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The Application of Metal Cutting Technologies in Tasks Performed in Radioactive Environments (U)

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THE APPLICATION OF METAL CUTTING TECHNOLOGIES IN TASKS PERFORMED IN RADIOACTIVE ENVIRONMENTS

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ABSTRACT

The design and use of equipment to perform work in radioactive environments is uniquely challenging. Some tasks require that the equipment be operated by a person wearing a plastic suit or full face respirator and donning several pairs of rubber gloves. Other applications may require that the equipment be remotely controlled. Other important, design considerations include material compatibility, mixed waste issues, tolerance to ionizing radiation, size constraints and weight capacities. As always, there is the "We need it ASAP" design criteria. This paper will describe 4 applications where different types of metal cutting technologies were used to successfully perform tasks in radioactive environments. The technologies include a plasma cutting torch, a grinder with an abrasive disk, a hydraulic shear, and a high pressure abrasive water jet cutter.

INTRODUCTION

Each task described in this paper was unique and required a different metal cutting technology. In the first application, a plasma cutting torch was used to remove an elbow section of pipe from a 36 inch diameter, 1/4 inch thick, stainless steel, ventilation duct contaminated with radioactive materials. The plasma cutting torch system was remotely controlled and cut the elbow section from within the duct itself. The second task involved removing a constrained, 3-legged, stainless steel table located in a below grade, contaminated, confined-space area. A grinder with an abrasive cutting disk was used in a design that required an operator to remotely manipulate the cutting tool. The third application used a hydraulic shear to size reduce a contaminated pipe so that it could be disposed of in an approved waste container. Because of the radiation exposure and contamination potential, this equipment had to be remotely controlled. In the fourth application, the release mechanism of a piece of equipment had become jammed, and the equipment could not be released from permanent, irreplaceable piping nozzles inside a large waste tank. A high pressure abrasive water jet was used to sever the large steel pins in the connecting mechanism of the equipment. The tool was deployed and manually operated by personnel wearing protective clothing.

PLASMA CUTTING TORCH APPLICATION

A robotic pipe crawler and plasma torch cutting system was developed to crawl into a radioactively contaminated ventilation pipeline and remove a 36 inch diameter, 1/4 inch thick, stainless steel pipe elbow from the inside. The pipeline is part of an exhaust ventilation system connected to a plutonium processing facility. The exhaust ventilation system uses a number of high capacity fans to draw building air through ventilation pipelines and an underground concrete tunnel. Before leaving the plutonium facility, airborne radioactive materials present in the pipeline's exhaust air are removed using high efficiency particulate air (HEPA) filters. The pipeline exits the plutonium processing facility through the underground, concrete, air tunnel which is contaminated with radionuclides. After some distance in the air tunnel, the pipeline elbows up and makes a right turn into a separate concrete containment system. From there, the ventilation pipeline extends 230 feet where it "Y's" into the north exhaust fan and continues another 35 feet where it "elbows" into the south exhaust fan as shown in Figure 1. The exhaust air in the concrete tunnel is filtered by a large sand bed filter. Because of safety and environmental concerns about the physical condition of the pipeline, its exhaust had to be redirected into the air tunnel. To accomplish this, it's elbow section located in the air tunnel had to be removed.

Several metal cutting technologies were considered Plasma arc cutting (PAC) technology, invented in the mid 1950s to cut nonferrous metals like stainless steel and aluminum, was chosen. When compared to mechanical cutting processes such as saws and grinders, the amount of force required to hold the workpiece in place and move the torch is much lower with the "non-contact" plasma arc cutting process. The PAC process severs metal by using a constricted arc to melt a localized area of the workpiece and removes the molten material with a high-velocity jet of ionized gas issued from the constricting orifice. PAC derives its name from passing a gas through an arc and partially or completely ionizing the gas into a plasma capable of conducting an electric current. Plasma arc torches operate at temperatures ranging from 18,000 - 25,000 degrees F (10,000 - 14,000 degrees C). The super-heated plasma stream passes through a constricting orifice where its intensity and velocity is determined by several variables including the type of gas, the flow pattern, the electric current, the orifice size and shape, and the distance to the workpiece. The orifice directs the super-heated plasma stream toward the workpiece. As the cutting arc transfers to the workpiece, the super-heated arc melts the workpiece and the high-velocity jet of plasma blows away the molten metal to form the cut or kerf. PAC torches are available in various amperage capacities up to 1000 amps.

