SEQUOYAH FUELS CORPORATION

REPORT NO. 1
DESIGN AND USE OF PLASMA ARC CUTTING EQUIPMENT

THIS REPORT IS PREPARED AND SUBMITTED AS A TASK 1 REQUIREMENT IN ACCORDANCE WITH CONTRACT DE-AC06-83 RL10382

U. S. DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE
P. O. BOX 550
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I. EXECUTIVE SUMMARY

This report discusses the use of the plasma arc cutting system in the decommissioning of the Sequoyah Fuels Corporation Plutonium Fuels Fabrication Facility ("The Cimarron Facility"), Crescent, Oklahoma.

The system uses a plasma arc cutting torch modified for either manual or automatic operation and adaptable for use in either a normal glove box environment or in one which has been inerted to eliminate potential hazards of flammable or explosive materials.

The program to decommission the Cimarron Facility will not be completed for several more years, but sufficient amount of work has been done with the plasma arc cutting system to allow the following conclusions to be drawn:

1. Major cost savings can be realized by the use of plasma arc cutting (rather than the more conventional mechanical methods) for the large amounts of thick stainless steel used for process equipment and glove boxes in a plutonium production facility. These savings are primarily due to the extremely rapid rate at which the plasma arc torch can cut the thick stainless steel. Experience to date has indicated a major reduction in operating man-hours by use of this equipment, even under the most difficult conditions of remote automatic operation in an inert atmosphere.

2. The speed of operation, and the fact that the cutting can be done in a ventilated glove box, markedly increases operator efficiency by eliminating the need for cumbersome protective clothing and decreases potential operator exposure to the hazards of plutonium contamination and gamma radiation.

II. INTRODUCTION

The Cimarron Facility was constructed in 1969 to produce mixed uranium-plutonium oxide fuel pins for various government research and testing programs for fast reactor fuel.

The production processes carried out in the facility consisted of: (1) blending proper proportions of plutonium and uranium nitrate solutions; (2) coprecipitating plutonium and uranium solids from this solution by neutralizing with ammonium hydroxide; (3) drying and calcining the precipitate to produce an intimate, homogenous mixture of UO_2-PuO_2 powder having the proper chemical and physical characteristics for fast reactor fuel; (4) pressing and sintering the powder into fuel pellets having the physical, chemical, and thermal characteristics needed for fast reactor fuel; (5) encapsulating the sintered pellets into fuel pins; and (6) recovering and purifying uranium and plutonium fuel values in off-specification pellets and other side streams by solvent extraction.

Production and recovery operations were terminated in 1975 and the plant was placed in standby under its license. In 1979 it was decided that the facility would not be used further for nuclear production activities and a program was developed to remove all plutonium contaminated material and equipment from the facility in order that the buildings could be used for other activities. This decontamination and decommissioning program is scheduled for completion in 1986. The D&D program will be the subject of a number of reports on various phases of the work.

This first report deals primarily with the adaption of previously unused plasma arc cutting procedures to: (1) the removal of contaminated process equipment, reaction vessels, piping, valving, etc., from glove boxes and the cutting of such equipment into pieces sized for N.D.A. measurement and disposal packaging and (2) the cutting of the contaminated glove box segments into pieces sized for N.D.A. measurement and disposal packaging. It also discusses the use of mechanical sawing techniques to cut glove boxes into segments which can be finally cut up for disposal by a plasma arc torch.

III. GENERAL DESCRIPTION OF PLANT AND EQUIPMENT TO BE DISMANTLED

All operations involving plutonium were carried out in enclosed, ventilated glove boxes. These boxes and the process equipment contained therein constitute a major portion of the items requiring disposal as plutonium contaminated (TRU) waste.

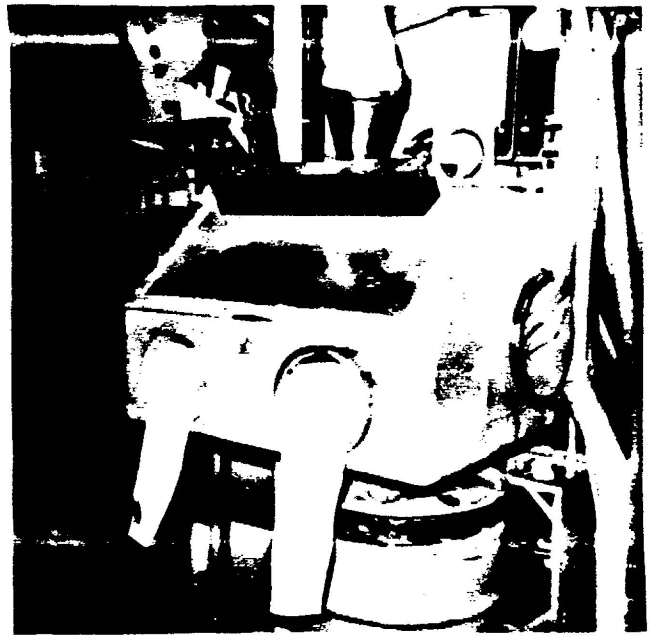
The plant contained some 80 glove boxes varying in size from 30'x36'x2' to 4'x4'x2'. All boxes were fabricated from 300 series stainless steel having various thicknesses between 3/16" and 1/2". See Figures 1 and 2.

The processing equipment in the glove boxes consisted of the following:

1. pipes, valves, vessels, and pumps used in wet chemical production and scrap recovery operations;
2. calciners, granulators, presses, sintering furnaces, and storage containers used in the dry processing of powder and pellets; and,
3. assembly tools, welding equipment, and inspection gauging equipment used for encapsulating the pellets into fuel pins.

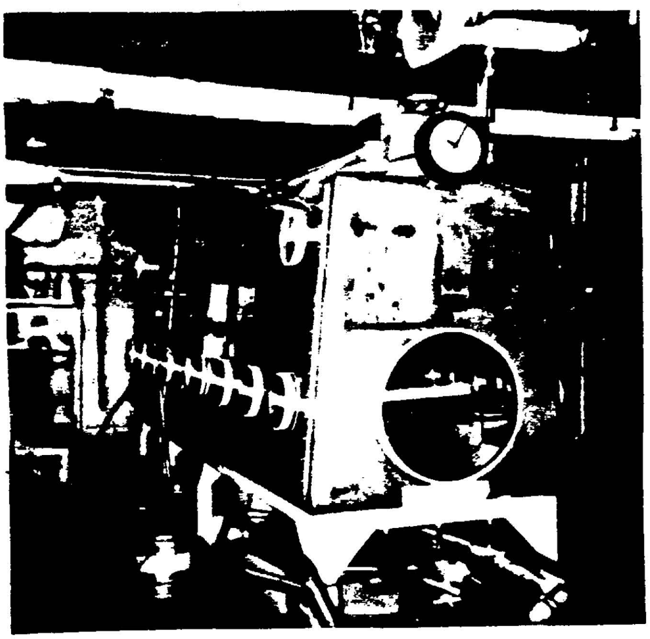
Criticality control in the "dry" portions of the plant operation was achieved by control of the mass of the dry powder and pellets. "Ever safe" geometry was used for criticality control in all "wet" operations. This geometric control dictated that process equipment, storage and transfer vessels, and piping in the portions of the plant dealing with "wet" process have a diameter of no more than

5". There were a total of 83 five inch columns in the wet chemical area of the plant. Sixty of these columns were 30' high and were used for storage and processing in the main wet processing line. Twenty-three such columns, varying in height from 10' to 30' were used in the solvent extraction scrap recovery.



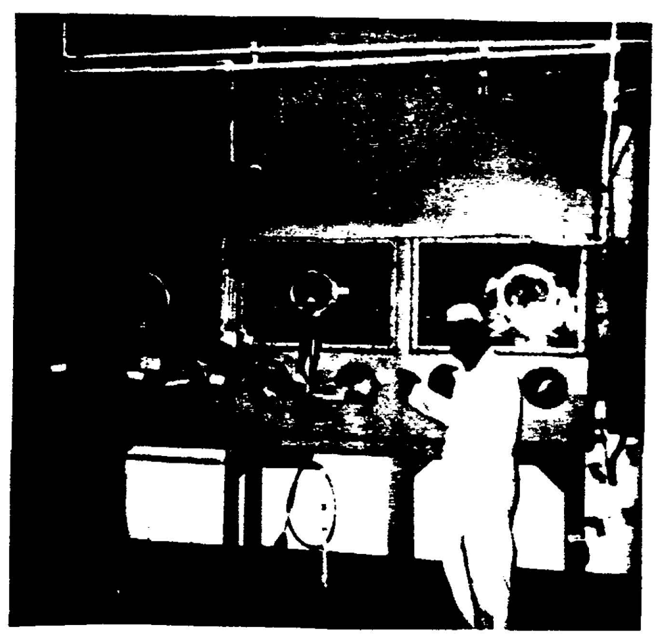
Small glove box

Cementing waste operation.



