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Evaluation of Two Commercial Decontamination Systems

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SUMMARY

Decontamination technologies from two commercial decontamination vendors were evaluated to determine their applicability and effectiveness for further demonstration at the Idaho Nuclear Technology and Engineering Center (INTEC). Eight vendors initially responded to a Commerce Business Daily solicitation for information on novel decontamination methods. Two of these, ADA Technologies and Universal Ice Blast Incorporated, were selected for further evaluation. These two vendors completed a criteria questionnaire and performed effectiveness tests, using Simulated Contamination (SIMCON) coupons that are reported herein. The Universal Ice Blast, Incorporated ice blasting system had the highest score of the test and is recommended for further radioactive testing and/or purchase.

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ACRONYMS

ADA	ADA Technologies,Co.
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
SIMCON	Simulated Contamination
UIBI	Universal Ice Blast Incorporated

Evaluation of Two Commercial Decontamination Systems

1. INTRODUCTION

The Radioactive Liquid Waste Reduction (RLWR) Group seeks to develop effective alternatives to high waste generating decontamination methods currently in use at the Idaho National Engineering and Environmental Laboratory (INEEL). Historical processes operating at the Idaho Nuclear Technology and Engineering Center (INTEC), located at the INEEL, have generated hazardous, highly radioactive liquid waste. Additional waste is generated during decontamination of various items for reuse or to reduce radiation levels. Approximately 50,000 gallons/year of typically acidic waste is generated from decontamination activities. The decontamination waste is stored in large, underground tanks at the INTEC Tank Farm. Discontinuing tank farm use and eliminating liquid waste generation is an INTEC goal.

For the past two decades, the RLWR Group has tested various methods of decontamination for the INTEC (formerly the Idaho Chemical Processing Plant (ICPP)) and supported decontamination projects for many processes. Since the chemical processes were typically flushed to remove radioactive contamination prior to major repair work, the evaluation primarily focused on chemical decontamination methods. There has been extensive work at the INTEC during the '70s and '80s on chemical decontamination testing, with an emphasis placed on effective decontamination of first cycle process equipment.

The use of chemical decontamination has become undesirable because of restrictions on use of hazardous chemicals and INTEC waste handling issues. The use of chemical decontamination methods usually entails the generation of large quantities of secondary waste (in addition to the contaminant and substrate waste). The increased regulation and concern about secondary waste has caused many nuclear facilities to abandon many of their former chemical decontamination methods.

The RLWR Group has evaluated two novel, low waste alternative decontamination methods, an electrochemical coating method and an ice blasting method, to reduce the volume from decontamination activities. The two technologies being evaluated, ADA Technologies' electrochemical coating method and Universal Ice Blast, Incorporated's ice blasting method, were selected from a variety of different techniques offered in the commercial cleaning/decontaminating arena. The INEEL RLWR Group has previously performed demonstration/evaluation activities on CO₂ pellet blasting, liquid abrasive grit blasting, novel chemical flushing, light ablation decontamination, liquid nitrogen blasting, CO₂ snowflake blasting and improved concrete scabbling equipment. The unique advantages of the ADA' and Universal' technologies, particularly low waste generation, lead to their selection for evaluation in this effort.

2. BACKGROUND

2.1 Selecting The Decontamination Vendors

This evaluation had four main goals: 1) identify companies with decontamination technologies, 2) provide funding for the companies to demonstrate their decontamination technologies on DOE surrogate materials, 3) evaluate the suitability of the decontamination technologies for incorporation into INEEL (INTEC) operations, and 4) determine the interest the participating companies have in partnering with the INEEL to subsequently provide 'hot test' data.

The project began by advertising in the Commerce Business Daily (CBD) to solicit proposals from companies with mature decontamination technologies. Excerpts from the CBD announcement are included below.

“The Idaho National Engineering and Environmental Laboratory (INEEL), operated by Bechtel BWXT Idaho, LLC under contract with the U. S. Department of Energy (DOE), is seeking one or more industrial partners to evaluate commercial, pilot-scale, or near-term radioactive decontamination technologies. Technologies are sought that will effectively strip loose and fixed radioactive contamination from stainless steels and provide for a minimal amount of generated wastes. It is also preferred that the technologies be economically competitive to implement and operate, and that they can be readily adapted for remote operation. It is estimated that up to three technologies will be considered for evaluation over a one-year period of performance and anticipated for initiation at the beginning of calendar year 2001. Technology demonstration can be conducted at the INEEL or the Supplier’s facilities, subject to negotiation and benefit to the INEEL. Follow-on funding may be provided to assist in implementation efforts for successful technologies. Companies interested in working with the INEEL to demonstrate stainless steel decontamination technologies should provide a written Letter of Interest that includes descriptions of: 1) their Corporate capability to participate in, and contribute to the proposed effort, 2) the specific decontamination technology and performance characteristics (do not include proprietary information), and 3) the state of development of the technology. Respondents are encouraged to provide ancillary documents like annual reports, resumes of key individual participants, and technical publications and patents. All respondents will be notified within four weeks of the closing date regarding receipt of the Letter of Interest; whereupon, those companies offering technologies of interest will be requested to submit a proposal. Preference will be given to those companies offering the most promising technologies and those willing to provide reasonable levels of cost sharing.”

There were eight respondents to the CBD announcement that acknowledged their desire to participate in the project. Telephone conversations followed to clarify further details regarding INEEL needs, the technologies being offered, and a reasonable scope-of-work. Two of the eight companies were ultimately contracted to complete scope relevant to the project.

ADA Technologies, Inc. and Universal Ice Blast, Inc. were granted contracts to demonstrate their respective technologies at their facilities with surrogate coupons supplied by the INEEL. The scope-of-work was relatively informal and instructed the companies to conduct tests representing a wide range of operating parameters; centering around what they believed to be optimal conditions. The surrogate coupons were fabricated/prepared/analyzed at INTEC prior to sending them for testing. Twenty five ‘SIMCON II’ coupons were supplied to each of the companies. The companies were also instructed to return the coupons to the INEEL after completion of the tests, for analyses, provide a written summary of their test procedures and parameters, and provide a video recording of the actual testing. Portions of this information are incorporated in subsequent tables.

The six remaining respondents were: 1) Fuel Tank Maintenance, L.L.C., 2) TESSAG NUKEM, 3) Arcadia Consulting, Inc., 4) TRUTech L.L.C., 5) Hemispheric Center for Environmental Technologies (HCET), Florida Int’l Univ., Center for Eng. & Applied Sciences, and 6) ToxCo. Conversations with representatives from these organizations revealed three types of conflicts that precluded our pursuing them for contract. Four of the companies were offering technologies that we had previously evaluated and did not require additional information. One of the companies offered a technology that did not directly address decontamination and withdrew their request to participate. The HCET did not offer a technology for evaluation, but wanted to participate in evaluating the data collected from other participants. This report will be forwarded for their review.

2.2 Ice Blasting Technology

The technology of ice blasting is a novel technique with a considerable history. As early as 1955, a patent was granted for a method of cleaning automobiles using ice blasting.¹ The technique of ice blasting is essentially an offshoot from other abrasive blasting, such as sand blasting. Sand blasting has always had drawbacks, and has recently come under increased regulation because of increased incidents of silicosis among sand blast workers. The technique of ice blasting eliminates concerns of silicosis and generation of large volumes of secondary waste, and reduces airborne contamination. Because the process uses water ice, it is also quite inexpensive and performs a partial rinse of the contaminated equipment during operation.

Ice blasting consists of propelling ice crystals across the surface of the subject material to remove contaminants. This technique is useful for removing corrosion deposits, paints and general debris from the surface. The system consists of an ice making machine and a blasting device with a hopper to hold the ice crystals. The ice crystals are generated in an ice making machine, which is basically a powerful refrigeration device, and delivered into a blast hopper. They are then propelled at high velocities through a blast hose and nozzle with compressed air. Other parts of the equipment may include generators and compressors to service the primary equipment.

The Universal Ice Blast Incorporated (UIBI) system is a robust and readily available unit that has undergone significant testing. This machine has been used in many different locations around the world. The UIBI system has also been used to radiologically decontaminate lead brick at Oak Ridge National Laboratory with resulting decontamination factors of up to 2750². It has been tested on cleaning zirconium alloy tubing for bimetallic, nuclear reactor components.³ These tests demonstrated that a superior cleaning could be achieved without the use of aggressive acids and hazardous, chemical wastes. A demonstration of this technology was also performed on the Point Lepreau Generating Station (PLGS) steam generators during a maintenance outage⁴. Typical radiological, decontamination factors from 5 to 6 were achieved during this project. The standard ice blasting unit costs approximately \$70,000.

2.3 Electrochemical Coating Technology

The electrochemical cleaning technique developed by ADA Technologies is somewhat unique in the field of decontamination. Other electrochemical methods have been used to decontaminate radioactive materials. Most notably, electropolishing techniques have received wide attention and been used at several DOE Sites^{5,6}. However, electropolishing has been mainly used for the careful removal of small amounts of surface contaminants and the preservation of the underlying substrate. It has also typically generated significant quantities of hazardous waste. The ADA system operates on a much more aggressive type of philosophy, removing more surface material and producing far less waste, with no hazardous chemicals.