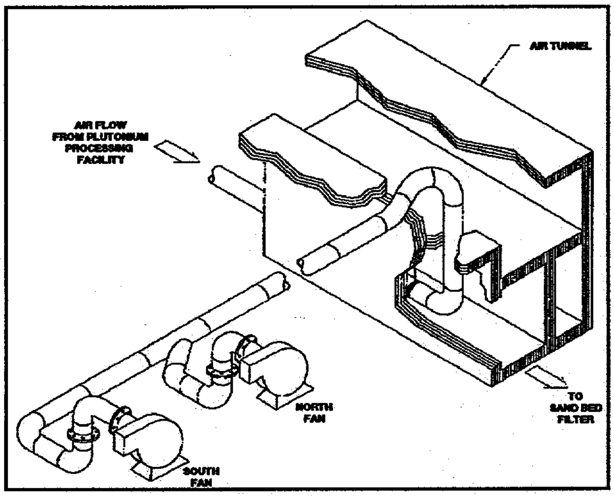

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Figure 1. Ventilation system

During the course of the development work, 2 plasma torch systems were tested; a 50 amp torch and a 70 amp torch. Both PACs used the same size torch head and lead. Additionally, they operated on either air or nitrogen gas. The initial PAC system tested was the 50 amp torch. It was designed to cut as much as 1/2 inch of steel. The 50 amp torch could complete a circumferential cut of the pipe in 13 minutes. Therefore, the 2 cuts necessary to remove the elbow would take approximately 26 minutes to complete. Because the torch nozzle has a life of 45 minutes, a higher capacity torch was needed to ensure that the torch nozzle could remove the elbow without having to return from the cut site and be replaced. A 70 amp system capable of cutting through 3/4 inch thick steel was the highest amperage plasma torch the vendor offered that used the same torch head and lead as the 50 amp model. The 70 amp torch made the circumferential cut of the pipeline in 4 minutes. By using the 70 amp instead of the 50 amp torch, the elbow removal cutting time was reduced from 26 minutes to 8 minutes.

The pipe crawler developed to carry the plasma torch cutting system is shown in Figure 2. It is nearly 7 feet long, 34 inches in diameter, and weighs approximately 125 pounds. The crawler chassis is fabricated out of aluminum and can be divided into 3 sections; front, middle and rear. Two universal joints located on either end of the middle section link all 3 sections together. A combination of omni-directional wheels and rubber feet are mounted to the front and rear sections. Steel wheels are mounted to the midsection. The crawler is propelled through the pipe using a combination of 14 pneumatic gas cylinders. Six pneumatic air cylinders are mounted on the front section and eight on the rear section. Six cylinders on each of the front and rear sections act as legs and are mounted radially from the center and are located 60 degrees apart from each other. They simultaneously extend or retract to alternately grip and release the pipe wall. Two of the eight rear mounted cylinders are mounted inline with the chassis and extend or retract simultaneously causing the crawler to go forwards or backwards depending on the position of the front and rear leg cylinders.

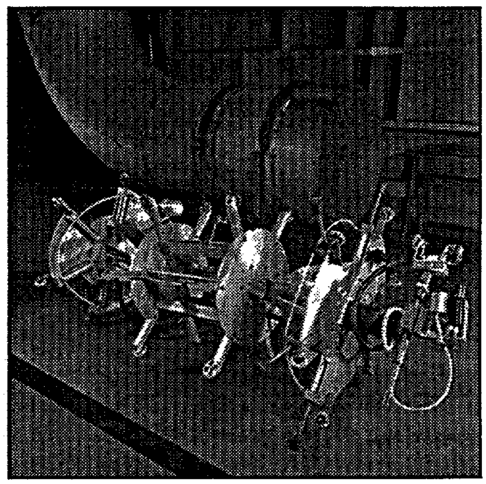

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Figure 2. Pipe crawler

The pipe crawler can move in either 1 of 2 modes; manual or automatic. Both act to properly sequence pneumatic solenoid valves located on the pipe crawler. Manual mode is used to help propel the crawler through difficult sections of the pipeline where the force of gravity had a significant effect. For manual mode, a set of 3 paddle switches control the pipe crawler's 14 pneumatic actuators. The automatic mode of crawling utilizes a programmable logic controller (PLC) mounted within the control cabinet. The pipe crawler program on the PLC was optimized for speed in crawling through the long, straight and level sections of the ventilation pipeline.

