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TECHNOLOGY-URANIUM

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MACHINING OF URANIUM FOR

BROOKHAVEN REACTOR

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ABSTRACT

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MACHINING OF URANIUM FOR BROOKHAVEN REACTOR

The metal for the Brookhaven reactor consisted of natural uranium slugs of the same overall dimensions as those used at Clinton. However, the slug design, and consequently the machining, was complicated by addition of a button and slot required by the helium system.* Even apart from this, the machining presented virtually a novel problem because no written information, and little other information, could be obtained on previous experience in machining uranium. As a result, the methods used had to be developed empirically, and various improvements were made during the course of the work. Furthermore, requirements with respect to boron contamination and health physics were much more rigid than on previous jobs. For these reasons it has seemed worthwhile to present a record of the experience gained during the machining of the uranium for the Brookhaven reactor.

The uranium machining was done by the Chapman Valve Manufacturing Company of Indian Orchard, Massachusetts. This company was the only one of a number approached that was willing to make a firm proposal. One of the other companies had had previous experience in machining uranium, but declined to make a proposal because of the requirements with respect to boron contamination, machining tolerances, and health physics.

The contract called for 110 tons of finished slugs. It was originally estimated that 170 tons of bars would be required to produce this

*For a description of the Brookhaven nuclear reactor see Brookhaven National Laboratory Nuclear Reactor Progress Report BNL-21, October 1, 1948.

amount of slugs. Actually, 155 tons of bars were supplied, and slightly more than 112 tons of accepted slugs were produced.

The work was initiated by a letter of intent on November 27, 1947 and was completed on October 7, 1948; most of the production was carried out during the last 4 months of this period.

Material

The uranium was supplied by AEC from the Hanford Engineering Works in the form of bars approximately 1.2 inches diameter, with a somewhat variable length averaging 12 feet 7 inches. The bars had been prepared by extrusion in the gamma phase. This method of forming was selected on the basis of costs as well as of information that gamma extruded material does not elongate on temperature recycling. The following data show the phase transition temperatures for uranium:

Alpha to beta phase 662°C.

Beta to gamma phase 772°C.

Melting point 1125°C.

Gamma phase extrusion range 850 to 900°C.

The bars had an average weight of about 116 pounds (the specific gravity of uranium ranges from 18.7 to 19.1, depending on the purity).

The uranium was shipped in four box-cars; it was placed in built-in compartments at the two ends of the car. The compartments were constructed by laying 1/2-inch plywood on the floor of the car and building up 4-inch by 6-inch timbers around the sides and ends of the cars to a height of about 18 inches. Similar timbers were laid lengthwise to the same height to form compartments into which the bars were loaded. A 1/2-inch plywood cover was nailed down securely and shored into place and all seams were sealed with masking tape. The compartments retained

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any oxide which had been rubbed off the surfaces of the rods in loading and transit. This oxide was collected with a vacuum cleaner and saved. All lumber used for packing and shoring was salvaged and burned for reclamation of any particles of metal or oxide.

After shipment, it developed that one of the cars contained about 10 tons of so-called TX metal. TX metal was reported to have been extruded from ingots reclaimed by remelting scrap and to be somewhat inferior to virgin metal in chemical, physical and nuclear properties. TX metal bars were not separately identified, which necessitated segregating and separately processing the entire contents of this car, so that it could be identified for appropriate use in the pile.

Upon arrival, the uranium bars were unloaded, and weighed under the supervision of Chapman and Ferguson representatives using scales certified by the Springfield, Massachusetts Sealer of Weights and Measures. It had been expected that the bars would be supplied in a straightened condition to facilitate machining. This was not the case. On unloading it was reported that about 90 per cent of the bars showed a flattening tendency at the ends, resulting perhaps from a shearing or cutting off operation. Chapman Valve later reported that some of the rods showed "grip" marks which led them to believe these rods had been drawn through a die. Some bars were so crooked as to be beyond the possibility of straightening. Chapman was therefore required to straighten all rods possible to make them suitable for economic machining, and to saw off an average length of about 3 inches from each end of all such rods. This along represented a waste of approximately 4 per cent from which no useful recovery of finished slugs was possible.

All bars were black with natural oxide although there was little,

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if any, scale.

Specification and Procedure

The work was done under a letter of intent between the H.K. Ferguson Co. and the Chapman Valve Mfg. Co. dated November 25, 1947, and identified as:

Prime Contract AT-30-2-Gen-16

Subcontract No. S-26

Subcontract No. PRO-30

The specification under which the work was performed is identified as "No. 702-M-5, revised January 26, 1948", which is given in Appendix A. The Specification includes a sketch of the finished slug, which is 4.000 ± 0.002 inches long by $1.100 + 0.000 - 0.001$ inches diameter. Included in the 4-inch length is a button 0.250 ± 0.001 inch diameter by 0.020 ± 0.001 inch deep, centrally located at one end. A slot 0.0625 ± 0.002 inch wide by 0.073 ± 0.002 inch deep runs lengthwise in the slug surface.

Following is a list of the operations called for in the production of the slugs:

(1) Defective ends of the rods were cut off with a power-driven hack-saw, and the rods were run through straightening rolls.

(2) The uranium rods were cut to rough slug lengths in a 6-spindle automatic machine. The diameter of the slug was roughed to 1.180 inches or 1.190 inches and rough finished to 1.108 to 1.118 inches, leaving, on the average, 0.013 inch to be removed from the diameter.

(3) The slug was degreased with trichlorethylene vapor and then underwent the first annealing operation at 600°C . for 12 hours in an atmosphere of welding-grade argon to relieve forming and machining stresses.

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(4) The slug was ground on centerless grinders four times. First grind to a range of diameters from 1.103 to 1.105 inches. Second grind to a range from 1.101 to 1.102 inches. Third grind to a range from 1.1001 to 1.101 inches. Fourth grind to a range of diameters from 1.0998 to 1.1001 inches.

The grinding operations left the slug with a finished diameter and a rough length.

(5) A hand-operated turret lathe machined the button, finished both faces and the length of the slug.

(6) The slot was milled into the slugs with high speed steel cutters hardened by deep freezing. This was a once-through operation.

(7) The slug was returned to the centerless grinders to remove burr, with not more than 0.0003 inch taken off not including burr.

(8) The slug was again degreased and was annealed at 400°C. for 4 hours in an atmosphere of lamp-grade argon.

(9) The slug was brushed clean if necessary and given final inspection before packing.

Rigid laboratory tests for boron were made on all items coming in contact with the metal and in soap used by the workmen. Permissible soaps were as follows:-

<u>Trade Name</u>	<u>Manufacturer</u>	<u>Boron, Parts Per Million</u>
Ivory	Proctor & Gamble	5
Klex	Swift	1
Vulcan-Premiers	Swift	0
Vel	Colgate-Palmolive-Peet	0
Oxydol	Proctor & Gamble	0

Changes in Specification

As machining progressed, suggestions were made from time to time with a view to increasing production rates, eliminating bottle necks, salvaging slugs rejected for certain defects and economizing in the use of materials and labor.

Among such changes were the following:

1. Substitution of welding-grade argon for lamp-grade argon in the first degassing operation was permitted.
2. The time which slugs should be held at temperature in the first degassing or annealing operation could start as soon as the temperature in the interior of the annealing pot reached 1080°F. (582°C.) rather than 600°C.
3. Degassing pots could be externally cooled with water, using extra care to prevent water contact with the cover sealing gasket.
4. Slugs could be removed from the pot in both the first and second degassing operations when the interior of the pot had reached 150°F. rather than 140°F.
5. Uranium butt ends, but preferably degreased uranium turnings, were to be placed inside the degassing pots at the argon gas inlet as well as around the interior periphery of the pot shell adjacent to the cover gasket.
6. Deburring the ends of the slot was omitted on recommendation and statement of Chapman inspector that this burr was only at the base line of the slot (at end) and would not exceed 0.007 inch.
7. In cases where it was possible to salvage finished slugs by reworking and reheating (i.e., giving a total of 3 degassing operations), such pieces if necessary could be exposed to the atmosphere for a total

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of more than the 24 hours. This modification would be subject to withdrawal if excessive oxidation appeared.

8. Because of what appeared to be defects inherent in the metal itself, pit or pox marks developed at times on the surface of the slugs, Brookhaven approved inspectors passing such finished slugs if such marks as these appearing at the ends of the slugs were not larger than 1/8-inch diameter. Slugs with pox marks larger than 1/8-inch diameter were not to be rejected but rather to be shipped in separate containers with special identification.

9. With approximately 60 per cent of the slugs completed in accordance with the drawing shown in Appendix A, a major change was requested by Brookhaven in the size of slot and end button. Listed below are the old and new dimensions. Approximately 40 per cent of the completed slugs were finished with the smaller slot depth and larger button diameter called for under this revision.

Dimensions, Inches		
	<u>Old</u>	<u>New</u>
Slot	1/16 wide x 0.073 deep	1/16 wide x 0.015 deep
End button	1/4 dia. x 0.020 deep	0.90 dia. x 0.020 deep

Changes in Salvage Specifications

1. Scratched surfaces - If scratches yield a volume less than one per cent of slot volume material will be acceptable but should be packed to identify this defect.

2. Length - Slugs 3.970 ± 0.002 inches but without button and with 0.073-inch depth of slot are acceptable for salvage. Indicate defect on package.

3. O.D. tolerances - If slugs are $1.100 + 0.000 - 0.002$ inches, they shall be salvaged and defect indicated on the package.

4. Shallow slot - If depth of slot falls between 0.068 and 0.073 inch the slug is salvable. If slot is narrow and falls with $0.0625 \pm 0.002 - 0.004$ inch, it too shall be salvaged. Defects shall be indicated on package.

The following sub-specification slugs under the salvage changes in specification were shipped to Brookhaven National Laboratory.

	<u>Virgin Metal</u>	<u>TX Metal</u>	<u>Total</u>
No button	554	103	657
Short and no button	229		229
Shallow slot	24		24
Minus diameter	135		135
Scratched surfaces	43		43
Total	985	103	1088

Salvaged Freak Slugs. Two special slugs were sent to Brookhaven for examination. Despite normal dimensions and surface these weighed only 2.25 pounds each instead of the average of 2.568 pounds.

Manufacturing Operation

Building

The machining was done in a remodeled portion of an old foundry building with painted concrete floors. The building was well lighted and ventilated and accessible by rail or truck transport. Photographs of the buildings are shown in Figure 1 and Figure 2. Figure 3 is a plan view of the area reserved for straightening, machining, inspection, packing and storage of packaged products and for the storage of uranium bars and finished slugs. It also shows the traffic arrangement for the guards and workmen, with street clothes locker room, dining room, and

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Fig. 1. Uranium Machine Shop Building, West View
(BNL Log No. P-312)

Fig. 2. Uranium Machine Shop Building, South View
(BNL Log No. P-311)

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REVISED LAYOUT - CHAPMAN MFG.
CO. JOB 1000, SHOP DWG. 128
FOR - M.K. FERGUSON CO. SEPT. 20, 1948
R.R.G.

LAYOUT OF MACHINE SHOP FOR URANIUM
FIG. NO. 3

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change house with lockers for work clothes and laundering of work clothes. As indicated by the sketch, access to the work area was through the guard's office. The doors between the guard's office and street clothes locker room, between the street clothes locker room and lunch room, and between the lunch room and wash room were controlled by push buttons from the guard's office. Glass in the walls of the guard's office made visual observation of the area possible at all times.

The entire project area under cover was approximately 96 feet by 70 feet, or 6720 square feet. It should be noted that there was no spare equipment; in a future operation some spare equipment might be necessary, and in such a case it would be well to consider providing 10,000 square feet for a job of similar magnitude. A production rate of 1200 slugs per day (3 shifts) was reached toward the end of the present job, with full use of the equipment and space.

The building was provided with a 5-ton traveling crane over the entire work area and with two swinging jib cranes for handling argon gas tanks and materials into and out of the degreaser.

The following additional services were provided within the building:

Steam coils to keep paper cartons dry.

Water line to centerless grinder to make coolant.

Compressed air for pneumatic tools.

Hot and cold toilet and laundry waters.

Electrical connections and outlets including heavy duty.

Piping systems for argon gas tanks, degassing pots and to vent same to outside of building.

Steam heating system.

Figure 4 shows a photograph of the interior of the bar storage area, and the method of storing the bars. The conditions of the bars

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Fig. 4. Bar Storage Area (BNL Log No. P-335)

Fig. 5. Medart Straightening Machine
(BNL Log No. P-314)

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can also be observed and the need to straighten them prior to machining is clearly evident.

Production Schedule

While the work was initiated by a letter of intent dated November 27, 1947, considerable time was required to set up equipment, clear workmen, and develop methods. An initial experimental lot of 200 slugs was completed on about April 15, 1948. However, experimental work was still going on with respect to feeds, speeds, cutting fluids or coolants, grinding media, separation of fines, personnel training, inspection procedures, etc. By the week of May 6 about 30 operators had been cleared but only about a half dozen were regularly engaged in the work area.

As of June 1, 9 per cent of the raw bar stock had been put into process, and the work was well under way on a one-shift basis. About a week later the grinder, turret lathe and milling machine were on a two-shift, 6-day schedule. Early in July a second turret lathe was installed, and production was placed on a three-shift, 6-day basis, resulting in about 1000 slugs per day. A production rate of 1200 slugs per day was reached by providing extra men to fill in during the rest periods. The job was continued on this basis until its completion at the beginning of October.

Security clearance for personnel is a considerable factor in a job such as the present one, since it requires several months to obtain. The problem was eased by the fact that Chapman's regular employees could be cleared in advance of the actual need for them, so that no lost time was involved. Thus, during a preliminary stage 70 men had been cleared but only 45 were engaged in the uranium operation. A total of 72 men were cleared, of whom 70 had regular work stations during full-scale

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production.

Individual Operations

Rod Straightening and Sawing. Figures 5 and 6 show the Medart straightening machine employed. Each bar was passed through the rolls several times - up to four - depending on its condition. The ends of the bars were given extra attention and rolling since these were the worst portions. A copious coating of L.S. Cutting Base Gulf "A" oil was applied to the rotating bar with a brush to prevent escape of uranium-oxide dust into the atmosphere. Approximately thirty-six bars could be processed in a period of three hours. Straightening materially increased the recovery of slugs and also permitted a roughing cut much closer to the final diameter than that called for in the specification.

The bad ends were then cut off with a power hack saw (Fig. 7), using regular hack saw blades under a flow of Gulf "A" oil used as coolant. The flow of oil helped to prevent the metal taking fire and also kept down the dust.

Roughing Slugs in Six-spindle Automatic Machine. This operation consisted of rough turning and cutting off the slugs in a 2-5/8-inch six-spindle automatic screw machine made by Cone Automatic Machine Company, Windsor, Vt., Shop #1340, Serial No. 3544, Model SE (see Fig. 8). Collets of bronze were provided to prevent sparking. After a considerable amount of experimental work, it was found that the only satisfactory material for cutting tools was carbide-tipped tools. High-speed steel cutters would not stand up due to excessive abrasive action of uranium and attendant high heat. The carbide tools made by Kennametal Company proved satisfactory and allowed the subsequent grinding operation to be reduced to a minimum.

