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NONRADIOACTIVE DEMONSTRATION OF THE ALPHA D&D PILOT FACILITY

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INTRODUCTION

An Alpha-Contained Decontamination and Disassembly Pilot Facility (AD&D) has been constructed and is currently being used to obtain technical data and operating experience for a future plant unit. The pilot AD&D facility has been operated 16 weeks under nonradioactive testing and processed several nonradioactive feed items. After the facility startup in November 1982, four process runs were conducted, one dedicated to size-reduction techniques, two to decontamination techniques, and finally an integrated process run, designed to simulate the entire AD&D process flowsheet. The secondary waste generated reduced storage volume by a factor of 20. Chemical decontamination sprays at 60°C removed from 1 to 3 mils of glovebox surface per 4-wash cycle, producing 265 to 378 liters (70 to 100 gal) of liquid waste per feed glovebox. Monitoring of the exhaust system showed no signs of pluggage due to plasma arc cutting gases or high-humidity conditions encountered in the spray chamber. Design improvement in several areas are needed, including waste bagout, and master/slave manipulators.

This report contains detailed information on the operation of the facility and data obtained during experimental runs.

SUMMARY

The AD&D pilot facility was designed to demonstrate the process flowsheet under conditions typical to those expected in a production facility. To achieve this, nonradioactive waste items similar to those in retrievable storage at the Savannah River Plant burial ground (e.g. gloveboxes), were chemically sprayed and size reduced. During process runs, parameters such as feed rate, oxide

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removal, etching rate, and secondary waste generation were determined. The exhaust system was monitored during operation to ensure that exhaust from the facility was sufficiently filtered before release to the atmosphere.

The strategy for decontamination techniques required development during the nonradioactive testing period. Under investigation during process runs were both once-through and recirculating washes, and their correlation to oxide removal and etching rates on the stainless steel feed items. Wash products of the decontamination process were analyzed for concentration of Ni, Cr, Fe, Mn, and Si, major components of stainless steel.

Size reduction techniques were also developed during the nonradioactive testing period. An array of conventional power and pneumatic tools were tested and evaluated. Plasma arc torch operating parameters; standoff distance, ampere setting, and cutting angle were determined.

BACKGROUND

As part of an integrated program to dispose of transuranic (TRU) waste, a Disassembly and Decontamination Facility will be built at the Savannah River Plant (SRP) to process noncombustible waste. Cabinets, gloveboxes, and other large items of contaminated process equipment are currently stored retrievably on concrete pads beneath an earth cover in the SRP burial ground in compliance with DOE regulations. The waste is wrapped in plastic, boxed in sealed plywood containers, and in turn placed inside large, specially designed steel burial boxes which occupy substantial volumes on the concrete pads. Smaller waste items are stored in 55-gal galvanized steel drums. Drums containing more than 0.5 Ci are in turn placed inside concrete culverts on the pad.

The plant facility will remove more than 99% of the initial surface activity from the waste by decontamination with chemical sprays. The radioactive solutions will be transferred to the SRP high-level liquid waste system (HLW). HLW will be encapsulated in glass in the Defense Waste Processing Facility (DWPF), planned for operation in the late 1980's. The waste will be remotely disassembled and sectioned for volume reduction. Waste that is decontaminated to <100 nCi/g will be permanently disposed of in the SRP burial ground. Present design plans call for packaging and certifying processed waste that is not decontaminated to <100 nCi/g by chemical sprays for shipment to the Waste Isolation Pilot Plant (WIPP) for geologic storage. Alternatively, additional decontamination techniques such as vibratory cleaning, electropolishing, or chemical etching would be used to decontaminate waste to less than 100 nCi/g for disposal as low-level waste in the SRP burial ground.

The initial feed for the plant will consist of equipment removed after the renovation of a plutonium processing line which has produced hundreds of kilograms of Pu-238 and other TRU isotopes over 25 years. At a later date, the plant will process the TRU inventory already stored on pads and the waste in 208 L (55-gal) drums.

To support the design and operation of the proposed plant facility, a pilot scale facility was built at the Savannah River Laboratory (SRL) during FY-1981 and 82. It will continue to implement, adapt, and evaluate available technology and demonstrate viable modes of operation. Contaminated gloveboxes generated by research and development programs at SRL will be used as feed in the radioactive phase of its operation. The facility will later routinely dispose of TRU contaminated equipment retired from service at SRL.

The design, equipment, and instrumentation for the pilot facility have been chosen on the basis of previously demonstrated technology or operating experience at SRP and a number of sites [Pacific Northwest Laboratory (PNL), Los Alamos National Laboratory (LANL), and others].

Process components were tested prior to initial nonradioactive operation to ensure correct performance.

DISCUSSION

Facility Description and Operation

The pilot facility consists of a main cell 7.3 m long, 2.7 m wide, and 4.8 m high with large, open areas for unpacking and disassembling waste and an inner room for initial decontamination. Figure 1 shows a plan view of the facility. The cell floor and frame are stainless steel with transparent wall panels of fire-retardant Lexan® (General Electric) polycarbonate. Three sides of the facility are in a regulated service area and have numerous gloveports at various levels for hands-on operations. The fourth wall is in a clean area where most process controls are located. Remote disassembly cutting operations and heavy lifting are performed with two pairs of Master/Slave Manipulators (MSM) and a bridge-mounted electromechanical type manipulator (Programmed and Remote Systems, Inc., (PaR) Model 3000).

Feed is introduced into the cell through a walk-in airlock. Once through, air ventilation provides the primary contamination control barrier. Air leaving the cell is filtered through a dual-pac HEPA filter inside the cell and then passes through two more banks of external HEPA filters prior to entering the building exhaust. The dual-pac filter will be replaced remotely from inside the cell. The demister portion of the dual-pac filter minimizes clogging due to moisture.

The decontamination room is separated from the main cell area by a roll-up door to contain the spread of contamination during pressurized water and chemical spray treatment. It has its own set of high efficiency particulate air (HEPA) filters and a separate drain and liquid waste hold tank.

Processing steps in the AD&D are overpack removal, spray decontamination, size reduction, and assay. Figure 2 shows a conceptual flowsheet for the D&D process. An artist's conception of the facility is shown in Figure 3.

Spray Decontamination

Spray decontamination is composed of periods of chemical makeup, heating, spraying, drying, and assay.

