Sectioning of Contaminated Components for Decontamination by Vibratory Finishing and Electropolishing

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September 1981

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SUMMARY

This report summarizes work conducted at Pacific Northwest Laboratory to develop, adapt, and evaluate a variety of techniques for sectioning glove boxes, chemical processing equipment, pipes, ducts, and other contaminated components in preparation for decontamination by vibratory finishing and electropolishing. These sectioning studies were conducted with a special 10-ft x 20-ft x 10-ft stainless-steel, walk-in glove box equipped for either hands-on operation via gloves and personnel entry, or remote operation using master slave manipulators and a bridge crane.

Several sectioning techniques have been evaluated with respect to effectiveness, versatility, secondary waste generation, and capability for remote operation. The methods include wet and dry plasma arc torch cutting, mechanical sawing and nibbling, abrasive cutting, and hydraulic shearing and punching. The results of these comparison studies show that the plasma arc torch is a very rapid and effective metal cutting tool for size reduction applications. However, its use to prepare material for decontamination should be minimized because of problems with smoke generation, torch manipulation, waste generation, and entrainment of contamination.

Mechanical saws eliminate all but the waste generation problem, but are very slow and labor intensive. Mechanical nibblers are fast and produce a waste form that can be decontaminated, but are limited with respect to the geometry and thickness of material that can be sectioned. High-speed abrasive saws provide high cutting rates, but produce nontreatable waste from the cut as well as from blade wear. Hydraulic shearing rapidly produces sectioned material in the small sizes required for decontamination by vibratory finishing. The kerf material also can be decontaminated. However, the glove box first must be sectioned into relatively narrow strips by one of the other techniques.

Although these evaluation studies are still in progress, the work conducted to date demonstrates that, with certain requirements, contaminated components can be sectioned safely, efficiently, and with minimal waste generation

into the sizes needed for subsequent decontamination by vibratory finishing and electropolishing. Requirements include proper design of the sectioning facility, flexibility in its mode of operation, and the use of an appropriate combination of available industrial metal cutting techniques.

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SECTIONING OF CONTAMINATED COMPONENTS FOR DECONTAMINATION BY VIBRATORY FINISHING AND ELECTROPOLISHING

INTRODUCTION

Large quantities of surface-contaminated transuranic (TRU) waste are generated by operating nuclear industry facilities and by decommissioning retired facilities. Under current practice, this TRU waste must be placed into interim storage and then, at some future time, retrieved, processed, transported, and emplaced in a permanent repository. Studies are in progress at Pacific Northwest Laboratory (PNL) under U.S. Department of Energy sponsorship to develop electropolishing and vibratory finishing into large-scale decontamination techniques capable of converting a substantial fraction of the surface-contaminated TRU waste into non-TRU waste suitable for relatively inexpensive disposal as low-level waste (Allen et al. 1978; Allen, Arrowsmith, and McCoy 1981; Allen and Arrowsmith 1979; and McCoy, Arrowsmith, and Allen 1980).

Before glove boxes and other contaminated components can be processed using these advanced decontamination techniques, they must be disassembled and sectioned into pieces that are compatible, from a size and geometry standpoint, with the decontamination system and equipment. Although a variety of safe, effective, and economical metal cutting techniques have been developed for industrial sectioning applications, the sectioning of contaminated components for decontamination purposes imposes an additional set of constraints and considerations. These include contamination containment, radiological and criticality safety, nonstandard component geometries, unique combinations of materials, secondary waste generation, entrainment of contamination, and remote operation.

This report summarizes the work that has been conducted at PNL to develop the sectioning technology required to prepare contaminated components for decontamination to non-TRU levels by vibratory finishing and electropolishing. The approach has been to identify candidate industrial sectioning processes, obtain and cold test the necessary equipment, modify and adapt the equipment

and procedures as required for operation with contaminated material, and then evaluate and compare the sectioning techniques in a special sectioning facility working with representative plutonium-contaminated components.

The first section of the report is a description of the sectioning facility used for the evaluation studies and a discussion of some of the major considerations relating to its operation and design. The remainder of the report is a summary of the development and evaluation studies for the individual sectioning techniques. The discussion includes the problems encountered in the development and use of these techniques, as well as the accomplishments, so that this work will be of maximum benefit to those who have similar sectioning requirements for TRU waste or for related applications.

CONCLUSIONS AND RECOMMENDATIONS

Contaminated components can be sectioned safely and efficiently, with minimal secondary waste generation, into pieces of the size and geometry required for decontamination by vibratory finishing and electropolishing. However, sectioning of contaminated material requires a properly designed and operated sectioning facility and the use of a combination of industrial metal cutting techniques.

