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LIQUID ABRASIVE GRIT BLASTING LITERATURE SEARCH AND DECONTAMINATION SCOPING TESTS REPORT

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ABSTRACT

This evaluation report is a summary of the research efforts and scoping tests using the liquid abrasive grit blasting decontamination technique. The purpose of these scoping tests was to determined the effectiveness of three different abrasive grits; plastic beads, glass beads and alumina oxide.

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ACRONYMS

DF	decontamination factor
ICPP	Idaho Chemical Processing Plant
NWCF	New Waste Calcine Facility
SIMCON	simulated contamination
WINCO	Westinghouse Idaho Nuclear Company
XRF	x-ray florescence

Liquid Abrasive Grit Blasting Literature Search And Decontamination Scoping Tests Report

1.0 INTRODUCTION

Past decontamination and solvent recovery activities at the Idaho Chemical Processing Plant (ICPP) have resulted in the accumulation of 1.5 million gallons of radioactively contaminated sodium-bearing liquid waste. Future decontamination activities at the ICPP could result in the production of 5 million gallons or more of sodium-bearing waste using the current decontamination techniques of chemical/water flushes and steam jet cleaning. Chemical decontamination flushes have been used and studied for the last ten years and have provided a satisfactory level of decontamination. However, this method requires repetitive flushes to achieve a clean surface while generating large amounts of sodium-bearing secondary waste. Steam jet cleaning has also been used with a great deal of success but cannot be used on concrete or soft materials. With the curtailment of reprocessing at the ICPP, the focus of decontamination is shifting from maintenance for continued operation of the facilities to decommissioning. As decommissioning plans are developed, new decontamination methods must be used which result in higher decontamination factors and generate lower amounts of sodium-bearing secondary waste.

Treatment of sodium-bearing waste is a particularly difficult problem due to the high content of alkali metals in the sodium-bearing liquid waste. It requires a very large volume of cold chemical additive is required for calcination. This is due to the low melting points of the sodium and potassium salts which contribute to the agglomeration of salts in the bed of the calciner. In addition, the sodium content of the sodium-bearing waste exceeds the limit that can be incorporated into vitrified waste without the addition of glass-forming compounds (primarily silicon) to produce an acceptable immobilized waste form.

The primary initiative of the WINCO Decontamination Development Program is the development of methods to eliminate/minimize the use of sodium-bearing decontamination chemicals. One method that was choosen for cold scoping studies during FY-93 was abrasive grit blasting. Abrasive grit blasting has been used in many industries and a vast amount of research and development has already been conducted. However, new grits, process improvements and ICPP applicability was investigated. The following report discusses the research and scoping tests completed for abrasive grit blasting.

2.0 LITERATURE RESEARCH

Abrasive grit decontamination is accomplished by propelling a grit media against a contaminated surface. The abrasive action of the grit then strips the contaminant from the surface. There are various types of commercially available abrasive systems including dry blasting, which utilizes air, or liquid blasting, which utilizes water, to propel the grit media. In most cases, liquid blasting is preferred because it reduces the amount of airborne contamination. Some advantages of wet abrasive decontamination are:

- High decontamination factors.
- Grit recycling.
- Abrasion depth variability (type of grit, system pressure).
- Liquid recirculation reduces the amount of secondary waste generated.
- Effectively removes smearable, fixed, alpha, beta and gamma contamination.

2.1 Technical Performance

2.1.1 Operability/Simplicity

Most of the wet abrasive grit blasting systems examined are glove box type systems. They are self-contained, recirculating systems that can be operated by a single operator. In glove box type systems, the item to be deconned must be loaded into the system. A single operator could load small items such as hand tools and valves. On larger items, two or more operators may be required. Some systems have hoists to load the equipment. A disadvantage to the glove box systems is that the items or equipment cannot be deconned in place. They have to be removed, transferred and loaded into the system. To help reduce the transfer distance, the decon equipment could be setup in-cell or near the equipment area at the risk of contaminating the decon equipment.

KUE Engineering in Canada developed the "System 918" which is a variable, low pressure, wet abrasive cleaning unit.[1] This unit is mounted on a trailer which can be transported between buildings or sites. Two operators can work up to 600 feet from the control unit, thus allowing the control equipment to be kept free of contamination. One operator must remain at the control unit. This system consumes air at a rate of 350 c.f.m, water up to 1.5 gallons per minute and abrasive up to 5 lbs per minute. Water and abrasive supplies being carried on board, enable a minimum of 8 hours running time. Advantages to this system include the ability to do in-situ decontamination while keeping the decontamination equipment free from contamination. A disadvantage is the volume of secondary waste generated since a recirculatory system is not used.

Wet abrasive grit blasting can remove both smearable or fixed contamination. Bartlett Nuclear Inc. suggests pre-deconning items with high pressure water jetting to remove the loose contamination that could adhere to the abrasive media.[2] This will extend the life of the media. The loose contamination would be recycled though a filter system where the bulk of the contamination would be transferred to the filters. Bartlett's two-stage decontamination unit uses a 2000 psi high pressure hot water jet in the first stage to remove the loose contamination and liquid abrasive in the second stage to remove the fixed contamination. A disadvantage to using this type of system is the increase of secondary liquid waste generated.

Wet abrasive grit blasting will damage the electrical components of equipment, such as motors. Mechanical equipment, such as valves and hand tools, can be reused provided the correct abrasive is used. An abrasive such a plastic beads, that will not remove the metal substrate, will allow the equipment to be cleaned while maintaining operability.

2.1.2 Cleaning Rates and Decontamination Factors

The decontamination factor (DF) that is achievable by abrasive grit blasting varies depending on the type of abrasive that is used and the operational parameters associated with each abrasive. These operational parameters include:

- Composition
- Size
- Concentration
- Speed of Impact
- Angle of Impact
- Time of Application
- Distance to the Surface

Westinghouse Electric Corp. studied the decontamination factors that were achievable using boron oxide, magnetite and alumina.[3] The results from these tests are in Table 1. The laboratory column of the table is the expected DF based on laboratory experiments and the field column is the DF that was actually achieved using the different abrasives.