A motorized, high torque, continuous turn rotator was mounted to the front of the crawler. The plasma arc cutting torch was attached to the rotator as shown in Figure 3. The rotator's speed could be accurately controlled and was dictated by the capacity of the plasma torch used in the application. The higher the torch amperage, the faster the rotator could travel while achieving 100% metal penetration. The plasma arc torch head was held in a bracket. The bracket had 2 wheels that allowed it to roll against the pipe wall. Slots in the wheel brackets allowed the torch's standoff distance to be adjusted. In testing, a standoff distance of 1/8 -1/4 inch was found to be optimal. The torch bracket was connected to an air cylinder which extended the torch to the pipe wall. Stainless steel springs were added between the torch bracket and the air cylinder to improve compliance in the deployment tool and to compensate for pipe wall irregularities like weld seams.

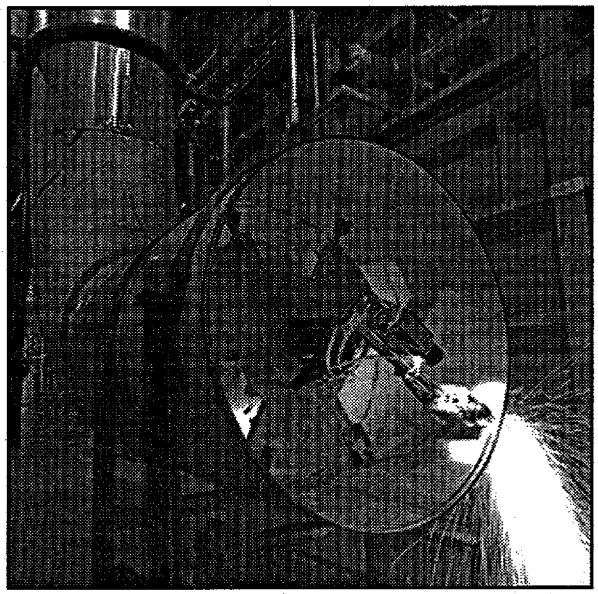

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Figure 3. Plasma torch cutting

To locate the right places in the pipeline to perform the elbow cuts and to verify the elbow's removal, six miniature, low light level, CCD cameras were installed on the crawler. One camera with a wide angle lens was mounted at the very front of the crawler. It's function was to get a full 360 degree view of the pipe, locate any pipeline obstructions, and help position the crawler for the elbow removal. Another 2 cameras were mounted to the plasma arc torch deployment mechanism located on the front of the crawler. With small angle lenses to narrow their field of view, these cameras were positioned to follow the plasma arc cutting torch head as it made a cut. A fourth camera was mounted to the crawler's front section plate. It was useful in locating pipeline welds and deploying the plasma torch head against the pipe wall. A fifth camera was mounted to the crawler's midsection and pointed toward the front of the crawler. It had a wide angle lens and was used to help determine the crawler's orientation in the pipeline by viewing a plumb bob displayed in its view. The sixth camera was also mounted to the crawler's midsection and it viewed the rear of the crawler. It helped prevent the crawler operator from accidentally backing the crawler over its tether cable. Several 20 watt lights were installed on the crawler.

A 300 foot tether cable bundle extended from the rear of the crawler to the crawler control console. The tether bundle included tubing for the pneumatic cylinders, a torch cable, video coaxial cables, a rotator power cable, a crawler control cable, and a 1/8 inch stainless steel aircraft cable for emergency retrieval purposes. The tether bundle was attached to the rear of the crawler and strained relieved using a braided steel sleeve.