Development of the ADA technology was initiated under a Small Business Innovative Technology Research (SBIR) Phase I grant from the DOE in 2000. Under this grant, ADA completed the fabrication of an electrochemical manipulation device that could be transported to the field and used to decontaminate radiologically contaminated items. The system was designed to electrochemically apply a gel for a glovebox type decontamination environment. During the phase I development, the system was tested with non-radioactive cerium surrogates that would behave similar to plutonium in the field. These tests were promising, though no quantitative results were reported, and the phase II development was not funded.

The method of performing electrochemical decontamination using the ADA equipment is fairly straight-forward. The system is composed of a 12 volt, 20 amp power source and controller, a peristaltic

pump and a chemical reservoir. The positive lead connects to the work piece (anode) and the negative lead connects to the scrub shoe, where the electrolyte is delivered and worked across the surface of the contaminated item. The scrub shoe contains a switch to deliver additional electrolyte and a 3M ScotchBrite™ pad to facilitate scrubbing the surface. The electrolyte is delivered and worked on the surface until a certain electrical potential is achieved, at which point either more electrolyte is used, or the surface is found to be clean. This system is expected to cost between \$5,000 and \$10,000; with chemical costs of about \$30 per gallon.

The system actually incorporates several well known decontamination techniques. First, it uses mechanical abrasion in the form of scrubbing. Second, it takes advantage of the electrochemical attraction of the predominantly positive radionuclides. This tends to draw the contaminants towards the negatively charged scrub shoe (cathode), away from the metal surface, which will be connected to the positive anode. The electrochemical action also degrades the surface of the metal and causes a small amount of corrosion. Third, the electrolyte dries to a strippable coating and encapsulates the contaminants for later removal.

Another advantage of this system is the type of waste that is produced. No hazardous chemicals are used in the decontamination gel. The gel is composed of a latex binder with proprietary electrolytes for decontamination. When the decontamination is visually complete, a thin layer of the gel is dispensed to “cap” the spent waste solution. This purple coating dries in about 1 1/2 hours to a yellow color. Once dry, the rubbery patch may be removed by lifting it’s edges and “stripping” the coating.

2.4 Criteria for Evaluation

The two decontamination methods were evaluated in two ways. First, simulated contamination coupons (SIMCON) were supplied to both vendors and cleaned according to their standard methods at their facilities. The second part of the evaluation used a criteria matrix to judge the value of the system. This criteria takes into account such variables as waste produced and costs. The two vendors were asked to respond to the matrix with a short (one or two sentence) justification on each criteria. The criteria were then judged by the INEEL staff to arrive at an overall evaluation. On the basis of these evaluations, interest may be expressed in further demonstrations or purchase of equipment. The criteria for assessing decontamination technologies were established in September 1992 for evaluating technologies available for decontaminating equipment and facilities at the INTEC⁷. These criteria have been expanded and updated to include information considered important in the comparison of various decontamination techniques. The criteria have been put into a decision tree and a matrix format. Each technique is scored between 1-10 based on a positive (up to 10) or a negative (to 1) evaluation of that criteria for the technique. A ranking of 5 is used as a baseline comparison; i.e. the current technology would represent at least a 5 in any given category. In most cases the baseline technology for comparison is chemical decontamination which achieved a 6.7 overall score. If no response was available, the result is scored as a 5 (neither positive nor negative). The ranking was multiplied by the weighting factor to determine the score in the overall category.

The criteria matrix consists of five categories, which are subdivided into three to five items each. These five criteria are: Technical Performance, Waste Considerations, Environmental, Safety and Health, Additional Costs, and Remote (robotic) Application. The full criteria and explanation that satisfy each of the five categories is shown in Appendix A. Each technique is scored on each multiple, sub-criteria by INEEL staff that are familiar with decontamination technologies. The various scores are then compiled and shown in Section 3.2 of this report.

3. THE EVALUATION OF DECONTAMINATION METHODS

3.1 SIMCON Effectiveness Testing

The two decontamination methods were tested using SIMCON coupons to determine their comparative effectiveness at removing the surrogate contaminants. This testing occurred at the vendors facility, Universal Ice Blast in Renton, Washington and ADA Technologies in Littleton, Colorado. Each vendor was instructed to perform the decontamination under their typical type of setup and procedures, and to take photographs and video to record their actions. Some of the photographs have been reproduced in appendix of this report, and the videos are available at the INEEL.

SIMCON II coupons have non-radioactive cesium and zirconium salts baked onto the surface to simulate fixed contamination. The amount of cesium and zirconium salts on the surface of the coupons is determined using X-ray fluorescence before and after they are put into the decontamination process. A wide variation exists in the initial quantity of salts adhered to the surface of the coupons. However, each coupon is numbered and tracked so that only the relative removal (before and after analyses) is important and consistency is maintained in this manner. This is attributed mostly to the vigorous (though inherently inconsistent) hand scrubbing they undergo to remove loose contaminants after baking. These coupons have been used at the INEEL to determine the effectiveness of many types of decontamination techniques (laser ablation, CO₂ pellet blasting, alternative chemicals, abrasives, strippable coatings, etc.) prior to using the techniques in radioactive environments⁸.

Over 1000 coupons have been prepared and tested using the various methods evaluated by the RLWR group. During these evaluations, two observations have surfaced which were also noted in the tests detailed in this report. First, physical cleaning methods (non-chemical methods such as abrasive blasting) tend to preferentially remove the zirconium salts. This has been observed for several hundred coupons in all 15 non-chemical methods tested. Chemical methods tend to remove cesium preferentially. These differences were consistent with the tests of the quasi-chemical method of ADA Technologies coating and the physical method of Universal Ice Blasting Incorporated. We theorize that this is partly due to the mobility of the small cesium molecules, which tend to stabilize in the porous surface of the metal and not be as amenable to surface abrasion. However, the zirconium is less soluble in most decontamination chemicals (high fluoride solution excepted), and therefore more difficult to chemically dissolve. These observations have never been tested (as our primary objective has been engineering evaluations) and could prove an interesting scientific study.

3.1.1 ADA Technologies SIMCON Test Results

ADA Technologies performed well in the SIMCON testing portion of this evaluation. This electrochemical method is not fully developed and does not compete firmly against the fully functional commercial techniques of abrasive blasting. However, the ADA technology did a satisfactory job of removing the SIMCON Contaminants, with an average of 92% removal of cesium and 89% removal of zirconium (under standard conditions). This result is quite high when compared with traditional chemical techniques, and higher than most mechanical methods. A typical chemical decontamination would remove 85% of the cesium and 30% of the zirconium; and average mechanical method removes 78% of the cesium and 92% of the zirconium⁹. The results of the different parameters and overall effectiveness are shown in Table 1. The raw data is collected in Appendix B.

The ADA technology is not well suited for use in a test of a one inch coupon. It was designed to be used on several square foot patches of contamination on stainless steel. This fits well to it's original

intended purpose of a small decommissioning activity in a glovebox type application. This is not to prohibit its use as a general decontamination technique, and this technique is well within the scope of this

Table 1, ADA Technologies Electrochemical Decontamination Technology

Testing Parameter	Cs, SIMCON Percent Removed	Zr, SIMCON Percent Removed
Standard conditions	92	89
Extra time treatment	98	95

project. It is simply that ADA’s technology may have been at a disadvantage in these tests. Also noted was the fact that a “lip” of difficult area was encountered on the surface of the coupons during ADAs testing. This is a result of punching the one inch coupons from the sheet during manufacture. ADA noted that it was difficult to treat these depressions in the coupons. This may represent more of a “real world” scenario though, because welds and seams are quite common. This has not been a concern before with more commercially available techniques and will be evaluated during future testing.

Based on the results from the SIMCON coupons, this method shows significant promise and with additional development should produce even greater effectiveness. The INEEL has begun discussions with ADA to cooperate on development of their electrochemical.

3.1.2 Universal Ice Blast, Inc. SIMCON Test Results

Universal Ice Blast, Inc. performed very well in the SIMCON tests portion of this evaluation. At their optimal conditions, they achieved nearly complete decontamination of the SIMCON coupons. Their best campaign on SIMCON coupons averaged 92% removal of cesium and greater than 98% removal of zirconium. This corresponds to decontamination factors of 12 and 42, respectively. These are quite high and demonstrate the power of this technique. As noted earlier, the preferential removal of zirconium is consistent with other blasting methods that have been tested before. The testing results are tabulated in Table 2. The raw data is collected in Appendix C.

Table 2, UIBI Ice Blasting Decontamination Technology

Testing Parameter	Cs, SIMCON Percent Removed	Zr, SIMCON Percent Removed
80 psi, 90 degrees, 10 sec.	88	≥97
80 psi, 45 degrees, 10 sec.	82	≥97
115 psi, 90 degrees, 10 sec.	88	≥98
115 psi, 90 degrees, 20 sec.	91	≥98
150 psi, 90 degrees, 30 sec.	92	≥98

At the optimal conditions of 150 psi blast pressure, 90 degree angle to the surface and 30 seconds of operation, the SIMCON coupons are nearly completely decontaminated. This places UIBI near the top of it's class in terms of cleaning efficiency. It clearly is an improvement over dry ice blasting (63% Cs, 78% Zr), while providing some of the advantages of the lower waste dry ice blasting method.⁹ While the results are not quite as high as the more aggressive abrasive blasting techniques (which typically leave no contamination), there is some significant advantages to using ice (melting to water) instead of an abrasive grit⁸.

