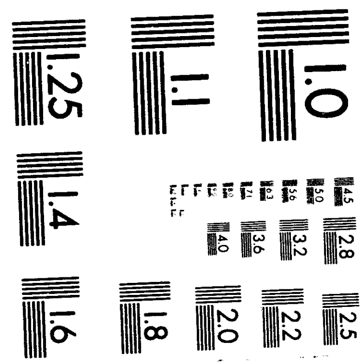
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EG&G ROCKY FLATS
WASTE MINIMIZATION PROGRAM

CARBON DIOXIDE CLEANING PILOT PROJECT

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DISCLAIMER

INTRODUCTION

In 1989, radioactive-contaminated metal at the Rocky Flats Plant (RFP) was cleaned using a solvent paint stripper (Methylene chloride). One-third of the radioactive material was able to be recycled; two-thirds went to the scrap pile as low-level mixed waste. In addition, waste solvent solutions also required disposal. Not only was this an inefficient process, it was later prohibited by the Resource Conservation and Recovery Act (RCRA), 40 CFR 268. A better way of doing business was needed. In the search for a solution to this situation, it was decided to study the advantages of using a new technology - pelletized carbon dioxide cleaning.

A proof of principle demonstration occurred in December 1990 to test whether such a system could clean radioactive-contaminated metal. The proof of principle demonstration was expanded in June 1992 with a pilot project. The purpose of the pilot project was three fold: 1) to clean metal[a] so that it can satisfy free release criteria for residual radioactive contamination at the Rocky Flats Plant (RFP); 2) to compare two different carbon dioxide cleaning systems; and 3) to determine the cost-effectiveness of decontamination process in a production situation and compare the cost of shipping the metal off site for waste disposal.

The pilot project was completed in August 1993. The results of the pilot project were: 1) 90% of those items which were decontaminated, successfully met the free release criteria , 2) the Alpheus Model 250 was selected to be used on plantsite and 3) the break even cost of decontaminating the metal vs shipping the contaminated material offsite for disposal was a cleaning rate of 90 pounds per hour, which was easily achieved.

PHASE I CLEANING AND RECYCLING PILOT PROJECT

A period of 90 working days was allocated for this project. The initial 15 days were allotted for a subcontractor to build an approved containment structure to house and isolate the contaminated material to be cleaned during the course of the pilot project. The structure was designed to have a negative pressure differential from the outside caused by air movers equipped with High Efficiency Particulate Air (HEPA) filters. The HEPA filters were each rated for 1,000 cubic feet per minute (cfm). This rate allowed the air in the room to changed every 80 seconds. This feature, coupled with the negative pressure, was to ensure that no radioactive particles would escape into the building containing the containment structure.

To protect personnel, it was decided to take the precautionary step of having employees wear full-face respirators and tyvek suits. During the course of the testing, there was not a problem with personnel becoming contaminated.

a All materials being cleaned are considered to be contaminated with low-level radioactivity

Following construction of the containment structure[b], two testing periods were established; one for 30 days, the second for 45 days. Each period consisted of a contractor bringing in a machine to be evaluated based on the following criteria: pellet density, carbon dioxide usage, equipment performance, decontamination effectiveness, pellet production capacity, and equipment reliability.

The first equipment system tested was an Alpheus Model 250 supplied by Environmental Alternatives, Inc. (EAI). The test period for this system lasted approximately 35 days. The second equipment system evaluated was a Cold Jet Model RDS 1000J provided by Environmental Control Division, Inc. (ECD). The evaluation period for this system lasted approximately 20 days. the test period was reduced from the anticipated 45-day time frame when it was learned that extensive containment structure modifications would be required in order to solve problems experienced with the equipment.

Although differing in design, each system uses essentially the same basic method to clean material. The method is to create a carbon dioxide "snow" from liquid carbon dioxide. This snow is then pushed through a die compressing the snow and creating hard pellets of carbon dioxide.

