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ABRASIVE CUTTING OF IRRADIATED URANIUM

INTRODUCTION

The preparation of radioactive metallurgical specimens for microscopic examination is one of the responsibilities of the Radiometallurgy Sub-Unit.

Experience teaches that without adequate preparation of the surface that is to be examined little can be learned regarding the internal structure of a metal by microscopic examination. With the use of modern metallurgical microscopes and precision optical parts where the possible resolution obtainable is a fraction of the wavelength of light used, perfect specimen preparation is of extreme importance. Improper
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preparation is likely to obliterate the actual structure of the material and ultimately produce a microstructure that appears entirely different from that which is truly characteristic and representative of the metal.

Whenever possible, sampling techniques should provide a specimen of such a size that it can be handled conveniently. Specimens that have large surface areas, exceptionally rough surfaces or surfaces with badly flowed metal will usually require prolonged polishing to produce a satisfactory metallurgical specimen.

Frequently, precautions must be taken to prevent the specimens from becoming excessively heated during the cutting operation. For example, the structure of certain metals may be completely altered by tempering, due to the heat involved in cutting, and thus the purpose of the examination may be defeated.

Accordingly, the cutting-off operation, which is the first step in metallurgical sample preparation must keep metal flow and scratching to a minimum, and in addition must keep inclusion retention at a maximum. The surface to be examined should also be relatively flat and free from burrs and burns. These are strict requirements and their accomplishment no easy task. Thus, a great deal of consideration must be given to the design and construction of the cutting-off machine used.

Abrasive cutting has long been recognized as a modern and efficient method of meeting the cutting-off requirements and has been investigated and reported on as a means of cutting metallurgical samples from irradiated uranium by L. D. Turner.(1)

The cutting of radioactive materials further complicates the design and construction of equipment by introduction of the additional requirements listed below:

1. Airborne and solid contamination control.
2. Radioactive waste collection and disposal.
3. Remotely controlled operation and handling.
4. Remotely conducted maintenance.

OBJECTIVE

An abrasive cut-off machine development program, based upon a previous experimental model, was undertaken to provide a method for sectioning of irradiated materials without undue personnel exposure or spread of contamination and finally to provide data for the design of an abrasive cutting unit for use in the work cells in the Radiometallurgy Building.

SUMMARY AND CONCLUSIONS

A horizontal-feed type cut-off machine, powered by a 7 1/2 hp motor with V-belt drive, has been developed for the submerged sectioning of irradiated uranium and is currently being used successfully to obtain samples for metallurgical, chemical and physical investigations without excessive personnel exposure or spread of radioactive contaminates.

(1) HW 9430, "Interim Report - P.A. 3-M Examination of Irradiated Uranium", by L. D. Turner, April 7, 1948
Reduction of the radiation level of the cutting unit has been accomplished by flushing with water and separating the radioactive material and abrasive from the flushing and submerging water in a simple gravity type separator. Airborne contamination has been effectively controlled by cutting under reduced pressure and filtering the air removed from the cut-off box.

Successful Rockwell hardness readings and macroetches have been made on the surface of sectioned irradiated uranium samples without additional surface preparation. Approximately thirty minutes of lapping time has been sufficient for the preparation of metallurgical samples before electropolishing.

The problems encountered in the development of the abrasive cut-off unit have provided information for the design of a smaller, more compact unit for cell use. At the present time it appears possible to install an abrasive cutting machine in a multicurie cell, by surrounding the machine with two inches of lead to protect personnel from the normal radiation level remaining after flushing, and still allow unlimited access for decontamination and maintenance of other items of equipment.

**ABRASIVE WHEEL SELECTION**

Preliminary attempts to section unirradiated uranium with a Buhler #436 abrasive wheel and a jet of water for cooling were unsuccessful because of excessive wheel breakage. This was caused by misalignment between the vise guide rods, Figure 1, and the plane of the cut-off wheel. In addition, the cut surface was severely burned and in some instances the aluminum slug jacket melted because of insufficient coolant, see Figure 2.

Following correction of the misalignment problem, tests were conducted on different type cut-off wheels to obtain an indication of wearability characteristics. One cut was made on 1 1/2-inch diameter stainless steel rod with each wheel, and the average diameter decrease noted. An attempt was made to keep the rate of cutting uniform. The table below shows the relative wearability (defined as the ability to endure under wear) of the wheels tested based on the Buhler wheel, #436, as unity.