After 2 successful elbow removals in a mockup facility, the crawler system was disassembled and transported to the fan house where a radiological containment hut had been erected around the fan entrances to the pipeline. Inside the fan house, the crawler and torch system were reassembled and tested. When testing was completed, the elbow removal system was placed in a special radiological hut extension which was then sealed from the outside. Workers inside the hut removed the crawler from the hut extension and inserted it into the south fan entrance some 265 feet from the elbow to be removed. A tool that resembled a partial wall was installed in the north fan entrance and allowed the crawler to travel past the "Y" branch of the pipeline. Because of some irreparable damage to the 70 amp torch system's cable during travel in the pipeline and a long delay in getting a new cable, a 400 amp torch system located in a nearby facility was installed on the crawler.

A minimum of 2 circumferential torch cuts were required to remove the elbow from the ventilation pipeline. The travel time to the first of the 2 cut sites took approximately 2.5 hours. The first cut was located in the horizontal section of pipeline just past a weld seam which joined the elbow to the straight section of pipe leading to the plutonium processing facility. It was important to position the crawler in the right spot for the first cut since facility drawings indicated that a pipe hanger existed within 2 feet of the elbow 's lower weld seam. With both the front and rear leg cylinders extended out and in contact with the pipe wall, the torch rotator was activated to move the torch head to its start position approximately midway between the top and bottom of the pipe. The torch was extended toward the pipe wall and ignited just before the torch bracket's front wheel contacted the wall. Penetration of the wall took less than 2 seconds. The torch was then rotated clockwise as viewed from the back of the crawler. The operator used the 2 cameras mounted on the torch rotator to view the quality of the kerf made by the torch. If the penetration of the pipeline wall was not completely through, the operator would immediately reverse the torch rotation and retrace that section before reversing direction again to continue the clockwise cutting method. The front wheel on the torch bracket was painted in such a way that its rotation could be clearly observed using the 2 torch cameras. Just enough gas pressure was applied to the deployment tool's pneumatic cylinder to keep the torch bracket's front wheel rotating. The gas pressure ranged from 15 - 30 pounds per square inch, depending on where the torch was located along the pipe's circumference. Too much gas pressure in the pneumatic cylinder caused the deployment tool to bind and skip over weld seams. A skip was found to cause as much as an 1/8 inch of metal to be left intact. This was more than enough metal to prevent the elbow from falling. After the first cut, the ventilation pipeline swung freely in the air tunnel. The crawler was then manually driven back through the elbow and positioned for the second cut. The second cut was located just before the elbow in a vertical section of pipeline. The same procedure as the first cut was followed. The system was able to successfully remove and record the elbow dropping to the bottom of the air tunnel. Exhaust air from the pipeline was now directed into the air tunnel. The crawler was removed from the pipeline and put in a metal box for safe storage.

In summary, a pipe crawler and plasma arc cutting torch system was developed to remove a 36 inch diameter, 1/4 inch thick, contaminated stainless steel pipe elbow located 265 feet from the pipeline's entrance. The task was particularly challenging due to time constraints, high noise levels at the work location, the distance of the elbow in the pipeline, work space limitations, and radiological conditions. During the elbow removal task, contamination rates on the crawler and its tether cable were measured and found to range from 25 mRad - 1 Rad of beta radiation and 80,000 - 400,000 disintegrations per minute of alpha radiation.

ABRASIVE CUTTING TOOL APPLICATION

Changes to one of the Site's processes necessitated the redirection of high level radioactive liquid from one waste tank to another. The redirection of waste is accomplished by making changes in a structure known as a diversion box. A diversion box is simply a below grade, steel lined, concrete box which contains piping that leads to the various waste tanks, pump pits, or other Site processes. Normally concrete covers are placed on top of the diversion box to reduce radiation exposure and the spread of contamination. A device known as a jumper is used to interconnect the open ends of the piping in the diversion box. A jumper is a stainless steel pipe with Hanford connectors attached to its ends, a lifting bail welded to its center of gravity, and counterweights strategically located to balance it when lifted. Jumpers are custom made to suit the needs of the application. Once the custom jumper is delivered to the diversion box, a crane operator removes the concrete covers, lifts the jumper, and sets it into position. It then releases from the jumper, and with the same crane hook operates an impact wrench to tighten the Hanford connectors onto mating connections in the diversion box.