Facility design recommendations include the capability for either remote or hands-on operation, the use of polished surfaces for cleanability, attention to materials handling requirements, and the provision of adequate tool and equipment storage. The recommended operating procedure for preparing and sectioning TRU-contaminated glove boxes includes: 1) removal of filters and extraneous material, 2) precleaning to remove gross contamination, 3) application of a fixative to control airborne contamination, 4) mechanical disassembly, 5) in situ fracturing of plastic panels, and 6) sectioning of the metal structure.

Of the available metal cutting techniques, the plasma arc torch should only be used to the extent necessary to remove major supports and prepare the component for further reduction by other methods. Metal plate and other planar surfaces should be sectioned into strips by mechanical nibblers wherever possible. Final sectioning of strip and angle material to the small sizes required for decontamination should be by hydraulic shearing.

SECTIONING FACILITY

The sectioning studies described in this report were conducted in the specially-designed sectioning facility shown in Figure 1 . Representative plutonium-contaminated glove boxes and other components were used for the evaluations. The facility was designed specifically for testing and comparing various types of commercial sectioning and materials handling equipment with respect to effectiveness, ability to accommodate a variety of geometries, waste generation, and ease of adaptation for remote operation. In its 3 years of operation, material representing several thousand square feet of contaminated surface area has been sectioned for subsequent decontamination studies. Some of the types of plutonium-contaminated components processed include:

- glove boxes used for fuel fabrication, chemical processing, and R&D studies
- ducting used for building exhaust systems and to service glove boxes and open-face hoods

FIGURE 1. Stainless-steel Walk-in Glove Box Used for Sectioning Studies

- piping used to carry highly contaminated and corrosive liquids
- tanks used to store contaminated solutions
- various storage and shipping containers.

The sectioning facility has been modified and improved based on the experience gained through these sectioning studies. The following sections describe the facility, outline the operating procedures used to section contaminated material, and summarize some of the resulting conclusions.

FACILITY DESCRIPTION

The sectioning facility is a 10-ft-wide x 20-ft-long x 10-ft-high, walk-in glove box. It has a large door (4 ft wide x 7 ft high) at one end to admit the equipment to be sectioned and an air lock at the other end to admit properly dressed personnel. The facility is equipped with several glove ports and windows, a 4000-lb-capacity bridge crane, and a pair of 100-lb-capacity master-slave manipulators (shown in Figure 2 holding a dry plasma arc torch). The

FIGURE 2. View Inside the Sectioning Facility Showing Manipulators and Polished Stainless-steel Surfaces

versatile design of this facility permits either hands-on sectioning operations via gloves and personnel entry, or remote operations using the master-slave manipulators and bridge crane.

All interior surfaces of the sectioning facility are stainless steel polished to a 3- μ in. finish (Figure 2) to facilitate maintaining a low background radiation level. The floor is slightly sloped with a sump in one corner to promote drainage and collection of the water used to preclean components prior to sectioning and to wash the polished walls and floor of the facility itself. The washing is usually accomplished with a high-pressure (1000 psi) washing system which pumps water at the rate of 2 gpm and allows the injection of surfactants and detergents into the high pressure stream. The combination of the smooth surface finish on the interior of the sectioning facility and the high pressure washing system allows the room to be decontaminated from the very high contamination levels experienced just after sectioning highly-contaminated equipment to levels less than 5000 dis/min 100 cm².

Based on the experience obtained with the sectioning operations in the 10 x 20 x 10-ft room, a 2.5-ft-wide x 8-ft-long x 8-ft-high glove box was added to the back wall. This box opens directly into the larger room (Figure 3). This addition was specifically designed to facilitate final sectioning operations using gloves to avoid the labor and maintenance costs associated with extensive use of remote handling equipment. A second, smaller glove box (2.5 ft wide x 8 ft long x 3.5 ft high) was attached to the end of the open glove box for storage or disassembly of small items. As illustrated in Figure 4, a tunnel and chute lead from the junction of the two glove boxes to the inlet of a high production annular vibratory finisher (McCoy, Arrowsmith, and Allen 1980) to permit direct transfer of the sectioned material from the sectioning facility into the vibratory finisher decontamination system. Sectioned material also can be passed directly into the electropolishing facility from the sectioning facility through a separate air lock door and glove box (Figure 4).

FIGURE 3. View of the Glove Box Used for Final Sectioning Operations as Seen from Inside the Sectioning Facility

FIGURE 4. Floor Plan of the Hanford 231-Z Building Decontamination Facility Showing the Relationship of the Sectioning Facility to the Electropolishing and Vibratory Finishing Decontamination System

OPERATING PROCEDURE

The equipment to be disassembled and sectioned is transported to the sectioning facility, and all noncontaminated external hardware is removed. The contaminated equipment is then introduced into the facility through the 4-ft x 7-ft door (Figure 5) and prepared for disassembly by technicians working inside the facility. The ability to readily decontaminate the inside of the facility to low contamination levels means that the door can be opened and equipment carried inside as illustrated in Figure 5 without constructing an external greenhouse or taking precautions other than papering the floor adjacent to the door.

