Dr. Convey

[redacted]

Declassified
Déclassifié

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 66-10

EXTRUSION OF URANIUM ALLOYS

by

J. A. PERRY AND E. WINKLER

PHYSICAL METALLURGY DIVISION

COPY NO. 15

FEBRUARY 16, 1966

1167

Declassified
Déclassifié

Restricted Government Use Only

Mines Branch Investigation Report IR 66-10

EXTRUSION OF URANIUM ALLOYS

by

J.A. Perry* and E. Winkler**

- - - - - -

SUMMARY OF RESULTS

The extrusion of three alloys of uranium was successful in the gamma phase. The alpha phase was too stiff for practical work. These alloys were extruded unclad contrary to the experience of others. The experience demonstrated that scale losses and tool wear were not excessive with the heating conditions and tool material chosen. Alpha swaging of the extruded product is not likely to be commercially useful. A prediction is made for the future industrial extrusion of similar alloys in small sizes.

---

* Section Head and ** Scientific Officer, Metal Forming Section, Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

INTRODUCTION

At the request of the Directorate of Weapons and Engineering Research, Defence Research Board, (DRB), Ottawa, Ontario at a meeting September 16, 1965, the Physical Metallurgy Division undertook to produce worked rods of several uranium alloys for Dr. Tardif of Canadian Armament Research and Development Establishment, (CARDE), Quebec, P.Q. The billets were to be provided by Eldorado Mining and Refining Ltd., to dimensions agreed upon at the meeting.

The alloys are listed in Table 2.

While the Metal Forming Section has had considerable experience in working natural uranium, only one billet of the uranium-2% molybdenum alloy had been extruded. A cautious approach was therefore considered necessary. The meeting very generously agreed that two billets of each grade were to be provided, anticipating a yield of about 50%. The order required 25 pieces, 9/16 in. round by 6 in. long of each of three compositions.

Problem

It was proposed to extrude 3-5/16 in. diameter unclad cast billet of 6 to 8 in. lengths from a 3-1/2 in. container to 3/4 in. rounds. The extrusion ratio of 22:1 was felt to be high, particularly if the extrusion temperature was to be in the high alpha range. At ratios above 16:1, excessive work energy input can raise the temperature into the beta region where extrusion is, for practical purposes, impossible. Lower temperature alpha extrusion is likewise very difficult due to the rapid increase in strength with falling temperatures.

Gamma extrusion in unalloyed uranium takes little force but the very plastic extrusion is most difficult to handle out of the press. There is usually considerable scaling and dimension loss and, if billets are too long, a risk of beta transformation in the die during the latter part of the extrusion cycle.

The 3/4 in. size was, however, dictated by swaging machine capacity and personal safety of the operators. Fortunately, the extrusion press has somewhat greater capacity when using the 3-1/2 in. container than the normal working limits of comparable industrial equipment.

Billets

The billets, as-received, were sawn on at least one end, had a good surface and showed no defects on the cut surface except for No. 168. This billet had two small central voids, the largest 1/64 in. by 1/8 in. and shallow. A gammagraph made with a 1-1/2 Curie source failed to show this defect, the source being too weak.

EXTRUSION

Billet No. 156 (U-2% Mo) was heated in a retort in commercial argon changed at a rate of 80 net retort volumes per hour for 2-1/2 hours. Both figures were chosen arbritarily. The furnace temperature was 650°C, which is in the beta plus gamma range. Billet and furnace colours matched at extrusion time. Scaling of the billet was negligible.

Extrusion pressures were very high because while the billet was upset quickly, the extrusion was deliberately slow to avoid temperature rise. As a result, the butt chilled and only 38 in. was extruded. Container temperature was 450°C. As it was, the trailing 15 in. of the extrusion was undersize, possibly due to beta formation in the die land. Extrusion surface was good and there was no die damage.

The extrusion die was cast to the profile in Figure 1 of a proprietary alloy containing approximately 70% Ni, 8% Al, 22% Mo. A steel dummy was used with a fiberglass matt separator. The lubricant was graphite in "Bentone" grease.

