

Title: **Development and Deployment of a Reciprocating Machine Tool for Large-mass Activated Metal Segmentation**

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ABSTRACT:

Decommissioning of radiologically contaminated facilities often requires segmentation of large metallic components to manageable sized subcomponents. Radiological contamination and/or activation of these metallic components present special challenges that make thermal cutting undesirable. Mechanical segmentation employing a hybrid of machine tooling and reciprocating saw methods can be effectively utilized for disposition of large dimension metallic waste streams.

INTRODUCTION:

MOTA Corporation developed and successfully operated a reciprocating machine tool (RMT) capable of mechanically segmenting metallic objects with dimensions of up to 75 inches width by 72 inches thick. As subcontractor to Argonne National Laboratory, MOTA faced unique cutting challenges for the Building 211 60-inch Cyclotron. MOTA's work scope included segmentation of the roughly 250 ton activated steel magnetic yoke and poles into segments weighing less than 19,000 pounds each.

The MOTA RMT was developed after evaluation of existing thermal and mechanical cutting methods determined no suitable technology existed. Thermal cutting was not desirable due to safety hazards from massive volumes of smoke and molten steel. Diamond wire sawing and water-jet technologies generated unacceptable amounts of secondary waste such as cooling water slurries. Additionally, the large cutting dimensions of the cyclotron components (typically 75" wide by 32" deep) made uniform deep cutting challenges even greater. The MOTA RMT hydraulically drives a 103" long straight machine tool blade that incorporates cold sawing bits typically used on large circumference concrete saw blades. Figure 1 is a photograph of the MOTA RMT.



Figure 1 – MOTA Corporation's Reciprocating Machine Tool in field use at Argonne National Laboratory Bldg. 211 Cyclotron D&D Project.

Numerous mechanical engineering challenges have been successfully met as part of the cutting operations including: construction of a support system for the upper yoke segmentation; saw mounting and cutting on the tapered radii of the magnetic poles; horizontal cutting and support of ~19,000 pound dynamic cut pieces on vertical yoke sections. MOTA completed the mechanical segmentation of the Cyclotron, making 20 rectangular cuts (14 vertical and 6 horizontal) on the magnetic yoke and 4 vertical cuts on the tapered cylindrical magnetic poles. MOTA's unique mechanical cutting process has potentially broad D&D applications for the non-thermal segmentation of large mass metallic objects such as cyclotron magnets, steel shielding components, rotor shafts, "tube and shell" components, platforms and other structural members.

CHALLENGES OF THE CYCLOTRON DISMANTLEMENT

With a total assembled weight of 265 tons, the electromagnet of the Argonne National Laboratory Building 211 - 60 inch Cyclotron was a standard "double yoke" design, roughly 206 inches long, 164 inches high and 75 inches wide. The diameter of the pole base was 75 inches, with a 62 inch diameter of the pole face. Figure 2 is an original construction photograph of the Building 211 Cyclotron Electromagnet.



Figure 2 – 1949 Construction Photograph of Cyclotron Electromagnet.

The cyclotron was located in a 40 feet by 50 feet vault, constructed of 7 feet thick concrete walls and a 4 feet thick roof. Ceiling height of the vault was 28 feet providing sufficient clearance for a 10-ton precision hoist bridge crane. Hydraulic systems allowed lowering of a 120-ton equipment (“Dee”) door to provide a material removal path, via an integral “rail and cart” system. Maximum floor loading inside the vault and its adjoining loading dock through which the rail removal pathway ran was limited to 1,000 pounds per square foot.

The Cyclotron electromagnet was activated during particle acceleration operations. **As a result of this activation, all segmentation activities had the potential to generate “loose” contamination, ranging from machine cutting chips to airborne particulates created by thermal cutting.** This fact resulted in the evaluation of numerous cutting methodologies and the decision to develop MOTA’s RMT. Further description of this evaluation and the selection of the RMT is addressed later in this presentation.

The combined limitations of a 10-ton overhead crane and 1,000 pound maximum floor loading mandated that the **“target weight” for sections to be removed from the cyclotron could not exceed 19,000 pounds.** This ‘target weight’ allowed for a 5% margin of weight error in the combination of the weight of rigging required to lift the cut pieces plus any variations in the dimensions of the cut. Mass weight calculations were made and a segmentation plan was developed in order to minimize the number of cuts to 24 in accomplishing the 19,000 pound segmented piece target weight.