TABLE 1. Westinghouse Electric Corp. decontamination measurements.

ABRASIVE	DECON FACTORS MEASUREMENTS	
	Laboratory	**Field**
Boron oxide	3-6	4
Magnetite	50-200	>6
Aluminum	250-4000	200-300 (nominal)

Only a lower limit was established for the DF during the magnetite application. However, additional testing conducted subsequent to the field application indicates decontamination factors in the 50-200 range are achievable.

There are a number of abrasives that can be used in the abrasive grit blasting process. Bartlett Nuclear Inc. uses glass beads, plastic beads and alumina. The glass beads have a DF in the range of 10-50. The glass beads and alumina will abrade the metal substrate of the item that is being decontaminated, therefore, some metal removal will be experienced. The plastic beads will not remove the metal substrate and will leave the surface polished. If metal removal is desired, glass beads or alumina can be mixed with the plastic beads to provide a more abrasive slurry. By using different combinations of abrasives, a wide range of decontamination factors can be achieved.

AEA Technology in England has patented a process that uses a metallic media, stainless steel powder or zirconium oxide, as the abrasive.[4] The metallic media can achieve the same DF as glass beads or alumina but lasts up to ten times longer, thus reducing the amount of secondary waste. The USA licensee of this process is Kleiber and Schulz. Kleiber and Schulz can design and build a "Vapomatt System" to the user specifications or standard units can be purchased.[5]

2.2 Remote Applicability

Several companies have incorporated remote systems in their glove box type units. A stand alone, non-glove box, remotely operated abrasive decon system is not available. The limiting factor for remote decon possibilities is the amount of secondary waste generated. Without a recirculating system that allows the abrasive to be reused, secondary waste generation will be high. If an in-situ recirculatory system could be developed, it would greatly enhance remote wet abrasive decon possibilities.

2.3 Waste Considerations

Most abrasive grit blast systems use a recirculating process to reduce the amount of secondary waste generated during the decontamination process. As mentioned in Section 2.1.1, the KUE "System 918" is not a recirculating system and therefore the volume of secondary waste generated will be of concern. In the majority of the systems, the slurry that is recirculated through the system consists of a 20% volume ratio of abrasive grit and water (20% grit & 80% water). However, the wet abrasive system developed by AEA utilizes a specially designed pump that is capable of pumping a slurry of 70% grit and 30% water.[5] This would greatly reduce the amount of secondary liquid waste generated. The grit life depends on its break down rate and the type of contamination being removed. When disposing of the slurry, the grit can be separated from the solution leaving a liquid and a solid waste.

Tables A-1.0 to A-3.0, in Appendix A, show abrasive decontamination test results from various companies that have implemented and tested the abrasive decontamination technology. Shown in these tables are water and grit usages for their particular application along with the amount of contamination or radioactivity that was removed.

The compatibility of this technique with the current chemicals and solutions used at ICPP is an area which requires future research efforts. Savannah River was able to alleviate waste disposal problems by selecting a frit useable in glass production as the abrasive.[6] Because the frit was compatible with the vitrification waste stream, they were able to combine the abrasive with the waste, then feed it into the glass melter. Other possibilities, such as incineration of plastic or glass beads, should also be investigated..

2.4 Environmental, Safety and Health

Research efforts will involve classification and disposal of the final waste generated by the wet abrasive decontamination process. One present area of concern is the possible classification of stainless steel as a hazardous waste. If stainless steel is classified as a hazardous waste, it would not be beneficial to use the long life stainless steel abrasive because the waste would be classified as mixed hazardous thus making disposal more difficult. Also if any stainless steel material was removed during the decontamination process, the resultant waste could be classified as mixed hazardous waste.

Present safety concerns involve operator safety. Depending on the system, the operator could be required to use high pressure water or high pressure air. The operator may also be in an area where high voltage is in use. If the operator loads the equipment into a glove box type system, proper lifting procedures are important. In general, safe, concise and clear operating procedures will need to be developed.

2.5 Costs

Development costs will be low since this is a well developed technique. The equipment costs for these systems vary depending on the added features, size, type of abrasive to be used and additional design requirements. Depending on the company, the basic wet abrasive system will cost between $50,000 and $300,000. Labor costs should be investigated although only one or two operators will be required for this type of system.

3.0 SCOPING TEST

The purpose of the scoping test was to test the effectiveness of three different abrasives in removing simulated contamination from a stainless steel coupon. The aggressiveness of liquid abrasive grit blasting can be varied by either changing the abrasive media or by adjusting the air pressure to the blasting nozzle. For the following tests, a mockup of a liquid abrasive grit blaster was used to test the effectiveness of three different abrasives; plastic beads, glass beads and alumina oxide. The effectiveness of these abrasives was tested by determining their ability to remove a known amount of simulated contamination (SIMCON) from a 1 inch diameter stainless steel coupon.

SIMCON 1 coupons consisted of 1-inch diameter stainless steel coupons with cold zirconium and cesium salts dried onto the surface. SIMCON 2 coupons consisted of a 1-inch diameter stainless steel coupon with cold zirconium and cesium dried onto the surface then baked in a oven at 700°C for 24 hours thereby making the simulated contamination harder to remove. Two alloys of stainless steel were tested, 304 and 304L, for both the SIMCON 1 & SIMCON 2 coupons. This represents the bulk of the metal used at the ICPP.

Plastic beads are the least aggressive of the three abrasives. Plastic beads are used to remove paint, oxide layers or rust without damaging the metal substrate. Glass beads are more aggressive plastic beads but less aggressive than alumina oxide. Glass beads are also used to remove paint, oxide layers or rust with minimal damage to the metal substrate. Alumina oxide is an aggressive abrasive. It can remove metal substrate as well as paint, oxide layers or rust.