Billet 168 (U-2% Mo) was heated at 780°C in the gamma phase under the same conditions as before. A heated graphite block (approximately 600°C) was used between billet and dummy. Extrusion product rate was about 16 in. per second, and pressures were well within the capacity of the press. A small hollow butt remained. Figure 2 is from a gammagraph of the graphite penetration of the "extrusion defect". Surface and size were acceptable for swaging.

Billets 165A (U-1% Mo-1% Zr-1% V) and 166B (U-1% Mo-0.5% Zr, 0.5% V-0.5% Nb) were extruded under similar conditions to No. 168 with satisfactory results. The butt scrap was slightly smaller as the graphite block was heated to the furnace temperature. It should be explained that in the use of a hot graphite block, there is a critical temperature at which the block itself extrudes sufficiently to separate the extrusion from the butt. The extrusion is then expelled from the press violently and may damage itself, the furniture or the onlookers. This violent separation occurred in both the latter cases. Fast action had to be taken to hand-straighten the hot product to make it acceptable for swaging.

The die, after being used for three gamma extrusions, showed slight local washing and pick-up and will be re-conditioned. However, this material is obviously superior to the iron-base AISI, H-14 material commonly used in non-ferrous work.

Figure 3 is adapted from the load-displacement indicator on the press. A malfunction allowed only the maximum pressure of extrusion in No. 166B to be recorded. The relative extrusion pressures of No. 156 and 168 should be noted. The ratio of alpha to gamma strength is about 2.5:1. For unalloyed uranium this ratio can be as great as 10:1. It should be noted that so called "extrusion constants" often quoted are lumped constants and include a very variable and large factor in friction.

All extrusions were covered with E.F. Houghton No. 980 salt and allowed to cool overnight. This reduces oxidation and possibly danger of quench cracking.

SWAGING

The extruded bars were cut into 8-1/2 in. lengths and hot swaged to 9/16 in. nominal size, 13 in. long through the following passes.

TABLE 1

Die Size (in.)	Reduction of Area From Previous Size %
0.735 (Extrusion)	
0.700	9.2
0.675	6.5
0.630	12.0
0.590	12.0
0.555	12.0
Total reduction from 0.735 to 0.555 = 42.6	

Furnace temperatures varied from 450°C to 500°C. The original soak was 30 minutes and reheats between passes were 10 minutes. The swaging operators were given liberty to adjust time and temperature between the extremes of difficult swaging and excessive oxidation. The work temperatures may not be true to the furnace because of production rate, die chilling and delays. In general, the 2% Mo alloy was the easiest to work and the others much more difficult. The scaling rate of the 2% Mo was apparently higher.

Swaging dies were low angle, long land patterns with little ovality in the land. Lubricant was a thin mix of graphite and SAE 50 machine oil.

DISCUSSION AND RECOMMENDATIONS

At the time of writing, the order was complete and there remained one billet of each composition. Permission had been obtained from Dr. Tardif to attempt to extrude this balance directly to 9/16 in. rounds.

Swaging is an expensive operation and very hard on manpower. With the best of equipment and careful operation, one broken finger resulted. Mechanical holding and feeding does not appear to be useful. Production rate by hand was about 4 lb per man hour.

Gamma examination of the finished swaged bars was left to CARDE due to the size of the Mines Branch source and the haste to ship.

Due to the apparent strengthening of the gamma phase by alloys and in view of U.S. information very recently received, the 3-1/2 in. billets would be copper clad in the future without too great fear of the sheath enfolding in the extrusion.

Instructions have been sent to Eldorado to use 1/16 in. cladding and an outside diameter of 4-3/16, measured on the copper, for two billets to be extruded from the 4-1/2 in. container. Normally, 4-5/16 in. would be acceptable but there is some risk of distortion of gamma uranium during heating and handling. A deformed billet has little chance of entering the container without damage.

The die design shown in Figure 1 produces in both alpha and gamma a separated shear cone of uranium. Use of such tools with clad billets would almost certainly strip the cladding. For the 4-1/2 in. experiment, a 45 degree die cone of low carbon steel will be used, along with a large radius shear die. The proposed tools are shown in Figure 4. The diameter chosen assumes that the copper sheath will be reduced in thickness proportional to the diameter ratio of billet and extrusion.