In the Alpheus system, these pellets are inserted into a high pressure (40 to 250 psi) dried air stream and shot at a high velocity at the material to be cleaned. The pellets, upon impact with the material to be cleaned, penetrate through the surface coating to the substrate. When the pellets impact the substrate, they sublime into a carbon dioxide gas expanding 400 times the pellet's original volume. This action acts as a "gas wedge" separating the surface coating from the substrate. After the pellets sublime, they become part of the atmosphere and there is no secondary waste requiring disposal. (For our purposes, secondary waste is considered to be by-products often associated with other cleaning methods, such as abrasive grit or solvents.)

In contrast, the Cold Jet process uses the CO_2 pellets to create a thermal shock effect causing a rapid change in the temperature of the material on the substrate. The material contracts and freezes, separating the radioactive material from the substrate.

b The dimensions of the containment structure are 20 feet long x 12 feet wide x 10 feet high. The materials utilized for the containment structure are 20 guage brushed stainless steel quarter-inch thick Lexan (a type of Plexiglass) panels. The structure was manufactured by Item Products, Inc. It had a modual construction method that allowed easy modification as well as assembly. This feature was especially useful during the assembly of the structure when it was determined that it was to large for the available space. We had to shorten the width and 16 feet so that forklifts would have clearance on one side. We also had them attach brackets for two (2) roughing filters for the air movers with HEPA filters. We also had them attach a row of three (3) intake filters on the roof and one (1) intake filter on a wall.

PHASE II CLEANING AND RECYLING PILOT PROJECT

A period of 90 working days was allocated for this project phase. This phase of the project focused on requirements that had to be met to transfer the pilot program to a production operation. Other project goals were to expand the cleaning operation, improved production rates and become more efficient and economical than Phase I of the project.

EQUIPMENT OPERATION

Both machines use a pelletizer to manufacture pellets, an air compressor, an air dryer, and a liquid carbon dioxide storage tank. One difference in equipment operation is the Cold Jet combines the pellets with the dried air in another piece of equipment called a hopper and delivers the pellets to the nozzle of the gun by means of a singe hose. The Alpheus uses a patented two-hose delivery system where the dried, high pressure air and the pellets are delivered to the gun in separate hoses. This is done to try to maintain pellet size and shape from the pelletizer to the gun.

One advantage of the Cold Jet one-hose system is that it is more mobile than the Alpheus system. (Alpheus does market other equipment with a similar mobility.) A disadvantage in the one-hose system design was discovered when a rock entered the system and lodged in the nozzle of the gun. This caused all of the pellets to sublime before exiting the nozzle. Had the Cold Jet had a closed system, this would not have been a problem[c].

The two systems used slightly different ways of producing pellets, but the end result was dramatically different. The Alpheus system utilized a mechanical roller that continuously pushes the carbon dioxide snow through a die. As the product exits the die, the material breaks off as a result of its own weight, producing pellets of uneven length and consistency.

Another observation learned during the test period was that neither machine is totally efficient in its use of pellets. When the trigger of the Alpheus system is not operating, the pelletizer discharges its pellets to the ground. On the other hand, since the Cold Jet pellets are made at a slower rate than the nozzle discharges them, the operation of this system requires a supply of pellets to be on-hand before cleaning operations are initiated. This also requires that when the cleaning procedure starts, pellets have to be manually moved from insulated containers to the hopper. In addition, once cleaning operations are started, the equipment contractor recommends not allowing the trigger of the nozzle to be shut off until all the pellets in the hopper are used. Consequently, pellets are wasted using this system, as well as when cleaning operations cease. Although each system has some pellet waste associated with it, this cost is not considered significant.

c It is thought that a shovel, used to load pellets into the hopper, must have been dirty and thus allowing debris to become mixed with the pellets.

Another consideration is that because the Cold Jet uses a hydraulic system, there is a possibility the seals could leak and contaminate the pellets with hydraulic fluid. This possibility is unique to the Cold Jet design, but neither RFP nor the vendor that operated the equipment (ECD) has ever experienced this problem.

