

RADIOACTIVE LIQUID WASTE REDUCTION AT THE IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY

By Rick Demmer, Kip Archibald, Mark Argyle, Lance Lauerhass, and Julia Tripp
Lockheed Martin Idaho Technology Company
P.O. Box 1625
Idaho Falls, Idaho 83415-5218

ABSTRACT

The Idaho National Engineering and Environmental Laboratory (INEEL) Radioactive Liquid Waste Reduction (RLWR) group, located at the Idaho Nuclear Technology Engineering Center (INTEC), continues to evaluate and demonstrate new waste minimization and decontamination techniques. Increased concern about secondary waste associated with traditional methods has caused INTEC to discontinue using old “reliable” methods. The RLWR group has been implementing various novel techniques for waste minimization. These newer techniques have application to most other DOE sites, especially for D&D projects.

Several new methods have been demonstrated recently. A portable carbon dioxide (CO₂) blaster was evaluated and purchased for use at the INTEC. Protective removable and non-removable coatings are being used to prevent and even to decontaminate some items. PENTEK 604 is a decontamination coating that has been very successful, and is also self-removing. Several novel chemical methods, including some “off the shelf” methods were evaluated and demonstrated on INTEC projects. Novel abrasives and blasting nozzles have been evaluated for use. Two new scabbling projects were completed with good results. An INTEC laboratory is currently using waste minimizing absorbent and solidification methods introduced by the RLWR group.

In addition to the reports on development and demonstration, some insight is given into the process of gaining operator acceptance for the new technologies. This is an area that is often forgotten in the development process. Unless the new tools are accepted into the workplace, they will show no benefit. Strategies for implementation, along with successful and unsuccessful examples are discussed.

INTRODUCTION

For over 40 years the INTEC (formerly known as the Idaho Chemical Processing Plant) has played an important role in the Department of Energy (DOE) nuclear complex.(1) Until 1991, INTEC processed spent nuclear fuel, from receipt and storage, through dissolution and separation of usable uranium, to management and solidification of the highly radioactive byproducts. Currently the mission of INTEC is to safely and cost effectively manage the radioactive and hazardous waste produced from past spent nuclear fuel processing activities. The storage of spent fuel continues, along with solidification of liquid waste in the New Waste Calcining Facility (NWCF). Development of new waste processes is ongoing to more efficiently remove the remaining tank farm waste to meet the Idaho State mandated milestones.

The INTEC RLWR Group has the task of evaluating and assisting in implementing new decontamination techniques for waste minimization and effectiveness. For the past two decades, the Decontamination Development Group, and now the RLWR Group has tested various methods of decontamination and waste minimization for the INTEC processes.(2, 3, 4) Since the chemical processes were typically flushed to remove radioactive contamination prior to major repair work, evaluations were primarily focused on chemical decontamination methods. There has been extensive work at the INTEC during the 70s and 80s on decontamination testing.

The RLWR Group is working to evaluate and implement new methods of waste minimization to solve the problems of waste generation. The RLWR Group has performed on-site demonstration/evaluation activities at the INTEC on CO₂ pellet blasting, liquid abrasive grit blasting and novel chemical flushing. Additional off-site testing sponsored by, or in cooperation with, the INTEC has resulted in the testing/evaluation of light ablation decontamination, liquid nitrogen blasting, CO₂ snowflake blasting and improved concrete scabbling equipment. By evaluation, testing and working with our operations customers to implement new technologies, the RLWR Group has been effective in reducing liquid waste output by over 43%.

EVALUATION CRITERIA

The evaluation criteria must be adequate to balance the concerns of operations personnel for personnel safety and overall economics. The safety and health concerns range from environmental compliance to employee exposure to radiation. Costs and benefits are evaluated from the development through deployment before a demonstration is begun. At INTEC, additional concerns such as technical performance, waste considerations, safety and health, and cost in determining whether to use a particular decontamination technology are also considered.(5) Some of the technical concerns examined are the operability and simplicity of the technique, the cleaning efficiency and any additional development that may be required for our application. The waste considerations examined are the volume of waste produced, the potential to recycle the waste, and the compatibility of the waste with the plant systems.