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Fig. 6. Close-up of Straightening Machine
(BNL Log No. P-321)

Fig. 7. Power Hack Saw (BNL Log No. P-329)

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Fig. 8 Six-Spindle Automatic Screw Machine
(BNL Log No. P-315)

Fig. 9. Set-Up of Automatic Screw Machine
(BNL Log No. P-323)

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Set-up: See Figure 9.

Surface feet per min., 78; RPM 238; speed gears 36-60.

Feed per revolution tool slide, 0.019 inch.

Feed per revolution across slide, 0.005 inch.

Tools: See Figure 10.

Position No. 1: Rough turn first half of slug 2 inches long with a knee turner to a diameter of 1.125 to 1.135 inches, tool bit $5/8$ inch square by 3 inches long, Kennametal #6-3T40.

Position No. 2: Rough turn second half of slug 2 inches long with a knee turner to a diameter of 1.125 to 1.135 inches, tool bit $5/8$ inch square by 3 inches long, Kennametal #K6-3T40.

Position No. 3: Finish turn first half of slug, with a knee turner to a diameter of 1.108 to 1.115 inches, 2 inches long, tool bit Kennametal #K6-3T40.

Position No. 4: Face front end of slug, cross slide form tool Kennametal #6-3T40. Simultaneously slug was given a slight chamfer on the forward edge.

Position No. 5: Finish turn second half of slug with a knee turner tool, Kennametal #K-6-3T40.

Position No. 6: Cut off, standard $1/4$ -inch blade high speed steel cross slide. Carboloy was not used in cut-off position because tool width was not sufficient for a carboloy tip. Rather than increase the width and thereby lose more metal in the form of turnings this tool was hardened by freezing to minus 120°F. with de-natured alcohol and dry ice. Carboloy was also not used in cut-off position as it was said to be impracticable due to surface feet drop-off.

It was found that both ends of the bars were more abrasive than the rest of the bars. Tools were reground about every 2000 pieces.

Running on a 3-shift basis, 1200 slugs were produced every 24 hours.

The rates of feed and speeds were quite naturally determined by the depth of cuts and it appears characteristic of uranium that a cutting tool will have a longer life under a heavy cut and fast feed than under a light cut and slow feed. There appears to be less surface abrasion and generation of heat in removing a heavy cut than in removing several light cuts. In all cases it is desirable to shape the cutting tools to minimize

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Fig. 10. Tools for Automatic Screw Machine.
(BNL Log No. P-316)

Fig. 11. Oil Coolant for Automatic Screw Machine
(BNL Log No. P-324)

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friction and abrasion as far as possible.

In addition to tools, there were also problems to be solved with respect to coolant for the rough-machining operation. Water-soluble coolants were tried including "Cimcool". These were used with water in varying proportions. There was some overheating and consequent burning of uranium turnings using water-soluble coolants. The water in contact with uranium caused it to oxidize and the liberation of hydrogen gas was a fire hazard; the storage of uranium turnings dampened with water was an additional hazard. Water-soluble coolants on the automatic screw machine were abandoned in favor of a high-flash-point oil coolant of high viscosity, L.S. cutting Base Gulf A. This oil meets the following specification:

Gravity A.P.I	26.7
Viscosity SUV at 70°F.	448
Viscosity SUV at 100°F.	201
Viscosity SUV at 130°F.	109
Viscosity SUV at 210°F.	50
Flash, open cup, °F.	345
Fire, open cup, °F.	390
Pour, open, °F.	325
Carbon residue, per cent	0.56
Sulphur B, per cent	2.49
Sulphurized lard oil, per cent	22.00

In order to prevent firing of the turnings, the oil was circulated on all tools at the rate of 50 GPM, and the base of the machine was kept filled with 150 gallons so that the turnings were covered at all times. It is important to note (see Fig. 11) that in order to properly flood the work during machining, it was necessary to add extra oil outlets to those normally supplied and used on the automatic machine. Approximately 30 gallons of coolant were replaced daily. From time to time the turnings were removed from the base of the machine and following natural drainage an oil film was left amounting to about 3 to 4 per cent of the weight of turnings. This film served as an excellent preventive against oxidation

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and fire hazard. The life of the tools was prolonged with the oil coolant and a smoother cut was possible than with water-soluble oil.

Oil from all equipment was used over and over again, being put through settling tanks, sterilizer and centrifuge in order to purify it. This equipment is partially visible in Figure 12 behind the conomatic six-spindle machine. This photograph also shows a pile of turnings in process of draining after removal from the base of the conomatic, and an accumulation of cans packed with turnings, ready for shipment.

Vapor Phase Degreasing. The rough-machined slugs were cleaned by washing in a vapor phase degreaser. The first degreasing operation was primarily to prevent oil contamination within the heat-treating or degassing pot in the next operation. Such deposit of oil could carbonize and possibly convert some uranium metal to uranium carbide. The oil-coated slugs were placed in wire mesh baskets, elevated by the crane and lowered into the degreaser onto a supporting rack just above the level of the trichlorethylene solvent. This solvent was heated to its boiling point of about 190°F. The vapor condensed to liquid in contact with the cooler slugs and took with it oil until, by repeated vapor to liquid cycles, the slugs were free of all traces of oil.

Because of the toxic effect of trichlorethylene it was found necessary to provide a vent from the degreaser to the outside atmosphere with the aid of a blower. Exclusion of these vapors from the work area became of extreme importance when it was early discovered that contact of the vapors with the hot degassing pots, as these were brought out into the work area from inside the heating furnaces, caused generation of phosgene gas. The degreaser used at the Chapman plant was a Ball washing machine of 40 gallons tank content converted from a washing or spray

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Fig. 12. West End of Shop
(BNL Log No. P-326)

Fig. 13. Heat-Treating Furnace
(BNL Log No. P-309)

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machine to vapor phase operation.

First Degassing or Heat-Treating Operation. For the degassing operations two electrically operated heat-treating furnaces were provided. The furnaces were of the same size and were equipped with automatic control. They were built by the American Furnace Company of Boston, Mass. Serial No. 4024, Catalogue No. B-4884, 100 KW, 230 volts, 217 amperes, 2 phase, 60 cycle, #793 hearth - size 45 inches by 82 inches. Figure 13 shows one of these furnaces with a heat-treating pot loaded with slugs resting on a carriage in front of the furnace charging door.

Suitable carriages with roller conveyors and other equipment for transporting the heat-treating boxes into and out of the furnaces are shown in Figure 14. At the left in this figure can be seen a stanchion with eye-bolt, pulley and cable. This stanchion is located between the two furnaces and thus serves both of them.

The heat-treating boxes were constructed, top, bottom and sides, of 1-inch thick steel plate heavily welded. The inside pot dimensions were 27.5 inches by 35.5 inches by 14.5 inches deep. A 4-1/2-inch flange extended around the entire top edge of the pot. The top cover plate was recessed to fit into the inner edges of the pot where it rested on a double thickness of asbestos gaskets 0.0625 inch thick. The cover was secured to the flanges with sixteen 1-inch diameter bolts. Figure 15 shows a heat-treating box at the completion of the loading operation preparatory to having the cover put in place. The cover plate contained a welded vertical pipe well extending downward into the box for observing interior temperatures with a thermocouple.

Racks were built of 0.125-inch stainless steel plate to hold 512 slugs in vertical position in the heat-treating pots. Holes were drilled

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Fig. 14. Loading Box into Furnace
(BNL Log No. P-333)

Fig. 15. Heat-Treating Box About to be Closed
(BNL Log No. P-319)

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in each rack to a diameter slightly larger than that of the slugs. On these racks the slugs were spaced approximately 0.1875 inch apart to permit circulation of inert gas (argon in this case) to effectively flush out oxygen and thereafter maintain an inert atmosphere through every part of the box until the heat-treating operation was completed and the pot cooled to the point where it could be opened and discharged.

Initially only one rack and 512 slugs were placed in the box for each heat. Later a second rack was superimposed above the first and 1024 slugs were processed per heat. As production increased a third rack was added and 1536 slugs per heat were processed.

The argon inlet to the pot was located on one side near one end of the pot. The outlet was located at the opposite end. Argon was brought to and taken away from the pots with flexible 18-8 stainless steel hose. To these, outside the furnace, flexible hose was connected to the argon supply tanks and to the argon exhaust piping.

The inlet was provided with a baffle to distribute the gas within the pot. The exhaust piping contained a by-pass to divert samples of effluent gas into a Burrell contact bubbler with Burrell solution No. 2 (alkaline pyrogallol) for oxygen determination. Tests were also made for hydrogen. Figure 16 shows the layout, grouping and manifolding of the argon supply tanks together with gas testing apparatus connected to the effluent gas line. The pot was flushed until the effluent gas showed substantially no oxygen. (Burrell Technical Supply Co.'s Gas Analysis Apparatus Built-Up Model No. A39-281). The pot was then put into the furnace with one thermocouple inserted in the well in the pot cover and a second thermocouple placed against the outside of the pot along one side. Heat was supplied at such a rate that slugs near the side walls

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Fig. 16. Argon Supply Tanks (BNL Log No. P-334)

Fig. 17. Use of Turnings in Box
(BNL Log No. P-320)

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were not overheated appreciably before the slugs in the interior had attained approximately the desired temperature. For this first heat-treating operation, the slugs were held at 1112°F. for 12 hours. This heat treatment was primarily for stress-relieving the rough machined metal. There was some fear that warpage of slugs would result from this operation, but none was detected. At the end of the heating period the pot was set in a water bath with side wall spray for cooling. Originally the pot was not opened until the interior temperature had fallen to 100°F. Later, in order to shorten the cooling period, the pots were opened at 150°F. The flow of argon through the pot was approximately ten liters per minute with a reduced pressure from the argon tanks of about 3 pounds per square inch.

During the early stages of this project, some excessive oxide dusts formed on the slugs during these first degassing treatments. These oxides were of a powdery nature and ranged in color from yellowish tan through brown to a deep black, but all could be easily brushed off. These dusts indicated the presence of oxygen contamination from gasket or other leakage of air into the pot or from oxygen, CO, CO₂ or H₂O in the argon gas. After taking precautions to eliminate gasket and pipe-line leakage, oxide dusts could still be detected. However, the difficulty was overcome by placing degreased dry uranium turnings inside the pot near the argon inlet line and around the sides and ends of the pot near the gasket to absorb and capture the oxidizing impurities. With this expedient oxidation of the rough-turned slugs was eliminated and this improved condition aided in making it possible to change from lamp-grade argon to the more readily available and less expensive welding-grade argon. Figure 17 shows the manner in which the uranium turnings were applied near the cover gasket. Figure 17 also shows the stainless steel perforated plate con-

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struction, the manner of supporting the slugs within the pot and the opening within the stainless steel perforated plates to receive the thermocouple well attached to the cover plate.

Linde Air Products Co. supplied the following data respecting the quality of welding-grade and lamp-grade argon. Welding-grade argon contained 20 ppm oxygen, 40 ppm hydrogen, and 3 grains of moisture per 1000 cubic feet. Lamp-grade argon contained a total of 5 to 10 ppm of hydrogen and oxygen combined, of which only 1 to 2 ppm would be oxygen. Lamp-grade also was said to contain a maximum of 10 ppm of all contaminants.

To provide continuity of flow of argon, the cylinders were set up as two groups of 6 cylinders each. Two 6-cylinder Linde manifolds were installed, one for each heat-treating furnace. This made it possible to remove and replace three tanks at a time without disturbance to the heat-treating operations.

Each charge of slugs to the first heat-treating operation constituted a unit which was given a heat number. Each heat was then carried through all subsequent operations including inspection, packing and shipment as a specifically designated unit. This necessitated considerable extra handling and storage of slugs. Slugs which were rejected and salvaged by reworking were also put through as separate heats.

The fact there was no warpage of slugs in this operation was possibly aided by the fact that the slugs were mounted in a way so that each slug would support only its own weight, a precaution suggested by Dr. D.H. Gurinsky of Brookhaven. The fortunate circumstance of no warpage at this stage decreased the amount of finishing required in subsequent operations.

Deburring. If any deburring was needed at this stage it was accomplished manually by means of files or other hand tools.

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Centerless Grinding. It appeared that in order to finish the slugs to dimensions grinding would be the fastest method, and that centerless grinding would eliminate special holding equipment. Therefore a #2 Cincinnati Centerless Grinder Serial No. 2M2H1E #275 was installed.

Very little information was available on grinding uranium and a number of difficult problems had to be solved to secure satisfactory production.

The grinder was originally set up with three rather hard abrasive wheels of 6-inch face of vitrified carborundum. The results were unsatisfactory. With the cooperation of the Norton Company wheels were developed which gave excellent results (Crystolon 20" O.D. x 8" x 12" hole #37C-46-J5-B5 with an 8" feed wheel 12" x 8" x 5" - A60-ROR-30). The slugs were ground under a continuous flow of coolant, as previously described, using an 8-inch feed-through mechanism. Attempts were made to use oil as a coolant to avoid water and generation of hydrogen with the fine uranium particles. The use of both high and low flash-point oils, however, proved unsuccessful; the fog of oil resulting from the centrifugal effect of the wheel was invariably and quickly converted to a wreath of flame by the abraded uranium particles. The use of water-soluble coolant became necessary.

The original water-soluble oil tried was "Cimcool", which did not produce a good finish. Next tried was "Silver Chip" (Machinery Lubricants Inc. Boston) which proved satisfactory. Texas Co. Soluble Oil D was tried and used thereafter with very good results. The original mixture was 50 per cent soluble oil and 50 per cent water, but this proved to be too rich a mixture. It was later reduced to 7 gallons of soluble oil to 100 gallons of water, to which 1/2 gallon of kerosene was added.

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The presence of water with uranium grindings rendered the operation hazardous with respect to fire, which necessitated cleaning the grinder immediately at the end of each day's run. The grindings, well covered with water in the coolant settling tank, were cleaned out and burned twice weekly. A daily cleaning would be preferable. It is extremely important that damp grindings be burned as soon as possible. One fire occurred when such grindings consumed the water content of the bucket in which they were stored (for 2 days), and ignited by spontaneous combustion. Fortunately, the fire did little damage but probably did deposit some oxide throughout the work area. With this exception, all grindings were quickly burned to oxide in an incinerator which will be described later.

The centerless grinder was originally set for a "through feed" or "continuous feed", whereby the slugs were fed continuously by gravity down an inclined V or angle steel bar (see Fig. 18). This system proved satisfactory and time saving. The system initially was not satisfactory when the abrasive wheel was only 6 inches wide. This width was not sufficient to attain the desired uniformity of diameter between different slugs or between the two ends of the same slugs. In this case it was necessary to individually place the slugs in the grinder.

The initial rest bars upon which the slugs rotated were of mild steel, hardened steel and chilled cast iron. These surfaces proved unsatisfactory. They, together with the rather hard abrasive wheel first used, set up a high frequency vibration of the slug, evidenced by "squealing". These factors contributed to the production of oval-shaped slugs, multiple-sided slugs, slugs with burned surface areas due to excessive localized friction and a complete lack of uniformity in results. The

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Fig. 18. Feed Arrangement for Centerless Grinder
(BNL Log No. P-328)

Fig. 19. In-Process Check of Slug Diameter.
(BNL Log No. P-308)

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harder vitrified-bond abrasive wheel first used also loaded itself with the rather ductile or malleable uranium, causing the wheel to lose its cutting qualities and its grinding face to lose its contour. This necessitated frequent and almost prohibitive redressing to maintain a fresh cutting surface.