The segmentation plan identified 6 vertical cuts across the top yoke section. This allowed one section to be cut from either end of the top yoke section, with the weight continuing to be supported by the side vertical sections. However **on the second lateral top yoke section cut, a support bridge had to be installed to support the dynamic load.** This was accomplished by the installation of an engineered I-beam mounted by bolting to the vertical uprights.

Segmentation of the side yoke sections required horizontal cutting that produced a 19,000 pound dynamic load “stack.” This was accomplished by designing the RMT to allow both horizontal and vertical mounting configurations. The weight of the cut segment dynamic loads was supported by insertion of hardened steel self-tapping bolts into the kerf behind the blade back. This method allowed removal of the bolt in the event that the blade would have to be removed. Figure 3 is an engineering graphic of the Cyclotron Segmentation Plan and Support Scheme.

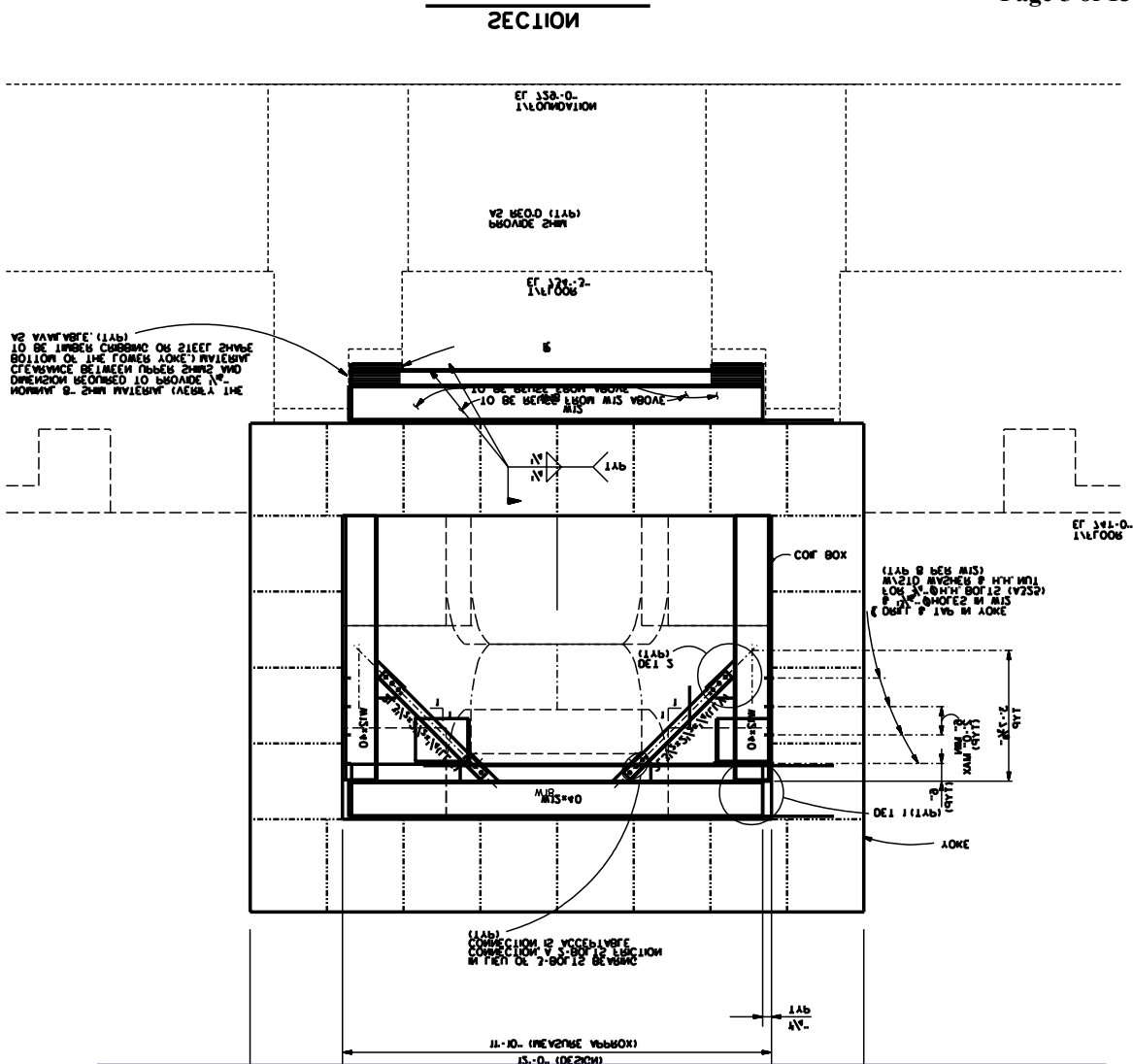


Figure 3 – ANL Bldg 211 Cyclotron Segmentation Plan and Support Scheme.

COMPARISON OF CUTTING METHODOLOGIES

Without doubt, the greatest technical challenge in the Cyclotron D&D effort was disassembly and segmentation of the magnetic yoke. MOTA engineers exhaustively evaluated this challenge, considering three primary types of cutting methodologies – mechanical, grinding, and thermal.

Mechanical cutting involves the removal of small bits of metal using a hard chisel surface as in a hack saw, band saw or circular milling saw. Grinding uses an abrasive media impregnated in or on a disc or wire to heat the metal at the point of contact to cause it to flow. Once the metal is hot enough to flow, the abrasive carrier mechanically removes it. Thermal segmentation uses a heat source such as a rapidly oxidizing metal rod or gaseous flame to melt and volatilize the metal.

Each methodology was thoroughly researched and the advantages and disadvantages weighed. A comparison of the evaluated methodologies is set forth in Table 1.

Table 1. ANL 60 Inch Cyclotron Yoke and Poles Segmentation Methodology Comparison

<i>Mechanical</i>					
Specific Type	Cutting Ability	Secondary Waste	Surveillance ⁴	Heat Stress	Practical
Hack Saw	Yes, Unlimited ¹	Dry metal filings	Minimal	No	Yes
Band Saw	Yes, Unlimited ¹	Metal filings, lubricant	Minimal	No	No – cost, size, lube