There are many jumpers in a diversion box. When a change is to be made to the jumper configuration in a diversion box, a computer simulation is used to determine what jumpers will be effected. In a recent change, the computer simulation detected an interference between a new jumper and a formally used jumper support table. The support table was made out of stainless steel and was supported by 3 steel legs which were welded to the diversion box's stainless steel liner as shown in Figure 4. The new jumper could not be installed until the table was removed.

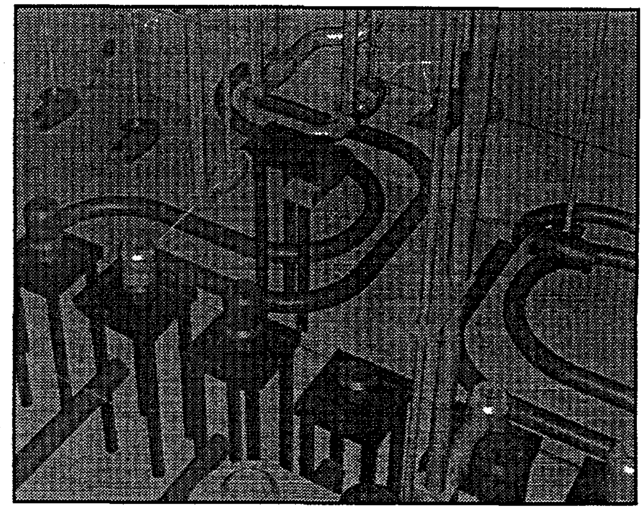

Figure 4. Diversion box and table

The table could not be removed manually by personnel since the diversion box was a confined entry space with high levels of radiation and contamination. The work had to be done remotely and quickly because it negatively impacted an important Site process. To save valuable time, the equipment or tool had to be made out of materials on hand. The application required the tool have the following 4 features; 1) it must be able to cut 2 inch, schedule 40 stainless steel pipe, 2) the tool must also be able to remove the pieces that it cut, 3) it must include a remote viewing capability, and 4) the tool must minimize the spread of contamination. A hand held grinder with an abrasive disk was selected for use in this application because it had these features.

In Figure 5, the hand held grinder with a 9 inch abrasive disk was modified and placed in a stainless steel housing. The housing provided both physical protection and acted to contain the metal fines and other cutting residue produced during the grinding operation. A HEPA filtered vacuum was attached to the housing to remove most of the grinding residue. A slot was made in the front of the housing to accept a table leg. Pneumatic clamps positioned on either side of the slot firmly held the leg in place. The abrasive disk was fed into the leg at a constant cutting pressure by an air cylinder. A miniature camera and light system was installed in the housing to help position the leg into the cutting tool and verify that the material had been cut completely through.

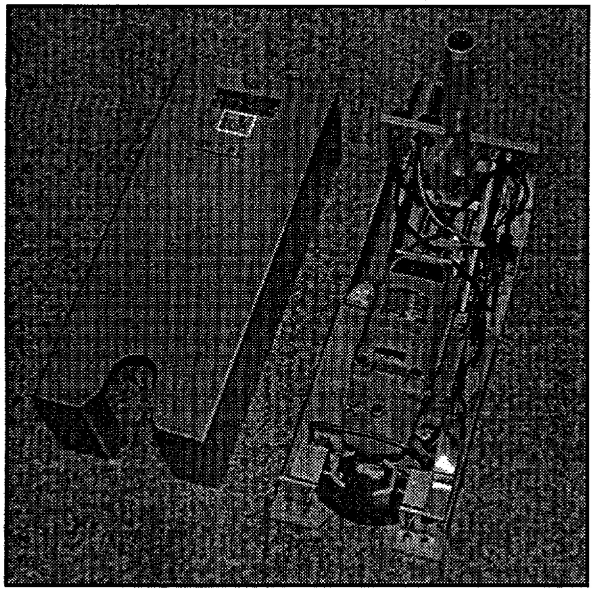

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Figure 5. Abrasive cutting tool

At the diversion box, personnel involved in the task were required to wear a full face respirator, coveralls, gloves and other protective clothing. The cutting tool was attached to an existing 25 foot long mast and lowered by crane into the diversion box. Under direction by those persons controlling the tool's functions, others supporting the mast carefully guided the tool into position to clamp and cut each of the support table's legs. The support table was cut in five places and all resulting pieces were safely put in a waste disposal container by the cutting system. The operation took approximately 3.5 hours including the set up and clean up times.