3.1 Experimental Equipment

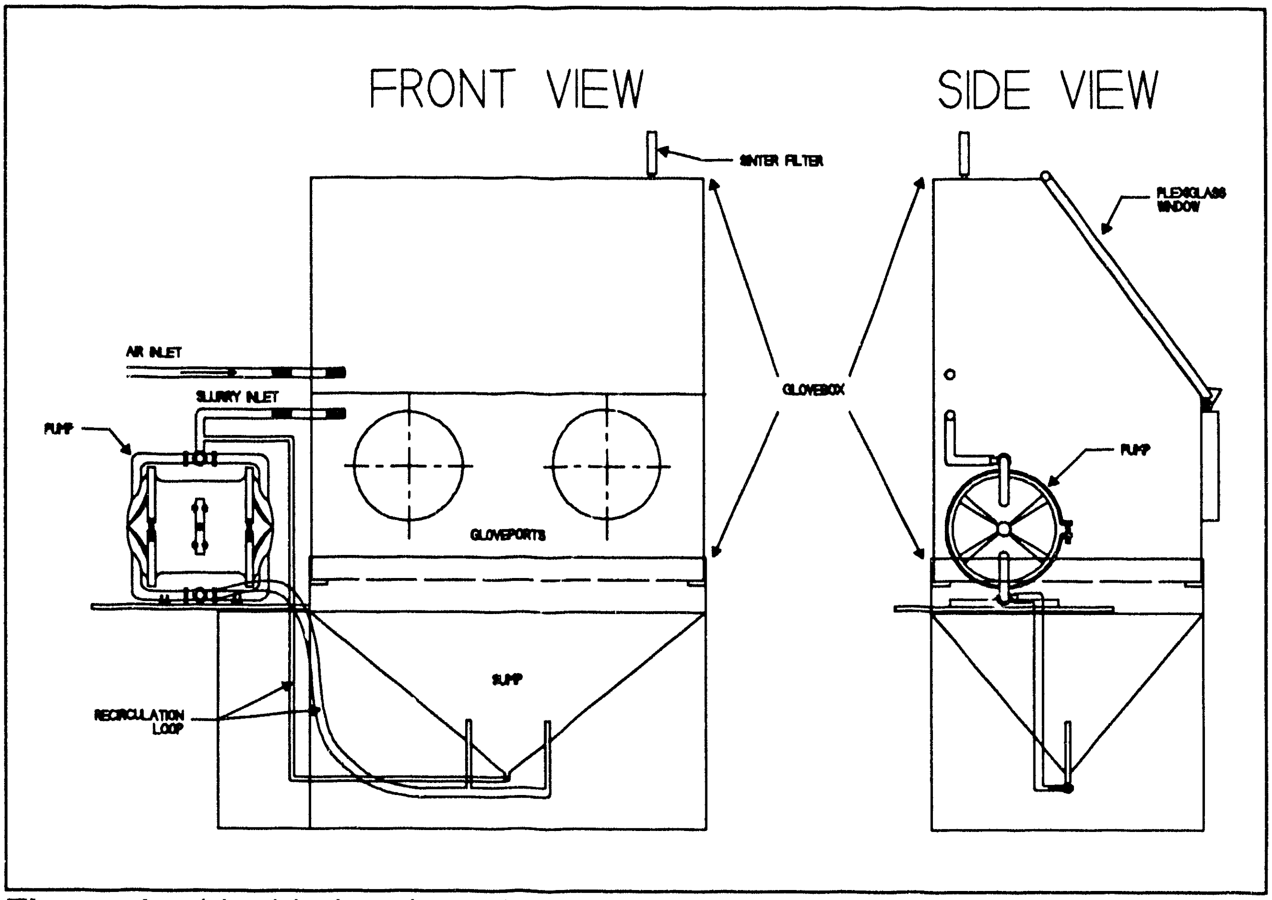


Figure 1 Liquid abrasive grit blaster mockup.

To test the effectiveness of the different abrasive grits, a mockup of a liquid abrasive grit blaster was designed and built (see Figure 1). This is a glovebox type grit blaster. The item to be cleaned is placed into the grit blaster through the plexiglas window. The window is then sealed to prevent leakage and the nozzle or spray gun is operated through the glove ports. The abrasive slurry is contained within the grit blaster sump. A recirculatory system is used to ensure uniform abrasive distribution throughout the slurry. The system uses an air operated double diaphragm pump which is capable of pumping solids up to 1/16" in diameter. The spray nozzle has two inlets, one for the slurry and one for the air. The slurry flow to the spray gun is controlled by a valve and the air flow is controlled by a trigger on the spray gun. The air atomizes the abrasive slurry. This increases the aggressiveness of the system by reducing the cushioning effect the water has on the abrasive grit. A sinter filter located on top of the grit blaster allowed the system to vent to the atmosphere, thus preventing over pressurization of the system.

3.2 Experimental Procedure

The item to be cleaned was placed onto a metal screen, inside the glovebox, through the plexiglas window. The metal screen served two purposes. First, it collected debris larger than 1/16" diameter. Second, it acted as a blast table on which the item could be cleaned. The screen was removable to allow for removal of large debris. Once the item was in the grit blaster, the window was sealed. The diaphragm pump was started and the slurry was circulated at low pressure to ensure uniform abrasive distribution. The slurry and air valves to the spray gun are then opened and the pump pressure is increased. The trigger on the spray gun controlled the air flow into the slurry stream hence controlling the aggressiveness of the system. The operating parameters of the system were held constant for each grit tested, these parameters were as follows:

Pump inlet air pressure:	40 psig
Spray gun inlet air pressure:	40 psig
% of abrasive grit to H_2O:	10% (1l grit to 9l H_2O)
Total volume of slurry:	10 Liters
Plastic Beads abrasive:	20-40 Grit
Glass Beads abrasive:	30-40 Grit
Alumina Oxide abrasive:	240 Grit

To help determine the efficiency of the abrasives, the cleaning time was varied for each set of coupons cleaned. Cleaning times ranged from 1-3 minutes for the plastic beads abrasive and 30-90 seconds for glass beads and alumina oxide.