3.2 CRITERIA EVALUATION

Both Vendors responded to the INEEL criteria questionnaire and provided sufficient detail to permit an evaluation of their decontamination method for the INEEL reviewers. Any additional information needed was provided via telephone (and noted on the response). The questionnaires and the responses from the vendors are included in Appendix B and C. The three reviewers are current or former RLWR Group members and are familiar with decontamination techniques. The reviewers scored the responses appropriately; from 1 to 10, with 10 being the most advantageous response and achieving all of the desired advantage for that criteria. The reviewers were also guided by previous results for five other decontamination methods. The overall evaluation scores are shown in Table 3. The raw data for the 36 separate criteria and sub-criteria were tabulated and are shown in Appendix A.

Table 3, Criteria Evaluation Scores for ADA and UIBI.

Criteria	ADA	UIBI
Technical Performance	8.2	8.7
Waste considerations	6.6	7.5
Environmental, Safety and Health	7.5	8.7
Costs	8.0	9.4
Remote Applicability	7.5	8.7
Total Score	7.7	8.5

4. SUMMARY OF RESULTS AND RECOMMENDATIONS

The results of this evaluation demonstrate that both of these decontamination methods are valuable additions to the decontamination toolkit. The Universal Ice Blast, Inc. ice blasting system is a versatile and effective method of removing contamination. It is a robust system that has demonstrated it's effectiveness at various locations with many different contaminants. Blasting radioactive contamination has disadvantages; however, if the ventilation is managed well, it is a worthwhile technique. The ADA Technologies electrochemical cleaning system was very effective at removing the contaminants, but not quite as effective as the UIBI system. However, it may have an advantage in waste reduction over chemical systems, because it forms a strippable coating, and therefore could be

quite useful and save on liquid waste. The authors do not believe that the score of 6.6 reflects advantage of a strippable coating waste form. However, the reviewers did not judge this as a strong advantage and it retains a lower score than the UIBI system.

For large scale decontamination, like decommissioning projects, the ice blasting technique is the better choice. The waste production is much less than with chemical, or even water jet cleaning, but greater than dry ice blasting and strippable coatings. It is amenable to most INEEL processes, which use aqueous waste collection systems and have 15 Kilowatt power sources available. In some locations, this type of electrical service and ventilation systems are not available. Ice blasting is not a robotic technique, and some ALARA concerns with airborne contamination and working in high radiation fields need to be addressed. Overall, there were very few disadvantages of the ice blasting system, and no real drawbacks were identified, as reflected in the relatively high scores accorded this technique.

The electrochemical technique of ADA Technologies is an attractive decontamination method that needs some development before it is truly functional. The reviewers indicated that it is probably not robust and “foolproof”. While the ADA system may not be foolproof, it requires far less utilities than the UIBI system. It may never be as versatile and foolproof as a blasting system, but the strippable coating waste consideration may cause it to be a better choice. This advantage could be significant, as our site priorities are still to reduce liquid waste and stop using our underground tanks. However, one of the reviewers was unsure whether there was any advantage to the solid waste form of the ADA method. Also, since it uses a chemical formulation, the costs of operation could be significantly greater than using the ice blasting technique, which uses water.

While both of these decontamination systems clearly have advantages and disadvantages, the easy choice for routine use with guaranteed results, is the Universal Ice Blast, Inc. ice blasting system. It was the winner in effectiveness and also in nearly every category of this criteria evaluation. The ADA system was not clearly as versatile, but remains viable, with very good scores on most criteria. For these reasons, it is recommended that the UIBI ice blasting system be purchased, or at least demonstrated on site, when funding becomes available. Further development should proceed on the ADA Technologies’ electrochemical system and further optimization and testing be investigated, possibly as a cooperative venture.

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**APPENDIX A, CRITERIA MATRIX DESCRIPTIONS, RESPONSES AND
RAW SCORES FOR ADA TECHNOLOGIES AND UNIVERSAL ICE
BLAST, INC.**

Criteria Responses from ADA Technologies

2.1 Technical Performance Criteria (28.0%)

The first non-mandatory category is Technical Performance. Cost related items in this category account for 11.8% out of the 28% weighting factor. This category is broken down into the following three areas:

2.1.1 Operability/Simplicity (36.7%)

To enable measurement of the easiest to operate and simplest decontamination techniques, this area was broken down into the following ten categories:

Plant Utilities Available - Decontamination techniques not requiring modifications to existing plant utilities are preferred. (14.0%)

ADA's electrodecontamination system uses 120 VAC line voltage, and draws less than 2 amps. No other facility mods are necessary.

Operator Training Time - Decontamination techniques that are simpler to operate (i.e. require less training time) are preferred. (5.1%)

Operator training consists of learning to set up the equipment (plug in, connect hoses and electrical connectors, and attach electrolyte container) and to decontaminate an area. Decontamination may be thought of as similar to "painting". Some operator "skill" is required to leave behind a sufficient gel layer to permit post-cure peeling, but this is mastered with a little practice.

Equipment Set-up Time - Decontamination equipment requiring less time to prepare for operation is preferred. (6.7%)

Equipment set-up takes less than 10 minutes, and is very simple (connecting a hose and some keyed electrical connectors). Connectors are sized to make wrong set-up impossible. Connectors are also selected for ease of handling while wearing full PPE.

Pre-conditioning Time - Decontamination techniques not requiring any type of pre-treatment (i.e. water blasting) are preferred. (9.6%)

No preconditioning or pretreatment are required.

Equipment Clean-up Time - Decontamination equipment requiring less or simpler cleaning is preferred. (6.2% - cost related)

Equipment is designed for staged disposal. If desired, system may be fully cleaned by water flush. If not, pieces may be removed beginning with the scrub pad, then the handle, tether, and complete pump unit. Entire unit cost is not prohibitive to throw away (approx. \$5K), and select pieces may be replaced if desired. Disposal is graded to match the extent of contamination and economics of worker time.

System Clean-up Time - Decontamination techniques having minimum impact on surrounding systems (i.e. off-gas systems) are preferred. (14.7%)

See above. Cured electrolyte is simply peeled off the surfaces to which it has been applied. Removal difficulty varies with part geometry, etc.

Maintainability - Decontamination equipment requiring a minimum amount of maintenance is preferred. (14.9%)

System is modularized to allow replacement of pieces as required. No maintenance is required.

Number of Operators Required - Decontamination equipment requiring the least number of operators is preferred. (4.9%)

Aside from standard radiological support personnel, the system is highly portable and may be easily handled by a single operator.

Fieldability - Decontamination equipment adjustable to use in the field is preferred. (14.4%)

ADA's electrodecon unit is specifically designed as a portable unit to be deployed at the contamination source. The unit has overload protection, short circuit (anti-spark) protection, hydraulic over pressure relief, and an anti suck-back (check) valve to completely protect the worker and facility.

Flexibility - Decontamination techniques adaptable to a variety of situations (i.e. insitu, exsitu) to remove varying degrees of material (i.e. remove substrate or just clean delicate items) are preferred. (11.8%)

The system is designed for spot cleaning (areas of 9 square feet or less per electrolyte pack, and electrolyte packs are easily exchanged), and difficult areas such as threads, cracks, corners, and general holdup areas. The quantity of material removed varies with the time electrodecontamination is carried out on a given spot.

Required Development (20.0%)

To aid in determining the decontamination methods requiring the least amount of development, this area was divided into the following four categories:

Probability of Success - Decontamination techniques with a high probability of successful application to the ICPP problems are preferred. (38.3%)

The electrodecontamination system has been shown to clean non-radioactive surrogates. No remaining technological hurdles remain, simply some additional hardware evolution.

Test Facilities - Decontamination techniques not requiring the use of extensive test facilities (i.e. pilot plants) are preferred. (28.3%)

ADA is currently searching for a location for testing using radioactive contamination. Existing facilities are fine; a new plant, extensive facility mods, etc. are not required.

Development Time and Scope - Decontamination techniques requiring a minimum of development time with a limited scope are preferred. (8.3%)

ADA's system is available now; (desired) additional development/optimization could be achieved within six months.

Transferrable Technologies - Decontamination techniques applicable to a variety of other locations (i.e., other DOE facilities or industry) are preferred. (25.0%)

The electrodecontamination process is being explored for use in auto body rust removal, weld surface preparation, and owing to the bacteriocidal electrolyte, medical decontamination.

2.1.3 Cleaning Effectiveness (43.3%)

To aid in determining the decontamination methods providing the best cleaning, this area was divided into the following five categories:

Variety of Materials - Decontamination techniques with the ability to clean a variety of substrate materials are preferred. (11.0%)

ADA believes the system will be effective on any electrically conductive substrate. Further testing is planned.

Variety of Configurations - Decontamination techniques with the ability to clean a variety of configurations (i.e., pipes, valves, flat surfaces) are preferred. (21.0%)

The system will work on flat surfaces, threads, cracks, corners, etc. The system may also be deployed in inert atmospheres with no ill effects, decontamination is not effected.