DEVELOPMENT OF SIMCON COUPONS

A relatively independent method of testing various technologies was developed to demonstrate the cleaning effectiveness of various decontamination methods. A simulated, non-radioactive contaminant system (SIMCON) was developed to simulate both "loose" and "fixed" contamination. SIMCON 1 coupons were developed to test methods for cleaning "loose" contaminants.(6) SIMCON 1 consists of about 1 mg of non-radioactive cesium and zirconium salts dried on the surface of a 1 inch diameter metal disk. The concentration of these salts was estimated by analyzing previous data on equipment surface area and decontamination effectiveness.(4) These coupons were analyzed using X-ray fluorescence before and after cleaning. SIMCON 2 coupons were produced by placing 5 mg of cesium and 1 mg of zirconium salts onto the metal coupon surface and baking the coupon at 700°C for 24 hrs. The excess salts were removed from the surface by brushing and rinsing the coupons (leaving about 0.2 mg of cesium and zirconium). This resulted in a "fixed" type of simulated contaminant that was very difficult to remove. Several offsite vendors have used SIMCON coupons to satisfy testing requirements. Over 1000 coupons have been used in testing of various methods.

CO₂ PELLET BLASTING AND OTHER CRYOGENIC TECHNIQUES

The RLWR Group performed CO₂ pellet blasting demonstration at the INTEC decontamination facility in 1993.(7) This method uses CO₂ pellets (which sublime after impact) to clean nondestructively while producing virtually no additional secondary waste. An outside contractor was brought in to provide portable CO₂ pellet blasting and manpower to operate the equipment. INEEL engineers provided test plans, test specimens, and data evaluation. Operators and engineers from the decontamination facility were able to become familiar with the blasting equipment and performed many roles.

TABLE I. SIMCON AVERAGE % REMOVALS FOR NON-CHEMICAL DECON TECHNOLOGIES

Technology	SIMCON 1-Cs % Removal	SIMCON 1-Zr % Removal	SIMCON 2-Cs % Removal	SIMCON 2-Zr % Removal
Water rinse	100	99	0**	0**
Ultrasonic	100	100	70	88
CO ₂ Pellet Blasting	91	92	63	78
SDI CO ₂ unit	100	99	84	100
CO ₂ Snowflake	83	94	26	78
Centrifugal CO ₂	*	*	83	98
ZAWCAD	99	99	76	95
Plastic grit	100	100	80	93
Glass Beads	99	100	96	100
Alumina Grit	100	100	92	100
Dissolvable grit	*	*	91	97
CO ₂ cw laser	97	86	*	*
Nd:YAG laser	98	99	75	99
Excimer laser	99	98	77	99
TLC Stripcoat	87	66	42	73
ALARA 1146	83	76	45	76
PENTEK 604	96	90	57	75

* Tests not performed

** All SIMCON II coupons are cleaned with water rinses prior to initial analysis

The CO₂ system waste tested for effectiveness on a variety of materials. The results from cold testing indicate that the CO₂ pellet system is very effective for general cleaning. The system removed rust, tape, polyken wrap, and enamel paint from a variety of materials. The system

removed the substrate from wood, but removed only the top layer of concrete which consisted of cement and sand. The SIMCON tests performed involved maintaining a constant cleaning time of 1 minute and varying the pressure and die size. The pressure used varied from 125-205 PSI. All of the pressures and dies were effective on cleaning SIMCON 1, however, the system was not as effective on SIMCON 2. The average percent removal for both SIMCON 1 & 2 coupons can be seen in Table I.

The second portion of the CO₂ pellet blasting test demonstrated that this method could be highly effective in decontaminating radioactive tools and materials. Several tools were cleaned to below detectable limits for both smearable and fixed contamination. One screw driver had readings of 450 c/m beta/gamma fixed and 800 c/m beta/gamma, 40 c/m alpha smearable, prior to cleaning with the CO₂ pellet blaster. After cleaning, these were reduced to <100 c/m beta/gamma fixed and <200 c/m beta/gamma, <10 c/m alpha smearable. Eight tools were cleaned during the test, all showed significant decontamination, with a decontamination factor of up to 22.