TEST PROCEDURE AND DATA

An operational goal of the test program was to achieve the most efficient operation as possible - that is, to get as much material cleaned and prepared for disposal in the shortest time. To meet the free-release criteria, the material needed to meet the following standards as established by RFP Health and Safety Practices manual, Section 18.10:

	Removable	Fixed Plus Removable
Alpha	20 dpm/100 cm^2	300 dpm/100 cm^2
Beta and Gamma	1,000 dpm/100 cm^2	5,000 dpm/100 cm^2

Ninety percent of the material cleaned in this program met or exceeded these residual radioactivity reduction criteria.

Another goal of the project was to better define the cleaning operation, that is, to define what production rates could be achieved given their operating conditions, and to determine how the operation could be made more efficient and economical.

ECONOMIC ANALYSIS

The primary avenue for disposing of low-level waste material at RFP today is to ship it by truck to the Nevada Test Site (NTS). Any alternative disposal method considered has to be measured against this practice. The cost of preparing and shipping a standard 5,000 pounds of waste to Nevada is calculated to be $16,851.

It is estimated that the cost of operating the Alpheus system is $297 per hour. If the system were capable of cleaning 100 pounds of material per hour, the cost of cleaning the standard 5,000 pounds would be $14,850 (see Table I); a savings of $2,001 relative to the $16,851 cost of shipping 5,000 to Nevada. In comparison, if the cleaning rate were 50 pounds per hour, the cost of cleaning 5,000 pounds of material would be $29,700, or a cost increase of $12,849 relative to the standard cost. Using this same calculation process, it was determined that the cleaning rate necessary to break even would be approximately 90 pounds per hour. (See Table I)

TABLE I

Rate of Cleaning (lbs/hr)	Amount to be Cleaned (lbs)	Hours Required	Total Cost of Cleaning
10	5,000	500	148,500
50	5,000	100	29,700
80	5,000	63	18,711
90	5,000	56	16,632
100	5,000	50	14,850
120	5,000	42	12,474
130	5,000	38	11,286

With this benchmark reference established, a primary objective of the study was to determine if the carbon dioxide cleaning system was economical. To get the data required to make such an assessment, a data sheet, assigning a control number to each item to be cleaned, was established. Information such as: estimated weight for each item, time spent cleaning the item, dimensions, and final radiological conditions, were recorded.

RFP Solid Waste Operations personnel were utilized to record necessary information to complete each data sheet. An equipment operations log was also maintained to track equipment downtime, carbon dioxide usage, cleaning time, material items cleaned and was referenced by a control number.

Each contractor was required to: have personnel on site for 15 working days, run their equipment and clean material. During this period, RFP personnel were trained on how to operate the equipment. The equipment manager would stay for the duration of the testing period to run the equipment and provide any assistance to newly trained RFP personnel after the 15 day period.

TESTING PROBLEMS

Neither machine performed flawlessly. In the third week of operation, the Alpheus developed problems in the pellet production process. After extended periods of operation, the pellet- making equipment would freeze preventing further production of pellets until the equipment thawed and dried out. The problem was later determined to be caused by a screw loose during transportation of the machine to RFP. EAI decided, after two attempts, to correct the problem in the field. It would be more prudent to replace the machine to minimize the amount of downtime. To regain lost time, the test period was extended one week. Other small problems occurred, such as the diesel compressor battery failing to hold a charge, resulting in small periods of downtime. There were no problems with the nozzle-gun or the operations inside the containment structure.