Variety of Contamination - Decontamination techniques with the ability to clean a variety of contaminants (i.e., alpha, beta, greases, oils, corrosion products, dirt) are preferred. (19.0%)

Electrodecontamination is a "brute force" cleaning method, i.e. it will strip off all surface constituents—corrosion, contamination, oil, grease, paint, etc. The sole requirement is that an electrical path be established for the process to begin. Thick coatings of paints, oxides, plastic, will present a problem if electrical contact cannot occur.

Cleaning Rate - Decontamination techniques that clean faster are preferred. (21.0%)

Rate has not been determined.

Decontamination Factor - Decontamination techniques with the ability to reach the desired endpoint in a single pass are preferred. (28.0%)

Research using strippable coating ONLY has shown decon factors around two to four orders of magnitude. This system also removes fixed, so even greater factors are anticipated.

2.2 Waste Considerations Criteria (25.0%)

The second non-mandatory category is Waste Considerations. Cost related items in this category account for 19.2% out of the 25%. This category is broken down into the following three areas:

2.2.1 Recycling Capabilities (23.3%)

Decontamination techniques allowing the recycle of materials are preferred.

Electrolyte may not be recycled. The system equipment may be used repeatedly, and makes use of no other items that lend themselves to “recycling.”

2.2.2 Volume of Secondary Waste (30.0%)

Decontamination techniques generating the minimum amount of secondary waste are preferred. This includes the cost to dispose of the various types of waste. As an aid in determining the rankings the following information is needed.

The generation of hazardous non-radioactive waste is preferred over other wastes (except for clean). The generation of low-level radioactive waste is preferred over high-level or mixed waste. The generation of high-level radioactive waste is preferred over mixed waste. The generation of mixed waste is the least preferred. It is also important to remember, in general, solid waste is preferred over liquid waste and gaseous waste is generally the easiest form for the ICPP to treat.

2.2.3 Compatibility with ICPP Waste Treatment Systems (46.7%)

Decontamination techniques generating waste compatible with existing ICPP waste treatment systems are preferred.

The final waste form produced is a dry, cured plastic film with embedded contamination fully entrained in the layer. The cured plastic film will support combustion if ignited. The waste form should be suitable for the same waste stream as hot PPE, plastic houses, containment plastic, etc. The waste form is not mixed, and high- or low-levels are determined by the amount of contamination entrained in the coating.

2.3 Environmental, Safety and Health Criteria (19.0%)

The third non-mandatory category is Environmental, Safety and Health. Cost related items in this category relate to 12.0% out of the 19.0%. This category is broken down into the following three areas:

2.3.1 Ease of Environmental Compliance (46.7%)

To aid in determination of the techniques which create less problems in compliance with environmental regulations, this area has been broken down into the following three areas:

Final Waste Form - Decontamination methods creating waste easily converted into an environmentally acceptable final waste form are preferred. (50.0%)

The final waste form is a dry, cured plastic film with the stripped contamination embedded within. This is a normal, routine waste form for most sites.

Closure Plans - Decontamination methods allowing easier development and approval of closure plans are preferred. (23.3%)

Electrodecontamination may be used to remove hot trouble spots in facilities slated for closure, to clear the facility in advance of general D&D.

Permits - Decontamination methods which can be permitted easier/faster are preferred. (26.7%)

ADA does not believe any special permitting is required to use electrodecontamination.

2.3.2 Ease of Safety Compliance (16.7%)

To aid in determination of the techniques which create less safety compliance problems, this area has been broken down into the following three areas:

Special Requirements - Decontamination techniques requiring a minimum of special safety controls (such as interlocks on lasers) are preferred. (46.7%)

No special preparations or safety controls are required.

OSHA - Decontamination techniques meeting OSHA requirements with a minimum of controls are preferred. (16.7%)

ADA has not reviewed the OSHA requirements for decon, but is not aware of any controls imposed by the law. In fact, the electrodecontamination process is specifically designed for ease of deployment and worker safety, in support of OSHA objectives.

Safety Documentation - Decontamination techniques requiring a minimum amount of safety documentation to address concerns (criticality, chemical, electrical, optical, radiological) are preferred. (36.7%)

ADA's system includes electrical and hydraulic controls to protect worker safety (short circuit, overload, pump over pressure relief, etc). These systems are built in and automatic requiring no worker input. Electrolyte gel is packaged in small quart Cubitainer packages having an inherently safe criticality geometry in the unlikely event the used container were accidentally filled with fissile solution. The

system does not pump or transport nuclear contamination internally, so holdup, etc. is of no concern. A worker's user manual is being prepared to teach operators how to use the system.

2.3.3 ALARA Considerations (36.7%)

Decontamination techniques minimizing exposure to personnel are preferred.

Electrodecontamination is relatively rapid, and places a barrier layer over contamination making areas safer for workers. A prime driver for ADA's development work is in support of ALARA, as hot spots that elevate workers' general exposure may be removed.

2.4 Additional Cost Criteria (16.0%)

The fourth non-mandatory category is Additional Costs. Costs are distributed throughout the matrix as noted in the "cost-related" comments. The total cost related items account for 68% of the overall evaluation. This category is broken down into the following five areas:

2.4.1 Development (34.0%)

Decontamination techniques requiring minimum development costs are preferred.

ADA's system has been technically proven as feasible, some remaining development work will focus on improving speed and effectiveness based upon information discovered during the research to date.

2.4.2 Chemicals/Materials (14.0%)

Decontamination techniques requiring a minimum chemical/material cost for ongoing operations are preferred.

The basic system is anticipated to cost between \$5k and \$10k, with the electrolyte costing around \$150 per five gallons. These numbers are crude and may be adjusted upward somewhat.

2.4.3 Equipment (19.0%)

Decontamination equipment requiring a minimum expenditure is preferred.

See above.

2.4.4 Labor (25.0%)

Decontamination equipment requiring a minimum expenditure for labor is preferred.

The system will require at least one operator charging at the normal hourly rate to operate the system.

2.4.5 Utilities (8.0%)

Decontamination techniques requiring minimum utility costs are preferred.

ADA's system is powered on line power (120 VAC, 2 amps). No other utilities are necessary.

2.5 Remote Applicability Criteria (12.0%)

The fifth non-mandatory category is Remote Applicability. This category is broken down into the following three areas:

2.5.1 Development Time (23.3%)

Decontamination techniques requiring the minimum time required to adapt to remote work are preferred.

Question is unclear. ADA believes the system could be readily adapted for robotic deployment if desired, cost and lead time are unknown.

2.5.2 Development Costs (30%)

Decontamination techniques requiring the minimum cost to adapt for remote work are preferred.

ADA believes robotic deployment could be achieved relatively easily, even using the existing portable system.

2.5.3 Advantages (46.7%)

Decontamination techniques creating the maximum advantages by using them remotely are preferred.

Electrodecontamination permits true surface decontamination through the removal of *both* fixed and smearable contamination with a minimum of physical exertion, certainly within the realm of most

Criteria Responses from Universal Ice Blast, Inc.

Technical Performance Criteria (28.0%)

2.1.1 Operability/Simplicity (36.7%)

To enable measurement of the easiest to operate and simplest decontamination techniques, this area was broken down into the following ten categories:

Plant Utilities Available - Decontamination techniques not requiring modifications to existing plant utilities are preferred. (14.0%) The ice blast process requires water (20 GPH), electrical power (15 kW) and compressed air (280 CFM). Air supply from any sand blasting operation can be used for ice blast. Note: The system requires a 50 amp, welding outlet.

Operator Training Time - Decontamination techniques that are simpler to operate (i.e. require less training time) are preferred. (5.1%) Any person with experience in sand blasting or water blasting can transfer the skill immediately to ice blasting. We also offer a one-day operator training program for operating the equipment as well as basic blasting techniques.

Equipment Set-up Time - Decontamination equipment requiring less time to prepare for operation is preferred. (6.7%) Ice blast machines require about a one-minute startup time. There is no media preparation, transfer and loading. Just connect the machine to air, water and electricity.

Note: The system is fully operational 2 minutes after being turned on.

Pre-conditioning Time - Decontamination techniques not requiring any type of pre-treatment (i.e. water blasting) are preferred. (9.6%) None.

Equipment Clean-up Time - Decontamination equipment requiring less or simpler cleaning is preferred. (6.2% - cost related) Ice blast machines can be remotely located, up to 200' from the blasting area, to minimize machine contamination. The machine can be decontaminated by ice blasting itself.

System Clean-up Time - Decontamination techniques having minimum impact on surrounding systems (i.e. off-gas systems) are preferred. (14.7%) Plastic curtains can stop mist drift and contain blast spray.

Maintainability - Decontamination equipment requiring a minimum amount of maintenance is preferred. (14.9%) Ice blast machines are based on the two most reliable industrial components: refrigeration and ice making. Our entire food supply infrastructure depends on their reliability and maintainability. In fact, Ford has approved ice blast as a process meeting its newly established Reliability & Maintainability criteria.

Number of Operators Required - Decontamination equipment requiring the least number of operators is preferred. (4.9%) Same as any blasting operation. Unlike water blast, there is no requirement for additional labor to manage the huge volume of waste generated.

Note: The system requires only one operator.

Fieldability - Decontamination equipment adjustable to use in the field is preferred. (14.4%) Ice blast machines can be truck-mounted. Such mobile ice blast systems provide field or on-site industrial

cleaning. Currently there are truck mounted field units in California, Michigan, Ohio, Washington D.C. , Australia & Holland.