The normal dress for the technicians working inside the sectioning facility is two pairs of cotton coveralls, a bonnet, and several pairs of gloves. A thin vinyl rainsuit is worn over the coveralls as added protection if the facility has or will be wet down with water to control airborne contamination. Although a standard respirator could be used for work in the sectioning facility, the preferred procedure is to use the fan-powered respirator shown in

FIGURE 5. Introduction of Contaminated Components Into the Sectioning Facility Via the 4-ft x 7-ft Door

Figure 6. The fan-powered respirator is a self contained, battery operated, filtered, full-face respirator that is 99.97% efficient against 0.3 μm DOP smoke and provides a protection factor of 1000, as determined by a NIOSH-funded study. It is more comfortable than the standard respirator because it has a 4 ft³/min airflow through the face piece which keeps the face cool and the window of the respirator free of fog.

A typical sequence for disassembling and sectioning a plutonium-contaminated glove box once it is placed in the sectioning facility is as follows. A flexible auxiliary HEPA filtered exhaust line is attached to the glove box to be sectioned through a bag port or glove port so that the pressure inside the box can be maintained negative with respect to the sectioning facility. Working through the glove ports of the box to be sectioned, major sources of loose contamination, such as HEPA filters and nonprocessable items, are wrapped or bagged. When possible, these packages are removed from the box prior to further work. The next step is to wash down the interior of the box by using a high-pressure spray wand that penetrates one of the bags or gloves.

FIGURE 6. Portable Fan-Powered, Battery-Operated Respirator Used by Personnel Inside the Sectioning Facility

The water thus introduced is removed via a wet/dry vacuum. Additional washing may be necessary depending upon the contamination levels in the box. The box is allowed to dry and a fixative is then applied to the interior of the box by a spray wand to control airborne contamination during the disassembly and sectioning steps. The fixative generally used is a polyvinyl alcohol that is compatible with and removed by the vibratory finishing decontamination system (Allen, Arrowsmith, and McCoy 1979). Smears of the box interior determine the need for additional applications of the fixative.

Once the contamination has been fixed, disassembly is started. Components that can be removed mechanically are removed by technicians working inside the sectioning facility as shown in Figure 7. Plexiglas® panel supports are removed and the Plexiglas panels are broken to suitable sizes with a hammer. The box is then sectioned as appropriate using the equipment and techniques

FIGURE 7. Mechanical Disassembly of Plutonium-Contaminated Glove Box

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described in the subsequent sections of this report. The size requirement for pieces that are to be decontaminated by vibratory finishing is approximately 8 in. x 8 in. for plate, corner to corner dimensions of less than 10 in. for angles and other irregular pieces, and pipe and tubing sectioned to lengths not greater than six times the diameter or else split lengthwise.

The general approach is to use the various sawing, nibbling, punching, and torch techniques to section the box into approximately 8-in.-wide strips, and then to feed the strips through the stationary hydraulic shear for sectioning into ~8-in. lengths. Metallic sections that are to be electropolished rather than vibratory finished do not have a fixative applied, as this would adversely affect the decontamination process. However, less sectioning is required since the electropolishing system can accommodate pieces approximately 4 ft x 3 ft x 1 ft (Allen et al. 1978).

DESIGN CONSIDERATIONS

From the experience gained in operating the demonstration sectioning facility at PNL, some general design considerations have evolved that should be applicable to other similar sectioning facilities and operations. These considerations are:

- materials handling and flow - The ability to easily maneuver and position components within the sectioning facility is crucial to an efficient sectioning operation for contaminated components. The use of an overhead bridge crane, monorail cranes, transport baskets, a hydraulic lift table combined with an air caster system, properly positioned glove ports, and two master-slave manipulators all help facilitate materials handling in the sectioning facility and provide a simple, direct flow path for the sectioned material.
- facility cleanability - The use of polished stainless steel for the interior walls and floor in combination with a high-pressure wash system permits rapid decontamination of the facility to low levels of smearable contamination. This facilitates entry of personnel and equipment and minimizes airborne contamination problems during sectioning operations.

- tool and equipment storage - The provision of adequate, cleanable storage inside the facility for the tools and equipment used in the disassembly and sectioning operations is essential to conserve worker time, minimize entries, and maintain a clean, safe working environment.
- operational versatility - The ability to select from a variety of available sectioning techniques combined with the ability to operate either remotely or in a hands-on mode permits selection of the most effective and efficient sectioning approach for each type of contaminated component.

METAL SECTIONING TECHNIQUES EVALUATED

Several industrial sectioning techniques can be considered for sectioning contaminated metal components. The methods evaluated in the PNL facility were selected because of their effectiveness, versatility, compatibility with radioactive safety requirements, and potential for remote operations. These methods are: plasma arc torch, mechanical nibblers, abrasive saws, hand-held mechanical saws, pipe-cutting powered hacksaw, pipe and tubing cutter, hydraulic shear, and hydraulic web press.