With the Cold Jet, more serious problems were experienced that proved to be too difficult to resolve in the test period. The difficulty was that the equipment created hazardous working conditions for personnel in the containment structure. Namely carbon dioxide levels were to high and oxygen levels were to low. With the ventilation rate at 2,000 cubic feet per minute (cfm) in the containment room, it was possible to keep the carbon dioxide levels within the threshold limit value (TLV) of 5,000 parts per million (ppm) for an eight-hour period while operating the Alpheus equipment. However, while operating the Cold Jet equipment, carbon dioxide levels increased significantly and were measured at 25,000 ppm one minute after beginning operations. Oxygen levels during this same period ranged from 18.8% to 19.4% within a three minute period. The Occupational Safety and Health Administration (OSHA) required range for oxygen is 19.5% to 22.0%.

Another problem experienced was moisture. The Cold Jet machine lowered the temperature of the object being cleaned so much that ice formed during cleaning. The ice eventually melted but, the cleaning process caused moisture to build up in the room as the water evaporated. The roughing filters, used to capture larger particles as air exited the containment room, became clogged with moisture. This lowered the efficiency of the air movers and took longer for the air in the room to change over. Further, this caused the dew point to drop, forcing more water to condense, and clogging the filters even more. This cycle aggravated the carbon dioxide and oxygen problems discussed earlier. The only way to break this cycle would be to add more air movers and a de-mister filtration system. This would have required re-engineering and modification of the containment structure. Given the short time frame to work with, this was not possible. The test was canceled.

TEST ANALYSIS AND TRENDS - PHASE I

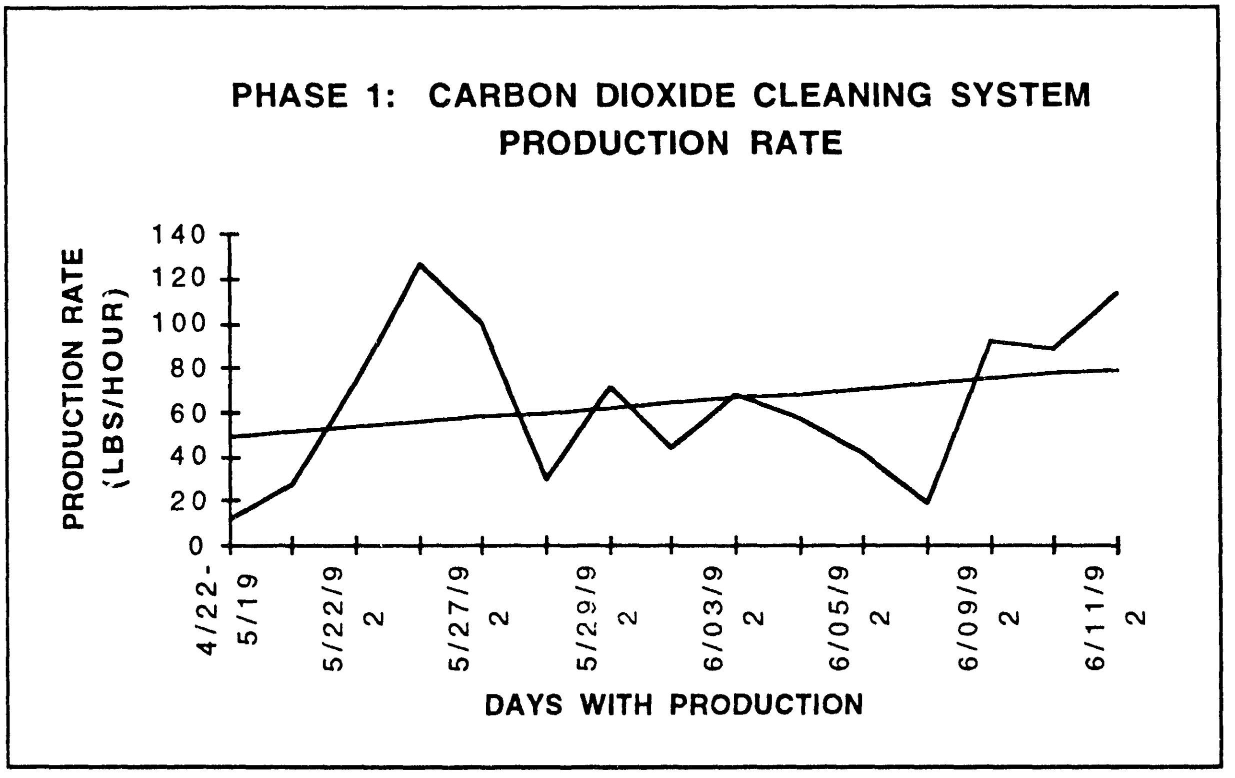
The cleaning rate Phase I with the Alpheus machine averaged 52.3 lbs/hr (See Figure 1). This rate included a three week training period for RFP personnel. Once the personnel became proficient in operating the equipment, the rate jumped to 72 pounds per hour. During five of the last 14 days of the evaluation period, a cleaning rate of more than 90 lbs/hr was achieved.