Chemicals are made up in 190 L (55-gal) tanks in a chemical feed area located along the perameter of the facility. Thermostatically controlled induction heaters maintain the temperature of solutions at 60°C.

Inside the spray chamber, a spray nozzle is inserted into a waste glovebox. The heated chemicals are pumped from the makeup area to the spray chamber, through the nozzle, and onto the contaminated surface. The liquids are channeled via a large drip pan to a 190 L (50-gal) holding tank. Respray of the feed chemicals is accomplished by an in-cell recirculation system. The same system serves to transfer spent chemicals to storage, adjust them as necessary, and consign them to the high-level waste system. The waste item is dried by ambient or 6.1 atm (90 psi) compressed air.

Disassembly and Size Reduction

The Disassembly and Size Reduction portion of the AD&D process encompasses overpack removal, unwrapping, and preparation for decontamination, as well as final disassembly and size reduction of the waste item.

Pry bars and a circular saw will be used to remove the plywood overpacking from a waste item, performed in a temporary enclosure outside of the facility. The waste item will be unwrapped with the aid of a hot knife inside the facility, and transferred to a worktable with the PaR manipulator.

To prepare the waste item for decontamination, a drainage hole is cut with a holesaw, and combustible materials and other items incompatible with the decontamination process are removed.

Final disassembly and size reduction is accomplished with commercially available tools which are adapted for remote operation. Final waste pieces are limited to 35.6 cm (14-in.) in their largest dimension for bagout into 208 L (55-gal) drums. Future program elements include bagout into a WIPP-Certified box approximately 3.7 m x 3.7 x 6.4 m (4 ft x 4 ft x 7 ft) in dimension thereby relaxing the size limitations of final waste pieces to approximately 2.7 m x 5.5 m (3 ft x 6 ft).

Experimental Program

Prior to each process run, a detailed run plan was issued containing pertinent information about the run. Run plans follow the outline given below:

1. Run identification
2. Date scheduled
3. Purpose of run
4. Feed
5. Reference process

6-7. Duration of run

8-9. Shift supervisor and operators assigned

10-11. Photography and videotape schedule

12. Samples to be taken
13. Run schedule

The following sections of this report summarize facility operation and results of the research program.

Decontamination

Historical Development

J. H. Crawford performed studies at SRL with TRU contaminated noncombustible waste in 1978. Feed consisted of full scale gloveboxes approximately 1.22 x 1.52 m (4 x 5 x 6-ft) in dimension. The program involved the use of alternating flushes of the box interior with an alkaline permanganate solution (3 wt % $KMnO_4$ in 16 to 18% NaOH), and a 15% oxalic acid solution. All flushes were hand sprayed at ambient temperature, and repeated as necessary on a once-through basis. 757 to 1211 L (200 to 320 gal) of liquid waste were produced per glovebox for decontamination to below 10 nCi/g. Recirculation of wash chemicals was not considered in the program.

Laboratory development continued at SRL through 1982 by J. R. Cadieux. His benchscale work determined acidic permanganate to be a better reagent than alkaline. Acidic permanganate is a stronger oxidizing agent than the alkaline removing more metal surface and thus producing higher decontamination factors (DF's). Acidic permanganate reacts with oxalic acid by the following reaction:

$$2\ KMnO_4 + 5H_2C_2O_4 + 6H^+ \rightarrow 2Mn^{+2} + 10\ CO_2 + 8H_2O + 2K^+$$

Previously in the reaction of alkaline permanganate with oxalic acid, sodium oxalate was precipitated.

$$3\ H_2C_2O_4 + 6\ NaOH \rightarrow 3Na_2C_2O_4 + 6H_2O$$

Down-line treatment that may have been required to remove the precipitate are eliminated by substiting an acidic permanganate wash for the alkaline.

It was also found on the benchscale that both elevated temperatures and higher contact time generally increased the effectiveness of decontamination solutions.

Process Modifications

In the original design of the Alpha D&D Pilot Facility, only once-through capabilities were considered. As a result of findings on the benchscale, recirculation of feed chemicals was considered to be a viable method to increase decontamination effectiveness by increasing contact time, while simultaneously reducing waste volumes. Consequently, the following process modifications were made (see Figure 3):

- A single compartment liquid waste holding tank was divided into both a recycle compartment as well as a spent chemical storage compartment.
- An induction heater was added to the recycle compartment to ensure that feed chemicals were kept up to temperature during recirculation.
- A small transfer pump was replaced by a high pressure model with sufficient output pressure to respray chemicals.
- Respray piping was added.

Fixative Removal

Fixatives are generic coatings applied to contaminated surfaces to fix loose contamination prior to equipment transfer. The most common fixative used at SRP is a water-based acrylic polymer, by the trade name Clear Coat (Oakcite Products, Inc.).

On the bench scale, Clear Coat was successfully dissolved when coated stainless steel coupons were dipped in 5% sodium hydroxide solutions at ambient temperature.

During Run #2 in the pilot facility, 5% sodium hydroxide was sprayed on the waste glovebox at room temperature. The fixative did not dissolve but sloughed off in gummy sheets, and plugged drain filters (see Figure 5). In attempts to affect dissolution, the caustic was heated from ambient temperature to 60°C, larger spray nozzles were used, and contact time was increased. All failed to dissolve the fixative.

A commercially available product which combines a low concentration of caustic with surfactants was successfully employed under conditions in the pilot facility to dissolve the fixative. Successful test conditions employed 0.35 wt % caustic in 1.13 wt % surfactant at 60°C with continuous recycle.

Etching Rates

Run #2 tested four cycles of 40 L (105 gal) 1% $KMnO_4$ in 1N HNO_3 wash followed by a 40 L (10.5 gal) 7% $H_2C_2O_4$ wash at 3.4 atm (50 psi) (total 32 L (84.5 gal)). Run #4 examined four cycles of 20 L (5.3 gal) 1% $KMnO_4$ in 1N HNO_3 followed by 20 L (5.3 gal) H_2CO_4 at 50 psi (total 160 L)(4.23 gal). However, each 20 L change was recirculated for approximately 7 sec at a rate of 18 L/min (9.8 gal/min) for an equivalent of 40 L sprayed on the waste glovebox. Both process runs were performed on the same glovebox.