Flexibility - Decontamination techniques adaptable to a variety of situations (i.e. insitu, exsitu) to remove varying degrees of material (i.e. remove substrate or just clean delicate items) are preferred. (11.8%) Ice blast is not abrasive, therefore does not damage substrate. The blast pressure can be regulated to offer light decon or aggressive decon.

2.1.2 Required Development (20.0%)

To aid in determining the decontamination methods requiring the least amount of development, this area was divided into the following four categories:

Probability of Success - Decontamination techniques with a high probability of successful application to the ICPP problems are preferred. (38.3%) Ice blast machines have proven reliability in other industrial cleaning applications. Compared to sand blasting, ice blast does not generate solid waste and has much lower airborne readings. Compared to water blast, ice blast provides physical scrubbing on impact to achieve a much higher level of decontamination.

Test Facilities - Decontamination techniques not requiring the use of extensive test facilities (i.e. pilot plants) are preferred. (28.3%) Ice blast can be used in any existing blasting cleaning facility. Ice blast is used extensively in both fixed facility and field environments.

Development Time and Scope - Decontamination techniques requiring a minimum of development time with a limited scope are preferred. (8.3%) The manufacturer of the ice blast units has extensive engineering capability to build turn-key systems. They are in the process of designing and building the first automated ice blast gear cleaning production line for Ford. Much of the knowledge from sand or water blasting can be readily transferred to ice blast in decontamination.

Transferrable Technologies - Decontamination techniques applicable to a variety of other locations (i.e., other DOE facilities or industry) are preferred. (25.0%) Ford has initiated a program to replicate ice blast throughout Ford Powertrain Operations worldwide. Within the DOE facilities, there is generally good experience in sand and water blast operations. Ice blast can be transferred and implemented through the DOE with a minimum of retraining.

2.1.3 Cleaning Effectiveness (43.3%)

To aid in determining the decontamination methods providing the best cleaning, this area was divided into the following five categories:

Variety of Materials - Decontamination techniques with the ability to clean a variety of substrate materials are preferred. (11.0%) Ice blast is not abrasive. It has been used to clean a variety of materials including steel, soft metal, glass, plastic, stone and masonry, rubber, etc.

Variety of Configurations - Decontamination techniques with the ability to clean a variety of configurations (i.e., pipes, valves, flat surfaces) are preferred. (21.0%) Ice blast routinely clean machinery, conveyors, pumps and motors, valves and pipes, ducts and vents, buildings, and large tanks.

Variety of Contamination - Decontamination techniques with the ability to clean a variety of contaminants (i.e., alpha, beta, greases, oils, corrosion products, dirt) are preferred. (19.0%) ORNL found

that ice blast could remove alpha, beta and gamma, as well as oil and grease removal, loose rust removal, and removing the oxide layer from lead bricks for decon purposes.

Cleaning Rate - Decontamination techniques that clean faster are preferred. (21.0%) The design of the ice blast units is modular. By doubling up the ice making capacity, we can double up the production rate. Also production rate increases with increasing blast air pressure.

Decontamination Factor - Decontamination techniques with the ability to reach the desired endpoint in a single pass are preferred. (28.0%) Decon factors depend on the nature of the contamination, the dosage and the complexity of the surface structure. In general, much experience is available with water blast decon. As ice blast is fundamentally superior to water blast for decon purpose, due to the scrubbing ability of the ice particles on impact, it will be relatively simple to develop a procedure to provide desired endpoints, based on water blast experience.

2.2 Waste Considerations Criteria (25.0%)

The second non-mandatory category is Waste Considerations. Cost related items in this category account for 19.2% out of the 25%. This category is broken down into the following three areas:

2.2.1 Recycling Capabilities (23.3%)

Decontamination techniques allowing the recycle of materials are preferred. Ice is the solid phase of water. On impact, ice particles disintegrate into water. Water can be filtered or treated for reuse again to make ice. However, the volume of water required for ice blast is minimal, to the extent of about 20 GPH.

2.2.2 Volume of Secondary Waste (30.0%)

Decontamination techniques generating the minimum amount of secondary waste are preferred. This includes the cost to dispose of the various types of waste. As an aid in determining the rankings the following information is needed.

The generation of hazardous non-radioactive waste is preferred over other wastes (except for clean). The generation of low-level radioactive waste is preferred over high-level or mixed waste. The generation of high-level radioactive waste is preferred over mixed waste. The generation of mixed waste is the least preferred. It is also important to remember, in general, solid waste is preferred over liquid waste and gaseous waste is generally the easiest form for the ICPP to treat. Ice particles melt to water, which can be treated for reuse. Alternatively this liquid waste can be disposed off. However, the volume of residual water from a typical ice blast operation is only 5-10 GPH. As ice particles shatter on impact, much of the blast mist evaporates into water vapor. The ice blast process in fact is double phase transition process: ice melts to water, water evaporates into vapor. Hence, much of the liquid waste can be made to turn into gaseous waste for ICPP handling. A higher blast air pressure normally promotes evaporation. We have found that warm blast air can reduce the liquid waste volume significantly. Compressors normally have an internal aftercooler to cool the hot air exiting the compressor. Bypassing the aftercooler provides warm blast air. In practice, less than 1 GPH liquid waste generation is possible with proper design of operating parameters. ORNL determined that ice blast did not generate mixed waste based on TCLP tests. Note: HEPA filters may become saturated with water due to high vapor quantity.

2.2.3 Compatibility with ICPP Waste Treatment Systems (46.7%)

Decontamination techniques generating waste compatible with existing ICPP waste treatment systems are preferred.

2.3 Environmental, Safety and Health Criteria (19.0%)

The third non-mandatory category is Environmental, Safety and Health. Cost related items in this category relate to 12.0% out of the 19.0%. This category is broken down into the following three areas:

2.3.1 Ease of Environmental Compliance (46.7%)

To aid in determination of the techniques which create less problems in compliance with environmental regulations, this area has been broken down into the following three areas:

Final Waste Form - Decontamination methods creating waste easily converted into an environmentally acceptable final waste form are preferred. (50.0%) Waste from ice blast can be in liquid form for treatment so that it can be recycled. Or through enhanced evaporation, most of the liquid waste can be transformed into gaseous waste for simple handling.

Closure Plans - Decontamination methods allowing easier development and approval of closure plans are preferred. (23.3%)

Permits - Decontamination methods which can be permitted easier/faster are preferred. (26.7%) Ice blast combines the benefits of sand blast and water blast without the generation of solid waste and PM (Particulate Matter) and a huge volume of liquid waste. Existing permits for sand blasting and water blasting should be sufficiently broad to cover ice blast operation.

2.3.2 Ease of Safety Compliance (16.7%)

To aid in determination of the techniques which create less safety compliance problems, this area has been broken down into the following three areas:

Special Requirements - Decontamination techniques requiring a minimum of special safety controls (such as interlocks on lasers) are preferred. (46.7%) Ice blast is sufficiently similar to sand blasting and water blasting that all safety procedures and requirements for safe and proper use of ice blast should be already imbedded in existing safety controls.

OSHA - Decontamination techniques meeting OSHA requirements with a minimum of controls are preferred. (16.7%) In hazardous material decontamination, airborne exposure to workers is a major OSHA concern. Sand blasting creates serious PM levels and dispersion. In a pilot project, NYSDOT confirmed that airborne readings during ice blast operation were sufficiently low that only half-mask protection was required, as opposed to full-face with air supply for sand blasting operation. Compared to water blast, ice blast pressures are much lower to reduce worker fatigue and the potential incidence of injury.

Safety Documentation - Decontamination techniques requiring a minimum amount of safety documentation to address concerns (criticality, chemical, electrical, optical, radiological) are preferred. (36.7%) As a result of the generally low airborne readings and the low waste generation during the NYSDOT pilot project, NYSDOT now does not require negative air; class A containment for ice blast operation.

2.3.3 ALARA Considerations (36.7%)

Decontamination techniques minimizing exposure to personnel are preferred. See item above.

2.4 Additional Cost Criteria (16.0%)

The fourth non-mandatory category is Additional Costs. Costs are distributed throughout the matrix as noted in the "cost-related" comments. The total cost related items account for 68% of the overall evaluation. This category is broken down into the following five areas:

2.4.1 Development (34.0%)

Decontamination techniques requiring minimum development costs are preferred. Ice blast machines are commercially available. These are proven industrial machines. In the DOE sector, labor skilled in the operation of sand blasting and water blasting can readily transfer their expertise to ice blast operation. Ice blast machines can be used in existing blasting facilities. Ice blast is a new technology requiring no wholesale change in operating procedures and support services.

2.4.2 Chemicals/Materials (14.0%)

Decontamination techniques requiring a minimum chemical/material cost for ongoing operations are preferred. No chemical additives are recommended in ice blast.

2.4.3 Equipment (19.0%)

Decontamination equipment requiring a minimum expenditure is preferred. Commercially available ice blast machines are cost competitive in the industrial cleaning industry. There are little hidden costs such as purchase, handling and disposal of large volumes of blast media. MSRP for a Model CX-91 is \$69,900, they have offered to sell one of these for less.

2.4.4 Labor (25.0%)

Decontamination equipment requiring a minimum expenditure for labor is preferred. Ice blast requires the same type of labor as sand blasting or water blasting, except it does not require additional labor to help manage the large volumes of waste generated during blasting.