Medium size glove box

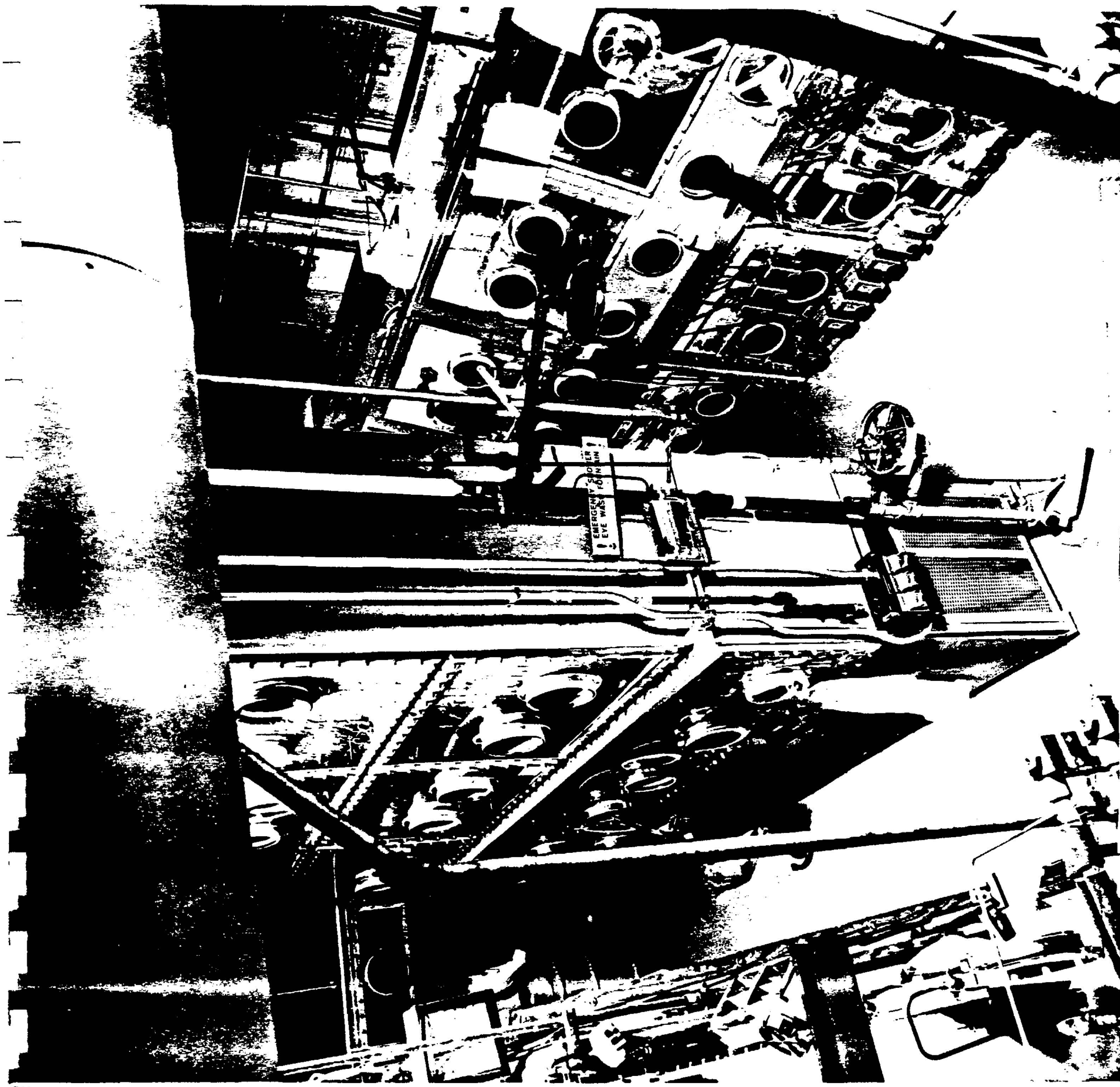
Mechanical maintenance operation.



Large size glove box

Production operations.

Figure - 1



5 B-O-1 On Stairway Looking East

Figure - 2

IV. CONSIDERATIONS IN SELECTION OF PROCESSES TO CUT CONTAMINATED EQUIPMENT AND GLOVE BOXES

In selecting methods to segment and cut contaminated metal, just as in the selection of methods for other operations involving radioactive material, factors such as: (1) protecting the health and safety of operators and the public; (2) safeguarding materials; (3) protecting the environment; and (4) cost to the operator, must be considered. However, in cutting and packaging contaminated metal the problems of health and safety, safeguards and environmental impact lend themselves to easy solution, regardless of the process selected.

The major factor is cost. This is the only factor which was considered in evaluating the use of a modified plasma arc cutting tool versus mechanical cutting. Experience in industrial use of plasma arc cutting, confirmed by Sequoyah Fuels in non-plutonium work, showed that it could cut thick stainless steel of the type used in the Cimarron plant hundreds of times faster than that possible with standard mechanical saws.

The system seemed to have the flexibility needed to make it generally useful for the desired cutting activities. A potential problem of smoke generation seemed solvable by proper engineering design. Maintenance, while not insignificant, seemed to be well within an acceptable range. Construction and modification costs would be quite low - in the range of $6,000. It did not appear that appreciable amounts of secondary waste would be generated (possibly a few extra H.E.P.A. or prefilters). It was recognized that the plasma arc had never been used under glove box conditions involving flammable liquids and/or explosive atmospheres and that some modifications would be needed to adapt it to such conditions. It was further recognized that operating experience could show up problems that had not been evident in analysis or experimental operation. However, because of its tremendous potential to markedly decrease the known high labor costs of conventional cutting operations, plasma arc cutting was selected for development and use.

V. BASIC PLASMA ARC CUTTING PROCESS

The Thermal Arc PAC 10 cutting system manufactured by Thermo Dynamics was chosen as the basic tool because of the design simplicity of the PCH/M-4B hand torch and the adaptability of the equipment to remote operation. The unit was adapted to two work stations, each equipped with a hand torch which connects to a single power supply using quick disconnect fittings. Only one torch unit can operate at a time.

The power supply consists of sequencing controls for primary and secondary gases, a high frequency A.C. starting circuit, and a D.C. plasma arc circuit (50-100 ampers 100% duty cycle plasma arc circuit).

The torch in the standard unit is cooled by discharging a mixture of argon and hydrogen around a conductive cup through a ceramic nozzle. This gas also acts as secondary shielding. The D.C. straight polarity plasma arc is established by high frequency A.C. between the negative tungsten electrode and the positive tip of the conductive cup and the positive work piece. See Figure 3.

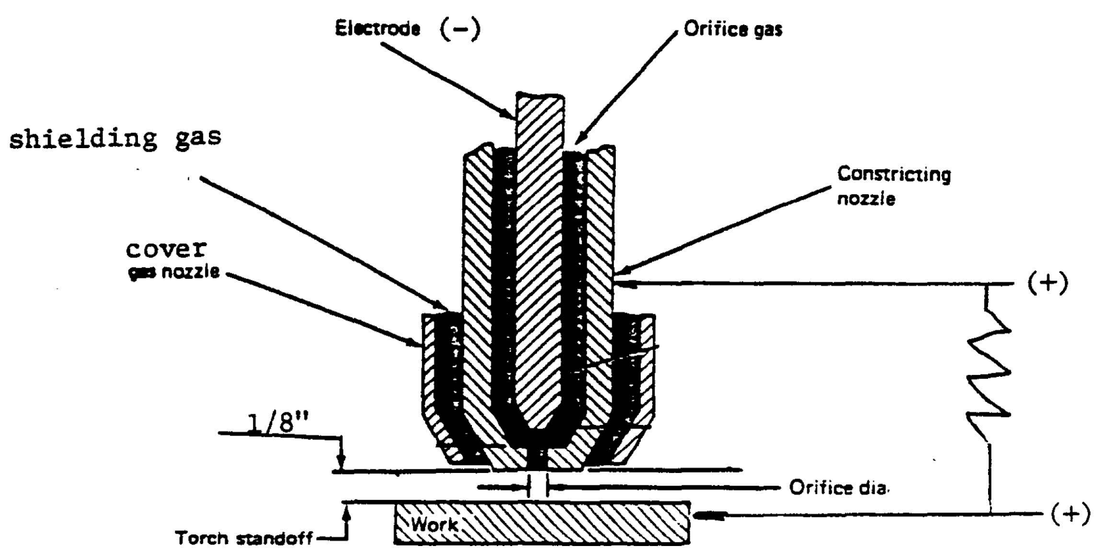


Figure 3 - Configuration of the plasma arc torch head.