To offset the above faults softer wheels, able to shed their grit and continually present fresh sharp cutting surfaces, were bought. The Norton Co. supplied 6-inch face resin-bonded Alundum A46I5B5. This was quite an improvement but slightly harder than desired. The Norton Co. also supplied 6-inch face crystolon 37C46J5B5. This wheel was satisfactory in every way. It was fast cutting, did not load with uranium and maintained its contour with little dressing. This type wheel wears rather rapidly which was, of course, expected. Feed wheels were Norton Co. Alundum A60R0R30.

Having established the desirability of the softer wheel, the grinding operation was again set up for continuous or "through feed" with new wheels having 8-inch face Norton Co. No. 37C46K5B5 and No. 37C46L5B5. The former gave a better finish to the slugs than the latter type of wheel. It was stated previously that Norton Crystolon 37C46J5B5 proved satisfactory in every way as the type grinding wheel eventually used. The surface speed of the wheel should be 5000 to 6000 feet per minute. The speed of the work varied from 6 inches to 3.3 feet per minute, depending on depth of grind.

A supply of rest bars, upon which the slug rotated, made of soft cast iron were substituted for the previous hard ones. The rotating slug under the abrasive action of uranium metal quickly grooved itself in this soft rest.

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The capacity of the coolant settling tank was trebled to reduce agitation and allow improved settling and it was changed frequently to a new or clean mixture.

In order to insure a satisfactory grinding job, triple dial gauges were used to check the slugs as they came through the machines. The great abrasiveness of uranium made it necessary to replace the rest practically once each day. It was necessary to remove grindings from these frequently.

In addition to the grinder operator there was required one (preferably two) inspectors to inspect each slug for diameters by means of dial gauges and immediately notify the operator of slug diameter enlargements due to wear of its grinding wheel (see Fig. 19). The rough slugs were received with diameters ranging from 1.108 to 1.118 inches. These were passed through the grinder five times.

First grinding reduced slug diameter to range 1.103 inches to 1.105 inches

Second grinding reduced slug diameter to range 1.101 inches to 1.102 inches

Third grinding reduced slug diameter to range 1.1001 inches to 1.101 inches

Fourth grinding reduced slug diameter to range 1.0998 inches to 1.1001 inches

Fifth grinding reduced slug diameter to range 1.0995 inches to 1.0997 inches

The fifth grinding was essentially a slot deburring operation to remove burrs left by the milling cutters at the outer edges of the slot. This grinding operation, therefore, was performed after the ends of the slug had been faced and the slot cut. After the fifth grinding the slugs were ready for final degreasing and the second heat-treating.

Finishing Blank End. Because the slug specification called for a button at one end, it was necessary to finish the ends in a turret

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lathe. Two Midland Turret lathes were installed for this, though the turret feature was not employed. Following the fourth grinding in the centerless grinder the slugs were placed in the chucks of the lathe against fixed stops. This operation, done on one lathe, removed 0.010 inch to 0.015 inch from one end of the slug to produce a smooth flat surface. The slug was held in a collet chuck ground to the correct bore in the machine (1.100 in.). A stop to locate the piece was set inside the spindle so that each slug was held as nearly as possible in the same position. The facing tool was then fed by machine across the piece and the feed was reversed to allow the tool to take a light cut coming back. The spindle speed was 657 RPM. The crossfeed was 0.015 inch per revolution. The tool used was Kennametal bit K6 style 9T50 held in a special tool holder. The coolant was L. S. cutting oil Base A of the Gulf Oil Co. At the high speed of the spindle it was very important that the tool be constantly flooded with oil to prevent fires. The burr left by the tool was removed by passing a file lightly over the edge of the slug while running in the machine. A dial gauge on the cross slide saddle aided in maintaining the length. The cutting tools were fixed rigidly with respect to the longitudinal axes of the slugs and lathes.

Finishing Button End. The second lathe with a tool bit having a 2-step cutting edge was used to finish the button end and the button in one operation. This gave the correct diameter and height to the button (see Fig. 20). An attempt was made to use high speed cutters. They were unable to withstand the excessive abrasion, and carboloy cutters were employed. L.S. Cutting Base Gulf A oil was the coolant and proved highly satisfactory. In this operation the slug was held in a collet chuck ground to size in the machine. The slug was put into the collet up to a stop in-

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Fig. 20. Finishing Button End on Lathe
(BNL Log No. P-331)

Fig. 21. Milling Slots (BNL Log No. P330)

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side the spindle. The cut was taken by the cross slide tool at 675 RPM with 0.015 inch feed. The diameter of the button was maintained by feeding into a stop by power and finishing the cut by hand to predetermined setting of a dial gauge mounted on the cross slide. The feed was reversed and the tool fed out by power taking a light chip. The tool used was a triangular Kennametal bit held in a special tool holder (tool bit A6-T-6, tool holder 3T-K70). A dial gauge on the cross slide saddle allowed close overall dimensions. The burr left on the edge of the end was removed by filing lightly as in the preceding operation. These tools were able to stand up against high speeds and required redressing for approximately 500 slugs. The cutting tools were so shaped as to require a re-grinding on the top end. Lathes were Midland Model No. 5, with Kennametal cutters No. K6 and K2S.

Milling Slots. A full length slot was machined in the slug on a Van Norman milling machine #118 with hydraulic feed. The machine was equipped with a special jig holding two slugs. The spindle speed used was 137 RPM using 3-inch diameter slitting saws with a feed of 6 inches per minute. The width of slot was 0.0625 ± 0.002 inch and depth was 0.073 ± 0.002 inch, until this was changed to 0.015 ± 0.002 inch. Coolant used was L.S. cutting oil base A, Gulf Oil Corp. The cutters were 3-inch O.D. by 1/16-inch by 1-inch bore Union M103 high speed steel. Cutters were designed for cutting both on the front and sides of the teeth but because of abrasion they were only satisfactory after treatment by deep freezing at minus 120°F. for a period of 2 hours. With this treatment the cutters were good for approximately 400 slugs per treatment. There was no burning or oxidation of chips. The chips were considered to be too fine for safe storage and therefore were burned in the inciner-

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ator. Considerable difficulty had been found in attempting to find carboloy cutters as thin as required and it was feared their brittleness would render them impracticable. Carboloy tools for this operation were also considered very costly. The set-up for this operation is shown in Figure 21.

Final Centerless Grinding to Size. The milling operation left a burr along the top edges of the slot which, as stated previously, was removed by regrounding on the centerless grinder. As also noted before, the slugs were left slightly oversize in the previous grinding operation. This final (fifth) grinding not only removed the burrs left by milling, but permitted very close finish grinding to permit the slugs to pass through a barrel gauge having a bore of 1.1013 inches. This finished the actual machining operations.

Vapor Phase Degreasing. It is essential that slugs be completely cleansed from all grease or other materials of an animal or vegetable nature. To accomplish this the slugs were again given a vapor phase degreasing and throughout all subsequent operations, including final inspection and packing, they were not allowed to come into contact with contaminating oils, water or unclean surfaces. Clean gloves were worn.

Second Degassing or Stress Relieving Operation. On this final heat treatment the second electric furnace was used. This furnace was the one located near the end wall of the work area as shown in Figure 22.

On this operation the time at temperature of 750°F. was four hours, computed after some experiments, from the time the interior thermocouple first reached 720°F. At the start of the project some difficulty was experienced with surface oxidation of slugs in this step. The exact cause was never precisely isolated but was stopped once degreased turnings were used inside the pot to capture oxidizing impurities which entered by leak-

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Fig. 22. Second Heat-Treating Furnace (in Rear)
(BNL Log No. P-325)

Fig. 23. Checking Slot Depth
(BNL Log No. P-318)

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age or in the argon gas. Lamp-grade argon was regularly used for this second degassing operation but some tests were made on full heats of slugs using welding-grade argon in this final degassing step, and it was found that slugs free of oxide or oxide dusts were obtained when bright degreased uranium turnings were placed inside the pot with the slugs. To the left of the second degassing furnace in Figure 22 are located the degreaser, served by its swinging jib crane, and the machines for finishing the ends of the slugs and for milling the slot. To the right of the furnace is the area for final inspection and for weighing and packing the finished product.

Brushing and Cleaning. It had been anticipated that slugs at this stage would have to be brushed and wiped to remove dust. However, with the use of uranium turnings in the degassing operation, the slugs were very clean and required no such treatment but went directly to final inspection.

Inspection - In Process. Physical inspection during the manufacturing operations was performed by the Chapman Valve Mfg. Co. On the automatic six-spindle machine, once the machine characteristics were learned, 2 or 3 checks per shift of spindle No. 2, which was approximately the mean diameter of the range, was enough to assure control. Slugs were given 100 per cent inspection at the centerless grinder for each grinding operation. This was done by resting each slug in carboloy-surfaced V blocks while rotating the slugs under carboloy-tipped dial gauges graduated to 0.0001 inch (see Fig. 19). Three dial gauges were employed - one at the center and one at each end of the slug. Possibly an indicating device could be developed for direct attachment to the grinding machine. The depth of slot was gauged by a slot depth pin and jig rigged on a

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"CHECK ALL" dial (Fig. 23). Go and no-go gauges were used for the width of the slot. The diameter of the end button was inspected by go and no-go snap gauges. The height of the button was determined by a dial gauge. The overall length and the length of the body of the slug were noted with go and no-go snap gauges. Various gauges are shown in Figure 24.

Inspection - Final. Final inspection was made by the H.K. Ferguson Co. (see Fig. 25). Their inspection equipment to a considerable extent was made by the Chapman Co. The equipment was designed to eliminate handling of the pieces and minimize hand exposure to radiation, and to rotate each piece so that all lengths and diameters could be checked in one revolution of the piece. Diameters were checked at each end and at the middle of the pieces. Dial gauges reading to 0.0001 inch were used and readings were actually checked on a range during rotation inasmuch as the measuring machines had an eccentricity error of 0.00015 to 0.0002 inch.

This method of rotating proved to be fast, yet quite sensitive to picking up flat portions on the diameters. It was, however, insensitive to minor burrs which contributed to oversize and rejection by a barrel gauge. From a manufacturing standpoint, however, it worked well since it kept the pieces up to size and the oversize pieces could be ground to size. The barrel gauge acted as a final check for warpage and any previously undetected high spots.

Where slugs were rejected it was principally because dimensions were larger than specified or on account of oil stains. These were reworked and salvaged as good slugs at subsequent inspections. All such reworked slugs were put through the second heat-treating process a second time and on shipment were designated as "three-heat" material. Slugs damaged in process, undersize slugs and slugs showing excess porosity or

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Fig. 24. Collection of Gauges
(BNL Log No. P-307)

Fig. 25. Final Inspection
(BNL Log No. P-327)

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blow holes (defective metal) were permanently rejected as scrap.

The most frequent rejections during processing were due to diameter oversize and defective metal, which Chapman has reported to be 1.20 per cent to 1.24 per cent, respectively. Rejections from scratches, burrs and dents due to handling amounted to 0.34 per cent, and the overall figure for a total of seventeen causes for rejection in process amounted to 3.46 per cent. Total rejects for all causes from the first turning on the automatic screw machine through final inspection averaged 4.1 per cent.

Weighing and Packaging. The slugs without any wrapping or packing were weighed as a unit of 10 pieces at a time on a platform beam scale of about 35 pounds capacity (see Fig. 26). The scales were graduated to 1/16 ounce. All scales were examined and sealed by the official sealer of weights and measures of the City of Springfield, Mass.

The slugs were placed individually into a snugly fitting paper carton with closely fitted paper cap (see Fig. 26). Ten such cartons were placed inside of a metal can. At the middle of the can was placed a hollow cylindrical paper board tube of 1/4-inch wall thickness which served to hold the slugs in place. A metal cover was placed on the body of the can and the joint was then hermetically sealed with heavy masking tape with considerable overlap. All cans were numbered consecutively from the first to the last for the entire project.

Four such cans were placed in a wooden box, partitioned inside, and a wood top was nailed on tightly (see Fig. 27). Each box was marked with a lot number (assigned to batches at first degassing operation), quantity of slugs in the box, shipment number, and gross and net weights. All pieces of a lot were kept separate and distinct from any other lot throughout the subsequent process.

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Fig. 26. Weighing and Packing Slugs
(BNL Log No. P-322)

Fig. 27. Boxing of Cans of Slugs
(BNL Log No. P-313)

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GROUP 1

The following method of identification was adopted:

- (a) wood boxes or crates containing 40 pieces from virgin metal were stenciled in black paint.
- (b) wooden boxes or crates containing less than 40 pieces from virgin metal were stenciled in red paint.
- (c) 40 pieces TX metal were stenciled in yellow paint.
- (d) less than 40 pieces of TX metal were stenciled in green paint.

In addition all boxes with TX metal were marked TX. Slugs which were reworked lost their original lot number identity. These pieces underwent a third heat treatment and were kept separate from those which had the normal two heat treatments. Reworked virgin metal had its cans and boxes stenciled in black or red to indicate a full or less than full condition, and in addition were painted with blue paint to indicate "3 heat treatments". Reworked TX metal was placed in cans and boxes marked in yellow or green to indicate full or less than full condition, and in addition with brown paint to indicate "3 heat treatments".

Virgin and TX metal butt ends and rejected finished slugs were packed for shipment in wooden boxes holding 100 to 105 pounds of metal each.

Production Results

Cost of Machining

A contract settlement price agreed on at the conclusion of the job, including extras for changes in specifications and other reasons unforeseen at the time the original letter of intent was executed, amounted to \$175,473.87. Following is a summary of the unit costs.

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Final completed contract price	\$175,473.87
Machined finished slugs	
a) Passed inspection and shipped to Brookhaven	87,290
b) Rejected because of defective metal and shipped elsewhere as scrap	1,623
c) Total number of slugs finished	88,913
Average cost per slug finished	\$1.97
Average cost per pound finished	\$0.77

Metal Utilization

The following figures show the proportion of metal appearing in finished slugs and in various forms of scrap.

	<u>Pounds</u>	
Average weight per finished slug	2.568	
Average weight rough finished slug from automatic	2.650	
Average weight of crude metal received per finished slug	3.550	
	<u>Pounds</u>	<u>Per cent</u>
Slugs	224,487	72.3
Turnings, coarse and fine	62,322	20.2
Scrap, including butt ends and finished slugs rejected because of defective metal	17,570	5.6
Metal converted to oxide (by burning)	5,936	1.9
Total shipments	310,315	100.0

Had the rods as received at the Chapman plant been in a straightened condition as was initially contemplated, the percentage of finished slugs would have exceeded 75 per cent.

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Disposal of Uranium ScrapTurnings and Other Scrap

Turnings from the automatic screw machine and the two lathes were accumulated in a metal tray 6 feet square by 10 inches deep and allowed to drain. A centrifuge was installed, but it was decided that the heavier film of oil left on the turnings under gravity draining gave added protection against the danger of fire, and the centrifuge was therefore not used regularly on the turnings. The turnings were placed in 10-gallon, 16-gauge metal cans and packed tightly by means of a ram in a home-made press (see Fig. 28). A metal cover with 1/2-inch overlap was placed on the can. A rather loose fit was intentionally provided and the cover was attached to the can by means of a metal strap. The purpose of this type cover and method of holding it in place was to provide for the escape of any gases which might be generated within the can, without providing a hole in the cover of the can through which water could enter during transportation or storage. The cans were 13-1/8-inch diameter, 18-inch high and weighed 17 pounds each. Each can held about 125 pounds of turnings initially but with the aid of the vertical ram in compressing the turnings the contents were brought up to about 160 pounds. After packing, the cans were watched carefully for any tendency for heat generation through possible oxidation during storage, but none was detected.