PLASMA ARC TORCH

The plasma arc torch was the initial major metal cutting technique selected for evaluation in the sectioning facility. Based on its extensive use for industrial metal cutting applications, it was expected to provide a unique capability for rapidly sectioning odd shapes, thick stock, and hardened metals. Also, the smaller, hand-held torches could be operated through the gloves in physically restrictive areas as illustrated in Figures 8 and 9. The results of the sectioning studies conducted using the plasma arc torch have confirmed these expectations. However, there are a number of problems that have been encountered with this technique that limit its application for sectioning contaminated components and that have motivated a search for alternative techniques. These problem areas are described below.

Spark Generation

The plasma arc torch generates a shower of sparks (Figure 8) that represent a potential fire and contamination hazard. Although combustibles within the sectioning facility are kept to a minimum, an occasional small fire is started by the sparks. The facility has been equipped with a series of quick disconnect fittings that permit the rapid discharge of an external, dry-chemical fire extinguisher onto the fire through a flexible hose and discharge cone positioned inside the facility. Although this system works well, the use of the high-pressure water spray system has been equally effective. Since two technicians are present during the sectioning operation, one can monitor for

FIGURE 8. Dry Plasma Arc Torch Cutting of Plutonium-Contaminated Stainless-steel Glove Box

FIGURE 9. Dry, Hand-Held Plasma Arc Torch and Section Cut from Plutonium-Contaminated Glove Box

fire while the other is operating the torch. At the end of a sectioning operation, adequate time is allowed before leaving the area to ensure the absence of fires.

The sparks also represent a possible-contamination control problem because they can melt through the Hypalon® gloves used in the sectioning facility. This problem has been eliminated by gluing a fire-resistant canvas sleeve over the upper portion of the gloves used by the torch operator. The hand area is protected by wearing leather welding gloves over the Hypalon gloves.

Eye Protection

Another difficult requirement is to provide suitable eye and face protection from the ultraviolet light of the arc while still maintaining adequate visibility before the arc is established. An attempt to use conventional welding helmets was unsatisfactory. Since the operator's hands are inside the gloves holding the torch, the visor cannot immediately be moved into position when the arc is initiated. The next solution attempted was to tape large pieces of protective glass to the outside of the sectioning facility window. However, the entire window either had to be covered with eye protection or blanked off to avoid ultraviolet burns to the skin, severely limiting operator visibility before arc initiation. The final solution to this problem was to purchase light-sensitive, battery-powered lenses. These lenses respond rapidly to the light generated by the arc and provide good visibility of the work area prior to arc initiation and adequate operator protection once the arc is established.

Smoke Control

The plasma arc torch generates a copious quantity of smoke that impairs visibility and forms a dirty film on the interior surfaces of the sectioning facility. In addition, the particulate matter in the smoke rapidly plugs the HEPA filter servicing the sectioning facility. For example, at a discharge rate of approximately 200 CFM, the HEPA filter plugs with 3 hr of cutting time.

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The addition of a fiberglass prefilter, similar to a furnace filter, extends the life of the HEPA filter to about 5 hr of plasma torch cutting time.

This smoke problem has been controlled by the addition of an 800 CFM electrostatic air cleaner to collect the smoke particulates before they migrate to the facility exhaust. Since the smoke generated tends to rise from the cutting area, the air cleaner was positioned over the cutting area with a flexible collection hose positioned as closely as possible over the actual cutting zone. With proper placement of the hose, the system worked very well. In extended usage, however, frequent repositioning of the pickup hose was impractical. The best solution is to mount the suction end of the air cleaner over the general cutting area. This placement of the air cleaner, although not completely effective, has reduced the problems associated with smoke generation to an acceptable level.

The use of the electrostatic air cleaner does, however, present another problem in that the cleaner not only collects the smoke particulates but also the airborne contamination adrift in the facility. Periodic cleaning of the collection plates must be handled carefully to avoid extensive contamination of the facility. Although sophisticated electrostatic air cleaner systems offer hopper collection of particulates or internal washdown capabilities, the best solution for our air cleaner has been to simply remove the collection plates and wash them after every 8 to 10 hr of torch operation. This procedure prevents the particulates from becoming airborne and permits them to be collected and handled in the facility washdown collection system that is designed specifically for contaminated material.

Torch Positioning

The dry, hand-held plasma arc torch used for the sectioning studies (Figure 9) has the power supply and controls installed outside the sectioning facility for easy maintenance and protection from contamination. The torch head and leads are connected to the power supply through bulkhead fittings in the wall of the facility. The 100 A capacity of the torch is ample to cut 0.25-in.-thick stainless steel at 40 in./min. However, the torch is very sensitive to standoff distance or height above the workpiece. The maximum

distance for this torch is only about 3/8 in. Maintaining the torch within this narrow spacing without either extinguishing the arc or shorting out the torch is very difficult when working at a distance, through gloves, and under conditions of relatively poor visibility.