The primary gas flows around the electrode through the A.C. arc stream and discharges as a collimated ionized plasma arc stream, whose temperature is in the range of ten to fourteen thousand degrees centigrade, through an orifice in the bottom of the conductive cup to the work piece. The A.C. starting current terminates when the plasma arc is established at the work piece.

VI. MODIFICATION OF BASIC UNIT TO MEET SPECIFIC CIMARRON REQUIREMENTS

A. Change in the Primary and Secondary Gas

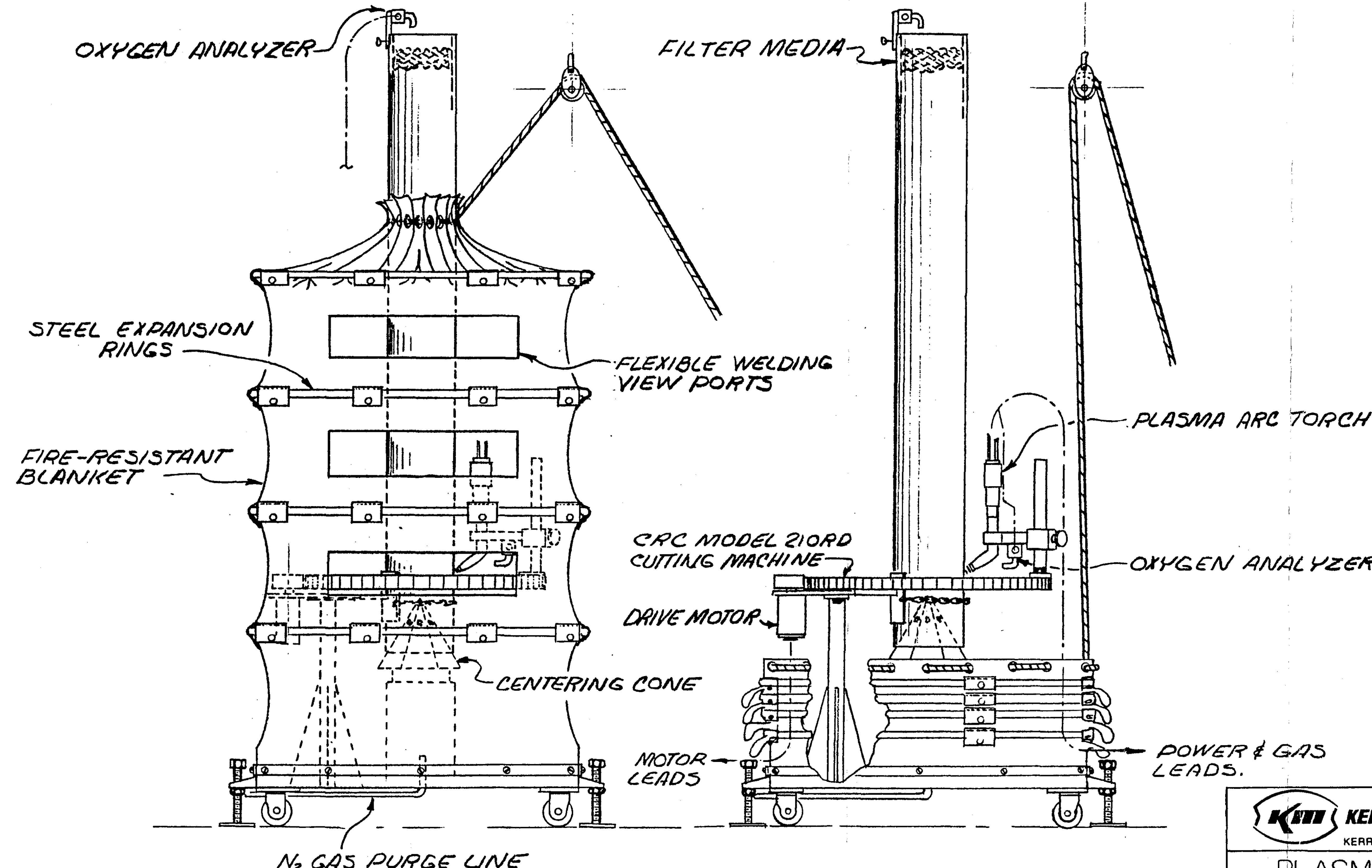
Because of the need to eliminate hazards inherent in the handling and use of hydrogen and for economic considerations, nitrogen was substituted for the argon-hydrogen mixture recommended by the manufacturer as the cooling and shielding gas. See Figure 3

B. Conversion From Manual to Remote Controlled Automatic Operation in Glove Boxes

Since much of the disassembly work in the glove boxes involves repetitive cutting of long vertical stands of pipe, remote controlled automatic operation would result in a major increase in efficiency. To accomplish this, a standard portable 3" to 8" capacity pipeline cutting/beveling machine (CRC-CROSE "Space-O-matic" Machine No. 1, Model No. 210R0031051) was fitted with:

1. A variable speed reversible Dayton Gear Motor Machine (Model 2Z800) controlled by a Dayton Electric Motor Speed Control (Model 4X599); and,
2. A torch holder modified to accept the plasma arc torch. Drawing Number ATO-05 shows the details of this consolidation.

The basic plasma arc unit, modified for nitrogen gas, when used in conjunction with the automated pipeline cutting equipment, can cut the pipe stands and other equipment in all glove boxes except those where previous use of dodecane and tributyl phosphate present unacceptable risk of fire or explosion. For full economic potential of plasma arc cutting



KERR-McGEE NUCLEAR CORPORATION

KERR-McGEE CENTER ■ OKLAHOMA CITY, OKLAHOMA 73125

PLASMA ARC CUTTING ENCLOSURE ASSEMBLY

DRAWN BY	DATE:	SCALE:
L. HAMPTON	9-15-83	NONE
APPROVED W. Spence		DRAWING NUMBER ATO-05

to be realized it was necessary to make modifications that would allow it to also be used in gloveboxes containing tributyl phosphate and dodecane.