A new, smaller portable shaved dry ice (SDI) CO₂ blasting equipment was recently purchased at the INTEC.(8) This equipment is much less expensive (\$40,000) than the typical large pelletizing units (\$500,000). The SDI unit is available from the Alpheus Co., Rancho Cucamonga, CA. This unit performed as well as the more expensive equipment but uses blocks of dry ice. A successful demonstration of the new shaved dry ice carbon dioxide (CO₂) blasting unit was performed last year, with the results of SIMCON testing reported in Table I. This unit costs far less and performs nearly as well as the larger units. It was purchased by the RLWR group for testing use at the New Waste Calcining Facility (NWCF) decon shop as a very low waste method.

Several miscellaneous cryogenic methods (CO₂ snowflake blasting, liquid nitrogen blasting) were tested using the SIMCON coupons.(6) The CO₂ Snowflake blaster uses compressed carbon dioxide (CO₂) to produce a solid CO₂ "snow" under pressure for a gentle cleaning action. This machine was developed by Hughes Aircraft Co. to clean the high quality optic systems of sophisticated, large mirror telescopes. SIMCON 1 and SIMCON 2 coupons were cleaned with the snowflake gun. Results of the testing were not entirely conclusive, as they were somewhat erratic. Again, on average, 94 and 84 percent of the zirconium and cesium, respectively, were removed from SIMCON 1, and about 70 and 26 percent of the zirconium and cesium, respectively, were removed from SIMCON 2.

The ZAWCAD (Zero Added Waste Cutting Abrading Decontaminating) cryogenic tool is a technique that was developed by the INEEL for cutting and cleaning various materials with zero added secondary waste. A very high pressure jet of liquid nitrogen and CO₂ crystals is directed on a work piece like an "abrasive blaster". These results in Table I may not truly representative of the effectiveness of this device, since it was only in the prototype development stage. The results, though, were better than those we achieved with the CO₂ pellet blasting. On average, 99 % of the SIMCON 1 was removed, and 95 % of the zirconium and 76 % cesium were removed from the SIMCON 2. Employees of LMITCO have licensed this technology to Dun Environmental and

formed a spinoff business named ZawTech International (zero added waste technologies) to produce cryogenic tools.

LIQUID ABRASIVE GRIT

Liquid abrasive grit blasting was demonstrated at the INTEC in a mockup unit.(9) Liquid abrasive grit systems use a slurry of grit and water to remove contaminants. These systems allow minimal waste generation via recovery and recycling equipment. Very high decontamination factors were achieved for SIMCON coupons, indicating that this is a very effective technique. Several different grits were tested (plastic grit, alumina, glass beads) and data was collected and evaluated for each one. The average percent removal on SIMCON coupons can be seen in Table I. From these tests, liquid abrasive grit has been suggested as a decon technique for use at the INTEC decontamination facility where liquid and grit may be recycled and reused. Liquid abrasive blasting equipment will be incorporated into a glovebox with CO₂ pellet blasting equipment being designed for the INTEC decontamination facility.

During these tests, it was discovered that all three abrasives clean the SIMCON coupons differently. Plastics beads, being a relatively soft and mild abrasive, tend to "wipe" the contaminants off the surface. Glass beads, being a harder more aggressive abrasive, use the impact of the abrasive to remove the contaminants. 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 the most aggressive abrasive tested, tends to "grind away" the contaminants. 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. Adjustment of grit to water ratio permits a significant reduction of liquid waste volume. Nozzles that clean interiors of pipes and vessels using less chemical solution were also tested. The development and testing of acid soluble grits (like dolomite) make this option more attractive as they provide an excellent decon yet are more easily processed in the waste systems.

LIGHT ABLATION

Light ablation is a novel approach to radioactive decontamination that is now in the deployment stage. INTEC contracted with Ames Laboratory, a leader in the field of radioactive metal decontamination, in 1992 to provide ablation of SIMCON and radioactive coupons. The Ames approach to laser surface decontamination is to use high power, short pulsed, laser beams to decontaminate metals by removing contaminated surface layers.(10) When metals, or other materials such as ceramics and plastics, are exposed to highly localized and intense photon sources, such as a focused laser beam, material is ablated from the surface into the surrounding atmosphere. This material can be collected via HEPA filtration of particulate-laden off-gases to prevent

deposition back onto the surface or other nearby surfaces. High decontamination factors were realized in these tests (see Table I).