Each can was consecutively numbered for each shipping destination. Each can was labeled with the specification of the cutting oil which filmed the turnings and an estimated weight of the film of oil (3 per cent) together with the gross, tare, and net weights, after which it was stored for shipment.

The importance of an oil film in sufficient amount for good pro-

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Fig. 28. Equipment for Cleaning Oil
(BNL Log No. P-332)

Fig. 29. Incinerator (BNL Log No. P-310)

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tection is emphasized by the necessity of storing turnings and fines for considerable periods of time and with a minimum risk of fire. At Chapman this oil was necessarily that used in the machining operations.

Due to the high percentage of animal oil content (22 per cent; see previous analysis), it was necessary to clean and sterilize the coolant oil frequently, since animal oil deteriorates rapidly and becomes objectionable. Furthermore, the fine particles of metal which accumulated in the oil were a health hazard, being liable to cause severe cases of dermatitis. Therefore, a Barret chip separator and sterilizer was installed, together with a centrifuge (see Fig. 28). The L. J. Barrett Co., Worcester, Mass. chip wringer, Serial 252198-E was used. Prior to using a centrifuge, filtering proved unsatisfactory and consumed much time and labor. The oil sterilizer (L. J. Barrett Co. Serial 110179) was electrically heated and permitted sterilizing at 160°F. to prevent fatty oil, such as lard oil, from becoming rancid and reacting on the hands of the machine operators. Settling of metal fines in the sterilizer was permitted and these were caught in a cone bottom. The oil was taken from the tank above the cone and passed through the centrifuge, the fines being retained in the cup and the clean oil being returned to the system. The recovery of fines from the oil was also necessary to account properly for their uranium content.

Briquetting Uranium Turnings. At the time the Chapman Valve Company was processing the initial lot of 200 slugs for experimental work at Brookhaven, the question of the best coolants had not been finally determined. At about the same time AEC proposed that turnings be briquetted at the point of production, in the Chapman plant.

Dr. H. A. Wilhelm, of Iowa State College, was consulted on both

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of these problems, which were somewhat related. He recommended a mineral oil - lard oil mixture, containing 20 per cent lard oil and 2-1/2 per cent sulphur, as a good coolant for machining, and for producing turnings suitable for direct conversion into ingot metal. Such a coolant should eliminate the hazards during storage and transportation that would exist if a water-soluble coolant were used.

The question of briquetting turnings at the Chapman plant proved to be a much larger subject than anticipated. It would involve degreasing the turnings, and crushing or shredding them to fine sizes to release any entrapped iron or other foreign matter so that these could be effectively removed by magnetic separation or other means. A small quantity of magnesium metal powder was said to be a necessary addition to the turnings for each individual briquet. Then would follow the briquetting operation under pressure and the packaging and storage of the briquets, in this case without any protecting film of oil. All of this seemed to be a major operation to be avoided at the Chapman plant, if possible. Investigation by Mr. A. Levine of AEC disclosed that Oak Ridge was preparing to set up equipment for briquetting, and the idea of doing this in the Chapman plant was abandoned for the simpler procedure of shipping turnings to Oak Ridge. It was Dr. Wilhelm's opinion that with the turnings protected with a film of oil and placed in straight-sided cans with vented cover there would be little or no fire hazard in transit or storage. He had previously had unsatisfactory experiences with turnings kept under water. His advice was followed and was borne out by experience.

Incinerator

As previously described, all crop ends, rejected slugs and turnings heavy enough for direct reconversion into ingot, without passing through

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the chemical processes, were segregated for shipment in their natural or metallic state. Scrap in all other forms was converted to oxide before shipment. These other forms of scrap included floor sweepings of large and fine uranium turnings, chips from the milling machine all of which were considered to be too fine for safe permanent storage, grindings from the centerless grinder in their damp or wet condition, and all trash and refuse. These were burned and converted to oxide in an incinerator. A similar procedure was used in the disposal of dunnage from the cars containing the uranium bars received at the Chapman plant, waste paper towels, paper slippers used on the feet between the lunch room and wash room, waste paper, wood and all other flammable waste.

A specially designed incinerator was installed in one corner of the work area next to an outside wall and connected for passage of the waste gases and products of combustion through a separator located outside the work area and then through a Roto-Clone blower to the atmosphere. It was planned that before discharge to the atmosphere these gases should be filtered, and filtering equipment was ordered, but the project was completed before the filter was received.

In Figure 29 the incinerator is shown in operation, with two jets of flame visible through the opening near the base. The flame jets were directed toward the material in the pan. The incinerator was constructed of stainless steel plate 1/4-inch thick. It was cylindrical, 30-inch diameter by 44 inches high, set up on a fire-brick platform with a retaining wall around the platform. Inside the incinerator and at the bottom of it was located a stainless steel tray with side wall to retain the burning materials and burned residues. Flush with the top of this tray, about 6 inches above the base of the incinerator, was the bottom

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edge of a 15-inch by 15-inch opening for loading and cleaning out the incinerator. On each side of this opening and located 90° from the center line of it were located two jets of propane gas burning under induced draft. A pronged rake was used from time to time to gently stir the contents in the pan to accelerate the oxidation process.

The hood of the incinerator was a cone of stainless steel welded to the circular body. The cone outlet was connected to an 8-inch diameter duct leading through an outside wall of the building. This duct may be seen in Figures 1 and 2, leading from the work area to a lean-to building housing the separator and fan. The discharge duct from the fan to the atmosphere, above the roof of the building, can also be noted. The discharge point was approximately 20 feet above the building floor level. Three sloping baffle plates were welded inside the cone to trap particles escaping from the combustion zone. The gases were passed through a steel drum equipped with baffles and a bottom clean-out which acted as a separator and which was located inside the small lean-to building with the fan. The fan produced a draft sufficient to maintain a velocity of about 600 feet per minute through the exhaust piping.

Oxides were segregated according to source material from which they were produced and were stored in 10-gallon metal cans with covers attached, as previously noted for turnings.

This incinerator design proved not only simple but very satisfactory. Experience with it was gained first with small quantities of the different materials.

Health and Safety Measures

Experience on this project indicated the importance of making health physics arrangements at an early state. Because of lack of previous ex-

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perience, this need was not fully appreciated at the start. However, the problem was finally placed in the hands of Mr. C.R.E. Merkle, Jr. and Mr. C.F. Murphy of the Health Physics division of Brookhaven National Laboratory. With assistance from the New York office of AEC they handled successfully the various health physics problems that were encountered. They also took charge of the final decontamination of buildings, machinery, equipment and other materials following completion of the project.

Health Physics

The manner in which health physics matters were controlled can probably be best indicated by giving, in full, copies of a series of reports by Mr. C.F. Murphy to Mr. T.P. Musgrave, resident engineer for the H.K. Ferguson Company in the Chapman plant. This series of reports is dated June 28, July 13, August 12 and September 17, 1948. These together with health physics rules and regulations as promulgated initially are attached as Appendix B.

Clean-Up and Decontamination

Appendix C contains a detailed report on the decontamination operation, with recommendations for future projects of the same nature. A large part of the equipment which was in contact with uranium could not be reduced to an acceptable level of activity. Therefore, it was necessary to discard and ship such equipment to a point designated by the Atomic Energy Commission for final disposal. Briefly, this included all heat-treating pots, trays, sterilizer, degassing equipment, pumps, roto-clones and fans, together with small tools and gauges. A complete list of equipment and material disposed of is given in Appendix D, and illustrates the extent of permanent contamination which was encountered.

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Fire Hazards

Since finely divided uranium will ignite spontaneously in air, precautions had to be taken against fires. There were two fires, both of which turned out to be minor. In the first, a bucket of fine grindings from the centerless grinder was left for two days, and developed insufficient water coverage. The grindings took fire spontaneously. CO₂ extinguishers were rather ineffectual against this fire. Complete coverage with CO₂ from above the fire did not smother the fire below the top surface. A wetting action by an extinguisher of bicarbonate of soda and sulphuric acid was more effective. Flaked graphite was effective in smothering the fire at all levels and thereafter supplies of graphite powder were kept at several stations for immediate use.

A second fire occurred in attempting to spot-weld a cover to a 10-gallon steel can filled with oil-filmed turnings. Some turnings evidently were in contact with the welded spot and caught fire. The cover was removed and the fire was easily extinguished with flaked graphite. Welding was not tried thereafter but loose covers to give ventilation were held in place with metal straps.

A third occurrence, which did not actually develop into a fire, involved smoldering lint in the laundry drier. This no doubt came about from some fine pieces of uranium mixed with the lint. It was possible to remove this debris and dispose of it without damage to the drier and without any bursting into flame.

The experience at Chapman indicated strongly that:

1. Partially submerged uranium turnings or grindings should be avoided regardless of whether oil or water is used.
2. Turnings completely submerged in oil, in event of a fire, would be more hazardous because of the greater volume of oil.

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In the event of spillage in transit or otherwise, this could result in a partially submerged condition, which is to be avoided.

3. With an oil film protection only, a fire is not likely to occur, but should a fire occur it may be extinguished without great difficulty using powdered graphite. Two cans of turnings protected with only a film of oil and located only 2 feet from the can of grindings which took fire and definitely exposed to this fire, did not ignite.

Waste Disposal

The Chapman plant was favorably situated with respect to liquid waste disposal. Liquid wastes containing some radioactivity required disposal from the laundry and coolants. Under the health physics standards the AEC has prescribed a maximum degree of permissible contamination for liquid wastes. It was estimated that the normal plant disposal amounted to 250,000 gallons of water per day. This together with disposal of the entire Springfield area made for large quantities of diluent. These discharged through 7-foot diameter storm sewers to pumping stations and then into the Connecticut River, which is reported to have a normal flow of 14,000 cfs. Samples of wastes from the work area were analyzed from time to time under AEC direction, as were samples of river water taken to include the Springfield effluent, and at a point in the river above the point of Springfield discharge into the river. Permissible levels were not exceeded.

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APPENDIX A

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SPECIFICATION FOR MACHINING URANIUM RODS

shipped to Chapman Valve Mfg. Company -
Indian Orchard, Massachusetts

Specification 702-M-5 Revised January 26, 1948

Raw Material

Rods as extruded and as straightened at Hanford, Washington shall be supplied the contractor. The rods will be 1.20 inches diameter by approximately 12 feet long and in quantity of approximately 170 tons.

Rough Machine the rods to 1.130" diameter by 4 inches plus long.

Anneal and Degas (1st Degassing Operation)

The rough machined slugs shall be annealed and degassed at a temperature of 600°C. for twelve (12) hours at temperature in an atmosphere of argon gas. The argon gas shall be of high purity known as lamp grade.

Heating shall not be started until the effluent flushing gas has fallen in oxygen content to below two (2) per cent.

Flushing with argon gas shall be continued after heat is cut off until the slugs have cooled to a temperature of 60°C. before the slugs are allowed to come in contact with air.

Finish Machining

Slugs which have been annealed and degassed as outlined above shall be machined to dimensions and tolerances given on H. K. Ferguson Company Drawing No. SP.4-D and specification dated January 26, 1948, and deburred - no corner or edge to be broken more than 0.010" maximum chamfer of 45 degrees.

Degrease and Degas (2nd Degassing Operation)

The finished and deburred slugs shall be degreased in a vapor phase degreaser with trichlorethylene and then degassed by heating to 400°C. for four (4) hours at temperature in an atmosphere of argon gas of high purity known as lamp grade.

Heating shall not begin until the effluent gas has fallen in oxygen content to below two (2) per cent.

Flushing with argon shall be continued after heat is cut off until the slugs have cooled to a temperature of 60°C. before slugs are permitted to

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CYLINDRICAL SECTION TO
BE GROUND FINISHED

TOOL MARKS ON ENDS ARE NOT
TO EXCEED $.003"$ DEPTH.

ALL SHARP EDGES ON ENDS AND
SLOT MUST BE DEBURRED

$.010"$ MAX. RADIUS
OR CHAMFER

ENLARGED SECTION AT A

SUPERSEDES SKETCH SP.3-D

APPROVED FOR CONSTRUCTION

H. H. Ferguson Co. F.W. Buck 7/25/48

RHG. 1/24/48

COPY N°

THE H.K.FERGUSON CO.
NEW YORK, N.Y.

1-26-48

SP.4-D

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come in contact with air.

Slugs should be so arranged in the furnace that they support only their own weight and shall be so supported as not to contribute to warpage under their own weight. In the event that final degassing results in more than 0.001" warpage in the 4" length of the finished slugs, the requirements with respect to temperature and time of heating in this degassing operation are subject to change and shall read "heat to 200°C. at temperature for a period of two (2) hours"....

Final Handling

Special precautions shall be taken to insure that slugs, following the final degassing operation, shall not be permitted to come in contact with or pick up water or moisture including possible moisture through accidental handling of slugs with bare hands or damp gloves.

Slugs shall be brushed and wiped after the 2nd degassing operation to remove any adhering dust and scale. The time limit for slug exposure to the atmosphere after final degassing shall be limited to a maximum of 24 hours.

Inspection

Inspectors, among other things, shall check approximately one out of ten finished slugs for warpage and if the warpage exceeds 0.0015" in 4" length for five (5) per cent or more of the quantity of slugs contained in a single batch from the 2nd degassing operation, The H. K. Ferguson Company - engineering department shall be advised immediately in order that they may determine whether a modification other than that already contained above (under 2nd degassing) should be made, including the possibility of eliminating the 2nd degassing operation.

Packing

Finished slugs accepted by inspectors of the purchaser shall be packed by the contractor in hermetically sealed metal containers. Each container shall contain ten slugs. Individual slugs shall be inserted into a mailing tube protector (snug fit).

The mailing tube materials must be submitted to chemical analysis and shall not contain "boron" exceeding 10 parts per million.

The use of sealing tape is permissible, preferably one with cloth backing, in sealing the metal containers. Tape shall be 1-1/2" wide and firmly applied throughout with a two (2) inch end overlap.

Metal containers shall be packed in wooden boxes to contain a total net weight of approximately 100 lbs.

Shipping Instructions

Material shall be shipped to:

Brookhaven National Laboratory
Upton, Long Island
New York

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OFFICE

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Security

"Q" clearance is required of all employees engaged in this work, including guard personnel.

Provision shall be made that all storage and work areas, locker and change rooms shall be restricted in accordance with requirements to be prescribed by the Atomic Energy Commission.

Precautions Required in Machining and Handling Uranium

Cutting and grinding tools and wheels, including any tools for dressing, cutting and grinding media and any cutting fluid or coolant used shall not contain "boron" in excess of 10 parts per million.

Wash room soap shall be free of "boron."

No water shall be permitted in the work area.

No smoking, chewing or eating shall be permitted in the work area.

All requirements respecting physical examination of employees and machinery, fire protection, health safeguards, change house facilities and provisions respecting work clothes changes, restrictions concerning manual handling of uranium, accountability for uranium metal, methods of handling uranium and disposal of its various forms of scrap and manner of preparing scrap for shipment of uranium metal and its various forms of scrap and manner of handling the cutting fluid and disposal thereof, all shall be as prescribed by the Atomic Energy Commission.