This torch positioning problem has been partially resolved by the recent development of a 250 A commercial torch with a maximum standoff distance of 1.5 in. This increased tolerance for torch-workpiece distance should facilitate cutting operations using gloves and also permit remote operation of the torch by using the manipulators. In addition to these two dry, hand-held torches, a 400 A, water-injected plasma arc torch also has been evaluated for use in the sectioning facility. Although the use of this torch in combination with a water muffle and water table could reduce some of the smoke and spark problems associated with the dry torches, it is too large and heavy for hand operation, and would require remote operation via the bridge crane or other special fixturing. Also, it would be less maneuverable than the hand-held torches and would generate more secondary waste because of its larger cut width.

Waste Generation

The plasma arc torch cutting process, in common with all fusion sectioning techniques, generates a secondary waste form that cannot be decontaminated and must be considered as TRU waste. Accordingly, it is desirable to minimize both the width of the cut (kerf) and the amount of material sectioned using this technique. The cut width is a function of the torch size and is approximately 3/16 in. for the 100 A, dry, hand-held torch as used in the sectioning facility. This size corresponds to a metal loss of less than 2 wt% for typical glove box material sectioned into plates larger than 2 ft x 2 ft. The waste generation rate would be unacceptably high if the torch were used to section material into the smaller sizes required for decontamination by vibratory finishing.

Contamination Entrainment

One disadvantage of fusion cutting techniques that is not shared by mechanical sectioning methods is the possibility of incorporating some of the

surface contamination in a difficult-to-remove recast layer that forms on the surface of the cut. This is not a problem for size reduction applications, but must be considered if the sectioned material is to be decontaminated to non-TRU levels (Allen et al. 1978).

Other Considerations

Two problems encountered in industrial applications of the plasma arc torch, high noise level and gas generation, are alleviated by use of the torch inside the sectioning facility with the operator on the outside. The noise is muffled by the facility walls, and the potentially hazardous gases generated by the cutting operation are removed by the facility exhaust system. Another anticipated problem area was the spatter from the cutting process adhering to adjacent surfaces on the component being sectioned and also to the nearby walls and floor of the sectioning facility. An antispatter compound was identified and used to prevent adherence of spatter to metal surfaces, and the floor of the facility was protected with a mat. However, these precautions were not necessary. The dross was easily removed from surfaces even without prior application of the antispatter compound. Moreover, the protective mat became a collector and source of contamination and was discarded. The current procedure is to remove the spatter by sweeping and use of a wet/dry shop vacuum.

MECHANICAL NIBBLERS

Because of the problems noted in the previous sections, the plasma arc torch is used only for the most difficult metal sectioning operations and to prepare large sections for further size reduction using other metal cutting techniques. One of the most attractive of these alternative methods is the mechanical nibbler. The punch and die cutting action of the nibbler provides minimal opportunity for contamination entrapment in the cut. Also, the punched material removed by the nibbler can be decontaminated by vibratory finishing or electropolishing.

Nibblers are available with both pneumatically and electrically powered motors. Two sizes of electrically powered nibblers are currently used in the sectioning facility. The smaller nibbler (Figure 10) has a rated thickness capacity of 0.17 in. for stainless steel. However 0.19-in.-thick stainless

FIGURE 10. Small, Hand-Held Mechanical Nibbler Used for the In Situ Sectioning of Thinner Glove Box Components

steel is routinely sectioned with this nibbler with only minor additional maintenance. The sectioning rate for 0.19-in. stainless steel is approximately 8 ft/min. This nibbler weighs approximately 23 lb, which is not unreasonable for manual use by one operator. The maneuverability of this nibbler is good with the ability to follow some reasonable nonplanar contours, as well as turn within approximately a 1-ft radius. Large quantities of 8-in.-diameter, stainless-steel ductwork with 0.125-in.-thick walls have been successfully sectioned circumferentially and longitudinally using this smaller nibbler.

The larger nibbler has a thickness capacity of 0.25 in. of stainless steel with a cutting rate of approximately 6 ft/min. This nibbler will follow only very gentle contours and the turning radius is very large. It weighs approximately 45 lb and is difficult to maneuver by hand. The usual operating practice is to either suspend the nibbler by a counterbalance or use the nibbler in a fixed position while feeding the stock through it.

Although nibblers are relatively straightforward in their operation, there are a few special operating considerations that should be noted. For nibblers

with clearance adjustments, the proper clearance must be maintained for the thickness range of stock being cut. Failure to do so causes rapid wear of the punch and die combined with tearing or jamming of the stock. A second consideration is to plan ahead on lengthy cuts. Particularly when sectioning large panels, stresses in the panel can be relieved by the cut and result in bending the sides of the cut and binding of the nibbler. The nibbler can usually be fed in the forward direction, but may not be backed up because of the movement in the sectioned panel. Therefore, it is advisable, whenever possible, to avoid dead ends when sectioning with a nibbler.

