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METALS, CERAMICS & MATERIALS
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QUARTERLY PROGRESS SUMMARY

APRIL TO JUNE, 1964

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AEC Contract Manager

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REACTIVE METALS, INC.
ASHTABULA, OHIO

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I. SUMMARYPROJECT 800-3 - MARK V-B PROCESS IMPROVEMENT

A basic heat treatment study involving the number of heating cycles and the time at each cycle was performed on Mark V-B uranium billets. Analysis of the extruded product from these billets indicate that a reduction in the number of cycles and time at each cycle could lead to a reduction in the amount of slug rejects for surface defects. The heat treatment of the billets had no effect on extrusion dimensions or pressure but rough surfaces were apparent on some tubes extruded from as-cast billets.

PROJECT 800-10 - EXTRUSION PIERCING DEVELOPMENT

A study was performed to determine the influence of extrusion press tooling alignment on the eccentricity of pierced I.D.'s.

PROJECT 800-11 - DYNAPAK FORMING

A description of the DYNAPAK equipment and process is presented including a summary of activities performed from its inception to its termination. Also presented is an engineering estimate of the cost of establishing a DYNAPAK extrusion facility for the production of Mark V-E Inner size uranium tubes.

PROJECT 801-32 - PICATINNY ARSENAL DEVELOPMENT

A final report concerning the refinement of coordinated extrusion, drawing and heading techniques for the fabrication of cubical items.

II. PROJECT 800-3 - MARK V-B PROCESS IMPROVEMENT

INFLUENCE OF BILLET ANNEALING ON THE HOT EXTRUDABILITY OF URANIUM

BY: C.A. Scharschu

INTRODUCTION

Regular practice for the hot extrusion of normal uranium tubing requires a heat treated billet. The annealing is specified as a three-cycle treatment for one hour per cycle in the beta range followed by quenching after each cycle. Previous experience had shown that this practice produced better surface quality, more randomization of grain structure in the extruded tube and lower extrusion pressures.

The question arose, however, whether or not this treatment was still necessary considering the general improvement in extrusion technique and the change in billet composition (i.e., the addition of alloying elements). Considerable improvement in the economics of the process could be foreseen if the heating time and/or the number of cycles could be reduced without impairment to either extrudability or metal quality.

The first objective, therefore, was to investigate the influence of these as variables on the mechanical and structural properties of the metal in the as heat treated condition (Ref. 1). Small differences in both structural and mechanical properties were observed, but the results were generally favorable and indicated that some reduction in the number of cycles and/or heating time would be possible without regression of as-extruded metal quality. On this basis, therefore, the subject experiment was initiated.

OBJECTIVE

The purpose of this experiment was to investigate the influence of reducing both the number of beta treatment cycles and the heat treating time employed for normal uranium billets on both the extrudability and the ultimate metal quality. The scope of the experiment was directed toward the potential improvement of the economics of the production process through decreasing the heat treating costs.

PROCEDURE

The practice employed conformed to the standard Mark V-B production process because of the broad experience developed in the extrusion and processing of this grade. The billet material was low-additive normal uranium. Experimental parameters were selected based on the results of Experiment U-176 (Ref. 1). Billets were beta heat treated (1365°F) by

single, double and triple cycles with heating times of 1/2, 3/4 and 1 hour. Billets were extruded at a constant interval and the preheat time for extrusion was held constant to avoid bias that might arise with different heating times.

Sixteen billets were extruded during the experiment, two of which were extruded in the as-cast condition. Billets conforming to the regular production practice were also extruded for control purposes. Approximately eight samples per extrusion were analyzed for grain structure and two per extrusion for machinability.

DISCUSSION OF RESULTS

Extrusion data and surface conditions are presented in Table 800-3-I. Contrary to previous experience, no significant difference is apparent in extrusion pressures as a function of the experimental variables. The surface condition for most of the tubes can be described as similar to the surface condition of the average production tube. Production tubes, on the other hand, often have surface defects similar to the worst conditions illustrated in Table 800-3-I. With the exception of the tubes extruded from the as-cast billets, therefore, no significant correlation is apparent between the extruded surface conditions and previous history.

Patches of rough surface were present on the as-cast billet extrusions, although these were spotty in nature. This roughness was more severe than that represented by an "orange peel" defect, but more similar in appearance to an "alligator hide" defect.

The macrostructure of all the heat treated billet extrusions were fine-grained and the grain structure is characteristic of that observed with the regular triple beta heat treated billet extrusions (Fig. 800-3-1). The differences observed in the grain structure of the billets after heat treatment (U-176) do not appear to influence the grain structure that develops in the metal after extrusion.