2.4.5 Utilities (8.0%)

Decontamination techniques requiring minimum utility costs are preferred. Ice blast requires truly minimal utilities: 15 kW of electricity, 280 CFM of air and 20 GPH of water.

2.5 Remote Applicability Criteria (12.0%)

The fifth non-mandatory category is Remote Applicability. This category is broken down into the following three areas:

2.5.1 Development Time (23.3%)

Decontamination techniques requiring the minimum time required to adapt to remote work are preferred. Ice blast machines can operate up to 200' away from the place of decon operation. We have truck-mounted systems comprising an ice blast machine, a genset and a diesel air compressor for field or remote work. Time to set up is mainly time to connect to available services, and to connect hoses.

2.5.2 Development Costs (30%)

Decontamination techniques requiring the minimum cost to adapt for remote work are preferred. Truck-mounted ice blast systems are available. The US Naval Public Works in Washington, D.C. has such a system for the abatement of lead-based paint in military buildings.

2.5.3 Advantages (46.7%)

Decontamination techniques creating the maximum advantages by using them remotely are preferred. Many items requiring decon are large and not easily moved into decon buildings. Mobile ice blast systems are ideal for such applications. Set up a temporary enclosure for ice blast operation to contain blast debris. The waste minimization aspect of ice blast makes such remote operation feasible. As diesel compressors produce relatively hot air, and by by-passing the aftercooler, this air will cause almost total evaporation of the liquid waste.

A recent case in point: Envirocare of Utah contracted UIBI to perform a decon test on contaminated rail cars. The test was arranged so that the ice blast system was operated outside the “restricted” or contaminated area. This required the entire ice blast system to be completely portable.

A 16 foot flat bed truck was used to transport the diesel generator, ice blast unit, hoses and water delivery system. A portable diesel air compressor was used to provide the compressed air source.

The environment was relatively harsh. The ice blast system was operated in the field exposed to 100°F ambient temperature and 15 to 25 mph wind gusts, which stirred up volumes of dust from the desert floor. The water supply was outside optimal specifications (80°F temp) and the compressed air source was exceeding temperatures of 150°F.

150 lineal feet of ice/air delivery hoses were used to reach the work area. The hoses are non-insulated and were exposed to ambient heat from direct sunlight and radiant heat from the desert floor.

The system was engaged and ran for the entire duration of the test (approx 3 hours).

The test results show that ice blast process cleaned the surface contamination well below the specifications required for RTS use.

APPENDIX B, ADA TECHNOLOGIES REPORT

September 6, 2013

Dear Mr. Demmer:

We have completed the execution of our electrodecontamination process on the simulated contaminant coupons you provided to us. A total of 24 samples were run, and with two exceptions explained in the enclosed notes, were each subjected to identical processing.

Our tests were conducted in the ADA wet chemistry laboratory, and we have made no effort to artificially make the process look better through concentrated scrubbing or other cheating methods, as we are very interested in establishing a baseline performance. The process was carried out using the same equipment design and operating parameters that would be used at your facility in the future.

We are very interested in your assessment of our process, and any feedback and data you can supply would be greatly appreciated. We look forward to hearing from you soon.

Sincerely,

Bradley D. Veatch
Senior Research Engineer

Enclosure
pc:

SIMCON Decontamination Testing Notes

August 14, 2001

Testing to evaluate the effectiveness of ADA's electrodecontamination process on the simulated contaminants supplied by INEEL was conducted in the ADA wet chemistry laboratory located in Littleton, Colorado. A total of 24 samples were subjected to the process for 10 minutes each. It was clear from the testing that material was removed from the coupons, but the thickness of the simulant and its location in a concave pocket on the steel substrate made the cleaning effort more difficult. Nevertheless, the samples were run with the intent of establishing a baseline functional performance for ADA's process.

General Notes:

- 1.) Coupons appear to be punched from stainless steel sheet, with a pronounced concave dish where simulated contaminant was applied and apparently "fired" in an oven.
- 2.) Sample "contaminant" material is extraordinarily thick, on the order of mill scale. Contamination of this thickness [or baked on] would most likely be removed with a scraper prior to electrodecontamination with our process. Our process is intended to remove only the top few atomic layers from the substrate, along with other loose scale and surface debris.
- 3.) Both front and rear faces of the samples show significant surface pitting, similar to a hot rolled finish, making cleaning more difficult.
- 4.) Concave face shows spiral punch marks around the periphery.
- 5.) Samples were each run for 10 minutes with moderate rubbing to keep electrolyte fresh.
- 6.) The coupons were cleaned with our electrodecontamination process only; no scraping or other "cheating" processes were used for the samples.
- 7.) The equipment configuration used is the same as would be applied at present in hot tests at another facility (i.e. same cleaning shoe, power supply, electrolyte formulation, current densities, etc.)

- 8.) A test jig was created to secure and permit cleaning two buttons simultaneously, better using the cleaning shoe area and electrolyte.
- 9.) Following decontamination, the samples were rinsed with tap water.
- 10.) A total volume of 1/3 Quart of electrolyte was used for the tests, with the major part “lost” onto the jig and experiment table.

Specific Sample Notes:

Samples V1-V15 were cleaned in pairs on the test jig for 10 minutes with moderate scrubbing. Pad material was ScotchBrite Blending Pad 7446 for stainless steel. No special effort was made to dig the pad into the concave sample face. Shoe pressure was manually applied by the technician’s arm and hand, and is in line with those forces a normal male operator can supply. Current was measured and found to vary between 300 mA at the start to 800 mA near completion (as contaminant is removed, it exposes clean substrate allowing better electrical contact.) This yields a calculated current density of between 0.38 A/in² rising to 1.02 A/in² for the tests. The electrodecon system can maintain 2.22 A/in² continuously if required.

Sample V27 was the first sample randomly selected and used as the “learner” sample to ascertain how quickly the contaminant could be removed. Initially, the back side of this sample was cleaned to “get used” to the process and test fixture, and to get a feel for how the basic (clean) substrate would appear. The obverse (concave) sample side was run for 30 minutes with moderate scrubbing action. Current density was the same as for the samples above.

Sample V26 was cleaned for 20 minutes, again with no attempt to force or concentrate scrubbing in the center. Current densities were in line with those above.

Samples V28, V30, V46-V50 were cleaned in identical fashion to Samples V1-V15 above, with the same results.

These tests were conducted in good faith at the ADA wet chemistry laboratory, with no special intent or actions to make the process look or perform better than would otherwise be expected for a true field “hot” application. In service, more or less time might be used, along with other scrubbing shoe designs and

abrasive pads to enhance the cleaning action and better contact recessed surfaces, similar to the convex cup on these samples. Time was limited to 10 minutes for each sample (with two exceptions), simply to establish how well the process works and get a qualitative feel for the cleaning rate.

Special thanks are due to Mr. Ken Cramsey and Mr. Allan Carlson for their assistance in completing the test plan.

Bradley D. Veatch, PE

Research Engineer

ADA Technologies, Inc.

SIMCON Coupon data for ADA Technologies, Electrochemical Technique.

	Sample Name	Initial Conc. Cs ug	Final Conc. Cs ug	% Clean	Initial Conc. Zr ug	Final Conc. Zr ug *	%Clean
v-1	10 min.	211	14	93%	388	30	92%
v-2	10 min.	234	29	88%	293	60	80%
v-3	10 min.	316	29	91%	235	41	83%
v-4	10 min.	259	3	99%	162	3	98%
v-6	10 min.	151	25	83%	255	40	84%
v-7	10 min.	177	16	91%	220	29	87%
v-8	10 min.	187	13	93%	73	11	85%
v-9	10 min.	159	12	92%	188	22	88%
v-11	10 min.	163	8	95%	117	6	95%
v-12	10 min.	140	13	91%	236	26	89%
v-13	10 min.	109	8	93%	241	23	90%
v-15	10 min.	133	7	95%	128	7	95%
v-28	10 min.	140	3	98%	263	3	99%
v-46	10 min.	202	18	95%	293	28	95%
v-47	10 min.	90	13	86%	123	18	85%
v-49	10 min.	138	18	87%	395	47	88%
v-50	10 min.	116	15	87%	301	36	88%
		Average totals		92%			89%
v-26	20 min.	147	3	98%	79	4	95%
v-27	first coupon	184	5	97%	333	37	89%