Identification and Segregation of Car A.T.S.F. 151412 Containing TX Metal

This car shall be segregated and identified throughout the entire processing, finishing, inspection and packaging operations. Work on material from this segregated car shall not be done while work is performed on other materials. After packaging in metal containers each container shall have a special identification mark "TX" painted on the outside covers of the metal containers.

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Appendix B

Health Physics

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HEALTH PHYSICS RULES AND REGULATIONS

A copy of the health-physics rules established for the project is given below. These rules and regulations were formulated in conformity with the information sources mentioned (AEC, Oak Ridge National Lab., and Brookhaven National Lab.) and the physical dictates of the Chapman Company plant.

1. GENERAL**A. Application of Regulations:**

- (1) Installations performing operations involving radioactive materials shall establish procedures and practices that will insure maximum safety for all employees. The provisions of this part (Part XIV of AEC Standard Safety Requirements Safety No. 3) are based upon established safe practices, and any rules adopted shall be consistent therewith.

B. Enforcement:

- (1) It shall be the duty of management and supervision to enforce meticulous compliance with established rules and procedures.

2. TOLERANCES (Maximum permissible exposure)**A. Personal Monitoring:**

- (1) All persons entering areas of potential radioactivity, or handling, or transporting radioactive material, shall wear personal monitoring instruments, -(Film badge meters). This applies to visitors as well as working personnel.
- (2) Film badge meters shall not be tampered with in any way, nor used for any purpose other than personnel monitoring.

3. PROTECTIVE CLOTHING AND DEVICES**A. Clothing:**

- (1) It shall be the responsibility of the individual and his immediate supervisor to see that suitable protective clothing and shoes are worn wherever clothing contamination is probable.

- (2) Protective clothing used in the process area is to be worn for a maximum of one day (unless determined otherwise).
- (3) Cloth hats are to be worn over the hair when in the process area.
- (4) Operating personnel are to wear overalls or coveralls in the process area.
- (5) Operating personnel are to remove their overalls or coveralls and replace these with clean coats before entering the lunch room.
- (6) Visitors may not be required to remove clothing to enter or leave the process area but must wear a coat in the process area in addition to the hats and shoe covers mentioned elsewhere.
- (7) Plant shoes or shoe covers are to be worn by personnel and visitors in the process area.
- (8) A shower must be taken by the personnel before leaving the plant at the end of the shift.
- (9) Leather gloves shall be worn as much as possible to reduce exposure to the hands.

B. Laundry:

- (1) Laundry equipment is to be operated only by designated personnel.
- (2) Articles having particles of metal or heavy grease or oil must not be placed in the laundry equipment.
- (3) Laundry equipment operators must take extreme care that no radioactive material is passed into the drains.

4. EATING AND SMOKING

A. Process Area:

- (1) No eating, smoking, chewing or drinking is to be permitted in this area at any time.
- (2) Cigarettes, cigars, chewing tobacco, pipes, food or drinks should be left in the uncontaminated rooms and kept out of the process area -- even though not used there.

B. Wash Room: (Laundry, Shower & Toilet Room)

- (1) Smoking may be permitted in this room on the conditions as stated below and on the condition that the door between this room and the process area is kept closed by a spring door closer (not locked or latched).

- (2) Personnel and visitors entering this room from the process area may smoke or chew after washing hands and face.
- (3) Personnel and visitors may smoke or chew in this room when entered from the lunch room.
- (4) No food is to be prepared or eaten in this room. Drinking water from a fountain is permitted.

C. Lunch Room:

- (1) Visitors and personnel must wash their hands before entering the lunch room from the process area.
- (2) Eating is to be permitted only within the lunch room.
- (3) The preparation of coffee, drinks or food and the storage of same in the area is to be allowed only on approval of A.E.C. inspectors.
- (4) No protective clothing or equipment used in the process area shall be allowed in the lunch room. (This does not apply to underwear).
- (5) Plant shoes for use in the process area may not be worn in the lunch room unless covered with clean shoe covers.

D. Street Clothes-Locker Room:

- (1) Smoking is to be permitted in this room.
- (2) No food or drinks are to be used in this room.

E. Guard Room:

- (1) Smoking is to be permitted in this room.
- (2) No food or drinks are to be used in this room.

5. OPERATING REGULATIONS

A. Service Departments:

- (1) Work by servicing departments in the area shall be done under the rules incorporated in this bulletin and only after approval by authorized individuals.

B. Operating Personnel:

- (1) Gloves used in the area are not to be removed from the area.
- (2) Gloves showing excessive radiation (as determined by meter readings) shall be discarded.

- (3) Tools and equipment must not be removed from the process area until it is determined (by instrumental tests) that their level of contamination will permit their safe removal. This applies to stationary and portable tools. Privately owned tools or instruments are not to be exempted from this rule. Individuals should not take private tools into the area.

6. HYGIENE

A. Personal:

- (1) All persons working with or exposed to radioactive material shall observe the following precautions:-
- (a) Keep fingernails cut short.
 - (b) Wash hands thoroughly before eating, smoking or leaving the area for any purpose.
 - (c) When rubber gloves are worn, they shall be washed before removing from the hands.
 - (d) Hands or absorbent gloves must be kept out of contaminated machine cutting coolants as much as possible.

B. General:

- (1) Lockers must be kept clean. Contaminated clothes must be kept in "contaminated lockers." Clean clothes must be kept in "clean lockers."
- (2) Urinals, lavatories, showers and all facilities shall be kept in such sanitary conditions as to encourage the requisite hygiene.
- (3) Floors in all areas shall be kept clean.
- (4) Cleaning devices used in the process area and the wash room shall not be permitted in the lunch room, street clothes locker room or the guard room.
- (5) Good ventilation shall be maintained at all times with air intakes directly from the outside of the building.
- (6) Ventilation intakes shall be located well away from contaminated exhausts.
- (7) All solid wastes are to be collected and stored or burned as directed.
- (8) There shall be no direct access between the guard room and process area in either direction. This door to be used for emergency exit only.

7. MEDICAL

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A. Injuries:

- (1) All injuries of whatever nature or cause must be immediately reported to the supervisor in charge and the plant physician. It shall be the duty of the plant physician to keep a record of all injuries. All wounds must be dressed so as to exclude all possible entry of radioactive particles into the blood stream.
- (2) Any instances wherein radioactive chips or particles (of whatever size or quantity) are taken into the mouth or lodged under the skin, or in a wound, must be immediately reported to the supervisor and plant physician.

8. AUTHORITY

- (1) The foregoing rules and regulations are interpreted from official sources of U. S. Atomic Energy Commission who may alter, and add to or eliminate the above at their discretion. The specifications for the product being manufactured for the H. K. Ferguson Company requires that AEC regulations be made a part of the specifications.

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June 28, 1948

Mr. Thomas P. Musgrave
H. K. Ferguson Co.
c/o Chapman Valve Mfg. Co.
Indian Orchard, Mass.

Refer: T. P. Musgrave to C. R. E. Merkel, June 4, 1948

Dear Tom:

Thank you very much for your informative letter concerning the fire incident of May 23 at Chapman. Results of our visit of June 1st showed nothing of serious consequence and accordingly our report has been held in abeyance pending a more complete evaluation of the grinder coolant samples.

Briefly, the data may be summarized as follows:

1. Floor contamination is evident in the shop and detectable in the washroom, as expected. The shop contamination is located primarily near the incinerator, conomatic and grinder. No contamination was found in the lunchroom, dressing room, or guard room - reflecting excellent contamination control.
2. Air samples taken in the shop showed no detectable contamination.
3. The grinder exhaust parapet shows no contamination detectable by smear, however, the incinerator exhaust quite evidently contaminates the roof. In the vicinity of the exhaust pipe, smears showed 1500 c/m (β); 25 feet away 60 c/m was detectable.
4. Air samples taken on the roof with no fire in the incinerator showed no detectable contamination.
5. Air samples taken on the roof during the course of a fire in the incinerator showed ~ 40 d/m/m³ (α) at a distance of 12 feet from the exhaust pipe and ~ 120 d/m/m³ (α) at a distance of 20 feet. The differential seems to indicate a slight updraft at the greater distance, however, it is apparent that the atmospheric dilution is effective at relatively short distances from the exhaust pipe.
6. Centrifugation of the grinder coolant at ~ 1475 RPM shows ~ 30 per cent improvement over the filter press technique, while the filter press shows no apparent improvement over the plain sample.

7. By radio-assay methods it appears entirely safe to dispose of the grinder coolant directly down the drain and be within the AEC standard of 5 ppm by a wide margin. Certain stipulations and assumptions governing this disposal are contained within the appended detailed analysis.

Very truly yours,

/s/

C. R. E. Merkle, Jr.

C. F. Murphy

cc:

B. S. Wolf - W. Harris	- AEC
F. R. Kemmer	- H.K.F.
D. H. Gurinsky	- B.N.L.
F. P. Cowan	- B.N.L.

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Detailed Analysis - Grinder Coolant

The grinder coolant samples were evaluated primarily by radio-assay at comparable geometry. All liquid samples were accurately measured with 1 ml volumetric pipette and evaporated to dryness for counting. While this method is obviously not entirely quantitative, it does indicate the pattern of behavior.

I Sample Data

<u>Description</u>	<u>c/m/ml</u>
Plan - (1000 slug run)	71
Centrifuged - (Plain centrifuged at 1475 RPM)	52
Filtered - (Plain filtered through 14 plate press)	72

II Solids Determination

Standard evaporation techniques showed no apparent differential in solid content between each of the three samples. This analysis is obviously inconclusive due to the small sample size and insensitivity of the method.

<u>Description</u>	<u>Pan Weight</u>	<u>Sample Weight</u>	<u>Total Wet Weight</u>	<u>Total Dry Weight</u>	<u>Weight Lost</u>	<u>Per Cent Solids</u>
Plain	3.41 g	1.00 g	4.41 g	3.47 g	0.94 g	6%
Centrifuged	3.35	1.00	4.35	3.41	0.94	6%
Filtered	3.54	1.00	4.54	3.60	0.94	6%

III 48 Hour Settling

Equal volumes of each sample (~43 ml) were allowed to settle for 48 hours and each layer and residue was analyzed as follows:

Plain

	<u>β Count</u>
Top Layer (1/8") - Oily, brown	94 c/m/ml
Bottom layer (4-7/16") - Dark gray	69 c/m/ml
Residue - (0.10 g) - Black	7000 c/m/g

Centrifuged

	<u>β Count</u>
Top layer (3/16") - oily, brown to light gray	103 c/m/ml
Middle layer (3/4") - Medium gray	149 c/m/ml
Bottom layer (3-3/4") - Light gray	29 c/m/ml
Residue (0.03 g) - Black	5100 c/m/g

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Detailed Analysis - Grinder Coolant (Cont'd.)

Filtered

	<u>β Count</u>
Top Layer (1/16") - Oily, brown	228 c/m/ml
Middle Layer (3/16") Brownish gray to dark gray	
Bottom Layers (4-1/2") - Light gray	69 c/m/ml
Residue - (0.05 g) - Black	12,000 c/m/g

IV Calculation of diluted coolant to ppm assuming 100,000 gal/da dilution:

$$\frac{72 \text{ c/m/ml}}{0.08 \text{ (geom.)}} = 900 \text{ d/m/ml} = 15 \text{ d/s/ml}$$

According to Cork ("Radioactivity and Nuclear Physics") 1 gram U^{238}
 $= 12,400 \text{ d/s}$

$$\therefore 1 \text{ d/s} = 8 \times 10^{-5} \text{ g } U^{238}$$

Assuming that our sample is in equilibrium with its decay products in the chain

we then can take a conservative viewpoint and assume that each β particle counted reflects each α disintegration.

$$\therefore (15 \text{ d/s/ml}) (8 \times 10^{-5} \text{ g/d/s})$$

$$= 1.20 \times 10^{-3} \text{ g U/ml}$$

This concentration represents an average production run of 1000 pieces. If 50 gallons of solution are involved, the average metal content is $(1.2 \times 10^{-3} \text{ g U/ml}) (1.9 \times 10^5 \text{ ml}) = 2.3 \times 10^2$ or 230 grams. Using an apparently conservative estimate of 100,000 gallons of drainage water per day as a dilution factor (250,000 gal/day estimated by Mr. Fox) and converting to ppm:

$$\frac{2.3 \times 10^2 \text{ g}}{3.8 \times 10^8} = \frac{X}{10^6} \quad X = \frac{2.3 \times 10^8}{3.8 \times 10^8} = 0.6 \text{ ppm}$$

We find that the resultant concentration at its entry into the river is about 1/8 of the acceptable AEC standard of 5 ppm. This means that without centrifugation as much as 400 gallons of grinder coolant after a 1000 slug run under comparable conditions could be disposed down the sewage drain daily.

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CONFIDENTIAL

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July 13, 1948

Mr. Thomas P. Misgrave
H. K. Ferguson Co.
c/o Chapman Valve Mfg. Co.
Indian Orchard, Mass.

Dear Tom:

Preparation of the coolant samples for counting procedures took several days, the evaporation process being extremely time-consuming. The results of the most recent survey are as follows:

The several smears taken in the shop area indicate that the contamination level is holding fairly constant and in fact, around the conomatic and grinder, is down a little. The level in the washroom is up a bit, but it is still below the general level in the shop. The lunch room is free from contamination.

Three air samples taken in the shop area demonstrate the fact that the air is non-contaminated. One sample shows a small count, but the count is well below the tolerance figure, and undoubtedly reflects a temporary local condition. The E. A. Filter unit on the vacuum cleaner is evidently 100% effective, for an air sample taken at its exhaust point gives only background. The air sample obtained on the incinerator roof shows only background. When the sample was taken, it was quite windy, and the oil-smoke coming from the pipe swirled around the pipe-end of the roof. The smoke vanished at a distance of about 20 feet, indicating good air dilution. Since the direction of the wind was not towards the sampler, it is logical to assume that little if any contamination came that way. The count of the roof sample reflects this. The air sample was taken about 20 feet away from the pipe end.

The contamination on the incinerator roof is increasing, with the greatest increase in the immediate vicinity of the incinerator pipe. The grinder exhaust appears to be ejecting some liquid, undoubtedly the coolant, onto the roof. A triangle of low level radiation has now appeared on the roof. A smear taken on the parapet does not show much change from the level existing on 2 June 48. It is felt that a forthcoming survey will show just how significant this change is. Present indications are that it will increase, but still not approach anything like that present on the incinerator roof.

Instrument surveying of the shop area shows the average ALPHA reading to be approximately 100 to 150 d/m. Maximum 750 d/m near incinerator, medium 350 d/m near conomatic and grinder. Exclusive of areas where material is stock piled, the maximum reading is 0.5 mrep/hr. Approximately 0.2 m4/hr of this is Gamma. Around stock piles, maximum gamma is 7 mr/hr, max. mrep/hr is 11. Washroom shows average of 75 to 100 ALPHA d/m. Incinerator roof at a distance of twenty feet from the pipe gives 0.4 mrep/hr. The black spot on roof in vicinity of pipe gives a maximum of 100 mrep/hr, and a maximum of 5.0 mr/hr. On the grinder exhaust roof the maxi-

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To: Mr. Thomas P. Musgrave

July 13, 1948

mm reading on parapet is less than 0.1 mrep/hr. About 70 per cent BETA. Highest reading is partway between pipe and parapet and is 3.0 mrep/hr.