The macrostructure of the as-cast billet extrusions is heavily banded in a "whorl" type pattern (Fig. 800-3-2). Examination of the microstructure shows heavily banded areas of fine grain texture dispersed in an as-cast matrix. The co-existence of these two textures is probably the cause of the rough surface, possibly through a difference in elongation between the two during deformation or difference in contraction during cooling.

The surface of 10-inch-long samples from each tube was machined on the O.D. centerline to cleanup in order to determine depth of surface defects. The results of this analysis are presented in Table 800-3-II, which also includes inspection data of the as-extruded tubes. The O.D., I.D. and wall thickness dimensions of the extruded tubes were all within production tolerances. O.D. and I.D. circularities as well as I.D. concentricities are good with little overall variation. No significant differences are apparent in the hardness values.

Some increase in depth of penetration of surface defects is indicated in Table 800-3-II with increasing heating times and increasing number of cycles. This may be caused by salt penetrating further into defects in the billet surface with increasing time and through elongating and deepening cracks on the billet surface during quenching. The trend appears strong enough to be possibly significant, but not conclusive, due to the limited amount of data.

CONCLUSIONS

Extrusions from 7-3/8" O.D. billets heat treated with fewer cycles and/or shorter times appear to be comparable from the standpoint of extrudability, extrusion surface, dimensions and grain structure to the extrusions presently produced from billets triple beta heat treated for one hour. A reduction in the percentage of finished slugs rejected for non-cleanup appears to be a good possibility through shorter heat treatment time or fewer cycles.

Aside from differences in grain structure and surface defects, extrusions produced from the as-cast billets compare favorably with the heat treated billet extrusions. There is usually, however, an appreciable difference in the physical properties (tensile strength, plasticity, ductility, etc.) between a cast and a recrystallized texture so that when they are co-existent they respond differently to deformation and often cause localized strain areas. Unforeseen complications could result for this reason which are not predictable based on only two extrusions.

A reduction in production costs should be possible through adjusting or eliminating billet heat treating without significant alteration of metal quality or ultimate rejection rate of the machined slugs. The feasibility of completely eliminating heat treating could best be determined by an extended pilot test to examine performance and deviation in critical areas. In addition to the standard extrudability, surface quality, dimensions and grain structure analyses, comprehensive property evaluations should be made at the reactor site.

REFERENCES

1. Q. C. Carloni and L. Robins, "Heat Treatment of Uranium Mark V-B Extrusion Billets: Experiment U-176", Havens-238, June 29, 1964.

TABLE 800-3-I

U-229: EXTRUSION DATA

RUN NO.	BILLET NO.	BETA CYCLES	HEAT TIME-Hr.	EXT. PRESSURE		EXTRUSION SURFACE CONDITION
				UPSET	RUN	
1	93317T	2	1	2300	2025	Good
2	91005B	Cast	-	2325	2100	Rough-spotty
3	93426T	3	1	2300	2050	Light seams, slivers
4	91500B	2	1/2	2300	2050	Light seams
5	91900T	1	1/2	2350	2050	Good
6	93389T	2	1	2325	2050	Seams, gouges
7	93388B	3	3/4	2250	2025	Light to deep seams
8	91600B	1	1	2250	2025	Good
9	91500T	1	1	2350	2075	Light seams
10	93379T	2	3/4	2350	2075	Good
11	91900B	1	3/4	2375	2050	Good
12	93389B	3	1/2	2275	2000	Seams, gouges
13	91200B	Cast	-	2325	1975	Rough-spotty
14	93427B	3	3/4	2250	2000	Good
15	91600T	2	1/2	2300	2025	Good
16	93434B	3	1/2	2225	2025	Light to deep seams

Extrusion Date: March 16, 1964
 Billet Size: 7-3/8" O.D. x 2" I.D. x 20"
 Extrusion Size: 2.807" O.D. x 1.847" I.D.
 Heat Treat Temp.: 1365°F Media: Salt
 Preheat Furnace: Ajax Media: Salt
 Preheat Temp.: 1165°F Time: 1 Hour, 20 Min.
 Ram Speed: 18 inches/minute

NOTE: Light seams are frequently encountered on the surface of production tubing. The surface condition of most of the above tubes could, therefore, be classified as normal.