Milling Saw	Yes, Unlimited ¹	Dry metal filings	Minimal	No	No, cost
Stitch Drill	Yes, Unlimited ²	Metal filings, lubricant	Minimal	No	No, setup
<i>Abrasive</i>					
Specific Type	Cutting Ability	Secondary Waste	Surveillance	Heat Stress	Practical
Abrasive Disk	No	Some smoke, metal filings	Light	No	No
Diamond Wire	No	Some smoke, metal filings	Light	No	No
<i>Thermal</i>					
Specific Type	Cutting Ability	Secondary Waste	Surveillance ⁴	Heat Stress	Practical
Oxy-Magnesium Rod	Yes Unlimited	Copious smoke, tons of slag, and molten metal	Heavy	Yes	No
Oxy-Gasoline Torch	Limited, up to 14 inches	Copious smoke, some slag ,and molten metal	Heavy	Yes	No
Powder Torch	Limited, up to 18 inches	Copious smoke, some slag and molten metal	Heavy	Yes	No
Plasma Torch	Limited, up to 7 inches	Copious smoke, medium slag and molten metal	Heavy	Yes	No

Notes:

- 1.) The size of the blade and the configuration of the supporting equipment limit the depth and width of cut. Currently there are commercially available saw blades and equipment that are capable of cutting material 110 inches thick with a depth of cut 55 inches and greater.
- 2.) Drill bits are commercially available in 32 inch lengths
- 3.) Cutting thicknesses are in accordance with manufacturer’s specification and The US Department of Energy Decommissioning Handbook DOE/EM-0142P, March 1994
- 4.) Surveillance is defined as those activities necessary to insure safe and efficient operations and include fire protection and inspections, Health Physics support, controlled and uncontrolled area surveys, airborne monitoring, stringent personnel protection requirements

Several unacceptable mechanical technologies were researched, including diamond impregnated wire and milling saws. Excessive diamond glazing and abrasive wear from the all-iron cutting made these methods both impractical and cost prohibitive. Cold sawing with hardened, metal-alloy, circular, milling blades requires an extremely heavy saw apparatus. Although superior in cutting, it requires the piece to be brought to the saw. Band saw technology readily available from several manufacturers is widely used in the metal fabrication industry to mechanically segment billets of up to 60 inches from virtually all varieties of ferrous and non-ferrous metals, including stainless steel and inconel. Capital expense and coolant control requirements make this cutting method impractical for segmenting the Cyclotron yoke and poles.