3.3 Analysis

XRF (X-Ray Florescence) analysis was used to determine the amount of zirconium and cesium on the coupons both before and after cleaning. The zirconium and cesium levels were measured in micrograms. The XRF is capable of measuring down to 1 microgram, anything below 1 microgram is considered below detectable limits. The effectiveness of the abrasive grits was determined by the ability to reduce the amount of zirconium and cesium to below detectable limits (less than 1 microgram). Therefore 100% reduction would mean that the zirconium or cesium was reduced to below detectable limits.

3.4 Results

Tables A-4.0 and A-5.0 in Appendix A show the results from the SIMCON 1 & SIMCON 2 tests using alumina oxide, glass beads and plastic beads abrasives on 304 and 304L stainless steel coupons.

Chart 1 summarizes the data from the tests performed using SIMCON 1 coupons. All three abrasives were effective at removing SIMCON 1 contamination. SIMCON 1 can be compared to loose or surface contamination. Notice there is very little difference between the 304 and the 304L coupons.

Chart 2 summarizes the data from the tests performed using SIMCON 2 coupons. With SIMCON 2, alumina oxide and glass beads were the most effective abrasives at removing both the zirconium and the cesium contamination. SIMCON 2 can be compared to fixed contamination, where the contaminant is held within the grain boundaries of the material, thus making it harder to remove. With all three of the abrasives, the cesium was the hardest to remove from the SIMCON 2. Again there is very little difference in the abrasive ability to remove the simulated contamination from 304 versus 304L.

During these tests, it was discovered that all three abrasives clean the coupons in a different way. Plastics beads, being a relatively soft and mild abrasive, tend to "wipe" the contaminates off the surface. Glass beads, being a harder more aggressive abrasive, use the impact of the abrasive to remove the contaminates. Even though the glass beads are impacting the surface, surface photographs of the coupons at 50X and 500X show no adverse damage to the metal substrate. Due to the "peening" effect of the glass bead abrasive, the coupons had a shiny reflective surface after being cleaned. Alumina oxide, being to most aggressive abrasive tested, tends to grind away the contaminates. This was evident on both visual inspection of the coupons and with surface photographs. With some of the coupons, it was apparent some metal material had been removed. The exact amount of surface metal that was removed was not determined. This "grinding" effect may cause some of the contaminants to be trapped within the substrate if the item is not cleaned for a long enough period of time to allow the surface substrate to be removed.

Chart 1. Results from SIMCON 1 tests.