The nibbler is a valuable tool but is largely limited to planar surfaces and gentle contours. With the exception of the plasma arc torch, the nibbler is the fastest of the sectioning techniques that have been evaluated for large planar surfaces. Therefore, its primary use in the sectioning facility has been to rapidly reduce the large sections cut by the plasma torch into strips suitable for final sectioning by the hydraulic shear (to be discussed in a later section).

ABRASIVE SAWS

Sectioning studies were conducted using the electrically powered, hand-held abrasive saw shown in Figure 11. Cutting rates of approximately 10 in./min were obtained for 3/8-in.-thick stainless steel. However, the waste generation rate from abrasive sawing was high. The kerf may be 3/16 in. wide and the resulting waste, which cannot be decontaminated, is in the form of highly dispersed shavings that are messy and may create airborne contamination. In addition, the edges produced by the abrasive saw are extremely sharp, creating a severe safety hazard. The advantages of abrasive saws, on the other hand, are that they can cut through double-wall construction and are unlikely to entrain contamination.

The electrically powered units are fairly heavy and, therefore, physically demanding on the operator. Hydraulic-powered units are available with a driver head that is attached to the power unit by hydraulic lines. This cutting head is much lighter than the electric unit and the power rating can be considerably higher. In other words, abrasive sawing is a technique that is highly

FIGURE 11. Hand-Held, Electrically-Powered Abrasive Saw

equipment and operator dependent. Cutting rates can be quite varied depending upon the material being cut, the type of blade used, the speed and power of the saw, and operator technique. Based on the evaluations conducted with the electrically powered unit, abrasive sawing is not a significant part of the sectioning facility operations. However, the results of a planned evaluation of the lighter, more powerful hydraulic unit may justify greater use of this sectioning technique.

HAND-HELD MECHANICAL SAWS

Hand-held, portable reciprocating hacksaws (Figure 12), although relatively slow for cutting thick metal sections, have proven invaluable because of their light weight, maneuverability, and versatility. Their ability to cut in a fairly restricted area and the variety of geometries that can be sectioned make this type of saw very useful.

Mechanical sawing speed and efficiency is highly dependent upon operator techniques, the type of material being sectioned, the type of cutting blade,

FIGURE 12. Hand-Held Reciprocating Hacksaw

the use of lubricants and coolants, and the rigidity of the workpiece. Probably the two major considerations for the successful use of these saws are: 1) the quality of the blade and 2) the rigidity of the workpiece. If the workpiece is not rigid, or not pulled up against the saw foot securely, the workpiece will flex and merely follow the saw blade motion, resulting in very slow cutting rates. When cutting pipe, tubing, or ducting, the use of a power hacksaw that clamps to the workpiece is usually more efficient.

The use of a portable band saw (Figure 13) also has proven very effective. Cutting rates and blade life are considerably greater than for the reciprocating saw. Although the portable band saw is maneuverable and effective, the limited depth of cut precludes its use for sectioning large items.

PIPE-CUTTING POWER HACKSAW

A portable power hacksaw that clamps to the pipe or ductwork (Figure 14) has been very effective for rapid sectioning of this material, primarily due to the rigidity of the setup. The saw is clamped with a chain to the pipe or

FIGURE 13. Portable Bandsaw

FIGURE 14. Clamp-on Power Hacksaw Used to Section Large Pipe and Ductwork

duct and pivots around a fixed point. Large quantities of pipe and ductwork have been successfully sectioned with this apparatus. Even large ducting can be sectioned by only cutting one side at a time and advancing the pivot point about the duct. Although designed specifically for cutting pipe and duct, it might be possible to adapt this type of saw for sectioning glove boxes or other structuring components. However, for sectioning large quantities of smaller diameter pipe or tubing, the pneumatically powered pipe and tubing cutter, described in the next section, should be considered.

PIPE AND TUBING CUTTER

Equipment capable of rapidly cutting tubing and pipe into lengths suitable for processing in the vibratory finisher or electropolishing systems has been evaluated (Figure 15). An air-driven cutter (Figure 16) is used to section rotating tubing with no waste and minimal probability of entrainment of surface contamination. The unit can accommodate tubing or pipe $3/4$ to $5-1/4$ in. in diameter and with wall thicknesses up to $3/16$ in. Typical sectioning times

FIGURE 15. Air-Driven Pipe Cutter for Rapid Sectioning of Pipe and Tubing

FIGURE 16. Cutting Head for the Air-Driven Pipe Cutter Shown in Figure 15

range from 9 sec for small tubing to 7 sec for the larger pipe. Although this equipment sections very rapidly, it requires rotation of the workpiece. Therefore, the pipe or tubing must be straight with minimal protrusions.

