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PROGRAM FOR THE DEVELOPMENT OF EXTRUDED BERYLLIUM SHAPES

L. M. Christensen
R. R. Wells

NORTHROP CORPORATION
Norair Division
Contract AF 33(600)-36931

Final Technical Engineering Report
20 April 1958 - 31 December 1961

Successful completion of this extruding process development has demonstrated techniques by which aircraft structural shapes can be extruded from unalloyed beryllium. Pilot production of five 20 foot lengths of a structural channel 1.50 wide by 1.00 high with a nominal wall thickness of .060 inches proved acceptability and reproducibility of the developed process.

BASIC INDUSTRY BRANCH
MANUFACTURING TECHNOLOGY LABORATORY

Aeronautical Systems Division
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

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FOREWORD

This Final Technical Engineering Report covers all work performed under Contract AF33(600)-36931 from 20 May 1958 through 15 December 1961. The manuscript was released by the author on 22 January 1962 for publication as an ASD Technical Report.

This Contract with Norair Division of Northrop Corporation, Hawthorne, California was initiated under ASD Manufacturing Methods Project Nr. 7-644. It was administered under the direction of Mr. T. S. Felker of the Basic Industry Branch of the Manufacturing Technology Laboratory, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio.

Mr. L. M. Christensen of Norair's Materials Sciences Laboratory was the engineer in charge. Others who contributed in the performance of the research and in the preparation of this report included Drs. R. L. Jones and R. D. Johnson and Messrs. R. R. Wells, W. R. Roser, A. L. Scow, and K. Kuschell. This report has been assigned Norair Report number NOR-62-25.

Major extruding development contributions were made by Nuclear Metals, Inc. of Concord, Massachusetts under subcontract to Norair. Messrs. J. M. Siergiej and V. Nerses were engineers in charge of this development effort. Providing assistance in their respective areas of interest of the subcontract activity were, among others, Dr. Kauffman, Mr. J. L. Klein, and Mr. Paul Loewenstein.

Other subcontractors who participated in portions of the research and development were the Beryllium Corporation, Reading, Pennsylvania and Wolverine Tube, Detroit, Michigan. The beryllium material used for the majority of the effort was provided by Brush Beryllium, Cleveland, Ohio.

The primary objective of the Air Force Manufacturing Methods Program is to develop on a timely basis manufacturing processes, techniques and equipment for use in economical production of USAF materials and components. This program encompasses the following technical areas:

Rolled Sheets, Forgings, Extrusions, Castings, Fiber and Powder Metallurgy
Component Fabrication, Joining, Forming, Materials Removal
Fuels, Lubricants, Ceramics, Graphites, Non-metallic Structural Materials
Solid State Devices, Passive Devices, Thermionic Devices.

Your comments are solicited on the potential utilization of the information contained herein as applied to your present or future production programs. Suggestions concerning additional Manufacturing Methods development required on this or other subjects will be appreciated.

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PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER

JACK R. MARSH
Assistant Chief
Manufacturing Technology Laboratory
Directorate of Materials and Processes

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I INTRODUCTION

The Norair Division of Northrop Corporation, was awarded a prime contract, AF 33(600)-36931, by the Manufacturing Technology Laboratory of ASD to determine the feasibility of bare or unclad extrusion of beryllium shapes, and subsequently to develop commercially feasible extrusion methods. The objective of the program was to extrude beryllium shapes of aircraft quality comparable in size, shape, and tolerances to their aluminum alloy counterparts.

The conventional method for extruding beryllium had been to jacket the billet in a thick evacuated steel can which served not only to prevent oxidation and minimize the toxicity hazard, but also to keep the beryllium from direct contact with the tooling, thus preventing damage to the extrusion die. In an attempt to make the process more economical, and to generate complex beryllium shapes to closer tolerances, unclad beryllium extrusions were attempted extensively under this program. As a substitute for the steel jacket, several alternates were tried including the use of molten glass based on the Ugine-Sejournet process which NMI was authorized to employ as a sub-licensee.

The subcontractors were requested to use their best efforts to develop extrusion techniques for the production of 20 foot lengths of the U-shape channel having tolerances and surface quality comparable to similar extruded shapes of aluminum.

Nuclear Metals Incorporated of Concord, Massachusetts and the Beryllium Corporation of Reading, Pennsylvania were selected to conduct work of an experimental nature to determine the feasibility of such extrusions.

After competitive efforts to achieve Phase I objectives, Nuclear Metals was selected to continue experimentation. Subsequently, extensive efforts were made to perfect the process by improvements of die material, lubrication, heating and die design and by faster and more variable press speeds.

Successful completion of program goals was achieved by adaptation of a refinement of the clad technique.

II CONTRACT SYNOPSIS

The following brief summary of primary contract work elements is presented to explain continuity of effort.

PHASE I

Survey of the aircraft industry to select configurations and specifications for the extrusions to be produced in this program. Two subcontractors are to be selected to participate in the development of extruding techniques to produce the simplest selected shape. The most successful of these subcontractors will produce a pilot quantity of five extrusions.

The pilot extrusions will then be tested to show the acceptability of the quality of the beryllium extrusions produced.

PHASE II

Upon approval of work under Phase I, the contractor will further develop beryllium extrusion techniques by selecting the most qualified of the two subcontractors of Phase I to extend his techniques to develop Category II - a more complex shape. Production and testing of the pilot quantity of five extrusions will proceed as in Phase I.

PHASE III

Upon approval of Phase II work, the program will proceed to further develop beryllium extrusion techniques to produce Category III - the most complex of the selected shapes. Again, pilot production and testing will follow as in Phase I.

III CONCLUSIONS

1. Composite lubrication of metallic and liquid (nonglass) lubricants is better adapted to utilization with beryllium than is bare glass lubricated extruding by the Ugine-Sejournet technology.

2. Composite lubricant technology is more easily optimized within the limits of the process than is glass lubricant extrusion.

3. Flat faced dies are best for the glass lubricant approach while a conical entrance is best for composite lubes.

4. It is not necessary to seal or evacuate the outer metallic shell to yield a good product or to maintain safe toxicity limits.

5. The tendency for cracking or rattlesnaking is greatly reduced by composite lubricant technology.

6. Both an internal straightener and an auxiliary track type straightener are not only practical, but very beneficial, even when working with a crack prone material such as beryllium.

7. Fillet radii as small as 0.03 inch radius can be produced in beryllium.

8. The technology established under the auspices of this program with the difficult to extrude U-channel section is adaptable to other airframe shapes.

9. It is technically feasible to produce beryllium extrusions as thin as 0.06 inch with the same tolerances and surface quality as their aluminum alloy counterparts.

10. As the physical quality of beryllium extrusions improves, so does the tendency for better mechanical properties.

11. As the mechanical properties increase, apparently with improvement in quality, so does the uniformity of those mechanical properties.

12. The transverse yield and ultimate tensile strengths are about 50 percent of those in the longitudinal direction.

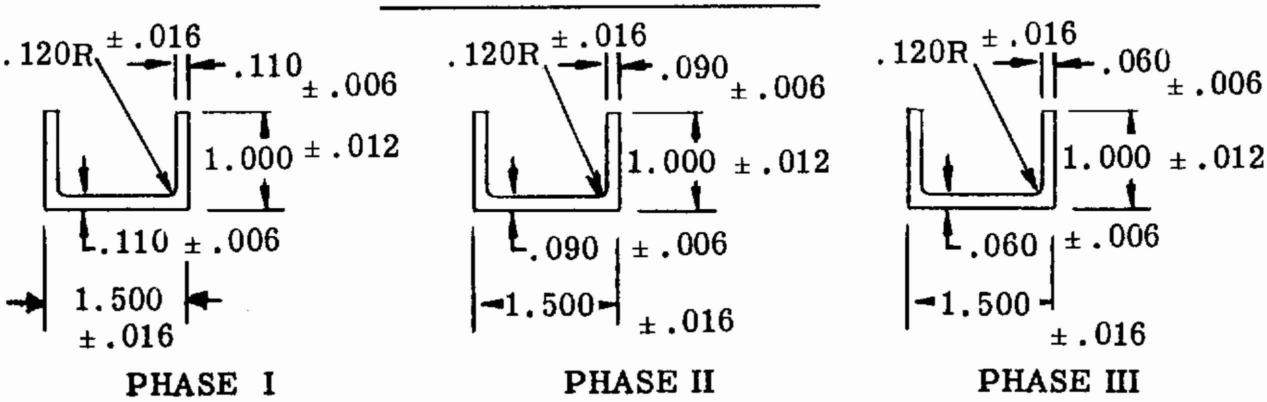
13. The tensile ultimate strength and elongation of the 0.06 thick extrusion increases from a low at the front end of the extrusion up to values at the back end similar to those found for other thickness extrusions. Tensile properties were quite uniform in the 0.12 and 0.08 extrusions.

14. As the difference between ultimate tensile strength and yield strength, $\Delta (F_{tu} - F_{ty})$, increases, the elongation increases.

IV PRODUCT SPECIFICATIONS & OPTIMUM PROCESS

The following section is presented to permit the reader to be able to quickly evaluate the best product and optimum process conditions. To provide brevity and not defeat the purpose only the most pertinent factors are presented. Further detail is given elsewhere in the report with reference given in some instances.

TARGET SHAPE SPECIFICATIONS



The shape selected for experimentation was a channel shape as shown above. It was selected largely because of its considerable complexity from the standpoint of lubrication and metal flow. In line with ultimate airframe requirements the increasing complexity of each phase was accomplished by progressively thinning the cross-sectional thicknesses.

In addition to the target tolerances shown in the sketches above other criteria such as straightness, twist, surface finish, etc. were to conform to tolerances of equivalent sections in aluminum.

For complete details of requirements see Appendix III, Page 195.

DIMENSIONAL QUALIFICATIONS OF OPTIMUM SHAPE EXTRUDED

The best dimensional integrity obtained was on the last extrusion pushed in the program. The thickness tolerances were most critical and were measured along the 20 feet of length as follows:

EXTRUSION #34

	L.H. Leg Thickness (Target .060 ± .006)	R.H. Leg Thickness (Target .060 ± .006)	Base Thickness (Target .060 ± .006)
Front	.061	.060	.064
℄	.060	.058	.063
Aft	.058	.058	.061

Beside the dimensional variation obtained along the length of an individual extrusion it is interesting and informational to study the deviation from extrusion to extrusion. This can be done by study of Table XII which appears on Page 167. Results were quite consistent.

PHYSICAL AND METALLURGICAL PROPERTIES OF OPTIMUM SHAPE EXTRUDED

The best mechanical properties obtained were on Extrusion #12 (thickness) of .110). Averages of those results from specimen at front, mid portion and aft end are shown below in the first two entry lines. Also shown are the averages for the .090 and the .060 thick sections:

Extra Thickness	Direction	Fty (KSI)	Range (KSI)	Fty (KSI)	Range (KSI)	Elong. %	Range
.110	Longitudinal	52.5	50.7 to 54.7	99.9	94.0 to 104.8	5.7	4.5 to 7.0
	Transverse	28.3	26.4 to 31.6	52.4	48.9 to 55.8	.69	.25 to 1.4
.090	Longitudinal	50.3	47.6 to 54.1	96.2	88.0 to 101.4	7.2	3.5 to 9.5
	Transverse	28.0	23.2 to 31.7	56.4	53.4 to 59.5	2.0	1.0 to 3.0
.060	Longitudinal	49.6	47.8 to 51.7	-	62.9 to 102.8	-	1.5 to 9.0
	Transverse	27.2	22.8 to 31.8	51.4	45.5 to 56.5	1.17	.5 to 2.0

See Section XI on Page 149 for more complete details.

OPTIMUM EXTRUDING CONDITIONS

Salient features of extruding criteria of the optimized process are as follows:

Die Design

A conical approach die of a developed geometry to encourage smooth flow was established from many variations. In the evolution of the final die configuration it was necessary to further blend the entrance radii after experimental pushes in order to avoid clad rupture in the critical inside portion of the channel. See Figure #87, Page 140 for details of die design.

Die Material

M-2 steel and EDS cobalt base alloy die material was used interchangeably throughout the program. M-2 dies with an Rc hardness range of 54-57 resisted washout, but did often crack severely during extrusion. The cobalt base material exhibited plastic deformation, but was minimized with adequate support tooling.

Duplicast Die Company of Detroit cast the dies to shape by the Shaw process and the dies were finished at the Moczik Tool & Die Company, also located in Detroit.

Billet Material

Extrusion billets were prepared from pressed and sintered 200 mesh QMV beryllium powder. The round bar was procured from Brush Beryllium Corporation of Cleveland, Ohio.

Billet Temperature

During the final phases of the program billets were heated for three hours at temperatures ranging from 1700°F to 1875°F with 1850°F being predominant. The higher range of temperature was necessitated by pressure considerations associated with the higher extrusion ratios.

Extrusion Speed

Best results were obtained with the Nuclear Metals press operating at the maximum speed of which it was capable. This was a comparatively slow rate of approximately 120 inches for per minute ram speed.

Extrusion Pressure

Press tonnages required to effect an extrusion, ranged between 500 and 600 tons. With the container diameter of 3.04 inches, this resulted in a pressure exerted on the billet of approximately 150,000 psi.

CLADDING AND LUBRICATION PRACTICE DETERMINED BEST

The hot pressed beryllium stock was turned down to a 32 rms finish and encapsulated in a carbon steel sheath. The sheath was fabricated from a piece of seamless steel tubing with the I.D. lightly polished with a fine polishing paper. Wall thickness of the steel sheathing was .115 in. A 20 to 30 mil thick copper electroplate was deposited to the exterior of the steel container to which steel end caps had been tack welded. No attempt was made to seal or evacuate the capsule. See Figure #76, Page 123 for a detail drawing of composite billet coatings. The liner was swabbed with a mica base lube called "Necrolene" manufactured by Crawford Emulsions.

UNIQUE EXTRUDING CONDITIONS

Of considerable significance was the utilization of both an external and an internal straightener developed by Nuclear Metals. They functioned very successfully even with such a crack prone material as beryllium. See Figures 80 and 81 on Pages 128 and 129, for details of the straightening apparatus.

TOXICITY CONTROL

During the earlier extrusion effort in which beryllium was extruded bare except for the use of glass as a lubricant, the extrusion was emitted from the press into a catch tube with a vacuum line attached. Hoods drew fumes from the furnace area and also from above the container area of the press. In addition air monitors were placed at strategic locations and resulting air samples were analyzed.

At no time did the contamination exceed allowable limits. This was even true during one experiment when the bare extrusion was pushed out without an evacuating catch tube and without a hood in the area of the cooling extrusion.

All operating personnel wore shop coats and respirators during the extrusion cycle.

V PRELIMINARY SURVEYS, PHASE I

In order to insure proper direction of all aspects of the ensuing program and to select shapes, materials, and subcontractors offering maximum benefits to the program, a number of surveys were made. These surveys took the form of both written questionnaires and facility visits by a team of contractor technical representatives. A summary of those surveys and their results are as follows:

AIRCRAFT INDUSTRY SURVEY

Contractor submitted comprehensive questionnaires to 19 producers of flight vehicles. These questionnaires included inquiries into practically all aspects of current and projected flight vehicle requirements. Approximately 95 percent of the questionnaire recipients replied. Some replies were quite detailed while others stated that they were entirely unfamiliar with the subject. Appendix I summarizes the replies to the questionnaires which were submitted to the aircraft industry.

The Phase I extrusion configuration was selected by creating a composite of the extrusion shapes recommended in replies to the aircraft industry questionnaire survey. This beryllium extrusion configuration, hereafter referred to as the selected channel section, represented a great advancement in the state-of-the-art, particularly in achievement of the target tolerances, surface finish, and extrusion length. The selected channel section, along with basic target extrusion requirements are presented in Appendix II.

BERYLLIUM EXTRUDERS SURVEY AND SELECTION OF SUBCONTRACTORS

In order to assist Contractor in selecting subcontractors for this program, comprehensive questionnaires were prepared and submitted to twelve domestic extruders believed to be potentially qualified to participate in this project. The organizations in the following list were contacted:

Allegheny Ludlum Steel Co., Pittsburgh, Pa.
Bridgeport Brass, Adrian, Michigan
Brush Beryllium Co., Cleveland, Ohio
Canton Drop Forge & Mfg. Co., Canton, Ohio
H. M. Harper Co., Morton Grove, Ill.
Harvey Aluminum, Torrance,
Jones & Laughlin Steel Co., Pittsburgh, Pa.
Nuclear Metals, Inc., Cambridge, Mass.
Superior Tube, Norristown, Pa.
Babcock and Wilcox Co., Beaver Falls, Pa.
Beryllium Corp., Reading, Pa.
International Nickel Co., New York, N. Y.

Except for Beryllium Corp., Brush Beryllium and Nuclear Metals, all other extrusion vendors listed above declined interest in participating in a project to develop beryllium extrusions. Allegheny Ludlum Steel Corporation stated that they would support their affiliate, Nuclear Metals, Inc. in any way possible. Canton Drop Forge & Manufacturing Company was the only organization which failed to reply to Contractor's inquiry. Bridgeport Brass indicated an interest to participate in conjunction with Brush Beryllium Company.

Initial visits were made to the facilities of potentially eligible beryllium extrusion producers. These included Brush Beryllium Co., Beryllium Corporation, and Nuclear Metals, Inc. Northrop project technical representatives visited the Brush plant and were joined by Mr. T. S. Felker, ASD Project Engineer, at Beryllium Corporation and Nuclear Metals Facilities. Each vendor was given a brief verbal description of the project and its objectives and a drawing of the selected channel section with written target requirements. The vendors were also invited to submit fixed price bids on the development portion of Phase I and pilot production.

An Attempt was made to evaluate the relative merits and capabilities of each beryllium extrusion producer in accordance with the following consideration:

- Recent past experience
- Technical competence
- Enthusiasm and willingness to employ new methods and procedures
- Adequacy and type of available equipment and its adaptability for use in this project
- Ability to conduct work required without exposing personnel to toxicity

Technical work programs and cost proposals were received from each of the three prospective subcontractors. Because of the relative newness of the beryllium extruding science, the technical programs proposed were of wide variance both in latitude and magnitude. Negotiations continued with all prospective participants until all programs were based upon similar precepts to insure fair and impartial evaluation.

After careful evaluation of the technical programs submitted and a consideration of the facilities, experience, and attitude of all bidders, Beryllium Corporation and Nuclear Metals, Inc. were chosen to participate in Phase I of this program.

BERYLLIUM PRODUCERS SURVEY AND MATERIAL REQUIREMENT SPECIFICATION

Contractor submitted comprehensive questionnaires regarding beryllium extrusion materials; i.e. billets and their preparation, costs, scrap and scrap refunds, availability, composition, contaminants and degrees of contamination, salvageability, etc., to Beryllium Corporation and Brush Beryllium who are the only domestic suppliers of beryllium metal. Replies from both organizations were in essential agreement and both suppliers expressed willingness to supply extrusion billet materials for this project, regardless of who was chosen to perform the extrusion production development.

The material selected to begin extrusion production development was the QMV (or equivalent) sintered pure beryllium powder billet made from -200 mesh powder. This material was chosen because very little mechanical and physical property data exist on any other type or form of beryllium available which could be converted into extrusion billets. See Appendix III for details of beryllium material specification requirements.

VI EXTRUDING DEVELOPMENT AT THE BERYLLIUM CORPORATION, PHASE I

For approximately three weeks following receipt of Contractor's purchase order by the Beryllium Corporation, responsible project personnel of the Beryllium Corporation conducted a comprehensive survey of available literature pertaining to the extrusion of beryllium.

EXTRUSION PRESS & TOOLING

Upon completion of the literature survey, the Beryllium Corporation formulated plans and schedules to be followed throughout the developmental portion of Phase I. Program planning included beryllium extrusion billet procurement and production, billet heating techniques and heating equipment details, extrusion press tooling design and production, etc. The 1700 ton capacity Lake Erie oil hydraulic press employed by the Beryllium Corporation in this project is shown in Figure 1 and Figure 2.

The experimental nature of this program required that special tooling be designed and produced to adapt the Beryllium Corporation's press to accomodate the relatively small beryllium billets. The following figures illustrate this specialized tooling: Figure 3 is a drawing of four different cone lead-ins employed in determining the optimum lead-in angle for bare beryllium extrusion production. Figure 4 is a sketch illustrating design of the dummy block which was used in the Phase I development.

In attempting to develop successful die insert configurations for this project, the Beryllium Corporation elected to make the transition from the round rod to the Target "U" channel through a series of steps which included a

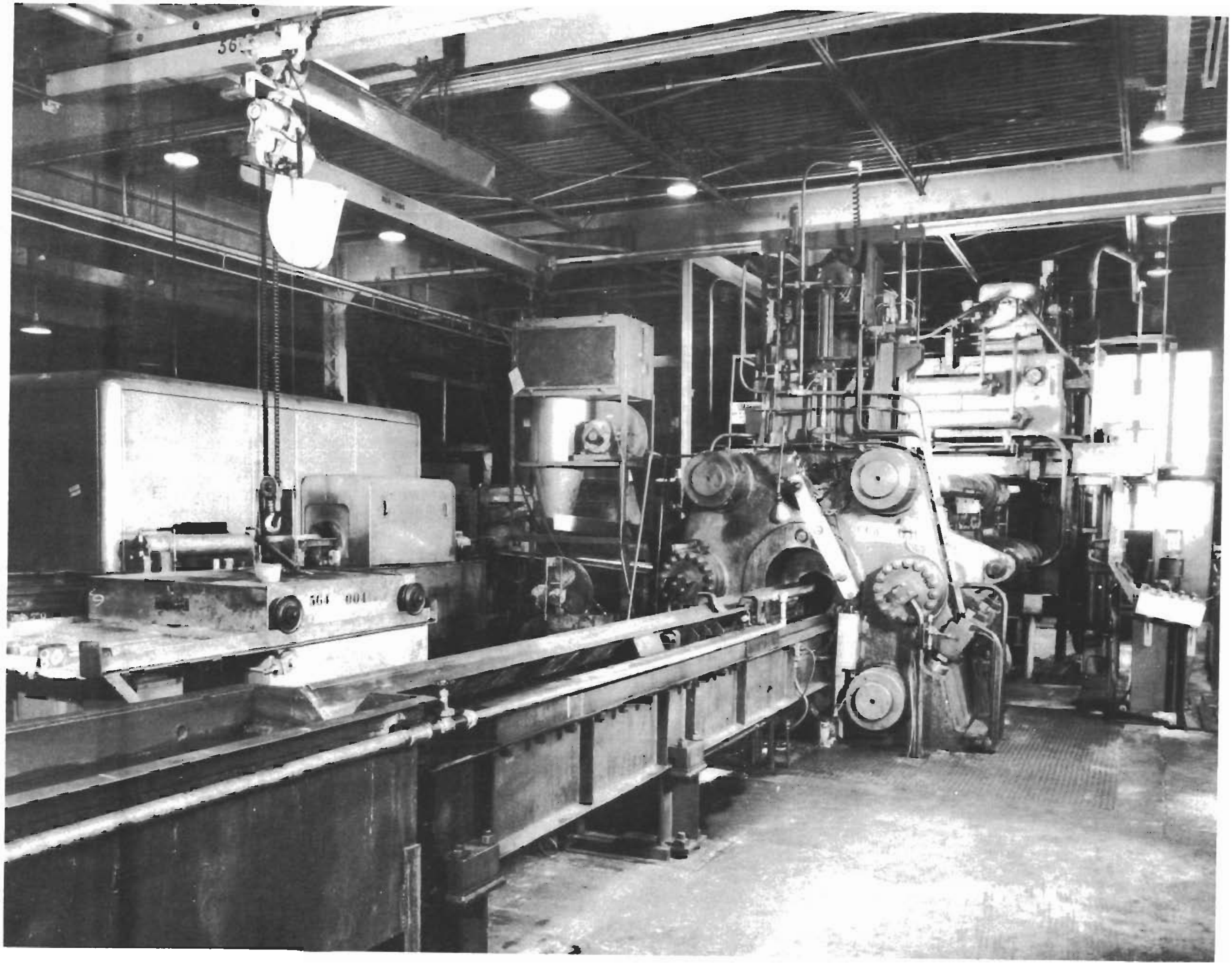


FIGURE 1 THE BERYLLIUM CORP. 1700 TON "LAKE ERIE" OIL HYDRAULIC EXTRUSION PRESS EMPLOYED IN PHASE I BERYLLIUM EXTRUSION DEVELOPMENT.

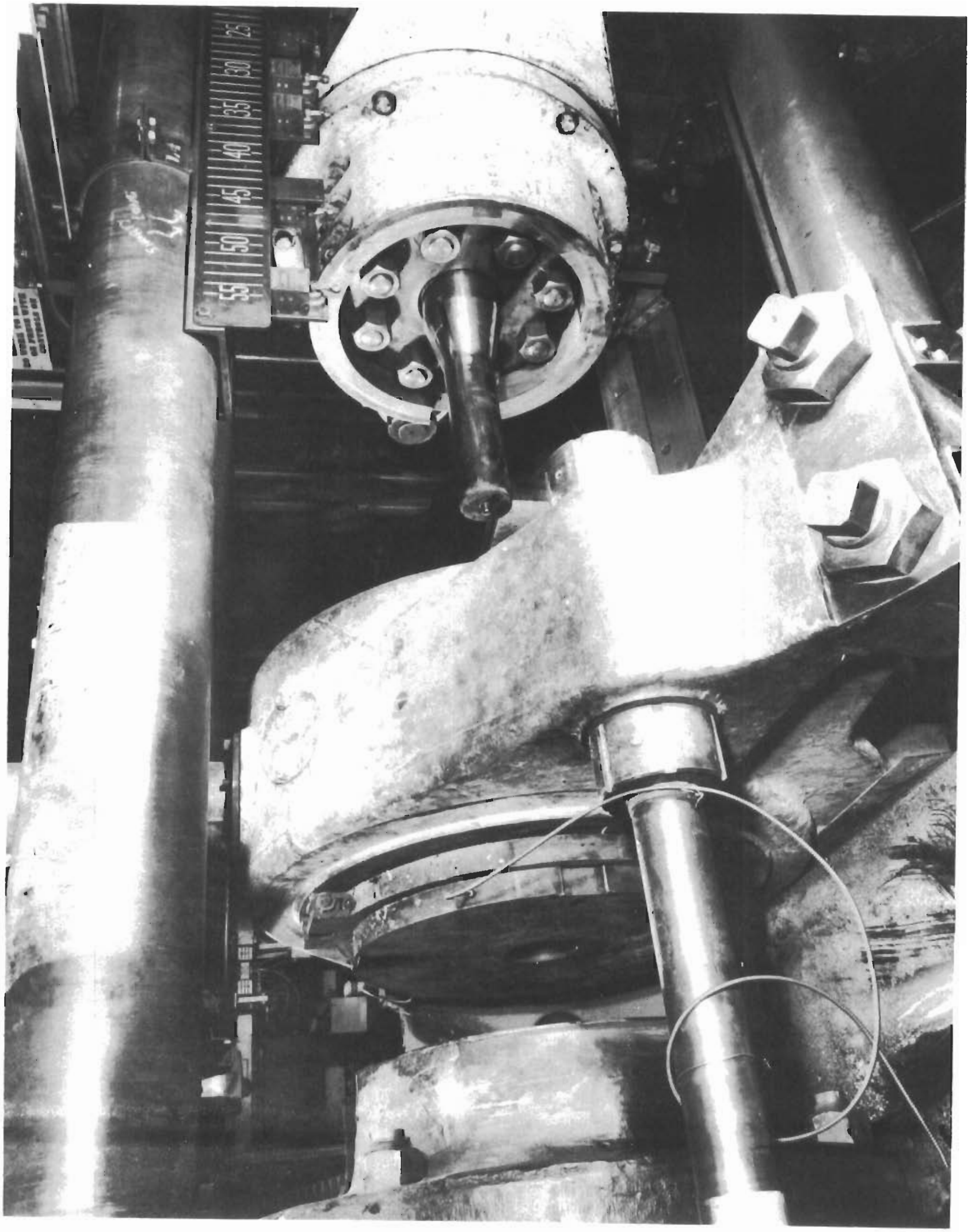


FIGURE 2 THE BERYLLIUM CORP. STEM AND CONTAINER ASSEMBLY OF THE 1700 TON OIL HYDRAULIC PRESS.

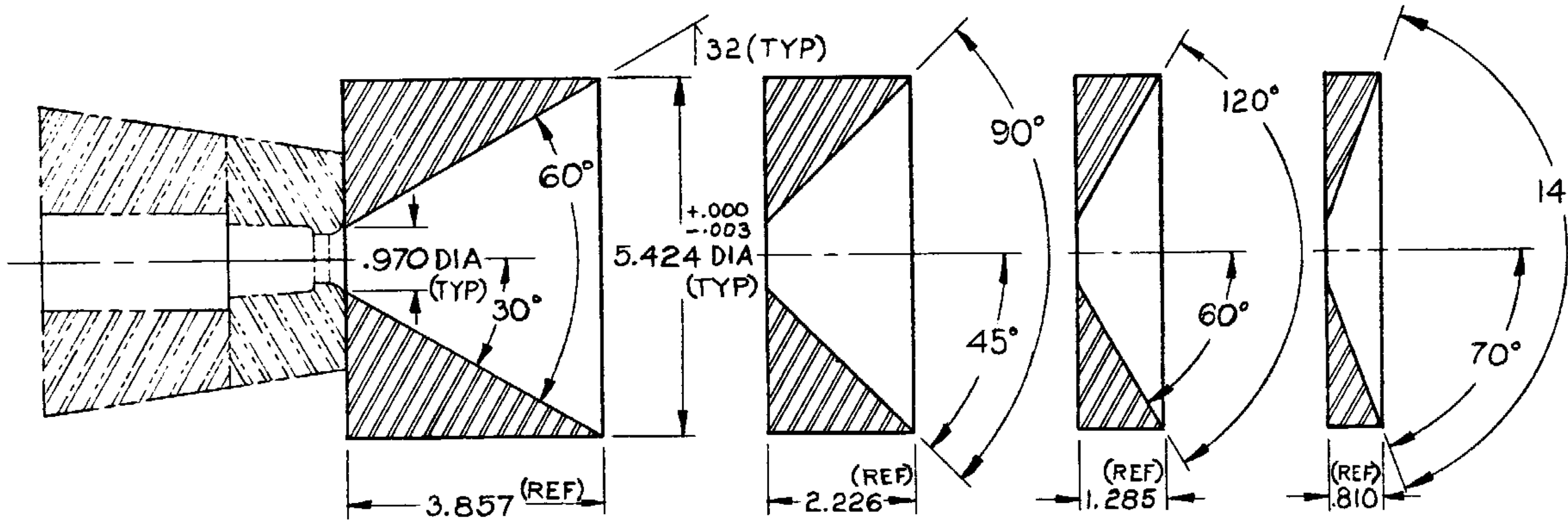


FIGURE 3 THE BERYLLIUM CORP. DRAWING OF FOUR EXPERIMENTAL BERYLLIUM EXTRUSION CONE LEADINS WITH EXTRUSION DIE BACKER.

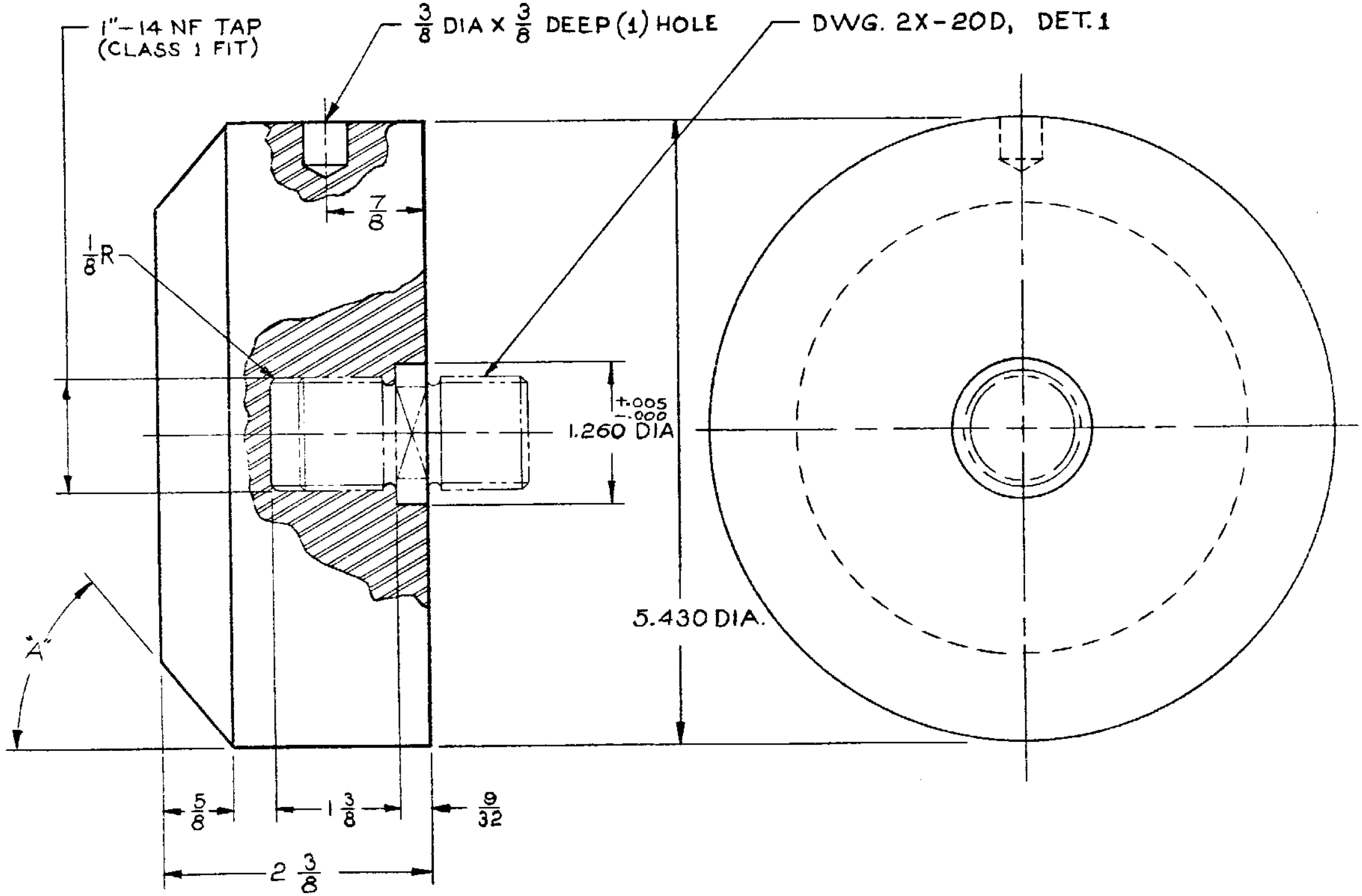


FIGURE 4 THE BERYLLIUM CORP. SKETCH ILLUSTRATING DESIGN DETAILS OF DUMMY BLOCK AND RELATED EQUIPMENT EMPLOYED IN BERYLLIUM EXTRUSION DEVELOPMENT.

rectangle with outside dimensions equal to that of the target channel, a "U" channel which was 1/8 inch oversize on all thickness dimensions, then the final shape. Drawings of these dies and backer assemblies are shown in Figures 5 through 9. These dies were made from hard-faced 5% chrome die steel.

Figure 10 shows four Beryllium Corporation die inserts which were used in development of bare beryllium extrusions. Die 1 is a flat-faced rectangular die with a 20° lead-in; Die 2 is the flat-faced rectangular die without lead-in; Die 3 is a split oversize "U" channel die; and Die 4 is a split target "U" selected channel section die.

PREPARATION OF EXTRUSION BILLETS

The bare beryllium billet length varied in accordance with the developmental item being studied. Relatively short billets were employed in cone lead-in studies while longer billets were required for extrusion length tryouts. The general configuration (including diameter) was, however, the same for either long or short billets. Figure 11 is a sketch of the beryllium extrusion billet configuration which was utilized in the Phase I developmental work by the Beryllium Corporation. The extrusion billet diameter was approximately 5 inches.

The Beryllium Corporation employed a barium chloride-sodium chloride (90% BaCl - 10% NaCl) salt bath for heating of bare beryllium extrusion billets (Figure 14). The beryllium billets were placed in either a steel of graphite container which was subsequently placed in the salt bath. The steel and/or graphite containers also acted as radiation shields to prevent heat loss during transfer of the billet from the salt bath to the extrusion press. Figure 12 is a sketch of the beryllium billet container assembly made from machined graphite. Figure 13 is a sketch of the beryllium billet container assembly made from steel.

A preliminary billet heating study consisted of the heating of hot pressed beryllium powder specimens for fifteen (15), thirty (30) and forty-five (45) minutes at 1800°F in a molten salt bath composed of 90% barium chloride - 10% sodium chloride. After removal, the specimens exhibited no evidence of surface attack or corrosion.

Beryllium billet heating on billets numbers 1 through 5 was accomplished in electrical resistance furnaces because the salt bath equipment was not installed at that time. Subsequent billets were preheated in an electric resistance furnace to drive off moisture and to reduce thermal shock prior to insertion into a salt bath furnace. Figure 15 shows the electrical resistance furnace.