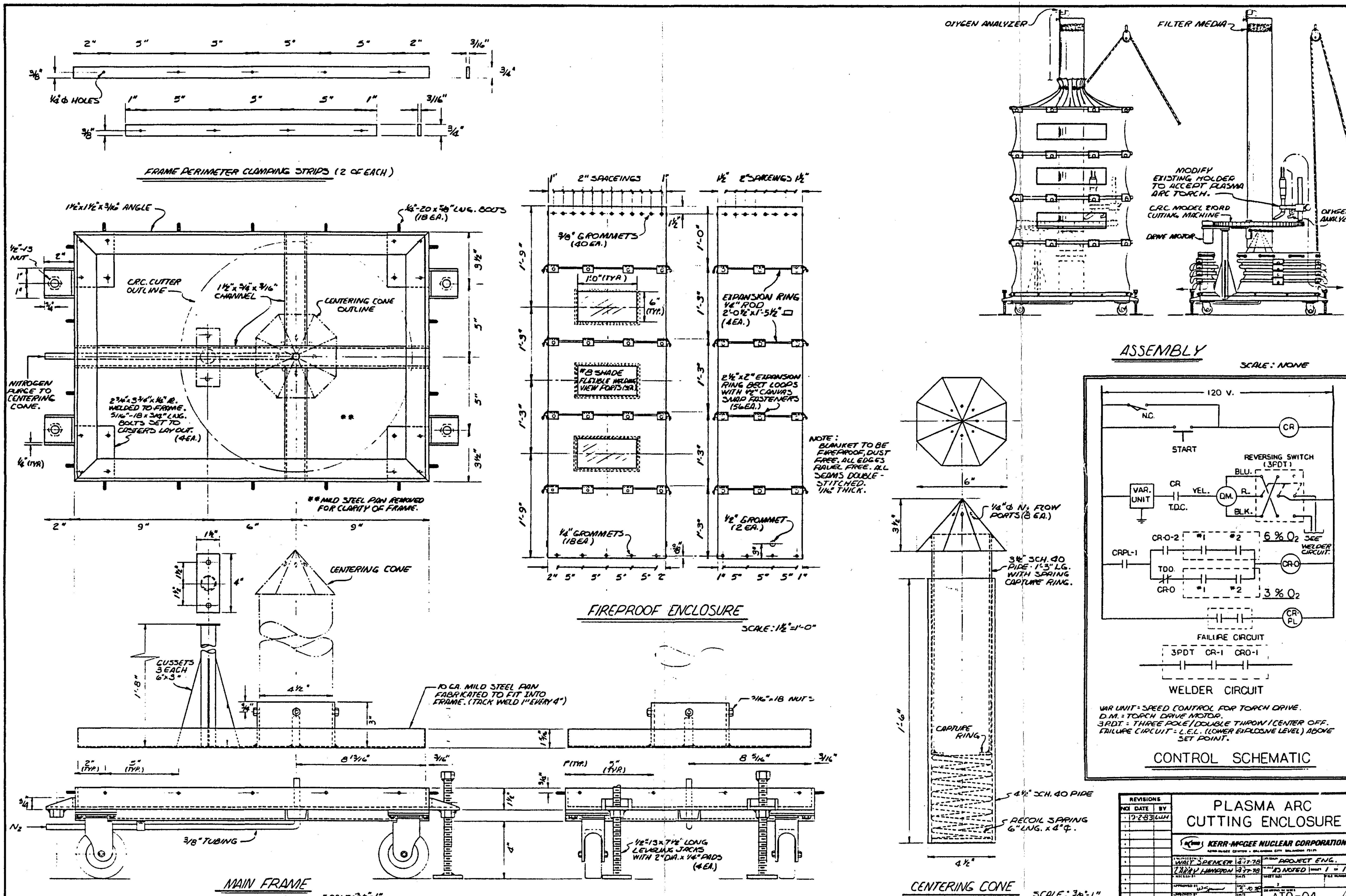
Since operator protection against exposure to plutonium contamination depends upon a positive flow of air through the box at all times it is impractical to purge the oxygen content in a glove box to a level where the heat of the plasma arc could not ignite the combustible mixtures. The approach is to isolate a small "work volume" from the remainder of the glove box, and assure that the oxygen content of this isolated small volume was reduced to and maintained at safe levels during cutting.

Isolation of the "work volume" is accomplished by attaching a collapsible asbestos "tent" to the base plate of the stand for the automatic pipeline cutting/beveling machine discussed previously. This tent is raised to cover the cutting location and attached firmly to the pipe being cut at a point well above the cut. The volume inside the pipe is purged with nitrogen entering the bottom of the pipe through a centering cone that is a part of the stand assembly. The volume between the pipe and the tent is purged with nitrogen entering through the plasma torch.

Measurements of the oxygen content of the gases in the pipe and in the tent is accomplished by a Teledyne Oxygen Analyzer (Model 322) having a Class B-I Micron Fuel Cell, a dual range of readings (0-10 and 0-25 percent oxygen), and a two-channel system with two probes. One probe samples the gas inside the pipe; the other samples the gas at a point near the cut.

This system is wired to (1) prevent initiation of the plasma arc cutting process until the oxygen content in the tent and in the pipe has been lowered to 3% and (2) terminate the plasma arc operation if the oxygen content reaches 6%. The 3% level for start of operation is set deliberately low in recognition that the "chimney effect" of the open pipe as it heats up during cutting could increase the oxygen level at the site of the cut. The shut down level of 6%, which allows for some in-leakage of air, is below the ignition range.

Drawing Number ATO-04, attached, illustrates the complete machine including the electrical circuity, oxygen analyzer system, and all mechanical details and dimensions necessary to duplicate the system.



FRAME PERIMETER CLAMPING STRIPS (2 OF EACH)
1/4"Φ HOLES
1½"x1½"x3/16" ANGLE
½"-20 x 7/8" LNG. BOLTS (18 EA.)
½"-13 NUT
C.R.C. CUTTER OUTLINE
1½" x 3/4" x 3/16" CHANNEL
CENTERING CONE OUTLINE
NITROGEN PURGE TO CENTERING CONE.
2 3/16" x 3 1/4" x 1/16" PL. WELDED TO FRAME. 5/16"-18 x 3/4" LNG. BOLTS SET TO CASTERS LAYOUT. (4 EA.)
** MILD STEEL PAN REMOVED FOR CLARITY OF FRAME.
CENTERING CONE
GUSSETS 3 EACH 6"x3"
10 GA. MILD STEEL PAN FABRICATED TO FIT INTO FRAME. (TACK WELD 1" EVERY 4")
5/16"-18 NUT
3/8" TUBING
½"-13 x 7½" LONG LEVELING JACKS WITH 2" DIA. x ¼" PADS (4 EA.)
MAIN FRAME
SCALE: 3/8"=1"
2" SPACEINGS
3/8" GROMMETS (40 EA.)
1'-0" (TYP.)
#8 SHADE FLEXIBLE WELDING VIEW PORTS (3 EA.)
1/4" GROMMETS (18 EA.)
EXPANSION RING 1/4" ROD 2'-0½" x 1'-5½" (4 EA.)
2½" x 2" EXPANSION RING BELT LOOPS WITH ½" CANVAS SNAP FASTENERS (56 EA.)
½" GROMMET (2 EA.)
NOTE: BLANKET TO BE FIREPROOF, DUST FREE, ALL EDGES RAVEL FREE. ALL SEAMS DOUBLE-STITCHED. 1/16" THICK.
FIREPROOF ENCLOSURE
SCALE: 1½"=1'-0"
1/16"Φ N₂ FLOW PORTS (8 EA.)
3½" SCH. 40 PIPE 1'-3" LG. WITH SPRING CAPTURE RING.
CAPTURE RING
4½" SCH. 40 PIPE
RECOIL SPRING 6" LNG. x 4" Φ.
CENTERING CONE
SCALE: 3/8"=1"
OXYGEN ANALYZER
FILTER MEDIA
MODIFY EXISTING HOLDER TO ACCEPT PLASMA ARC TORCH.
C.R.C. MODEL 810RD CUTTING MACHINE
DRIVE MOTOR
OXYGEN ANALYZER
ASSEMBLY
SCALE: NONE
120 V.
N.C.
START
CR
REVERSING SWITCH (3PDT)
VAR. UNIT
T.D.C.
YEL.
D.M.
BLU.
R.
BLK.
CR-O-2
CRPL-1
T.D.O.
CR-O
6% O₂
3% O₂
SEE WELDER CIRCUIT.
CR-O
CR-PL
FAILURE CIRCUIT
3PDT CR-1 CRO-1
WELDER CIRCUIT
VAR UNIT = SPEED CONTROL FOR TORCH DRIVE.
D.M. = TORCH DRIVE MOTOR.
3PDT = THREE POLE/DOUBLE THROW/CENTER OFF.
FAILURE CIRCUIT = L.E.L. (LOWER EXPLOSIVE LEVEL) ABOVE SET POINT.
CONTROL SCHEMATIC
REVISIONS
NO. DATE BY
1 9-2-83 LWH
PLASMA ARC CUTTING ENCLOSURE
KERR-McGEE NUCLEAR CORPORATION
WALT SPENCER 4-17-78
LARRY HAMPTON 4-17-78
PROJECT ENG.
AS NOTED
1 OF 1
ATO-04

VII. PARAMETER DEVELOPMENT FOR THE MODIFIED PLASMA ARC CUTTING SYSTEM

Since the system uses nitrogen as the primary and secondary gases rather than those recommended by the manufacturer and since, in some cases, the torch will operate as an automatic machine-mounted cutter, the operating parameters furnished with the basic machine needed modification.

Experimental operation in a mock-up of the glove box environment revealed that the cutting rate of the torch and the amperage settings were the parameters offering the greatest latitude for variation. In the basic plasma arc process, some variation in the flow rate of the gas is possible. This is not true, however, in the process as modified. The higher ionization potential of the nitrogen causes more rapid wear of the consumable gas distributor and the Lo Amp tip than in the basic process. To minimize this wear problem, maximum cooling is supplied by maximum nitrogen flow rate. No significant variation is possible.