In addition to the air-driven cutter, a portable pipe cutting device (Figures 17 and 18) capable of cutting up to 2-in.-diameter, stainless-steel pipe was successfully tested. This device has a self-feeding pipe cutter which can be attached either to a motor driven device or a hand-operated ratchet device. Power is supplied to the motor drive with a portable drill motor.

The portable cutter has the unique capability of cutting pipe in situ. In situ cutting is accomplished by inserting an end of the pipe to be sectioned into the opening in the power drive, attaching the pipe cutter, and then clamping the power drive device in place and starting the drill motor. If the pipe is continuous in the area where cutting is desired, the ratchet drive device can be installed around the pipe and used to cut out a section of pipe to permit installation of the power drive. As little as 1.5 in. of clearance is required for the power drive. Consequently pipes can be cut in close proximity to walls and other pipes, such as in pipe galleries.

FIGURE 17. Portable, Motor-Driven Pipe Cutter

FIGURE 18. Portable, Hand-Operated Pipe Cutter

HYDRAULIC SHEAR

Shearing is a rapid sectioning technique that is particularly well suited to the type of size reduction operation required to prepare contaminated components for decontamination. Shearing produces virtually no contamination entrainment in the cut, and the waste from the cutting operation can be decontaminated by vibratory finishing or electropolishing. The power unit for the hydraulic shearing equipment can be installed outside the sectioning facility for ease of maintenance and to conserve space. Only the very powerful, but relatively small, sectioning head is located inside the contaminated zone. Hydraulic shearing does require the prior sectioning of material to fit in the shear; however, once this is accomplished, large amounts of material can be rapidly sectioned, representing the least labor intensive method of sectioning metallic components into the small sizes required for decontamination by vibratory finishing.

The double cut, stationary shear (Figure 19) used in the PNL sectioning facility has the capacity to shear 9-in.-wide strips of stainless steel 1/4 in.

FIGURE 19. Double-Cut Hydraulic Shear Used for Final Sectioning of Contaminated Metal

thick with a cycle time of approximately 10 sec per cut. A strip 1/2 in. wide is removed from the workpiece by the dual blades. These strips (Figure 20) are processed in the decontamination system along with the rest of the sectioned material.

The dies and blades of the shear can be changed to accommodate either flat or angle stock. Attempts to use the flat stock configuration to cut both flat stock and angle material resulted in eventual damage to the dies and blade. During the initial portion of the downstroke, the blade acted as a press to flatten the angle stock, which tended to round the blade and eventually wedged the stock material between the blade and die.

The use of blades and dies designed to cut angle stock should eliminate this problem. Flat stock may be placed on the sides and sectioned with no damage to the equipment. The maximum width of the flat stock can only be approximately 6 in. as opposed to the 9-in. capability in the flat cutting arrangement. This method requires additional sectioning via other techniques

FIGURE 20. Carbon Steel Plate (3/8 in. Thick) Sectioned with the Double-Cut Hydraulic Shear Shown in Figure 19. The resulting 1/4-in.-wide v-shaped kerf is in the foreground.

to produce the narrower strips, but should result in longer shear life and less maintenance. An alternative method is to stockpile either the angle or flat stock until a die change is warranted.

HYDRAULIC WEB PRESS

As an alternative to plasma arc torch cutting, a hydraulic web press (Figure 21) was tested for use as a nibbler for initial sectioning of the metallic portions of glove boxes. The web press is a "C" shaped tool with a punch and die in the open ends of the "C". The tool is normally used to punch holes in the web of beams at construction sites and the tool can be maneuvered to make both horizontal and vertical punches.

Testing of the web press revealed that a deeper than normal die pocket is necessary to reduce die misalignment while nibbling. Nibbling, which uses a series of overlapping holes to section, places uneven stresses on the punch. The deeper die pocket provides the support necessary to overcome these unsymmetrical stresses.

FIGURE 21. Hydraulic Web Press Modified for Service in the Sectioning Facility

The web press is suspended from the bridge crane via a long, coiled spring. The press pivots about its center of gravity as it is suspended from the spring, which minimizes the effort required to position the press. The press can punch 1-in.-diameter holes in 1/4-in. stainless steel plate at approximately 5-sec intervals. The press can either be used in a nibbling fashion or as an aid to producing starting and ending points for other cutting techniques such as the mechanical nibblers or saws. As with the double cut shear, the hydraulic power unit for the web press is kept outside the sectioning facility. Also, the waste from the punching operation can be decontaminated. Although testing is not complete, the hydraulic web press should prove a very valuable and versatile tool for sectioning components for decontamination by vibratory finishing or electropolishing.