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TABLE 800-3-II

U-229: PROPERTIES & DIMENSIONS

BILLET NO.	CYCLES	HEAT TIME Hr.	HARDNESS R _C	OVALITY-EXTRUDED				ECCENTRICITY*		CLEAN UP DIMENSIONS - O.D.	
				O.D.		I.D.		EXTRUDED		MAX.	MIN.
				MAX.	MIN.	MAX.	MIN.	MAX.	MIN.		
91005B		As-cast	85.6	.011	.006	.013	.010	.013	.012	2.776	2.768
91200B		As-cast	85.2	.013	.009	.009	.004	.008	.005	2.715	2.711
91900T	1B	1/2	84.8	.016	.008	.010	.007	.004	.002	2.777	2.763
91900B	1B	3/4	85.1	.012	.007	.016	.012	.006	.006	2.779	2.763
91600B	1B	1	85.5	.012	.012	.010	.007	.016	.007	2.748	2.734
91500T	1B	1	85.5	.010	.006	.011	.003	.011	.007	2.783	2.783
91500B	2B	1/2	85.0	.012	.008	.018	.011	.016	.004	2.779	2.667
91600T	2B	1/2	84.6	.014	.012	.004	.003	.009	.007	2.770	2.767
93379T	2B	3/4	85.5	.010	.009	.021	.002	.015	.008	2.767	2.767
93389T	2B	1	85.0	.012	.006	.009	.007	.010	.007	2.745	2.581
93317T	2B	1	84.8	.016	.015	.023	.009	.022	.015	2.739	2.721
93389B	3B	1/2	85.3	.010	.010	.020	.004	.019	.013	2.770	2.569
93434B	3B	1/2	85.0	.008	.005	.008	.008	.009	.005	2.666	2.590
93427B	3B	3/4	85.0	.010	.005	.006	.005	.023	.006	2.750	2.739
93388B	3B	3/4	85.6	.012	.012	.010	.007	.016	.007	2.757	2.559
93426T	3B	1	85.5	.009	.006	.030	.007	.015	.003	2.757	2.655

* Eccentricity - 1/2" wall thickness variation.

Machined slug size O.D. - 2.682".

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(a) Transverse Macrostructure of a Sample Extruded From a Heat Treated Billet.

Photo No. HL64-081

Mag. 1X

(b) Transverse Microstructure of Sample Above at Midwall Showing Banding of the Fine Equiaxed Grains.

Photo No. HL64-084

Mag. 100X

Fig. 800-3-1 - Typical Grain Structures, U-229. Extrusion From Heat Treated Billet.

(a) Transverse Macrostructure of Sample Extruded From An As-Cast Billet.

Photo No. HL64-078

Mag. 1X

(b) Transverse Microstructure of Sample Above. Note the As-Cast Structure and the Heavy Banding of Fine Recrystallized Grains.

Photo No. HL64-082

Mag. 100X

III. PROJECT 800-10 - EXTRUSION PIERCING DEVELOPMENT

PROGRESS REPORT ON THE PIERCING OF NORMAL URANIUM BILLETS FOR THE EXTRUSION OF MARK V-B TUBING

BY: C.A. Scharschu

INTRODUCTION

At the present time billets are prepared for the extrusion process by either hollow casting or by solid casting and drilling the I.D. hole. The piercing process produces the I.D. hole at a significantly less cost than either of the above methods by eliminating either the casting cores or the drilling scrap loss.

Initial experiments indicated that no mechanical difficulties are experienced while piercing but that wall variations (eccentricity of the I.D.) of the billets were higher than those obtained by casting hollow or drilling. The most recent experiments contained herein (RMI experiments U-221 and U-234) are the first attempts to determine the influence of press tooling alignment upon the eccentricity of pierced I.D.'s.

DISCUSSION OF RESULTS

Two inch I.D.'s were pierced in 7-3/8" O.D. x 20" large solid billets. Four of these billets were pierced and extruded to standard size Mark V-B tubing. Data are given in Table 800-10-I.

Stem alignment relative to the liner was less than .050" deviation in any direction at each end of the liner in each experiment. The mandrel holder used for piercing was checked for straightness. It was found to be bowed or bent .008" at the rear, causing the front end to be about .020" off center. The concave direction of the bow is at nine (9) o'clock (looking from front to rear of the billet) when the holder is in the press. Although the front end of the mandrel was 1/8" to 1/4" below center when seated in the holder, it was perfectly level in both instances when the front was positioned in the dummy block I.D.

Pierced billet dimensions shown in Table 800-10-II are typical of the magnitude and direction of I.D. eccentricities (i.e. one-half the wall thickness variation) experienced in recent investigations. No correlation has been found between stem eccentricity relative to the liner versus billet I.D. eccentricity. While some exceptions exist, the recent tendency is for the mandrel to rise during piercing, producing the thin wall at or near twelve (12) o'clock. The bow in the mandrel holder, furthermore, does not appear to have any significant influence on the radial direction of the pierced I.D. eccentricities.