The experimental study showed that current values above 90 ampers caused excessive orifice erosion, therefore, the rate of the cut and the distance of the torch from the work (torch stand-off) were the only variables studied. The proper values for these parameters were judged by the narrowness of the kerf, the visual acceptability of the cut, and the extent of burrs, dross, and smoke produced during cutting.

The results of this study, using the PCH/M-4B torch with a 70° angle head Lo Amp tip were:

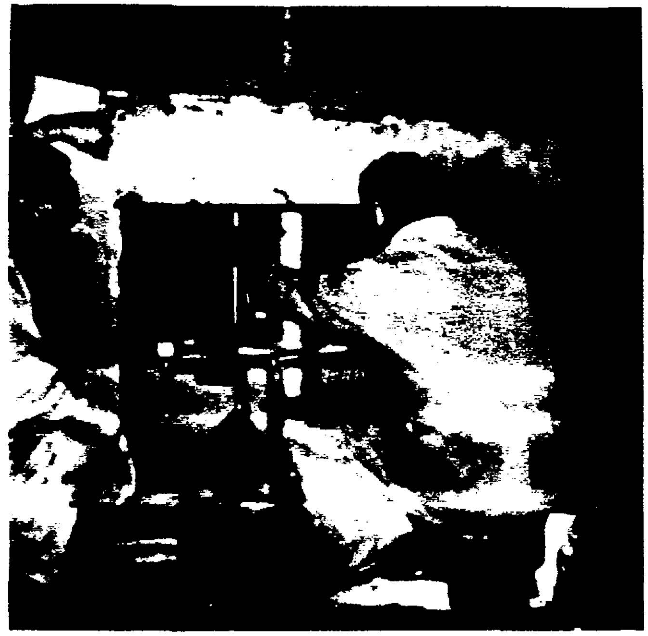
Torch Speed	23 inches per minute
Current	90 amps
Torch Stand-off (Maximum)	1/8"
Primary Nitrogen Flow	15 CFH at 30 PSI
Secondary Nitrogen Flow	250 CFH at 50 PSI

Using these operative parameters, a cross-sectional cut of a 5" diameter Schedule 80 304 stainless steel pipe could be made in approximately 40 seconds.

This photo shows the machine and cut sections of pipe. The 3 rings were part of the parameter study.

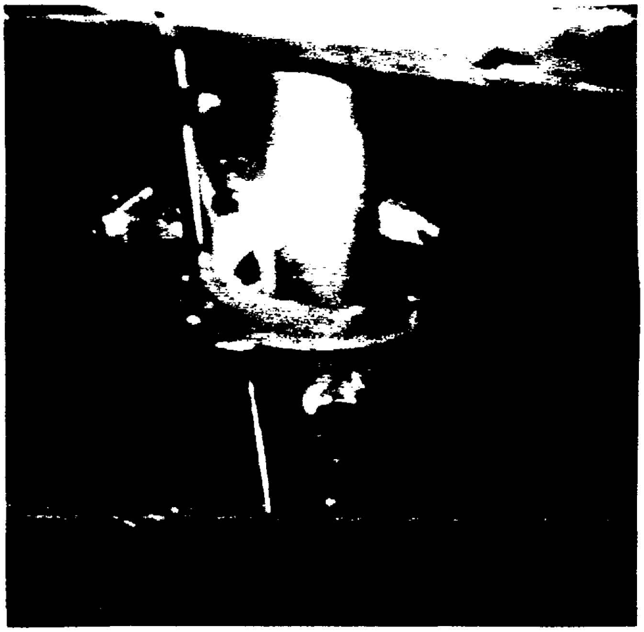
Figure - 4

Equipment set up during parameter study.



Equipment set up ready to cut.

Figure - 5



Cutting machine in operation.

Cut joint separated to show kerf and quality of cut.

Figure - 6

VIII. CLEANING PRIOR TO CUTTING

At the time the plant was placed in the "standby" condition, all process piping, reaction vessels, hold tanks, etc., were thoroughly flushed to recover essentially all of the removable plutonium in the equipment. At the same time, all tools and other loose objects were removed from the glove boxes and all surfaces of the boxes and fixed equipment in the boxes were wiped down.

This operation removed most of the plutonium and process reagents from the equipment internals and from surfaces in the glove boxes. There remained, however, small amounts of plutonium in solution, sludge, or solid in the process equipment. The solvent extraction equipment also retained small amounts of dodecane, tributyl phosphate, and organic degradation products, some of which are flammable and/or explosive.

The purpose of the cleaning operation discussed here is to reduce the levels of plutonium and combustible organic material to the lowest practical level prior to the cutting and disassembly operation, regardless of the cutting method used. Different processes are used to clean equipment contaminated with plutonium alone and that contaminated with plutonium and combustible organics.

A. Cleaning to Lower Plutonium Contamination and Minimize Combustible Organics in the SX Glove Box

The initial equipment cleaning was primarily to dissolve sludges and other solids and to reduce the amount of plutonium in the equipment to the greatest extent possible. Acidic mixtures of water, dodecane and tributyl phosphate were first circulated through the system. This was followed by rinsing with trichlorethane.

The second cleaning operation was to eliminate, or at least to decrease to a maximum extent practical, the combustible organic materials remaining after the cleaning to remove plutonium. This entailed the following operations:

1. All internal surfaces of the glove box and all surfaces of the equipment in the box were steam cleaned with a Steam Jenny (Multi-Job 600) combination steam-pressurized water cleaner using a highly alkaline cleaning solution containing sodium hydroxide (Turco "Powr-Steam" 4 pounds per 20 gallons of water). The residue from this operation was removed by steam cleaning with plain water.
2. All equipment small enough to be disassembled with hand tools was removed from the glove box, and the alkaline-plain water steam cleaning process was repeated.
3. The process and storage columns were opened at the top and repeatedly cleaned by the alkaline-plain water steam cleaning process until the condensate from the plain water steam came out clear at the bottom of the columns.
4. The liquids from this washing operation, as well as the liquids from the first cleaning operation, were absorbed in a layer of absorb-all spread in the bottom of the glove

box. When the cleaning operations were completed 2 liter plastic bottles half-filled with absorb-all were bagged into the glove box and filled with the wet absorb-all from the glove box floor. This procedure is used to assure that twice as much absorb-all is provided as is required to absorb the liquid.

This method produced ten drums of TRU waste.

5. The final step in the cleaning process was to wipe any alkaline cleaning residue from the glove box windows (to improve visibility) and to remove rags, papers, and other combustibles used in the window cleaning operation.

B. Cleaning to Lower Plutonium Contamination in Glove Boxes Having no Combustibles

In the wet chemistry glove boxes steam cleaning with the combination alkaline and plain water process as described previously was used. The cleaning solutions were filtered, treated with caustic and ion-exchanged to remove plutonium. Dry glove boxes were cleaned using trichlorethane solvent as the cleaning agent.

IX. CUTTING VERTICAL SOLVENT EXTRACTION COLUMNS CONTAMINATED WITH COMBUSTIBLE ORGANIC MATERIAL

This particular application of plasma arc cutting is described in some detail since it alone illustrates the use of all segments of the total system developed and assembled to take advantage of the economic benefits of plasma arc cutting in decommissioning plutonium production facilities. In all other uses of the plasma arc process, one or more of the adjuncts to the basic plasma arc equipment was not used.

The operational procedures followed in cutting the long vertical pipes used in the solvent extraction process were: (See Drawing Number ATO-05 attached to Section VI)

1. To simplify the task of placing the remotely controlled automatic cutting unit in the glove box, approximately 1500' of small diameter pipes, pipe racks, and associated structural members were cut, disassembled using conventional, explosion-proof, power driven equipment, such as pneumatic saws, hydraulic guillotine bolt cutters, etc., and removed from the glove box.
2. The remotely operated power driven cutting unit, with the "centering cone", cutting torch, and collapsed asbestos "tent" , was positioned in the glove box.
3. The column to be cut was removed from its supporting bracket and suspended over the "centering cone" on the base plate of the cutting unit.