SECTIONING OF NONMETALLICS

Glove boxes and other TRU-contaminated items have nonmetallic components such as Plexiglas panels, Hypalon gloves, vinyl bags, rubber gaskets and window channels, and glass tanks that can be decontaminated to non-TRU levels by vibratory finishing (Figure 22). Like the metallic components, these nonmetallics must also be sectioned or reduced to a size that is compatible with the vibratoy finishing equipment. The techniques used to accomplish this size reduction are described in the following sections.

PLASTIC PANELS

Most of the glove boxes that have been decontaminated as part of the PNL demonstration studies have large Plexiglas or other similar clear, thermo-setting plastic panels. Although the sectioning of these panels would not seem to be a difficult problem, several approaches were tested before arriving at a satisfactory solution.

FIGURE 22. Sectioned Metallic and Nonmetallic Materials from the Plutonium-Contaminated Glove Box Shown in Figures 7, 8, and 9

The first approach to sectioning Plexiglas was scoring and breaking. Cold tests on small panels showed that by scoring and breaking over an edge, proper sizes could be generated with almost no material lost as nonprocessable waste. A simple breaking mechanism was constructed to handle the large panels. However, this system proved unsuccessful even with deep scoring because of the glove and bag ports. Some moderate success was achieved by placing the removed panels on the floor of the sectioning facility and striking them with a large hammer, but this was physically very demanding work.

Several attempts were made to saw the panels. A standard carpenter's circular saw was used with wood cutting blades. This technique was unsuccessful as the plastic melted in the kerf and gummed up the blade. However, the use of a circular saw blade specifically designed for cutting Plexiglas was very successful. The special blade has cutting teeth that are ground with a negative rake to prevent the buildup of material in the kerf and permit cutting rates of 10 to 15 ft/min for 3/8-in.-thick Plexiglas. Similar gumming problems were encountered for reciprocating saws. Fine-tooth blades, designed for metal cutting, gummed up and were unsuccessful for cutting Plexiglas. The use of very coarse blades (three teeth per inch) produced satisfactory cuts in 3/8-in.-thick Plexiglas at the rate of approximately 4 ft/min. Although these sawing rates are quite satisfactory, the plastic sawdust volumes are significant. These cuttings also tend to migrate rapidly and, with highly contaminated Plexiglas, become a source of airborne contamination.

Because of these problems, the in situ impact breaking approach described in the operating procedure section was developed. The panel hold downs are removed and, with the panels still standing in place, a hammer is used to break them into pieces. Although the resulting sections are of irregular shape, they are readily decontaminated in the vibratory finisher. Moreover, this sectioning process does not produce dust or nonprocessable material.

GLOVES, BAGS, WINDOW CHANNELS

Gloves and bags can be decontaminated by vibratory finishing but must be cut open. The thinner materials must be cut into small enough pieces to remain flat during vibratory finishing. Common paper scissors do an acceptable job

for standard Hypalon gloves and vinyl bags. Rubber window channels and gaskets can be cut into suitable lengths in the same manner.

OTHER NONMETALLICS

Although broken glass is a potential safety hazard, it can be accommodated in a vibratory finisher. The glass is broken carefully using a hammer as required for sizing or media access.

HEPA filters are not decontaminated (with the exception of the metal frames) using the vibratory finishing or electropolishing techniques. However, it is sometimes desirable to section HEPA filters for drum packaging. Both wooden and metal frames can be sectioned with reciprocating saws. When the frames are removed, the tightly packed filter media tends to increase substantially in volume. Two approaches have been developed to overcome this increase. One method is to tie the media prior to removal of the frame. Another approach, which is particularly useful if the filter is grossly contaminated, is to bag the filter and cut the frame through the bag. This approach aids both in reducing airborne contamination from the filter and in containing the expanding filter media.

REFERENCES

- Allen, R. P., et al. 1978. "Electropolishing as a Decontamination Process: Progress and Applications." PNL-SA-6858, Pacific Northwest Laboratory, Richland, Washington.
- Allen, R. P., and H. W. Arrowsmith. 1979. "Radioactive Decontamination of Metal Surfaces by Electropolishing." Materials Performance 18(11):216.
- Allen, R. P., H. W. Arrowsmith, and M. W. McCoy. 1980. "Decontamination of Alpha-Contaminated Materials by Electropolishing and Vibratory Finishing." International Atomic Energy Agency Meeting (Management of Alpha-Contaminated Wastes) Proceedings. Vienna, Austria, January 1981, pp. 177-88.
- Allen, R. P., H. W. Arrowsmith, and M. W. McCoy. 1981. "New Decontamination Technologies for Environmental Applications." PNL-SA-8144, DOE Symposium on Decontamination of the Environment. USDOE Report CONF-791234, Oak Ridge National Laboratory, Oak Ridge, Tennessee, pp. 110-22.
- McCoy, M. W., H. W. Arrowsmith, and R. P. Allen. 1980. Vibratory Finishing as a Decontamination Process. PNL-3336, Pacific Northwest Laboratory, Richland, Washington.

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