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The mandrel holder threads were worn prior to piercing for U-221. The threads on both the mandrel and holder stripped during piercing and the head of the holder was replaced prior to piercing for U-234. The threads on both the holder and mandrel were damaged during this experiment and the mandrel end upset against the bottom of the mandrel holder hole. The position is indicated by "B" in Fig. 800-10-1. The mandrel had also been bent in the neck ("A" in Fig. 800-10-1) to the point that there was over 1/4" run out at the front of the mandrel when revolved in a lathe.

The above indicated insufficient bearing surface between the mandrel and holder allowing excessive stress to be placed on the threads during piercing. It further suggests that the resulting poor fit between the mandrel and holder had caused the bending of the mandrel which possibly resulted in or contributed to the eccentricities observed. The holder head and mandrel were, therefore, redesigned to change the bearing surface from the bottom to the front face of the holder which removes all stress in the threads during piercing and increases the bearing surface (Fig. 800-10-1). This tooling was used for piercing on experiment U-253, the results of which are still incomplete. Although the mandrel was nearly level as seated in the holder and there was no play between the mandrel and mandrel holder, preliminary tests have not shown any substantial improvement in the pierced concentricities with this tooling.

The investigation to date as to the influence of press and tooling alignment on pierced eccentricities has proved negative. If any relationship exists, it is of a lesser magnitude than that presently experienced and, therefore, masked. All alignment measurements have been made under static conditions, however, and may not reflect the actual alignment under load conditions. The increase in eccentricity variation, on the other hand, is not as great as it would seemingly appear. If the variation in eccentricity is considered as a deviation of the I.D. centerline from the O.D. centerline, the greatest variation occurs along the vertical or 12-6 o'clock axis. The variation that occurred along this axis during the initial experiments was above and below the O.D. centerline while in recent experiments it is entirely above the O.D. centerline. The variation along the horizontal centerline or 3-9 o'clock axis is negligible to the vertical variation and has remained fairly well centered on the vertical axis. The primary difference between the initial and recent experiments, therefore, is essentially a shift in pattern rather than an increase in the overall variation.

This would then suggest a change of press and/or tooling alignment under loading involved through upsetting and/or through piercing. It appears possible, therefore, that the effort directed by the stem or mandrel during upsetting or piercing is at an upward angle to the liner centerline under pressure. A possible cause of the exceptions to the general pattern noted may be due to un-uniform metal flow in back extrusion during piercing. Since no regularity of pattern could be anticipated from this source, it could explain the discrepancies experienced. Experiments have been outlined to investigate both of these potentials.

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To date, two (2) billets have been sectioned longitudinally and nine (9) transversely. Longitudinal and transverse sections of the pierced and extruded tubes have also been examined. In addition to physical measurements, these sections have been examined for surface and metal quality. In every instance, the I.D. surface quality of both the pierced billets and extruded tubes was very good. No evidence of open or rough surface has been observed. The area of the billet sections adjacent to the I.D. have shown no signs of cracks, voids, large inclusions or metal discontinuities. Macro-structure of the pierced and extruded tubes appears comparable to that of hollow billet extrusions. Small I.D. radial cracks are evident on two (2) samples of one (1) tube, however. No significant difference in grain structure adjacent to the tube I.D. appears to have resulted through metal upset during piercing.

Eccentricity data for the pierced and extruded tubes are presented in Table 800-10-III. While good concentricity was not anticipated for the extrusions, the purpose was to check for possible technical or operational difficulties that might exist from a production standpoint. No major difficulties are foreseeable, although the number extruded are perhaps too few for a reliable analysis.

CONCLUSIONS

The following conclusions appear to be justified, based on the investigation to date:

1. The practice under investigation appears to have the potential to produce concentricities within production tolerances. This can almost be accomplished by centering the vertical deviation on the horizontal axis.
2. Determination of the cause for the shift in vertical deviation will probably prove beneficial in reducing the overall variation along the vertical axis.
3. The practice appears to be generally adaptable to piercing and extruding in one operation on a production basis (using a cone and flow die) if the concentricity can be held to specifications.