LUBRICATION

Since the Beryllium Corporation is not a Sejournet licensee, their major lubrication effort was in the use of non-glass compositions. The lubricants studied included:

- Hot die lubricant containing Bentonite and graphite
- Boron nitride
- Lithium carbonate discs
- Glass powder

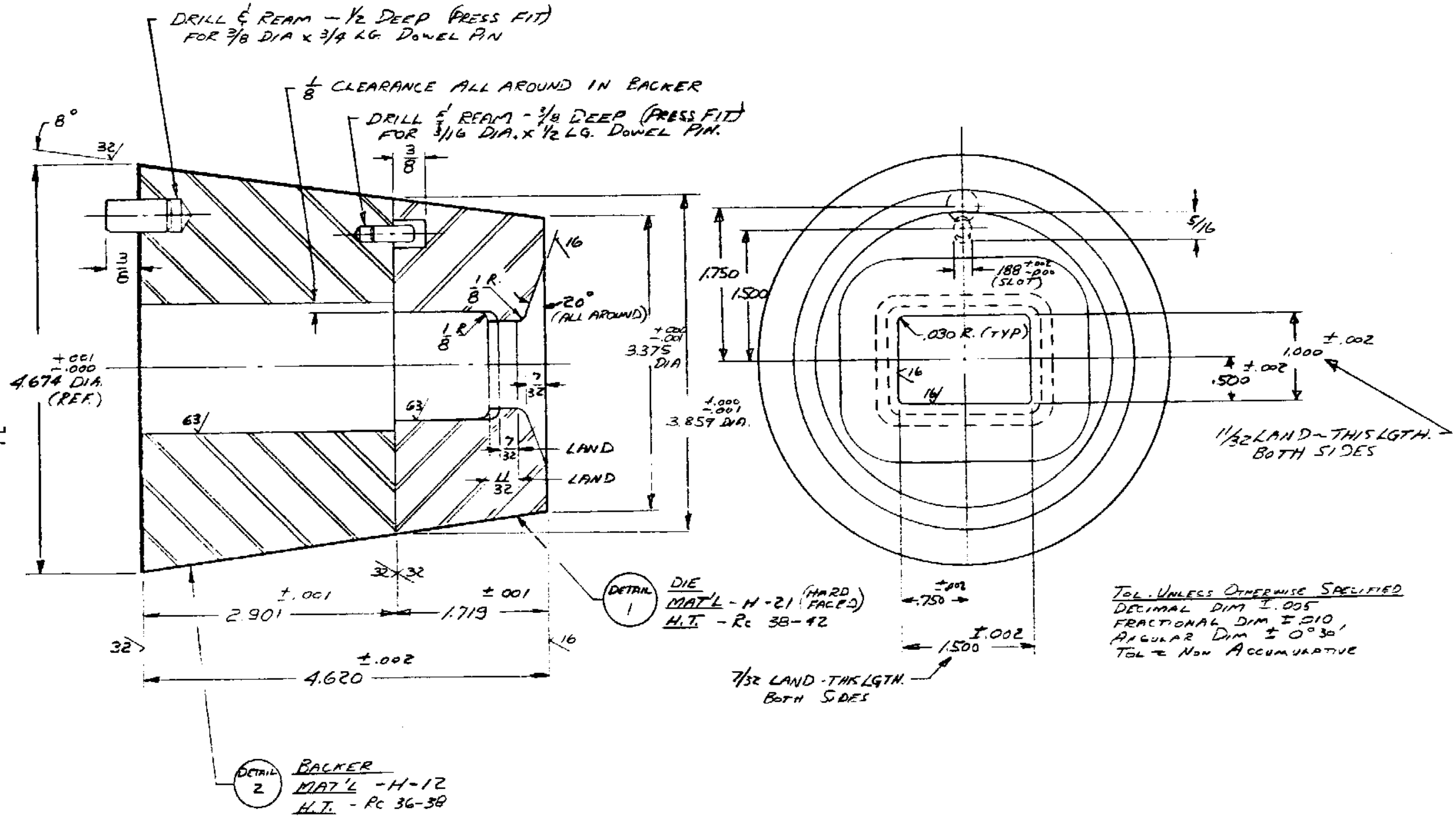


FIGURE 5 DIE & BACKER ASSEMBLY--TYPE II

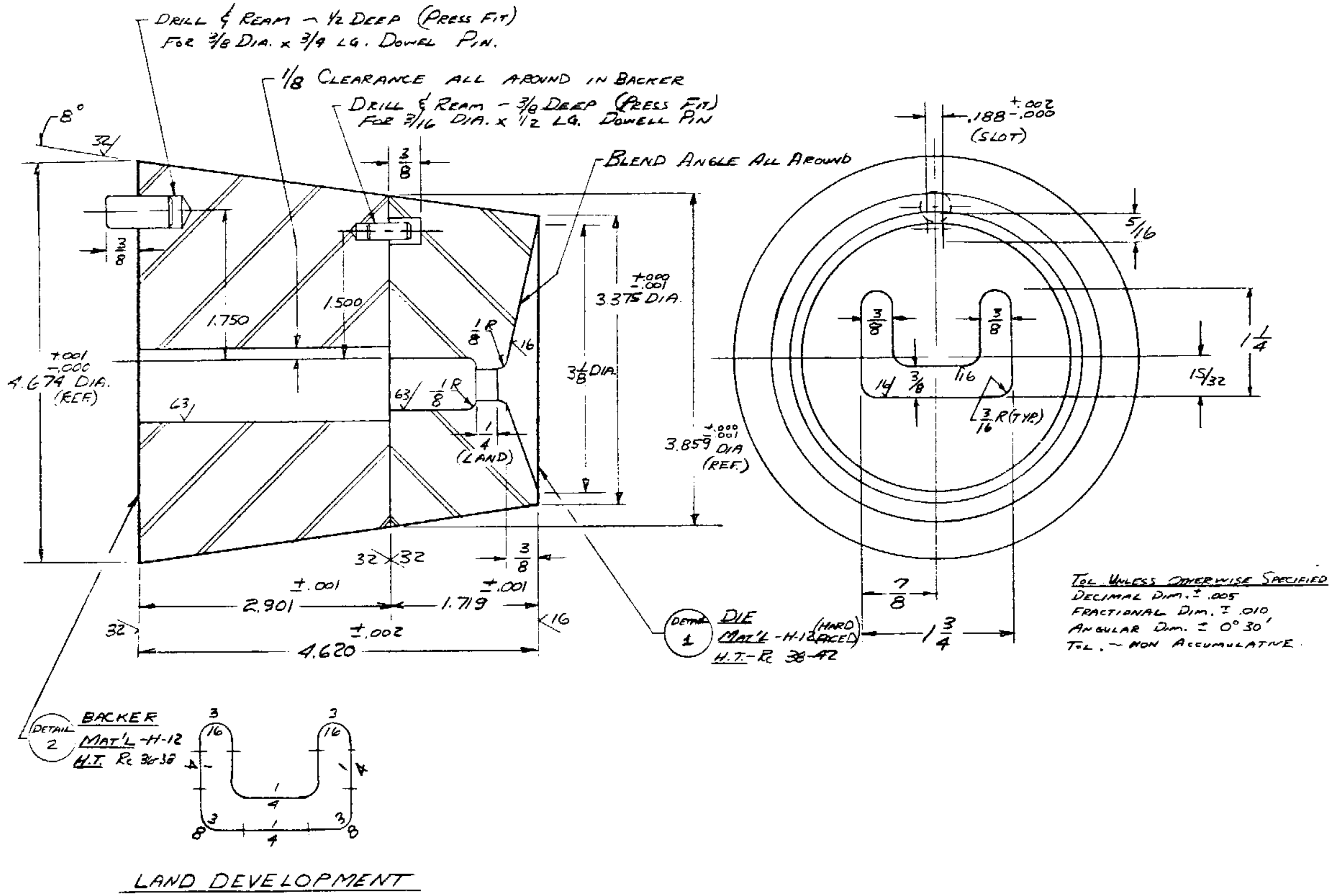


FIGURE 6 DIE & BACKER ASSEMBLY--TYPE III

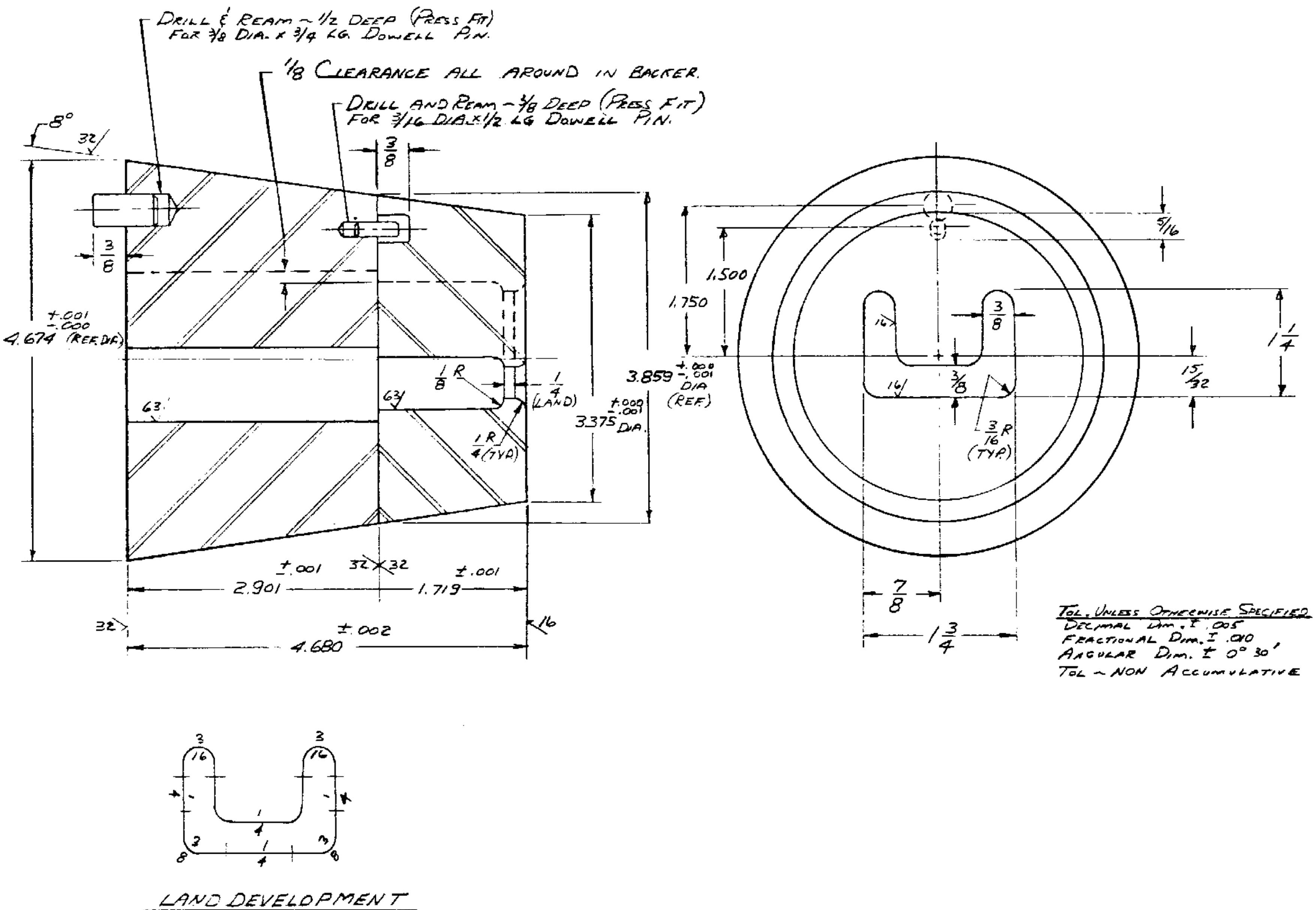


FIGURE 7 DIE & BACKER ASSEMBLY--TYPE IV

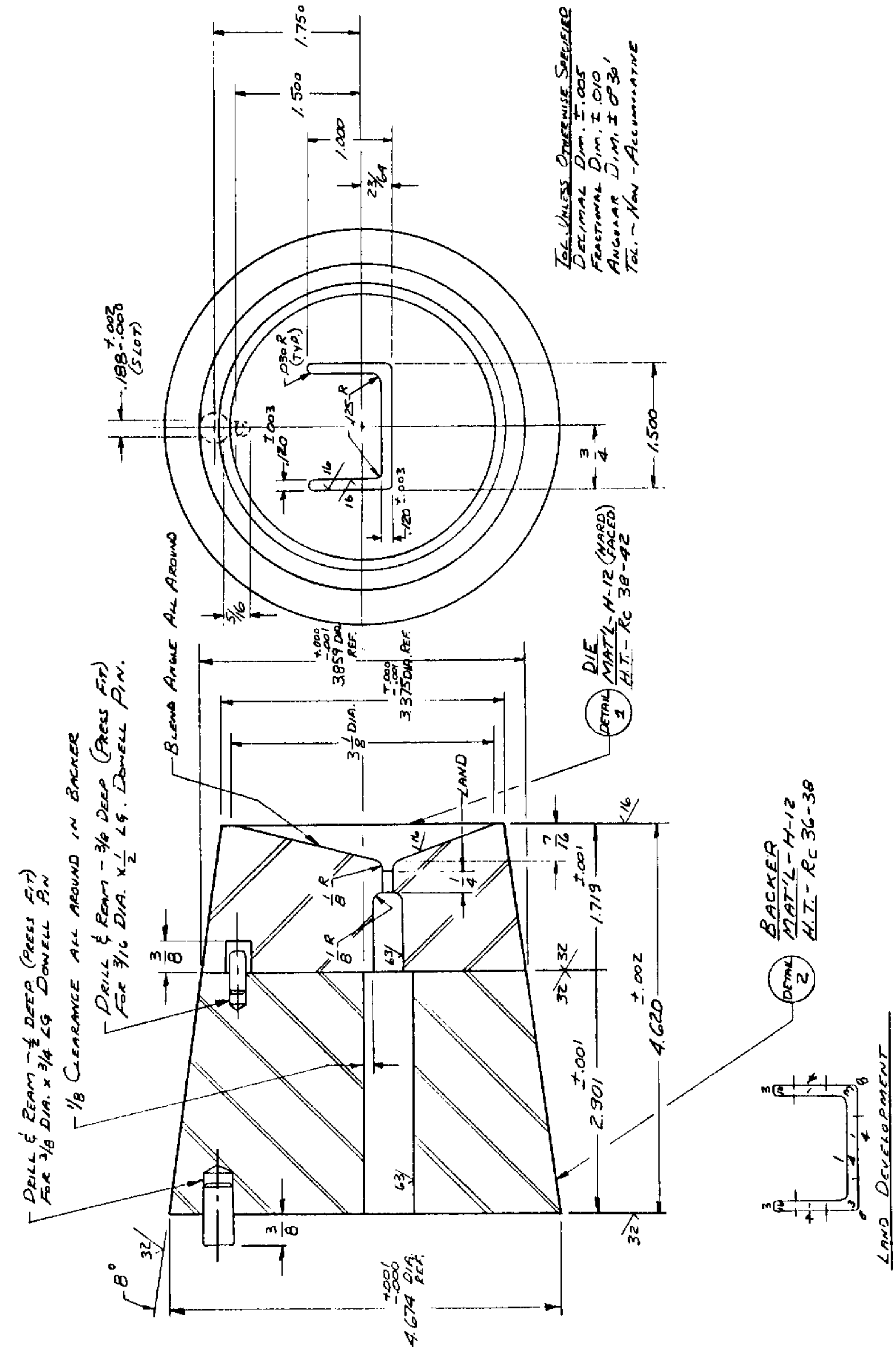


FIGURE 8 DIE & BACKER ASSEMBLY--TYPE VI

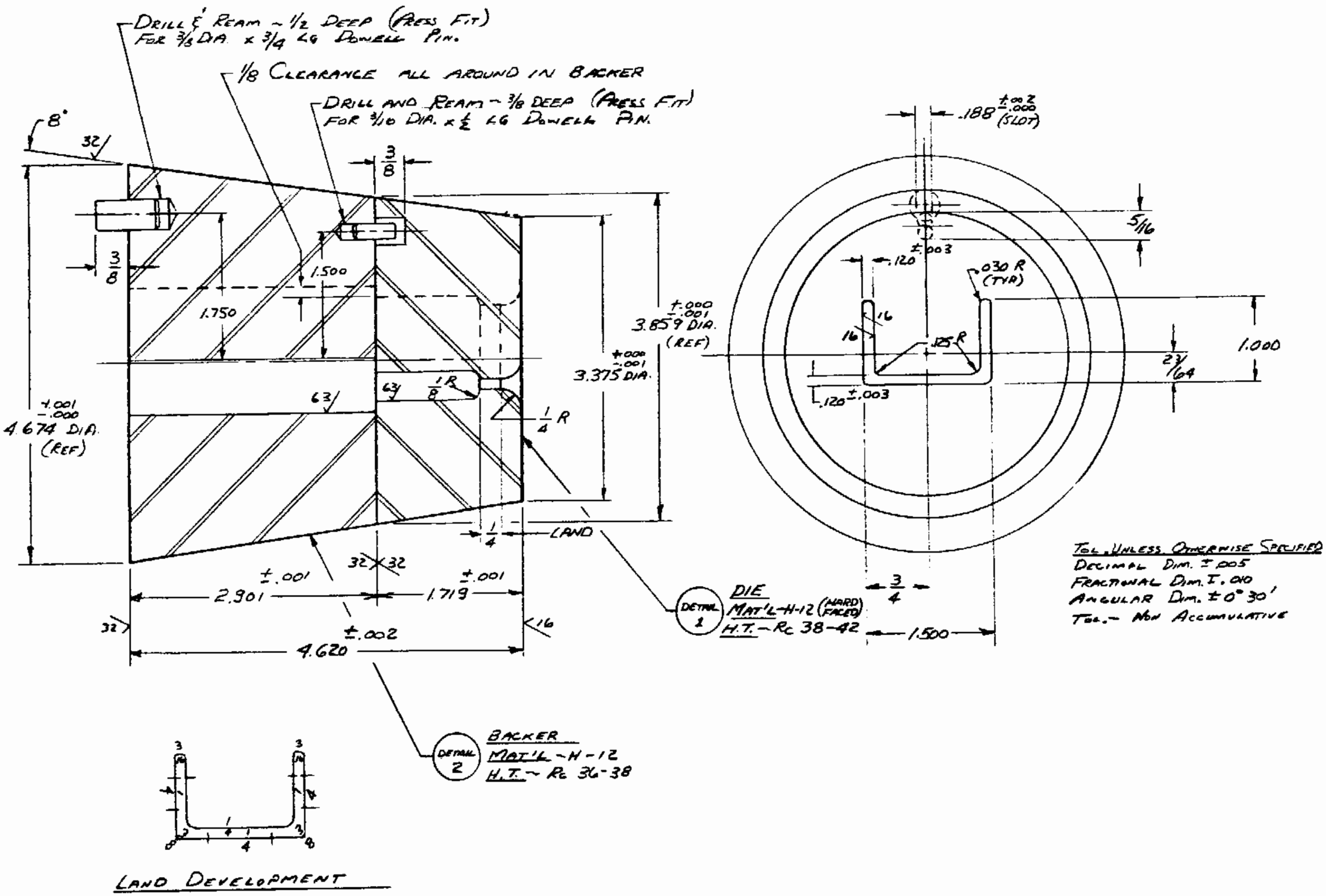


FIGURE 9 DIE & BACKER ASSEMBLY--TYPE V

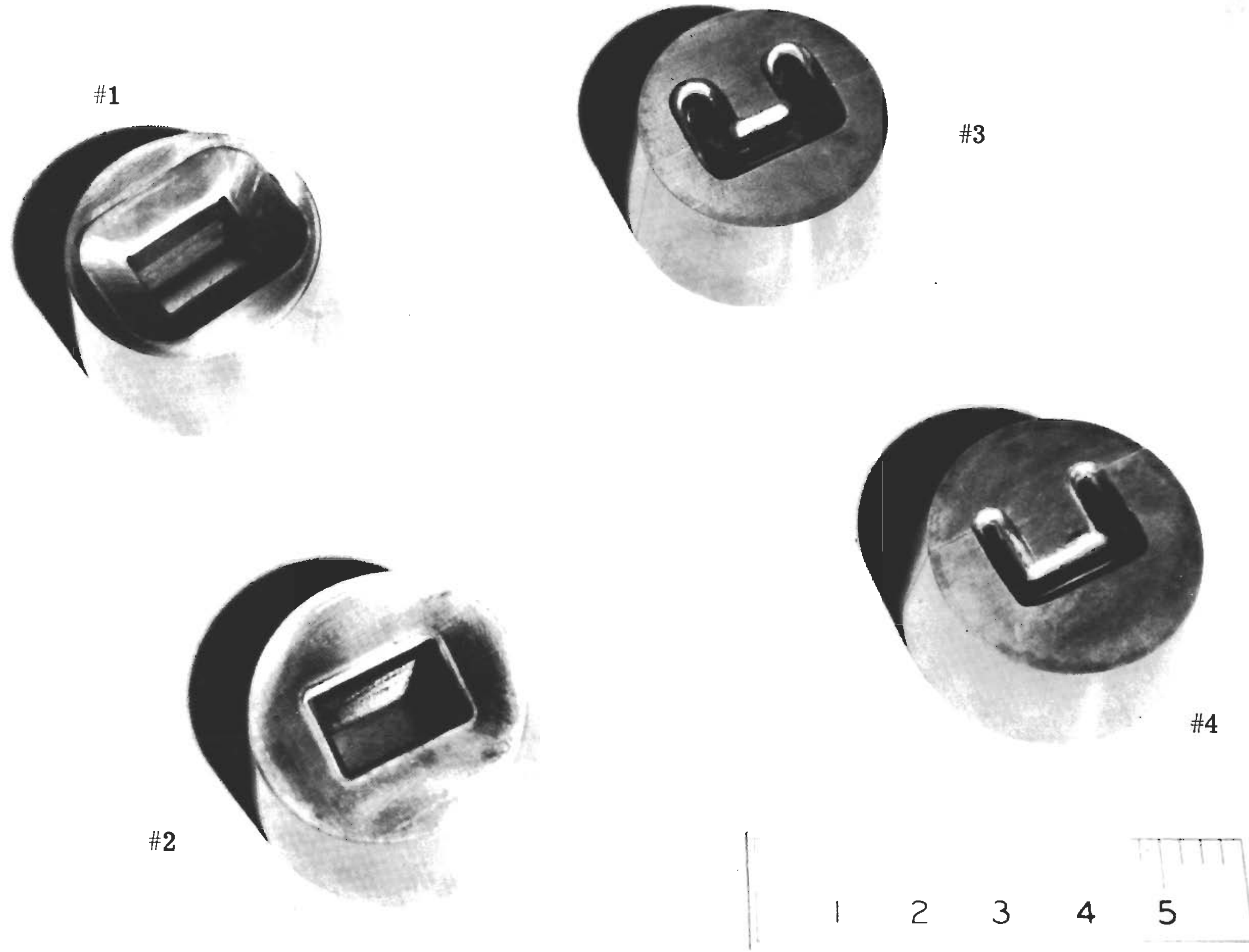
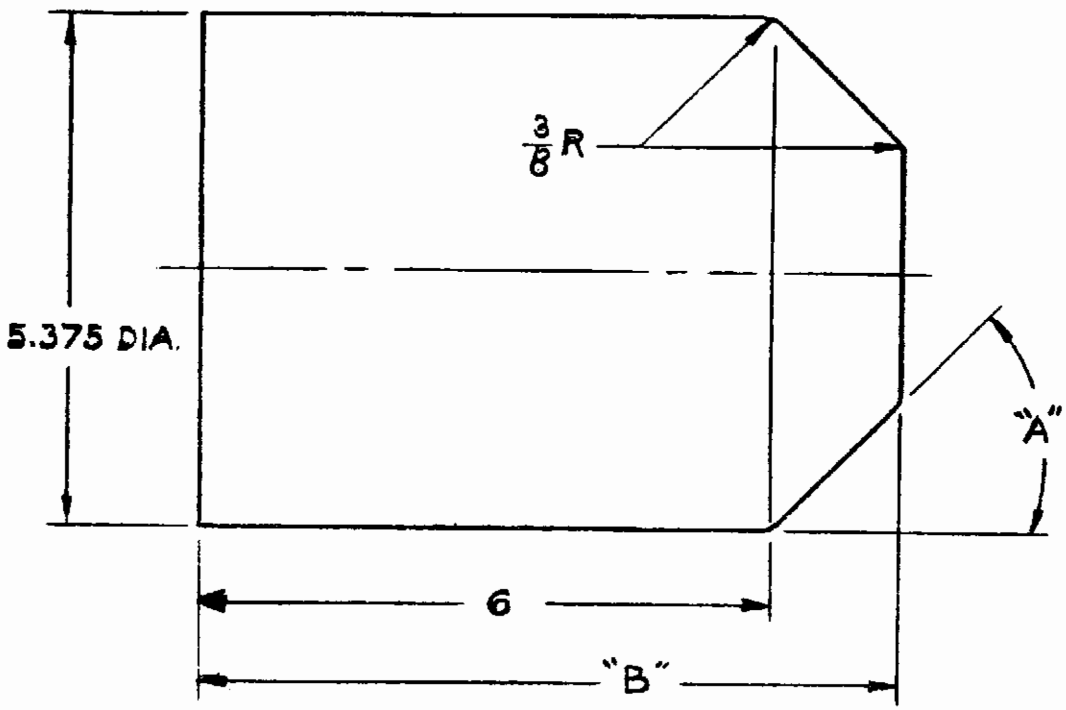


FIGURE 10 EXTRUSION DIES USED BY THE BERYLLIUM CORP. IN DEVELOPING THE PHASE I EXTRUDED BERYLLIUM CHANNEL.



TYPE NO	ANGLE "A"	DIM "B"	QTY.
I	30°	9 5/8	1
II	45°	7 31/32	1
III	60°	7 1/32	1
IV	70°	6 9/16	1
V	30°	6 1/4	1

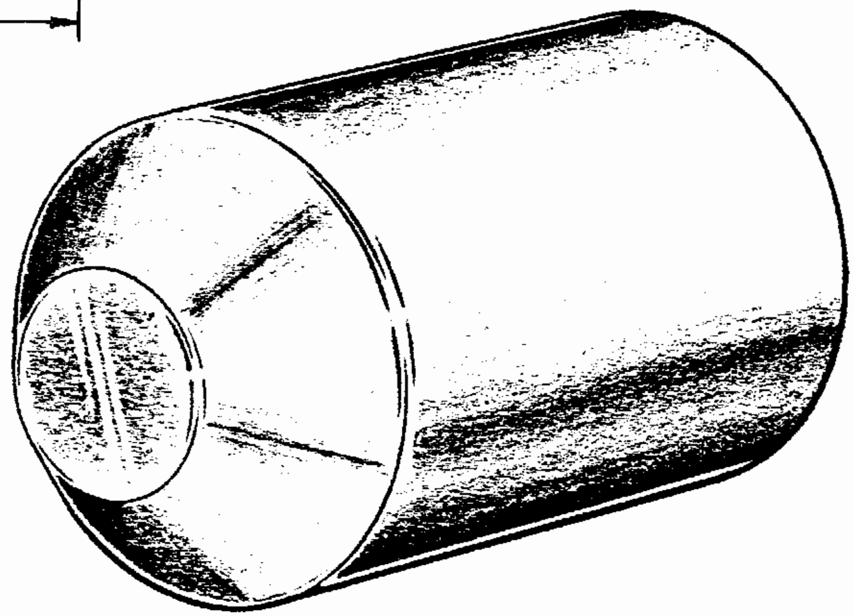


FIGURE 11 THE BERYLLIUM CORP. SKETCH ILLUSTRATING TYPICAL EXPERIMENTAL BERYLLIUM EXTRUSION BILLET CONFIGURATION.

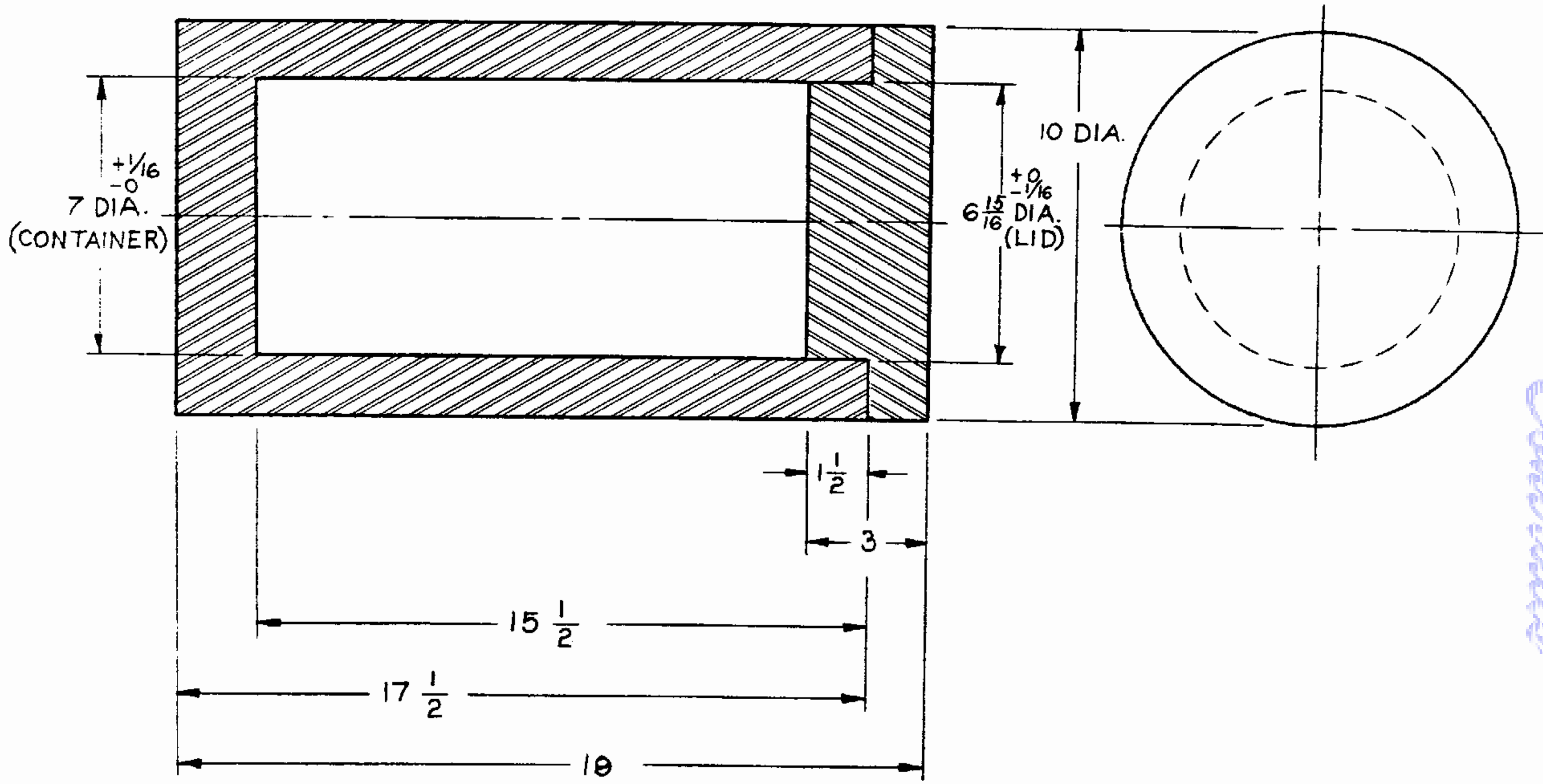


FIGURE 12 THE BERYLLIUM CORPORATION: SKETCH OF MACHINED GRAPHITE CONTAINER ASSEMBLY FOR HEATING BERYLLIUM EXTRUSION BILLETS.

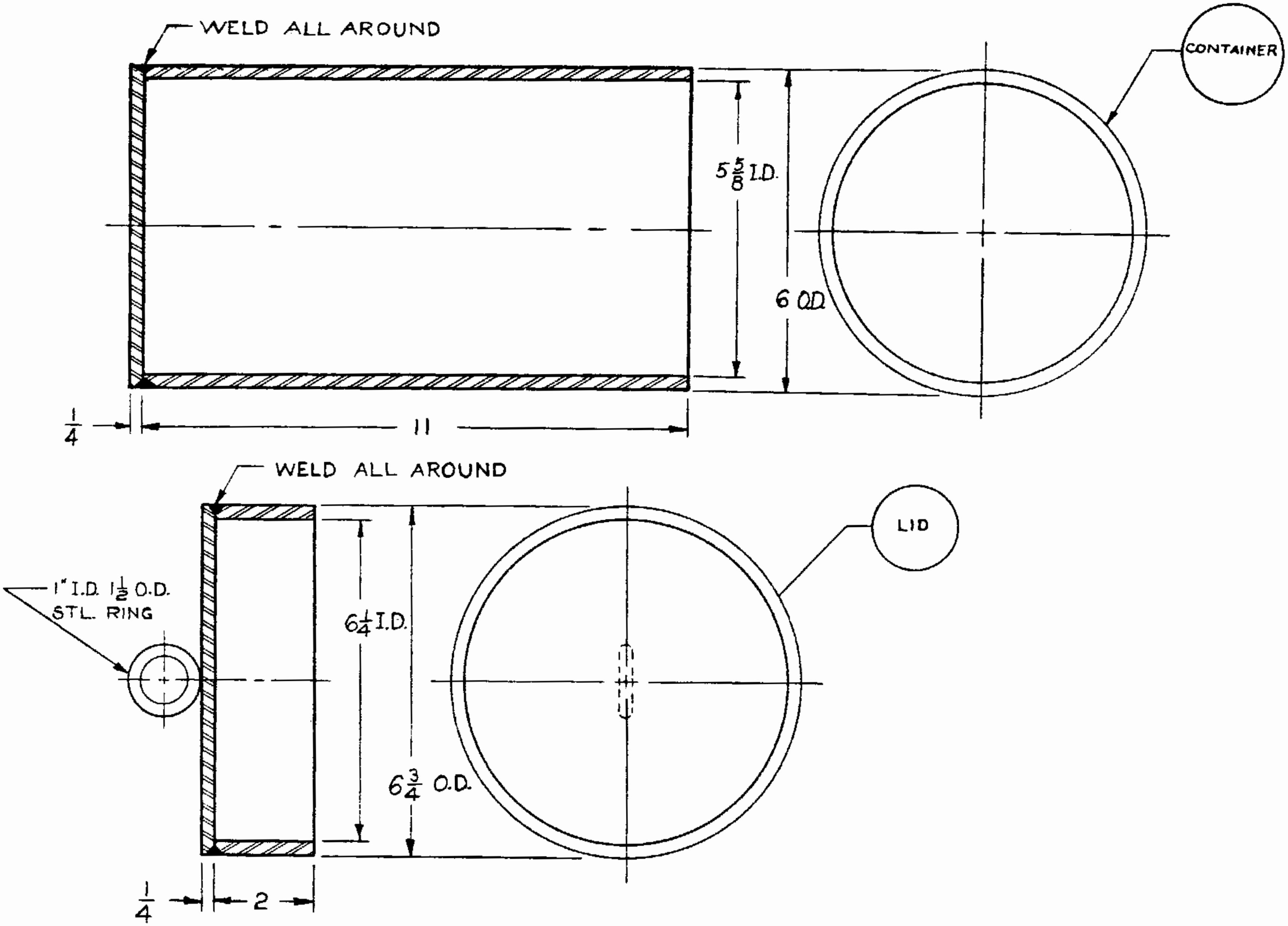


FIGURE 13 THE BERYLLIUM CORPORATION SKETCH OF STEEL CONTAINER ASSEMBLY EMPLOYED EXPERIMENTALLY IN THE DEVELOPMENT OF EXTRUDED BERYLLIUM SHAPES.

FIGURE 14 BERYLLIUM CORP. 75KVA AJAX SALT BATH, IMMERSION FIXTURE, AND SALT BATH CONTROL.

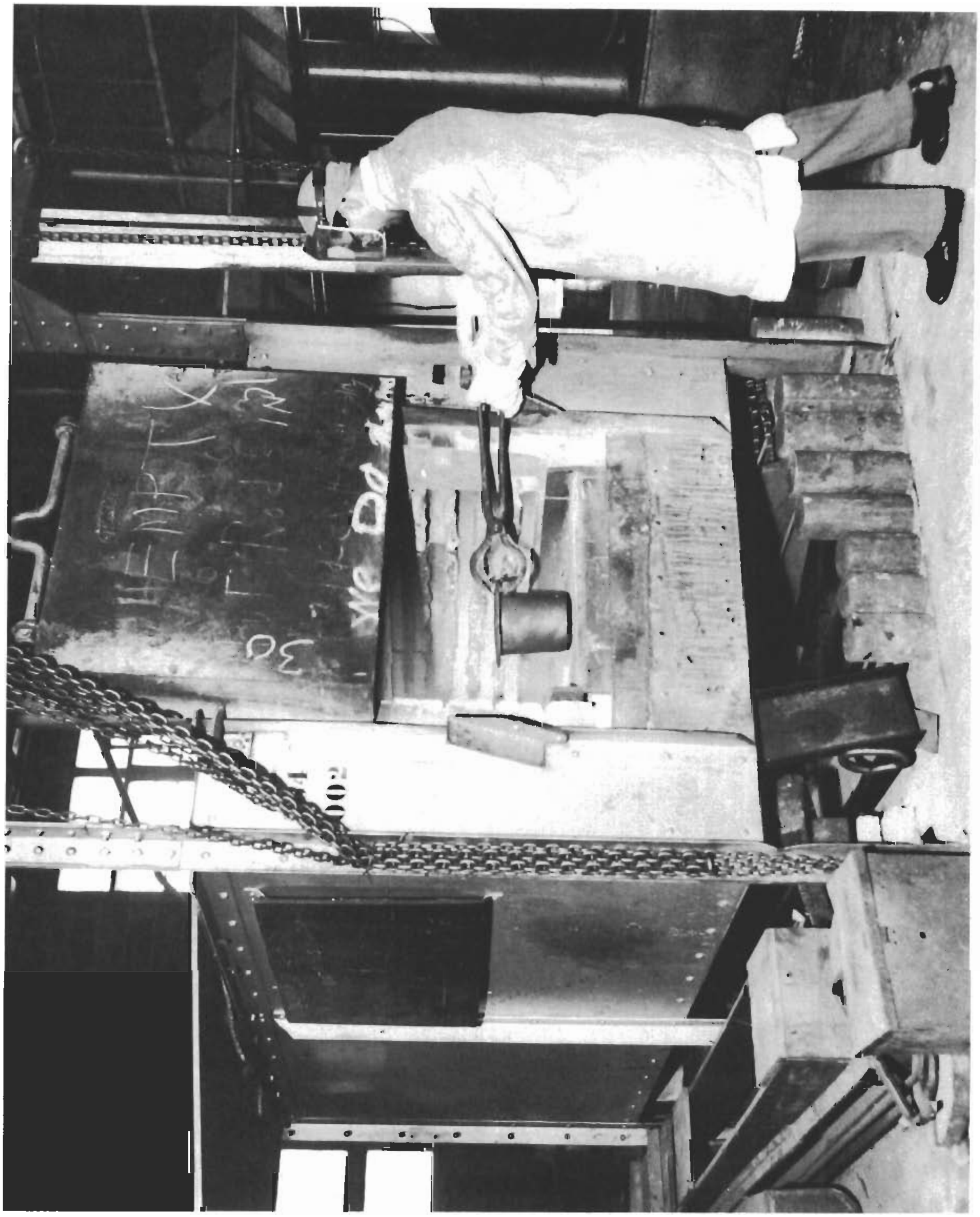


FIGURE 15 ELECTRIC RESISTENCE FURNACE USED TO PREHEAT BERYLLIUM BILLETS.

The glass powder was used on the cylindrical surface of the billets only. Boron nitride was not considered successful. The greatest lubrication success achieved from the standpoint of reducing die wear was the use of cast lithium carbonate discs placed betwen the billet and the die. None of the lubricants employed by the Beryllium Corporation appeared to visibly reduce cracking and severe rattlesnaking in the rectangles, the oversize "U" channels, or the final size (0.12 inch thick) "U" channels.

Figure 16 shows a hot beryllium billet being positioned for rolling through powdered glass lubricant.

BERYLLIUM COMPOSITION

Norair's Interim Beryllium Extrusion Materials Specification (Number ND-161) was developed concurrently with the developmental portion of Phase I. Therefore, it was necessary to employ billet compositions which were immediately available. Compositions of several billets used in the Beryllium Corporation work are presented in Table I.

These compositions varied considerably from those shown in Specification ND-161A. (Appendix III)

EXTRUSION TECHNIQUE

The same basic steps were followed in extrusion techniques by the Beryllium Corporation in the bare extrusion of beryllium as are followed in the extrusion of other metals requiring streamline flow, such as steel and titanium. Extrusion is normally accomplished in the following typical steps.

- Place lithium carbonate disc between die face and container through which billet will pass. An opening with the same general shape and size as that in the die is cast in the disc. Both openings are positioned so that they match.