Although superior in cutting metal/concrete composites and stone, diamond wire and diamond impregnated discs will not cut high purity, ductile iron. When the metal flows during cutting it fills or clogs (glazes) the diamond cutting surfaces rendering the saw useless after only a short period of cutting. Stitch drilling was not viable because of the extensive amount of set-up time and cut tracking problems when drill holes were overlapped.

Thermal segmentation with oxy-magnesium rods, oxy-acetylene, oxy-gasoline, powder torches, and plasma-arc torches is widely accepted in the decommissioning of facilities. Our assessment identified numerous complications associated with thermal cutting: requirement for elaborate containment and filtration systems; inability to cut through more than about 18” with some torches; heavy surveillance for contamination control and fire hazards; and, most significantly, serious personnel safety concerns from “gouging out” tons of molten metal and from the heat stress of hours running a torch in a containment with full PPE and respirators. These were all negative factors in considering thermal methods for segmenting the Cyclotron yoke and poles.

Mechanical segmentation was chosen due to its ability to effectively cut high-purity iron, the controllability and limited volume of cutting byproduct (secondary waste), and the Health & Safety advantages associated with the methodology.

Working jointly with Reverse Engineering (Columbia, SC) and INSCO Saw Division (Orangeburg, SC), MOTA Corporation developed an engineered cutting blade and delivery system to segment the yoke. The MOTA Reciprocating Machine Tool is a modified guillotine type saw with a frame network that spanned the entire width of the 75” yoke (see Figure 4). The RMT throat is capable of accommodating up to a 72 inch thick section of material. It is hydraulically powered and capable of cutting in both the vertical and horizontal position. The blades used for the Cyclotron segmentation are approximately 103 inches in length and resemble a hacksaw blade.

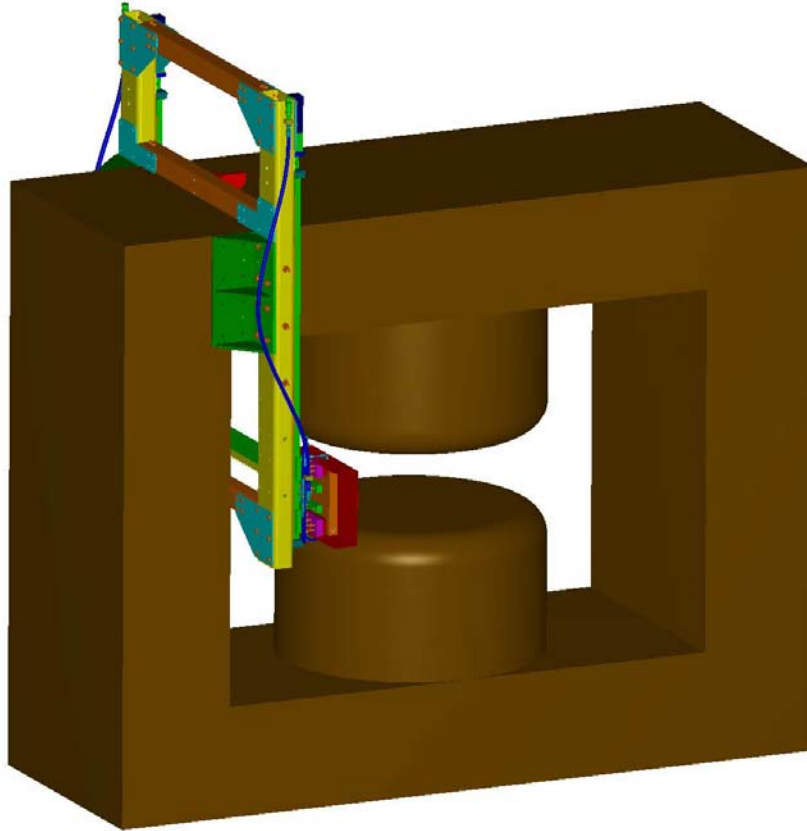


Fig 4 – Graphic of the MOTA Reciprocating Machine Tool mounting configuration on the ANL Building 211 Cyclotron Electromagnet

The RMT frame has a modular cross-member construction that allows a short configuration using a 65-inch blade. Special mounting brackets were also fabricated allowing the RMT to be fastened to the right cylinders of the magnetic poles (see Figure 5). This mechanical segmentation tool allowed sizing to optimize safe rigging and packaging efficiency, while virtually eliminating any concerns of environmental hazards such as smoke generation and molten slag. It also presented the greatest potential for “fine tuned” segmentation of the yoke materials to allow segregation of activated and non-activated materials, optimizing pollution prevention optioneering.