Wall thickness measurements of a single feed glovebox were taken by an ultrasonic thickness gauge before chemical sprays, after Run #2, once through, and after Run #4, with recirculation (Table 1). Run #2 removed an average of 63.5 μm (2.5 mils) surface, while Run #4 removed 38.1 μm (1.5 mils) average. Decontamination to <10 nCi/g of ^{239}Pu-contaminated waste has been demonstrated at PNL by removal of 5-50 μm of surface by electropolishing. Although recirculation removed 40% less surface than did once-through, 50% less chemical waste volume was generated.

Note also that once-through sprays were examined initially, while chemical recirculation was evaluated on the same glove box after the once-through test. Easily removable surface oxides on the glovebox surface were present during Run #2, and absent during Run #4, which contributed to greater difficulty in surface removal during Run #4, recirculation. Recirculation as opposed to once-through is a promising technique to obtain satisfactory decontamination levels while decreasing secondary waste generation.

Etching rates varied slightly at specific locations on the glove box. The glovebox ceiling experienced the least overall etching of 8.89×10^{-2} mm (3.5 mils) where the glovebox floor experienced the most 0.11 mm (4.5 mils). These results agree with our expectations, since liquids tend to drip off the ceiling and puddle on the floor, hence, decreasing contact time to the ceiling and increasing contact time to the floor.

Surface Oxidation

In addition, a qualitative measurement of oxide film removal was examined. Eight patches of surface oxide film approximately 60 cm^2 (9.3 in^2) on the glovebox were created by discoloration with a propane torch. After each respective decontamination process run, both surface area of the oxidized spots and their intensity were examined. Results are given in Table 2. As predicted, the oxidized spot on the glovebox floor experienced most change, disappearing completely. Oxidized spots in other locations (e.g., ceiling, walls) remained the same in physical dimensions, but considerably weakened in intensity.

Filter Pluggage

Process Runs #2 and #4 were conducted without the primary demister/HEPA filter in place. Some filter pluggage in the secondary HEPA filter from the decontamination chamber was experienced. Prior to Run #2, the pressure drop across that filter was 0.71 torr (0.38 in. H_2O). It rose over 4.11 torr (2.20 in. H_2O) during actual spray and reached an equilibrium after decontamination at 2.34 torr (0.38 in. H_2O). It rose over 4.11 torr (2.20 in. H_2O) during actual spray and reached an equilibrium after decontamination at 2.34 torr (1.25 in. H_2O). Run #4 experienced similar pluggage, however not as severe. Before sprays, maximum during spray, and equilibrium after spray pressures were 2.34 torr (1.25 in. H_2O), 3.31 torr (1.77 in. H_2O and 2.54 torr (1.36 in. H_2O), respectively.

Run #5, the simulated process run, was conducted with the primary demister/HEPA filter in place. No noticeable rise in pressure drop across any filter was observed.

Disassembly and Size Reduction

All tools evaluated for use in the pilot facility are operated by manipulators and two technicians. One technician performs manipulations while the other operates tool power.

Hand Tools

A variety of commercially available hand tools that were evaluated for remote operation in the pilot facility are listed below:

circular saw
saber saw
band saw
bibbler
pneumatic shear
drills
impact wrenches
pneumatic chisel
diamond glass cutter
hot knife

All tools were fit with stainless steel or aluminum-grooved blocks which manipulators could grasp easily (see Figure 6). On/Off trigger switches, which are normally hand-operated, were locked on, and controlled by a solenoid valve plugged into a switched receptacle.

The tools which proved most useful to remote operations are:

circular saw
drills
impact wrenches
pneumatic chisel
diamond glass cutter
hot knife

The saber saw, band saw, nibbler, and shear were difficult to handle remotely on irregularly shaped geometries.

The circular saws are easily handled by the PaR manipulator, and cut materials ranging from plywood to metal easily with different blades. Drills are fitted with hole saw bits to cut holes in stainless steel waste items for decontamination solution drainage and wall sampling. Chisels and impact wrenches provide diversified techniques for removing both by chiseling, shearing, or screwing nut and bolt assemblies from window frames, brackets, etc. The chisel was found to work well in numerous orientation, removing appendages that are tack welded to walls of the waste glovebox, and otherwise very difficult to remove.

A mechanically operated diamond glass cutter effectively etched the surface of glass plates frequently found on glovebox fronts. A small propane torch was used to complete the break at the etched location.

One of the most difficult aspects of remotely operating any modified hand tool was experienced in tool lineup. The PaR manipulator, which was used most frequently in cutting operations, possesses no "feedback" sensation to the operator, resulting in a loss of discrimination among forces placed between a tool and workpiece. Tool binding and jamming is a common occurrence in this type of work, although its occurrence lessens with greater operator experience.

The hot knife was found to work well in cutting heavy plastic in which waste items are wrapped.

Plasma Arc Torch

By far the most useful size reduction tool considered was a 100-amp plasma arc torch. It operates by heating cutting gas to the plasma range where it becomes ionized. The gas is then forced through a small nozzle and accelerated to form an intensely hot, constricted arc that can melt any metal. The concentrated heat energy of the arc melts and ejects thin section of the metal to form a kerf. A shielding gas both attenuates the plasma gas and blows the kerf from within the cut (see Fig. 7).

Plasma arc torch developmental areas includes smoke evolution, spark generation, standoff distance, and cutting speeds.

Smoke Evolution. Recommended plasma and secondary gases for the plasma arc torch by the manufacturer, Union Carbide Corp, are nitrogen and carbon dioxide, respectively. In work done at a size reduction facility located at Los Alamos National Laboratory (LANL), the manufacturer recommended gases that produced copious quantities of brown smoke which hampered visibility and plugged primary HEPA filters in less than one working day. However, using 20% hydrogen in argon as a plasma gas and nitrogen as a secondary gas produced no visible smoke during cutting when used in the pilot AD&D facility. No detectable filter pluggage from operation of the torch was observed.

Spark Generation. In the cutting process, sparks and hot slag are thrown in a direction perpendicular to the workpiece, potentially damaging nearby neoprene gloves and manipulator gauntlets. Deflectors fabricated of stainless steel or fire-retardant fabric successfully contained sparks and hot slag.