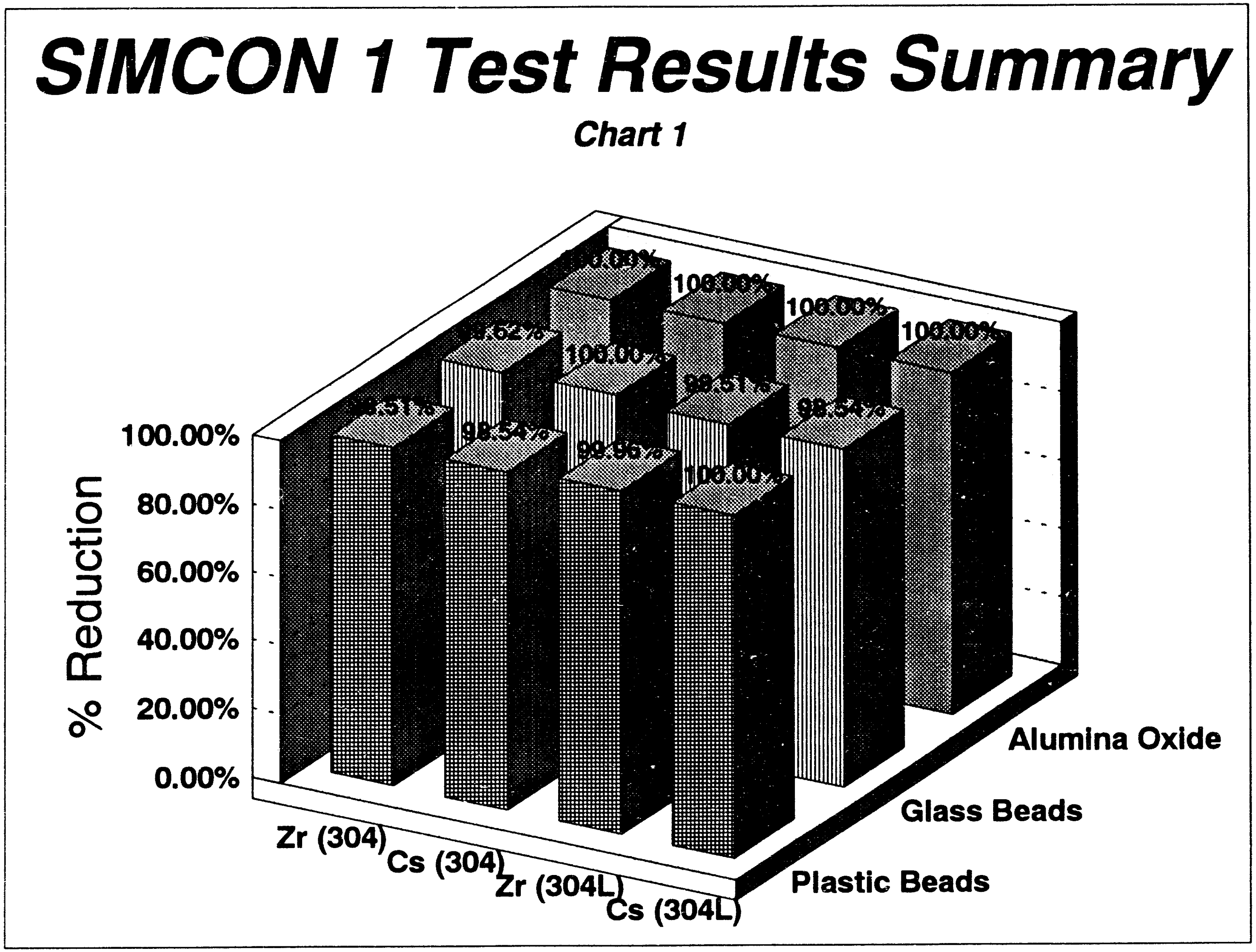
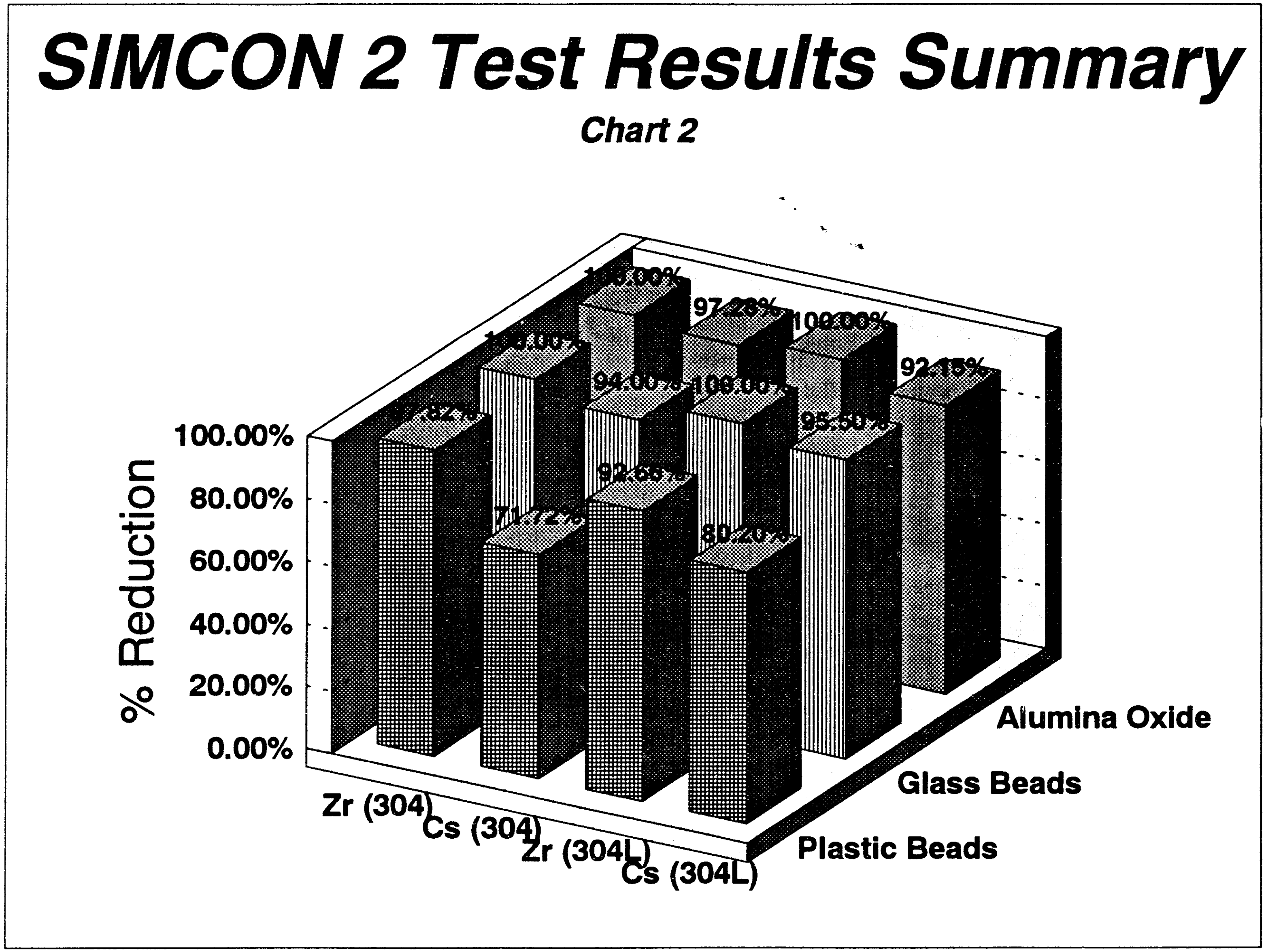


Chart 2. Results from SIMCON 2 tests.



3.5 Conclusions

Alumina oxide and glass bead abrasives are highly effective at removing both surface and fixed simulated contamination as demonstrated on the SIMCON 1 and 2 coupons. Therefore, they could be used to remove both fixed and loose contamination. The plastic bead abrasive was not as effective as the other two abrasives in removing the SIMCON 2 contamination but it was effective at removing the SIMCON 1 contamination. By change abrasive grits , liquid abrasive grit blasting can be a highly flexible system for removing both fixed and surface contamination.

The main draw back with liquid abrasive grit blasting, is the secondary waste that is generated. When used within a glovebox or walk-in booth type enclosure that uses a close-loop recirculatory system, the amount of secondary waste can be greatly reduced. Systems are currently being developed that would enable liquid abrasive grit blasting to be used outside of a booth or enclosure. These systems use a small amount of liquid (~5%) and use a vacuum recovery system to recover then recycle the grit.

4.0 RECOMMENDATIONS

Based on the current available technology, an economic study should be completed to determine the cost advantages of installing a walk-in booth, liquid abrasive grit blasting unit in the NWCF decon area. The study would compare the volume of chemical waste that is generated during the decon process and the cost of disposing of that waste with the volume and cost of disposing the waste generated by liquid abrasive grit blasting. Liquid abrasive grit blasting will not totally replace chemical decon but it will reduce the amount of sodium waste that is generated during ex-situ cleaning. The current available technology would allow CO_2 pellet blasting and liquid abrasive grit blasting to be used in the same walk-in booth enclosure.

Future research and development would be required to used liquid abrasive grit blasting for in-situ cleaning. Future developments efforts would involve the following:

- Development a recycling abrasive grit blasting system which could be used outside of a booth or enclosure.

- Development of robotics for in-situ cleaning.

5.0 REFERENCES

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2. Scott, Bob, Bartlett Nuclear Inc., phone conversation, September 1992.