- Remove beryllium billet from salt bath, roll in powdered glass, and place, radiused end forward, in the container (or container liner).

- Allow billet to cool to desired temperature, hold dummy block in front of ram with tongs, bring ram forward (placing dummy block in container) and extrude.

Numerous variations in the aforementioned steps were tried, particularly with respect to ram speed.

The initial efforts of the Beryllium Corporation were to extrude bare beryllium rounds (rods) with a cross-sectional area equal to that of the target selected channel section. Once this was successfully completed, the target "U" channel configuration development was to be accomplished in the following steps.

a. Bare extrusion of a beryllium rectangle with outside dimensions equal to those of the selected channel section.

b. Bare extrusion of a beryllium channel which is one-eighth (1/8) inch oversize on all dimensions.

c. Bare extrusion of the target of the selected channel section.

FIGURE 16 HOT BERYLLIUM BILLET BEING POSITIONED FOR ROLLING THROUGH POWDERED GLASS LUBRICANT.

TABLE I

Beryllium Billet Compositions

Pressing Numbers	Extrusion Numbers	Elements, Parts per Million or Percent as Shown									
		C(.15%)	Fe(.25%)	Ni(.08%)	Cu(.05%)	Al(.15%)	Mn(.03%)	Si(.10%)	Cr(.05%)	Mg(.05%)	BeO(1.0%)
93	1,2,3,4	.115%	2141	598	167	278	145	252	100	<30	2.25%
97	5	.112%	1904	765	186	310	145	723	103	200	2.05%
109	7,8	.090%	2099	431	114	556	150	320	109	876	2.03%
110	9,10	.048%	1960	500	111	1279	133	417	83	<30	1.76%
143	11,12	.076%	1610	528	122	545	125	875	97	194	1.60%
144	13,14	.084%	1670	625	144	585	158	485	114	197	1.78%
148	15	.082%	2195	695	128	545	108	460	97	161	2.22%
150	16,17,18	.065%	2127	505	114	685	122	430	95	<30	1.55%

NOTE: The bracketed percentages following each element show the maximum percentages for each element attempted in billet preparation by the Beryllium Corporation.

The die lead-in angle study was conducted, utilizing the best known lubrication and extrusion practices in the steps outlined in the following tabulation.

Test Number	Lead-in Angle Degrees
1	60
2	45
3	30
4	20
5	0

The quality was similar in the extruded rods from test numbers 1, 2, and 3, with medium to heavy rupturing and tearing observed throughout. The rods were heavily striated and oxidation was quite noticeable. Test number 4 exhibited some improvement. Rupturing occurred over the entire length of number 4; but to a lesser degree than in test numbers 1, 2 and 3. The final test, number 5, produced the best appearing results. Slight rupturing was noted on the first 50 inches and the final 30 inches of number 5. However, the center 73 inches exhibited no visible evidence of checking or tearing. Heavy striations and heavy oxidation were observed.

Hard-faced extrusion dies were employed, and after extrusion, these dies were badly eroded. Slight metal pickup was also observed. Figure number 17 is a photograph of the bare beryllium rods extruded in test numbers 1 through 5. The order is from right to left. Figure 18 is a photograph of a section of round beryllium extrusion which was considered good.

The unextruded butts which remained after extrusion of the round beryllium rod were examined in an attempt to determine flow characteristics of the metal. These butts are included in the photograph of Figure 17.

Figure 19 is a photograph of the flat-faced die employed in the bare extrusion of round beryllium rod. Figure 20 is a photograph of the lead-in cones, after extrusion, which were used by the Beryllium Corporation in Phase I development.

Beryllium Corporation billets were only partially extruded so that it was possible to examine the beryllium butts which remained after extrusion. In production practice, it would be economical to extrude as much as possible of the billet because of the high cost of beryllium.

In addition to a summary of data taken from the beryllium extrusion test data sheets shown in Appendix IV, the following pertinent information on extrusion tests 6 through 18 is presented to convey a more thorough understanding of the work.

Extrusion Test 6

The purpose was to determine the effect of boron nitride as a lubricant. Maximum pressure of the press was exerted, but it was only possible to move the extruded rod at a rate of about three inches per second at a temperature of 1750°F. This was much slower than desired. The resulting extrusion was severely striated and ruptured (rattlesnaked) indicating that the lubricant was not as satisfactory as that used previously.

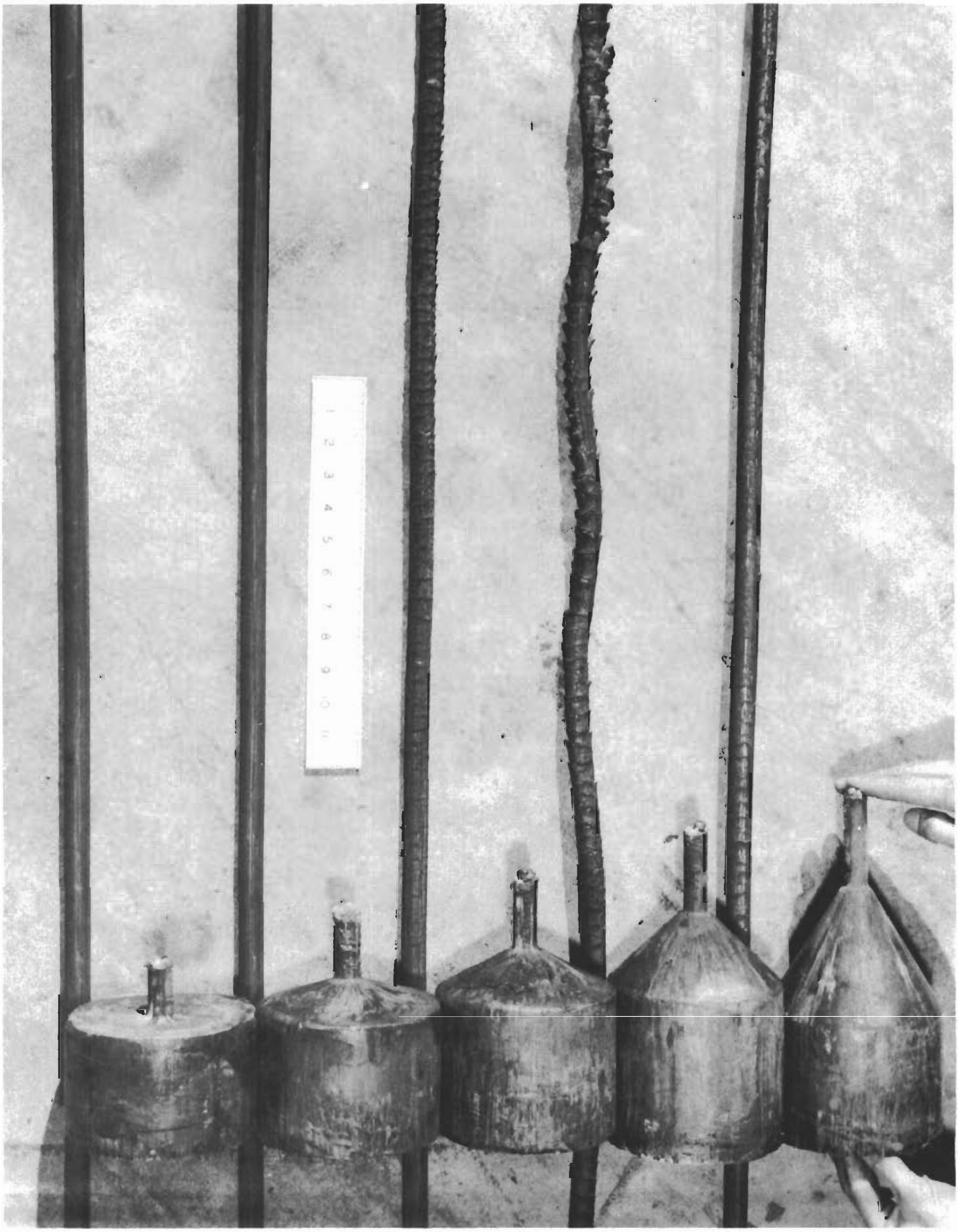


FIGURE 17 THE BERYLLIUM CORP. PHOTOGRAPH OF BARE EXTRUDED BERYLLIUM ROD NUMBERS 1 THROUGH 5, ORDER IS FROM RIGHT TO LEFT. BUTT SECTIONS OF BILLETS ARE SHOWN AT BOTTOM OF PHOTOGRAPH.

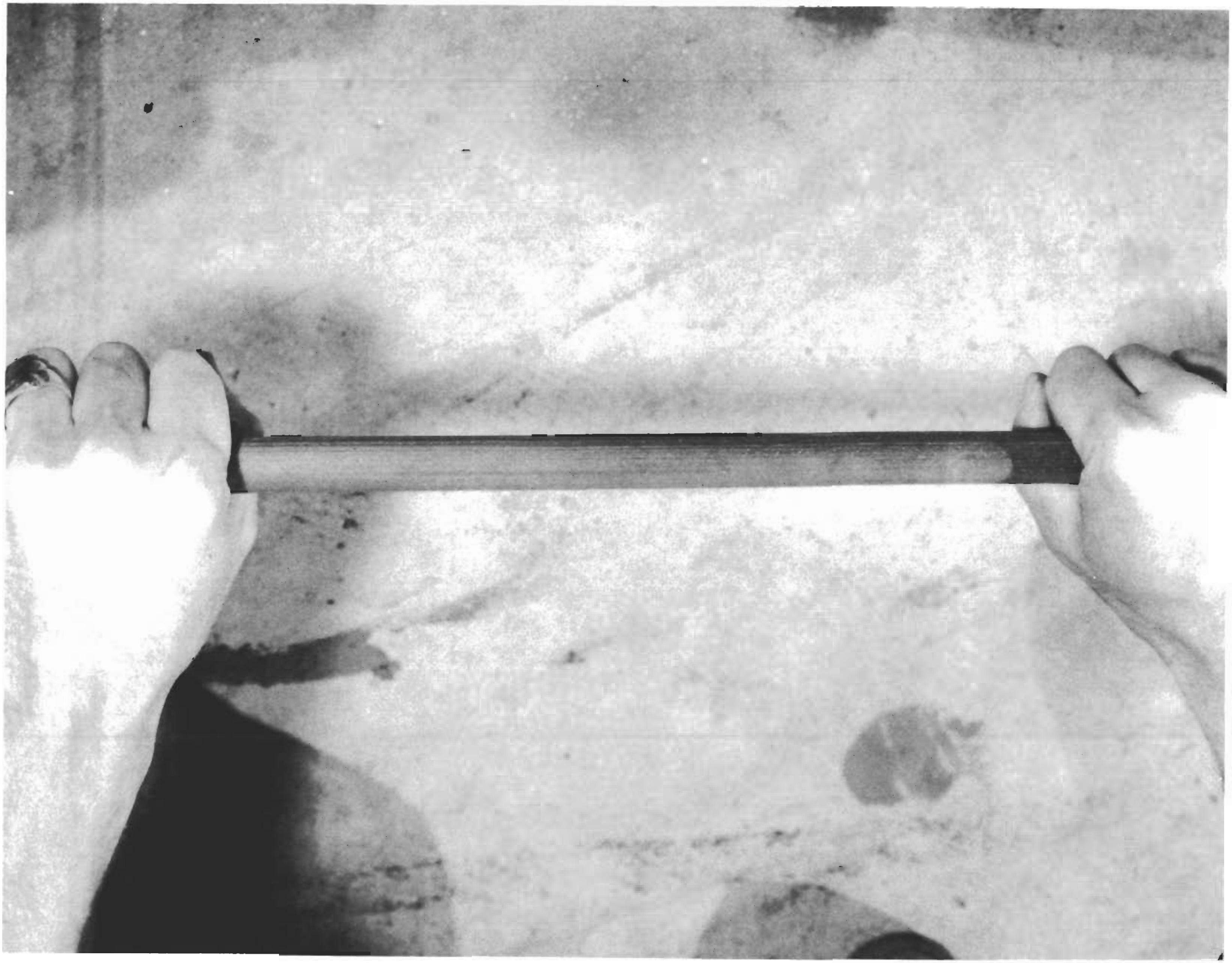


FIGURE 18 THE BERYLLIUM CORP. PHOTOGRAPH OF A SECTION OF BARE EXTRUDED BERYLLIUM ROD WHICH WAS CONSIDERED TO BE GOOD.

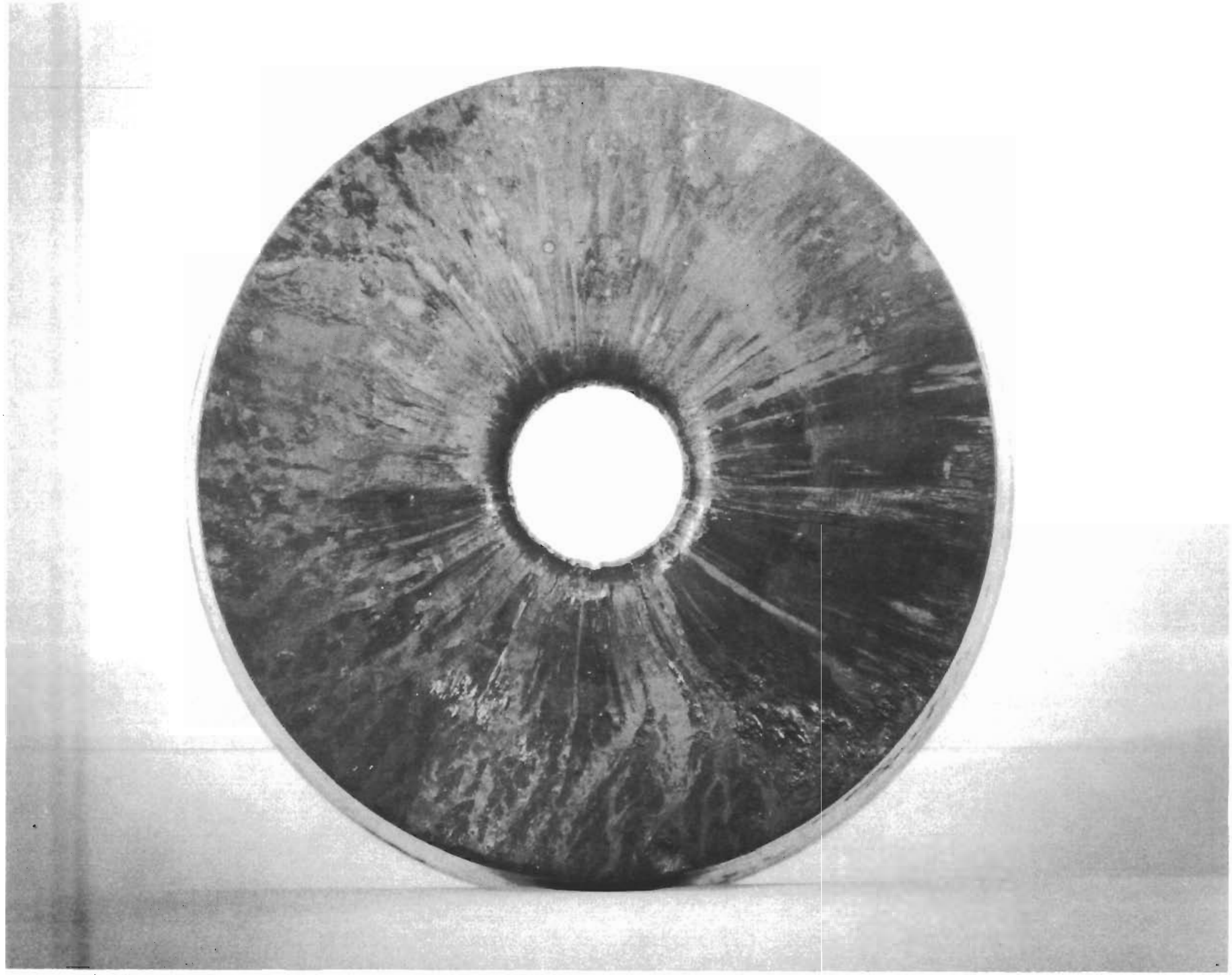


FIGURE 19 THE BERYLLIUM CORP. FLAT FACED DIE EMPLOYED IN THE EXPERIMENTAL EXTRUSION OF UNJACKETED BERYLLIUM ROD.

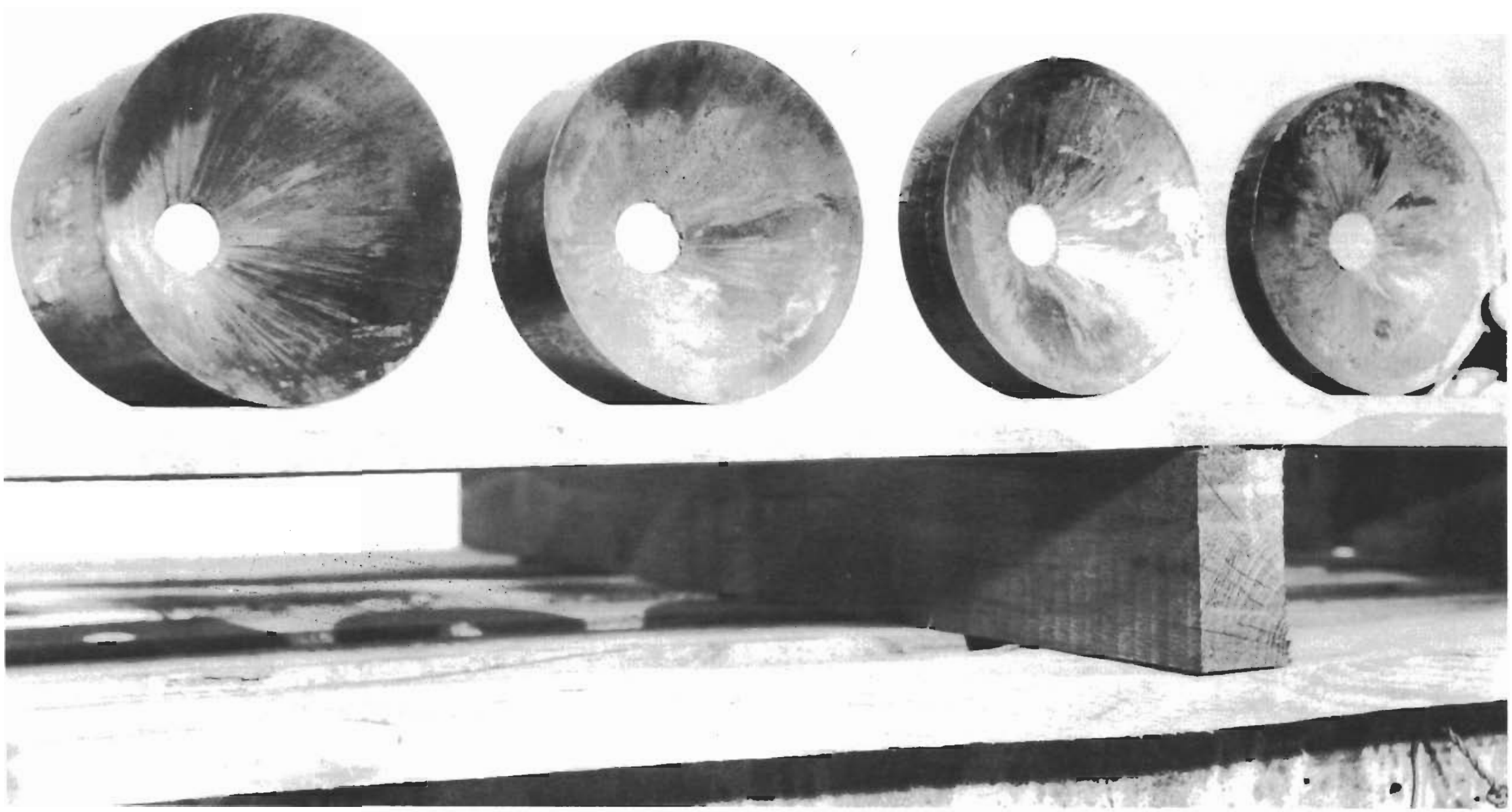


FIGURE 20 THE BERYLLIUM CORP. PHOTOGRAPH OF LEAD-IN CONES, AFTER EXTRUSION, EMPLOYED EXPERIMENTALLY TO DETERMINE OPTIMUM LEAD-IN ANGLE FOR UNJACKETED BERYLLIUM EXTRUSION PRODUCTION.

Extrusion Test 7

Observation of the butt section remaining after extrusion test 6 indicated that a shear plane developed at approximately 30°. This led to a decision to employ a 30° lead-in angle core for extrusion test 7. Another observation made while extruding number 6 was the stripping of the lubricant while the billet was being introduced into the liner. Therefore, residual salt (without addition of glass powder) was used as the lubricant. Results were unsatisfactory; an extrusion with extremely poor surface emerged.

Extrusion Test 8

During previous extrusions it had been observed that the relatively cold (650°F) liner walls caused a rapid flow of heat from the billet periphery immediately after loading. By loading a hotter billet and allowing a delay after loading until the desired extrusion temperature was reached, it was believed that extrusion conditions would be enhanced. The billet was loaded at 1950°F, and allowed to cool to 1800°F before extrusion was begun. Pressures were reduced and the extrusion speed was recorded at 20 inches per second. Although the die collapsed, the extruded rod was generally good with only moderate striation. Rattlesnaking was observed only at the front and back ends of the rod.

Extrusion Test 9

Review of the results of Tests 6, 7, and 8 revealed a question on the effect of die design. This question concerned the 30° lead-in angle of extrusion 7 which had failed due to wiping off the lubricant. Extrusion 9 was intended to duplicate previous parameters. Although the same extrusion conditions were held as for extrusion 8, the resultant extruded rod was worse with severe rattlesnaking throughout the entire length.

Extrusion Test 10

The best conditions established during the first nine extrusions were selected and full ram pressure was exerted on the tenth billet. From the time-pressure chart recording, the calculated speed at which the extrusion emerged from the die was 40 inches per second. The extruded beryllium rod was lightly striated throughout its length. Slight to moderate rattlesnaking was present in the front and back portions; the center portion of the rod was relatively good.

Extrusion Test 11

In extrusion 11 a 0.75 inch diameter round was attempted. The primary purpose of this extrusion was to determine the effectiveness of a cast lithium carbonate disc as a die lubricant. Although the extrusion was severely rattlesnaked, the die was relatively unaffected. This lubricant functioned well and flowed uniformly over the length of the extrusion.

Extrusion Test 12

Extrusion 12, a 1 inch by 1.5 inch rectangle, was the beginning of the extruded shape development effort. The cylindrical surface of the billet was lubricated with powdered glass while a shaped lithium carbonate disc was employed to lubricated the die. Although the die was unharmed and sharp corners were maintained, the entire rod was very heavily rattlesnaked.

Extrusion Test 13

This extrusion was essentially a repetition of extrusion 12. After loading of the billet an operational difficulty was encountered which resulted in a decrease of billet temperature to 1635°F before extrusion. The die stood up quite well while the entire extrusion was badly rattlesnaked.

Extrusion Test 14

Extrusion 14 was an attempt to produce a channel shape which was 0.125 inch oversize on all thickness dimensions. The lithium carbonate disc was again employed. The legs of the channel severely rattlesnaked while the inside surface of the channel base appeared quite good. The split die insert collapsed during the extrusion.

Extrusion Test 15

This extrusion was an attempt to produce another 1 inch by 1.5 inch rectangle. Die lubricant was Bentonite grease with graphite, while residual salt was the only billet surface lubricant. Even by employing the slowest possible extrusion speed, the entire extrusion was badly rattlesnaked and the die completely collapsed.

Extrusion Test 16

Number 16 was the first attempt to extrude the target channel shape. The cylindrical billet surface was lubricated with glass powder and the lithium carbonate disc was employed as the die lubricant. The billet began to deform and barely entered the die orifice when the extrusion press stalled. The unextruded billet was removed from the press and subsequently re-machined to required size, re-heated and extruded as number 18.

Extrusion Test 17

This extrusion was the same as No. 16 except that the extruding temperature was raised from 1750 to 1800°F. The channel came out in several badly rattlesnaked pieces. The split die insert collapsed during extrusion.

Extrusion Test 18

Number 18 was the extrusion of the billet which had stalled the press when extrusion 16 was attempted. An attempt was made to produce a 1 inch diameter round bar using optimum conditions developed during previous tests. Extrusion 18 was extruded successfully at 1650°F. The die held up well with no indication of galling. Rattlesnaking was present, however, throughout the entire length of the extrusion.

Mechanical Properties

The Beryllium Corporation conducted mechanical property tests on specimens taken from bare extruded round rod. Results of these tests are presented in Table II.

Discussion of Results

Lithium carbonate cast into discs and properly mated with the die orifice served as an excellent die lubricant, but may not be as satisfactory as competitive materials, such as glass, at extrusion temperatures below and well above the melting point of this material. Although lithium carbonate could be observed throughout the entire length of most beryllium extrusions on which it was used, it appears to have less "body" and poorer insulating properties than properly selected glass compositions.

The Beryllium Corporation's efforts were somewhat handicapped from the standpoint of flexibility, specifically in the area of reduction ratios. The smallest extrusion container (liner) available for this program was 5.5 inches in diameter. In order to extrude either the selected channel section or a round rod of equivalent cross-sectional area, the somewhat high reduction ratio of 54.1 was required. A smaller container would have also made possible the use of smaller billets and, thereby, more economical use of the available material.

VII PRELIMINARY EXTRUDING DEVELOPMENT AT NUCLEAR METALS, PHASE I

EXTRUSION EQUIPMENT AND FACILITIES

The extrusion press used for this program is a hydraulically operated Watson-Stillman press capable of exerting a ram force of 1100 tons. The extrusion press was equipped with a 3-5/8 inch ID container and a 3-1/2 inch diameter ram; however, the stress limitations on a ram stem of this size necessitated limiting the force during the beryllium extruding to 950 tons.

TABLE II

Longitudinal Mechanical Properties of Bare Extruded Round Beryllium Rod

Beryllium Corp.

Material Identification Number	Billet Number	Extrusion Temp. ° F	Reduction Ratio	Ultimate Tensile Strength	Yield Strength .2% offset	Proof Stress .01% offset	Percent Elongation	Elastic Modulus X10 psi	Grain Size, MM
C8-T1 (1)	P-109	1950	54:1	80,600 psi	*	*	0	43.3	*
E10-T1 (2)	P-110	1950	54:1	71,100 psi	57,700 psi	53,300 psi	2	41.6	.010
E10-T2 (3)	P-110	1950	54:1	61,500 psi	52,300 psi	49,300 psi	1	40.7	.010

* Not Given

NOTES: (1) Fracture eminated from a point below surface of specimen. Fracture occured before elongation was adequate enough to permit measurement of yield strength and proof stress. Specimen surface exhibited a few light pits in addition to transvers and longitudinal tool marks.

(2) Surface exhibited one large void which did not effect fracture: Tool marks (both longitudinal and transverse) were visible on specimen surface. Fracture eminated from an internal point.

(3) Surface pitted very slightly. Fracture eminated from a point below surface. Material exhibited a definite yield point analogous to that shown in low and medium carbon steels.

A photograph of the press is shown in Figure 21 and a cross section view of its tooling arrangement is shown in Figure 22.

BILLET PREPARATION

Originally, it was planned to purchase the beryllium in powder form, and cold compact the powder into a steel can which would then be sealed and evacuated. The can would then be hot pressed to densify the beryllium powder before removing the steel by machining the billet to size.

However, it appeared to be more consistent with the requirements of the program to purchase sintered billets of the 3-1/2 inches required diameter. In spite of the higher price per pound of metal so prepared, it was more economical because of the fewer processing steps subsequently required.

Fourteen billets 3-1/2 inches in diameter and 16 inches long were purchased for the program. The condition of the outer machined surface, as received, was considered acceptable for extrusion.

The 16 inch length was sawed into sections depending on the length of extrusion billet required. The ends were then machined as shown in Figure 23.

The chemical analyses of the stock procured from Brush Beryllium was certified to the following analysis:

Lot Number	LYD-1101	YB-5002	YB-5001
Assay	98.6%	98.7%	98.6%
BeO	1.24%	1.30%	1.26%
Fe	0.110%	0.140%	0.120%
Al	0.046%	0.058%	0.040%
Mn	0.009%	0.008%	0.009%
Ni	0.014%	0.018%	0.014%
Li	P- 0.0003%	P- 0.003%	P- 0.003%
Co	0.0002%	0.003%	0.003%
Density g/cc	1.855	1.846	1.855

P- = Present Less Than

DIE DESIGN

For the round rod extrusions, a conventional flat-face die was employed, having an entry radius and land length of 1/8 inch each.

Several different types of die design employed for the U-shape channel are shown in Figures 24 through 29.

Additional details concerning the U-shape die are supplied in Table III.

LUBRICATION

Glass As Protection and Lubrication

In conventional methods of extruding beryllium, the steel jacket not only prevents galling of the dies, but also serves to prevent oxidation of the beryllium during the heating and transfer times. Since the steel can was to be

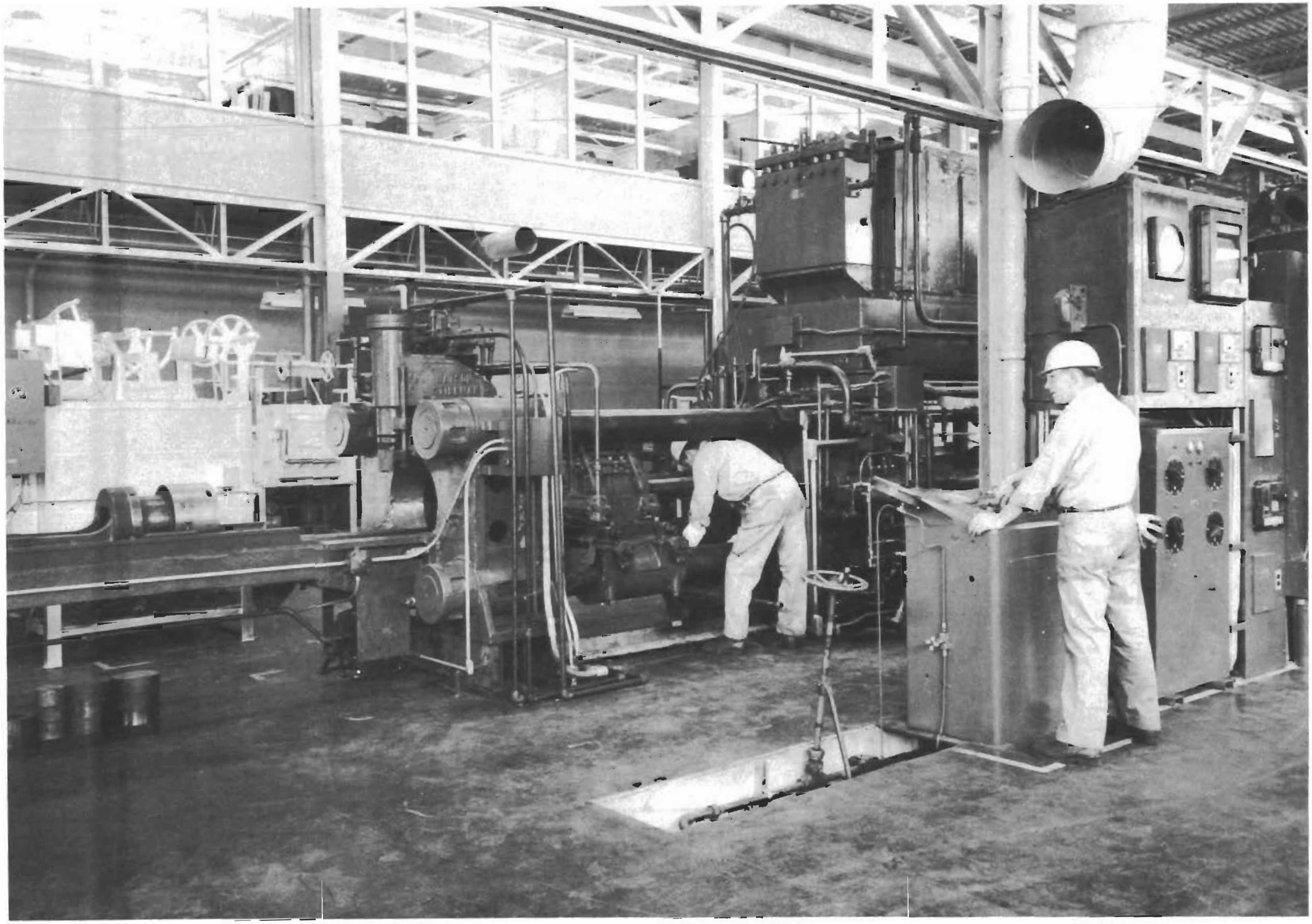


FIGURE 21   1,100 TON EXTRUSION PRESS, PRESS CONTROL PANELS, AND RESISTANCE FURNACE USED IN BARE BERYLLIUM EXTRUSION PROGRAM AT NUCLEAR METALS.

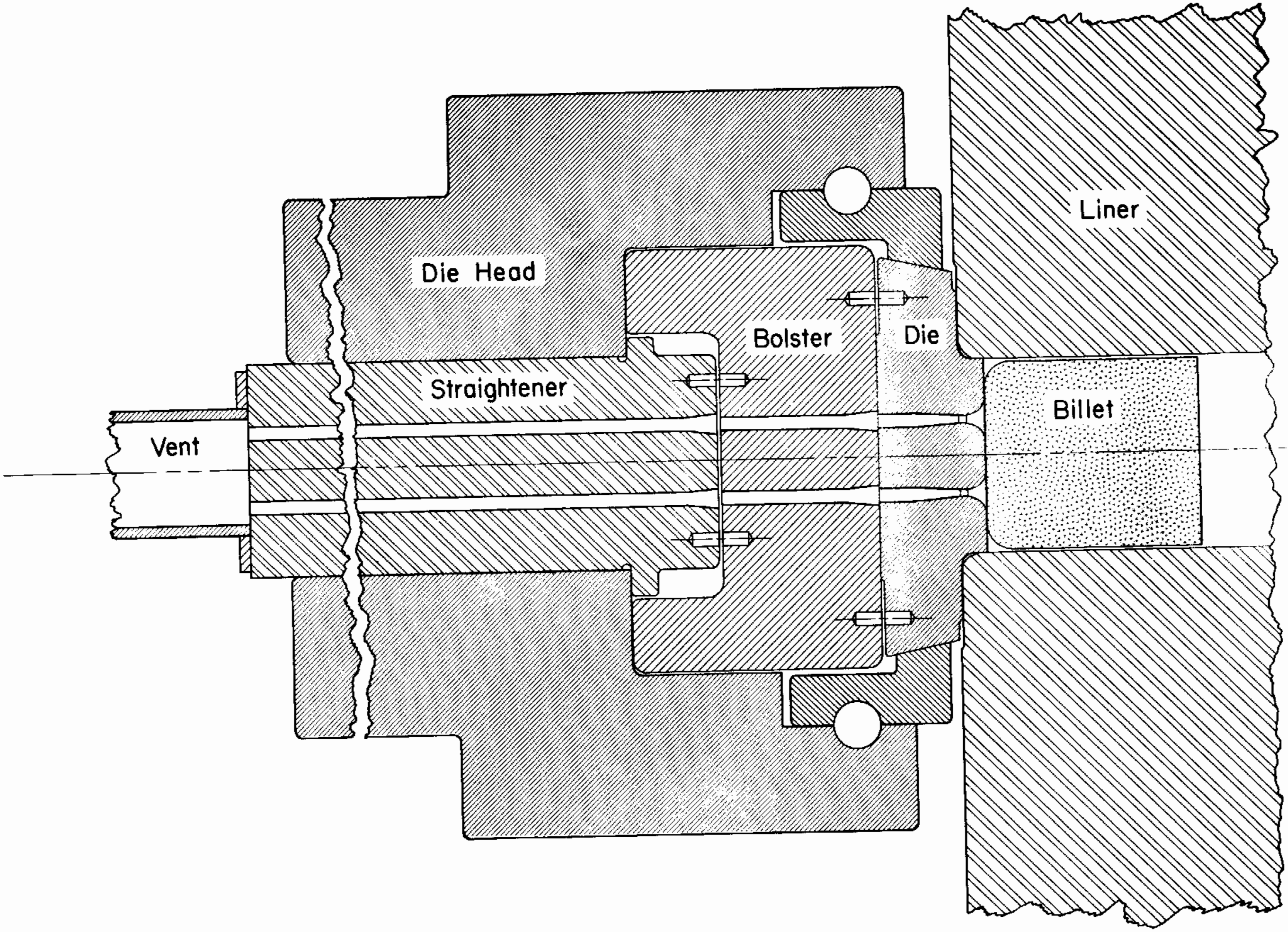


FIGURE 22 CROSS-SECTION VIEW OF NUCLEAR METALS EXTRUSION PRESS TOOLING AS ADAPTED FOR BARE BERYLLIUM EXTRUSION PROGRAM. VACUUM LINE IS ATTACHED TO VENT WHICH ALSO SERVES AS AN EXTRUSION CATCH TUBE.

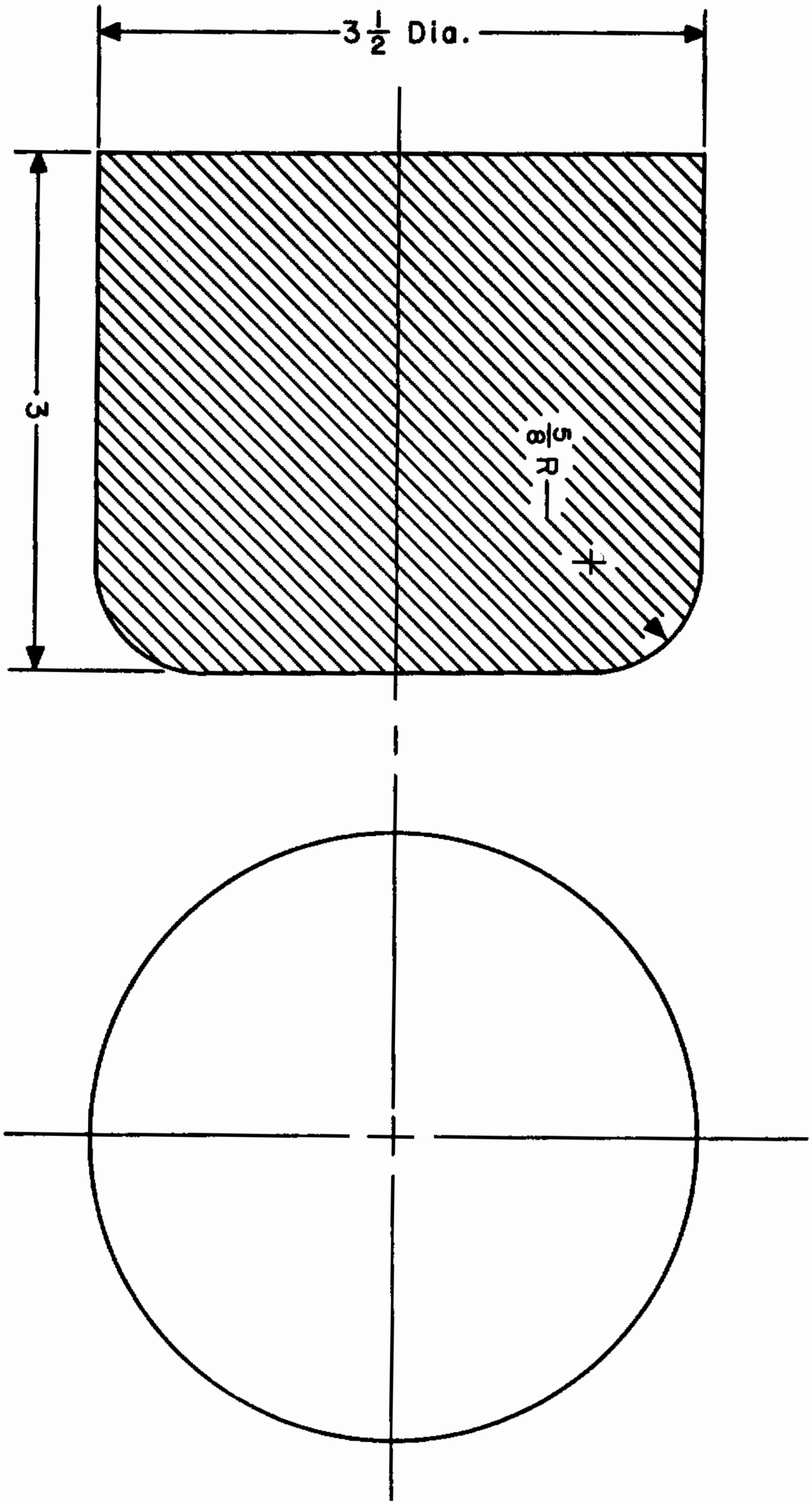


FIGURE 23 DIMENSIONS OF BERYLLIUM BILLET USED IN MOST OF THE EXTRUSION TRIALS AT NUCLEAR METALS.