* All 3 values are <3 ug

Criteria For Electrochemical

		Eval #1 Raw Score	Score 1	Eval #2 Raw Score	Score 2	Eval #3 Raw Score	Score 3	Average
	percent							
TECHNICAL PERFORMANCE (28.0%)	28.00		8.18		7.91		8.63	8.24
Operability/Simplicity (36.7%)	36.70		8.37		7.66		8.60	8.21
Plant Utilities Available (14.0%)	14.00	10.00	1.40	10.00	1.40	8.00	1.12	
Fieldability 11.6%	11.60	8.00	0.93	8.00	0.93	7.00	0.81	
Pre-conditioning required (9.6%)	9.60	10.00	0.96	10.00	0.96	10.00	0.96	
Equipment Set-up Time (6.7%)	6.70	9.00	0.60	8.00	0.54	8.00	0.54	
Equipment Clean-up Time (6.2%)	6.20	8.00	0.50	8.00	0.50	8.00	0.50	
System Clean-up Time (14.7%)	14.70	8.00	1.18	6.00	0.88	8.00	1.18	
Projected Maintenance Time Required (14.9%)	14.90	9.00	1.34	8.00	1.19	10.00	1.49	
Operator Training Time (3.1%)	3.10	7.00	0.22	6.00	0.19	8.00	0.25	
Number of op. Personnel (4.9%)	4.90	9.00	0.44	6.00	0.29	10.00	0.49	
Flexibility (insitu/exsitu) (11.6%)	11.60	5.00	0.58	5.00	0.58	9.00	1.04	
Required Development (20.0%)	20.00		9.24		8.94		8.94	9.04
Probability of Success (38.3%)	38.30	9.00	3.45	9.00	3.45	8.00	3.06	
Test Facilities Required (28.3%)	28.30	9.00	2.55	10.00	2.83	9.00	2.55	
Development Time & Scope (8.3%)	8.30	9.00	0.75	8.00	0.66	10.00	0.83	
Transferrable Technology (25%)	25.00	10.00	2.50	8.00	2.00	10.00	2.50	
Cleaning Efficiency (43.3%)	43.30		7.54		7.66		8.51	7.90
Variety of Materials (11.0%)	11.00	7.00	0.77	6.00	0.66	8.00	0.88	
Variety of Configurations (21%)	21.00	8.00	1.68	10.00	2.10	10.00	2.10	

Types of Contamination (19%)	19.00	8.00	1.52	7.00	1.33	7.00	1.33	
Cleaning Rate (21%)	21.00	5.00	1.05	5.00	1.05	8.00	1.68	
Decontamination Factor (28%)	28.00	9.00	2.52	9.00	2.52	9.00	2.52	
WASTE CONSIDERATIONS (25%)	25.00		8.40		6.87		5.90	7.06
Recycling Capabilities (23.3%)	23.30	7.00	1.63	5.00	1.17	5.00	1.17	
Compatibility w/ Waste Treatment Systems (46.7%)	46.70	10.00	4.67	9.00	4.20	5.00	2.34	
Vol. of Secondary Waste Generated (30.0%)	30.00	7.00	2.10	5.00	1.50	8.00	2.40	
ENVIRONMENTAL, SAFETY & HEALTH (19%)	19.00		8.16		7.65		6.75	7.52
Ease of Environmental Compliance (46.7)	46.70		9.53		8.57		7.03	8.38
Waste Form Accepted (50.0%)	50.00	10.00	5.00	9.00	4.50	5.00	2.50	
Closure Plans (23.3%)	23.30	8.00	1.86	6.00	1.40	8.00	1.86	
Permits (26.7%)	26.70	10.00	2.67	10.00	2.67	10.00	2.67	
Ease of Safety Compliance (16.7%)	16.70		9.01		8.64		7.54	8.40
Special Requirements (46.7%)	46.70	9.00	4.20	9.00	4.20	7.00	3.27	
Special OSHA Problems (16.7%)	16.70	9.00	1.50	9.00	1.50	8.00	1.34	
Safety Documentation Required/Time (36.7%)	36.70	9.00	3.30	8.00	2.94	8.00	2.94	
ALARA Considerations (36.7%)	36.70	6.00	6.00	6.00	6.00	6.00	6.00	6.00
COSTS (16%)	16.00		9.13		6.95		8.12	8.07
Development (34%)	34.00	9.00	3.06	8.00	2.72	8.00	2.72	
Chemicals/Materials (14%)	14.00	8.00	1.12	6.00	0.84	5.00	0.70	

Equipment (19%)	19.00	10.00	1.90	7.00	1.33	10.00	1.90
Labor (25%)	25.00	9.00	2.25	6.00	1.50	8.00	2.00
Utilities (8%)	8.00	10.00	0.80	7.00	0.56	10.00	0.80
REMOTE APPLICABILITY (12%)	12.00		7.53		7.00		8.00
Development Time (23.3)	23.30	8.00	1.86	7.00	1.63	8.00	1.86
Development Costs (30%)	30.00	8.00	2.40	7.00	2.10	8.00	2.40
Advantages (46.7%)	46.70	7.00	3.27	7.00	3.27	8.00	3.74
	total		8.31		7.01		7.43
							7.69

APPENDIX C, UNIVERAL ICE BLAST INCORPORATED REPORT

Universal Ice Blast, Inc. (UIBI)

Report no. 1070601

July 6, 2001

“Ice Blast Surface Decontamination Test”

Prepared in fulfillment of Bechtel BWXT Idaho, LLC (BBWI) Purchase Order no. 0000759

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Scope of Work:

Universal Ice Blast, Inc. (UIBI) report no. 1070601, prepared in fulfillment of Bechtel BWXT Idaho, LLC (BBWI) Purchase Order no. 0000759, per Statement of Work entitled: Scope of Work for Universal Ice Blast, Inc. Decontamination” as follows:

“Universal Ice Blast, Inc. (UIBI) will conduct surface stripping tests on surrogate coupons they will receive from the INEEL Radioactive Liquid Waste Group. The INEEL will supply five (5) plates with coupons glued to them. The plates will be nominally 4 or 5 inches square by ¼ inch thick, and will have 5 coupons glued to each plate, for a total of 25 coupons. The coupons will be made from 316 stainless steel and consist of 1 inch diameter disks a quarter inch thick. The coupons will be coated on one side with a mixture of non-radioactive, non-hazardous zirconium and cesium nitrate salts. The coupons will have been coated and baked at nominally 800 °C prior to supplying them to Universal Ice Blast, Inc.

Universal Ice Blast, Inc. will use their ice blasting process to attempt removing the surface coating from the coupons. UIBI will process the plates one at a time while varying the process parameters between plates so that the impact pressure, ice particle size, distance between nozzle and plate, angle of incidence, spray-time, etc. will be different between tests. The objective is not to vary all parameters independently, but rather, provide coupons back to the INEEL that vary in cleanliness from that achievable under routine to vigorous blasting conditions. One plate will be blasted under routine operating conditions comparable to those required to remove light to moderate adherent coatings like paint. Another plate will be blasted under rigorous conditions comparable to those anticipated for non-removable coatings like electroplated coatings. The conditions used for the remaining 3 plates will be intermediate between the first two described and represent somewhat of a continuum in the performance that might be expected over a wide operation range.

Universal Ice Blast, Inc. will determine which parameters are varied and report the information to the INEEL upon completion of the testing. In addition, UIBI will provide back to the INEEL, video footage of the blasting process, as the plates are undergoing testing. The work is to be completed during the 2001 fiscal year.”

Summary:

The sample coupons were received July 2, 2001 and subjected to ice blast cleaning on July 3, 2001.

The five (5) sample plates, each containing five (5) round disk coupons, were recorded prior to, and immediately after, test cleaning with a digital camera.

The sample plates were identified into Groups A-E. The individual coupons on each plate were removed from the backing plates and checked for identification. Each coupon had been metal stamped with unique identification prior to receipt by UIBI. After test cleaning, the coupons were remounted to the backing plates with silicon adhesive.

The test cleaning was performed under the following conditions:

- Blast Air Pressure (psig): 80, 115, 150
- Dwell Time (seconds): 10, 20, 30
- Blast Angle (degrees): 45, 90

The ice blast machine, model CX91, fitted with a M2 blast gun assembly, was supplied with:

- 240V-3Ø-60 power (15 KW)
- 280 CFM air (max pressure 150 psig)
- Municipal water supply (25 GPH)

A pressure gauge was installed at the working end of the blast air supply hose in order to correctly adjust the supply air pressure regulator to the desired setting for each phase of the testing.

The coupons were firmly clamped in a bench vise individually for blasting and re-glued to the original sample plate as received.

A distance gauge was fixed to the blast nozzle and set to a distance of 2.75 inches from the tip of blast nozzle to surface of target. All samples were blasted at this stand-off distance.

Video footage of the blasting was taken for each coupon tested on VHS-C format. Sample coupon V-18 was not recorded due to technical difficulties.

Test parameters were set to vary the blast pressure, dwell time and blast angle. The stand-off distance remained constant to ensure 100% ice particle coverage on the test coupons.

Test Parameter Comparisons:

1. Samples A/B = (Blast Angle)

- a. Compare blast effect by varying Blast Angle.
 - i. 90° versus 45°
- b. Light Impact Pressure.
 - i. 80 psig
- c. Constant Stand-off Distance.
 - i. 2.75 inches
- d. Constant Dwell Time
 - i. 10 seconds each coupon.

