics can reduce heat stress and improve worker efficiency by extending stay times in contaminated areas. Of course, extended stay times would reduce the number of sets of PPE that are worn each year, which further reduces PPE costs and LLRW volume.

Description of Equipment

The Sonatol equipment was located within a process building at US Ecology's facility in Oak Ridge, TN. The equipment included a dry cleaning machine (Figure One), accessory bag filter,

HEPA ventilation unit, chiller and a tent with a sorting/frisking glovebag (semirigid) (Figure Two). The tent was approximately 10' wide, 12' long, and 10' high. The tent contains a glovebag, which is used for sorting and frisking PPE. The glovebag has HEPA filters on the inlet and outlet ducts. There are ports to admit bagged PPE and a chute to discharge PPE into the dry cleaning machine. The glovebag will be wheeled up to the opening of the cleaning machine when PPE are to be discharged through the chute.

US Ecology provided radiological protection services . The air discharged to the process room at US Ecology was further HEPA filtered and monitored per US Ecology's license before discharge to the environment.

The complete cleaning cycle includes prewash, wash, rinse and drying steps (see enclosed Figure Three: Process flow chart). The cleaning, drying, and fluid recycling components are contained in the dry cleaning machine. The prewash and rinse steps use a Sonatol fluid with no surfactant added. As the dirty fluid is extracted from the cleaning drum, the fluid passes through a self-cleaning filter to the still. The distillate is returned to a tank in the dry cleaning machine for reuse. The self-cleaning filter drains to the still. Contaminants from the prewash and rinse steps are removed from the system as still bottoms and were packaged for return to SRS. The dirty fluid from the wash step was filtered through a one micron bag filter and returned to a tank in the dry cleaning machine for reuse. The wash fluid contains surfactants that cannot be recovered from the still. Periodically, the fluid in the wash tank may sent to the still for purification and a new surfactant concentrate is mixed with the recovered distillate. The spent surfactants are removed from the system as incinerable still bottoms. The bag filter is periodically removed and packaged as incinerable solid waste. US Ecology disposed a small amount of water condensate from atmospheric humidity in a licensed liquid waste treatment facility. Thus the fluids are reused in a closed loop system and there are no liquid effluents because the fluids are inert and filtration or distillation removes the contaminants.

The drying step involves tumbling the PPE in the cleaning drum, while passing heated air through the drum. The vapor-laden air that exits the drum passes over condensing coils that extract the vapors. The condensed vapors drain to the rinse fluid storage tank. The air recirculates over heating coils and returns to the cleaning drum. There is no air effluent from the cleaning machine.

Process Description

Each piece of clothing was tagged and frisked in a lower background area with a 100 square centimeter alpha/beta probe procured from Bicron. The clothing was organized according to the SRS bag numbers and Bartlett sublots. The locations of hot spots were identified on the clothing.

To prevent cross contamination of the clothing, frisking was conducted in a tent with HEPA ventilation. Only one bag of PPE was opened in the tent at any given time. The frisking was alternated between pre and post surveys to prevent mixing laundered and unlaundered PPE in the tent.

After decon, the PPE were frisked again in the lower background area and results were recorded. The PPE were considered to be reusable if the results showed a decrease in contamination and the net alpha count rate was below 300 cpm and the net beta/gamma count rate was below 1500 cpm in each 100 square centimeters. The count rates correspond to surface activity levels that are below the 1000 dpm alpha and 10,000 dpm beta/gamma criteria in the governing SRS procedure.

Because we were processing previously laundered clothing, the contamination was expected to be much more difficult to remove than normal PPE contamination. The residual contamination is essentially all in the weave of the fabric as opposed to being on the surface of the clothing. Therefore, the typical wash cycle was initially set up to include a prewash step, one or two wash steps, one or two rinse steps, and a drying step. The cycle was evaluated based on decon effectiveness and productivity and modified twenty one times during the demonstration. We investigated combinations of steps, cycle times, and repetitions of steps that would optimize the tradeoff between throughput and cleaning power. The total time for the cleaning cycle, 76 minutes, was determined by the time required by the still to recycle the quantity of rinse fluids used for each batch of clothing. Therefore, adding thermal power to the still may increase throughput. The throughput may also be higher for freshly contaminated PPE because the contamination may be easier to remove and less rinsing would be required. For comparison, a normal dry cleaning cycle in this machine is expected to be 30 minutes.