3. Dawson, P. H., and Sejvar, J., "Evaluation Of Abrasive Grit-High-Pressure Water Decontamination," Westinghouse Electric Corporation, NP-2691, Research Project 2012-4, October 1982.

4. Sanders, M. J., and Bond, R. D., "Development Of Decontamination Technique At The Winfrith Atomic Energy Establishment," Winfrith Atomic Energy Establishment, Dorchester, Dorset England.

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6. Rankin, N. W., "Decontamination Of Savannah River Plant Waste Glass Canisters," Savannah River Laboratory, September 1992.

APPENDIX A

TABLES

Table A-1.0 KUE Engineering

TABLE OF ESTIMATED RATE OF DECONTAMINATION, METAL REMOVAL AND SAND CONSUMPTION BASED ON DECONTAMINATION OF THE CO_2 DUCT MAIN BELLOWS BRADWELL & DUNGENESS POWER STATIONS								
NUMBER OF BLASTS	ESTIMATED METAL REMOVAL	AVERAGE SURFACE ACTIVITY (COUNTS PER SEC)	STAGE REDUCTION OF ACTIVITY	OVERALL REDUCTION OF ACTIVITY	STAGE SAND TONNE	OVERALL SAND TONNE	STAGE SAND USED per m^2 Kg	OVERALL SAND USED* per m^2 Kg
1	0.00025"	50	99.0%	99.0%	0.6	0.6	22	22
2	0.0005"	20	0.6%	99.6%	0.6	1.2	22	44
4	0.001"	10	0.2%	99.8%	1.2	2.4	44	88
5	0.001125"	5	0.1%	99.9%	0.4	2.8	15	103

* During the decontamination process a total of 2.8 tons of abrasive was consumed.

Table A-2.0 Westinghouse Electric

WESTINGHOUSE ELECTRIC CORPORATION WASTE SUMMARY RESULTS FROM THE DECONTAMINATION OF REACTOR CHANNEL HEADS						
TYPE OF ABRASIVE	NO. OF CHANNEL HEADS	WASTE WATER		GRIT USAGE		FILTERS
		TOTAL gal.	gal/ft^2	TOTAL lb	lb/ft^2	
BORON OXIDE	6	64,000	68	8,000	8.2	-
	1	12,000	125	1,800	12	-
MAGNETITE	6	-RECIRCULATION SYSTEM-		11,000[A]	17.5	100[C]
ALUMINA	6	-RECIRCULATION SYSTEM-		16,000[B]	11.4	60[D]

[A]Solidified in four 85 ft^3 liners utilizing a polymer solidification agent
[B]Solidified in eight 73 ft^3 liners utilizing concrete as the solidification agent
[C]Bag-type filters -- dewatered and placed in 10 drums
[D]Bag-type filters -- dewatered and placed in 73 ft^3 liners

Table A-3.0 Savannah River

SAVANNAH RIVER ABRASIVE BLASTING DECONTAMINATION TEST RESULTS USING FOUR DIFFERENT DECONTAMINATON TECHIQUES							
DECONTAMINATION TECHNIQUE***	SMEARABLE CONTAMINATION						PROJECTED CONSUMPTION RATE/CANISTER
	BEFORE			AFTER			
	BAKED-ON (α dis/min)	MELTER		BAKED-ON (α dis/min)	MELTER		
		α dis/min	β-γ c/m*		α dis/min	β-γ c/m*	
DRY-ABRASIVE BLASTING	200,000 to 400,000	4,000	$9x10^5$	Background**	Background**	Background**	500 lb Frit
DRY-ABRASIVE BLASTING WITH H_2O ATTACHMENT	200,000 to 400,000	4,000	$9x10^5$	Background**	Background**	Background**	500 lb Frit 200 gal H_2O
HIGH-PRESSURE H_2O BLASTING (1000 psi)	200,000 to 400,000	4,000	$9x10^5$	Up to 3690	Up to 354	Up to 68,000	50,000 gal H_2O
HIGH-PRESSURE H_2O BLASTING (1000 psi) WITH FRIT	200,000 to 400,000	4,000	$9x10^5$	Background**	Background**	Background**	500 lb Frit 3,500 gal H_2O

* One mR/hr = 4,000 c/m

** The smears from these specimens were counted in specially shielded counter where the background is <4 counts/24 hours alpha and <0.2 counts/min β-γ from ^{137}Cs.