Three lasers were tested during this effort.(11) The first was a CO₂ laser, continuous wave (cw) operated at 10,600 nm, 2000 watts. The CO₂ laser was used only for two tests, as significant metal surface heating was noted. It was theorized that this heating could vaporize and drive contaminants further into the surface of the metal. The second was a neodymium: yttrium aluminum garnet (Nd:YAG) rod laser operating at a wavelength of 1064 nm, in either the "Q" switched (8 nanoseconds) or free running (30 microseconds) pulsed mode, at 30 Hz, with 190 mj per pulse. The third was an excimer laser which operates at a wavelength of 248 nm, 28 nanoseconds, 120 Hz, and 350 mj per pulse using a krypton/fluorine gas. The Nd:YAG laser was effective at cleaning the SIMCON coupons as was the excimer laser. There is a tradeoff of advantages/disadvantages between these two lasers. While the Nd:YAG demonstrated very effective cleaning, and has the capability of being fiber optic coupled, it is not as powerful and is slower than the excimer.

The collaboration between Ames Laboratory and LMITCO resulted in the development of an acousto-optic q-switched, fiber optically delivered Nd:YAG laser cleaning system that can remove both surface contamination and metal substrate. LMITCO and Ames Laboratory filed for a patent on this system on July 25, 1995 and the patent was awarded on July 14, 1998 (U.S. patent number 5,780,806). This technology has since been licensed to Dunn Environmental (ZawTech International) Inc. for commercialization.

STRIPCOATING TESTS

Strippable coatings are most often used to protect areas that may become contaminated in the future. They are generally not very good for decontaminating, as they tend not to remove fixed contamination, and usually have limited effectiveness on loose contamination. Two available strippable coatings are ALARA 1146 (Imperial Coatings Co.) and TLC Stripcoat (Bartlett Nuclear Co.). They are only weakly affixed to equipment, so they can typically be peeled off the surface to which they are applied. The "paints" are typically formulated to contain no "hazardous" materials. They are considered environmentally benign. The results of our tests of the effectiveness of stripcoat using SIMCON I and SIMCON II materials is summarized on Table I. TLC Stripcoat was tested using SIMCON 1 to determine its effectiveness on the "loose" contamination equivalent. On average 66% of zirconium and 87% of cesium were removed. Some operating experience at the INTEC using ALARA 1146 has shown that this type of coating is difficult to use in the reprocessing environment, and returned little benefit, removing only loosely held contamination.

PENTEK 604 self stripping coating is better at decontamination SIMCON I coupons than the strippable coatings but not as good at removing SIMCON II. PENTEK 604 was applied to the surface of SIMCON I coupons and left to dry for approximately 12 hours. During this 12-hour period the coupons were checked after 5 hours and 90% of the coating had released from the surface. The remainder of the coupons were left overnight to finishing drying and the

coating released from the surface in large pieces. During the SIMCON II cleaning portion of the PENTEK 604 test, the first six coupons were coated with strippable coating and left to dry for approximately 12 hours. The coupons were checked after 5 hours and none of the coating had released from the surface. The coupons were then checked the following day and a small portion of the strippable coating had released from the surface but the majority of the coating remained attached to the surface. The coating was easily removed with a scraper. Two separate applications were applied to a second set of coupons. The second application was applied after the first application had been removed (by scraping). After letting the second application dry, the coating still did not release from the surface. A third set of coupons was used to see if the first dry coat could be removed from the coupon by applying a second application of strippable coating over the top of the first. The second application did remove some of the first coat but the majority of the strippable coating still remained on the coupon. This also had to be removed with a scraper. The coating was easily removed with the scraper but didn't come off in large pieces like the SIMCON I coupons. The PENTEK Company noted this problem and mentioned that if the surface is extremely dirty the coating will not release. Temperature and humidity of the area are also important factors. These results are shown in Table I.