4. A loosely packed fiberglass filter was placed in the open top of the column to minimize the amount of particulate matter reaching the H.E.P.A. filter of the glove box.
5. The accordian type asbestos "tent" was raised to enclose the cutting torch and secured around the suspended column.
6. The column was purged with nitrogen admitted through the "centering cone", and the space in the tent was purged with nitrogen admitted through the plasma arc torch head. The oxygen content of the gas in the column and in the tent was measured by the oxygen analyzers which took continuous samples from the top of the column and from a point near the cutting torch.
7. When the O_2 content reached a level of 3% or less (20 minutes), the cutting unit was energized and a circular outside-to-inside cut was made around the column.
8. The cutting unit was de-energized, the tent was lowered, and the cut piece removed from the cutting unit by hand. The cut piece is hot only in the immediate area of the cut. Since stainless steel is such a poor heat conductor, moving the cut piece from the cutting stand to the floor of the glove box can be done immediately after the cutting operation is completed. The cut edge can be taped for bag out 20 to 30 minutes later.
9. The remaining portion of the column was lowered and positioned on the "centering cone", the tent was raised and positioned on the column, the column and the space in the tent were purged as before to 3% O_2 or less, and the cutting process was repeated.

10. When the column had been completely cut into 12" long segments, the next column was moved to the cutting position and segmented. This process continued until all 23 columns in the glove box had been cut and removed from the box.

X. DISASSEMBLY AND CUTTING OF GLOVE BOXES

A. Disassembly

The physical size and shape of most of the glove boxes at the Cimarron Facility do not lend themselves to disassembly by the plasma arc torch since the operation must be done inside a glove box enclosure. Such disassembly operations are done inside plastic tents by operators using manually operated air saws and other suitable tooling as follows:

1. Following the removal of internals, the entire box is cleaned and coated with Oakite poly-vinyl alcohol contamination fixative paint. A plastic tent is then constructed around the entire structure. See Figure - 7 .
2. Operators wearing full protective clothing and bubble hoods (and/or full face respirators) enter the tent area and, using mechanical cutting equipment, disassemble the glove box into pieces that can pass through an 18" x 36" opening. These pieces are packaged in plastic bags and removed from the tent.

B. Cutting

The plastic bags containing the glove box segments are placed in a special (cut-up) glove box where operators, working through standard glove ports, cut the segments into proper packaging size using a hand held plasma arc torch. See Figure - 8

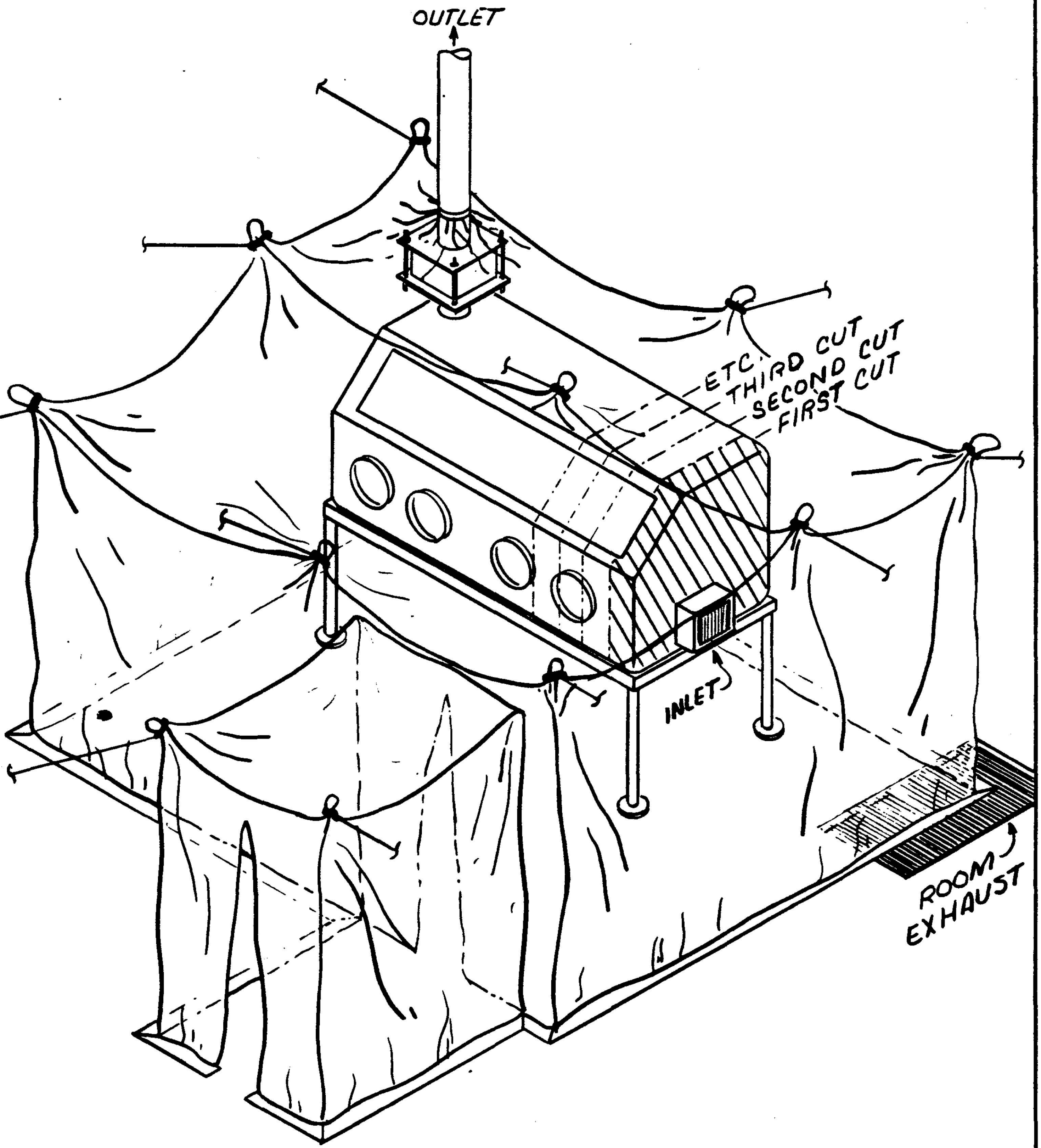
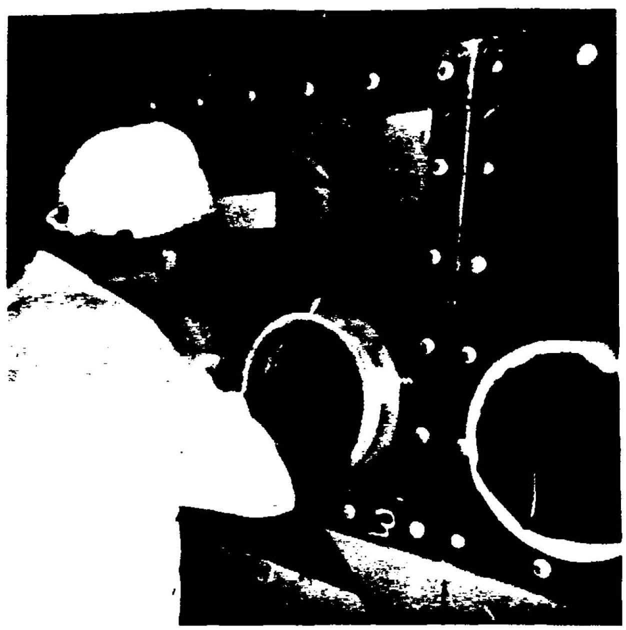


Figure - 7

PREPARATION FOR GLOVE-BOX SECTIONING



Shows plasma arc cut in glove box panel.

Figure - 8

XI. SAFETY

Safety in nuclear operations is based on strict adherence to a philosophy that well supervised experience operators, properly protected by clothing and adequately monitored equipment, will strictly follow the details of procedures which have been developed to assure safety of operation.

An important aspect of this philosophy is the use of Special Work Permits (SWP) which outlines special instructions, clothing, tooling and safety requirements for each assignment not covered by standard procedures. Figure 9 is the SWP for disassembly of a large glove box (shown in Figure 10) inside a plastic tent. The disassembly work has been completed. Figure 11 is the SWP for cutting the 23 columns in the SX glove box with the remote controlled automatic plasma arc torch. This work has been finished.