*** Frit was used as the abrasive in all cases where abrasive was used.

Table A-4.0 Test Results For SIMCON 1

ABRASIVE	TAG NO.	TYPE	MATERIAL	TIME	INITIAL ZIRCONIUM	INITIAL CESIUM	FINAL ZIRCONIUM	FINAL CESIUM	% REDUCTION ZIRCONIUM	% REDUCTION CESIUM
					(μg)	(μg)	(μg)	(μg)		
Alumina Oxide	G-1-27	SIMCON 1	304	30 sec.	560.77	302.58	<1	<1	100.00%	100.00%
Alumina Oxide	G-1-28	SIMCON 1	304	30 sec.	714.58	336.80	<1	<1	100.00%	100.00%
Alumina Oxide	G-1-29	SIMCON 1	304	1:00 min	595.90	313.42	<1	<1	100.00%	100.00%
Alumina Oxide	G-1-30	SIMCON 1	304	1:00 min	738.09	683.28	<1	<1	100.00%	100.00%
Alumina Oxide	G-1-31	SIMCON 1	304	1:30 min	670.87	386.20	<1	<1	100.00%	100.00%
Alumina Oxide	G-1-32	SIMCON 1	304	1:30 min	708.70	363.63	<1	<1	100.00%	100.00%
							AVERAGE REDUCTION		100.00%	100.00%
							STANDARD DEVIATION		0.00%	0.00%
Alumina Oxide	L-1-1	SIMCON 1	304L	30 sec.	723.30	665.54	<1	<1	100.00%	100.00%
Alumina Oxide	L-1-2	SIMCON 1	304L	30 sec.	622.14	591.46	<1	<1	100.00%	100.00%
Alumina Oxide	L-1-3	SIMCON 1	304L	1:00 min	809.63	685.75	<1	<1	100.00%	100.00%
Alumina Oxide	L-1-4	SIMCON 1	304L	1:00 min	781.35	681.88	<1	<1	100.00%	100.00%
Alumina Oxide	L-1-5	SIMCON 1	304L	1:30 min	668.37	529.80	<1	<1	100.00%	100.00%
Alumina Oxide	L-1-6	SIMCON 1	304L	1:30 min	671.61	588.88	<1	<1	100.00%	100.00%
							AVERAGE REDUCTION		100.00%	100.00%
							STANDARD DEVIATION		0.00%	0.00%
Alumina Oxide	G-1-25	SIMCON 1	304	30 sec.	805.33	635.39	<1	<1	100.00%	100.00%
Alumina Oxide	G-1-26	SIMCON 1	304	1:30 min	547.16	305.90	<1	<1	100.00%	100.00%
							AVERAGE REDUCTION		100.00%	100.00%
							STANDARD DEVIATION		0.00%	0.00%
Glass Beads	G-1-7	SIMCON 1	304	30 sec.	500.86	1894.93	7.53	<1	98.50%	100.00%
Glass Beads	G-1-8	SIMCON 1	304	30 sec.	503.40	2587.71	<1	<1	100.00%	100.00%
Glass Beads	G-1-9	SIMCON 1	304	1:00 min	470.58	2497.40	3.55	<1	99.25%	100.00%
Glass Beads	G-1-10	SIMCON 1	304	1:00 min	651.67	1852.63	<1	<1	100.00%	100.00%
Glass Beads	G-1-11	SIMCON 1	304	1:30 min	458.30	1562.52	<1	<1	100.00%	100.00%
Glass Beads	G-1-12	SIMCON 1	304	1:30 min	586.64	2817.48	<1	<1	100.00%	100.00%
							AVERAGE REDUCTION		99.62%	100.00%
							STANDARD DEVIATION		0.63%	0.00%

Table A-4.0 Test Results For SIMCON 1 (cont.)

ABRASIVE	TAG NO.	TYPE	MATERIAL	TIME	INITIAL ZIRCONIUM	INITIAL CESIUM	FINAL ZIRCONIUM	FINAL CESIUM	% REDUCTION ZIRCONIUM	% REDUCTION CESIUM
					(µg)	(µg)	(µg)	(µg)		
Glass Beads	L-1-31	SIMCON 1	304L	30 sec.	616.24	1681.66	1.81	<1	99.71%	100.00%
Glass Beads	L-1-32	SIMCON 1	304L	30 sec.	630.53	2016.19	1.21	<1	99.81%	100.00%
Glass Beads	L-1-33	SIMCON 1	304L	1:00 min	575.98	1295.95	<1	<1	100.00%	100.00%
Glass Beads	L-1-34	SIMCON 1	304L	1:00 min	611.93	2106.06	1.18	<1	99.81%	100.00%
Glass Beads	L-1-35	SIMCON 1	304L	1:30 min	587.65	1529.51	<1	<1	100.00%	100.00%
Glass Beads	L-1-36	SIMCON 1	304L	1:30 min	513.45	989.13	<1	<1	100.00%	100.00%
							AVERAGE REDUCTION		99.89%	100.00%
							STANDARD DEVIATION		0.13%	0.00%
Plastic Beads	A-81	SIMCON 1	304	1:00 min	693.36	1681.52	10.27	67.93	98.52%	95.96%
Plastic Beads	A-82	SIMCON 1	304	1:00 min	552.87	2560.06	11.51	31.85	97.92%	98.76%
Plastic Beads	A-83	SIMCON 1	304	2:00 min	614.44	2607.61	13.31	52.42	97.83%	97.99%
Plastic Beads	A-84	SIMCON 1	304	2:00 min	645.09	2760.86	9.03	28.63	98.60%	98.96%
Plastic Beads	A-85	SIMCON 1	304	3:00 min	534.36	2662.01	4.73	2.52	99.11%	99.91%
Plastic Beads	A-86	SIMCON 1	304	3:00 min	629.25	2086.99	5.65	6.90	99.10%	99.67%
							AVERAGE REDUCTION		98.51%	98.54%
							STANDARD DEVIATION		0.55%	1.44%
Plastic Beads	G-L-1-25	SIMCON 1	304L	1:00 min	533.80	1026.20	<1	<1	100.00%	100.00%
Plastic Beads	G-L-1-26	SIMCON 1	304L	1:00 min	600.49	1852.99	<1	<1	100.00%	100.00%
Plastic Beads	G-L-1-27	SIMCON 1	304L	2:00 min	605.51	2433.07	1.30	<1	99.79%	100.00%
Plastic Beads	G-L-1-28	SIMCON 1	304L	2:00 min	574.64	1224.33	<1	<1	100.00%	100.00%
Plastic Beads	G-L-1-29	SIMCON 1	304L	3:00 min	519.65	1254.53	<1	<1	100.00%	100.00%
Plastic Beads	G-L-1-30	SIMCON 1	304L	3:00 min	531.62	1822.89	<1	<1	100.00%	100.00%
							AVERAGE REDUCTION		99.96%	100.00%
							STANDARD DEVIATION		0.09%	0.00%