Standoff. The distance between the plasma arc torch tip and workpiece is called standoff distance. A standoff distance too great will not permit an arc to be established, or continued, while standoff distances too small will overheat and damage the torch. Typical standoff distance is 3.2 mm (1/8 in.) for a 100 amp torch. Manual control of the standoff distance is difficult at best. An automatic standoff control was installed with the plasma arc unit at SRL. Voltage between the torch top and workpiece at a critical set point is measured and maintained by automatic adjustment of the wrist extension/retraction motions of the PaR manipulator that hold the torch. The standoff unit was found to have difficulties when operated at the high speed at which the PaR manipulator traveled, the wrist motor not being able to react quickly enough, thereby exceeding standoff limitations. Speed controls on the manipulator motions were installed to allow operation of the PaR manipulator at lower speeds, thereby permitting feedback from standoff controls sufficient reaction time.

Speed. Results of the plasma arc torch characterization are given in Table 3. Cutting speeds range from 127 cm/min (50 in./min) for 1.6 mm (1/16 in.) aluminum, to 50.8 cm/min (20 in./min) for 6.3 mm (1/4 in.) aluminum and 38.1 cm/min) (15 in./min) for 1.6 mm (1/16 in.) stainless steel, to 22.9 cm/min (9 in./min) for 6.3 mm (1/4 in.) stainless steel. Plasma gas pressure was maintained at 2.1 kg/cm^2 (30 psig), secondary gas pressure at 3.5 kg/cm^2 (50 psig).

Size Reduction Factors. Process Run #5, a simulated hot run demonstrated the size reduction of an uncontaminated representative waste glovebox. The volume of final product of the AD&D process was smaller than the volume of that same waste as sent to interim storage at the SRP burial ground by a factor of 20 (see Appendix I).

Further Developments. Developments in progress include characterization of a 115 amp/1360 V power supply which replaces the 100 amp 200 V plasma arc power supply used for nonradioactive demonstration. Faster, cleaner cuts are expected (76.2-127.0 cm/min (30 to 50 in./min) on stainless steel). Standoff controls are expected to be relaxed, with standoff distances ranging from 4.8 to 19.1 mm (3/16 to 3/4 in.) for the 115 amp unit.

Process Timing

Process Run #5, a simulated hot run, required 58 process hours or 231 man-hours, utilizing three operators and one supervisor (see Appendix II). 8.4 of those process hours were dedicated to decontamination and 38.4 were dedicated to disassembly and size reduction operations.

PROGRAM

The AD&D pilot facility accepted the first contaminated feed item on 4/18. Future work includes processing 10 gloveboxes recently retired from a PuO_2 powder handling line at SRL. The boxes are contaminated to approximately 10^9 dpm/100 cm^2 with ^{238}Pu. Other elements of the program will be installation of a 3.7 m x 3.7 m x 6.4 m (4' x 4' x 7') bagout box, evaluation of a servo-assist master/slave manipulator, and processing drummed waste from plant operations.

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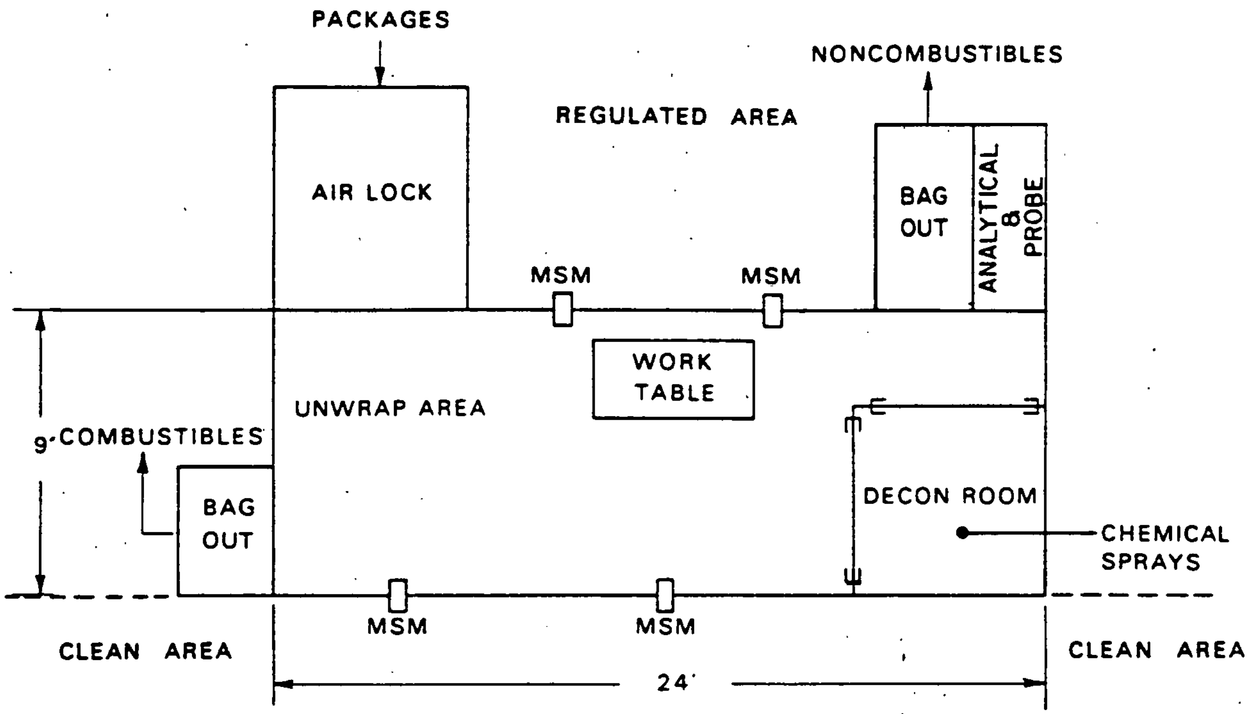