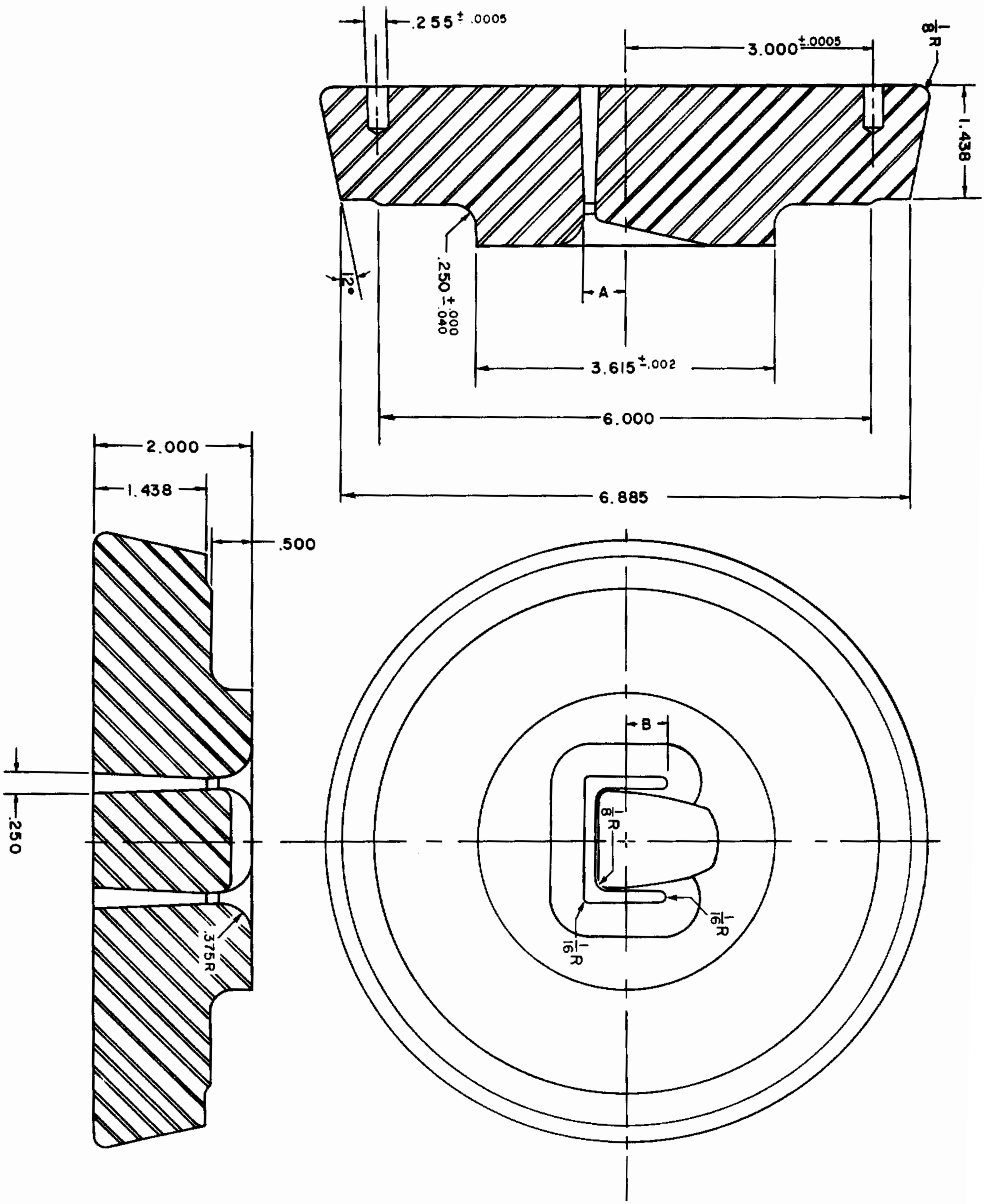


FIGURE 24 DIE DESIGN NO. Z-1-C

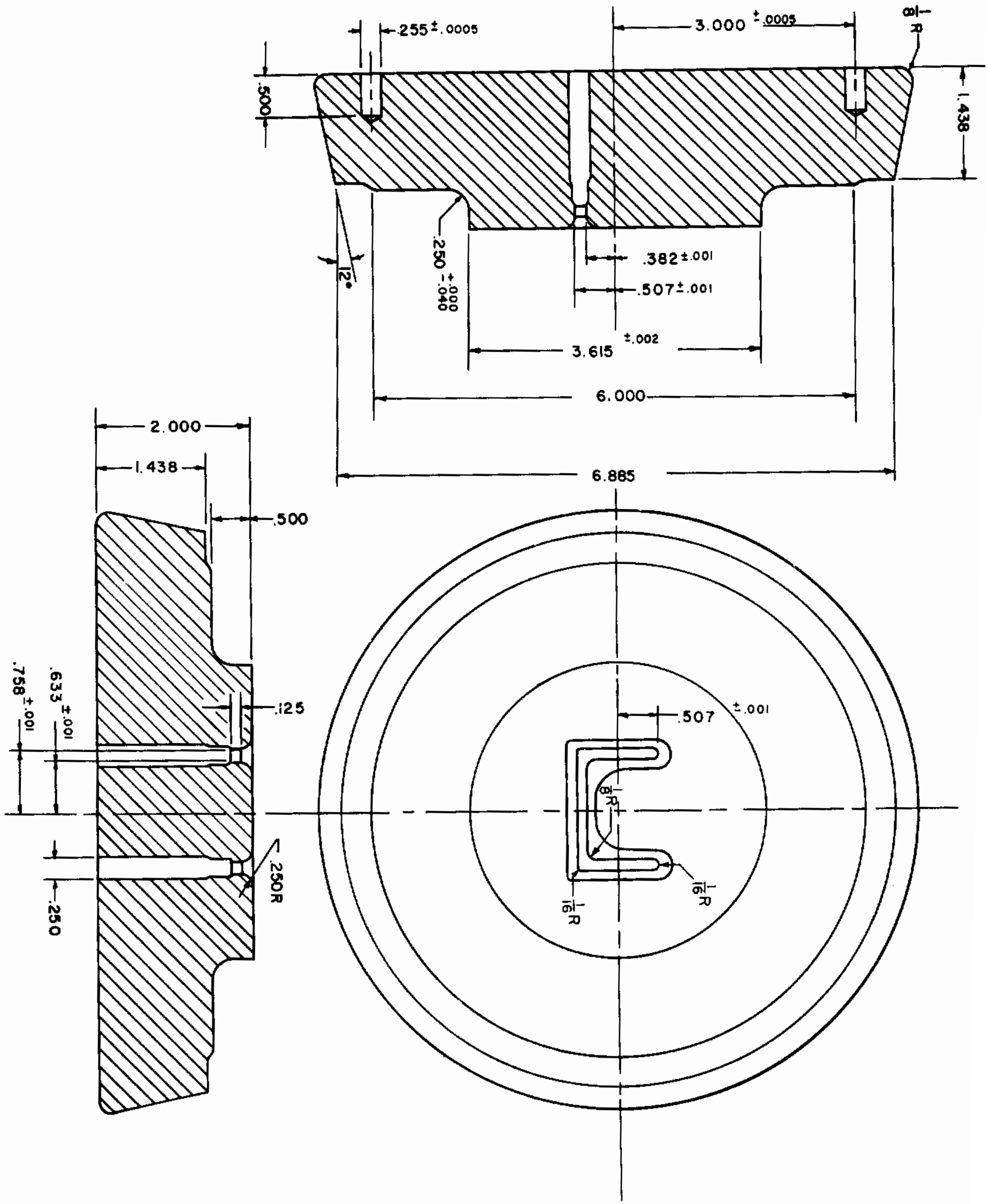


FIGURE 25 DIE DESIGN NO. Z-1-D

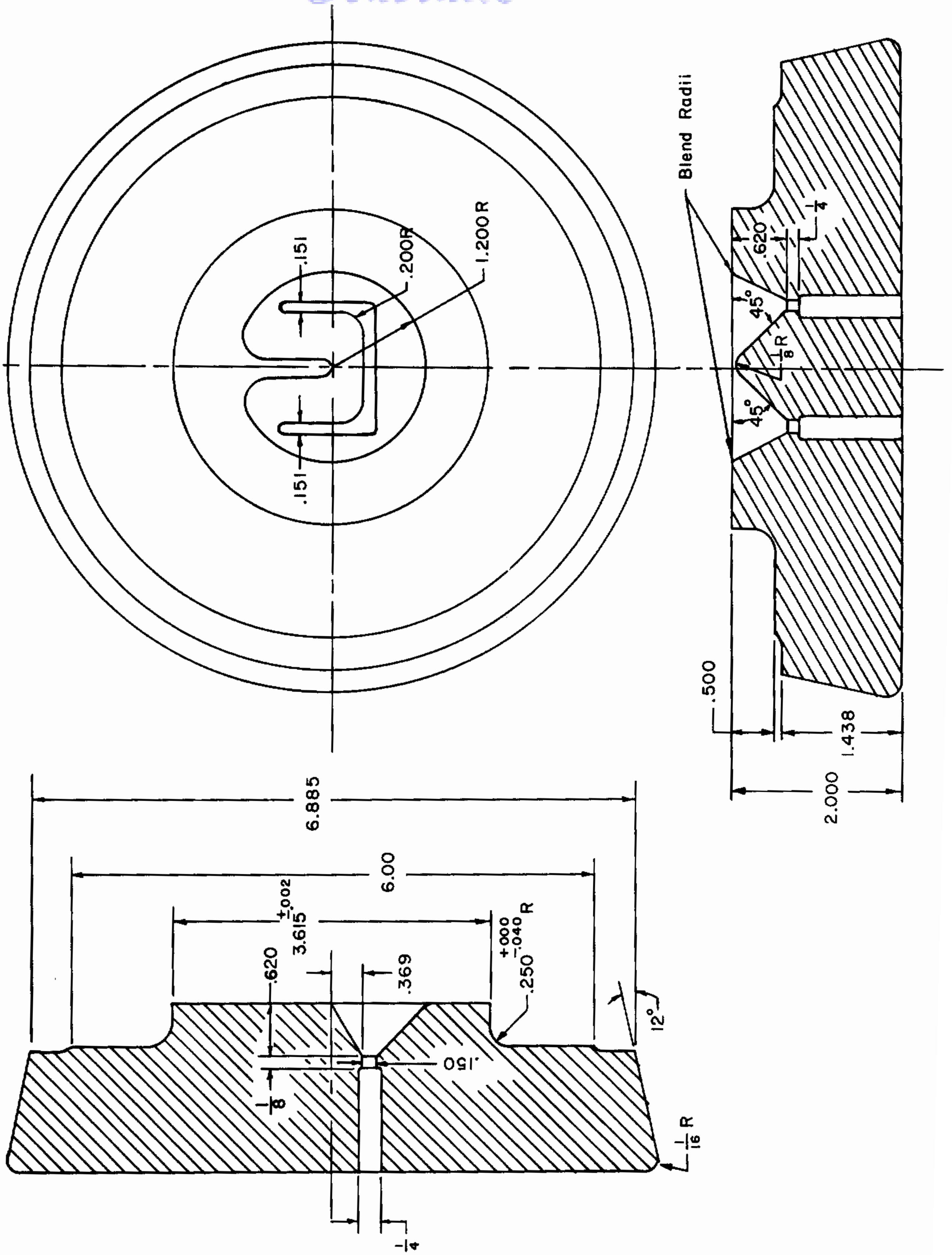


FIGURE 26 DIE DESIGN NO. Z-1-V

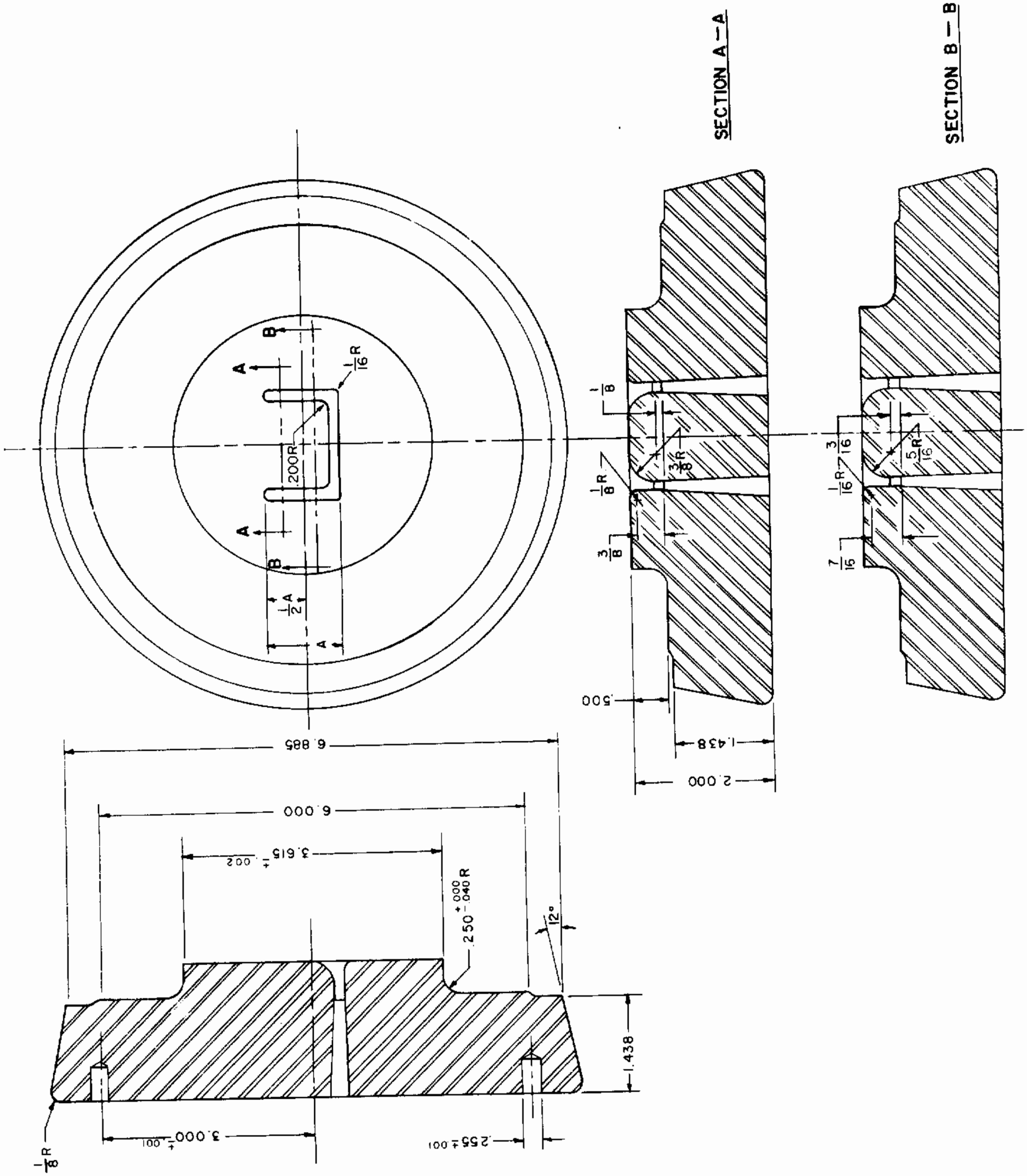


FIGURE 27   DIE DESIGN NO. Z-1-DL

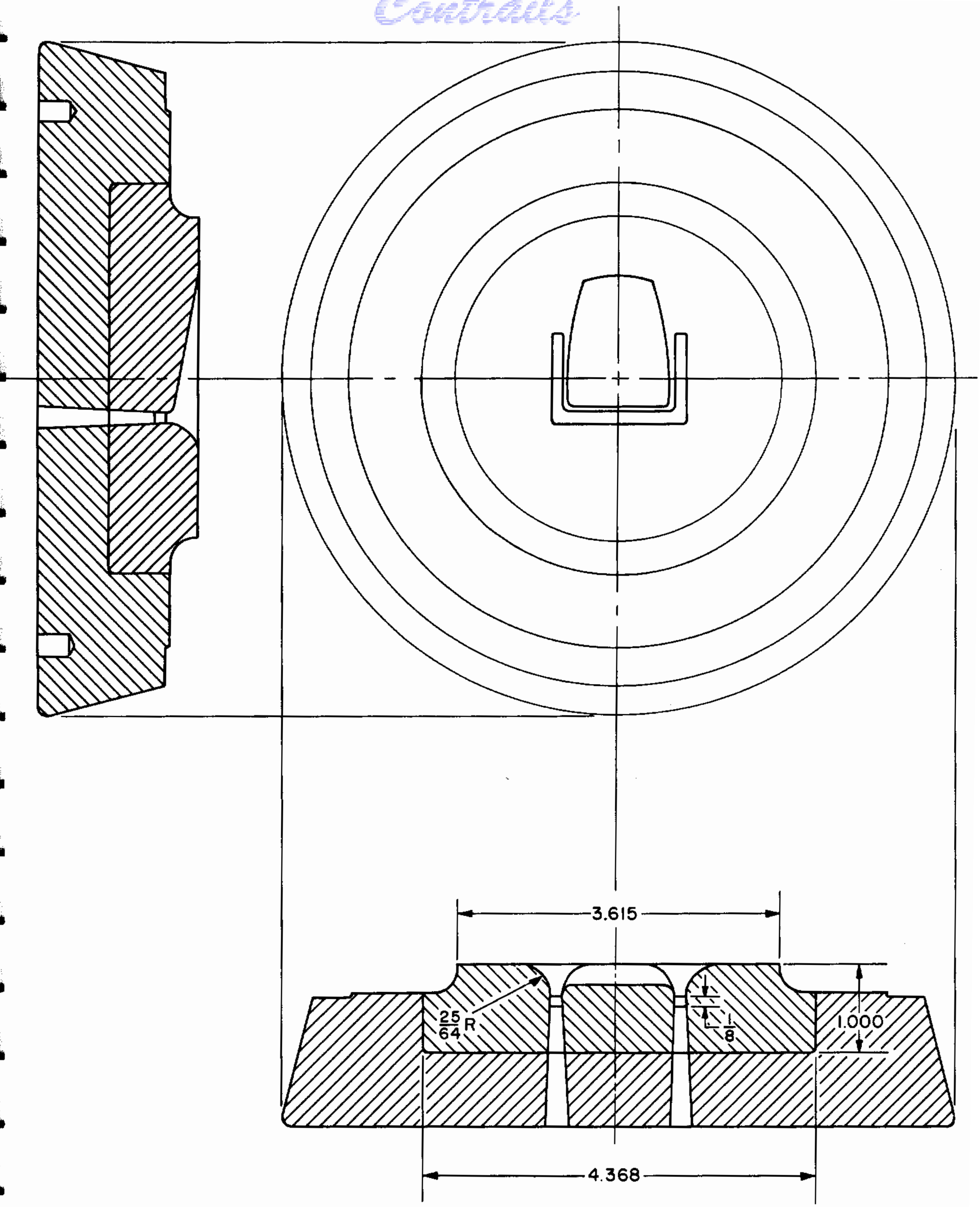


FIGURE 28 DIE DESIGN NO. PMD-1

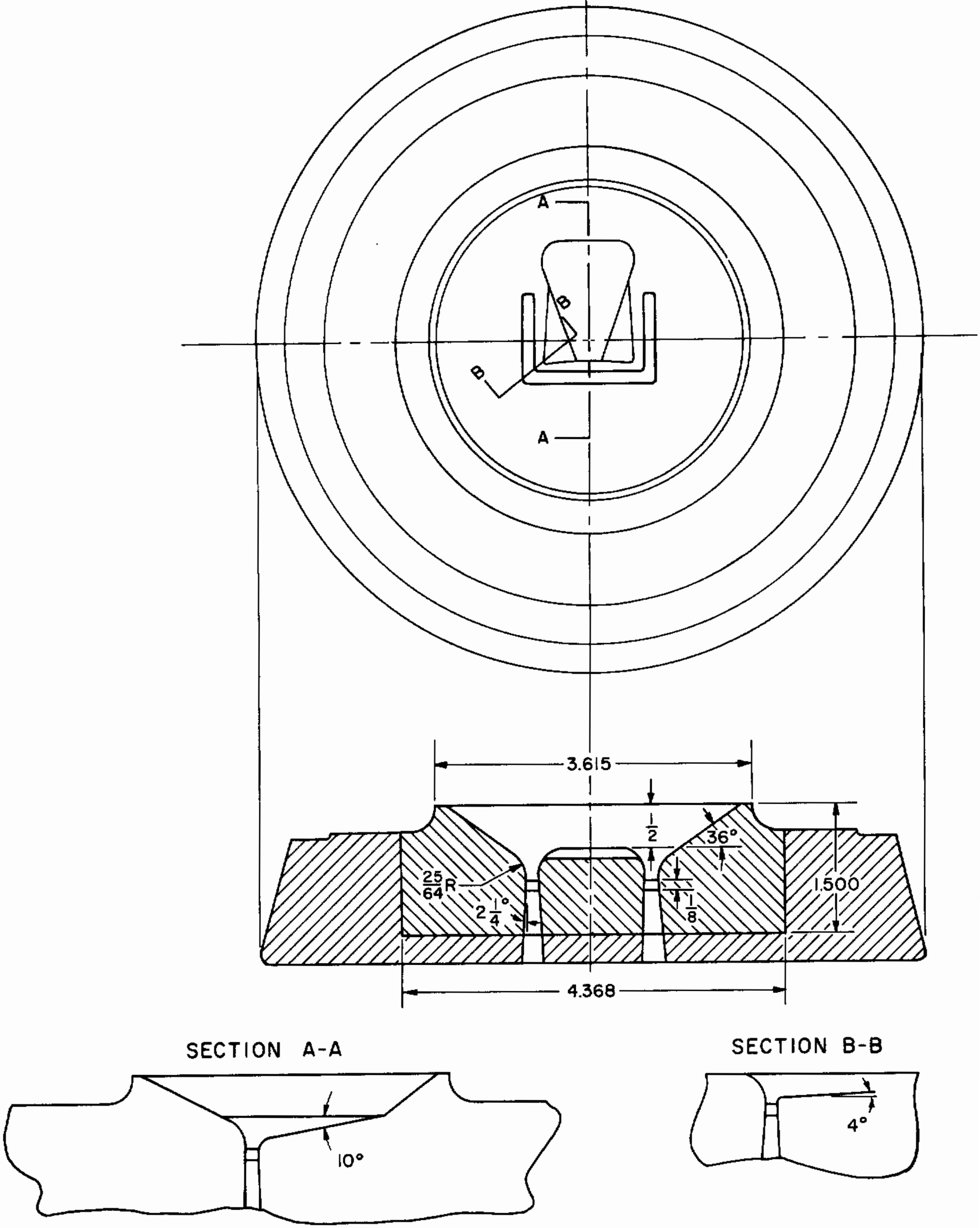


FIGURE 29 DIE DESIGN NO. PMD-2

TABLE III

Data for Dies Used in Extrusion of Channels

Total number of U-shape extrusions = 27
Number of new dies used = 19
Number of times a reworked die was used = 8

(Reworked dies include dies that were used for stalled extrusions and consequently were not severely damaged.)

Die Designation	Manufacturer	Material	Fabrication
Z-1-A	Moczik Tool and Die Co., Detroit, Michigan	H-13 steel	Forging, machined and hardened
Z-1-C	Moczik Tool and Die Co., Detroit, Michigan	H-13 steel	Forging, machined and hardened
Z-1-C modified*	Moczik Tool and Die Co., Detroit, Michigan	H-13 18-4-1 18-4-1 (chrome-plated)	Forging, machined and hardened
Z-1-D	Nuclear Metals, Inc., Machine Shop	M-2 steel	Forging, machined and hardened
Z-1-V	Nuclear Metals, Inc., Machine Shop	M-2 steel H-11 (nitrided)	Forging, machined and hardened
Z-1-DL	Nuclear Metals, Inc., Machine Shop	M-2 steel H-11 (nitrided)	Forging, machined and hardened
PMD-1	PMD Extrusion Die Co.	Co-Cr (face of die only)	Die face is cast, to shrink fit into die bottom
PMD-2	PMD Extrusion Die Co.	Co-Cr (face of die only)	

* The die tongue was raised 1/32 inch.

eliminated in this program, alternate means had to be found to prevent oxidation. Induction heating was considered as a possible means of cutting down the exposure time, and the use of salt baths was considered as a means of protecting the billets during the heating cycle.

Since glass was to be used as the lubricant for extrusion, experiments were planned to determine whether use of the glass would also protect the billet during the heating and transfer cycles. The first of these experiments were to utilize small laboratory samples for a study of salt, graphite, and various glasses, with and without inert atmospheres, as means of preventing oxidation at elevated temperatures. These tests indicated several possibilities that could be used during the heating cycle; the use of a glass coating, however, was the only method tried which would also serve to protect the billet during transfer from the furnace to the press.

There was some question whether the surface oxide formed would, in fact, be detrimental either to the extrusion process or to the properties of the extrusion itself.

Table IV lists the experiments tried on small laboratory samples. It was found that the best results were obtained by first coating the specimens with a slurry of a glass powder and binder, allowing the coating to air dry, and then heating the coated specimen in an argon atmosphere. Figures 30(a), (b) and (c) show some of the samples after exposure.

A billet coated with NMI-C type glass is shown in Figure 31 before heating.

The lubricant with the greatest probability of success in this program was glass used according to the Ugine-Sejournet method. Although the process is proprietary, NMI was already licensed to use it, and no delay was encountered.

The glass lubricants employed in this program can be divided into three main categories:

For Oxidation Prevention

To protect the beryllium billet during heating in the furnace and transfer from the furnace to the press, a glass slurry was used to coat the billet before insertion in the furnace. The two different types used for this application were coded as Glass Types NMI-B and NMI-C. In part, this protective coating also served as lubrication between the billet and the liner.

For Lubricating the Billet OD and the Liner

To supplement the lubrication afforded by the protective coating, glass powders of types NMI-D-1 to D-7 were added, supplemented by glass type NMI-F (a sheet of floss) to insure uniform coverage. The glass powder was sprinkled uniformly on the floss, and this was then wrapped around the billet.

For Lubricating the Die

To lubricate the die directly, but primarily to supply sufficient glass to form and maintain the glass reservoir, glass in the form of a spun pad or disc was placed in the liner against the die before inserting the billet. The glass wools used were Types NMI-E and NMI-G, and the glass discs were made from the NMI-D series of glass powders by adding a binding agent. Discs of lithium carbonate were also employed.

TABLE IV - EXPERIMENTS TO DEVELOP A PROTECTIVE COATING FOR BERYLLIUM WHEN HEATING TO EXTRUSION TEMPERATURES

Protective Medium	Experimental Details	Results
Glass Type NMI-C	Specimen coated with glass and placed in furnace at 1900°F; inspected at 5, 15, and 30 minutes.	Poor; after 30 minutes the specimen was removed for final inspection. Pieces of glass popped off as the specimen cooled and a bluish-white oxide coating was present on the Be.
Glass Type NMI-A	Specimen immersed in molten glass at 2075°F for 1/2 hour.	When the glass was chipped away a heavy bluish-white oxide was observed.
Graphite Powder	Specimen placed in furnace and covered with graphite. Furnace was heated to 1900°F and held for 1/2 hour	Specimen appeared bright and almost free of oxide coating.
Barium Chloride Salt	Specimen immersed in molten salt for 1/2 hour at 1900°F.	A coarse salt deposit adhered to the surface, and was chipped away. The Be surface was rough.
Argon Atmosphere	Specimen heated in argon atmosphere for 1/2 hour at 1900°F and cooled in air.	Specimen appeared clean. A rainbow oxide effect probably occurred from cooling in air.
Glass Type NMI-D-6	Specimen heated in molten solution of glass at 1900°F for 1/2 hour, then removed and air cooled.	Specimen was coated with a heavy green coating of glass, which was chipped off. Be appeared very clean.
Argon Atmosphere	Specimen heated for one hour, but removed every 5 minutes for 30 seconds and then placed back in the furnace at 1900°F, to simulate transfer time.	Heavy oxides were formed.
Argon + Glass Type NMI-B	Specimen painted with 4 coats of glass type B and placed in furnace at 1900°F for one hour with argon atmosphere flowing 10 ft^3/hr.	Glass glazed over the surface of the specimen during heating; specimen appeared very clean.
Glass Type NMI-D-6	Glass type D-6 and cornstarch were mixed with water to form a slurry. Specimen painted with 3 coats and heated at 1900°F for one hour.	Glass popped off rapidly when specimen was cooled in air. Specimen appeared clean and free of oxide.
Glass Type NMI-C + Argon Atmosphere	Specimen was painted with 3 coats of glass type C and heated for one hour at 1900°F in argon atmosphere flowing at 10 ft^3/hr.	Specimen was cooled in air. Glass popped off and left a very clean Be surface.

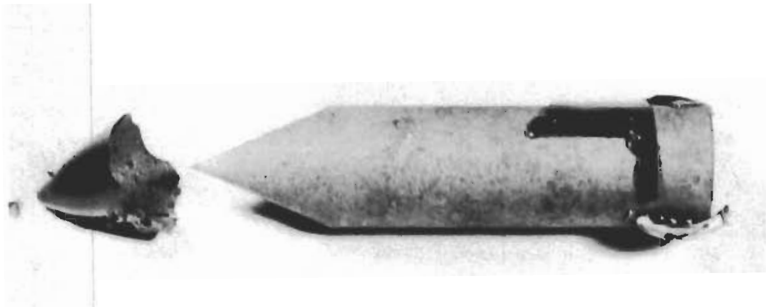


FIGURE 30 (a)

Specimen previously coated with NMI-C glass at 1900°F in argon atmosphere. Specimen was completely covered with viscous glass coating at end of 1 hour period. Specimen was cooled in air.

FIGURE 30 (b)

Specimen after being heated in an inert atmosphere and exposed to the atmosphere to simulate transfer time from furnace to press.

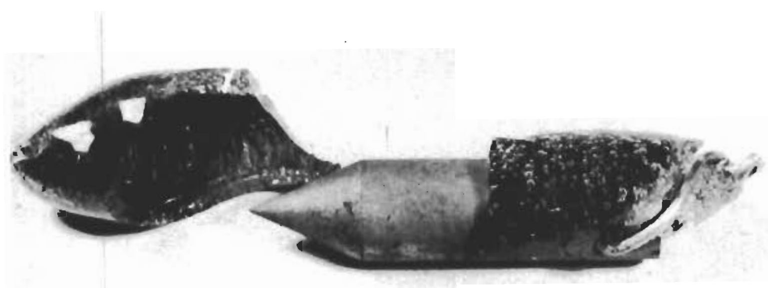


FIGURE 30 (c)

Specimen after being heated in molten glass type NMI-D6. Specimen was cooled in air to simulate transfer time from furnace to press.

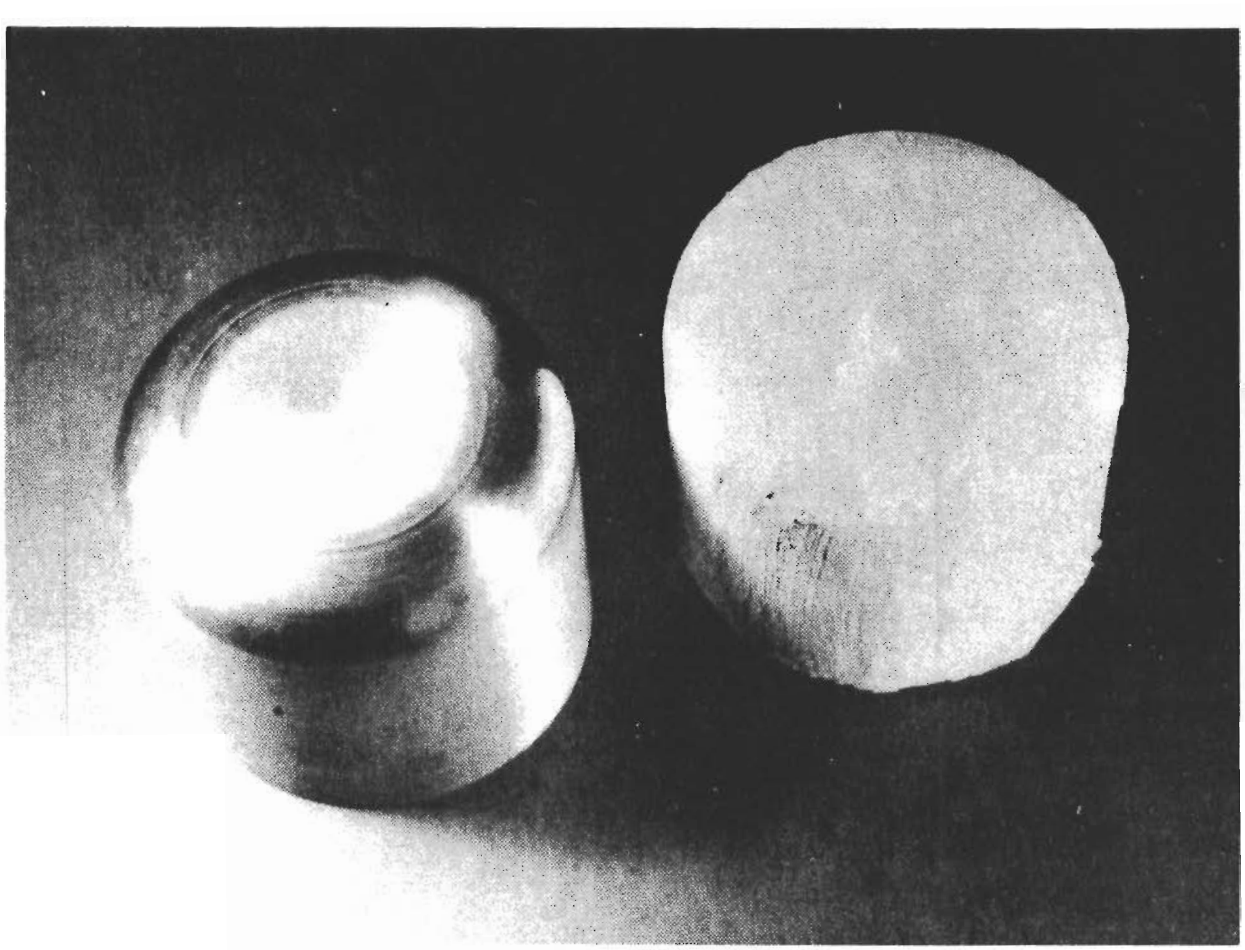


FIGURE 31 Photograph, 1/3X, of an uncoated Beryllium billet next to one which has been coated with NMI-C glass. The coated billet is ready for insertion into furnace and subsequent extrusion.

Figure 32 shows a glass from each of the four categories.

TOXICITY

At every step during the project, the extreme toxicity of finely dispersed and airborne beryllium and its oxide was taken into account. Of particular concern was the possibility of contamination during the extrusion process itself, and for that reason, a huge ventilating hood was positioned above the extrusion press in the vicinity of the extrusion liner; all bare beryllium was extruded directly into a catch tube connected to a vacuum system and double filter; all personnel in the vicinity of the press were required to wear respirators during the extrusion operation.

The continuous glass coating on the billet as well as the glass film on the channel as it extrudes serve to minimize the amount of airborne beryllium during the process.

Provisions for control of toxicity were such as to comply with the precepts of T.O. 00-80BB-1, 10 January 1958.

The extruding area was monitored with air sampling equipment as an additional safety measure and the results were reported by Nuclear Metals Safety Department as follows:

> "Relative to Project No. 3662 (the extrusion of bare beryllium, glass-lubricated shapes) we have found that air samples taken during this operation have been within permissible limits of 2 micrograms of beryllium per cubic meter of air, based on an eight-hour exposure. The Safety Department has kept a careful watch of these operations and is quite satisfied with the results of the air samples. The prime reason for the low concentrations was probably the beryllium being extruded into a ventilated catch tube. Subsequent removal of the bare rod from the catch tube also showed below permissible concentrations of beryllium in air. The highest concentration revealed during this work occurred during an extrusion on January 29, 1959; this was 1.23 micrograms of beryllium per cubic meter of air, still within acceptable limits.
>
> Provided that the remaining extrusions are done in the same manner and are extruded into a ventilated catch tube, you may conduct each operation without notifying this department. However, if production quantities of this material are extruded, we would be interested in periodic sampes to ensure continued safety."

EXTRUSION OF RODS

Having established the heating and transferring technique and the required safety measures, initial extrusion trials were performed on round rods rather than the more complex U-shape, for several reasons, including the availability and much lower costs of round dies. Equally important, however, were the considerations given to establishing proper conditions for streamline flow which would be more readily achieved with the simple shape.