<table>
<thead>
<tr>
<th>Wheel Type</th>
<th>Diameter Decrease, in.</th>
<th>Relative Wearability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buhler #436</td>
<td>0.375</td>
<td>1.00</td>
</tr>
<tr>
<td>Allison #465</td>
<td>0.125</td>
<td>3.00</td>
</tr>
<tr>
<td>Allison #120 A 1 1/2</td>
<td>0.875</td>
<td>0.43</td>
</tr>
<tr>
<td>Allison #120 C 1 1/2</td>
<td>2.750</td>
<td>0.13</td>
</tr>
<tr>
<td>Norton, Alumdum</td>
<td>1.375</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Actually, surface quality is paramount and wheel life secondary, but one cannot be obtained without sacrificing the other. Generally, wheels of relatively soft grade, open structure and fine grit sizes, which have low wearability characteristics are used for metallurgical specimen cutting. However, selection of the Allison wheel, #465, which exhibited the best wearability was deemed necessary to reduce the frequency of wheel changing behind the temporary lead brick shielding because of the personnel exposure involved. Installation of the cut-off unit in a multicurie cell will reduce
FIGURE 2 SEVERELY BURNED SURFACE CAUSED BY INSUFFICIENT COOLING.

FIGURE 3 SURFACE OBTAINED BY SUBMERGED CUTTING.

FIGURE 4 WAFER SECTIONED FROM AN IRRADIATED SLUG AND ELECTROLYTICALLY CLEANED.
personnel exposure rates during wheel changing and permit selection of a wheel that insures better surface quality.

SELECTION OF COOLING METHOD

In an attempt to reduce the amount of burning and produce an acceptable cut, an unirradiated uranium slug was submerged in water and the wheel speed reduced from 3500 rpm to 1750 rpm. The wheel speed was changed so that sufficient torque would be available for cutting the wafer and driving the partially submerged wheel (the power required to drive a flat circular disk in a given liquid varies as the cube of the disk speed)(2) An acceptable cut similar to that in Figure 3 was obtained.

CUT-OFF BOX DESCRIPTION

The cut-off box, Figure 1, consists essentially of a driven shaft with arbor mounted wheel and a remotely operated vise and vise feeding mechanism, all surrounded by an air-tight brass box. The abrasive wheel is held between two stainless steel washers on an arbor which is fastened to a hollow drive spindle by a draw rod arrangement. This arrangement permits the wheel and arbor to be removed from the spindle by merely loosening the draw rod which extends through the shielding around the box. A long wrench with a 90 degree off-set handle, which is inserted through an access hole in the shielding on top of the box, provides for removing the mounted wheel. The wrench is also used to hold the arbor during removal of the draw rod.

A stainless steel vise mounted on two one-half inch diameter stainless steel rods holds the slug during sectioning. The vise jaws are operated by a rod which engages the vise screw and extends through the side of the box and shielding. Straight-line motion of a rod attached to the vise forces the vise along the guide rods and feeds the material into the wheel.

The lid of the box is sealed during cutting and opened during loading and unloading of the vise. A lead glass window located in the shielding above the box gives visual control of the loading and unloading operations. Locking of the lid is accomplished by a bell-crank actuated locking mechanism with two arms, tapered on the ends, which are forced into slots and firmly compress a one-quarter inch thick neoprene gasket under the lid. A straight rod fastened to the bell-crank and extending through the shielding operates the locking mechanism.

A flushing system attached to the sides of the box near the top sprays water inside the box after cutting and flushes wheel abrasive and uranium down the sloping bottom of the box into a one inch drain pipe.

A rod with a flat bar on one end, which extends through the side of the box, engages the end of the slug while the vise is in the loading position and positions the slug for desired wafer thickness.

Sample removal is accomplished by removal of a small trough, located between the side of the box and the wheel, which catches the sample after cutting. The sample catcher is so constructed that removal from the cut-off box allows the bottom to swing open and the sample to drop down a chute into a receptacle located in a steel plug. For subsequent handling the plug may be drawn into a cask.

The installation of the cutting unit in a laboratory work area rather than a multicurie cell increased shielding and handling requirements. A transfer mechanism, consisting

of a box into which tongs could be introduced for removal of the irradiated material from a storage container and subsequent vise loading, was required. Entrance to the cut-off box is gained through a 2 1/2 inch brass gate valve for loading and unloading of the vise. The gate valve located opposite the vise effectively seals the box during submerged cutting.

The air filtering equipment, shown in Figure 1, consists of two mask filters separated by a calcium chloride container.