The addition of a new jumper in the diversion box was of critical importance to the startup of a major process. A remotely controlled cutting tool system that successfully removed the unused jumper support table was designed, built, and delivered in just 10 days. The remote nature of the tooling minimized personnel exposure to radiation. The cutting tool became contaminated to a level of 400,000 disintegrations per minute of beta/gamma radiation.

HYDRAULIC SHEAR APPLICATION

A transfer jet in a high level radioactive waste tank no longer operated properly. The jet was believed to have become plugged with radioactive waste. Several attempts to unplug the jet by flushing were not successful. The transfer jet and its connector head would have to be removed and replaced with a new assembly. The connector head would then be transported to a decontamination facility so that it could be reused. In the past, a carbon steel sleeve was custom built to transport the malfunctioning transfer jet and connector head assembly to the burial grounds where it would be permanently stored. This practice is expensive because of the high cost to fabricate a custom sleeve, to qualify the new container for both shipping and storage, and to bury the connector head which is a reusable part. A B25 container was the only choice for an approved shipping and storage container. Unfortunately, the jet and connector head assembly were too large to fit into a B25 container. A cutting system was required to size reduce the transfer jet and connector head assembly so that they would fit into a B25 container.

The function of a transfer jet is to transfer waste from one tank to another tank. Structurally, a transfer jet consists of 2 stainless steel pipes aligned in parallel. Steam is pumped through one pipe which initiates the flow of waste in the other. The transfer jet is fabricated from a 3 inch diameter pipe and a 1.5 inch diameter pipe. Physically, the jet resembles a "V" shape and is supported by some metal cross bracing and fixtured at the top to the connector head. Transfer jets come in several sizes with this one measuring about 8.5 feet long. With the connector head, the entire assembly is 13.5 feet long and weighs about 1800 pounds. On the other hand, a B25 container is 4 feet tall, 4 feet wide, and 6 feet long.

The idea was to design a cutting system that would rest directly on one end of the B25 container. Then, as the jet is cut up, its pieces would fall right into the B25. Both a grinder with an abrasive disk and hydraulic shear were considered for performing this size reduction application. As described earlier, an abrasive cutting wheel tool had been used successfully in severing the stainless steel legs of a table located in a diversion box. For the transfer jet size reduction task, the abrasive disk cutting system was ruled out. The combination of a spinning abrasive wheel and a transfer jet possibly filled with water and salt would likely spread contamination.

A commercially available hydraulic shear was found that could cut stainless steel pipe up to 6 inches in diameter. Instead of cutting in a scissors like fashion, the shear's blade tip pins the pipe against a backstop and pushes through the metal pipe. During mockup testing, numerous cuts were made with the shear and it was found that one advantage to this type of cutting was that it pinched the pipe nearly closed. This would help limit any salt in the pipe from escaping after a cut is made. The shear was mounted on a stainless steel platform. A splash guard was welded to the platform to prevent any contaminated water in the pipe from leaking over the edge of the B25. Also, 4 legs were attached to the bottom of the platform to prevent the cutter from possibly falling off the B25 during the cutting operation. A total of 3 cameras and one light were mounted to the platform to provide views of the transfer jet and cutting blade. Also, an electric actuator was mounted above the shear to help stabilize the pipe being cut. The transfer jet cutting system is shown in Figure 6.

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Figure 6. Transfer jet cutting system

The transfer jet removal and size reduction was scheduled during the evening and early morning hours to help reduce the likelihood of heat exhaustion to those donning radiological clothing. The transfer jet was rinsed free of salt sediment and lifted out of the waste tank using a crane. It was slipped into a double containment of plastic bags, tied off at the bottom, and lifted some 4 stories into the air in order to clear structures surrounding the waste tank. The crane then lowered the jet into a 2 story high containment hut adjacent to the waste tank. Figure 7 shows the cutting system resting on the edge of the first of three B25 containers located in the containment hut.