CHEMICAL DECONTAMINATION

While the search for non-chemical decontamination methods remains a high priority, those techniques are not generally available or proven for remote cleaning of vessel and piping interior surfaces. Tests were conducted to determine the effectiveness of several different decon chemicals.(12, 13) Table II lists the relative values generated for the evaluation. Specifically, the solutions were evaluated for effective cleaning by examining decontamination factor values (Df), and waste generation (cubic meters of evaporated volume and calcine produced per cubic meter of solution used). In the waste modeling for these tests, the amount of sodium/potassium contained in the solution was important. Calcination is sensitive to large amounts of sodium salts; less sodium and potassium generally meant less waste. SIMCON II coupons were used to determine effectiveness, the two elements (cesium (S2-Cs) and zirconium (S2-Zr)) showing different Dfs for each solution.

In the decontamination evaluation tests, SIMCON coupons were placed in a beaker of the chemical and heated to 55 C and stirred for a period of 3 hours. After this chemical soak, the coupons were rinsed with DI water, dried with compressed air and submitted for XRF analysis. Evaluating this information, for a relatively high Df and low waste volumes, resulted in a recommendation to use the nitric acid/ hydrofluoric acid solution for many future decontamination campaigns.

OTHER WASTE MINIMIZATION PLANS AND ACTIVITIES

Developing a radioactive liquid waste baseline was both challenging and essential to the development of the Waste Minimization Plan. There are many diverse individual inputs to the INTEC Process Equipment Waste (PEW), tank farm and associated systems. Fortunately most all of these inputs had been tracked as separate items during the past years. However, no true

“inventory” of the inputs had been integrated and maintained. The tank farm inputs are also heavily time dependent, since various processes (like full NWCF decontamination) are batch operations. The Waste Minimization Plan provided a way of predicting the future for these inputs; integrating them so that they could be tracked and managed.(14)

TABLE II. CHEMICAL DECONTAMINATION FACTOR AND WASTE VOLUMES

Chemical Reagent	Df S2-Cs	Df S2-Zr	evaporated volume(m ³ / m ³ of solution)	calcine volume(m ³ / m ³ of solution)
CORPEX 918	1.7	1.3	0.03	0.08
CORPEX Smearaway	2	1.7	0.03	0.02
Water	3.5	1.2	0.03	0
Nitric acid	4.7	1.3	0.03	0
nitric/oxalic	5	1.2	0.67	0.18
Turco ARR	5.5	1.2	0.5	0.35
nitric permanganate	6.4	1.2	0.0125	0.019
tartaric acid	6.5	1.2	0.03	0
formic acid	6.7	1.1	0.03	0
hydrogen peroxide	6.7	1.2	0.03	0
Turco 4502	7	1.4	0.45	0.34
citric acid	8.8	1.3	0.03	0
aluminum nitrate	11.4	1.4	0.273	0.23
Nitricacid/800ppm hydrofluoric acid	14.2	5.9	0.0525	0.0058
TECHXTRACT 100,200,300	17	6	0.03	0.018
fluoroboric acid	18.3	24	2	0.26
CORPEX 921	44.3	7.8	0.1	2.1

The second portion of the Waste Minimization Plan involved developing reduction goals and developing actions to achieve the goals. Each area was scrutinized, with the generator's input, to predict future needs. Less decontamination activities in some areas will certainly reduce the need for those waste streams. However, with increased D&D or stabilization in other areas, some other waste streams are expected to increase. Balancing these somewhat diverse inputs has resulted in a sensible basis from which a plan of action has been developed and implemented. The action plan details specific waste minimization technologies that are being evaluated and implemented for each waste stream.(15) Some are slated for future evaluation and funding, but some, like a new 3M "Web System" column are already being tested to remove contaminants from the NWCF utility tunnel rainwater infiltration water. The RLWR group has minimized some acidic laboratory waste through the introduction of a new absorbent and solidification method using Acid Bond A660, from the NoChar Company.