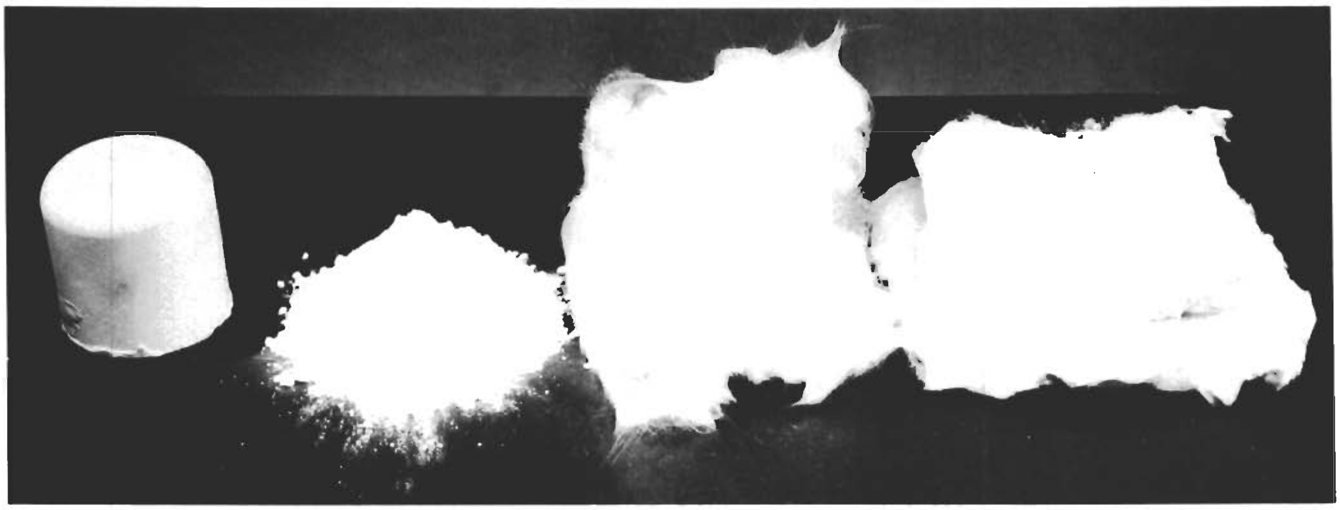


FIGURE 32 From left to right; (1) Beryllium Billet coated with NMI-B glass frit; (2) NMI-D-4 glass powder for lubricating cylindrical surface of billet; (3) A wad of glass floss type NMI-F; (4) Glass wool type NMI-G which is inserted between die and billet.

It was expected that the use of a glass pad, placed between the billet and die, would cause a glass reservoir to form a "conical" entrance to the extrusion die; this would result in streamline flow and cause a continuous film of glass to be fed between the beryllium and die. It was also anticipated that the glass protective coating on the cylindrical surface of the billet would furnish lubrication between the beryllium and the container, and would help replenish the glass reservoir during the extrusion.

Although the first rod extrusion was badly cracked, the results were encouraging; the flow pattern was certainly streamlined, and the glass had lubricated the beryllium enough to prevent die wear (see Figure 33). In an effort to eliminate cracking, the glass lubrication and protective coating was supplemented with a higher temperature glass in the form of a powder onto which the hot billet was rolled before insertion in the press. Because the powder adhered unevenly when the billet was rolled over it, a film of glass floss (having a very low melting temperature) was sprinkled evenly with the powder, and the hot billet then wrapped in the floss-powder layer.

Ram speed and extrusion temperature also were varied in an attempt to reduce cracking. For the extrusion temperature involved, however, the proper selection of lubricant appeared to be more significant in reducing cracking than the choice of temperature or ram speed. It is believed that the reason for the cracking (hereafter called "rattlesnaking") on the round rods was uneven feeding through the die. As the metal flows through the die, the friction on the outside cylindrical surface of the rod restricts the flow of the material on this surface compared with that at the center of the rod. This results in compressive forces in the center of the rod along the longitudinal axis and tensile forces on the outside cylindrical surface. If these tensile forces are sufficiently high for the temperature involved, the rattlesnaking effect will occur.

During the trial rod extrusions, a steel billet was substituted for beryllium and the extrusion was purposely stopped when half of the billet had been extruded. Examination of the partially extruded billet confirmed the fact that a substantial reservoir of glass existed between the billet and the die and that it maintained a contour which was complementary to the streamline flow pattern of the billet.

EXTRUSION OF THE U-SHAPE CHANNEL

After the results of the rod extrusions had been evaluated, an attempt was made to extrude the U-shape channel. The immediate results were both gratifying and discouraging. Although streamline flow was readily effected, die wear was severe and the extruded shape exhibited serious cracking.

There was some concern whether the optimum conditions for bare rod extrusions would apply to the more complicated channel shape. Turbulent flow patterns and higher frictional forces were expected during the channel extrusions.

Extrusion Number 10 was very encouraging. Even though the front and rear were rattlesnaked, and the die was badly washed out a four foot length of good channel was extruded, and the improvements that had to be made were clearly indicated.

FIGURE 33 NUCLEAR METALS, INC. PHOTOGRAPH OF BARE EXTRUDED BERYLLIUM RODS. FROM LEFT TO RIGHT EXTRUSION NUMBERS ARE 2, 7, 8, 3, 4, AND 6.

It was believed at the time that a refinement of the lubricating technique would simultaneously eliminate die washout and rattlesnaking. A great effort was made to refine the lubrication technique of the 27 channel extrusions, 13 of which were direct attempts to improve the lubrication technique, and 8 of which involved modification of the basic lubrication technique developed during the preliminary rod extrusions. Two extrusions were attempted with glass discs and three with lithium carbonate discs. After a number of unsuccessful attempts were made to eliminate die washout and rattlesnaking simultaneously, through improved lubrication, methods were used to treat them separately, as discussed below.

DIE WASHOUT

An examination of washed-out dies indicated that the washout resulted from plastic yielding of the die steel as opposed to a strict erosion or abrasive type of wear.

This plastic yielding of the die results from the combination of two related effects:

- The yield point of the metal decreases ad the die temperature is raised.

- Stresses that equal the lowered yield point of the metal are reached as the metal flows across the die face.

The die temperature increases when the hot billet is pressed against the die and when frictional heat is developed as the billet is extruded through the die.

Die temperature and stress are related in such a manner that any attempt directly to modify one will necessarily result in an increase of the other. For example: if the billet temperature is reduced to keep die temperature down, higher stresses are necessary to extrude the billet to a channel shape.

An improved lubrication technique is the basic way to modify die temperature and stress simultaneously. If lubrication is good, frictional stress and frictional heat are both lowered. As the investigation progressed, however, no lubrication technique was developed which would completely eliminate die washout.

Three forged steels had been used for the selected channel section: hot worked (H-13), M-2, and 18-4-1. Three additional modifications of die material were attempted:

a. A chrome-plated 18-4-1 die used for Extrusion No. 24 was unsuccessful.
b. Two nitrided, hot-worked steel dies used for Extrusion Nos. 31 and 42 were unsuccessful.
c. A cast stellite die was used for Extrusion Nos. 33 and 34 and no die wash occurred even after the second extrusion. A cast die of different design was used for Extrusion No. 35 and no die wash occurred.

It was apparent that the cast stellite die was a solution to the die washout problem.

RATTLESNAKING

Although rattlesnaking (Figures 34 and 35) occurs in the extrusion of other metals, it is more pronounced with beryllium, because of beryllium's low ductility.

It is apparent that during extrusion the flow velocity of the beryllium through the die must be equal in all areas; if the material flows through the web of the die faster than it flows through the flanges, the extruded shape will bow toward the flanges. Since the tooling prevents the bowing from occurring to any degree, tensile stresses will build up in the flanges; of sufficient magnitude to cause repeated fracture as the material issues from the die.

Because of the presence of rattlesnakes in the first 12 inches of Extrusion Number 28 and because of other factors observed in a stalled billet, it was suspected that rattlesnaking might have a tendency to be a cascading effect which could be eliminated completely if it was prevented during the beginning of the extrusion. For this reason Extrusion Number 34 was made with a copper-nickel billet in front of the beryllium billet. The resulting extruded channel was 125 inches long, 48 inches of Cu - 10% Ni and 77 inches of relatively straight, rattlesnake-free beryllium channel.

When the extrusion was examined, it was discovered that the beryllium had a thin coating of glass as well as copper-nickel on its surface. The possibility therefore existed that this extrusion was successful because some of the lead-in billet formed a cone which acted as a lubricant for the beryllium.

In either case, the use of a soft lead-in billet appeared to warrant additional investigation as a method of eliminating rattlesnakes.

Several other changes were made in an attempt to eliminate rattlesnakes. To supply more material to the upper corners of the flanges, the Z-1-V die was designed and used in Extrusion Number 27, but cracked severely in several places because of improper seating during installation. The quality of the extrusion was approximately equivalent to Extrusion Number 10. When a nitrided Z-1-V die was used, in Extrusion Number 31, heavy die wash occurred. Extrusion Number 35 was completely rattlesnaked along one flange only.

A die with wide flange openings (0.170 inch) and a narrow web (0.150 inch) was used for Extrusion Numbers 29 and 30. Both extrusions stalled. Extrusion Number 22 and 23 employed a 40° included angle cone; again, both extrusions stalled.

A close up photo of a foot long portion of rattlesnake-free area is shown in Figure 36.

MECHANICAL PROPERTY TESTS

Nuclear Metals

Because of Nuclear Metals background in beryllium technology, they were requested to conduct mechanical property tests on a portion of the beryllium channel extrusions. These test results and the applicable test methods were to be used as a guide in conducting mechanical property tests at the Contractor's laboratories.

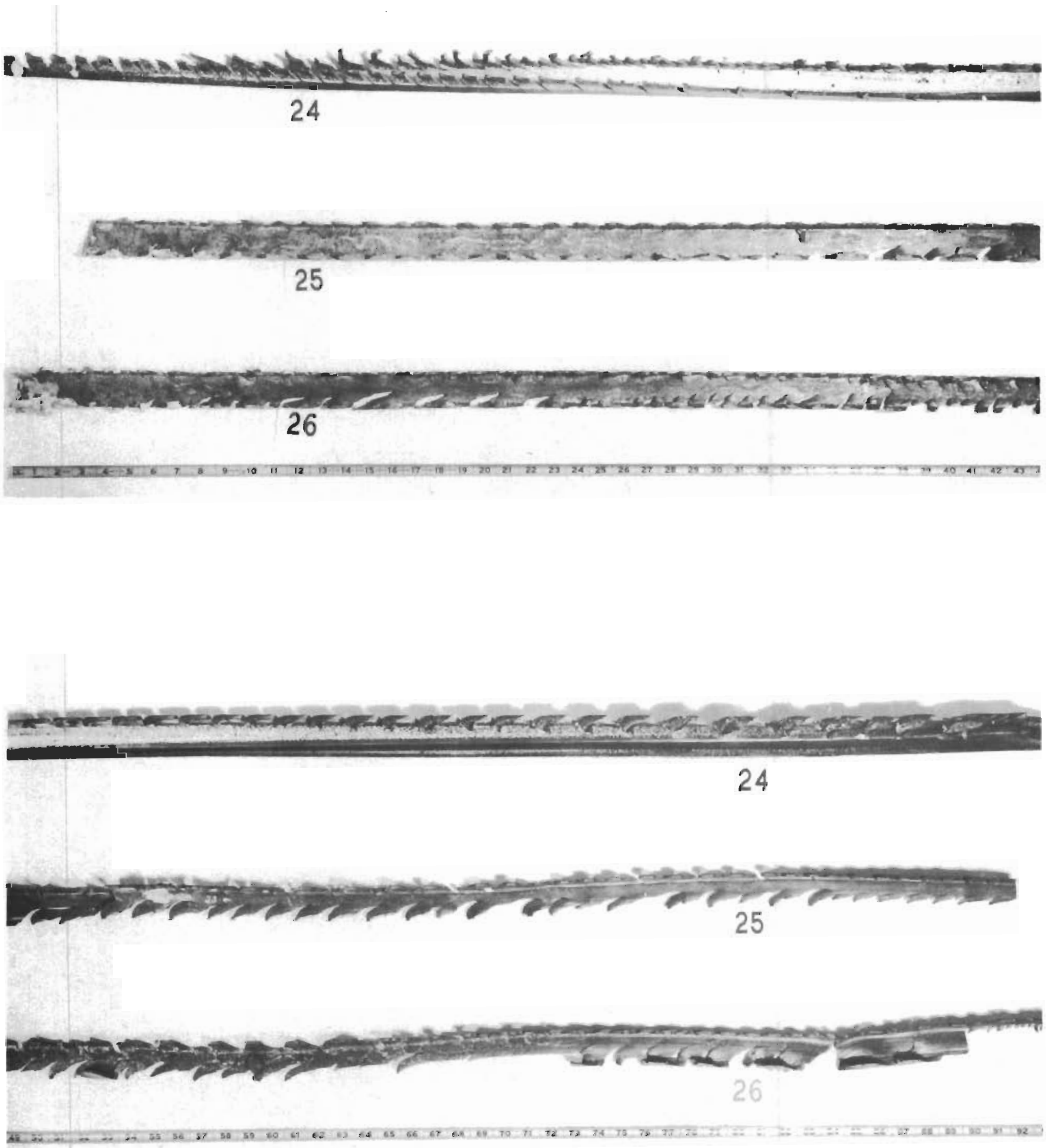
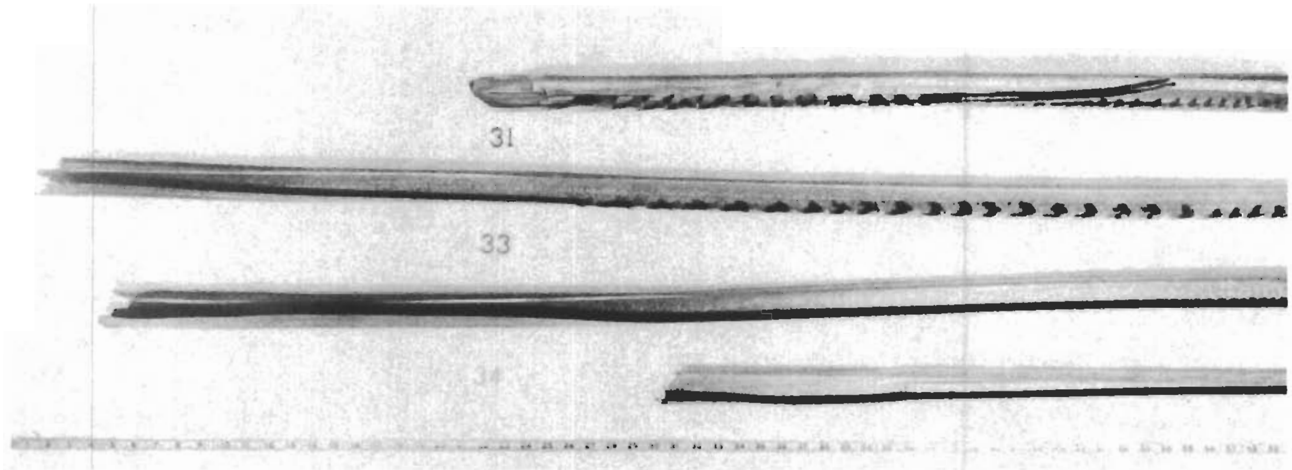


FIGURE 34 RESULTS OF EXTRUSIONS 24, 25, AND 26.



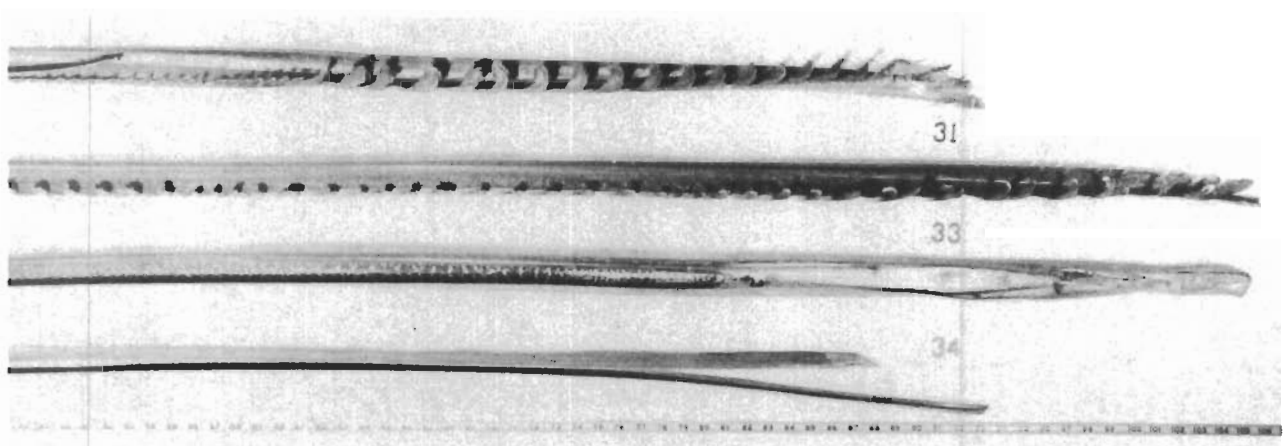


FIGURE 35 TRIALS 31, 33, AND 34. NUMBER 34 WAS MADE WITH A NICKEL-COPPER LEAD-IN BILLET.

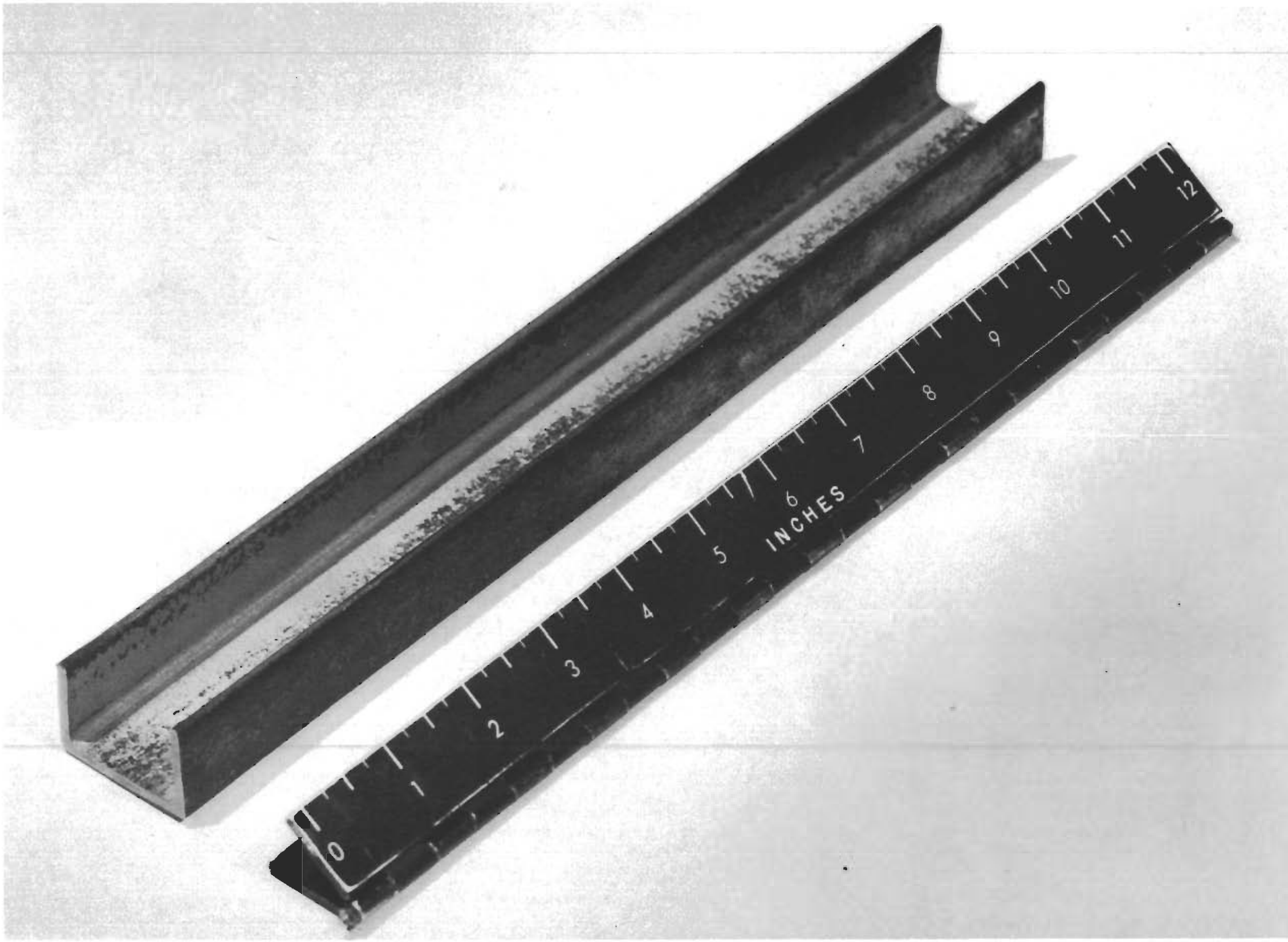
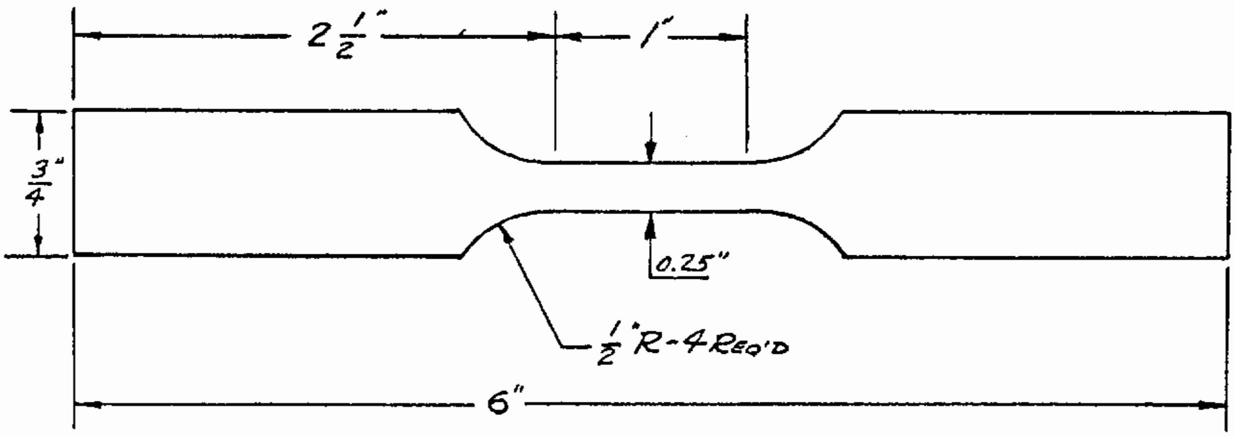


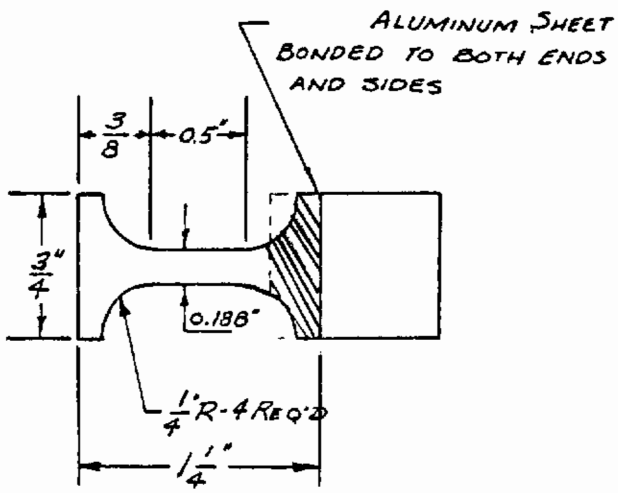
FIGURE 36 1 FOOT SECTION OF GOOD CHANNEL (AS EXTRUDED) TAKEN FROM EXTRUSION NUMBER 11. THE DARK PATCHES ON THE SURFACE ARE GLASS LUBRICANT PARTICLES WHICH FAILED TO SPALL OFF WHEN THE EXTRUSION COOLED.

In order to duplicate test conditions and to obtain comparative test data, identical longitudinal and transverse test specimens were designed. Figure 37 is a drawing of the specimens utilized in determination of mechanical properties in the longitudinal direction while Figure 38 shows the long transverse specimens.



(1) Taper 0.001 to 0.002 to assure gage length failure

Figure 37 Longitudinal Test Specimen



(1) Taper 0.005 to 0.001 to assure gage length failure

Figure 38 Transverse Test Specimen

Notes:
1. Clean up thickness on both sides to bring thickness to 0.100 ± .003
2. Surface finish 16 microinch maximum roughness
3. After machining, etch 0.001 to 0.002 from all surfaces
4. All dimensions ±0.002 unless otherwise specified
5. Break all sharp corners before etching

Nuclear Metals testing was conducted in accordance with the following significant considerations:

a. Specimen surfaces were etched in accordance with the requirement of Figures 37 and 38.
b. Crosshead speed was twenty microinches per second.
c. Perfect alignment (as nearly as possible) was maintained.
d. On longitudinal specimens, strain was measured with Type SR-4 Baldwin-Lima-Hamilton strain gages.
e. Two SR-4 strain gages were placed at the center of the gage length, one on each side of the specimen. Any bending could be observed and eliminated before it had adversely affected the test. Strain gages were used in parallel.
f. Duco strain gage cement, as recommended by the strain gage manufacturer, was utilized and was allowed to dry for twenty-four hours before testing was initiated.
g. The small size of the transverse specimens made it impossible to employ strain gages in their testing. It was also necessary to braze non-beryllium extensions to the grip ends of each small specimen in order to conduct mechanical property tests.
h. Special holding fixtures which would prevent crushing of brittle beryllium were employed in testing specimens where actual gripping of the beryllium was required.
i. Areas from which mechanical property test specimens were taken were subjected to fluorescent penetrant examination to eliminate the possibility of surface defects.
j. Areas from which mechanical property test specimens were to be taken were X-rayed to reveal any internal defects in specimens areas.

Results of the mechanical property tests conducted by Nuclear Metals are shown in Table V.

Nuclear Metals machined two additional longitudinal specimens which were subsequently shipped to contractor for test duplication attempts. Results appear in Table VI.

<u>Norair</u>

Contractor's test activity was conducted primarily to determine the following:

a. Verification of necessary procedures to duplicate the Nuclear Metals test conditions and test results on specimens which had been prepared by Nuclear Metals.
b. The mechanical properties of beryllium when tested by methods similar to those employed for conventional materials such as aluminum and its alloys.

The two longitudinal tensile specimens were received from Nuclear Metals, Inc. and tested. Insofar as Contractor's test facilities would permit, the Nuclear Metals test methods were duplicated. Specimen Number 1 was loaded at the rate of 0.0035 inches per minute throughout the entire test. Specimen Number 2 was loaded at the same rate as Specimen Number 1 except that after the 0.2 per cent yield loading was obtained, the head travel was increased to

TABLE V

Mechanical Properties of Bare Extruded Beryllium
Tested at Nuclear Metals

Specimen Number	Direction Of Grain	Ultimate Tensile Strength, PSI	Yield Strength, (.05% Offset)PSI	Percent Elongation, Dial Gage	Percent Elongation, Strain Gage	Percent Reduction Of Area	Modulus of Elasticity, PSI x 10^6
1	Longitudinal	68,330	54,000	6.6	1.66	1.0	Not Measured
2 *	Longitudinal	45,200	45,200	0.144	Not Measured	0.55	42.2
3	Longitudinal	78,400	50,200	7.0	1.61	0.3	43.7
4 **	Transverse	No Data	Not Measured	Not Measured	Not Measured	Not Measured	Not Measured
5	Transverse	39,500	Not Measured	1.0	Not Measured	Not Measured	46.5
6	Transverse	40,600	Not Measured	1.0	Not Measured	Not Measured	Not Measured

* Longitudinal specimen fractured prematurely

** Specimen pulled out; no values obtained

TABLE VI

NORAIR

Mechanical Properties of Bare Extruded Beryllium

Specimen Number	Grain Direction	Ultimate Tensile Strength, PSI	Yield Strength (0.2% Offset) PSI	Percent Elongation	Modulus of Elasticity PSI x 10^6
1	Longitudinal	80,700	54,100	3.5	43.0
2	Longitudinal	62,500	52,800	1.5	40.7

0.050 inch per minute which would correspond to slightly less than 50 micro inches per second. Results of these tests are shown in Table VI. These test values compared very well with those of Nuclear Metals.

After subjecting another section of beryllium extrusion to fluorescent penetrant inspection and X-ray examination and marking sound areas from which specimens were to be taken, test specimens identical in size and configuration to those produced by Nuclear Metals were produced. Since the Contractor had no beryllium machining facility at that time, arrangements were made with the Missile Systems Division of Lockheed Aircraft Corporation, Sunnyvale, California, to perform the necessary machining. Surfaces of these specimens were etched lightly prior to testing.

Attempts to test these specimens by methods similar to those used on aluminum alloy coupons resulted in very low tensile values. Even in longitudinal coupons which were long enough to accommodate an extensometer, no ductility values could be obtained; neither was it possible to determine yield strength. The results of these tests are presented in Table VII. Fractured longitudinal specimens are shown in Figure 39. Most of these specimens either broke at the border or outside of the gage length.

SUMMARY AND EVALUATION

Phase I proper of the program for "Development of Extruded Beryllium Shapes" was essentially completed during the month of March, 1959. The originally scheduled "pilot production" was not accomplished because capability had not been developed sufficiently to permit extrusion of twenty-foot long sections in the selected channel section configuration.

At the completion of work on Phase I proper, it became necessary to review program accomplishments and to compare the overall progress with the targets established at the beginning of the program. Although the feasibility of bare extruded beryllium shape production was proven, sufficient progress to enable production of twenty-foot long channels was not made. Studies of the program indicated that achievement of original Phase I goals appeared possible if additional production method development was conducted.

The competitive efforts of Phase I proper were performed by the Beryllium Corporation of Reading, Pennsylvania and Nuclear Metals, Inc., of Concord, Massachusetts. The greatest apparent progress was made by Nuclear Metals, Inc. Therefore, it was decided that an extension to Phase I was to be accomplished by one subcontractor, Nuclear Metals, Inc.

The Phase I extension was a continuation of production method refinement and developmental efforts to produce twenty-foot lengths of the selected channel section.

A series of conferences were held with ASD, Nuclear Metals and Norair personnel to formulate details of additional necessary development for the Phase I extension, an outline of which follows in Section VIII entitled "Phase I Supplementary Extrusion Parameter Investigation".

TABLE VII

Results of tests on beryllium coupons taken from bare extrusions and subjected to test methods used on aluminum alloys

Specimen Number	Grain Direction	Ultimate Tensile Strength, PSI	Modulus of Elasticity, PSI x 10^6
7	Transverse	21,480	Not Calculated
8	Transverse	11,030	Not Calculated
6	Transverse	14,320	Not Calculated
1	Longitudinal	41,330	40.32
2	Longitudinal	41,120	49.34
3	Longitudinal	41,220	46.73
4	Longitudinal	27,080	40.61
5	Longitudinal	37,290	51.88

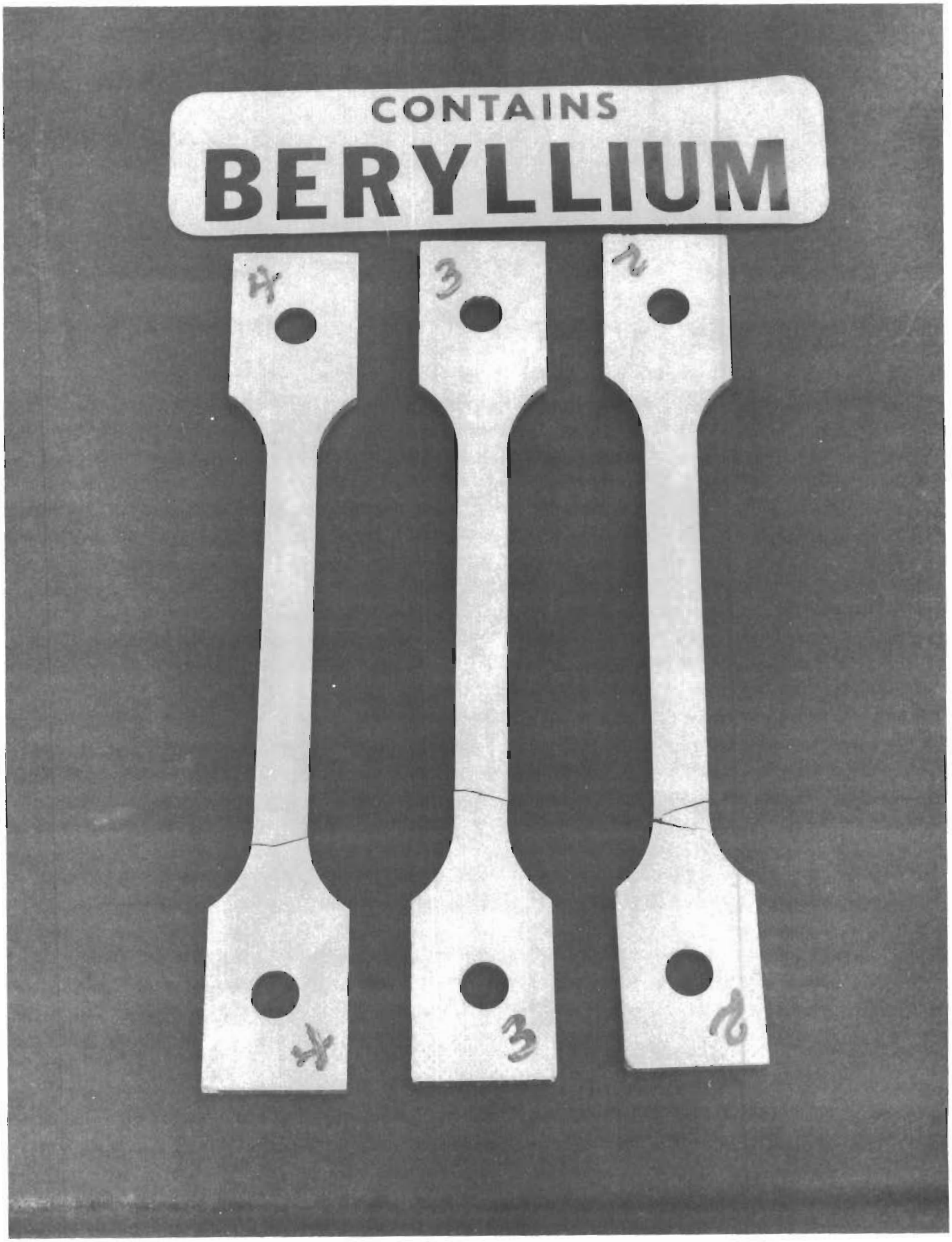


FIGURE 39 FRACTURED LONGITUDINAL TENSILE TEST COUPONS TAKEN FROM BARE BERYLLIUM CHANNEL EXTRUDED IN PHASE I.

VIII SUPPLEMENTARY EXTRUSION PARAMETER INVESTIGATION, PHASE I

OBJECTIVES

Phase I of this project was conducted in accordance with the plan presented in the Contract Synopsis except that pilot production of the selected channel section was not accomplished by either participating subcontractor. Pilot production was omitted because, at the scheduled termination of Phase I, neither participant was capable of producing twenty-foot long extrusions. Nuclear Metals, Inc. of Concord, Massachusetts, was the more successful of the two Phase I subcontractors; therefore, they were selected to continue developmental efforts.

A series of meetings between ASD Aeronautical Systems Center personnel, Nuclear Metals personnel, and Norair project representatives resulted in a decision to continue attempts to solve known problems toward practical production of the twenty-foot selected channel sections.

Similar to the original Phase I effort, the technical approach of the Phase I extension was predicated on the proprietary Sejournet system of using glass as a lubricant. Details of that approach involved further experimentation at Nuclear Metals and then an exploratory effort at Wolverine Tube in Detroit using their faster acting press.

The scope of the Phase I extension included the further study and evaluation of those factors in the extrusion process that appeared pertinent to the accomplishment of the purpose. The scope also included the determination and publication of fundamental principles which may be applied to the problem of extruding complex shapes in beryllium.

For purposes of convenience, the Phase I extension was divided into a series of tasks which will be accomplished, insofar as is feasible, in the order of their appearance herein. The following outline presents the titles of each planned task with a brief synopsis of the efforts that were to be included in each task:

Task A Extrusion Using Best Present Technique

Task A included attempts to produce as many as four short extrusions employing production techniques similar to those of Extrusion Number 34 of Phase I proper. In event that any of these short extrusions indicated success, a twenty-foot long extrusion (U channel shape and size) would be attempted using the same techniques. Task A extrusions were to be made to establish what might be termed the "present state-of-the-art" and possibly to demonstrate the feasibility of producing twenty-foot lengths by techniques developed to date. Up to four short billets and two long billets were required for Task A. Planned Nuclear Metals evaluation included up to twelve bend specimens and two tensile tests.

Task B Solution To The Ductility Problem

Clad beryllium extrusions have apparently exhibited greater ductility than their bare extruded counterparts. The object of Task B was to determine what caused the relatively low ductility in bare beryllium extrusions. Investigation was planned to include heating practice, lubricants, preferred orientation, cold work, internal defects, composition, etc. as possible causes of low ductility. Task B required extrusion of up to five short billets and testing of as many as twenty bend specimens and four tensile specimens.

Task C Lubrication Study And Investigation

Task C was divided into five possible sub-tasks which are listed below. In addition to specific lubrication investigation, salt bath billet heating was also available in the Phase I extension.

1. Use of lead-in glass discs for lubrication
2. Use of various metal coatings to enhance extrusion lubrication
3. Use of a wider variety of glass compositions than was possible in Phase I proper
4. Use of metal and glass mixtures as extrusion lubricants
5. Use of non-beryllium metal lead-in pieces to assist in "starting" beryllium extrusions

Task C, as planned, would require up to twenty small billets, six large billets, thirty bend tests, and four tensile tests.

Task D Extrusion Conditions (Temperature, Reduction Ratio, and Speed)

Temperature, reduction ratio, and speed are related to each other and within the limitation of the available (or possible) extrusion pressure. It was expected that experiments in Task A might indicate that 1750°F, would be considered best for the production of bare beryllium extrusions with adequate ductility. Because of this, experiments would be required to adapt the present techniques to such new temperatures as are necessary. It was also expected that investigation of extrusion ratios other than those of Phase I proper would be necessary. Because extrusion speed has some influence on the behavior and solidification of glass lubricants, this would be taken into account if speed became a critical parameter affecting lubrication. Task D would require extrusion of up to four billets for each temperature, each reduction ratio, and for the study of speed. Twenty bend specimens and two tensile specimens were considered maximum subcontractor test requirements for Task D.

Task E Die Design and Die Materials

It was expected that Task E dies would be basically flat type with a small radius approach. Some modification might be attempted in order to feed and provide glass more uniformly through the length of the extrusion. A more complex die design would be employed only if other approaches to the extrusion problem fail.

It was planned to use cast (stellite type material) insert dies unless they proved less satisfactory than during the first portion of Phase I. If twenty foot long beryllium extrusions are produced with these dies, some low cost carbon steel dies of the type used in glass-lubricated steel extrusion were to be tried.

As many as sixteen short billets and four long billets were planned for Task E. Up to forty bend specimens were anticipated.

Task F Post-Extrusion Treatment

The straightening backer then in existence at Nuclear Metals was not to be used until it was felt that the bare beryllium extrusion process was under control and that the straightening die was not likely to introduce any secondary difficulties. Work was also planned to establish optimum methods for cleaning the glass lubricant from the extruded section. Possible cleaning methods include the use of molten caustic, mechanical brushing, and chemical etching.