XII. ECONOMICS OF PLASMA ARC CUTTING

In preparing this section on the economics of the plasma arc process no attempt has been made to develop the true total costs of decommissioning a glove box using the plasma arc cutting system for sectioning the glove box for final disposal. The aim has been, however, to identify special factors which can be used in analyzing the comparative economics of cutting by plasma arc and by other systems. To do this certain assumptions were made:

1. The stainless steel equipment and glove boxes will fit into the same number of 55 gallon drums regardless of the method of cutting used to achieve this objective.
2. The total amount of secondary waste generated by preparation of the equipment and glove boxes for cutting, and by cutting will not differ for various methods of cutting.
3. All plasma arc cutting will be done in a glove box.
4. All equipment contaminated with combustible organic material will be cut by plasma arc procedures in a "purged" atmosphere.
5. All disassembly of glove boxes will be done in "tents" constructed around the box by operators in full protective clothing using conventional cutting equipment.

Actual experience has shown that it takes approximately six man-hours to cut through a 5" diameter Schedule 80 304 stainless steel pipe while the same job can be done by the plasma arc in approximately 40 seconds.

To allow time for nitrogen purging in those cases where combustible gas is present, and for routine operational maintenance, experience has shown that the cutting time should be assumed to be approximately 20 minutes rather than the 40 seconds mentioned above.

The labor cost comparison in Table I is based on the 560 feet of 5" diameter pipe in the 23 columns which had been used in the solvent extraction operation. Six man-hours are required for mechanical sawing each section compared to 20 minutes per section for plasma arc cutting.

TABLE I

Comparison of Man-hours to Cut 5" Diameter Schedule 80 304 Stainless Steel Pipe

No. of Pipes	Length of Pipes	Total Length	No. of Cuts	Man-hours for Conventional	Man-hours for Plasma Arc
10	30'	300	290	1740	97
7	20'	140	133	798	44
6	20'	120	114	684	38
23		560	537	3222	179

Data is not yet available for analysis of costs of disassembly of glove boxes in a plastic tent by conventional cutting methods, cutting of glove box segments by hand-held plasma arc torch in a glove box, or disassembly and cutting of equipment by plasma arc which was not contaminated with combustible organics. It is expected that the cost advantage of the plasma arc can be shown to be much greater than the 94% savings in man-hours for cutting shown in Table I.

DISTRIBUTION:
White - Job Site
Canary - Health Physics File

SPECIAL WORK PERMIT KM-2420-A

NO. 6610 EXAMPLE

VALID FROM: 11-29-83
TO: Completion
SUPERSEDES:

LOCATION
Room 128 Box 5A

JOB DESCRIPTION
Cut up Box 5A

Nuclear Criticality Safety Limits and Controls Considered [X] Yes [ ] No

RADIATION CONDITIONS
High level contamination

RADIATION MONITORING REQUIREMENTS
Lapel sample on 50% of people working in tent.
AIM-3S in tent.

INDUSTRIAL SAFETY (ITEMS TO CONSIDER ON BACK OF SHEET)
Ladders

PROTECTIVE EQUIPMENT REQUIREMENTS

	√	ITEM		√	ITEM		√	ITEM
HEAD		Safety Glasses	FEET	x	Safety Shoes	RESPIRATIONS		Half Face Mask
HEAD		Face Shield	FEET	x	Shoe Covers	RESPIRATIONS		Full Face Mask
HEAD		Cap	FEET		Canvas Boots	RESPIRATIONS		Scott Air Pac
HEAD	x	Hood	FEET		Rubbers	RESPIRATIONS	x	Fresh Air Supplied air bubble hoods
HEAD		Hard Hat	FEET		Rubber Boots	RESPIRATIONS		
HEAD		Goggles	HANDS	x	Surgeon Gloves	DOSIMETERS	x	Film Badge
BODY	x	No Personal Outer Clothing	HANDS		Canvas Gloves	DOSIMETERS		Neutron Badge
BODY		Smock	HANDS		Leather Gloves	DOSIMETERS		Gamma Pencils
BODY		One Pair Coveralls	HANDS		Rubber Gauntlet	DOSIMETERS		Finger Rings
BODY	x	Two Pair Coveralls	HANDS		Asbestos Glove	DOSIMETERS		

SPECIAL INSTRUCTIONS

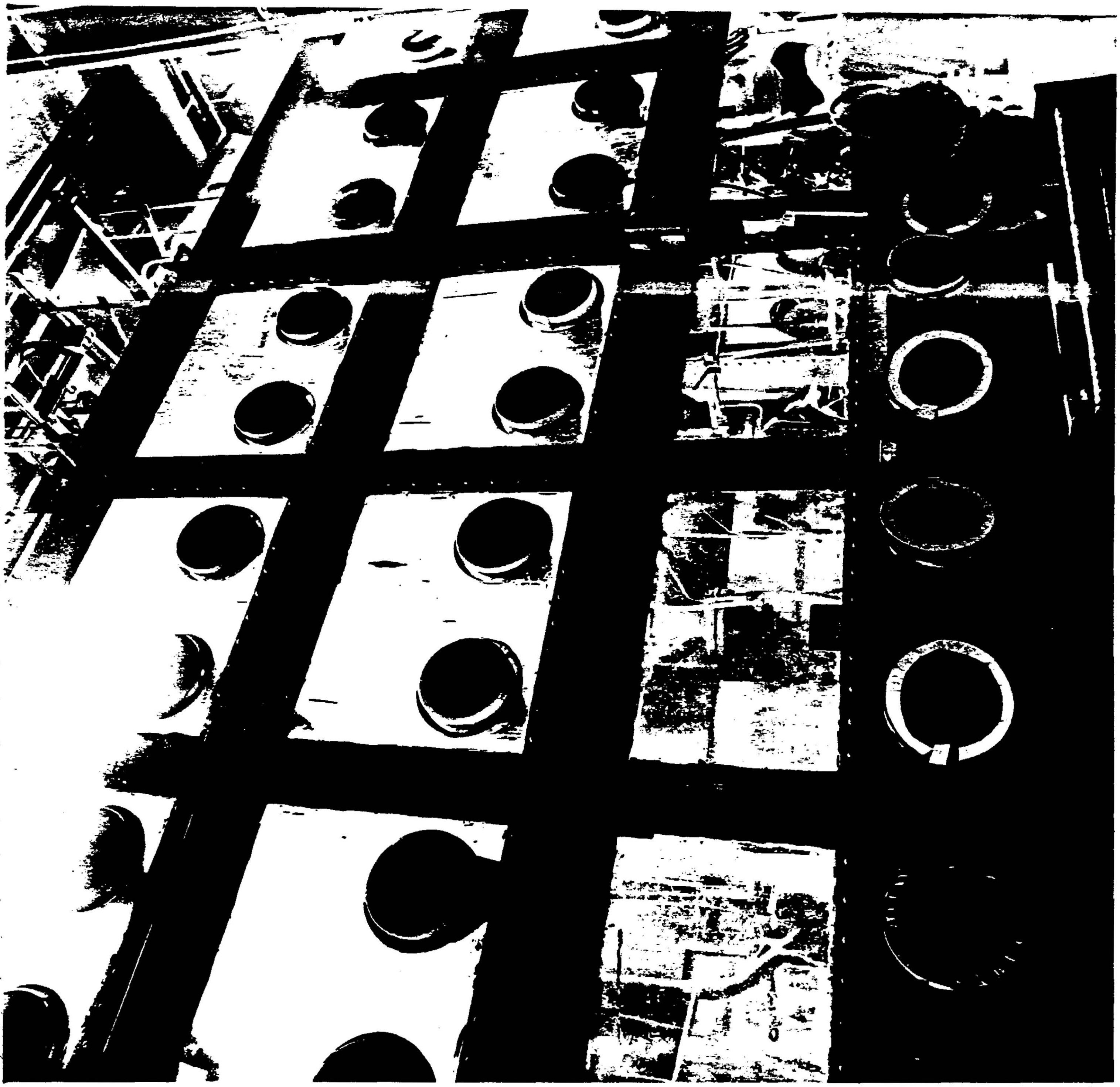
1) Bubble hoods to be used when cutting.
2) Use snorkel to help maintain proper ventilation control.
3) No plasma arc cutting in Box 3A while people are inside the tent.
4) Daily ventilation check by H.P. technician with smoke tube.
5) Room BO-2 will be a respirator area while this SWP is in effect.
6) The door between Room BO-1 and BO-2 will be sealed.
7) A respirator area will be established outside the tent door.
8) Clear coat box and tent as needed to control loose contamination spread.
9) All edges of cut pieces to be wrapped with tape to prevent snagging and tearing of gloves.