See Second Sheet for Oil Evaluation.

Conclusions: there are no radical changes in contamination conditions since the previous visit. There is a slight increase on the grinder exhaust roof as is to be expected. The shop area in some places has less contamination than previously, indicating that the floor was washed or at least wiped up. To insure the continuance of the non-contaminated condition of the lunch room, the washroom might be given more diligent cleaning, particularly in the vicinity of the drinking fountain and entrance to lunch room.

The numerical results of a radio-assay of the several coolants is on an attached sheet. Following the reasoning employed last time, it appears safe to dispose of the miller and lathe coolant down the drain, and yet be within the AEC standard of no more than 5 parts per million. The coolant from the screw machine while it can still be disposed of down the drain in the same fashion as the other two coolants, just about comes with AEC standards. It is suggested therefore, that if the method of disposal is to be into the sewage system, that the coolant be discarded quite soon, before it gets too contaminated.

Very truly yours,

/s/ C. F. Murphy
Health Physics Division

CFM:ck

cc:

B. S. Wolf - W. Harris AEC	
F. R. Kemmer	H. K. F.
D. H. Gurinsky	B. N. L.
F. P. Cowan	B. N. L.

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The coolant samples were weighed out and evaporated to dryness, re-weighed and then counted. Three samples weighed one gram each, the other three one-half gram each. These latter three were chosen lighter because of the excessive amount of time taken in the evaporation process. An End-Window Geiger Mueller tube was used for counting.

I Sample Data

Description of Coolant Sample	BETA c/m/ml
Conomatic	537
Conomatic after settling 24 hours	113
Iathe	54
Iathe after settling 24 hours	25
Miller	18
Miller after settling 24 hours	6

It is to be borne in mind that the samples labeled as having settled for 24 hours have only half the weight of the other samples.

II Solids Determination

As in the previous analysis of grinder coolant, the residue after evaporation appears to depend on the initial weight of the sample rather than on the sample's activity.

Description	Pan Weight	Sample Weight	Total Wet Wt.	Total Dry Wt.	Wt. Lost	Per Cent Solids
Conomatic	3.442 g	1.0 g	4.442 g	3.601 g	0.841 g	15.9%
Conomatic 24 hrs.	3.373	1.0	4.373	3.442	0.431	12.8
Iathe	3.539	1.0	4.539	3.694	0.845	15.5
Iathe 24 hrs.	3.442	1.0	4.442	3.513	0.429	14.2
Miller	3.414	1.0	4.414	3.585	0.829	17.1
Miller 24 hrs.	3.427	1.0	4.427	3.495	0.432	13.6

III Typical calculation of diluted coolant to ppm, assuming 100,000 gallons a day dilution.

As in the previous report, it is assumed that each sample is in equilibrium with its decay products U_{1UX2} , U_{11} . Further the conservative view is taken that each count is due to a BETA particle, and that each BETA particle reflects an ALPHA disintegration. As in the last report, $1 \text{ d/s} = 8 \times 10^{-5} \text{ g of } U^{238}$.

$$\frac{537 \text{ c/m/ml}}{0.08 \text{ Geom.}} = 6712 \text{ d/m/ml} = 112 \text{ d/s/ml}$$

$$\text{Therefore: } (112 \text{ d/s/ml}) \times (8 \times 10^{-5} \text{ g } U^{238}) = 8.96 \times 10^{-3} \text{ g } U^{238} \text{ ml.}$$

This means that in a 50 gallon barrel of this coolant there are $(8.96 \times 10^{-3} \text{ g } U^{238}/\text{ml}) (1.9 \times 10^5 \text{ ml}) = 1702 \text{ g } U^{238}$. Using the conservative figure of 100,000 gallons of sewage daily as a dilution factor, and converting to ppm, the result is:

$$\frac{1702 \text{ g}}{3.8 \times 10^8 \text{ g}} = \frac{X}{10^6}$$

$$X = 4.48 \text{ ppm.}$$

The concentration of the U^{238} in the conomatic coolant is within the AEC standard of 5 ppm. It was pointed out in an earlier report by Mr. Merkle (21 May 48) that "laboratory tests indicate that the activity in the centrifuged oil is reduced by about 67% of (in) the oil taken from the conomatic machine during operation. This oil can be used as a film for chip shipment or burned. The sludge removed during the purification process can be burned". This suggests that the activity can be reduced below ppm and that the oil can be disposed of in several ways, namely as a chip film, burned, put into sewerage system.

The concentration of the 6 samples in ppm is:

conomatic	4.48
conomatic 24 hours	1.92
lathe	0.44
lathe 24 hours	0.42
millar	0.15
millar 23 hours	0.10

Since up to 500 gallons of combined lathe and miller coolant could be disposed of into the sewage system during one day, and since the probability that there will ever be this much on hand is very small, the disposal of these coolants is no problem.

n.b.

In these reports, one m. of coolant has been arbitrarily set equal to one gram of weight. The various coolants have different densities and in fact these coolants weigh less than 1 g/ml. This calling one gram equal to one ml makes for ease of calculation and introduces a safety factor in the resultant ppm.

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August 12, 1948

Mr. Thomas P. Misgrave
H. K. Ferguson Co.
c/o Chapman Valve Mfg. Co.
Indian Orchard, Mass.

Dear Tom:

The data from the two recent surveys show that the contamination level in the shop area is staying approximately constant. The average ALPHA is 150/dm, the average BETA-GAMMA is approximately 0.5 mrep/hr. A temporary high reading occurs in localized spots, but it is of no danger. Some contamination is present on the lunch room floor, but it is below tolerance. The tables are clean. Inside the guard room, right next to the door leading to the shop, there is some below-tolerance contamination. Since the contamination on the dressing room floor is just above background, the guard room contamination is evidently due to the fact that occasionally a person steps into the guard room from the shop area momentarily.

Air samples reveal that the air in the shop area is still to be considered as non-contaminated. The vault air sample indicates that there is potential air contamination present. Undue movement of the material here will stir up dust. Should any extensive work be performed in the vault, masks should be worn.

In the vault area, the average exposure is about 20 - 25 mrep/hr (VGM). This allows the men to remain in the vault area two hours daily in the performance of their work and still not exceed tolerance. The men who work in the vault area estimated that they spent from 1 and 3/4 hours to 2 and 1/2 hours daily in the vault area. The lower figure is undoubtedly the more reasonable because despite further exposure to radiation in the chip-packing operation, etc., the badge readings for these men are below 50 mrep a day.

Sections were cut from the palms of the gloves taken back with me, counted then turned over and counted. The resultant c/m show that washing is ineffective. The metal becomes imbedded in the glove and, although some of it is removed, what is left is enough to render washing futile. I would suggest incinerating the gloves. On the subject of gloves, I repeat my recommendation of the use of leather gloves in all operations. Where leather gloves can't be used, it would be well to rotate men in the job if possible. Failing this, the man should attempt to minimize his handling time. The set-up in production makes such activities necessary in order to maintain the excellent NP record established previously.

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To: Mr. Thomas P. Musgrave

A worn cotton sock given to me by one of the workers, was cut up and counted. The result showed contamination to the extent of 50 c/m. This is not excessive, but does indicate the need for further investigation.

Very truly yours,

/s/

C. F. Murphy
Health Physics Division

CFM:ck

cc:

B. S. Wolf - W. Harris - AEC	
F. R. Kemmer -	H.K.F.
D. H. Gurinsky -	B.N.L.
F. P. Cowan -	B.N.L.

September 17, 1948

Mr. Thomas P. Musgrave
H. K. Ferguson Company
c/o Chapman Valve Mfg. Co.
Indian Orchard, Massachusetts

Dear Tom:

The only important change in the contamination picture revealed by my survey of September 1948, was that the tops of the two tables in the lunch room gave a count of 35 - 40 d/m of BETA-GAMMA. A good scrubbing of the table tops with soap and water should correct this situation. Air samples in the shop area and in the vault showed only background in all but one case, and that was only 2 or 3 c/m above background. Low-level floor contamination of the same magnitude as the table contamination is present throughout the lunch room, dressing room, and guard's office. Just outside the guard's office, a smear revealed no detectable contamination.

The material which backs up into the shower room during a recent flooding of the sewerage system due to heavy rains is quite contaminated, as you already knew. If plenty of non-contaminated water is poured down the drain along with, and after any drain-disposed-of contaminated liquid, the contaminated liquid should easily make its way to the main sewerage system and be thoroughly diluted. Of course, if the conditions here are anything like those in the sump at the west end of the shop - where basically the majority of entering liquid seems to be contaminated - then much contamination would remain. The system should be subjected to a large flow of non-contaminated water to dilute what remains stagnant in the system.

The average ALPHA reading is 300 d/m in the shop area, and the average BETA-GAMMA is approximately 0.5 mrep/hr. Average ALPHA in washroom is about 150 d/m. Using a VGM held 20" above the surface of the incinerator--exhaust roof, I obtained a reading of 24 mrep/hr. Most of this is BETA. Twenty feet from the exhaust, two feet above the roof surface, the reading was 0.2 mrep/hr. Fourteen feet from exhaust at same height, 2.0 mrep/hr. The roof, surrounding parapet, and shop windowpanes nearby plus the same items in the vicinity of the grinder exhaust will of necessity have to be decontaminated along with the shop area and machines when the job is completed.

It is unfortunate that the available man power is insufficient to permit rotation of the men in their jobs in order to reduce the increased exposure brought about by the stepped up production rate. As I mentioned to you during my visit last Friday, most men working in the shop wear canvas (cloth) gloves instead of the recommended leather ones. I realize that the men working with grease and coolants find leather gloves almost impossible to work with due to the resultant slipping of the slugs from their grasp. Some men, particularly the heat-treaters, final inspectors, and packers are not bothered by the grease or coolant problem and can use

To: Mr. Thomas P. Misgrave

leather gloves. However, all don't seem to wear them continuously at work in preference to the canvas gloves. Mr. Allan informs me that the three final inspectors are now using leather gloves. This is an excellent move on their part. Although the job will be completed in a few weeks, I still think it advisable to repeat my suggestion that leather gloves be worn by all personnel when and where possible.

Very truly yours,

/s/

C. F. Murphy
Health Physics Division

CFM/jf

cc: B. S. Wolf - W. Harris, AEC
F. R. Kemmer, H. K. Ferguson
D. H. Gurinsky, BNL
F. P. Cowan, BNL
J. B. H. Kuper, BNL

APPENDIX C

DECONTAMINATION PROCEEDINGS

BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

Date: January 17, 1949

TO: C. R. E. Merkle, Jr.

FROM: C. F. Murphy

Subject: Decontamination Proceedings
At Chapman Valve CompanyExtent of Contamination

During the last week of September and the first week of October, Chapman Valve Company of Springfield, Mass. completed production of slugs for Brookhaven National Laboratory. At this time, the area and machines given over to this work were surveyed by the BNL Health Physics representative in preparation for the decontamination program to be undertaken. Conferences were held with interested personnel from the H. K. Ferguson Company and Chapman Valve Company. The picture of the extent of contamination was presented and the prospective decontamination methods were discussed.

For the purpose of this report, the total contaminated area is broken down into six sections. 1) The roof areas. 2) The superstructure of the shop. 3) Walls and floor of the shop. 4) The two vaults and the area comprising the washroom, lunch room, dressing room and guard room. 5) The machines and ovens. 6) The miscellaneous pieces of equipment in the shop and aforementioned rooms.

For concentration of uranium-contaminated waste and the fines from the machines, etc., an incinerator was employed at Chapman. The incinerator, located in a corner of the shop, consisted essentially of a steel tank connected to an exhaust system. Two gas fed flames were directed at the material to be incinerated. The exhaust pipe was passed through a barrel which effected a slight filtering action. The end of the exhaust pipe was over a roof, approximately twenty feet off the ground and aimed at the roof at an angle of 45° with the horizontal. An elaborate filtering system which had been ordered by the New York AEC arrived too late for the job. Consequently, during the several months of production time, considerable contamination was vented onto the surface of the roof, nearby exterior shop wall, shop windows, parapet and to a much lesser degree, onto other shop roofs in the immediate vicinity. The grinder exhaust was vented onto another roof. Coolant in the form of a fine spray, once free of the grinder system, concentrated itself mostly on the roof and parapet. The

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contamination due to the grinder exhaust was quite low compared to that caused by the incinerator exhaust. A fire in a can of chips and fines from one of the machines, occurring in May, was the cause of extensive contamination in the shop area, particularly on the superstructure. Oxide immediately accessible was cleaned up the same day; some was left on the superstructure. Frequent air samples taken during the months following the fire indicated that the material on the superstructure was not causing contamination in the air in the shop. All machines were thoroughly contaminated because the coolant in each machine carried the resultant fines from the operation and spread them throughout the machine.

Decontamination Criteria

Tentative plans formulated at BNL and mentioned at the foregoing conferences called for vacuuming and washing areas like the superstructure and vaults. Walls, floors and windows were to be washed. Certain contaminated areas of the roof determined by survey were to be vacuumed, scraped, tar paper removed and incinerated. New tar paper, tar and gravel were to be put down. Other less contaminated sections were to have gravel removed and new tar and gravel placed on the roof. Ashes from the incinerated tar paper were to be barreled for shipment to the AEC storage grounds along with the gravel and contents of the vacuum cleaner. It was anticipated that a degreasing compound would get off most of the contamination from the various machines. Acid washes, it was felt, would get rid of most spots not affected by the degreasing treatment. It was fully expected that sections still giving trouble would have to be subjected to new treatments discovered in the decontamination process, and that some material would have to be discarded. The criterion for discarding would be the practicality (economically and physically) of cleaning up the material. With these two points in mind, the norm of radioactive cleanliness was established as follows: less than 500 d/m of alpha as revealed by an Alpha meter (Zeuto) in contact with the surface, and less than 300 d/m as detected by an end window GM tube reading the smears. (Smears taken with a 1-1/2 x 1-1/2" piece of bond paper over an area of 100 square centimeters).

It is agreed that these limits may seem a bit arbitrary, however some working criteria had to be established. The basic guiding philosophy leading to their establishment was the elimination of any health hazard. Furthermore, after the cleaning operations, all machine surfaces that could be painted were to be painted. All wooden material such as benches and chairs were to be painted, as well as piping, certain walls, etc.

Decontamination Problems and Techniques

It became obvious almost immediately that degreasing by itself did not free most of the loose contamination from the various machines. A search for the technique which would most quickly and effectively clean off the machines was instituted. After a period of trial and error, the following procedure was adopted. The machine was opened up until the chip-and-the-fine-holding surfaces were exposed. These chips and fines were removed and then the machine was wiped down until only a greasy surface was left on the machine. Then Lumen - a commercial degreaser - was brushed onto the machine and allowed to stand for several hours. This was then taken off by steaming. If the surface still had much grease left on, the

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treatment was repeated. Generally, two treatments were adequate, but occasionally, some spots needed as many as four or five treatments. At this point in the decontamination program, it was found that a soap and water washing would reduce the loose surface contamination (revealed by smears) considerably, and that a subsequent steaming and wiping with clean cloths would get the smear reading down to its lowest practicable limit. At times, the washing had to be repeated, but such occurrences were rare when the techniques were completely mastered and rigidly followed.