Task G Evaluation of Mechanical Properties

Mechanical properties of the extruded sections would be evaluated throughout the program whenever a sound section was produced. Most of the tests were to consist of small bend tests. The amount of deflection at fracture would be used as the main indication of ductility. Sections showing promising ductility from the bend test data would also be tested by more comprehensive tensile tests, both in the longitudinal and transverse directions.

Equipment used in Phase I extension was identical to that in the original Phase I except that the mode of billet heating was changed to molten salt to prevent oxidation not only during heating but during transfer from the furnace to the extrusion press.

BILLET PREPARATION

Billets were procured from Brush Beryllium in the same pressed and sintered form as was used in the earlier Phase I efforts. The condition of the outer machined surface, as received from Brush Beryllium, was considered accepable for extrusion.

The 16 inch as-received length was sawed into sections depending on the length of extrusion billet required. The ends were then machined into three basic types as shown in Figure 40.

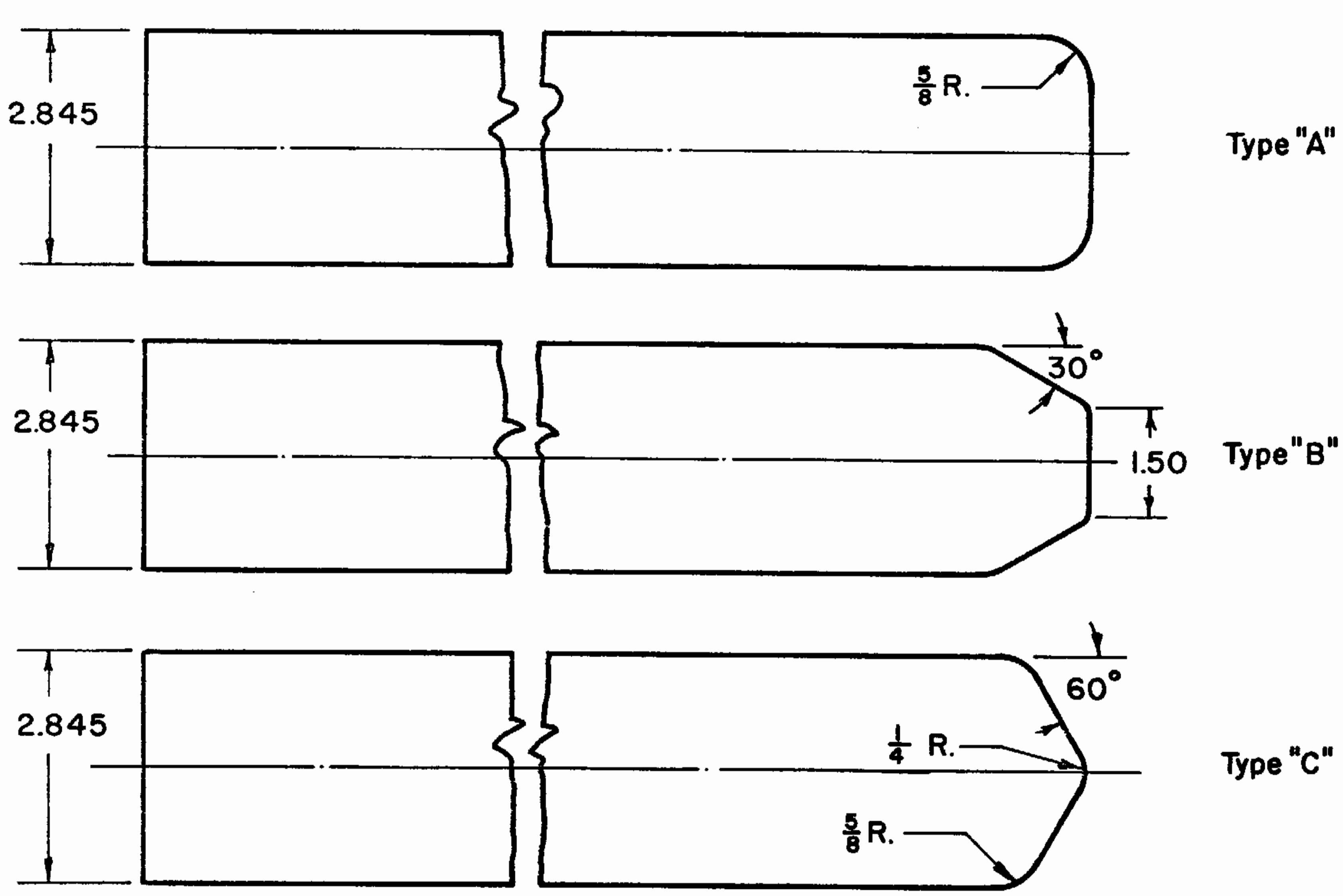


FIGURE 40 THREE BASIC TYPES OF BILLET FRONT-END PREPARATION. THE TYPE OF STARTING SHAPE GREATLY INFLUENCES THE SHAPE DURING EXTRUSION.

An investigation was conducted by the Contractor to determine the composition of the beryllium material being employed in the supplemental work. It was determined that the composition met the requirements of Brush Beryllium Company Specification Number S-200-A. The analysis of this material fell within the composition limitations shown below:

Beryllium Extrusion Billet Composition

Element	Percent of Element
Beryllium Assay	98.0 Minimum
Beryllium Oxide	2.0 Maximum
Aluminum	0.16 Maximum
Carbon	0.12 Maximum
Iron	0.18 Maximum
Magnesium	0.08 Maximum
Silicon	0.12 Maximum
Any Other Metallic Impurity	0.04 Maximum

However, this material was outside the composition limits of Specification Number ND-161A. It was felt that if it could be used in the production of extrusions having adequate combinations of ductility and strength, much would be gained, since this material was both less costly and more plentiful than the ND-161A material.

The material used in the program was purchased from the Brush Beryllium Company in four lots which were certified as follows:

	Lot 1	Lot 2	Lot 3	Lot 4
Assay	98.6%	99.13%	99.13%	99.07%
BeO	1.26	0.96	0.96	1.25
Fe	0.120	0.100	0.100	0.122
Al	0.040	0.036	0.036	0.075
Mg	0.005	0.010	0.010	0.009
Si	0.028	0.024	0.024	0.040
Density (g/cc)	1.855	1.833	1.833	1.855

DIE DESIGN AND DIE MATERIALS

The die material selected must resist the erosive and abrasive action of the extruding metal, and should resist the galling action and tendency for "pick-up" of the beryllium. The initial cost of the material, the cost of fabrication, and the number of extrusions per die (die life) would be economic considerations.

Tolerance control and surface roughness are dependent upon die wash, closure of the die opening, and variations in the lubrication action during extrusion.

At the beginning of this Phase dies were made of steels such as H-13, 18-4-1, H-11, and M-2. During the extrusion, however, severe die wash occurred and it was obvious that the die material chosen should not become tempered at the temperature it reaches during extrusion, and that it must have a high hot-hardness.

Cast stellite was therefore tried as an insert placed into a die holder. While the resistance to die wash increased considerably, the adverse tendency for die closure under pressure also increased.

The original optimistic estimates of die life were quickly tempered with the finding that the stellite insert flowed under load and decreased the size of the land opening. This major displacement occurred during the first push; however, after reworking, the die size remained relatively constant for additional extrusions. Under the worst conditions, the initial opening could close to 0.089 inch in the bottom of the U-shape. This problem did not occur to this degree when steel dies were used.

In an attempt to correct this tendency for die closure, and still prevent die wash, several different cast materials were tried. The original ED Stellite was replaced in subsequent dies by EDS Stellite, with no significant improvement. Two other castable materials, Rexalloy 33 and Haynes 98M2, were tried without minimizing the closure effect.

The dies used in this program were produced by Duplicast Corporation of Detroit by the following procedure. They are design Numbers PDM-1 and PDM-2, shown in Figures 28 and 29 in the previous section.

Step No. 1: A master oversize pattern of the die insert was fabricated from metal or plastic material. This pattern incorporated all features of the die insert design and allowed for the shrinkage of the cast die insert material.

Step No. 2: The master pattern was mounted on a base plate and surrounded by a metal flask. Mold material, a semi-liquid mixture of refractory and organic binder, was poured over the pattern and hardened. The pattern was then ejected, freeing itself from the solidified mold material.

Step No. 3: The mold was then baked at a high temperature to remove the binder and to produce a permeable body. After sufficient soaking at bakeout temperature, the mold was allowed to air cool.

Step No. 4: A gating system was attached to the ceramic mold cavity. At this point the mold was prepared to receive molten metal.

Step No. 5: A pre-weighed heat of the desired alloy was then melted and brought to the appropriate pouring temperature. When the metal had been poured in the mold and allowed to cool to a point near room temperature, the casting was removed.

Step No. 6: The casting was sand blasted to clean the surface and to remove all residual mold material.

Step No. 7: All gates and risers were removed by abrasive cutoff prior to finish-machining by grinding.

TOXICITY

The same precautions and safeguards were utilized as were developed for previous efforts. Air monitoring was continued and resulted in safe levels. One extrusion, extruded into open air purposely without the special ventilation equipment, still resulted in acceptable air-sample contamination levels.

EXTRUDING EFFORTS AT NUCLEAR METALS

Preliminary Efforts

On the basis of prior work of the originally scheduled Phase I, several short extrusions were attempted in Phase I extension incorporating techniques similar to that used on Extrusion Number 34, the best extrusion of the early series, which incorporated a copper-nickel lead-in plug in front of the beryllium billet. These extrusions, Numbers 36, 37 and 38, were made to establish "the-state-of-the-art" and to demonstrate whether it would be possible to attain the required length by techniques developed up to that time. Cast-stellite dies were used for the first two extrusions and a stellite-faced die for Extrusion Number 38. The cast dies, produced two 6 foot lengths free of cracking or damage. The stellite-faced die, however, began to deform under the load and caused rattlesnaking of the extruded piece in the portion corresponding to the deformed section of the die.

Although the results with regard to the product extruded from cast stellite dies appeared favorable, a discouraging aspect was the close approach to maximum force of the extrusion press toward the end of each extrusion, indicating that if a longer billet had been used, stalling might have occured in each case. Because it was not definitely known, however, that the high pressure pattern was due to the use of the short billets (which may influence the pressure by a butt-end effect, for example), a series of three longer extrusions (10 feet and 20 feet instead of 6 feet) was scheduled. From the results of these three attempts, it appeared that further work had to be done to improve the marginal lubrication which existed, and to eliminate the pressure-rise problem portrayed in Figure 41. In addition, the role of the copper-nickel had to be more thoroughly investigated since examination of Extrusion Number 40 indicated that rattlesnaking occurred where the copper-nickel film terminated on the legs of the U-shape, but continued in the web. When the termination of this film also occurred in the web, the section became sound since no differential lubrication existed to allow the web to extrude at a faster rate when only glass was present as a lubricating medium.

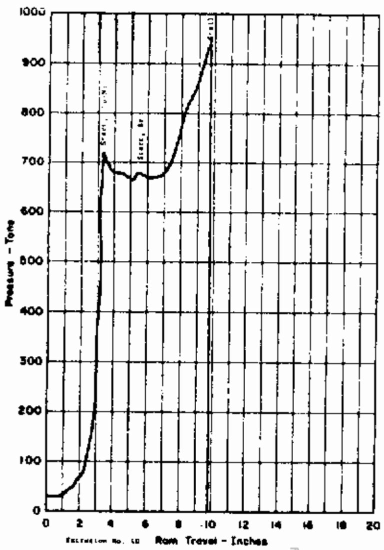


Figure 41

Pressure Chart for Extrusion No. 40. Note Sharp Pressure Increase as Extrusion Progresses.

In the next series of extrusions, it was planned to investigate the following items:

(1) The necessity of a copper-nickel lead-in plug when stellite dies were employed.

(2) The possibility of a favorable alteration in the pressure pattern by utilizing a different temperature-glass combination for the extrusion, or heating in a salt bath rather than in a resistance furnace.

(3) The existence of a butt-end effect caused by the shortening of the billet during the extrusion, and the role it played in the progressively increasing pressure towards the end of the extrusion.

Extrusion 42 was made, under substantially the same conditions as Extrusions 36 and 37, to investigate the effect of omitting the copper-nickel lead-in cone. A sound channel was produced with no evidence of rattlesnaking, indicating that the copper-nickel was not essential for proper lubrication or for preshaping the beryllium billet. Extrusion 44, a repetition of 42, confirmed this.

Although the type of pressure pattern could be varied slightly by different glass lubricants, none of the lubricants caused a significant change in pressure rise, nor did heating in the salt furnace.

Extruding Pressures

In a twofold experiment to evaluate the butt effect, the type of material used for the rear cutoff was varied to more nearly match the extrusion coefficients of the beryllium, and longer beryllium billets were employed. This check of a possible butt effect indicated that, while it might exist to some limited degree, it was not the primary cause for the sharp pressure rise. Nor did the cause appear to be the depletion of the glass film supply on the OD of the billet or of the glass that formed a conical approach to the die.

A test was also conducted at this time to entrap additional glass in the conical approach to the die. Extrusion resulted in a high pressure reading, however, even though more glass was present in the form of a cone at the end of the run than was normally present during the start of a regular extrusion. Because it was expected that the pressure rise might be associated with the starting temperature of the billet and cooling effects, extrusions were attempted with billets heated in the temperature range of 1750 to 2100°F, and with the liner heated at 900 and 1000°F. Comparisons were also made with pressure patterns obtained with billets which suffered delays during transfer from the furnace to the liner. In all these cases the pressure patterns built up to some degree. The only two findings of a more positive nature were indications that higher ram speed and large quantities of glass minimized the pressure rise.

Unfortunately, it was not possible to program a high speed extrusion for direct comparison with a slow speed extrusion; the force required to extrude the 3.625 inch billet was just below the automatic switch-over point from high to low speed which was mandatory above 600 tons because of the type of hydraulic pumps employed on the extrusion press. To check the possible correlation between pressure build-up and extrusion speed, the recording instrument was modified to superimpose a time trace every second on the extrusion charts. The findings appeared to be significant, and indicated that the pressure rise occurred during a change in speed of the forward motion of the ram. Extrusion Chart Number 86 (Figure 42), is shown with time pulses running in the horizontal center line of the chart, indicating that the ram speed remained at 140 in./min throughout the extrusion. Compare

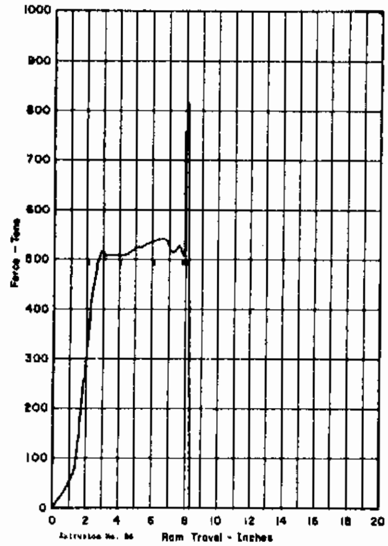


Fig. 42 - Pressure Chart for Extrusion No. 86

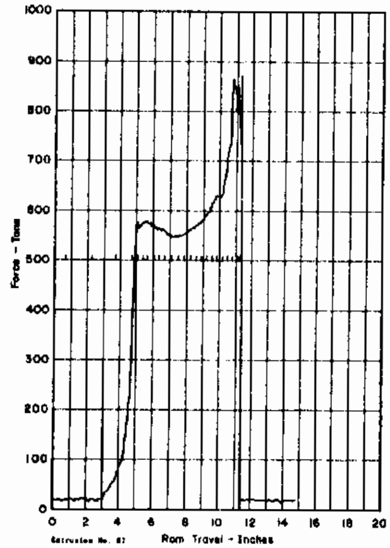


Fig. 43 - Pressure Chart for Extrusion No. 87

this with extrusion Chart Number 87 (Figure 43) which shows that the high speed was in effect until the high pressure caused an automatic switch to the lower ram speed.

It was not known, however, whether the increasing pressure was caused by the switch to lower speeds or whether the automatic switch to lower speeds was the result of the increasing pressure caused, for example, by the solidification of the glass lubricant.

Therefore, extrusions Number 86 and 104 were scheduled to utilize both steel and beryllium billets respectively during the study to achieve long lengths. This series of extrusions revealed that:

1. When extruding steel through a round die, either a slow or fast ram speed could be used to obtain a normal flat pressure pattern if no glass were present as a lubricant and a conventional 90° cone were employed (see Extrusions 88 and 89).

2. When extruding steel through a round die, and utilizing glass as a lubricant, it was necessary to maintain fast ram speed to obtain a flat pressure pattern (Figures 44 and 45). A slow ram speed, with glass resulted in an increasing pattern (compare Extrusions 86, 91, and 111 with 87, 91, and 98, Appendix V).

3. When extruding beryllium under conditions similar to the above cases where glass is employed, the rate of pressure increase is greater with beryllium than with steel (compare Extrusions 90 and 91). Unlike steel extrusions, beryllium, when extruded without glass through a 90° cone,

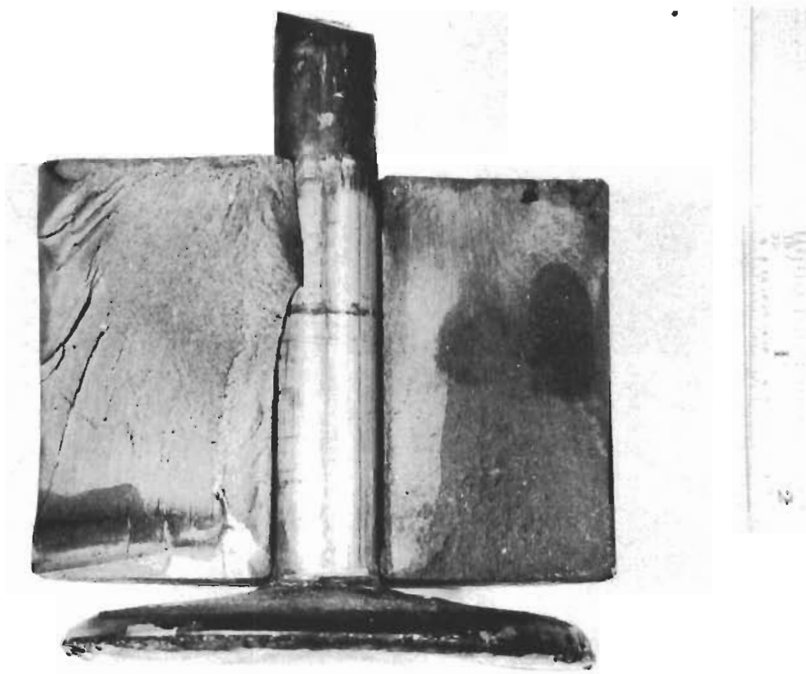


FIGURE 44 Photograph after fracture of round die. The space between the butt and die is where the glass lubricant formed a conical entry to the die.

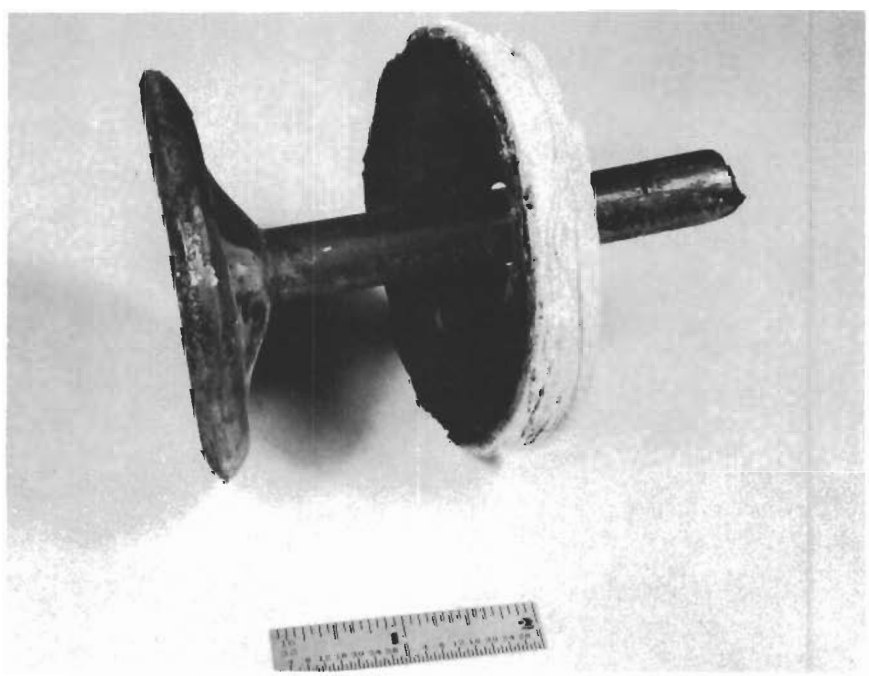


FIGURE 45 Photograph of glass cone (encircling rod) remaining after the extrusion. This cone of glass forms a gradual entry into the land of the flat die, serves to lubricate the extrusion, and insulates the hot billet from the die.

resulted in a pressure increase during the extrusion (see Extrusion 101).

4. At both slow and fast speeds, when a 150° steel cone is employed (to simulate the approach pattern to the die when using glass), a slight pressure rise occurs when extruding steel billets (compare Extrusions 95 and 107 with 88 and 89, and with Numbers 91 and 111 which employed a glass cone of 150° contour at low and fast ram speeds, respectively).

Items 1 and 2, above, indicate that a fast ram speed would minimize the pressure increase and would allow longer extrusions to be made. This indication was subsequently proven in Extrusions Number 105 and those following. The fact that the pressure increase does not occur (under the optimum condition of using a 90° cone to generate streamlined flow) when glass is not used indicates that the temperature at the billet-liner interface may be a critical factor with respect to quality of lubrication and related frictional forces on the surface of the billet.

Item 3 suggests that the cooling effect of a beryllium billet may be more severe than in the case of steel; this agrees with theoretical calculations which indicate that the temperature drop would be more severe in beryllium. The cooling rate of billets is discussed in more detail below.

The significance of Item 4 is not completely understood; the fact that the optimum geometric approach is not employed probably results in greater forces to effect the extrusion with such a flat cone. Since a point on the surface of the billet, under such conditions, must travel a much greater distance than a corresponding point on the longitudinal axis of the billet (greater than with a 90° cone) one might consider the shearing internal action within the billet to be the cause for the increase in pressure. If this perhaps oversimplified effect was the cause of the increased pressure in Item 4, it is possible that the same effect occurred in Item 3. A cooling effect on the OD of the billet would restrain the beryllium at the periphery while the hotter center core extruded at such a fast rate that shear forces between the slow and fast-moving section would generate the increasing pressure even though a 90° cone was employed (Extrusion 90). This effect is discussed in more detail in a later section.

Since these results indicated that fast ram speed was required to prevent chilling of the billet, all subsequent extrusions were performed in a smaller size liner, which resulted in ram force low enough to allow full press speed. The change was from a 3.625 to a 3.056 inch liner diameter.

Cooling of the Billet

A source of considerable concern was billet heat loss, a theoretical analysis of this loss is as follows:

Heat Loss from Billet During 30 Second Transfer from Salt Bath to Liner

Temperature of Billet	= 1850°F or 1010°C
Volume of Billet	= 48.1 in^3(3-1/2 D X 5 in long)
Weight of Billet	= 3.17 lbs or 1.437 Kg (W)
Q	= Heat Content of Billet
Qr	= Heat lost by radiation
Specific heat Be	= Cm = 0.78
Emissivity of Be	= E = 0.61

Assume 30 second in air

Q = WCmt = (1.437) (0.78)(1010) = 1131.2 Kg-Cal = 4488.9 BTU

$$Qr = 5.76E\left[\left(\frac{T_2}{1000}\right)^4 - \left(\frac{T_1}{1000}\right)^4\right] = (5.76)(.61)(2.70) = 9.49\ \frac{\text{Watts}}{\text{Cm}^2}$$

$$Qr = 4545.7 \text{ watts or } 258.58\ \frac{\text{BTU}}{\text{min}}$$

Qr = 129.3 BTU (for 30 sec)

$$T = \frac{\Delta Q}{WCm} = \frac{\Delta Qr}{WCm} = \frac{(1.29.3)(.252)}{(1.437)\ \ (.78)} = 29.08°C$$

T = 981°C or 1799°F = Temperature of billet before insertion into liner.

A 3-1/2 inch diameter billet with a thermocouple inserted in the center was heated in the salt pot to 1750°F, then removed and air cooled to simulate the cooling rate during the transfer of the billet to the liner. The measured cooling rate during the transfer time was 1.3°F per second; during the transfer time from the salt pot to the entrance of the liner, a nominal 15 seconds, the billet could thus be expected to lose approximately 20°F.

A repeat of the test on a 3-1/2 inch diameter beryllium billet confirmed that the temperature at the center of the billet decreased approximately 1.3°F each second during the transfer in air and decreased over 2°F per second after being inserted into the liner prior to upset. Tests on a 3 inch diameter billet, with the thermocouple inserted within 3/16 of the billet OD surface, indicated that the rate of cooling during an air transfer is approximately 3°F per second in air, approximately 2°F per second in air when coated with glass, and approximately 9°F per second when installed into the liner but not upset (Figure 46). The larger values for the loss during air transfer of the smaller billet are believed due to the billet size more than to thermocouple location. The higher rate of cooling for the smaller billet in the liner is believed due to the location of the thermocouple, located near the billet surface in contact with the liner, as well as the smaller size of the billet.

The more severe cooling of the small-size billet can also be observed by comparing the curve for Extrusion Number 105 (3 inch billet) with the curves generated on most 3-5/8 inch diameter billets through U-shaped dies. In the case of Extrusion Number 105, the pressure increased at a rate of 22 tons per second as compared with 14 tons per second average for the larger diameter billets. Since the smaller billet has a lower running pressure it might be more significant to express these values in Δ P/P per second, which would show a 5.5% pressure increase per second for the smaller billet. Since the smaller

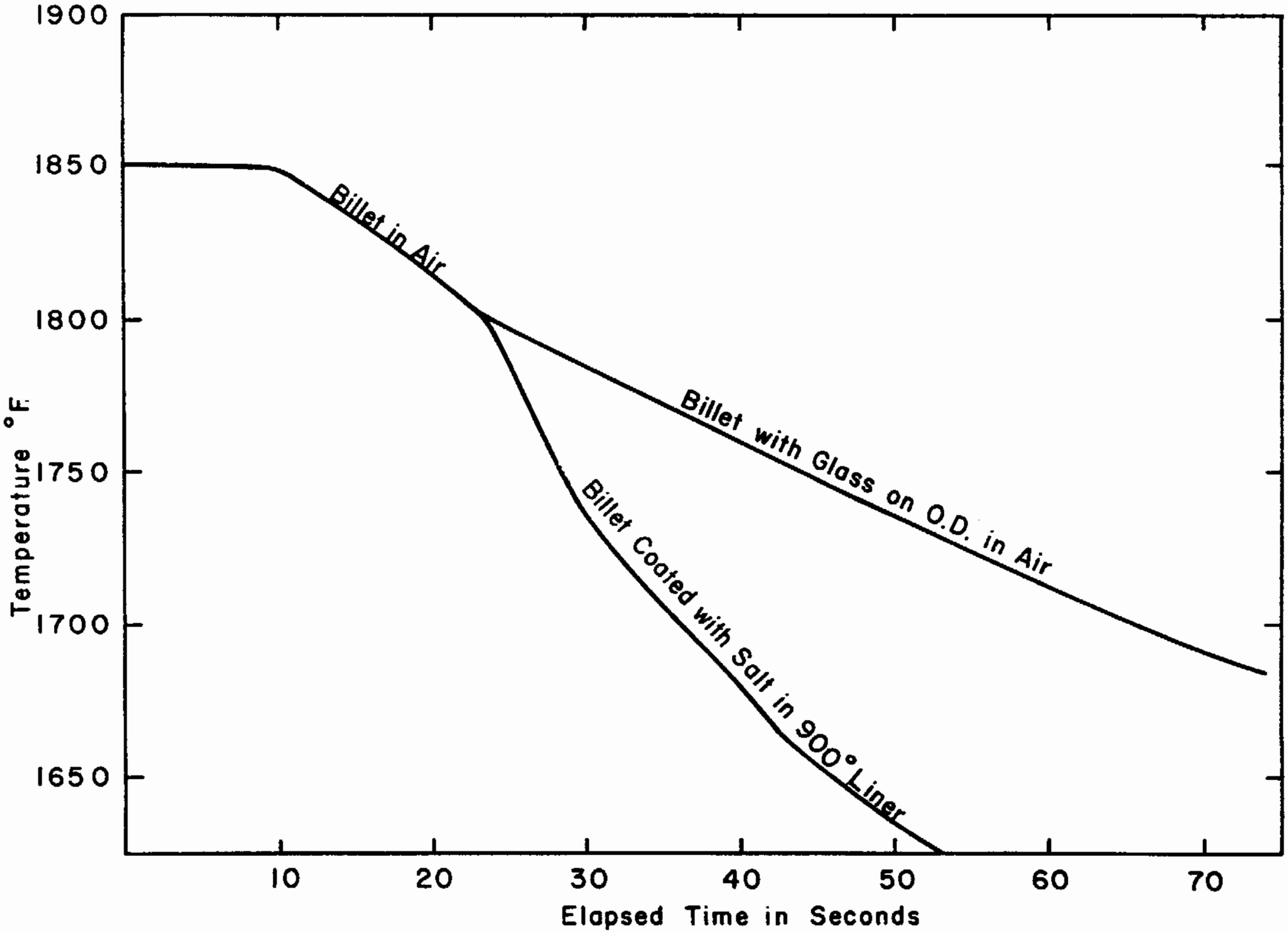


FIGURE 46 COOLING RATE OF 3 INCH DIAMETER BILLETS HEATED IN SALT. THERMOCOUPLE LOCATED 3/16 INCH FROM OD SURFACE AT MID-LENGTH.

diameter billet, however, can be extruded at 120 in./min vs 13 in/min for the larger billet, the total increase in pressure is much less when the fast speed can be employed with the small billet. This comparison of Extrusions Numbers 105 and 106, with the pressure pattern of larger diameter billets, is another point in favor of the cooling effect being the main cause of the increasing pressure.

Heat Loss Studies

In an attempt to insulate the billets from the relatively cold liner, two special tests were made:

a. The smaller liner was pre-treated by coating it with a .0025 inch layer of glass applied in the form of an enamel by allowing the glass coats to dry between several applications. This liner, which effectively had a glass cylinder covering its inner wall, was used in the extrusion of a steel billet (Extrusion 109). The results appeared very promising and it was the first extrusion where a glass film still remained and covered the die at the inside corners at the end of the extrusion. A repeat of this extrusion, with a beryllium billet (Extrusion 114), was not successful and the die was completely washed away.

b. In Extrusion Number 111, a steel billet was wrapped in three layers of glass sheet during its transfer from the salt pot furnace to the liner. This time, the pressure remained constant and the lubrication characteristics were excellent. This "thermal blanket" was used successfully on subsequent beryllium extrusions.

Rate and Uniformity of Flow

There were several indications of the faster feeding of the beryllium at the center of the billet. Figure 47 shows severe rattlesnaking in a beryllium round, believed to be caused by the development of tensile forces on the OD of the extrusion to offset the high compression forces in the fast-feeding core.

Figure 48, the cross-section of a butt remaining after a U-shape extrusion, shows the additional distance that must be traveled by a particle of beryllium on the OD of the billet compared to a particle in the center. Note also that the OD material which flows to fill the inside bottom of the U-shape has a longer and more rigorous path than the OD material which fills the ouside bottom. In turn, the outside sides of the U-shape are the closest to the supply of OD material.

For a study of material flow during a U-shape extrusion, the following experiments were scheduled:

1. Extrusion Number 119, which had steel and nickel wires imbedded longitudinally in the billet, one directly in the center and eight just inside the periphery of the billet. Figure 49 is an X-ray study of the flow of the wires after extrusion of the beryllium into a U-shape.

2. Extrusion Numbers 129 and 130 were made with aluminum billets having machined circumferential grooves to act as tracers of the shift in the U-shape extrusions. Figure 50 shows the shift that occurred.

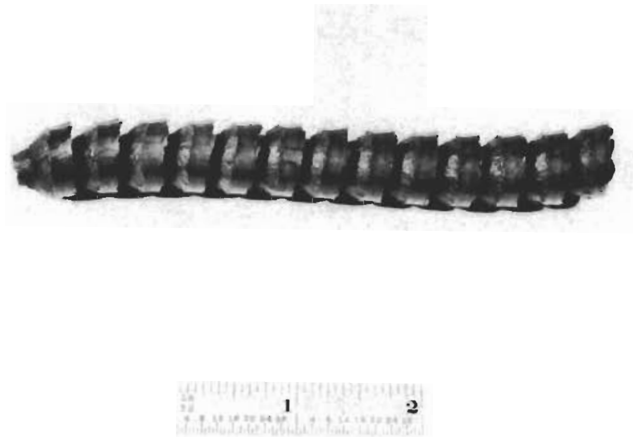


FIGURE 47

Extrusion 101, bare Beryllium through a round die, showing "rattlesnaking" caused by fast feeding of the core of the rod while the periphery was restrained, either by frictional forces on the die or by a chilling of the surface of the billet.

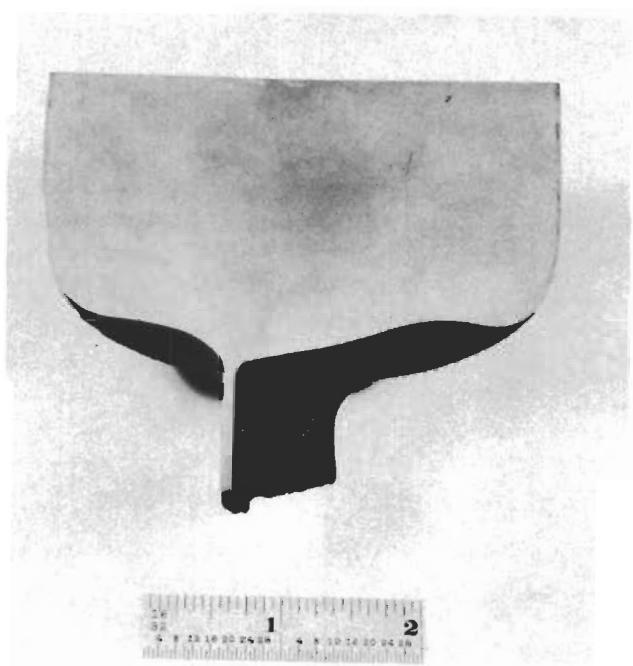


FIGURE 48

Cross-section of the butt remaining after a U-shap extrusion.

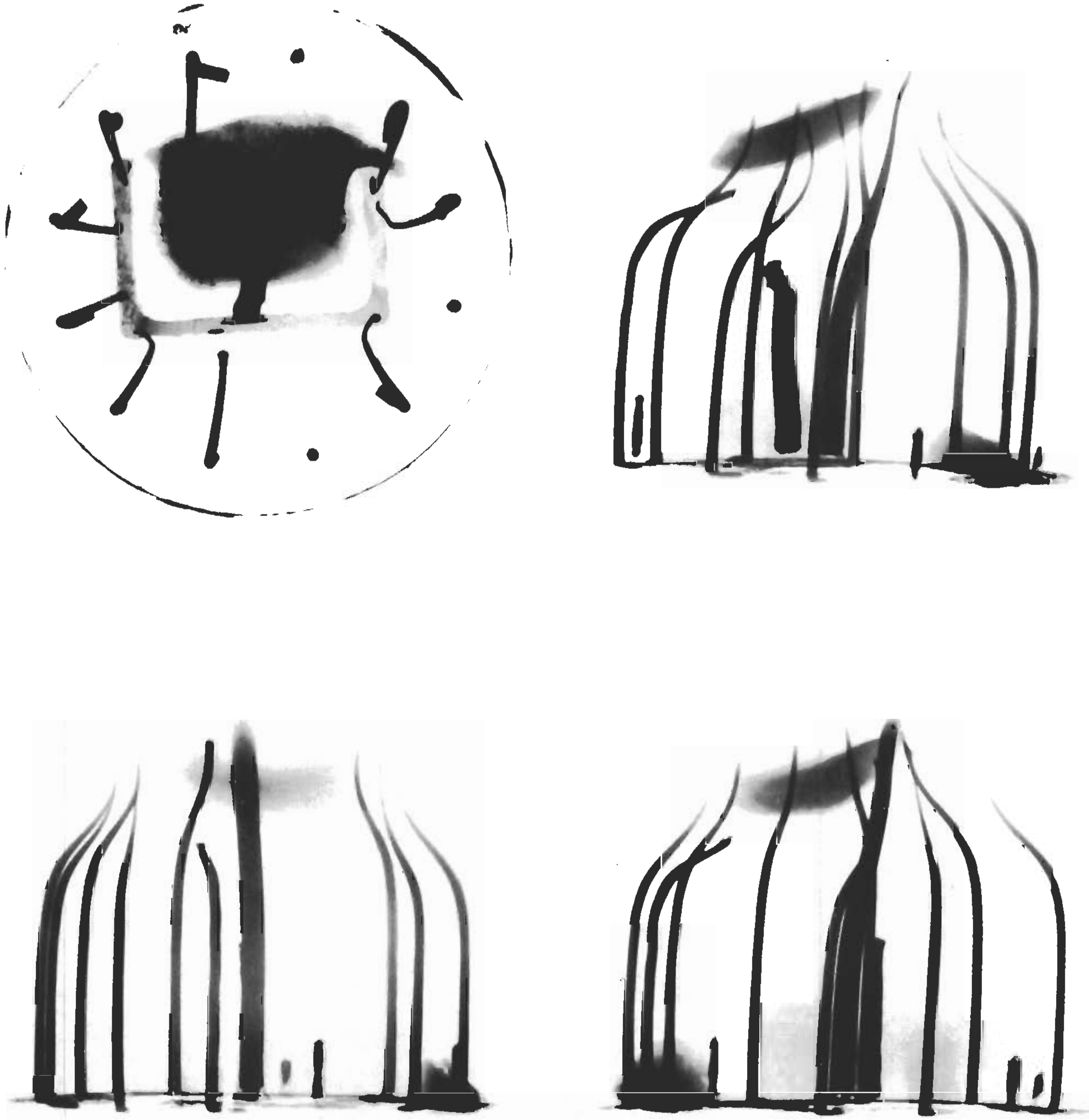


FIGURE 49 X-RAY PRINTS OF WIRED BILLET TO STUDY FLOW OF BILLET THROUGH DIE.