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TABLE 800-10-IEXTRUSION DATA

U- NO.	RUN NO.	PRESSURES				REMARKS
		PIERCING		EXTRUDING		
		UPSET	PIERCE	UPSET	RUN	
221	1	1650	1050			Shear die - no cone
"	2	1500	1000			" " " "
234	1	1500	1100			" " " "
"	2	1500	1100			" " " "
221	3	1500	1150			Shear die and cone
"	4	1500	1150			" " " "
234	3	1500	1200			Flow die and cone
"	4	1500	1200			" " " "
221	5	1300	1100			" " " "
"	6	1200	1150			" " " "
234	5	1500	1200	1700	1650	Pierce and extrude
"	6	1500	1100	1800	1600	" " " "
221	7	1200	1150	3200	2500	" " " "
"	8	1200	1175	2700	2350	" " " "

Material: Normal Uranium

Billet Size: 7-3/8" O.D. x Solid x 20

Mandrel Speed: 60 - 80 IPM

Ram Speed: 18 IPM

Tube Size: 2.807" O.D. x 1.847" I.D. x Tube

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TABLE 800-10-IIPIERCED DIMENSIONS

U- NO.	RUN NO.	O.D. VARIATION		WALL VARIATION			
		FRONT	REAR	FRONT		REAR	
				VAR.	CLOCK*	VAR.	CLOCK*
221	1	.004	.007	.088	12:00	.026	3:00
"	2	.009	.006	.216	10:00	.049	2:00
234	1	.024	.023	.131	5:00	.023	3:00
"	2	.028	.026	.108	12:00	.046	9:00
221	3	.006	.008	.237	2:00	.028	12:00
"	4	.005	.006	.144	12:00	.052	12:00
234	3	.027	.022	.128	2:00	.127	1:00
"	4	.003	.003	.110	1:00	.044	1:00
221	5	.007	.006	.293	12:00	.049	12:00
"	6	.005	.011	.232	1:00	.021	12:00

*Clock position of thin wall.

TABLE 800-10-IIIEXTRUDED TUBE WALL VARIATION

POSITION	U-221 94852-B RUN #7	U-221 94864-B RUN #8	U-234 94853-T RUN #5	U-234 94856-T RUN #6
1 - Front	.222"	.021"	.077"	.109"
2	.235	.035	.038	.066
3	.153	.018	.035	.083
4 - Rear	.051	.012	.053	.097

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ORIGINAL

- A. Mandrel Bending in This Area.
- B. Mandrel Upset in This Area.

REDESIGNED

Fig. 800-10-1 - Piercing Mandrel and Mandrel Holding Design

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IV. PROJECT 800-11 - DYNAPAK FORMINGSUMMARY OF THE DYNAPAK EXTRUSION OF URANIUM TUBES

BY: Q.C. Carloni
L. Robins

SYNOPSIS

Extensive development in the past few years has been devoted to the field of "high energy rate" forming. The status of the program performed at the Bridgeport Brass Company to develop this program for uranium tubes is summarized. The Model 1800 horizontal DYNAPAK machine was employed.

A description of a possible DYNAPAK extrusion production plant and rough estimates of the installation and operating costs are presented. The DYNAPAK fabrication route shows the potential to become economically competitive with the conventional extrusion route now employed in tube production. This assumes that late model equipment, such as the Model 1220 DYNAPAK machine, is employed.

DYNAPAK extrusion has been successfully employed to produce single slug length tubes of the (a) Mark VB-0 and (b) I&E sizes, relatively thin and thick walled tube types, respectively. Double slug length I&E tubes were produced in quantity under production test conditions, however, a warpage problem existed. The Model 1800 machine did not possess sufficient energy to fully extrude the double slug length Mark VB-0 tube. Details of this study may be obtained in BRB-83 entitled, "Summary of the DYNAPAK Extrusion of Uranium Tubes", by Q.C. Carloni and L. Robins, dated September 11, 1964, Unclassified, available from DTIC.

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V. PROJECT 801-32 - PICATINNY ARSENAL PROGRAMSUMMARY REPORT - FABRICATION OF CUBICAL ITEMS

BY: R.F. Kohanski
R.D. Heiser
Q.C. Carloni

SYNOPSIS

A fabrication process has been developed and demonstrated whereby cubical items can be produced in large quantities. The process route consists of extrusion, warm drawing and cold heading to a final cube size. Cubical items ranging from 0.276" square, 100 grains to 0.187", 26 grains have been fabricated by this technique. Several special shapes, 0.150" square x 11.0" long and tapered cubes with a concave bottom and a convex top, were also fabricated during the course of the program.

Detailed accounts of the fabrication procedure employed and the test data are presented including a recommended fabrication route with necessary equipment, process parameters, tooling and tool material in BRB-84 entitled, "Summary Report - Fabrication of Cubical Items", by R.F. Kohanski, R.D. Heiser and Q.C. Carloni, dated September 28, 1964, Confidential-DI.