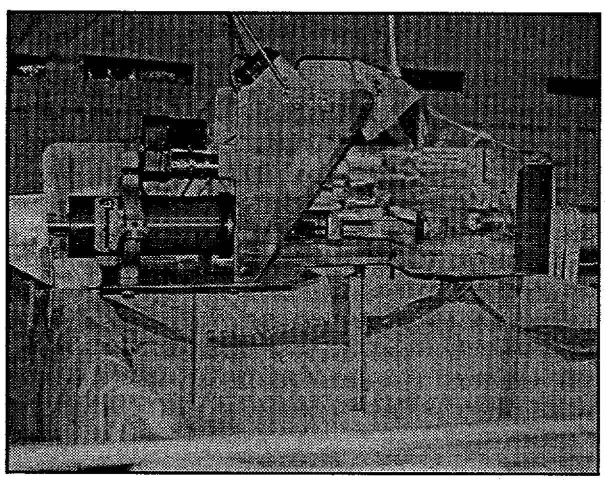

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Figure 7. B25 and cutting platform

An operator standing outside the hut and behind a lead shield helped guide and position the transfer jet assembly into the cutting system. The radiation from the jet was measured at 3 R/hour at contact. The distance of the operator to the jet, and lead shielding between them reduced the radiation level outside the hut to 1 mR/hour. A total of 4 cuts were made to the transfer jet assembly and its pieces fell into the first B25. The remaining section of the transfer jet and connector head assembly was put into the second B25 container. The cutting system was placed into the third container. The B25s containing the connector head and cutting system were shipped to a decontamination facility for cleaning. The B25 containing remnants of the transfer jet was shipped to the burial grounds.

In summary, by size reducing the transfer jet and connector head assembly with the hydraulic shear cutting tool, personnel were able to use an existing, approved shipping and storage container to house the components going to the burial grounds and salvage the expensive connector head assembly for reuse. Most importantly, personnel exposure to radiation was minimized by using remotely controlled equipment.

ABRASIVE WATER JET APPLICATION

In another application, the release mechanism of another transfer jet had become jammed and could not be disconnected from permanent, irreplaceable pipe nozzles inside a large waste tank. Inspection and several troubleshooting procedures confirmed that the linkage mechanism used to connect a transfer jet to the tank's permanent pipe nozzles had somehow seized in the closed position. Quick removal of the equipment was important because it impacted the continued operation of critical Site processing facilities.

A number of constraints were imposed on the design of a system to free the stuck transfer jet. The 2 process nozzles to which the jet was stuck could not be damaged because they were not replaceable. The equipment developed had to fit through a 10 inch diameter port and reach 6 feet down (with obstructions) to free the jammed release mechanism. No flames or sparks could be produced in the process due to flammability concerns. Any waste generated by the equipment would have to be compatible with the tank's chemistry. Finally, personnel exposure had to be kept to a minimum. The radiation level in the vicinity of the transfer jet ranged from 1 - 5 R/hr gamma. High pressure water jet cutting met all the constraints. This type of cutting technology produces no flame or sparks. Also, the waste products would be water, crushed garnet, and the metal fines of the transfer jet being cut. All were compatible with the tank's chemistry.

An abrasive water jet cutter consists of a pump capable of extremely high pressure (20,000 - 100,000 psi), low water volumes (1 - 10 gpm), high pressure tubing called stemming, a sapphire or diamond orifice, a focusing nozzle, and a fine abrasive grit material. The idea is to entrain the abrasive in a high velocity water stream. The orifice trades upstream pressure for downstream velocity. The low pressure, high velocity water stream creates a vacuum which pulls dry abrasive powder into the stream.

The nozzle simply acts to focus and aim the water and abrasive combination for cutting.

To assist in the design process, a full scale mockup was built of the waste tank top, the 10 inch access port, and the tank nozzles. A spare transfer jet was attached to the nozzles with all its linkages intact. Because of the short time allowed to complete this task and the complexity of the task, an automated cutting system was not possible. Instead, a cutting system that could be operated remotely was the only option. Since an operator would have to stand over the tank opening to manipulate the cutting tool, the design effort was focused on minimizing the time required to aim and move the cutting equipment. Minimizing time in a radiation field is an important ALARA practice. The cutting tool is shown in Figure 8.