A vacuum of at least one inch of water drawn on the cut-off box during sectioning prevents airborne contamination of the laboratory area. Contaminated air from the box travels through the filters and is exhausted into a hood. The calcium chloride absorbent removes any water vapor in the air.

Solid contamination control is accomplished by flushing the box after cutting and subsequent separation of the solid particles from the water.

The water from submerged cutting and flushing flows from the cut-off box through a gravity type separator, Figure 5, into a storage tank for re-use. Reduced flow through the separator permits the heavier uranium and abrasive particles to settle to the bottom of the separator. A flow diagram for the cut-off box is shown in Figure 6. A cylindrical cask with minimum shielding of two inches of lead furnishes sufficient protection for handling of the solid contamination during disposal.

RESULTS AND DISCUSSION

The table below shows the personnel exposures encountered during sectioning of irradiated uranium. The last line shows personnel exposures for a slug sectioned three weeks after discharge from the pile with four inches of lead shielding on top of the cut-off box.

<table>
<thead>
<tr>
<th>Slug Description</th>
<th>Wafers Sectioned</th>
<th>Maximum Exposure</th>
<th>Average Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal (goal exposed)</td>
<td>2</td>
<td>35 µr &amp; 150 mrep</td>
<td>20 µr &amp; 80 mrep</td>
</tr>
<tr>
<td>Rupture (#127)</td>
<td>2</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>Rupture (#15)</td>
<td>1</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td>Normal (420 MWD/T)</td>
<td>3</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Normal (goal exposed)</td>
<td>4</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>Normal (380 MWD/T)</td>
<td>2</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Normal (goal exposed - 3 weeks after discharge)</td>
<td>3</td>
<td>400</td>
<td>75</td>
</tr>
</tbody>
</table>

Air samples taken during the cutting operation indicate that air contamination was less than $1 \times 10^{-10} \mu\text{c}/cc$ (background) when the cut-off box lid remained closed for at least 30 minutes after cutting. The first mask filter, on the cut-off box side, must be changed every 10-15 cuts because of excessive contamination - approximately 15 mrep/hr at four inches. The radiation level of the second filter, however, is less than 2 mrep/hr at four inches after 25 complete transverse cuts on irradiated uranium.
FIGURE 5
SLUDGE SEPARATOR
FIGURE 6
CUT-OFF BOX WATER FLOW DIAGRAM
The maximum radiation level encountered during the changing of the sludge separator, after three or four transverse cuts, was approximately 100 mr/hr at two feet. The radiation level two inches from the surface of a gallon of water taken from the storage tank after five complete transverse cuts on irradiated material was 20 mr/hr and 50 mrep/hr. This indicates that the sludge separator has a good wheel abrasive-uranium chip retention efficiency. Storage of the submerging water for re-use materially reduces the water disposal problem.

The major item of maintenance other than the replacing of the sludge separator is wheel changing. A total of twenty complete transverse cuts were made on the first wheel before wear made changing necessary. Radiation readings obtained on the wheel and arbor assembly were 5 r/hr and 20 rep/hr at a distance of 20 inches. Undoubtedly the high readings were partly caused by the high activity of the last slug sectioned which had been out of the pile only three weeks. The cutting of a brass of stainless steel rod before removal of the wheel would have removed the periphery of the wheel which contained imbedded uranium and reduced the readings considerably. After breaking the periphery of the wheel from the arbor with a long rod, the radiation level was reduced to 2 r/hr and 5 rep/hr at a distance of 12 inches. Dipping the arbor in a 50 percent nitric acid solution further reduced the level to 20 mr/hr and 150 mrep/hr at six inches. Replacing the wheel consumed 200 mrem exposure time over a two day period.

The cut-off box, while not producing a surface of excellent quality because of high wheel wearability requirements, nevertheless has provided a surface on which Rockwell G scale hardness readings and macroetches have been made without additional surface preparation. Normally, only a short period of lapping, 15 to 30 minutes, on a lapping machine is required to prepare the surface before electropolishing.

The vise or work holding arrangement in the cutting unit does not support material on both sides of the cut and causes the formation of a small burr as the material being cut-off pivots around the last portion of uncut metal. The sectioning of a wafer from the center of a slug furnishes a flat surface on one side only, the opposite side having a small burr on the periphery. Burrs formed during cutting materially increased the time required for lapping or grinding. This defect may be easily remedied by use of a vise similar to those available on some commercial cut-off units in which the wheel passes through a slot in the vise, or a double vise arrangement with a narrow gap for wheel passage would be even better for holding warped or distorted material during sectioning.

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