We also investigated six different prespotting techniques to reduce contamination in hot spots on the PPE. The most effective prespotting results were obtained using a proprietary combination of surfactants and detergents. The results were dramatic. For example, PC #3 in Bag 103 A showed alpha contamination in a hot spot reduced from 2700 cpm to 75 cpm, a 97% reduction of previously "fixed" contamination. Likewise, PC #4 in Bag 103 A showed alpha contamination reduced from 4800 cpm to 200 cpm, a 96% reduction.

After all of the PPE had been processed, several batches were reprocessed in order to verify that the prespotting cocktail and the 76 minute cycle used in the final week were superior to previous iterations. The results (Figure Four) showed that the protocols used at the end of the demonstration were in fact superior to the initial procedures. The least effective results occurred when the main pump malfunctioned. The pump was replaced with a seal-free pump (a "canned" pump in naval terminology). Excluding this portion of the demonstration, the ability to clean the worst quartile of the clothing ranged from 68% at the start to 85% at the end.

Overall, 92% of PPE items had residual contamination below the reuse criteria after Sonatol dry cleaning. Among the 25% of the PPE with the highest contamination levels, 74% were below the reuse criteria after processing with Sonatol. In the last week, improvements in the process increased the overall pass rate to 95% and, of the 40% of PPE with the highest contamination levels, 85% were successfully processed.

Decontamination of the Machine

A periodic analysis of the cleaning fluid showed that Co-60 and Cs-137 were below the LLD of approximately 0.02 pCi/ml. This indicates that the filtration and distillation are effective in

trapping soluble and insoluble radioactive contamination. Nevertheless, the dry cleaning machine was operated with several blank loads after the PPE are processed and all tanks and filters were drained of fluid in order to remove any residuals that may exist in the system. The fluids drained from the system were distilled to ensure that contamination was removed from the fluids. No detectable contamination remained in the fluids.

A very small amount of Europium was discovered in the solid waste (approximately 1 uCi compared to 6000 uCi total contamination in the PPE). This Europium may have originated in PPE that were processed for the DOE's Oak Ridge Operations Office X-10 facility. Our normal procedure is to drain the tanks and external filters and to flush the internal filters to clean the machine between different waste streams. Due to the possible carryover of Europium, we changed the procedure to drain internal filters as well. There was no indication of any residual contamination (other than the still) after the machine was completely drained and the fluids were distilled.

Waste Volume Reduction

The demonstration processed a total of 1746 kg of PPE (4066 pounds of PPE, including rewashes). The resulting solid waste residues comprised approximately 12 liters of sludge and filters. The cleaning cycle used in the last week was the most efficient in terms of minimizing secondary waste. We estimate that using this cycle for the entire 1746 kg would have resulted in only 4 liters (<4 kg) of waste, resulting in a VR factor of (1746*0.92/4) which is >400 for the fraction of the PPE below the reuse limit. This is very close to the VR observed in our water-based laundries, which averages VR=500.

Problems and Solutions

As mentioned above, a pump was replaced with a magnetically coupled pump to prevent leakage of fluids through pump shaft seals. We believe the aggressive action of the cleaning fluid deteriorated the o-rings on the pump shaft. Also, we revised the procedure for cleaning the machine in order to prevent hide-out in the internal filters.

Initially, some of the hot spots on the clothing were not reduced or removed by Sonatol. We tested several commercially-available and proprietary prespotting agents with little success. Some prespotting agents actually seemed to increase the contamination levels in the spots. As a "last resort" we developed our own spotting agent by creating a cocktail blended from a half dozen sources. This was the "magic bullet." The spotting agent that we developed for the last week of processing was very effective and achieved a DF of approximately 30 on the most difficult spots. The frisking results for the PPE in the last series of batches showed that overall 95% were below the reuse criteria and, of the 40% with the most contamination, 85% were below reuse criteria after Sonatol cleaning.

Figure One:

Sonatol dry cleaning machine used in Phase II demonstration. This unit has a nominal 22 lb. Capacity and was actually loaded with 18–22 lbs. Per batch.