2. Samples A/E = (P & t)

- a. Compare blast effect between Light Impact Pressure/Rigorous Impact Pressure & Dwell Time of Blast Spray.
 - i. 80 psig versus 150 psig
 - ii. 10 seconds each coupon versus 30 seconds each coupon.
- b. Constant Stand-off Distance
 - i. 2.75 inches

3. Samples C/D= (t)

- a. Compare blast effect by varying Dwell Time
 - i. 10 seconds each coupon versus 20 seconds each coupon.
- b. Constant Stand-off Distance
 - i. 2.75 inches
- c. Constant Impact Pressure
 - i. 110 psig
- d. Constant Blast Angle

- i. 90°

4. Samples A/C =(P)

- a. Compare blast effect by varying Blast Pressure from Light Impact Pressure to Moderate Impact Pressure.
 - i. 80 psig versus 110 psig
- b. Constant Stand-off Distance
 - i. 2.75 inches
- c. Constant Blast Angle
 - i. 90°
- d. Constant Dwell Time
 - i. 10 seconds each coupon

5. Samples A/D/E= (P & t)

- a. Compare blast effect by varying Blast Pressure from Light Impact Pressure to Moderate Impact Pressure to Rigorous Impact Pressure & Dwell Time.
 - i. 80 psig (10 seconds each coupon), 110 psig (20 seconds each coupon), 150 psig (30 seconds each coupon).
- b. Constant Stand-off Distance
 - i. 2.75 inches
- c. Constant Blast Angle

Sample Group	Sample ID	Blast Air Pressure (1)	Blast Angle (2)	Dwell Time (3)
A	V-16	80	90°	10
	V-17			
	V-18			

	V-19			
	V-20			
B	V-21	80	45°	10
	V-22			
	V-23			
	V-24			
	V-25			
C	V-31	115	90°	10
	V-32			
	V-33			
	V-34			
	V-35			
D	V-36	115	90°	20
	V-37			
	V-38			
	V-39			
	V-40			
E	V-41	150	90°	30
	V-42			
	V-43			
	V-44			
	V-45			

Table 1: Test Settings

1. Air pressure supplied to blast nozzle (psig).
2. Angle of Blast Nozzle to Target (degrees).
3. Duration Target remains in Blast Spray (seconds).

Results:

The following are photographic records of samples before and after ice blasting per conditions noted. Samples were returned to Bechtel BWXT Idaho, LLC (BBWI) for examination and analysis.



Picture 1: Group A prior to testing.



Picture 2: Group A after testing.



Picture 3: Group B prior to testing.



Picture 4: Group B after testing.



Picture 5: Group C prior to testing.



Picture 6: Group C after testing.



Picture 7: Group D prior to testing.



Picture 8: Group D after testing.



Picture 9: Group E prior to testing.



Picture 10: Group E after testing.

Raw data for ice blasting SIMCON coupon tests.

Sample Name	Conditions			Initial Conc. Cs ug	Final Conc. Cs ug	% Clean	Initial Conc. Zr ug	Final Conc. Zr ug *	%Clean	
	Air Pressure (psi)	Angle (degrees)	Time (sec)							
V-16	80	90	10	159	11	93%	214	3	99%	Or greater
V-17	80	90	10	127	9	93%	322	3	99%	Or greater
V-18	80	90	10	165	11	93%	285	3	99%	Or greater
V-19	80	90	10	122	18	85%	69	3	96%	Or greater
V-20	80	90	10	117	31	74%	171	11	94%	
						88%			97%	Or greater
V-21	80	45	10	116	11	91%	185	3	98%	Or greater
V-22	80	45	10	108	26	76%	250	6	98%	
V-23	80	45	10	117	35	70%	233	13	94%	
V-24	80	45	10	153	24	84%	146	6	96%	
V-25	80	45	10	204	19	91%	191	3	98%	Or greater
						82%			97%	
V-31	115	90	10	107	12	89%	139	3	98%	Or greater
V-32	115	90	10	181	8	96%	103	3	97%	Or greater
V-33	115	90	10	70	8	89%	214	3	99%	Or greater
V-34	115	90	10	138	19	86%	142	3	98%	Or greater
V-35	115	90	10	116	22	81%	210	8	96%	
						88%			98%	Or greater
V-36	115	90	20	123	11	91%	313	3	99%	Or greater
V-37	115	90	20	96	8	92%	156	3	98%	Or greater
V-38	115	90	20	104	11	89%	75	3	96%	Or greater
V-39	115	90	20	84	10	88%	122	3	98%	Or greater
V-40	115	90	20	126	7	94%	381	3	99%	Or greater
						91%			98%	Or greater
V-41	150	90	30	150	18	88%	374	6	98%	

V-42	150	90	30	110	6	95%	312	3	99%	Or greater
V-43	150	90	30	117	8	93%	82	3	96%	Or greater
V-44	150	90	30	261	10	96%	197	3	98%	Or greater
V-45	150	90	30	92	9	90%	258	3	99%	Or greater
* All 3 values are <3 ug						92%			98%	Or greater

Criteria For Ice Blasting

	Eval #1 Raw Score	Score 1	Eval #2 Raw Score	Score 2	Eval #3 Raw Score	Score 3	Average
percent							
TECHNICAL PERFORMANCE (28.0%)	28.00	9.27		8.02		8.89	8.73
Operability/Simplicity (36.7%)	36.70	9.11		8.36		8.57	8.68
Plant Utilities Available (14.0%)	14.00	9.00	1.26	10.00	1.40	5.00	0.70
Fieldability 11.6%	11.60	9.00	1.04	8.00	0.93	7.00	0.81
Pre-conditioning required (9.6%)	9.60	10.00	0.96	8.00	0.77	10.00	0.96
Equipment Set-up Time (6.7%)	6.70	10.00	0.67	9.00	0.60	10.00	0.67
Equipment Clean-up Time (6.2%)	6.20	10.00	0.62	10.00	0.62	10.00	0.62
System Clean-up Time (14.7%)	14.70	9.00	1.32	7.00	1.03	10.00	1.47
Projected Maintenance Time Required (14.9%)	14.90	9.00	1.34	8.00	1.19	10.00	1.49
Operator Training Time (3.1%)	3.10	9.00	0.28	9.00	0.28	10.00	0.31
Number of op. Personnel (4.9%)	4.90	9.00	0.44	8.00	0.39	10.00	0.49
Flexibility (insitu/exsitu) (11.6%)	11.60	8.00	0.93	8.00	0.93	7.00	0.81
	97.30						
Required Development (20.0%)	20.00	9.99		7.77		8.94	8.90
Probability of Success (38.3%)	38.30	10.00	3.83	9.00	3.45	8.00	3.06
Test Facilities Required (28.3%)	28.30	10.00	2.83	10.00	2.83	9.00	2.55
Development Time & Scope (8.3%)	8.30	10.00	0.83	9.00	0.75	10.00	0.83
Transferrable Technology (25%)	25.00	10.00	2.50	3.00	0.75	10.00	2.50
Cleaning Efficiency (43.3%)	43.30	9.08		7.83		9.14	8.68
Variety of Materials (11.0%)	11.00	10.00	1.10	8.00	0.88	9.00	0.99

Variety of Configurations (21%)	21.00	10.00	2.10	10.00	2.10	8.00	1.68	
Types of Contamination (19%)	19.00	7.00	1.33	6.00	1.14	9.00	1.71	
Cleaning Rate (21%)	21.00	9.00	1.89	5.00	1.05	10.00	2.10	
Decontamination Factor (28%)	28.00	9.50	2.66	9.50	2.66	9.50	2.66	
WASTE CONSIDERATIONS (25%)	25.00		8.87		7.43		6.30	7.53
Recycling Capabilities (23.3%)	23.30	9.00	2.10	8.00	1.86	8.00	1.86	
Compatibility w/ Waste Treatment Systems (46.7%)	46.70	10.00	4.67	10.00	4.67	5.00	2.34	
Vol. of Secondary Waste Generated (30.0%)	30.00	7.00	2.10	3.00	0.90	7.00	2.10	
ENVIRONMENTAL, SAFETY & HEALTH (19%)	19.00		8.89		8.59		8.70	8.73
Ease of Environmental Compliance (46.7)	46.70		9.53		8.84		9.53	9.30
Waste Form Accepted (50.0%)	50.00	10.00	5.00	10.00	5.00	10.00	5.00	
Closure Plans (23.3%)	23.30	8.00	1.86	5.00	1.17	8.00	1.86	
Permits (26.7%)	26.70	10.00	2.67	10.00	2.67	10.00	2.67	
Ease of Safety Compliance (16.7%)	16.70		9.01		9.18		7.84	8.68
Special Requirements (46.7%)	46.70	9.00	4.20	9.00	4.20	8.00	3.74	
Special OSHA Problems (16.7%)	16.70	9.00	1.50	10.00	1.67	7.00	1.17	
Safety Documentation Required/Time (36.7%)	36.70	9.00	3.30	9.00	3.30	8.00	2.94	
ALARA Considerations (36.7%)	36.70	8.00	8.00	8.00	8.00	8.00	8.00	8.00
COSTS (16%)	16.00		9.84		8.92		9.32	9.36
Development (34%)	34.00	10.00	3.40	9.00	3.06	10.00	3.40	

Chemicals/Materials (14%)	14.00	10.00	1.40	9.00	1.26	10.00	1.40	
Equipment (19%)	19.00	10.00	1.90	9.00	1.71	9.00	1.71	
Labor (25%)	25.00	10.00	2.50	9.00	2.25	9.00	2.25	
Utilities (8%)	8.00	8.00	0.64	8.00	0.64	7.00	0.56	
REMOTE APPLICABILITY (12%)	12.00		8.53		8.00		9.53	8.69
Development Time (23.3)	23.30	9.00	2.10	8.00	1.86	10.00	2.33	
Development Costs (30%)	30.00	9.00	2.70	8.00	2.40	10.00	3.00	
Advantages (46.7%)	46.70	8.00	3.74	8.00	3.74	9.00	4.20	
	total		9.10		8.12		8.35	8.53