FIGURE 1. Cell Plan View

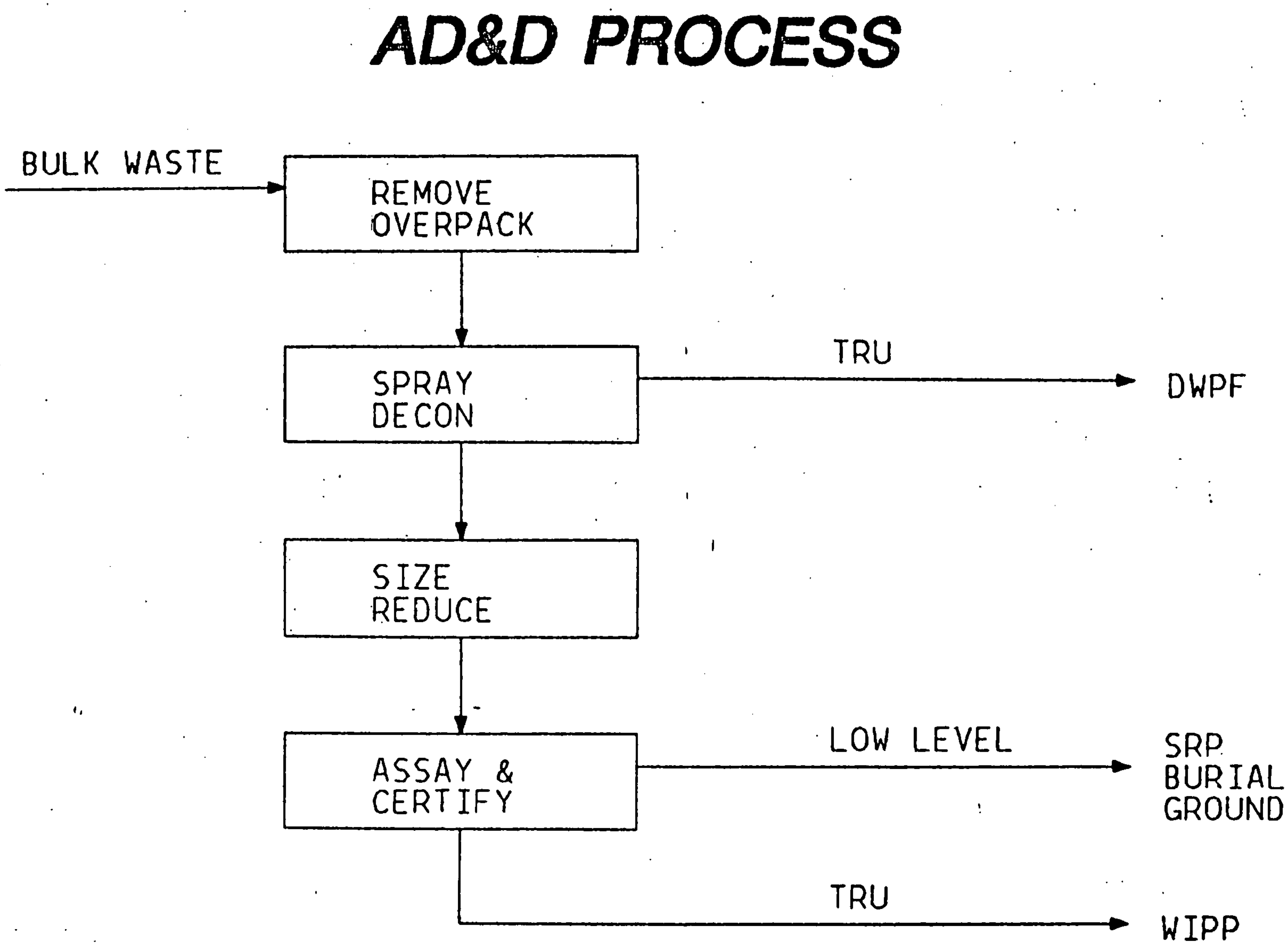

FIGURE 2. AD&D Process

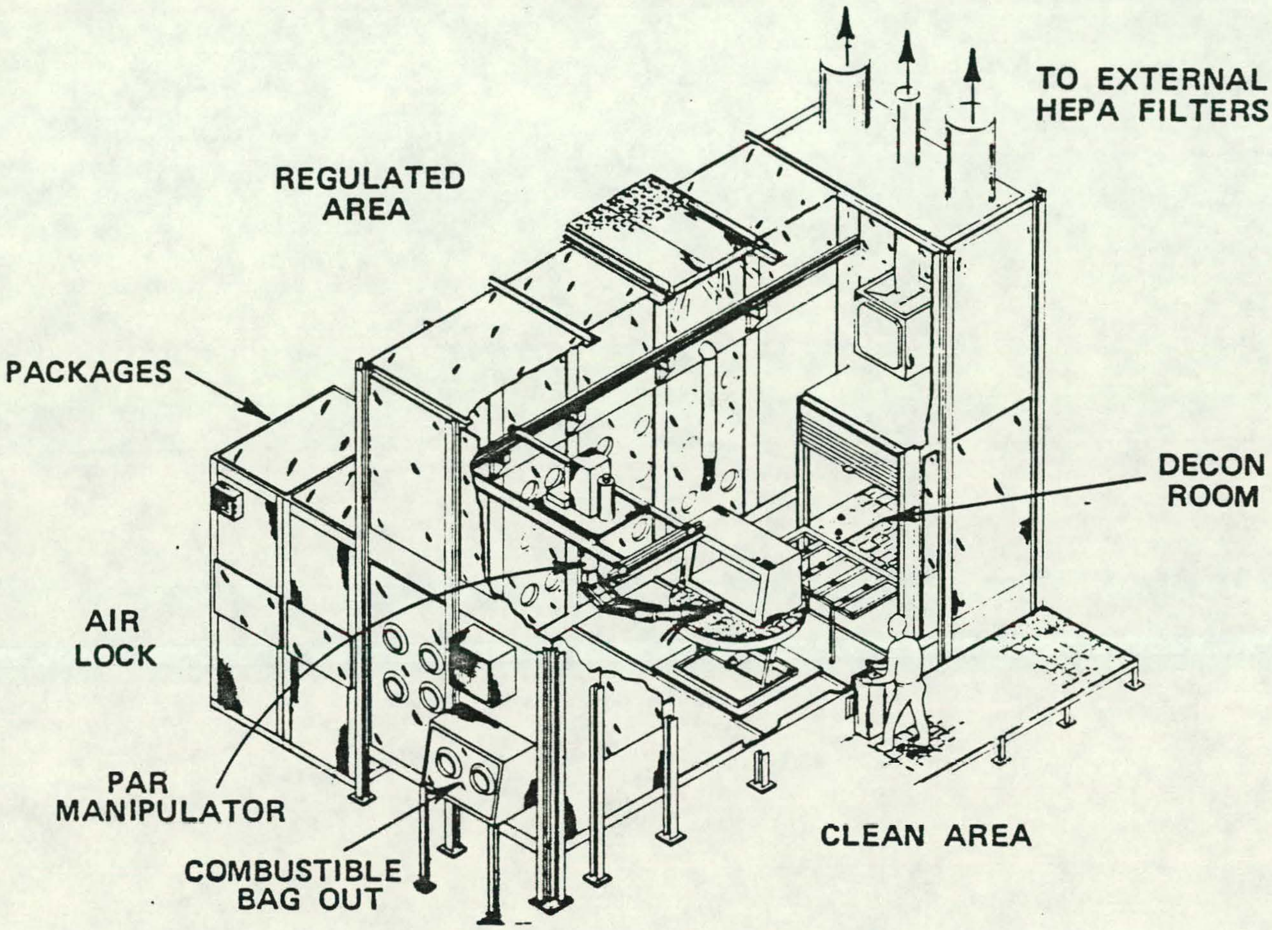

FIGURE 3. Alpha D&D Pilot Facility

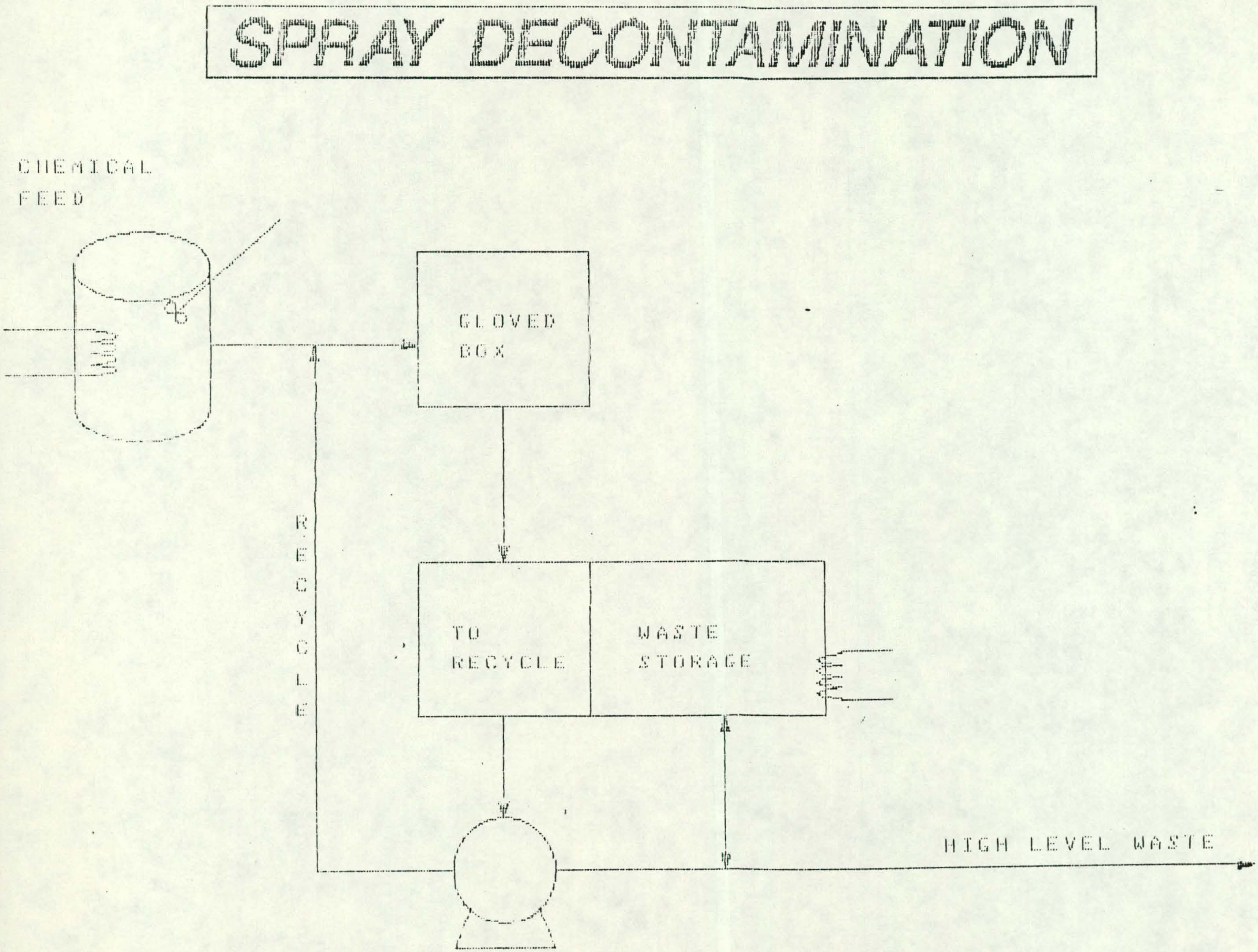

FIGURE 4. Spray Decontamination

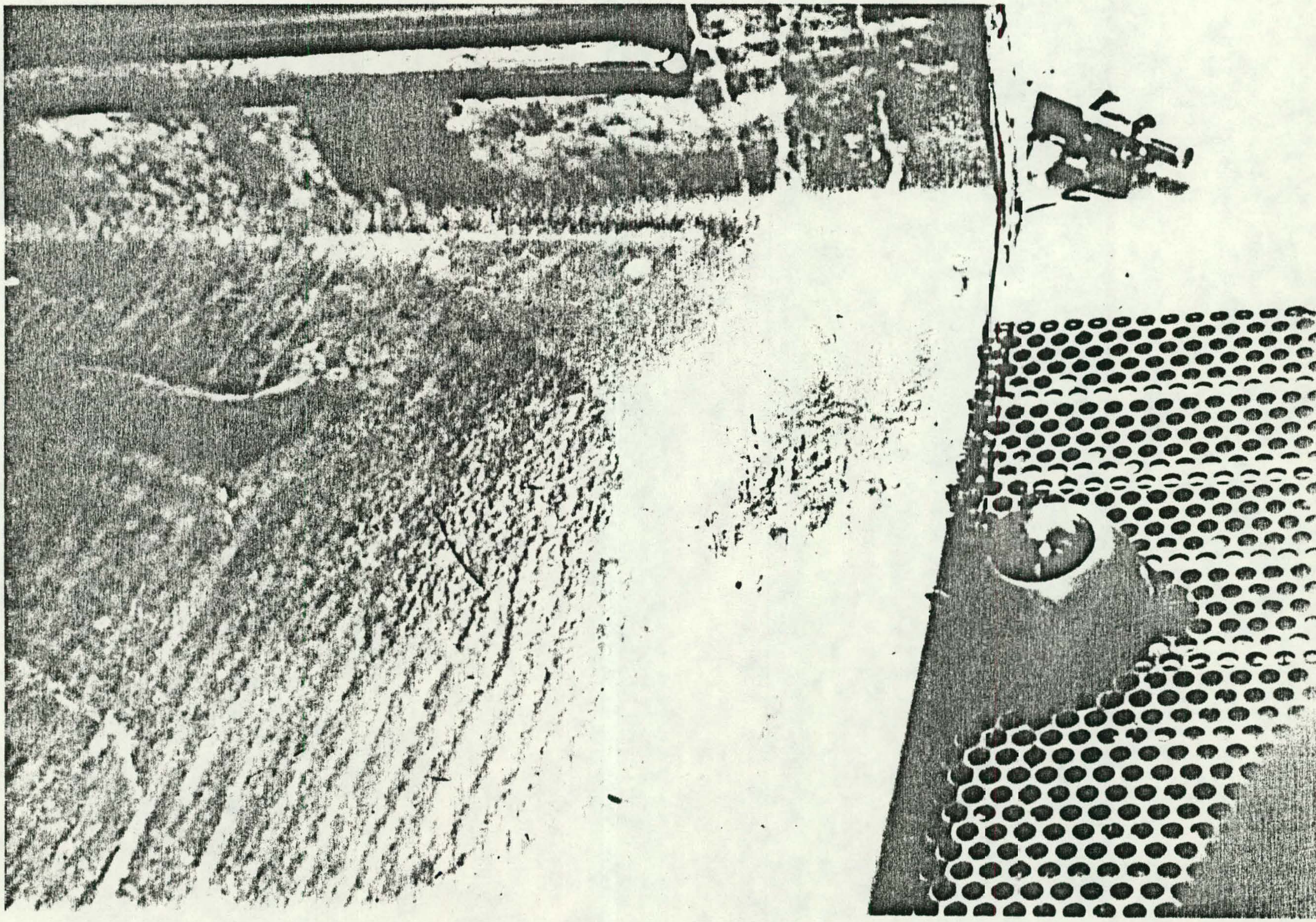

FIGURE 5. Poor Fixative Removal with 5% NaOH

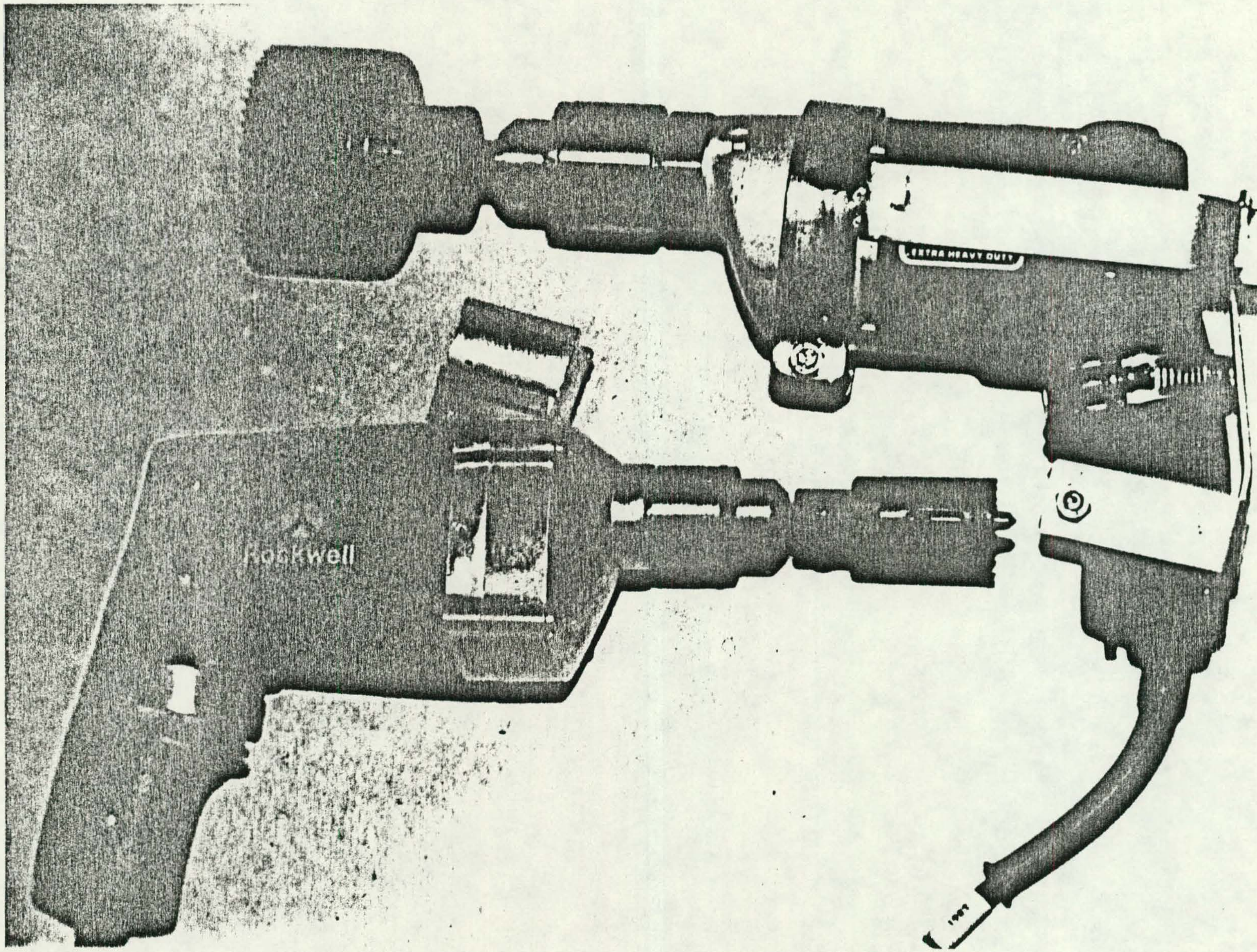

FIGURE 6. Tools Adapted for Remote Use

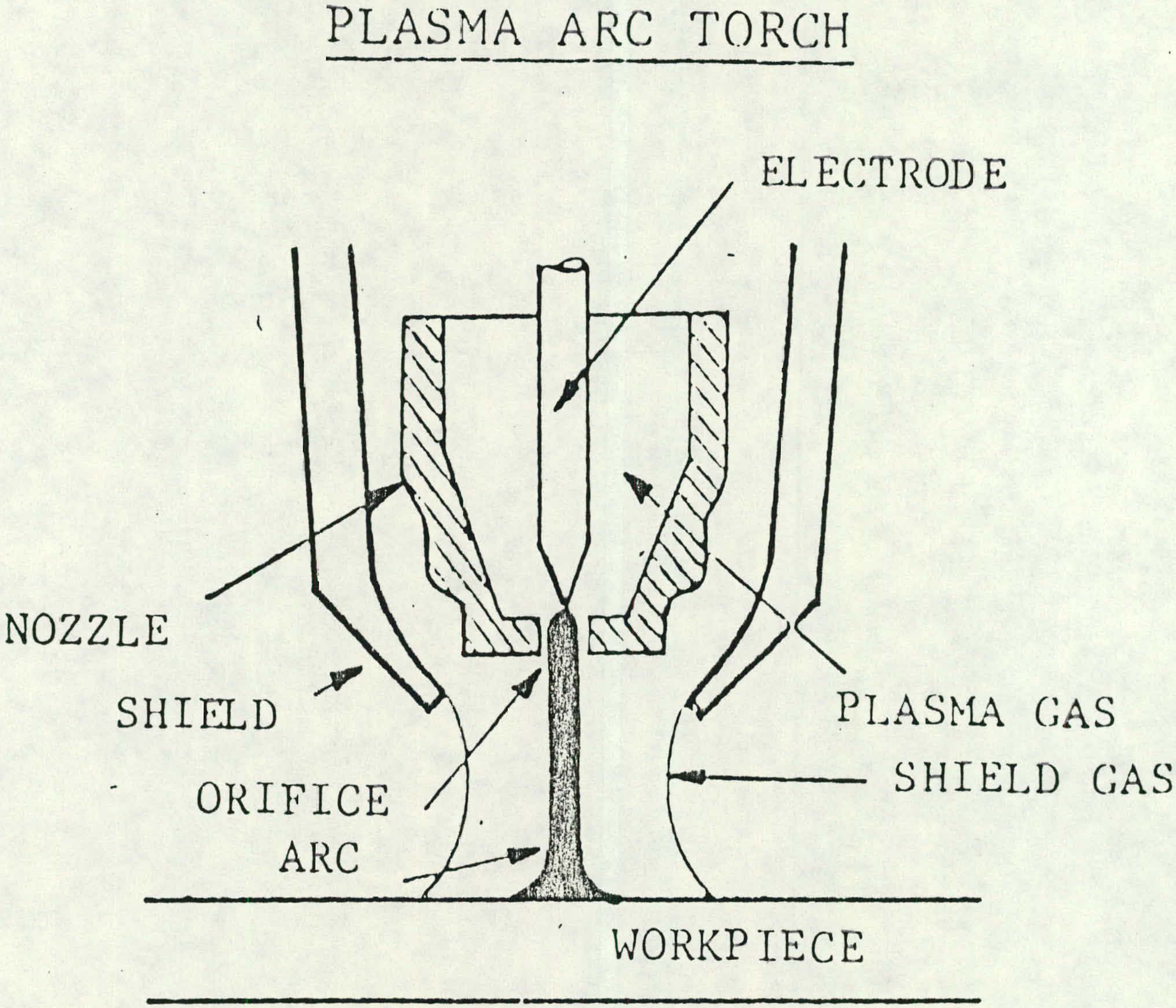

FIGURE 7. Plasma Torch Tip Cutaway

TABLE 1

Surface Removal*

Location on Glovebox	Before mm	Before mils	After Run #2 mm	After Run #2 mils	After Run 4 mm	After Run 4 mils