When all the foregoing had been done, smears were taken and counted in a lead pig, utilizing an end window GM tube. Since so many smears had to be taken, the duration of a smear's counting time was necessarily limited to between 3 and 5 min. The microphonics and general sensitivity associated with an Alpha counter precluded its use for counting so many smears in the time involved. A ratio of 1 alpha to 1 beta or gamma was decided upon and the GM tube employed in counting the Beta-Gamma. The Zeuto was employed to obtain surface readings. If it could not be brought close to the surface because of structural obstructions, an unshielded Beckman MX-5 was used.

If the readings on the Zeuto or MX-5 were high, then two further cleaning techniques were resorted to. These were sand blasting with a very fine grade of sand and swabbing with nitric acid. Sand blasting was tested and found to be quite effective in that it was able to take off a lamina of metal from the surface of a machine, thus removing the contamination that had diffused into this upper lamina. The health hazard was minimized by the wearing of masks and goggles by the operator and his assistant. Numerous air samples taken at varying distances from the blasting area indicated that air-borne contamination was not very high, but that it would be a definite problem if extensive sand blasting were to be undertaken for several months. This necessarily restricted the use of sand blasting. The acid treatment took much time and was not as effective as sand blasting, particularly on very porous metal. Large areas swabbed with acid presented a direct hazard to personnel and also produced very penetrating fumes. Certain surfaces could not be subjected to either much sand blasting or acid treatment or any at all. Tolerance-controlling surfaces which had been given the maximum treatment they could stand, and which gave low smear readings, and had relatively low Zeuto or MX-5 readings were passed. Such areas were always very small in extent. Some surfaces were either impossible to treat at all or else, despite a certain amount of decontaminating as just noted, were impossible to bring down to low smear counts and survey meter readings. These were condemned and set aside for shipment to AEC storage grounds. For example, some of the metal plates on the truing head associated with the centerless grinder were impossible to decontaminate with acid treatment without making them worthless, so they were condemned. The major portion of the coolant tanks was impracticable to clean because of the cost of cleaning. All coolant distribution - pipe systems were impossible to clean because of the decontaminator's inability to apply more than token cleaning effort. Sand blasting could only be applied to exterior surfaces of machines. Interior surfaces and certain outside ones were accompanied by gears, etc. Sand particles here would have caused extensive damage ultimately. If the coolant tank were an integral part of a machine and could not be replaced, then of necessity, much time, effort and money could be expended in an attempt to save it. In the case of the conomatic, the coolant tank was a huge wide tank which also served as the base of the machine. A crane was employed

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to separate the two sections of the machine. After a double degreasing and steaming treatment, the readings were still high. Blasting could not be used, the grains of sand would not all be cleaned out and future use would see these particles damaging the machine in all probability. An acid wash was used several times and flooded off with water. This reduced the high spot to a small area. The alpha meter contact reading was 2300 d/m. However, the total hazard for contamination of work passed through the machine would be minimum. The tank was to be painted before it went into use again. As coolant wore away, the paint in future use, the amount of contamination that would come loose from the exposed surface to affect metal being worked on would be practically nil.

Health Physics Precautions

The usual Health Physics practices introduced at the outset of the production program at Chapman were continued during the cleanup. Protective clothing, shoes and gloves were worn. The use of masks during the cleanup was recommended. They were worn by personnel engaged in sand blasting, vacuuming and the steaming of areas such as the walls near the incinerator.

Large scale incineration of lumber, rags, oil-soaked sawdust, etc. was impracticable in the regular incinerator referred to on the first page of this report. A deep metal pan 4' x 6' x 8" was set out in a dump owned by Chapman. The material was incinerated there. The men doing the burning wore protective clothing and kept upwind. Vegetation and dirt samples taken after two days of incinerating particularly heavily contaminated material showed no detectable contamination. The ashes were barrelled and put aside for AEC storage. The pan was used several times and then set aside for AEC storage also.

The sand employed in the sand blasting operation was changed several times and the used sand put in barrels for AEC storage. Water used in washing off the degreased and steamed machines was thrown into the sewerage system and was diluted by the sewage volume so that the average contamination was less than 5 ppm. Several months earlier, the oil used in the conomatic was checked after centrifuging, and found to have a prospective parts per million of less than the AEC stipulated, 5 ppm when diluted with the sewage. Tests made on samples from different catch basins on Chapman property verified this. The amount of contamination washed off a machine in the final stages of decontaminating a machine was very small, much less than that found in the conomatic oil. Thus no contamination problem was created. The contamination that came off with the degreasing and steaming operations, went onto the floor and was absorbed in sawdust which was incinerated, the ashes being stored for AEC.

The water used in washing the floor areas was thrown into the sewerage system. This was done over a period of two successive days and the total contamination was certainly no greater than that engendered by coolant disposal.

Roof Areas

A grossly contaminated section of the incinerator roof was vacuumed.

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Then the roof was scraped over an area embracing approximately 50 square feet, and this gravel and dirt were stored in steel barrels for shipment to AEC storage facilities. The tar paper in this area was torn up and incinerated in the Chapman dump, the ashes being set aside for shipment. The exposed wooden roof now read at its high point about 18,000 to 23,000 d/m on the Zeuto. Originally, the reading on the roof before vacuuming could not be taken on the X 10 scale with the instrument held near enough to evaluate the alphas without the needle's going off scale - greater than 60,000 d/m. After the scraping and prior to the removal of the tar paper, a surface reading with the Zeuto gave almost full scale on the X 10 scale. After the wood was exposed, a brisk rubbing of a chosen area with wet cloth did not appreciably diminish the reading obtained before the rubbing, the oxide obviously being imbedded in the wood. Since the wood was to be covered by tar paper, tar and gravel, no health hazard would be presented. The gravel on the rest of the same roof had a reading of 2200 d/m, which diminished to approximately 700 d/m at the section of roof under decontamination proceedings. But disturbing the gravel revealed that the reading on the dirt beneath the top layer of gravel went up by a factor of 2 or 3. This indicated that the contamination on top had been most probably washed from the upper surface of the gravel onto the dirt beneath. Since the reading beneath the gravel surface was still much lower than that existing on the wood just bared, and since that section would not present a health hazard when it was covered anew, all that had to be done here was to scrape the old gravel off and to have new tar and gravel put on. The same procedure was adopted for a further section of roof with lower readings. A second height of roof had contamination in spots beneath the gravel of about 700 to 1000 d/m. The area in this condition was quite small. The Chapman Co. was repairing this roof, so it had the gravel and dirt taken off, screened, and the gravel set aside for re-use on the roof. Tar was mopped on and three ply tar paper put back on and then, after another tar mopping, new gravel. After all the work had been done on the roof surfaces, the radiation level was less than 200 d/m and this was in spots at the far end of the roof where no gravel had been moved.

The dirt left from the screening read less than 150 d/m and was buried in the Chapman dump. The parapet and base of the windows siding the incinerator roof, was covered with a black paint. No radiation was detectable with the Zeuto after this painting. Prior to this cleaning operation, the side of the building above the roof (consisting of window panes set in steel frames and supported in red brick walls) had been steamed and washed with hot water, then gone over again with hot soapy water and steamed off. The smear readings were: window panes 0-50 d/m, brick walls 50-100 d/m, steel frames 175-225 in high spots, average 75-175 d/m. Much time had already been spent on the washing operation here. Since personnel were present infrequently, and since no health or contamination problem was posed, the area was considered clean.

The grinder exhaust system was vented onto a roof, the surface of which was tar paper, tar gravel and dirt. The coolant spray from the exhaust spewed out onto the roof and landed on the roof-surface and on the two-foot-high parapet surrounding the roof. The contamination of the roof area was centered primarily in a truncated "cone" with the narrow end 10" wide at the exhaust point. The cone widened greatly at the base, covering about 30'. Throughout the decontamination proceedings, all contamination

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measured with the Zeuto, invariably gave 80 to 85% alpha. The hot spot here was about 9500 to 12,000 d/m with the average in the cone about 2200 to 3000 d/m. Near the parapet, it was approximately 40,000 d/m. The edge of the cone gave about 1000 d/m. The entire area was vacuumed with a large size cleaner, and the contents stored for AEC disposal. The contamination level was immediately reduced and the area of contamination diminished by 50%; most of the contamination having been in the dirt and gravel picked up by the vacuum cleaner. The area was then scraped with a shovel and the material obtained thusly stored for AEC disposal. The parapet was scrubbed down with soap and water, but the level still read 1800 to 2100 d/m. The area that had been scraped was mopped with tar and then covered with new gravel. The parapet was given a coat of black paint. As on the incinerator roof, tarred or painted surfaces gave no readings on the Zeuto.

On the incinerator roof approximately 1800 square feet of roof was scraped, tarred and graveled. Of these 1800 square feet, about 400 square feet also had the old tar paper removed and new tar paper put down. On the centerless grinder roof, approximately 400 square feet were scraped, tarred and graveled.

Superstructure

Due to a fire which occurred in a can of chips in May, much oxide collected on the girders of the superstructure. A great deal of this was cleaned up at once after the fire by Chap. Job 1000 personnel. The remainder of it was not readily accessible to immediate cleaning and also, it stayed lodged on the superstructure. Frequent air samples had demonstrated this. Movement of the crane did not dislodge any detectable (air sample) contamination. The girders were vacuumed and the material collected, saved for analysis and stored separately. Certain sections were wiped down after the vacuuming and washing. The ledges just below the windows were wiped with a wet rag. The I beams supporting the crane in its travels were vacuumed. Smears taken after all this showed either background or an average of 75 to 150 d/m above background. There were occasional high spots, but the locations were such as not to constitute any health hazard.

Shop Walls and Floors

Smears taken at random upon the walls of the shop area indicated high contamination levels near the incinerator and the conomatic, and in the corner of the shop used by the degreaser. These areas were steamed down; the resultant smears were about 75 to 150 d/m above background, with an occasional high. The pipes & radiators were washed and some of them steamed when the need was indicated. The windows near the incinerator and conomatic and the steel safety floors and two wooden doors were steamed and cleaned. During the last 2 days of the program, the floors in the shop area were washed using lumen, soap and water. Some spots, notably near the incinerator were steamed. Water was then flooded over the area. The reading with the Zeuto gave about 700 to 1000 d/m at most, with an average around 700 d/m. The floor was mopped with tar and wooden blocks of about 3" thickness put down in preparation for future use of the shop. The shop walls from the floor level to a height of about 5' were painted. The radiators near the floor level were painted. The steel and wooden doors mentioned above were painted. The wall in the incinerator corner from the left of the safety doors to the corner, and continuing to the left for approximately 12 feet, from the floor level to the ledge of the upper windows was painted.

Vaults - Floors

The smaller vault had very little contamination in it. The walls were brushed down with a clean broom. Smears taken on the walls gave background only. The floor was washed and rinsed. Readings with the Zeuto gave about 300 d/m. (Floor has since been painted). The walls in the large vault (used for X metal storage) were broomed down from a height of approximately 8 feet. Smears taken on the walls gave background to 100 d/m above background with the high ones very near the floor. The vault was vacuumed and the material stored for shipment. The rough uneven floor was given a mopping and left for tarring and blocking. Zeuto readings were taken at several places on the floor. Some spots gave as high as 3100 d/m, the average being about 1000 d/m. The floors in the washroom, etc. were washed down and rinsed. The average reading with a Zeuto was 1000 to 1500 d/m for high spots and 700 d/m for low spots. Floor was tarred and covered with wooden blocks. All piping was washed. Smears were background to 50 d/m above. All plumbing equipment was washed and presented no problems due to smooth surfaces, and low original contamination. All tables, chairs, benches, etc.

were washed and painted anew. Smears gave 3 c/m on the average.

Ovens

The 2 ovens were relatively easy to decontaminate. The pots that had been put into each oven were practically clean on their exterior surfaces. As a result, the inside of each oven gave no Zeuto reading and interior smears were background with a rare 1 or 2 near the "hearth" of 25 to 50 d/m above background. A degreasing steaming and rinsing to the outside of the metal ovens resulted in Zeuto readings of less than 200 d/m, and smears ranging from background to 75 d/m at most. The 2 ovens were removed from the shop area and painted.

Rod Straightener

The first of the machines decontaminated was the rod straightener. The surface of each rod was covered with oxide, and much of this oxide was stripped from the rod when the rod passed through the machine. To reduce the air contamination hazard, oil was used to place a film over each rod during the process of straightening. The oil dripped onto the machine while the operation was in progress and spread itself over the surface of the machine. As a result of this, the machine became extremely contaminated. On the rear section of the machine, there was very little oil and steaming was tried alone in an attempt to remove the oil, but without success. Lumen was brushed on, then steamed off. The reading obtained with a Zeuto after this treatment was much lower than before. Another degreasing and steaming aided some, but a third had practically no further effect. The degreasing and steaming treatment was given to an extremely greasy and contaminated section at the front end of the machine. After three treatments, the Zeuto reading stayed approximately constant - 2600 to 3000 d/m. The entire machine was broken down and the degreasing and steaming technique tried on the gears and roller. The same result evolved; after two or three degreasings, the maximum effect had been achieved. While this had been going on, a few of the smaller gears had been placed in a degreaser. Here the trichlorethylene vapors were allowed to play over the surface of the gears for approximately 20 minutes. The grease was definitely removed, but a scaly surface - similar to rust - remained and it contained contamination. This scale could be rubbed off easily, but there still would be contamination left behind. At this point, the entire machine was degreased and steamed on all the upper and side surfaces. After the removal of all grease, it was then removed to the end of the shop and prepared for sand blasting. Previously to this, a small corner of the shop had been set up to test the efficacy of sand blasting. A pan that had been employed to hold slugs was sand blasted with gratifying results. Pieces of masonite, about 4 to 5 feet in height, were set up around the rod straightener to aid in checking the movement of the dust formed in sand blasting. The entire cleaned-off surface of the machine was sand blasted; the operator and his assistant working for about 5 to 10 minutes and then resting. This brought the average reading down to 300 to 400 d/m. Most of the few remaining high spots vanished with one more sand blasting. Several spots were gone over many times. In corners and crevices it was found that multiple sand blast treatments were not too effective. There was one section of the machine that was ridged like a fingerprint. Although the smear readings here were either background or 50 to 150 d/m as on the rest of the treated surface, the area (about 1/2 square foot) read 3300 d/m. This

was near where the oil fell from the rollers. The sand blasted portion of the machine was washed down with soapy water, rinsed and steamed. Smear readings were either background or 50 to 125 d/m above. Then the machine was turned over on its side and the same treatment given to it. Although the bottom had not been exposed directly to contamination, some had leaked through holes in the body of the machine and was well diffused throughout the greasy bottom. However, cleaning it was much simpler than on top. After the bottom had been cleaned, the machine was righted again, the top steamed once more, and the machine removed from the shop. The hot gears, universals and rollers were given the same treatment as the body of the machine. The entire machine was painted.