A regression analysis, performed on the data, shows that the average had not yet reached its highest point. With more time, the overall average would have increased.

Another trend discovered, that although the material items being cleaned have similar sizes and shapes, the amount of material, that can be cleaned in a given time period, increases. Experience in cleaning the material seems to be a more important factor than does the surface area when it comes to increasing the cleaning rate.

The value of experience is easily explained by an example. During one four day cleaning period, workmen achieved a cleaning rate of 50 pounds per hour for the first two days while cleaning angle and channel iron. The rate climbed, to above 90 pounds per hour during the second two day period, as their experience level increased. Not only do the personnel know the best cleaning methods after cleaning similar items, but they also become familiar with the contamination level. And so, they know what rate to move the gun over the surface of the material.

One area that we did not measure was the difference in cleaning heavily contaminated items versus lightly contaminated items. That was going to be tested during test of the Cold Jet equipment, but since the testing period was curtailed, this was not possible.

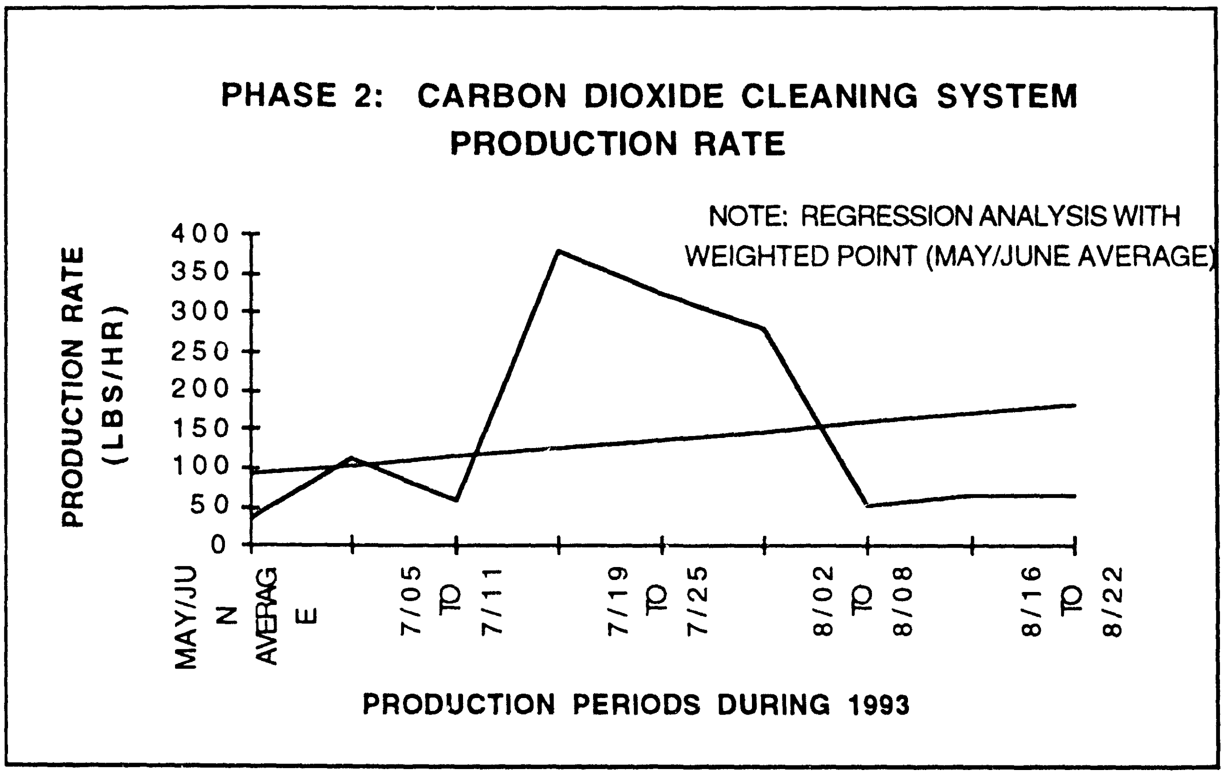


TEST ANALYSIS AND TRENDS - PHASE II

The cleaning rate for Phsae II averaged 77.0 lbs/hr (See Figure 2). This rate included two training periods in which personnel were familiarizing themselves with the operation of the equipment. The duration of the first training period was approximately six weeks. During this period the average cleaning rate was 33.3 lbs/hr. The second training period occurred during the last two weeks of operatins due to the addition of a night crew. The cleaning rate for this second training period averaged 44.1 lbs/hr. During the period before the introduction of the night crew, the average production rate was 250 lbs/hr.

The low production rate during the training periods can be attributed to the operating personnel's inexperience with the equipment and inefficient cleaning methods. The crew, that produced the high production period, had seven weeks of experience with the equipment. This experience factor is the most overriding criteria in efficient equipment usage. Even the type of material being cleaned is not as important of a factor as operator experience.

A regression analysis performed on the data produced an upward trend. The reqression was performed with the MAY/JUNE AVERAGE weighted to reflect six weeks of production. The upward trend would have been more pronounced was it not for the night crew data points that depressed the trend.