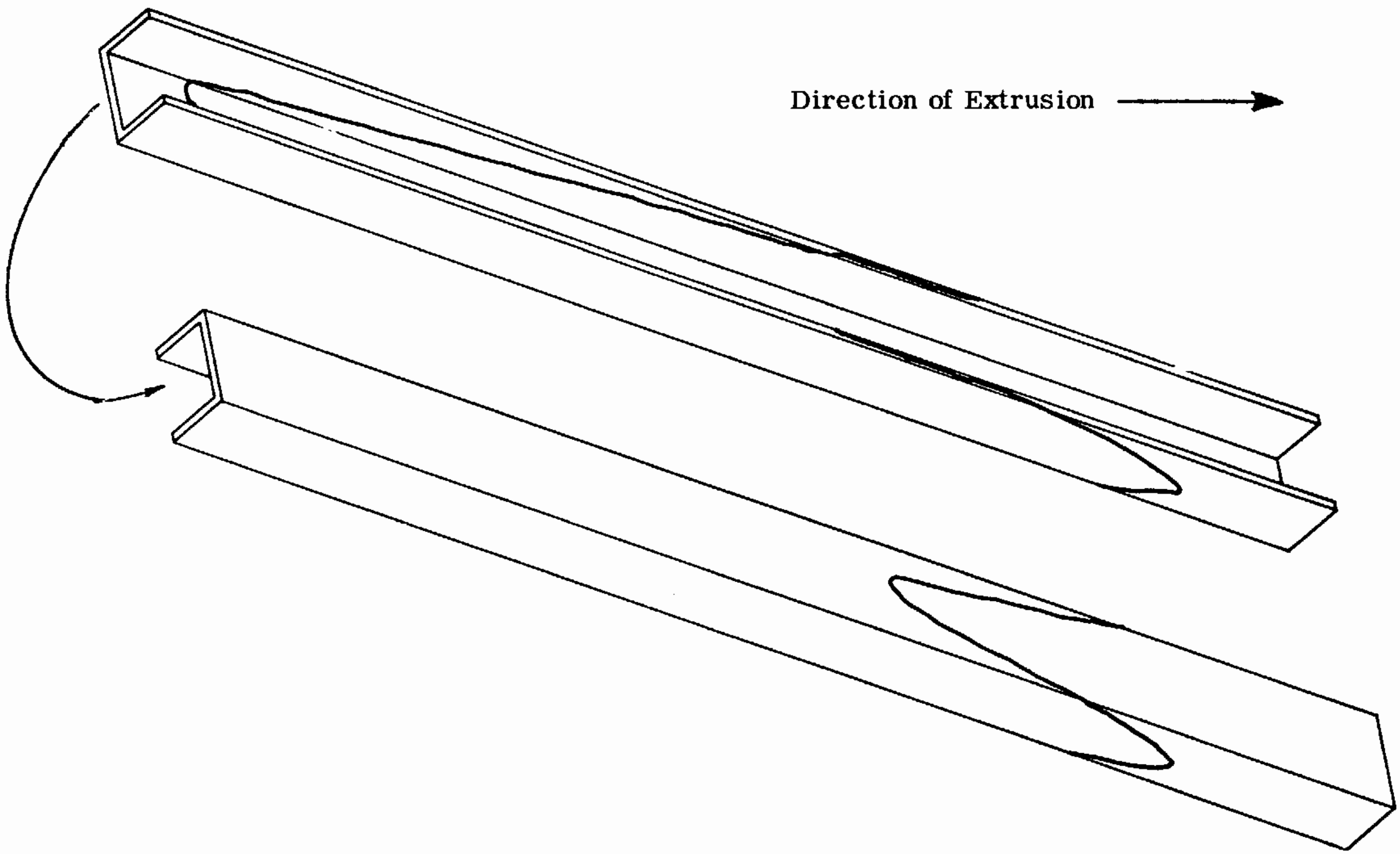


FIGURE 50 CIRCUMFERENTIAL GROOVES MACHINED IN THE BILLETS DELINEATED THE SHIFT THAT OCCURRED DURING EXTRUSION, AS SHOWN BY THE TRACERS IN THE DRAWING ABOVE. INTERNAL TRACERS INDICATE, BY X-RAY, THAT THE INTERNAL FLOW CAUSED BY THE FAST-FEEDING CORE RESULTS IN A SHIFT 23 INCHES LONG IN THE WEB SECTION OF THE H-SHAPE. NO SUCH INTERNAL FORWARD SHIFT OCCURED IN THE LEGS.

3. Extrusion Number 138 was made by fastening two 3 inch billets together with a 0.020 inch iron disc between them. When extruded, this disc showed a tracer indication very similar to that shown in Figure 49. X-ray studies, however, showed that the flow of iron in the fast-feeding core placed it 23 inches ahead of the iron at the surface. This occurred in the web of the U-shape. In the legs, the internal forward feeding was negligible.

Because it had been noted previously that this same side had been rattlesnaked when the other side of the U-shape was sound, a study was made of past extrusions and it was found that the rattlesnaking effect was definitely more severe on this the left hand side. Therefore, further work was performed in attempts to find the cause:

a. Extrusions were made with the die rotated 90°, 180°, and 270°, to its usual position.

b. In Extrusion 122, a copper-nickel billet was upset to check press alignment.

c. The bolster and straightener were modified.

d. Press alignment was improved.

e. A beryllium channel was extruded into the open air, with no catch tube or straightener to restrict the extrusion.

Although the tendency for the one-sided tearing was lessened, it was not eliminated. Either uneven feeding was occurring, with the right side flowing faster because of alignment problems, or interference was occurring when the tooling was under load.

Metallic Coatings

As an additional protective layer to prevent contact of the beryllium with the die, and to serve also as a lubricating medium, two beryllium billets were coated with a 0.010 inch layer of iron by electro-deposition (Extrusions 61 and 65), one was sprayed with a 0.010 inch layer of nickel (Extrusion Number 72), and two were sprayed with iron (Extrusion Numbers 73 and 94). In each of these, except the round extrusion Number 94, in which a steel cone was used, a glass pad was used to form the conical entry. No glass was used on Number 94 since the liner was lubricated with Fiske 604 "hot lube". In all cases, including Number 94, rattlesnaking occurred.

Because the thin metallic coating were tried primarily in conjunction with glass, and at a low press speed, it was not considered conclusive that thin metallic coatings were not desirable; further work was warranted with conical dies and conventional lubrication.

Cleaning of Extrusion

Both chemical and mechanical methods for removal of the glass film on the extrusion were investigated. Vapor blasting appeared to be a very practical method of surface cleaning (Figure 51).

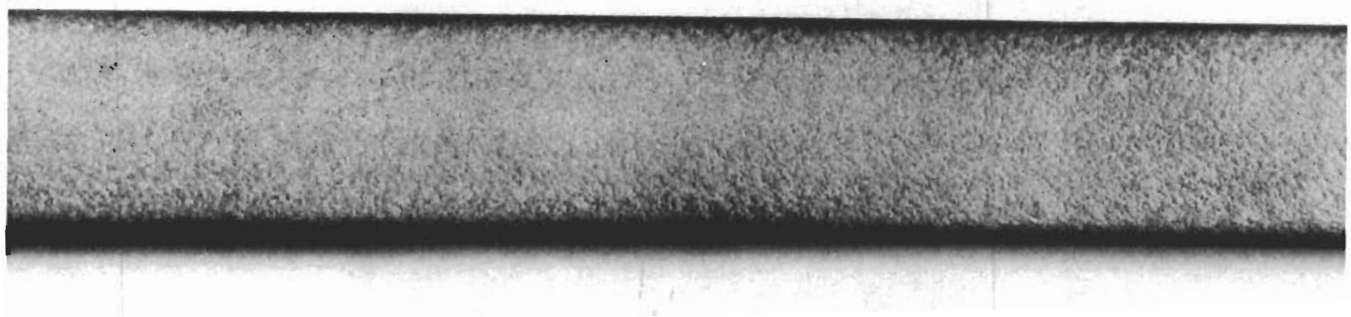


FIGURE 51 Surface of extruded channel after vapor blasting to remove glass lubricant. Vapor blasting appears to be more practical than chemical etch for the removal of the glass.

Glass Cone Die Lubricants

Figures 52 through 55 show the influence of the glass wool (or glass disc) in obtaining streamline flow on the shape of the billet nose during extrusion.

Ductility and Mechanical Properties at Nuclear Metals

To ascertain whether the use of sintered bar rather than compacted powder resulted in lower ductility of the extrusion, a comparison was made among bend samples from the following extrusions:

(1) Extrusion Number 48: sintered 3-1/2 inch diameter beryllium canned in steel, extruded into flat section.

(2) Extrusion Number 49: powder beryllium (not reactor grade) canned in steel, extruded into flat section.

(3) Extrusion Number 54: powder beryllium (reactor grade) canned in steel, extruded into flat sections.

(4) Extrusion Number 55: sintered beryllium, heated in salt, extruded bare into flat section.

(5) Extrusion Number 56: sintered beryllium, extruded into U-channel.

The equipment used for the bend test is shown in Figure 56; the bend samples, after test, are shown in Figure 57. A comparison of the data is shown in Figure 58. The results indicate that, for use as billets, the more economical sintered bar results in the same degree of ductility as powder stock.

Tensile test samples were obtained from extrusions 48, 54, 55, and 56 which are described above.

All specimens were machined with the long axis parallel to the direction of extrusion. Three specimens were annealed under dynamic vacuum for 1 hour at 1380°F and furnace-cooled under vacuum. Before testing, all pieces were etched in 10 percent H_2SO_4 to remove the machined-surface effects. Index lines were placed just outside the gage length and a strain gage pasted on the center of the specimen. Of the two types of specimen design used, the second (Figure 59) was preferable and is recommended for any future work.

Since alignment of the tensile specimen in the tensile machine is critical, the adapter shown in Figure 60 was used. Results of the mechanical property determinations, shown in Table VIII, indicate the same degree of ductility with sintered bar as with powder stock when used as billet material. Although additional work was to be performed on additional extrusions later in the program, the change of emphasis to other problems prevented further effort in this area.

Mechanical Properties Tests at Norair

Several pieces of extrusion were chosen at random from various extrusion attempts and tensile tested with specimens being machined under oil in Northrop

FIGURE 52 Same butt as in Fig. 28 with most of the glass removed. Thickness of glass and flow contour can be seen.

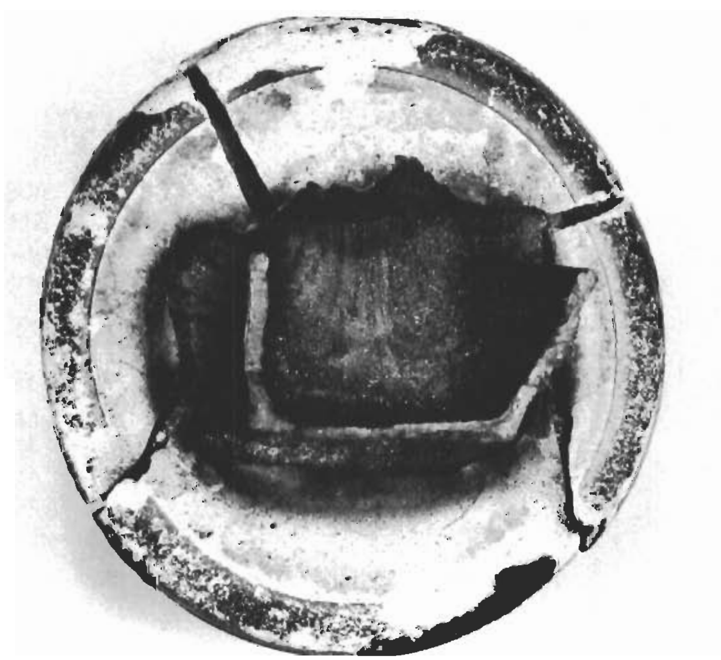


FIGURE 53 Glass lubricant remaining on the front of extrusion butt. Note that the inside of the U-shape is devoid of glass.

FIGURE 54 Shape of billet during glass extrusion when billet nose is machined as type A, Fig. 8.

FIGURE 55 Shape of billet during glass extrusion when billet nose is machined as type B, Fig. 8.

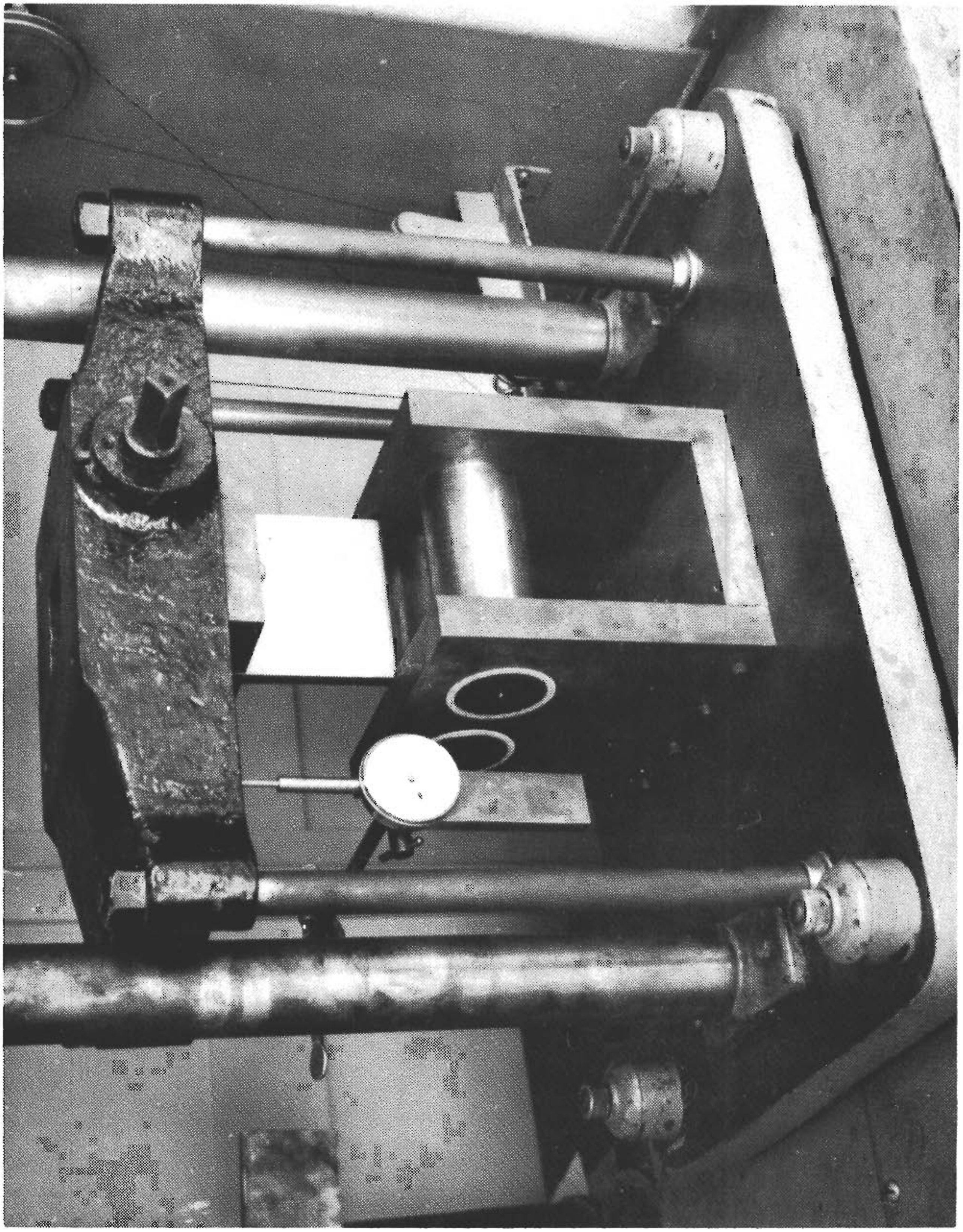


FIGURE 56 BERYLLIUM BEND TEST SETUP.

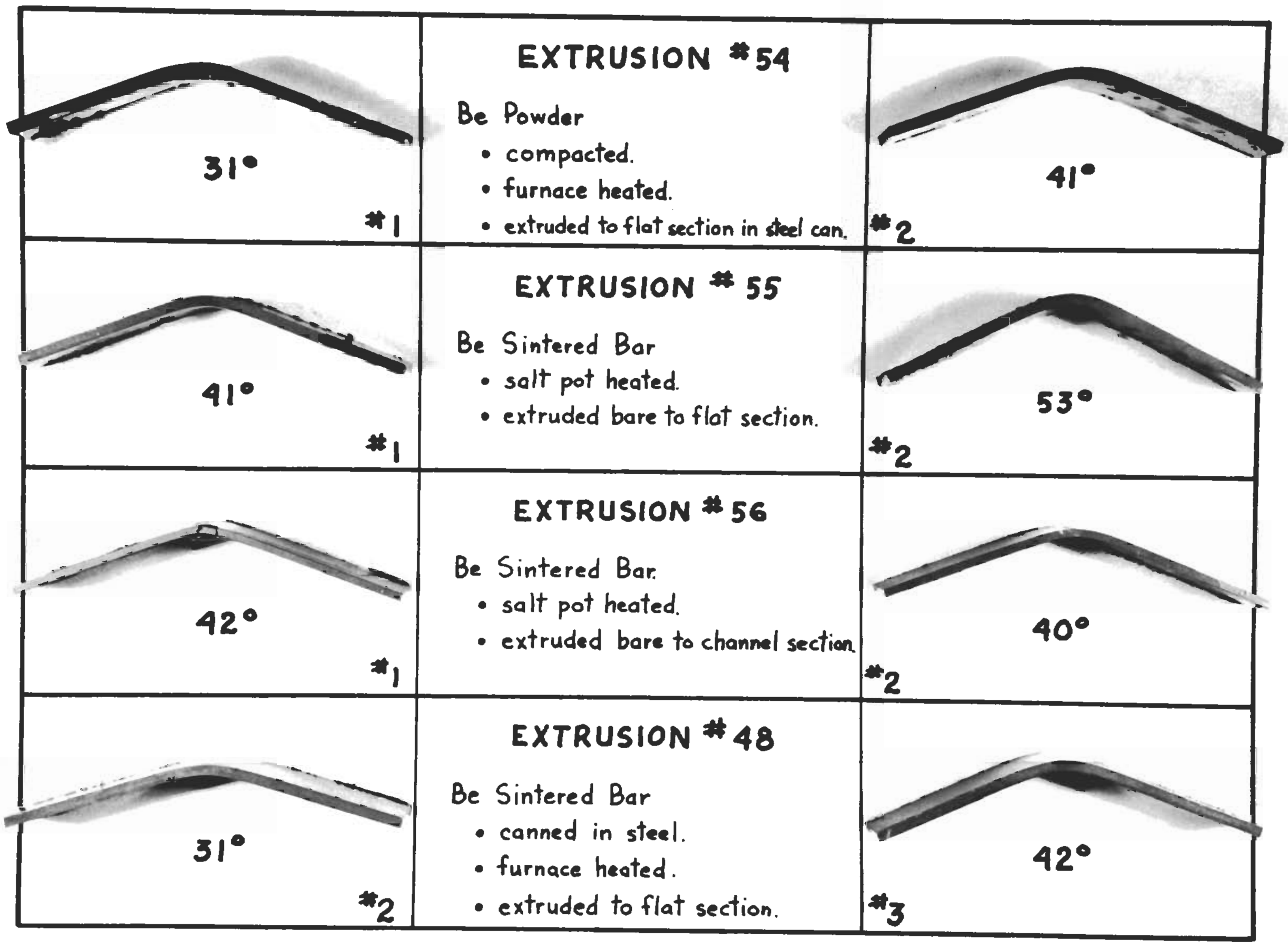


FIGURE 57 RESULTS OF BEND TESTS INDICATE NO SIGNIFICANT DIFFERENCE IN DUCTILITY BETWEEN THE FOUR EXTRUSIONS.

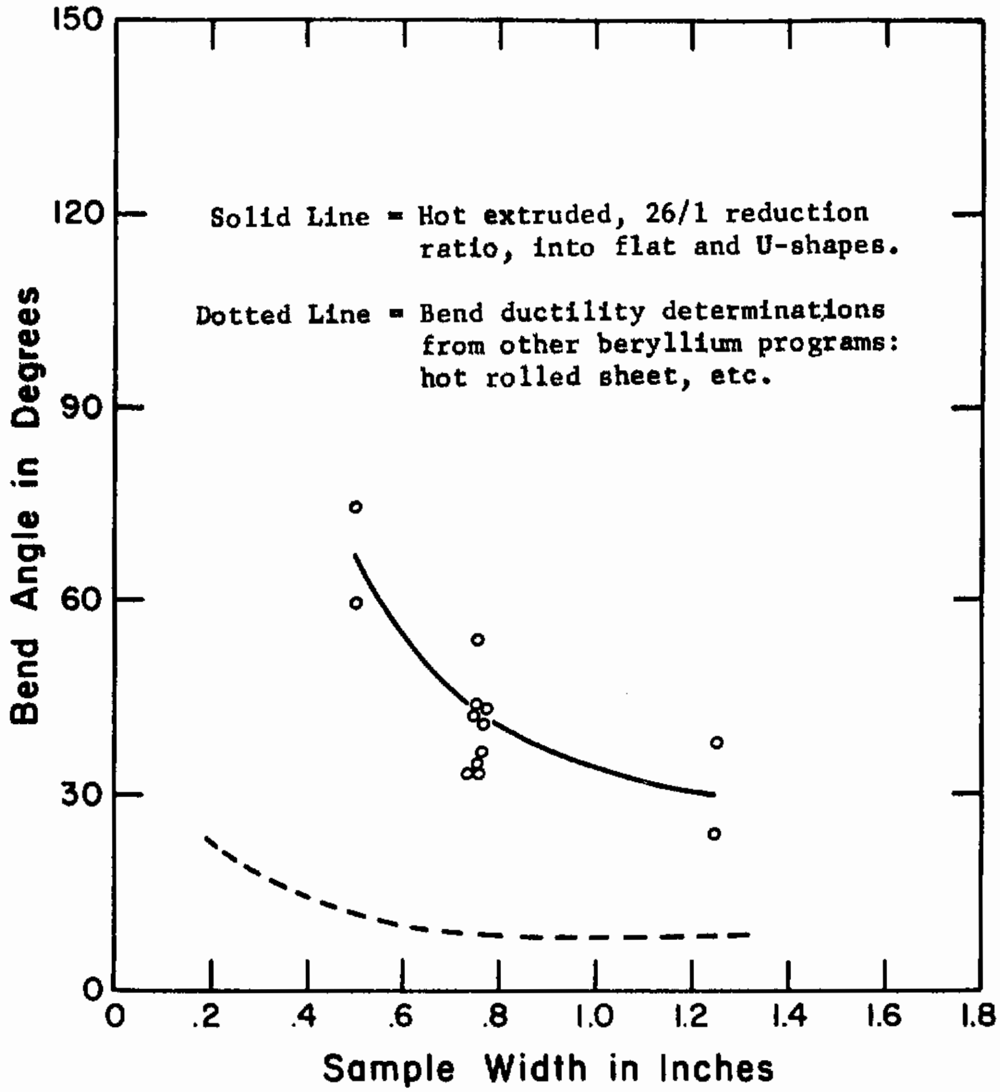


FIGURE 58 BEND DUCTILITY OF BERYLLIUM SAMPLES. BEND ANGLE AROUND 0.200 INCH RADIUS VS SAMPLE WIDTH, LONGITUDINAL TESTS ONLY.

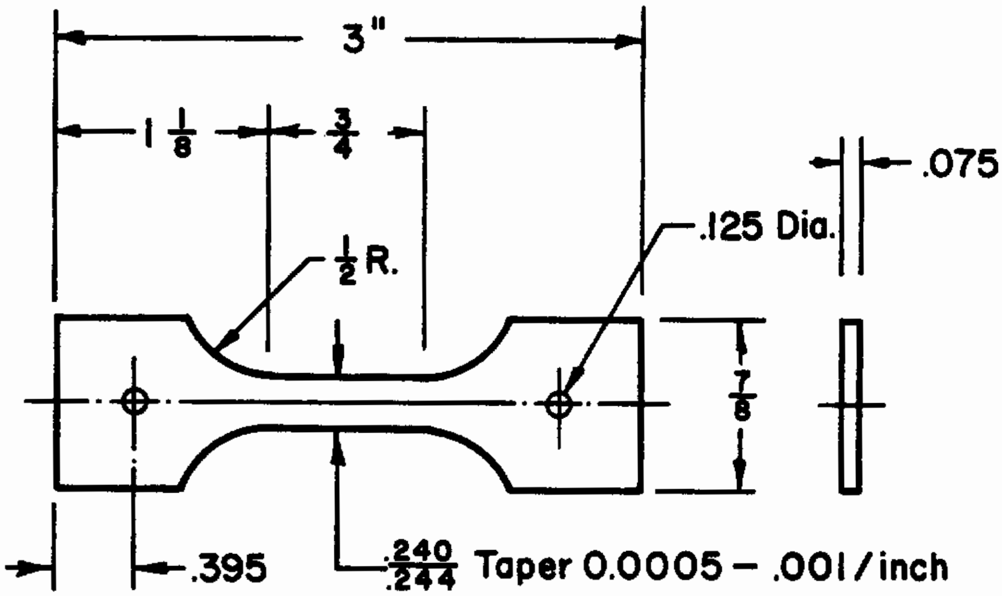


FIGURE 59 DESIGN OF TENSILE SPECIMENS USED FOR BERYLLIUM MECHANICAL PROPERTY DETERMINATIONS.

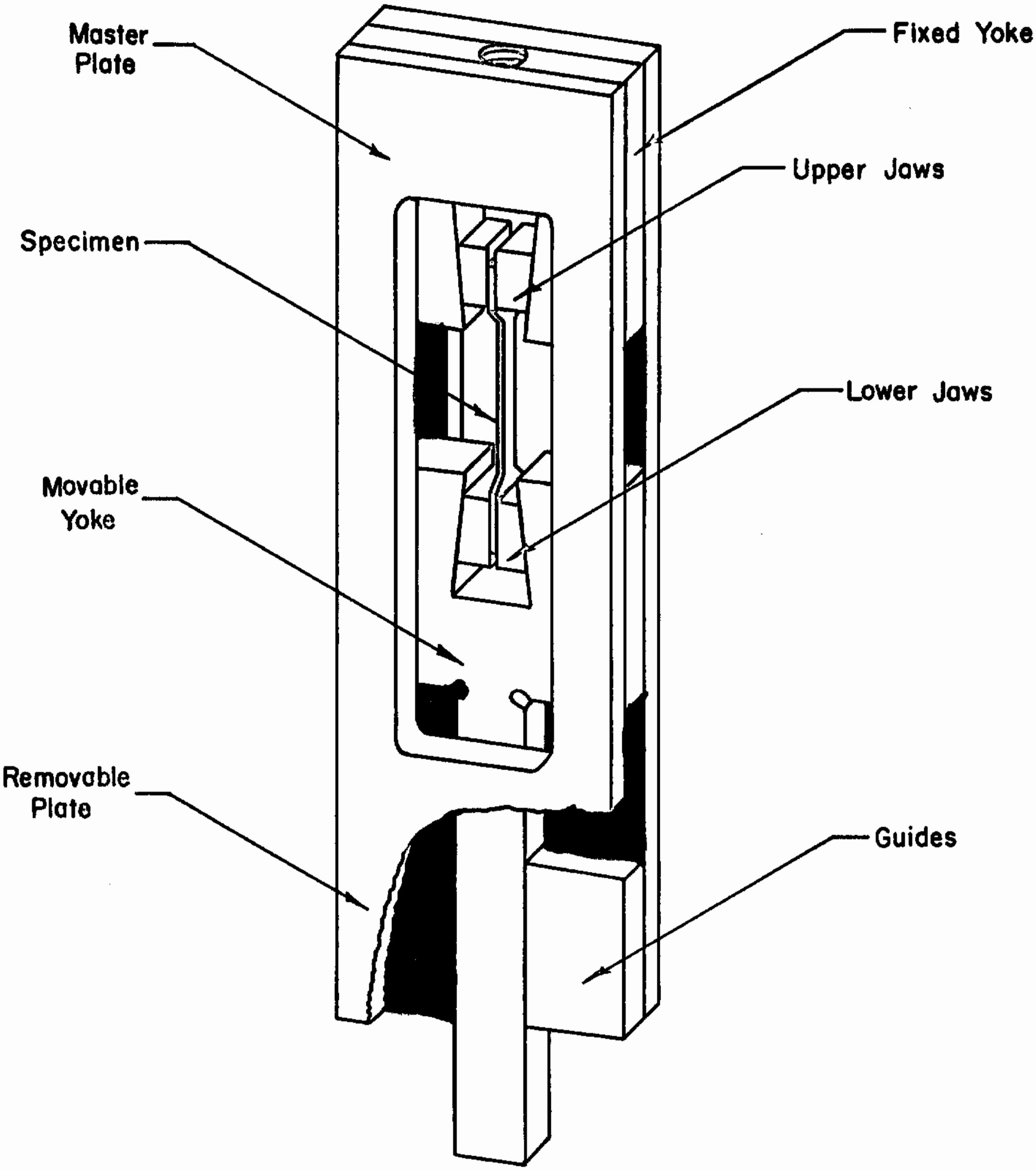


FIGURE 60 SPECIAL ATTACHMENT USED ON TENSILE MACHINE TO INSURE PROPER ALIGNMENT WHEN TESTING BERYLLIUM TENSILE SPECIMENS.

TABLE VIII

Tensile Test Data

Extrusion No.	Material preparation	Specimen	Condition* of Test Specimen	0.2% Yield (psi)	Ultimate (psi)	Elongation (%)
48	Be sintered bar canned in steel, furnace heated, extruded to flat section.	A	As extruded	53,000	65,000	3.1
		B	Annealed	41,000	77,000	7.3
		C	As extruded	53,000	90,000	8.1
54	Be powder canned in steel, furnace heated, extruded to flat section	A	As extruded	58,000	83,000	2.1
		B	As extruded	62,000	112,000	1.7
		C	As extruded	75,000	116,000	11.8
55	Be sintered bar, salt-pot heated, extruded bare to flat section.	A	Broke outside gage	—	—	—
		B	Annealed	48,000	55,000	6.3
		C	As extruded	42,000	66,000	1.6
56	Be sintered bar, salt-pot heated, extruded bare to U section.	A	Broke outside gage	—	—	—
		B	Annealed	31,000	38,000	6.3
		C	As extruded	59,000	92,000	4.1

* Where specified, specimen was annealed one hour at 1382°F under vacuum.

Norair's Materials Sciences Laboratory. Figure 61 shows the locations from which specimens were taken and Table IX gives the tensile results.

Results indicate that the material was improving in quality. Several ultimate strength values were in the vicinity of 90,000 psi and these tests resulted in at least 4% elongation.

The best results are considerably better than those obtained previously on earlier beryllium extrusions. This is true of both those tested by Northrop Norair and those tested by Nuclear Metals.

As shown in Figure 62, elongation increases when strength increases. This indicates that the low strength results are probably caused by extrusion quality. The results also manifest the probability that an improved extrusion process will consistently produce material having 90,000 psi ultimate strength, 45,000 psi yield strength and 5 percent elongation. It is significant that the later extrusion runs produced the best material and that most of the work and brittle specimen came from earlier shapes (37, 60 and 80).

In Figure 63, elongation and ultimate strength are plotted against strain rate. The lack of correlation shows that the material is not as strain rate sensitive as had been previously supposed. This belief was probably the result of great variability in the early material which was not noted because of the very limited number of test specimens then available. The experienced strain rate varied greatly during all tests even though a constant rate of head travel was used throughout each test. As indicated in Table IX, the strain rate was very low at the beginning of loading and increased toward 0.004 inch/inch/minute in the yielding portion of the load-strain curve. The strain rate values given in Table IX were, for the most part, the average rate over a two minute interval beginning one half to one minute from the start of loading for the elastic region and over a one minute interval beginning within one half minute after 0.2% offset strain was achieved for strain rate in the plastic regions.

Summary and Evaluation

An evaluation of the product and results of the extruding efforts at Nuclear Metals raised a question of the adequacy of Nuclear's press to fulfill the requirements necessary to produce a defect-free 20 foot length of bare beryllium. Stalled billets had appeared sporadically in sufficient quantity throughout the various pushes to cause considerable consternation. Corrective measures were taken, such as change of lubricants, which repeatedly improved the problem, but more and more changes had to be made to alleviate the excessive pressure increases that occurred as longer and longer billets were attempted. At one point, a new 3.04 diameter liner was fabricated to replace the previous 3.65 diameter liner in order to reduce the extrusion ratio and to build up the higher unit pressure. This, as other measures, helped somewhat but did not quite satisfy the full requirements.

The number of stalled billets by Nuclear Metals is reported as follows:

90 total beryllium billets attempted
25 beryllium billets stalled

An analysis of the factors involved yielded the following conclusions:

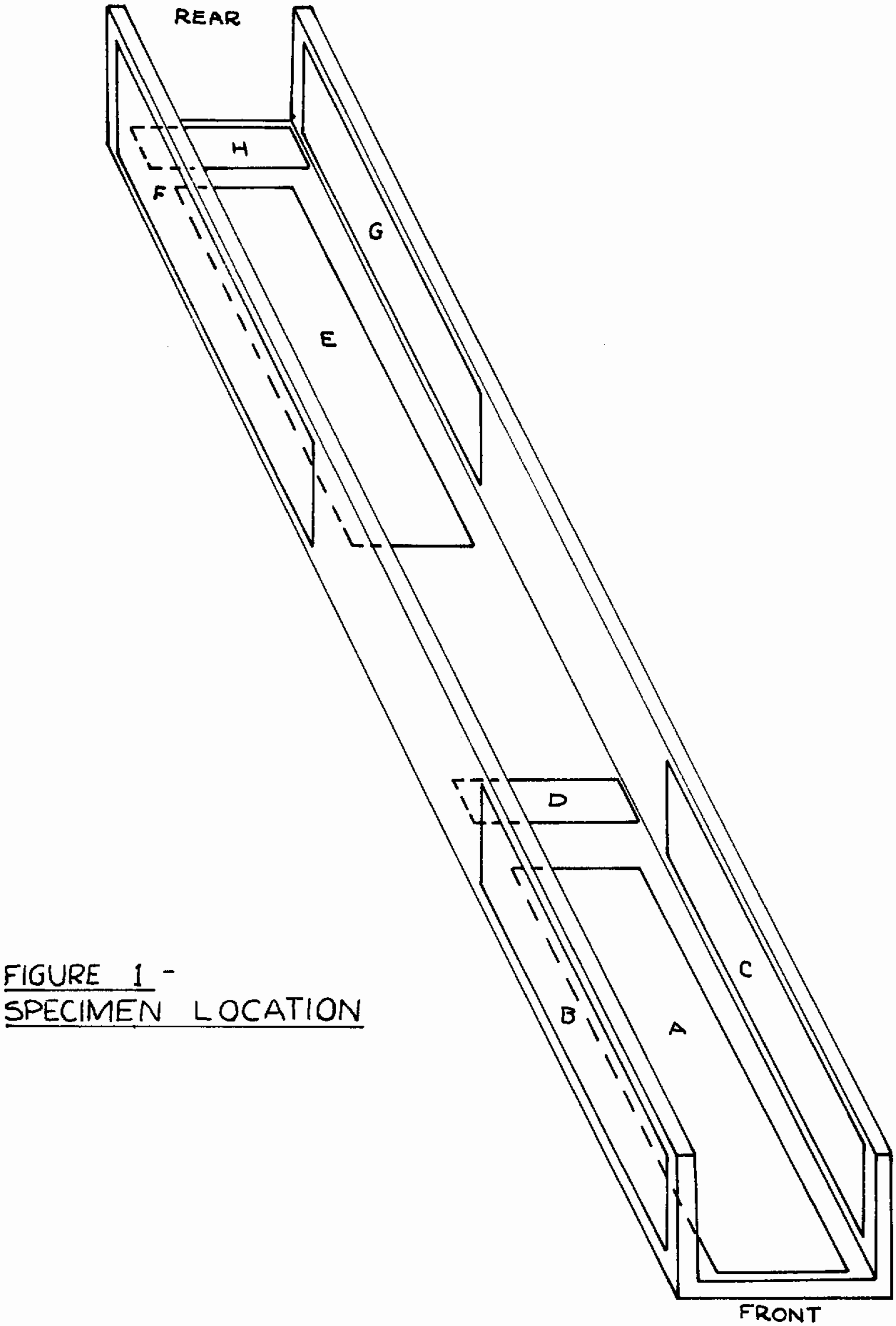


FIGURE 61 SPECIMEN LOCATION

TABLE IX TENSILE TEST RESULTS - BERYLLIUM EXTRUSIONS

Extrusion Number	Spec.	Initial Condition of Spec.	Yield Strength ksi	Ultimate Strength ksi	Elong. % in 2 in.	Strain Rate Micro in/in/min. Elastic	Plastic	Note
37	B	Good	48.6	79.1	4.0	30	1000	a,g
37	E	Good	----	39.0	0.03	50	----	a,c
56	A	Poor Bad Surf. Laps	50.0	51.7	2.0	70	1700	a,g
56	B	Good	48.6	79.1	4.0	170	3700	b
56	C	Good	49.8	85.7	6.0	110	4700	b,g
60	A	Good	52.3	60.3	1.5	140	3900	b
60	F	Good	50.8	72.7	2.5	140	3900	b,g
76	B	Good	48.7	91.8	7.5	130	3700	b
76	C	Good	48.8	87.9	5.0	50	1900	a
76	E	Very Poor Laminations	----	51.2	----	----	----	b
76	F	Good	50.5	82.8	4.0	80	3300	b,g
76	G	Good	51.7	8.10	4.0	60	2400	a,d,g
80	E	Good	----	49.2	0.17	30	600	a,c,g,i
80	F	Good	40.0	40.5	1.0	30	1300	a,f,h,i
83	A	Good	47.7	87.8	6.5	80	3700	b
83	B	Good	50.6	85.8	4.0	160	4100	b
85	A	Fair? Laminations?	44.9	56.8	1.0	160	3700	b,h
85	B	Good	46.5	83.6	5.0	170	4000	b
85	E	Fair - one side not Machined	----	43.1	0.14	180	2700	b,c,g,i
85	F	Fair?	----	38.1	0.02	180	----	b,c,e,h
85*	G	Good	51.2	91.7	7.0	220	3700	b,g
86	C	Good, some Edge Cracks	47.6	82.3	5.0	100	3800	b,g
86	E	Poor, Faces Not Machined	45.7	60.0	2.5	90	4100	b,g

NOTES (Applicable as given above):

a. Head Travel was 0.005 in/min
b. Head Travel was 0.020 in/min
c. Elongation from load-strain curve, insufficient for 0.2% offset (PS-3 strain indicator)
d. Specimen failed outside gage length
e. Specimen failed by longitudinal fracture
f. Evidence of Yield Point
g. Partially diagonal fracture plane
h. Longitudinal fracture
i. Short curve - Plastic Strain value is low

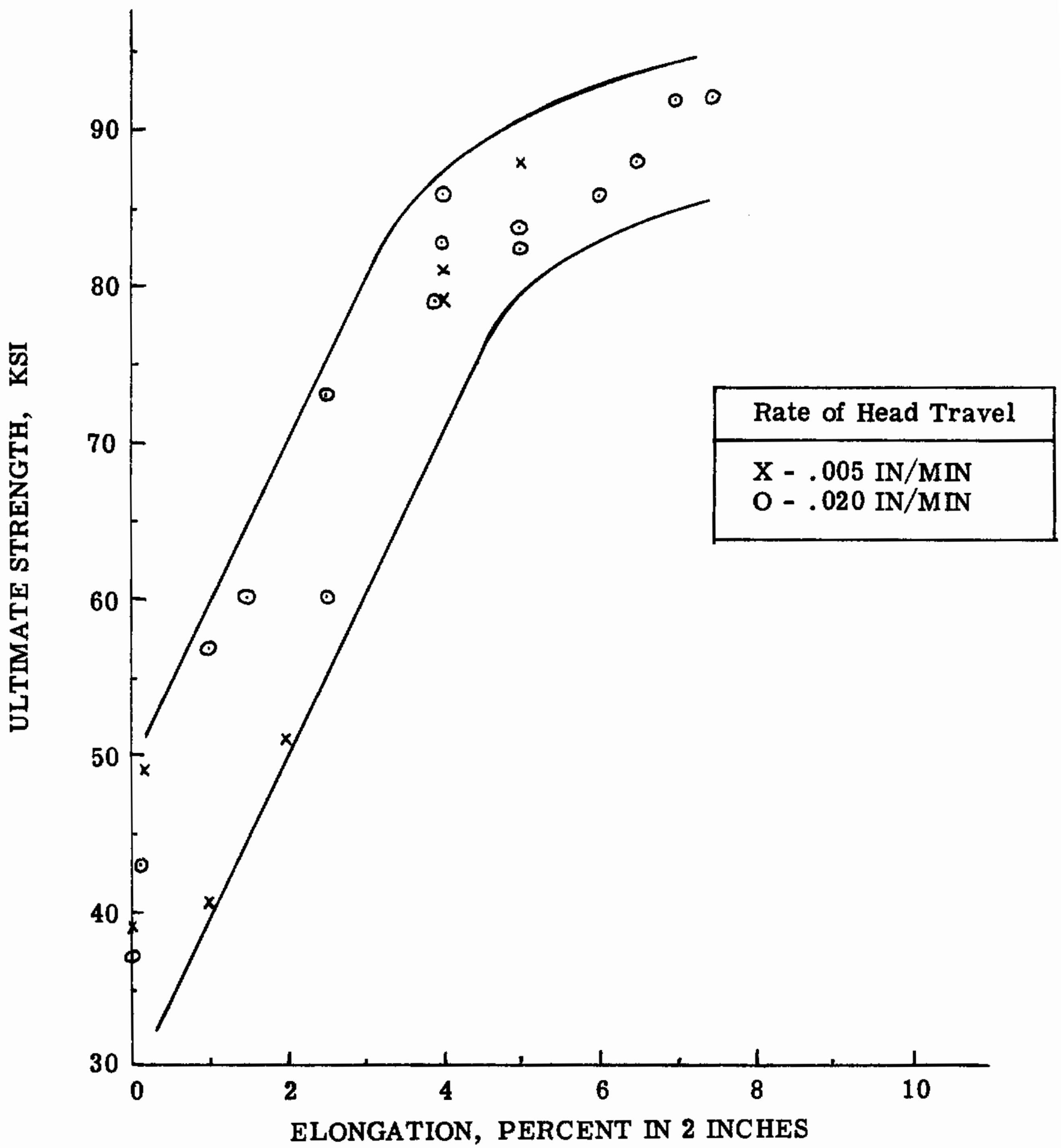


FIGURE 62 ULTIMATE STRENGTH VS ELONGATION FOR BERYLLIUM EXTRUSIONS.