Table A-5.0 Test Results For SIMCON 2

ABRASIVE	TAG NO.	TYPE	MATERIAL	TIME	INITIAL ZIRCONIUM	INITIAL CESIUM	FINAL ZIRCONIUM	FINAL CESIUM	% REDUCTION ZIRCONIUM	% REDUCTION CESIUM
					(μg)	(μg)	(μg)	(μg)		
Alumina Oxide	2-8	SIMCON 2	304	30 sec.	67.05	58.19	<1	4.29	100.00%	92.63%
Alumina Oxide	2-19	SIMCON 2	304	30 sec.	135.20	196.21	<1	12.30	100.00%	93.73%
Alumina Oxide	2-9	SIMCON 2	304	1:00 min	95.38	97.05	<1	1.37	100.00%	98.59%
Alumina Oxide	2-21	SIMCON 2	304	1:00 min	33.53	71.91	<1	<1	100.00%	100.00%
Alumina Oxide	2-10	SIMCON 2	304	1:30 min	86.42	81.68	<1	<1	100.00%	100.00%
Alumina Oxide	2-22	SIMCON 2	304	1:30 min	92.34	112.56	<1	1.41	100.00%	98.75%
							AVERAGE REDUCTION		100.00%	97.28%
							STANDARD DEVIATION		0.00%	3.25%
Alumina Oxide	L-1-16	SIMCON 2	304L	30 sec.	34.30	37.63	<1	2.73	100.00%	92.75%
Alumina Oxide	L-1-17	SIMCON 2	304L	30 sec.	15.61	20.23	<1	4.18	100.00%	79.34%
Alumina Oxide	L-1-19	SIMCON 2	304L	1:00 min	34.03	45.01	<1	6.29	100.00%	86.03%
Alumina Oxide	L-1-22	SIMCON 2	304L	1:00 min	25.09	54.14	<1	2.02	100.00%	96.27%
Alumina Oxide	L-1-23	SIMCON 2	304L	1:30 min	32.97	33.33	<1	<1	100.00%	100.00%
Alumina Oxide	L-1-24	SIMCON 2	304L	1:30 min	105.15	132.45	<1	1.92	100.00%	98.55%
							AVERAGE REDUCTION		100.00%	92.15%
							STANDARD DEVIATION		0.00%	8.02%
Alumina Oxide	2-23	SIMCON 2	304	30 sec.	95.57	150.14	<1	8.66	100.00%	94.23%
Alumina Oxide	2-24	SIMCON 2	304	1:30 min	102.40	96.97	<1	1.18	100.00%	98.78%
							AVERAGE REDUCTION		100.00%	96.51%
							STANDARD DEVIATION		0.00%	3.22%
Glass Beads	2-1	SIMCON 2	304	30 sec.	81.29	62.78	<1	8.26	100.00%	86.84%
Glass Beads	2-3	SIMCON 2	304	30 sec.	47.69	126.45	<1	9.62	100.00%	92.39%
Glass Beads	2-4	SIMCON 2	304	1:00 min	26.32	45.84	<1	1.77	100.00%	96.14%
Glass Beads	2-5	SIMCON 2	304	1:00 min	84.52	93.08	<1	4.83	100.00%	94.81%
Glass Beads	2-6	SIMCON 2	304	1:30 min	26.70	125.79	<1	2.96	100.00%	97.65%
Glass Beads	2-7	SIMCON 2	304	1:30 min	116.64	197.13	<1	7.59	100.00%	96.15%
							AVERAGE REDUCTION		100.00%	94.00%
							STANDARD DEVIATION		0.00%	3.92%

Table A-5.0 Test Results For SIMCON 2 (cont.)

ABRASIVE	TAG NO.	TYPE	MATERIAL	TIME	INITIAL ZIRCONIUM	INITIAL CESIUM	FINAL ZIRCONIUM	FINAL CESIUM	% REDUCTION ZIRCONIUM	% REDUCTION CESIUM
					(μg)	(μg)	(μg)	(μg)		
Glass Beads	L-1-8	SIMCON 2	304L	30 sec.	27.26	25.33	<1	2.32	100.00%	90.84%
Glass Beads	L-1-9	SIMCON 2	304L	30 sec.	47.64	37.91	<1	<1	100.00%	100.00%
Glass Beads	L-1-10	SIMCON 2	304L	1:00 min	23.17	45.22	<1	2.35	100.00%	94.80%
Glass Beads	L-1-11	SIMCON 2	304L	1:00 min	19.60	39.20	<1	2.34	100.00%	94.03%
Glass Beads	L-1-12	SIMCON 2	304L	1:30 min	16.16	90.20	<1	<1	100.00%	100.00%
Glass Beads	L-1-13	SIMCON 2	304L	1:30 min	22.33	22.58	<1	1.44	100.00%	93.62%
							AVERAGE REDUCTION		100.00%	95.55%
							STANDARD DEVIATION		0.00%	3.70%
Plastic Beads	1-60	SIMCON 2	304	1:00 min	21.72	14.05	<1	5.37	100.00%	61.78%
Plastic Beads	1-61	SIMCON 2	304	1:00 min	29.50	13.34	<1	1.41	100.00%	89.43%
Plastic Beads	1-62	SIMCON 2	304	2:00 min	75.79	18.95	2.52	3.61	96.68%	80.95%
Plastic Beads	1-63	SIMCON 2	304	2:00 min	28.49	14.59	2.78	4.45	90.24%	69.50%
Plastic Beads	1-64	SIMCON 2	304	3:00 min	3.32	14.72	<1	6.80	100.00%	53.80%
Plastic Beads	1-65	SIMCON 2	304	3:00 min	3.11	4.93	<1	1.24	100.00%	74.85%
							AVERAGE REDUCTION		97.82%	71.72%
							STANDARD DEVIATION		3.94%	12.91%
Plastic Beads	L-1-1	SIMCON 2	304L	1:00 min	31.17	33.19	5.97	11.11	80.85%	66.53%
Plastic Beads	L-1-2	SIMCON 2	304L	2:00 min	49.35	35.42	<1	7.07	100.00%	80.04%
Plastic Beads	L-1-3	SIMCON 2	304L	2:00 min	47.50	72.15	0.53	4.19	98.88%	94.19%
Plastic Beads	L-1-4	SIMCON 2	304L	3:00 min	46.14	33.71	7.57	10.53	83.59%	68.76%
Plastic Beads	L-1-5	SIMCON 2	304L	3:00 min	35.21	37.11	<1	3.16	100.00%	91.48%
							AVERAGE REDUCTION		92.66%	80.20%
							STANDARD DEVIATION		9.59%	12.66%

DATE FILMED

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END