Figure - 9

Bennie F Smith
Kevin Kiger
WORK COMPLETED BY
R. C. Borgmier

OPERATIONS APPROVAL: R. C. Borgmier
MAINTENANCE APPROVAL:
HEALTH PHYSICS APPROVAL: W. A. Rogers

Return form to Area Operations Supervisor when work is completed



11 128 Overall View - Box 5A (Precipitation)

Figure - 10

DISTRIBUTION:
White - Job Site
Canary - Health Physics File

SPECIAL WORK PERMIT KM-2420-A

NO. 6609 EXAMPLE

LOCATION
Room BO - 2

JOB DESCRIPTION
Cutting S.S. column into sections in Box 4 using plasma arc torch.

VALID FROM 10-12-82
TO Completion
SUPERSEDES

Nuclear Criticality Safety Limits and Controls Considered [X] Yes [ ] No

RADIATION CONDITIONS

Routine

RADIATION MONITORING REQUIREMENTS

Routine

INDUSTRIAL SAFETY (ITEMS TO CONSIDER ON BACK OF SHEET)

1) Hoists - Do not work directly under items held by hoist.
2) Effect on others - Do not observe arc without proper eye protection(#10 or barrier lens)

PROTECTIVE EQUIPMENT REQUIREMENTS

	√	ITEM		√	ITEM		√	ITEM
HEAD	x	Safety Glasses	FEET	x	Safety Shoes	RESPIRATIONS		Half Face Mask
HEAD		Face Shield	FEET	x	Shoe Covers	RESPIRATIONS		Full Face Mask
HEAD	x	Cap	FEET		Canvas Boots	RESPIRATIONS		Scott Air Pac
HEAD		Hood	FEET		Rubbers	RESPIRATIONS		Fresh Air
HEAD		Hard Hat	FEET		Rubber Boots	RESPIRATIONS		
HEAD		Goggles	HANDS	x	Surgeon Gloves	DOSIMETERS	x	Film Badge
BODY		No Personal Outer Clothing	HANDS		Canvas Gloves	DOSIMETERS		Neutron Badge
BODY		Smock	HANDS		Leather Gloves	DOSIMETERS		Gamma Pencils
BODY	x	One Pair Coveralls	HANDS		Rubber Gauntlet	DOSIMETERS	x	Finger Rings (as assigned)
BODY		Two Pair Coveralls	HANDS		Asbestos Glove	DOSIMETERS		

SPECIAL INSTRUCTIONS

1) All gloves not in use during cutting operation must be tied out or shielded against sparks.
2) Maintain clear access to wheeled CO_2 extinguisher for use in cooling windows in case of fire in box.
3) Monitor ΔP across G.B. filters to check for filter plugging.
4) Do not handle hot metal with glove box gloves.
5) All edges of cut pieces to be wrapped with tape to prevent snagging and tearing of gloves.

Figure - 11

Bennie F. Smith
Kevin Kigen

WORK COMPLETED BY
R.C. Borgmier

OPERATIONS APPROVAL
R.C. Borgmier

MAINTENANCE APPROVAL

HEALTH PHYSICS APPROVAL
W. A. Rogers

Return form to Area Operations Supervisor when work is completed

XIII. PROBLEMS ENCOUNTERED IN PLASMA ARC CUTTING

While extensive use of the plasma arc cutting process has demonstrated it to be an efficient, economical, flexible, easily operated tool, certain problems arose in its operation.

The potential for most of the problems encountered was recognized at the outset and taken into consideration in changes and adaptations to the basic system.

What could not be known until actual operating experience had been accumulated was the extent of the impact on each problem on operation and maintenance of the system. Following is a discussion of the problems.

1. Smoke

By far the most significant problem presented by plasma arc cutting was the generation of "smoke" in glove boxes where gases must pass through a very high efficiency filter system before they are released to the environment. This "smoke" is made up of particulate matter which, if it is not removed before it reaches the high efficiency (H.E.P.A.) filters, would quickly clog these units. Frequent changing of the H.E.P.A. filters would result in unacceptable maintenance and TRU disposal costs and a significant amount of lost operational time.

This problem, which is inherent in all thermocutting processes but is less serious in plasma arc cutting than in others, was recognized and resolved in the adaptations made for cutting columns in the SX glove box by installation of a loosely packed fiberglass filter in the top of the column through which essentially all of the gases in the tent space passed prior to reaching the final H.E.P.A. filters. The success of the pre-filter is indicated by the fact that only two H.E.P.A. filter changes were required at a cost of approximately $1,000 during the entire SX cutting operation.

The cutting "smoke" presented much worse problems when 18' x 36' "clear-coated" glove box panels were cut with a hand-held plasma torch in the glove box used for this purpose. In this case, the "smoke" could not be channeled through a fiberglass pre-filter plug. In addition, the amount of "smoke" generated was greater than in the SX glove box because the panels had been clear-coated with a material that produced smoke during the cutting operation.

The first attempt to resolve this problem was the installation of a cloth-like paper pre-filter in the exhaust duct ahead of the H.E.P.A. filter. This pre-filter protected the H.E.P.A. filter, but its plugging rate was unacceptably high.

This problem has been significantly improved by scraping the "clear-coat" from the back side of the area to be cut and by inerting the glove box to a level of 12% oxygen.

Further changes may be made as this operation is continued. That the "clear-coat" is the major culprit is indicated by the fact that one of the glove boxes, which had not been treated with "clear-coat", was disassembled and cut into packagable pieces in an oversized glove box with a greatly reduced "smoke" generation without inerting the box.

2. Dross

Another problem which is characteristic of thermocutting processes in general but which is less evident in the plasma arc process is the formation of droplets of a metallic material known as dross.

In the automated cutting of the columns in the SX glove box, small amounts of dross produced in the pierce cut spatter on the sliding surfaces and gear teeth of the base plate of the cutting machine and interfere with the rotation of the cutting torch. A guard for the torch head or a shield for the base plate could be included in any future design for the automatic cutter. The formation of dross is not a problem in hand operation of the torch when the cutting operation is positioned to prevent the hot dross from falling on the glove box glove.

3. Maintenance Requirements

Changing the operating gas to nitrogen resulted in an increase in the torch operating temperature which resulted in a decrease in the useful life of expendable items, such as the gas distributor and the Lo Amp tip, to the point where scheduled daily replacement is required. This generally takes 15 to 30 minutes, but additional development could possibly ease this problem.

Maintenance and assembly of the small parts of the torch is made difficult by the thick rubber gloves in the glove box ports. If a device could be developed to mitigate this problem, maintenance time could be reduced and overall economics improved.

4. <u>Noise Level</u>

   Operation of the plasma arc is noisy. At the cutting location, the noise level is in the range of 100 decibels. The operator working outside the glove box is subjected to about 90 decibels, which is within allowable limits, but continued exposure to noise at this level is unpleasant and steps might be considered to decrease it.

5. <u>High Light Intensity</u>

   The plasma arc produces a light of intensity similar to that produced by arc welding in its effect on operator's eyes and skin. This problem has been resolved by the use of a welding hood with a lens shade of No. 8 to No. 10. Use of such a hood for extensive periods is unpleasant, and the development of needed eye protection on the cutting glove box could improve operator efficiency.

6. <u>Tent Material</u>

   The asbestos material used to fabricate the tent in the

SX glove box proved to be less durable than required for the up and down accordian-like service to which it was subjected. A more servicable material such as heat resistant fireproof glass fiber might be a better choice.

XIV. CONCLUSIONS

1. The use of a modified plasma arc cutting unit, with additional equipment required to adapt it to operation in plutonium contaminated production scale glove boxes, results in a very large decrease in the manpower requirements for cutting operations, when compared to conventional mechanical equipment with sufficient power to handle the thick stainless steel involved.
2. Almost as important as its obvious economic impact is the fact that total personnel exposure to potential plutonium contamination and gamma radiation is significantly reduced by a decrease in the total man-hours spent in cutting contaminated stainless steel.
3. Because of the work done by Sequoyah Fuels Corporation and reported herein, any future program by industrial and/or government can be carried out at a savings.
4. The major problems presented by plasma arc cutting have been identified and either solved during operation to date or given sufficient thought to point the way to easy solution.