PROPHECY

Were large volume extrusion of small rounds to be undertaken in future, it is suggested that a vertical high speed hydraulic press be used to extrude small billets with a length to diameter ratio of about 2:1 maximum. A small extrusion ratio would be desirable. Heating would be by induction in an inert atmosphere and the extrusions would be led into a similar atmosphere. The billets would, of course, be unclad. A shear die would give clean, freshly developed surfaces. It would be hoped that suitable die and container materials could be found that would resist solution by gamma uranium. Operation would be completely automated. The press should also be capable of indirect extrusion. This would have the advantage of decelerating the extrusion against the force of gravity, thus avoiding a complicated run-out system. Container wear might also be reduced. Gas flushing would be simplified.

Rolling of small uranium rounds presents temperature and oxidation control problems on conventional mills. It is doubtful if a limited application such as this material has would justify set up of such a mill without auxillary business.

JAP:EW:lc

TABLE 2

Weight Balance

Billet	Grade	Length (in.)	Weight (lb)	Unswaged Extrusion (lb)	Butt and Tail Scrap (lb)	Usable Butt (lb)	Sound 9/16 in. Swaged Bars	Metal in Oxide By Diff. (lb)
156 Alpha	2% Mo	6	36.5	0	3.00	23	8.00 *	2.50
168	2% Mo	6	36.2	0	5.00	0	28.50 *	2.70
165A	1% Mo, 1% Zr, 1% V	6	35.4	0	6.00	0	26.75 *	2.65
166B	1% Mo, 0.5% Zr, 0.5% V, 0.5% Nb	8	44.4	11.75 *	2.75	0	27.00 *	2.90

Oxide recovered, mixed with salt - 11.00 lb.
Weights to Nearest 0.25 lb.
* Items shipped to CARDE Feb. 8/66.