Ceiling	3.00-3.02	(118-119)	2.92	(115)	2.90-2.95	(114-116)
Sidewall	3.00-3.02	(118-119)	2.95	(116)	2.90-2.92	(114-115)
Backwall	3.00-3.02	(118-119)	2.92-2.95	(115-116)	2.90-2.92	(114-115)
Floor	3.00-3.02	(118-119)	2.95-3.00	(116-118)	2.87-2.92	(113-115)
Average	3.01	(118.5)	2.95	(116)	2.91	(114.5)

* Measurement by ultrasonic thickness gauge

TABLE 2

Oxidized Spots

Location on Glovebox	Before	After Run #2	After Run #4
Ceiling	Spots 58 cm^2 (9 $in.^2$) heavily oxidized with comparable intensity	Spots still 58 cm^2 (9 in^2), but weaker in intensity	Spots still 58 cm^2 (9 in^2) weakened further in intensity
Side wall			
Backwall			
Floor		Spot disappeared	-

TABLE 3

Plasma Arc Torch Characterization

Material	Thickness	Speed cm/min	(in./min)
Stainless	0.063	38.1	(15)
Steel	0.125	31.7	(12.5)
	0.250	22.9	(9)
Aluminum	0.063	127.0	(50)
	0.125	76.2	(30)
	0.250	50.8	(20)

APPENDIX I

Run #5, Simulated Hot Run Size Reduction Factors

Steel burial box volume = 16.8 m^3 (593 ft^3)
(contains 2 plywood crates)

Plywood crate volume = 3.7 m^3 (132 ft^3)

Size reduced waste glovebox

2 - 208 L (55 gal) drums, each at	.2 m^3 (7.4 ft^3)
1 - 19L (5 gal) carton, each at	.02 m^3 (0.4 ft^3)

Total finished product = (2 x 0.2) + .02 = .42 m^3 (15.5 ft^3)

Size reduction factors

$$\frac{\text{Steel box volume}}{\text{Finished product volume}} = \frac{16.8 \div 2}{0.42} = 20$$

APPENDIX II

Run #5, Simulated Hot Run Process Timing

Operation	Process Hours
Preparation, move plywood box to cell airlock	2.75
Size reducte crate	2.50
Insert glovebox into facility	0.33
Unwrap, assay	0.63
Preparation for decontamination	3.30
Decontamination	8.40
Size reduction	35.11
Bagout	0.75
Cleanup	4.00
	57.77

$$57.77 \text{ process hours} \times 4 \frac{\text{men}}{\text{process hours}} = 231.08 \text{ man-hours}$$