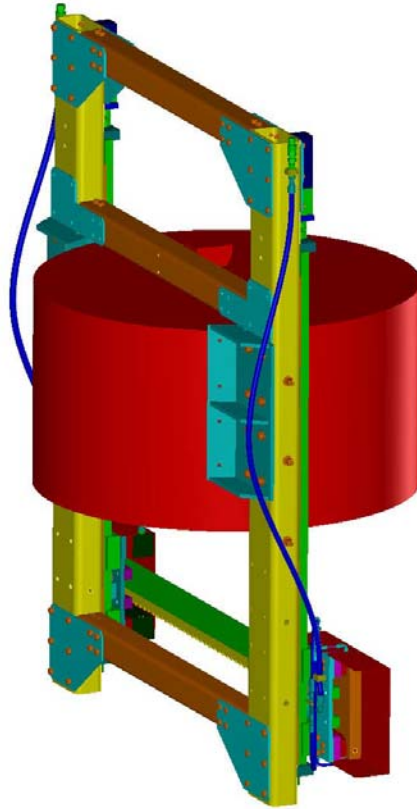


Fig 5 – Graphic of the MOTA Reciprocating Machine Tool mounting configuration on the ANL Building 211 Cyclotron Electromagnet Cylindrical Pole

FIELD DEPLOYMENT AND OPERATIONAL RESULTS

Upon award in October, 1999 of a subcontract for the decommissioning of the Building 211 Cyclotron facilities, MOTA Corporation began the process to design and construct the RMT. MOTA commenced decommissioning operations at Argonne in January, 2000. The RMT was “bench tested” on a clean steel mock-up at Reverse Engineering’s shop on January 17 and delivered to the project site on January 27.

Following the completion of all predecessor D&D activities and a demonstration of the saw’s operability, the RMT was mounted to the Cyclotron upper yoke by process of drilling and tapping. The first vertical cut commenced on April 17. The 32 inch penetration cut was completed on April 20. Figure 6 is a photograph of the mounting configuration and void space created by the first cut. The RMT was remounted progressively through each of the additional 6 vertical cuts on the upper magnetic yoke. This cutting process was completed in 49 days on June 23 including the 7 cuts that produced 8 roughly 16,750 pound blocks. Figure 7 is a photograph of four cut blocks removed from Building 211 after painting and exterior radiological survey.