Figure Two:

The tent was fitted to the front face of the dry cleaning machine. Semirigid glovebox fabricated from fire retardant plastic. The flexible wall facilitates arm movements yet provides an airtight edge seal.

Figure 3

Sonatol Dry Cleaning Process Flow Chart

(Blue - Mop material flow; Green - fluid recycle path)

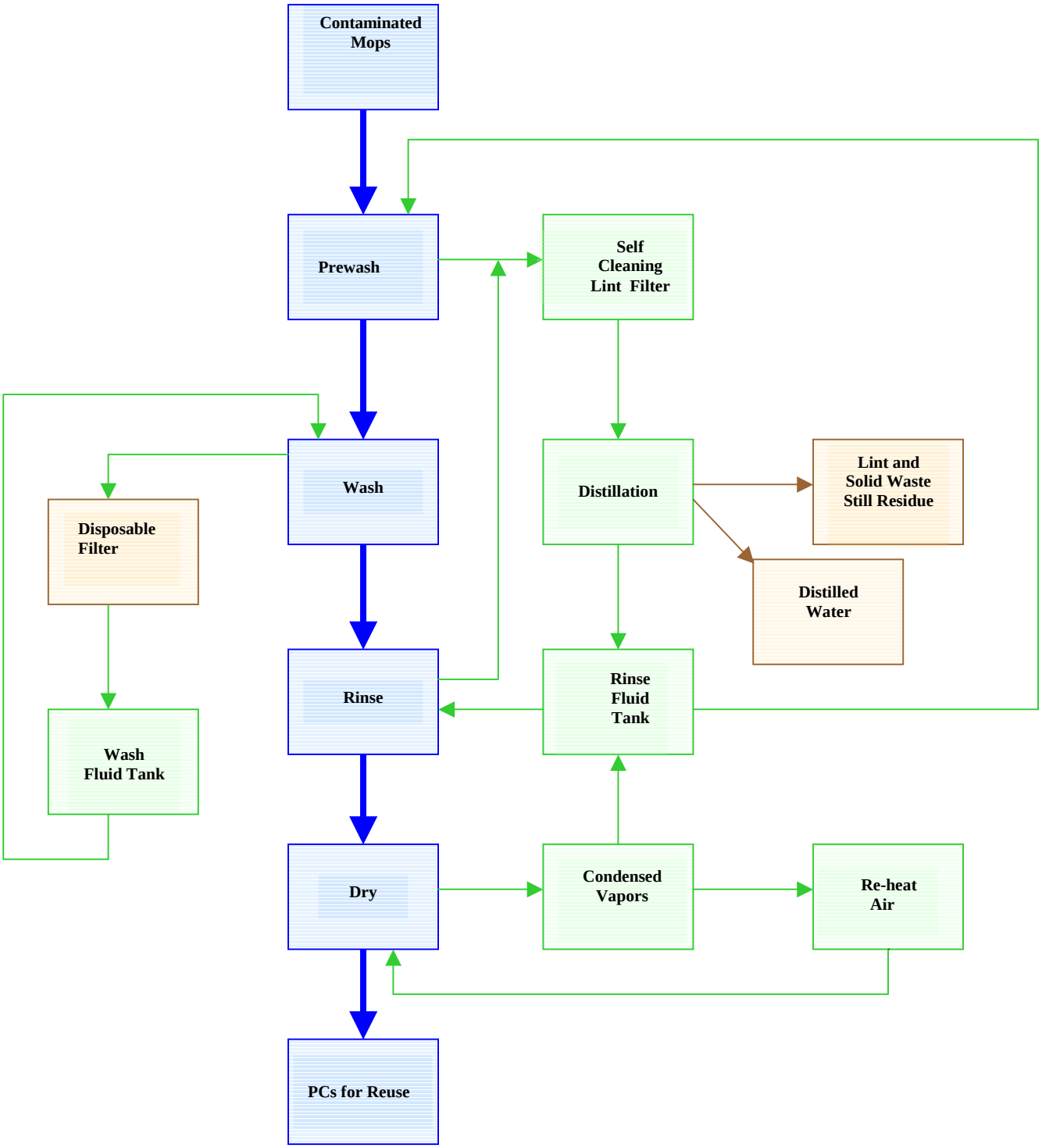

Figure 4
Phase II Drycleaning Results