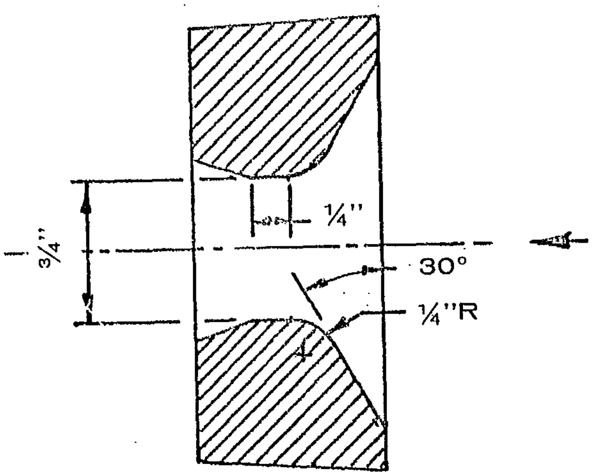

Figure 1 - ¾ in. Extrusion Die for 3½ in. Container

Full Size

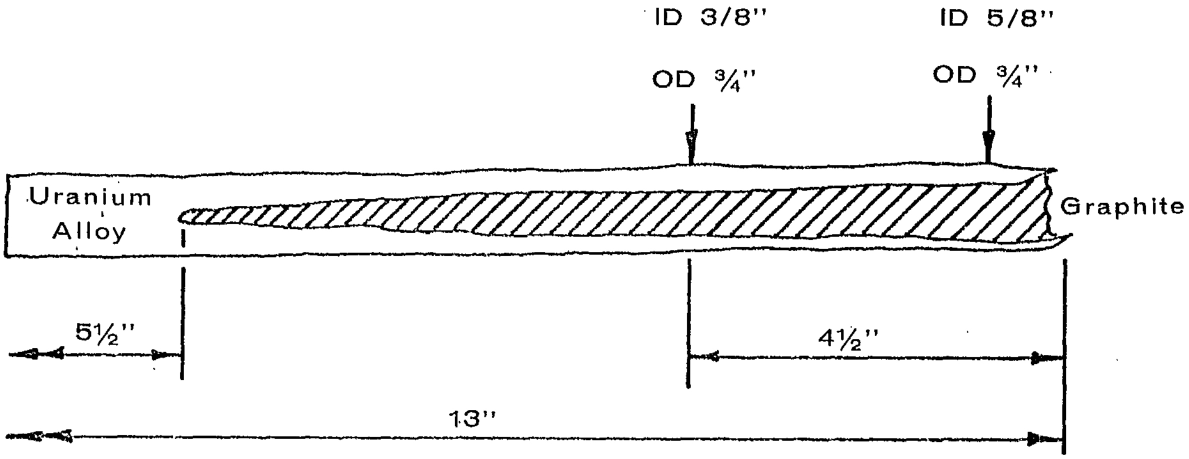

Figure 2 - Sketch from Tail End Radiograph of Billet No. 168