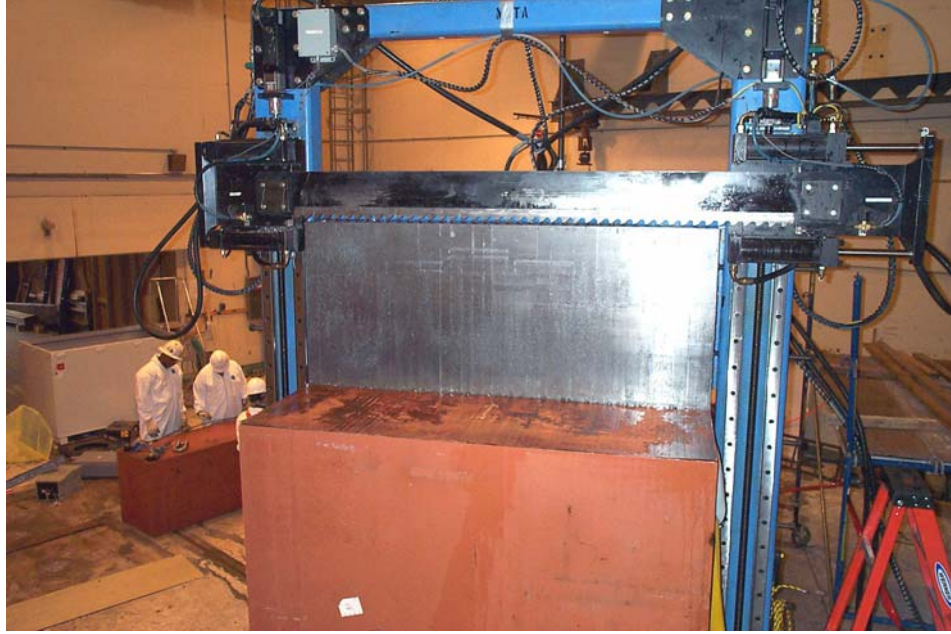


Fig 6 – Photo of the MOTA Reciprocating Machine Tool at conclusion of the first cut of the ANL Building 211 Cyclotron Electromagnet. First cut piece is resting on floor in background.



Fig 7 – Photo of painted and surveyed blocks from the upper magnetic yoke of the ANL Bldg 211 Cyclotron. Each block weighed roughly 16,750 pounds produced by MOTA RMT cutting operations

The RMT was reconfigured with right cylinder cutting brackets, and mounted to the upper magnetic pole. The first right cylinder cut began on July 6, and was completed July 10. Figure 8 is a photograph of the RMT mounted for the upper pole cutting operations. The final of four pole cutting configurations was completed August 8, producing 7 segments ranging roughly from 11,000 to 17,000 pounds, in 24 days. Figure 9 is a photograph of three cut segments of the upper pole removed from Building 211 after painting and exterior radiological survey.



Fig 8 – Photo of the MOTA Reciprocating Machine Tool mounted on the upper pole yoke immediately prior to start of cutting.



Fig 9 – Photo of sections from the upper magnetic pole of the ANL Bldg 211 Cyclotron. Each section weighed roughly 9,750 pounds

The RMT was reconfigured for horizontal cutting and drill & tap mounted for the first horizontal magnetic side post cut that began on August 10 and ended August 16. Figure 10 is a photograph of the RMT mounted for the North side post cutting operations. Self-threading case hardened steel bolts were placed in the cutting kerf behind the RMT blade to support the dynamic load of the upper cut section. The final side post cutting configuration was completed September 28, a total of 35 days for 6 horizontal cuts.



Fig 10 – Photo of the MOTA Reciprocating Machine Tool mounted horizontally on the North side post of the Bldg. 211 Cyclotron

The RMT was reconfigured for the final sequence of 7 progressive vertical cuts on the bottom cross member of the Cyclotron electromagnetic yoke. This cutting process began on October 3 and was completed in 35 days on November 20 producing 8 roughly 16,750 pound blocks.

Cutting chips collected from the approximately 3/8 inch thickness of the RMT blade kerf produced a total volume of roughly 0.6 ft³ per cut, based on a swell factor of 50% from the curling of the metal shavings from tooth cutting. A total volume of 14.4 ft³ (two – 55 gallon drums) of cutting chips were produced in total as a result of RMT operations. A total of 64 cutting blades were used during the 24 cuts.

CONCLUSION

The cumulative start to finish duration of all cutting operations for the 24 cuts was 154 production days, including cutting sequences, block & segment removal, incidental project cutting progress interruptions and reconfiguration of the saw. This is an average of roughly 6.4 production days per cut.

Table 2 contains a summary of cutting performance data produced during MOTA Corporation’s successful field implementation of the Reciprocating Machine Tool (RMT) on the Argonne National Laboratory Building 211 Cyclotron D&D Project.

[Table 2. Cutting Performance Data from MOTA RMT Operation at ANL Cyclotron D&D Project](#)

# and Configuration	Start Date	Complete Date	Total Duration	Average
7 Top Yoke Vertical Cuts	April 17	June 23	49 days	7 days/cut
4 Top & Bottom Pole Cuts	July 6	August 8	24 days	6 days/cut
6 Horizontal Side Post Cuts	Aug 10	Sept 28	35 days	~5.8 days/cut
7 Bottom Yoke Vertical Cuts	October 3	November 20	35 days	5 days/cut
CUMULATIVE START TO FINISH	April 17	November 20	154 production days	~6.4 days/cut

REFERENCES

1. The US Department of Energy Decommissioning Handbook DOE/EM-0142P, March 1994, *Table 10.1 “Summary of Application for Metal Cutting,”* pp 10-4 and 10-5