DISCUSSION AND RECOMMENDATIONS

As recently as four years ago, it was a common practice to clean material, as was used in this project, using solvents and other hazardous chemicals such as Methylene Chloride. However, since the passage of the Resource Conservation and Recovery Act (RCRA), this option is no longer available, and off site disposal has become the acceptable practice. However, even this practice has its consequences and viable alternatives are sorely needed.

This project should demonstrate that carbon dioxide cleaning is an alternative cleaning system that merits further consideration. As has been seen, this process is capable of removing low- level contamination from material in a production setting. Once the material is decontaminated, another option is now available - recycling. This material, would have otherwise been sent to NTS as low-level waste since cleaning with a solvent is not permitted The labor intensive method using scrub brushes is prohibitively expensive. The process of using carbon dioxide has the advantage of leaving no secondary waste requiring disposal. The radioactive particle that are blasted off of the material are filtered out of the air using a HEPA filter.

This pilot test program has shown, that the break-even cleaning rate of 90 pounds per hour, has been achieved and surpassed, and thereby providing evidence that an economical alternative to shipping material offsite does exist.

The technology of carbon dioxide cleaning is new. Given technological improvement, increased personnel experience and expanded facilities, it is logical to conclude, that improved cleaning rates will be achieved, making this process an even more economically viable alternative to offsite disposal.

In November 1992, 406 pieces of metal were cleaned in Phase I and in August 1993, over a thousand pieces of metal were cleaned in Phase II, using the carbon dioxide process. And, they were subjected to stringent inspection requirements that were approved for unconditional release. This action provides strong evidence of the viability and value of this cleaning technology. Without this project, this material would have been crated and shipped for underground disposal. This is at a cost of approximately $17,000 per 5,000 pounds.

In light of the political sensitivity of sites such as NTS, a system, such as the carbon dioxide cleaning process, should be given serious consideration as a solution to solving low-level waste issues at all DOE sites.

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