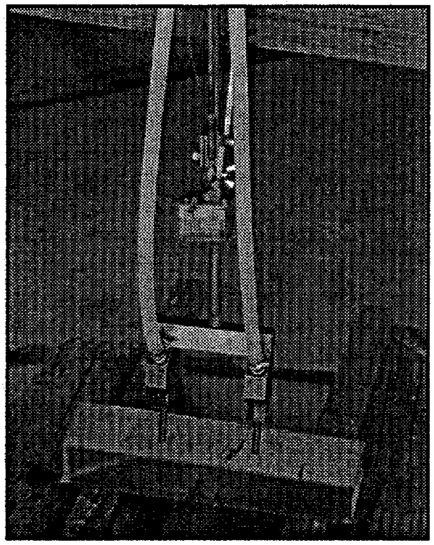

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Figure 8. Duel water jet nozzles

Based on the mockup, it was decided to cut through a connecting pin and attached linkages at 2 places for each of the 2 nozzles. A total of 4 cuts would be necessary. Each linkage had been precisely machined. Therefore, if a twin-nozzle water jet cutter were fabricated with the correct distance between the nozzles, lining up one nozzle would line up the other. The operator would then have to look down into the tank to aim the tool 2 times instead of 4. A simple set of guides straddled the 2 outside links of each pin to be cut, thus establishing left/right alignment of the cutting nozzles. A pivot arm, mounted to the high pressure stemming moved the tool forward. One end of the arm pushed against the back of the tank wall under the port and the other end was pulled by a threaded rod as an adjuster nut was turned from above the port. This way, only the operator's hand had to be over the tank opening during operation. A retractable hard stop provided a starting point. The end of the cut was measured by counting the number of turns made to the threaded rod's adjuster nut. A remote camera attached to the tool near the cutting heads was used in aligning the cut, but the mist from the high pressure water striking metal surfaces blinded the camera during the actual cutting.

Another advantage of the water jet cutting system is the thickness of the material it can cut through. In this case, it wasn't just a matter of cutting 1.5 inch diameter stainless steel pins. The pins were surrounded by linkages approximately 3 inches across. Cutting the connecting pin to free the transfer jet would actually require cutting the 3 inch stock. In the mockup, this was found to be easy with the abrasive water jet cutter. Also, it was noted that the water jet method was not especially sensitive to the distance from its nozzle to the material being cut. In both cases, slowing the rate of nozzle travel across the object overcame any disadvantage incurred, and a clean cut could still be obtained. Additionally, it was found that one nozzle of the equipment outperformed the other due to better "tuning" of the nozzle. One water jet was more focused and cut its linkage narrower and faster than the other. However, in the field, it turned out that the more unfocused nozzle gave the more desirable performance. It was still slower, but the wider cut it made gave more clearance for the linkages to move.

The cutting system was improved upon in the mockup and taken to the field in one week. Although the mockup of the tank top was dimensionally correct, the actual tank top had numerous other projections that made the job more difficult. Also, cardboard which had been placed over the top of the tank to make it easier to decontaminate after the job was finished, made it difficult to properly position the cutting tool over the 10 inch tank opening. A 3 inch tall riser was fabricated and sealed to the 10 inch port. This allowed proper alignment of the tool. Despite the minor difficulties, the abrasive water jet cutting system was used successfully in freeing the stuck transfer jet and personnel exposure was held to less than 125 mR.

SUMMARY

A number of metal cutting technologies have been successfully used in remotely performing tasks in radioactive environments. The selection of a particular technology to an application was driven by a number of factors. These factors include time constraints, physical restrictions, material compatibility with the process, and the tools ability to prevent the spread of contamination under normal operating conditions. In each application, the proof of the design was verified in a mock up demonstration before being taken to the field. Attention to detail and a proven design are essential in using equipment in radiological areas. Once the equipment has been in a radiological buffer area, making modifications to the equipment can be very difficult due to the wearing of protective clothing and time constraints.

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