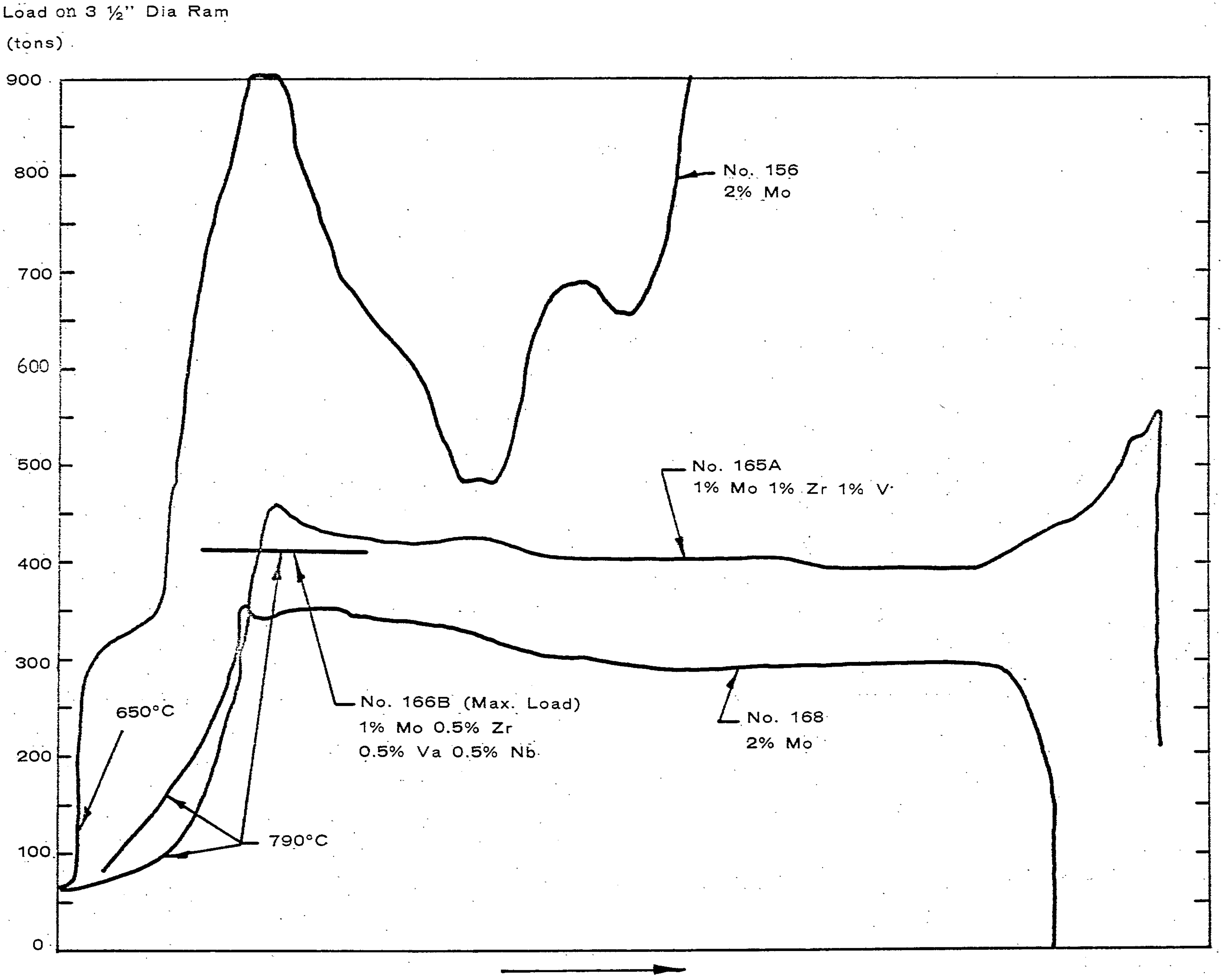

Figure 3 - Displacement

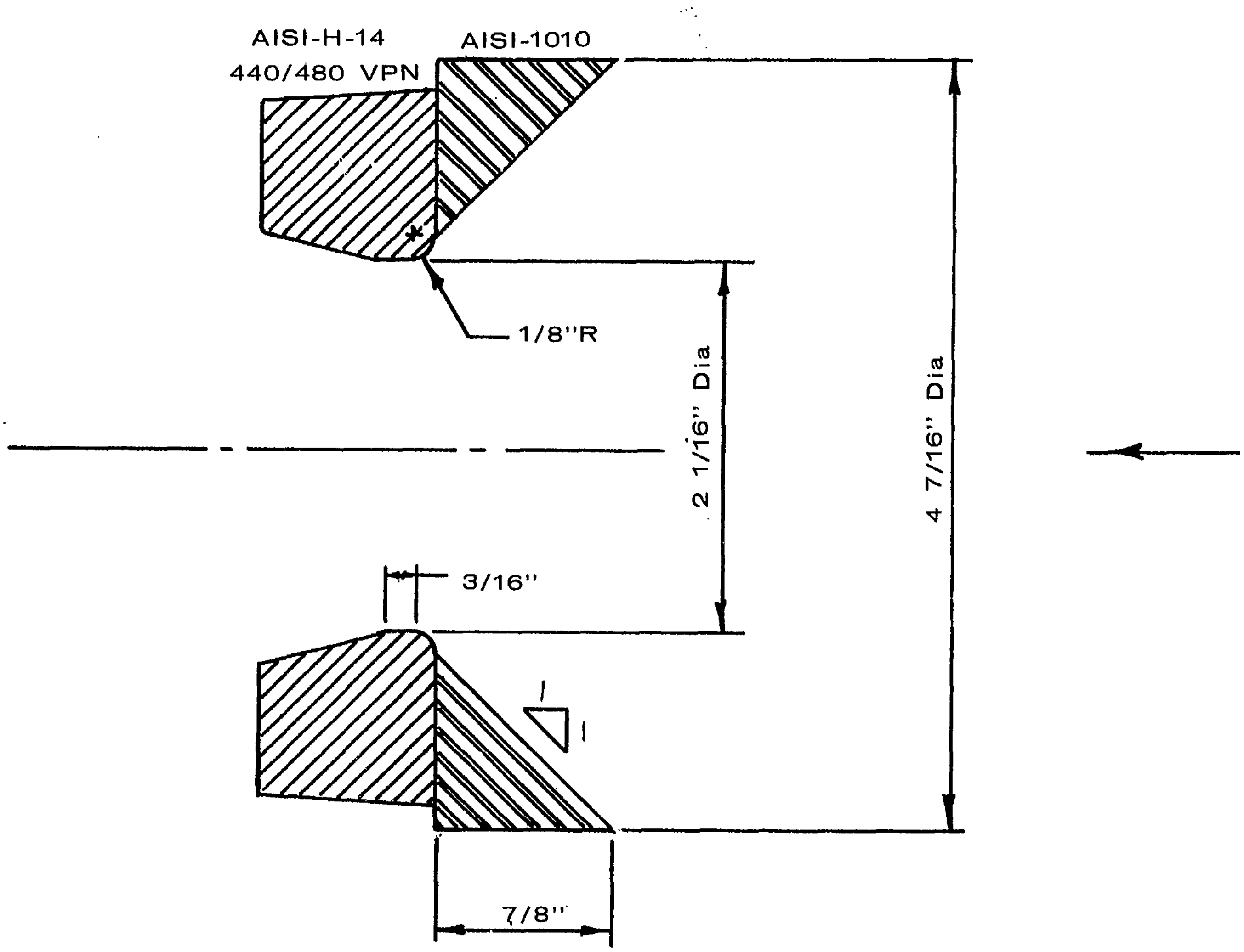

Figure 4 - 2-1/16 in. Extrusion Die and Cone for 4-1/2 in. Container

Full Size