Centerless Grinder

The centerless grinder was one of the most contaminated machines. After being opened up and cleaned of its fines and chips, then degreased and steamed several times, it was still very hot in its bed section and on the painted exterior surfaces. The painted surfaces and bed were sand blasted. Once the paint had been removed, the Zeuto readings in most places were less than 250 d/m. The bed section was sand blasted several times but one spot still read 2000 to 2500 d/m. Smears here gave only 25 to 100 d/m above background. Masking tape and cloths were applied to the head section of the machine to prevent the entry of sand, but still some sand did get through. This was the first machine that gave any indication how deep the contamination was spread. Several times a specific area was sand blasted, but after the first two blastings, the Zeuto reading did not decline much. Continued blastings were unwarranted. The coolant had poured directly onto this section of the bed and the fines from uranium had evidently diffused into the bed. How deep they went is impossible to say, but they were so deep that there appeared to be no way of getting them out. Except for a few places like this, the entire machine was brought down to a range of 0 to 325 d/m as determined by alpha meter readings. The interior of the machine was not as contaminated as the foregoing and steaming and degreasing of the contaminated sections lowered the readings to 250 to 350 d/m. Smears read background to 100 d/m above background. The entire machine was repainted. Undoubtedly much of the paint will be worn free by use of the machine in the future, but the rate of loosening of the metal will not be great. In all probability new metal will diffuse into the surface.

As has been pointed out in the earlier section of this report, most coolant tanks were impracticable to clean. The coolant had carried the fines around and they had diffused into the metal surface. The bed of the centerless grinder was an example of how much work could be done and just what could be accomplished. The coolant pumping and piping systems, because of their narrow tubular construction, were practically blocked to decontamination so they were discarded along with the tanks. With but one or two exceptions, the tanks could be replaced at little trouble and expense, and so could the coolant distribution systems.

Acid treatment had been tried. A crock of nitric acid was on hand and into the acid were set several pieces of metal. It became evident that certain ones, such as the plates associated with the truing head of the centerless grinder, could not be cleaned without rendering them useless.

Others, like certain pieces from the conomatic and lathes, were cleaned quite well. If the contamination weren't too deep (i.e., if the metal weren't too porous or else hadn't been exposed to a contaminated coolant for long periods of time) an acid treatment was an excellent method with which to attempt decontamination. If the contamination were deep, sand blasting would have a definite decontaminating effect.

Lathes and Millers

One at a time, each of the two lathes and millers, was opened up and decontaminated. The only sections that needed more than the usual degreasing, steaming, washing and steaming were the porous metal surfaces where the coolant flowed and the sections that held the cutting tools. In the case of the lathes, it was discovered that little holes around the tool holding section was filled with oxide. These were decontaminated by taking a pattern file, covering the end of it with cloth and then cleaning the hole with it. The section was also swabbed with nitric and then washed off. Final reading here was less than 1400 d/m with the Zeuto. An acid swabbing of the porous section of each lathe which was in the coolant flow reduced the readings to 330 d/m. Smears averaged background to 150 above.

In the case of one of the two millers, coolant had splashed uphill into a channel given over to wiring and then drained down into the main coolant channel. Some of the oxide had been left encrusted on the wall of the wiring channel. Much of this yielded to steam, soap and water. An acid treatment lowered it still more, but it was still quite high - 2700 to 3200 d/m on the Zeuto. Since the machine was to be painted and since the wiring channel would not have much coolant flowing over the painted surface, the machine was released. In another miller, the coolant tank was at the bottom of the machine and quite inaccessible. There was one small hole through which decontaminating work could be done. Acid washing did reduce the readings but not as much as in previous cases. The main difficulty here as in all other cases was the porosity of the metal. The cast iron surface was like sponge, and when the contaminated coolant had flowed over the surface, fines had worked themselves into these pores. It was very difficult to get much contamination free from the pores of such metal. Smears read 50 to 175 d/m above background. The Zeuto could not be placed inside the coolant tank, and so of necessity the GM tube from the MX-5 was put in to obtain a reading. The reading obtained was less than 1.0 mrep/hr. Smear readings were low, the surface was to be painted. The total amount of contamination was small, not loose, relatively inaccessible and conceivably presented no health hazard. The machine was released.

The Conomatic

The last item among the machines was the conomatic. The top of this was relatively clean and degreasing and steaming, except in one or two places, were adequate. The rear of the machine was in the same condition. The tubes which held the uranium rods were removed and condemned. Experience gained from cleaning smaller conomatic sleeves indicated that it would be much less costly to buy new ones than to try to clean out the old ones. The insides of the machine were exposed as much as possible by removing side plates. Degreasing and steaming were tried several times. Acid swab-

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lings were given to certain sections. After much work, the average smear was background to 175 above with a few spots reading as high as 275 d/m above background. The Zeuto readings ran from less than 250 to 1000 d/m with the average about 375 d/m. A crane was then employed to separate the top of the conomatic from the bottom and to set the top up on blocks. The grease on the underside had to be removed. This was a time-consuming and difficult undertaking. The coolant had splashed up into the greasy section and much contamination remained. Degreasing and steaming brought smear readings and Zeuto readings down to those existing on the upper side of the top of the conomatic. As pointed out earlier in this report, the coolant tank had to be degreased, steamed and then after several such treatments, given multiple acid baths and water rinses before it could be accepted as being decontaminated.

Miscellaneous Equipment

The physical construction and extent of contamination of the oil sterilizer and chip separator prevented their decontamination. The exteriors of these two were cleaned so that they would offer a minimum handling hazard. The carriages, tracks, pots and other sundry pieces of metal designed for the job had value only as scrap, but such use would contaminate any metal they were mixed with. Therefore, they were cleaned somewhat, some cut up and all set aside. The washing machine, drying machine, incinerator, power saw and final inspection bench were contaminated to varying degrees. Because of the nature of the use of the first two items, their use on other than contaminated clothes was automatically precluded. The incinerator and power saw were extensively contaminated. The low intrinsic value and great extent of contamination rendered decontamination of the low incinerator impracticable. The extent and magnitude of contamination and the physical construction made decontamination of the power saw likewise impracticable. The final inspection bench had been made for this particular job; its small value and the cost of decontamination work prevented its decontamination. Electrical and water conduits, switch boxes, etc. were degreased and steamed and painted for re-use. Motors of the incinerator and centerless grinder exhaust systems and duct work were condemned. The motor associated with the incinerator was in bad mechanical state. Other motors and power tools were cleaned using combination of degreasing, steaming, washing with water or carbon tetrachloride depending on the physical construction and housing of the motor being worked on. Grinding stones were condemned. All motors and power tools were painted. Wood and metal items such as desks, certain tables and filing cabinets were washed and then painted for re-use. Other wooden tables that were extensively contaminated from being used in checking and storing of slugs were incinerated. The washing machine, drying machine, final inspection bench, incinerator and power saw were sent to BNL. All the small-sized condemned material was packed into barrels and large condemned items, set aside for shipment to AEC storage grounds. All storage - material was moved by a special freight car.

Review of Contamination Status

The average smear reading of the machines passed read 0 d/m to 150 d/m above background. The average Zeuto reading was 0 to less than 275 d/m. The high smears were 250 d/m to 300 d/m above background. The high

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Zeuto readings were few and averaged 800 d/m to 1500 d/m. These readings occurred at such points as the chuck faces of the two lathes, the chuck faces of the conomatic, the coolant channels of the millers and part of the centerless grinder. One section of the centerless grinder had 2000 to 2500 d/m. The area had been sand blasted five times and worn down quite a bit. The metal was extremely porous and had been subjected to a concentration of coolant and fines. Some sections where the Zeuto couldn't be placed, and which could not be cleaned too well, gave reading of 0.3 to 0.7 mrep/hr on the MX-5. One or two spots read as high as 1.0 mrep/hr on contact with the MX-5. Drain inputs were steamed and flushed. Inside the shop the painting, etc. has eliminated any health hazard from the floor and the lower levels of the shop. The incinerator corner painting has removed any from that section. The walls and superstructure smears average background to 150 d/m above. An occasional high of 600 d/m might be found high up in the superstructure. No health hazard is offered.

The roofs which had been tarred and graveled had no detectable contamination. The parapets that had been painted showed none. (Corrugated iron roofs, about twenty-five feet in height which begin about one hundred feet from the incinerator exhaust, were checked with a Zeuto up to a radial distance of one hundred and seventy-five feet from the exhaust. Zeuto readings were 0 to 250 d/m. Smears gave background to 100 d/m above background. The brick and concrete in the vicinity yielded the same results.) Zeuto readings when the gravel on the highest section of the shop roof was disturbed, gave 0 to 400 d/m at the edge of the roof and 0 to less than 250 d/m towards the center of the roof. On the roof, it was noted that the tar had a concentrating effect on the oxide. This was undoubtedly due to the fact that during the warm weather, the tar was very soft and it trapped the contamination that came from the incinerator exhaust.

Summary

The contamination at Chapman Valve Company can be ascribed to three causes: 1. the fire in the can of chips and fines last May. 2. the material vented from the incinerator exhaust system and to a much lesser degree, that from the grinder exhaust system. 3. the handling and machining of the uranium. In the main, the first two mentioned contaminated the shop area (walls, superstructure, etc.) and the roof area. The last one contaminated the machines, and to a lesser extent, the floors and vault.

On future jobs of this type, more stringent safety precautions would serve to prevent the occurrence of a chip fire. The installation of effective working filter systems before production would serve to prevent the roof contamination found in this job. The remaining point for discussion is the handling and machining of uranium. This brings up several points.

Once the metal is put through any machine process, the coolant (or oil used to keep down the oxide on operations on the rod straightener and power saw) begins to spread the contamination (in the form of fines and chips) throughout the machine. Grease and oil collect in every conceivable corner and crack in a mixture with the fines. From the viewpoint of future decontamination several things occur. The coolant distribution system, because of its physical construction and inaccessibility to cleaning

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media, is beyond cleaning. The coolant tank is rendered extremely difficult to clean. Cleaning of this article is economically feasible only in the case of its being an integral part of the machine and replacement is either impossible or else quite expensive. The contaminant appears to diffuse into the skin of the machine.

In operation, the decontamination of a machine proceeds as follows: the machine is opened up, exposing as much as possible. Obviously, this cannot be carried out to each nut and bolt and screw. The chips and fines, in the form of a sludge, are removed. Lumen, a commercial degreaser, is brushed onto the oily and greasy surface, allowed to stand for a few hours, and then steamed off. This is repeated once or twice if any oil or grease is left on the surfaces. Survey meter readings indicate the condition of the machine. Areas reading high necessitate further treatment. The contamination causing the high reading is imbedded in the metal. Some of the metal can be removed by sand blasting with a fine grade of sand, or else swabbing nitric acid onto the surface. Limitations beset either method. In certain cases, just so much metal surface can be removed. If more is taken off, the machine tolerances are destroyed. Also, the contamination has seemingly burrowed into the surface and just so much surface can be removed before coming up against "diminishing returns" insofar as effort and cost are concerned. Moreover, there is the health hazard created by sand blasting and acid swabbing. Steaming will contaminate the air to a small degree. Sand blasting will increase this many times. It is true that a room given over exclusively to sand blasting, with an air exhaust filter system, etc. would solve this health problem. Acid swabbing besides bringing about irritating fumes, presents a hazard to personnel.

In addition to the foregoing, sand blasting is limited in its application by the machine to be cleaned. A machine such as a rod straightener, with no delicate gear mechanisms to be damaged by lodged sand particles, and with large open areas is a perfect object for sand blasting. Other machines offer only small areas to which sand blasting would be applicable. The coolant channel of machines, away from the "cooling area" is generally impossible to reach physically. And if working on it were possible, then the problem of getting out all the sand, etc. is raised. Here acid swabbing is resorted to. But as mentioned, the "diminishing returns" obstacle sets in. After a point, the porous metal will offer an approximately constant contamination indication. Places inaccessible to alpha meter-readings (Zeuto) must be investigated by G. M. tubes (Beckman MX-5). Because of differences in geometry and a host of other problems, it is difficult to equate the Zeuto reading to that of the MX-5. If the smear reading is low and the MX-5 reading is less than 1.0 mrep/hr on contact, the state of decontamination is approved. All machine surfaces that have been decontaminated and accepted which can be painted are given a coat of paint. A decontaminated machine is one offering no health hazard, and which offers minimum future metal contamination possibilities when it is used on other jobs.

Recommendations:

It would seem that machining of uranium is best done in a building designed for the job. Such a building should have a smooth faced interior (e.g. tile) to enable washing down of contamination caused by any means.

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Physical obstructions such as piping, etc. should be minimized. Such a building should have the necessary filter, blower and incinerator systems. All excess and unnecessary objects should be kept out of the building. Strippable enamel coatings could be employed advantageously. Machines employed on such work should be assigned permanently to the task. It has been demonstrated that such machines can never be completely decontaminated, but that they (in special instances) can be cleaned to the point that the health hazard can be said to be nil and that the probability for future metal contamination is minimum. If the AEC intends to do any significant amount of machining of uranium, it might consider selecting a group of machines to be used for all such work. An ideal location for such a set-up would be on an AEC site. Any deviation from this immediately brings in varying difficulties. Compromises can be effected, but they will bring with them all their inherent troubles and complications. The decontamination job at Chapman points up clearly the problems offered.

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APPENDIX D

EQUIPMENT DISCARDED BECAUSE OF CONTAMINATION

The following equipment was discarded and sent to burial following completion of the uranium machining project at Chapman Valve Manufacturing Company. The material was included in Car P. RR 74649 shipped to Electro-metallurgical Company, Niagara Falls, N.Y.

- Sterilizer Tank
- Centrifugal (DeLaval)
- Chip & Oil Separator
- Press Stand
- Drill Grinder
- Buffing Wheel Base
- Settling Tank (from Grinder filled with scrap steel)
- Comparators (frame & body - 2)
- Degreaser
- Settling Tank (filled with scrap steel)
- Stanchion
- Floor pan (washing & drying)
- Splash Pan
- Furnace Pot Car (2)
- Furnace Pot containing:
 - Grinder pump parts
 - Flattened smoke pipe & scrap steel
 - 1 slug pan
 - Cover
 - Nuts & bolts
- Steel Pan
- Furnace Pot Containing:
 - 2 Heating Elements
 - 1 Bar Support for rod straightening machine
 - 2 Oil Pumps & Pipe Fittings
- 27 Babbit Hammers
 - Pusher Pads (rolled brass)
 - Tool Bits & Files
- 38 Work rest plates for grinder
- 6 Through-feed Plates for grinder
- 1 Slug pan
- Flattened smoke pipe
- 4 Nuts & bolts
- Furnace Pot Containing:
 - 8 Slug Racks
 - 5 Slug Plates
 - 4 Nuts & Bolts

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Furnace Pot Containing:

- Oil hose for Conomatic
- 8 Slug racks
- Bar support tube leg (pipe)
- Oil Cocks & Spigots (Conomatic)
- Work Chute & support
- Assorted pipe & fittings
- 2 Nuts & bolts
- Steel Drums of Steel Scrap (14)
- Steel Drums of Roof Gravel (11)
- Steel Drums of Ashes (11)
- Steel Drums of Sand and Fire Brick (2)
- Steel Drums of Broken Grind Wheels (3)

Car Rails

Steel Tank containing:

- 1 Steel Motor base
- 2 Pot pushers
- 1 Rod Support Angle Iron
- 1 Rod Tube
- 2 Guide Strips
- 1 1-1/4" pipe 6' long
- 1 1" angle iron 7-1/2' long
- 3 Lathe chuck jaws
- 1 C. I. Stand foot
- 1 Chip pan hook for separator
- 13 3/4" pipe siphons
- 2 Steel hooks for furnace
- 6 Reel tubes for conomatic
- Miscellaneous steel scrap
- 2 Roller conveyors (42" long)
- 2 Crane Stops
- Steel I beam
- Drum Scrap
- Scale