PLANT APPLICATIONS OF NEW TECHNOLOGIES

The RLWR Group has been successful in incorporating waste elimination and reduction methods into the INTEC operations. One example was the successful floor decontamination in the INTEC-633 Waste Calcining Facility (WCF). A contamination incident in 1997 left high levels of both beta/gamma and alpha contamination. Large volumes of high sodium salt containing solutions were proposed for this decontamination, but under the direction of the RLWR Group, an oxalic acid/ nitric acid combination, provided satisfactory decontamination with much less waste. A similar type of decon was also accomplished during the decontamination of the INTEC-604 evaporator cell a month later. A new chemical method using dilute potassium permanganate and oxalic acid solutions was used for the decon of NWCF process equipment. The results were satisfactory (with about 1/1000 reduction of contamination levels) and mechanical work began on the valve. In both of these examples, RLWR engineers suggested the decon methods, assisted in training laborers, helped to complete safe work permits and obtained the materials.

Two successful implementations of the scabbling tools were also completed. In the first instance a combination of a needle gun and a Roto-peen were used to remove contaminated paint and concrete at the CPP-603 Fuel Storage Basins Truck Bay. This method was chosen because other stripping methods were deemed more hazardous, laborious and wasteful. Likewise, a valve-box in the CPP Tank Farm System required decontamination during NWCF turnaround maintenance work. The low waste needle gun scabbler was used in this application where the chemical flushes had not removed the contamination. These were high priority projects, where quick, convenient methods, like the scabbler and Rotopeen are valued. Most of this equipment is owned by the RLWR group and loaned out as needed around the plant. RLWR engineers are involved in the work packages and training on this equipment also.

Several smaller instances of waste reduction implementation were performed during the past year. The INTEC Waste Management Authority routinely asks that the RLWR group review any decontamination activities for application of low waste methods. The Analytical Chemistry Laboratories at the INTEC are currently using absorbent and solidification methods

introduced by the RLWR group. PENTEK 604, self-stripping coating, is gaining wide spread acceptance for its ability to remove significant amounts of contamination simply and easily with very low (solid) waste. One example is a contaminated sample capsule that was cleaned, saving about \$1000 by reusing the capsule. A gallon of PENTEK 604 was provided to D&D personnel to clean some trouble areas that would have required the use of harsh chemicals. This product is used at the NWCF decon shop, the tank farm, and fuel storage basin. Six new degreasers were identified to replace those currently used. Unlike the previous product used by maintenance, these have no RCRA hazardous components and should save significant waste management costs, as well as perform degreasing more effectively.

STRATEGIES FOR IMPLEMENTATION

Implementing new technologies into existing INTEC operations is sometimes a very challenging task. However, it is perhaps the most important and satisfying part of technology evaluation. New technologies do little or no good if they sit on a shelf or never make it to the plant. In the RLWR Group evaluations, solutions are provided for improving the process (minimizing the waste). But if that solution is not adopted, the job is not complete. Unfortunately the implementation step is one that requires many talents (ie engineering, research, marketing, motivating and even politics). To succeed means “championing” the technology.

To alleviate this reluctance to implement new technologies, implementation strategies have been developed. The ultimate goal of the implementation is to overcome the barriers to acceptance of the new technology. This strategy has the following steps: Evaluate, Educate and Motivate. The evaluation phase should involve the end users who are going to be involved with the new technology. End users should help define the problem, determine the criteria and select the solution. If this practice is not followed, then their acceptance at the end is much more difficult to obtain. By involving them in these steps, they find some “ownership” and want to help solve the problem. They feel the answer is their answer and not one imposed upon them from outside the organization.

During the education phase, the problem and potential solutions are shared with the whole organization. In large groups there is a lot of fragmentation, and telling one small group may not get the message across so that it is accepted by all. Most people will agree to help if they are presented with all the information on the problem and how this solution was developed. The RLWR engineers also often have to take a role in training, or at least organize training for the operators. If the evaluation process involved some development, that can be included in the training. Finally, if you have taken the other steps, the motivating phase begins. One barrier to adopting a technology is not knowing how to get it or not having the money to buy it. Quite often RLWR engineers will write the procurement documents and even find or provide funding. In the case of some waste minimization goals, the group has participated in setting up monetary incentives to get the new methods implemented.

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