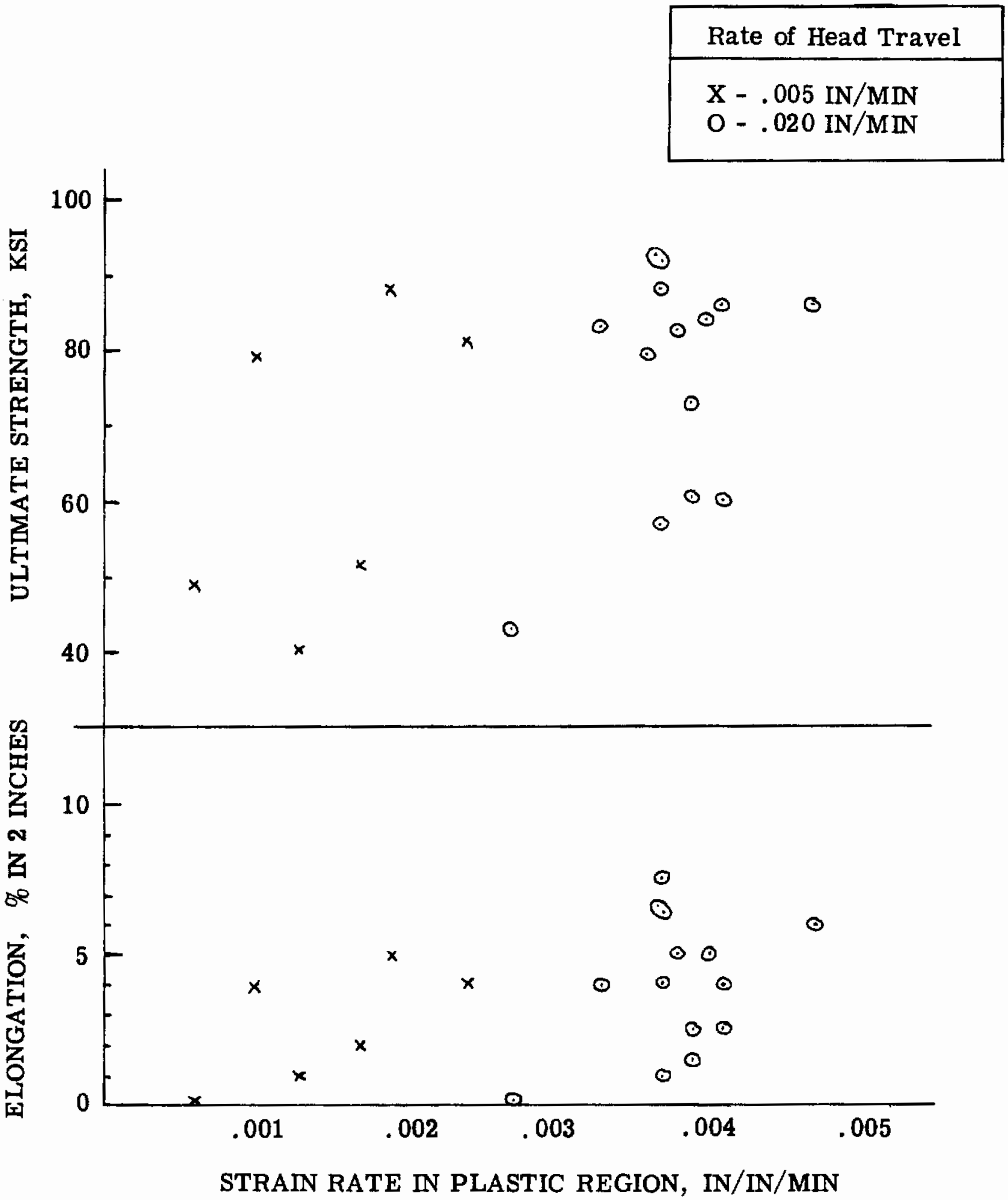


FIGURE 63 ULTIMATE STRENGTH & ELONGATION VS STRAIN RATE FOR BERYLLIUM EXTRUSIONS.

- Marginal lubrication appears to be a main problem area with respect to soundness, surface quality and lack of reproducibility. This is amplified by the ramifications of relatively slow speed.

- The rattlesnaking that persists and predominates on the left hand leg of the channel shape must be attributable to the NMI press or its tooling, although it was not possible to isolate the exact cause.

- Chilling of the billet during extrusion when slow ram speeds (13 in/min) were involved was the primary cause of limited lengths. A length of 20 feet and longer has been demonstrated to be feasible by maintaining the faster extrusion speed of 120 inches per minute. This is still considered to be relatively slow when compared with other extruding using glass at 500 to 700 inches per minute.

- The situation warrants Nuclear Metals making at least one extruding effort on a different press with faster speed.

- Although substantial improvement in die life was attained, the die materials used were not considered completely satisfactory for production operations under the condition of marginal lubrication. Die materials were temporarily adequate with prospects for improvements in later phases of the program.

EXTRUDING EFFORTS AT WOLVERINE TUBE

Introduction

A survey was therefore initiated to ascertain the adaptability and advisability of utilizing a press at some other facility. An investigation of the specifications of other presses was conducted to locate one that had slightly more pressure and a considerably faster speed. All presses with ram speeds of less than 10 inches per second were eliminated from consideration.

After a considerable investigation, Wolverine Tube in Detroit, Michigan was chosen for the following reasons:

- Their available presswas a 700 ton Loewy of recent manufacture with a ram speed in excess of 15 inches per second.

- The press was located at Wolverine's Research Facility and was manned by a highly competent press crew.

- There was an existing ventilation system over the press which could be reworked relatively easily to adequately handle the toxicity problem.

The final arrangements were predicated on Norair's rental of Wolverine's press time and crew with Nuclear Metal's technical personnel directing the preparation of the extruding effort. This was done in order to preserve the technical know-how and competence that had been achieved at Nuclear Metals. This was also necessitated by the Sejournet glass lubricant licensing arrangement in as much as Wolverine was not a license holder. The legal question of the use of glass at Wolverine's unlicensed facility was coordinated with Allegheny Ludlum and Sejournet and permission was granted providing Nuclear furnished and controlled the use of the lubricants.

Tooling

Extruding Press - Wolverine's press is a 700 ton accumulator type recently manufactured by the Loewy Hydropress Division of Baldwin-Lima-Hamilton. It is fast acting with a ram speed in excess of 15 inches per second. Container sizes range from 1 to 4-1/2 inches in liner diameter with a liner heating capability of 900°F. See Figure 64.

Container Size - In order to obtain a relatively true comparison between the capabilities of the two presses for extrusion of bare beryllium, it was necessary to reduce the number of variables between the Wolverine and the previous Nuclear Metals efforts. Because of this a compromise had to be effected to permit a shorter length since the existing 3.04 inch diameter container was not long enough to yield a full 20 foot section. However, the resultant 11 foot length was considered adequate to determine the effect of the accelerated rate of extrusion on bare beryllium. It would further determine whether misalignment of Nuclear's press was really a contributing factor to the rattlesnaking which had predominately appeared in the left leg only and which had defied all attempts at isolation and correction.

Dies and Holders - Lengthy coordination was necessary between Nuclear Metals, Wolverine Tube, and a Detroit tool and die company before a decision could be made on the configuration of the die periphery and the die holder. It was necessary to perform a careful stress analysis of the new tooling to justify the use of the small die insert of the type adaptable to short life operations. Figures 65, 66, 67 and 68, show the cast stellite die inserts with holders, backers, die rings, and bolsters, respectively.

Toxicity

Because of the complete lack of previous experience with beryllium at the Wolverine facility, the toxicity problem was thoroughly coordinated with both the Michigan State Safety officials and the Nuclear Metals safety experts. As a result, the existing ventilating hoods over the press and over the furnace were lowered and a larger capacity motor was installed to draw off the fumes at a faster rate. In addition, Nuclear Metals furnished an absolute filter which was tied into the catch tube system and filtered off the air coming from the hot extrusion.

Billet Preparation

Billets were prepared in a manner identical to previous efforts at Nuclear Metals.

The short beryllium billets employed in this effort were remaining from the previous program at Nuclear Metals and were all within specification limits on chemistry. For the Wolverine effort, three new ten inch long billets were purchased to ascertain the effect of extruding parameters on the longer shapes. Two of the three billets were slightly outside specification with regard to the beryllium oxide content. It was considered, however, that the slightly increased content would not be detrimental to the purposes of this program. The compositions of the three long beryllium billets were as follows:

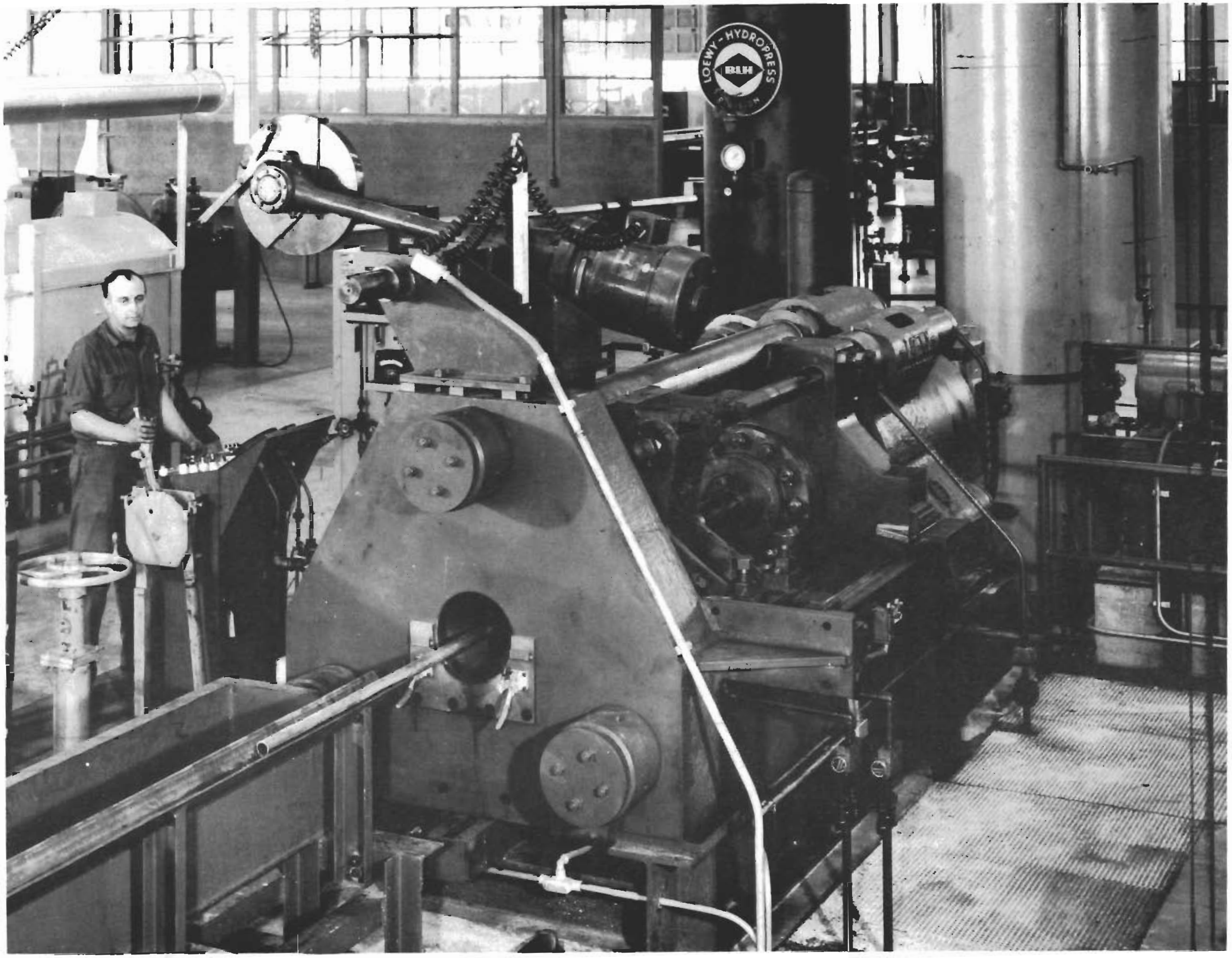


FIGURE 64 WOLVERINE TUBES 700 TON LOEWY PRESS.

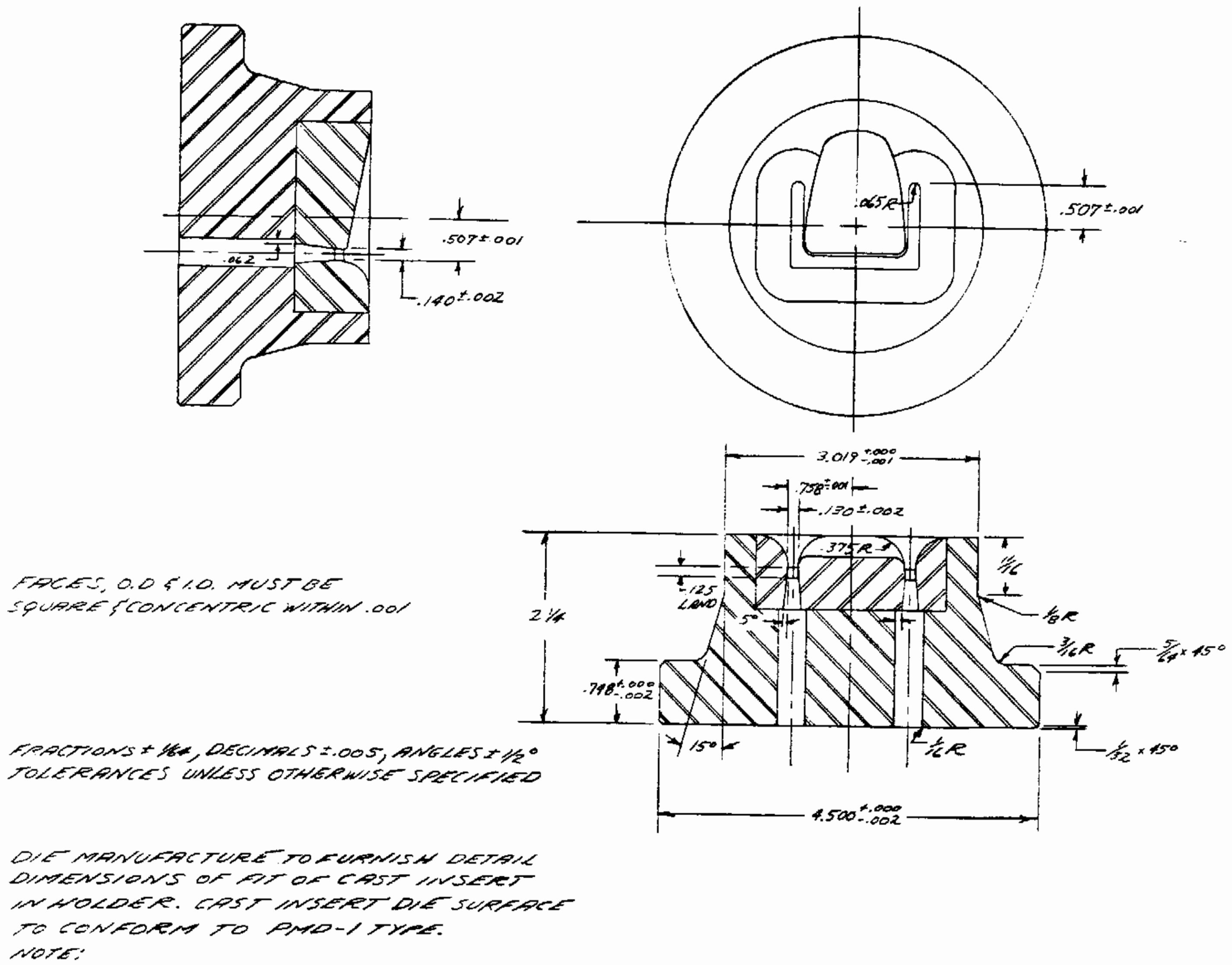


FIGURE 65 CAST STELLITE DIE AND HOLDER, WOLVERINE PRESS.

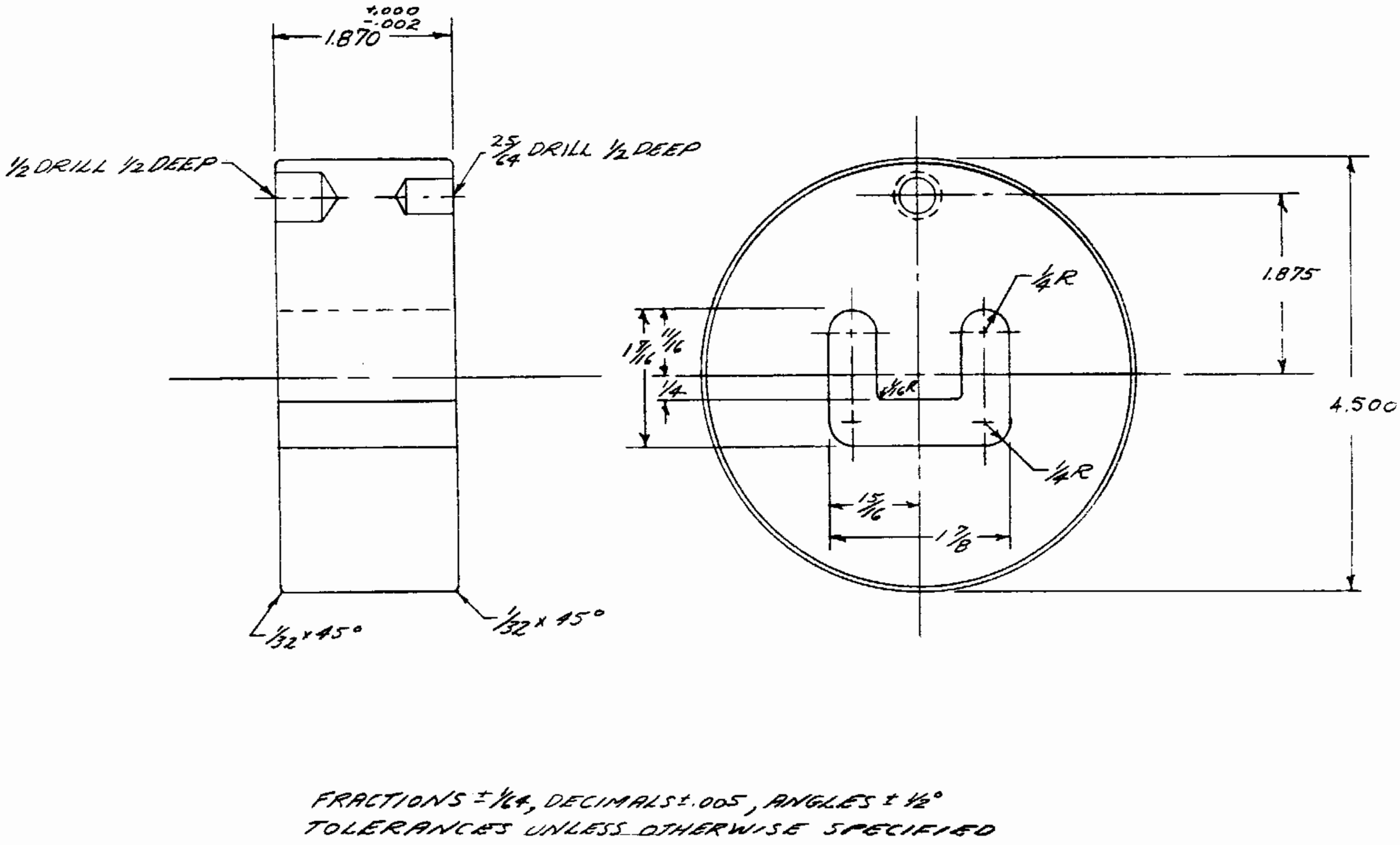


FIGURE 66 BACKER FOR CAST STELLITE DIES, WOLVERINE PRESS.

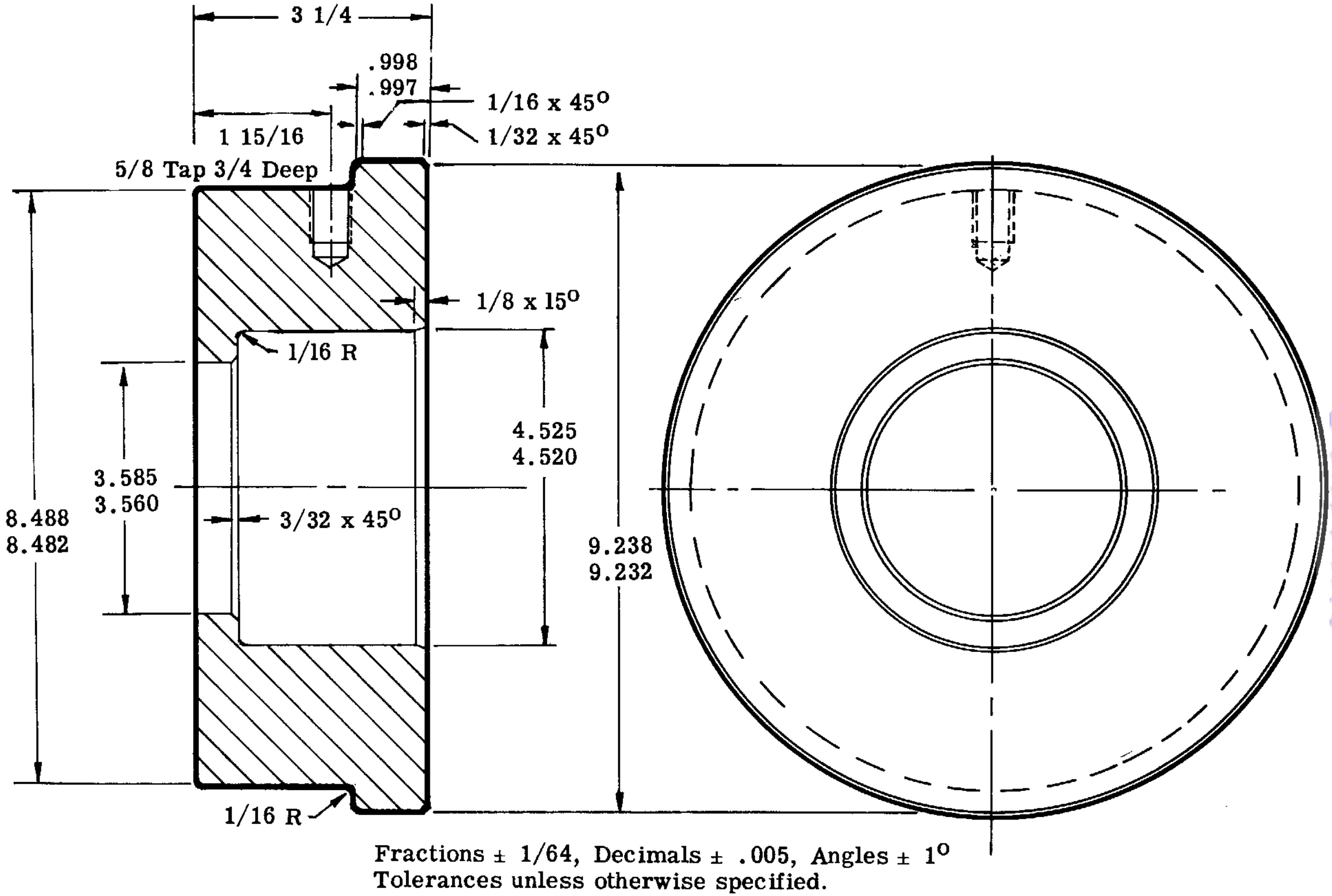
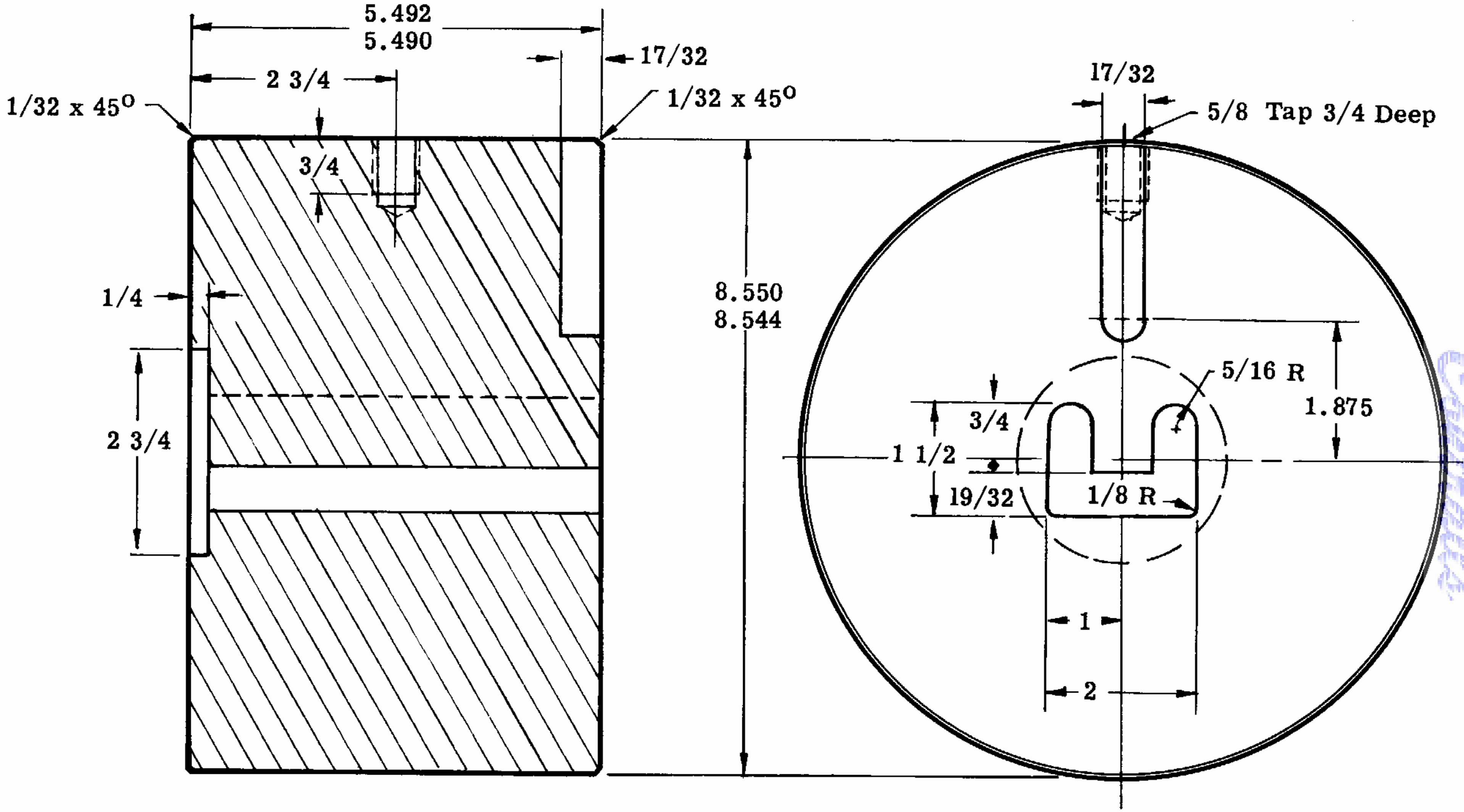


FIGURE 67 DIE RING FOR CAST STELLITE DIES, WOLVERINE PRESS.



Fractions ± 1/64, Decimals ± .005, Angles ± 1°
Tolerances unless otherwise specified

FIGURE 68 BOLSTER FOR CAST STELLITE DIE, WOLVERINE PRESS.

ELEMENTS	BILLETS #7 & 8 Heat No. 6702	BILLET #10 Heat No. 7613	SPECIFICATION LIMITS
1. BeO	1.71% max.	1.04%	1.50% max.
2. Fe	.188%	.095%	.15% max.
3. Al	.032%	.03%	.15% max.
4. Mg	.011%	.006%	.05% max.
5. Silicon	.025%	.020%	.10% max.
6. C	.13%	.09%	.15% max.
Density	1.85 gm/cc	1.85 gm/cc	

Billet Heating

The existing heating furnace at the Wolverine facility is located very close to the press but is of the muffled gas variety and, therefore, would contaminate bare beryllium billets. To prevent this, Nuclear Metals fabricated insert boxes with provisions for maintaining an atmosphere of argon inside the box. Thermocouples were inserted, and the billets were placed inside the gas furnace. The same arrangement has been previously used during the early stages of the program at Nuclear Metals and worked out quite satisfactorily. See Figure 69 for details of this heating arrangement.

A lower starting temperature was utilized than had been possible in the past. This was deemed feasible because of the much faster closing and pressing speed of the Wolverine press with its consequent lower loss of heat from the small diameter billet to the container walls. Selection of the billet temperature for subsequent pushes was dependent upon the results of the first attempt. The target temperature was the lowest that would yield a minimum ram speed of 500 inches per minute.

Auxiliary Equipment

As a part of the Wolverine ventilation equipment for extruding of beryllium, a catch tube was fabricated at Nuclear Metals to attach to the aperture of the Wolverine press. It received and contained the extruded section as it was emitted from the press outlet. A vacuum-line carried away the toxic particles or vapors that evolved from the hot beryllium.

Extruding Effort

To provide easy identification of extrusion or push numbers, the numeration started over again for the Wolverine effort.

Push No. 1

Conditions: -

Billet Material - Steel
Billet Temperature 1750°F
Die Lubricant - Type G one pad
Billet Lube - Type D-3 with B and F floss
Pressure 500 tons
Ram Speed - 720 in/minute

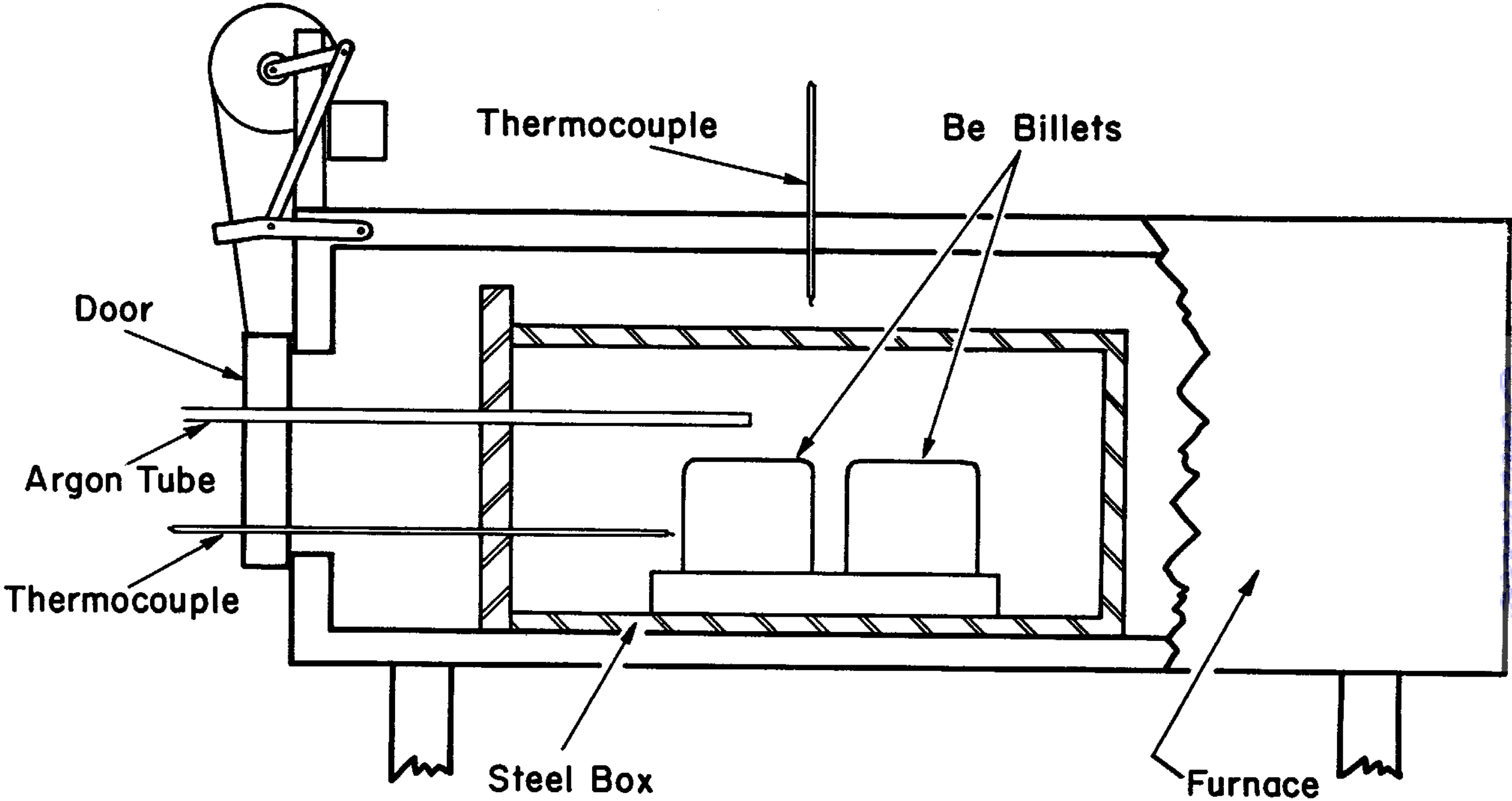


FIGURE 69 HEATING ARRANGEMENT FOR BERYLLIUM BILLETS.

Result:

A good, smooth, untorn 7/10 dia. round steel extrusion of the same cross sectional area as the planned U-shaped channel.

Push No. 2

Conditions:

Same as for Push No. 1 except that a channel extrusion die was utilized with another steel billet.

Result:

A good smooth, 11 foot long channel shape in steel was emitted from the press. Die wear was very light; section was quite straight and apparently without defects of any sort. However, upon attempting to remove the extrusion from the press, it was found that the stem could not be withdrawn because of flow of glass back over the dummy block portion of the stem. The dummy block had been made an integral part of the stem, thus a severe freezing of the glass made it impossible to withdraw the stem with the pressure available. Repeated efforts along several approaches failed to free the stem. Consequently, the stem and the container had to be dismantled from the press and sent to a press company in Detroit for removal. Consequently, the extruding effort had to be postponed to a later date and remedial measures had to be taken to avoid a recurrence of the problem. As a result, the stem was reworked to remove the dummy block portion, and separate dummy blocks with slip fit pins were fabricated. These allowed free assembly with the stems to reduce transfer time, but still allowed for dummy block withdrawal from the stem in event of glass freezing over the periphery. When this was accomplished another extruding effort was carried out, results of which are given below.

Push No. 3

Conditions:

The billet temperature, die lubricant, and billet lubricant were the same as Push No. 1, the difference in this push being the use of a ten inch composite billet of beryllium and steel with the beryllium being extruded first.

Result:

No edge cracking in either the beryllium portion or the steel portion. The die wear was rather excessive. The stem freed from container without difficulty. The beryllium portion of the extrusion yielded a five foot length of crack free extrusion.

The tonnage registered was 433 tons and it extruded in 1/2 second. The registered billet temperature was 1745°F.

Push No. 4

Conditions:

Same as Push No. 1 except that a channel die and a short beryllium billet was utilized with a lower melting point die lube. Surface roughness from the previous extrusion in beryllium indicated that lubrication was not completely adequate. Therefore, a lower melting point lubricant was tried in an endeavor to increase the flow.

Result:

Bad rattlesnake appeared at the start, then the entire flange, cracked off. Also, small cracks existed along the other edge. It appeared to be a hot break. Results were totally unsatisfactory.

Push No. 5

Conditions:

Because of the hot break in the previous effort, this push was made with a billet temperature of 1650°F. With such a low temperature it was deemed necessary to stay with the low melting point die glass tried on the previous attempt. About 8 inches extruded, broke into slivers, and then the press stuck.

Push No. 6

Conditions:

Same as No. 1 except that the billet temperature was raised to 1775°F. The higher melting point lubricant used in No. 1 was substituted in place of the lower melting point lube used in the previous extrusion. The purpose, of course, was to check the advisability and the effect upon the lubricant of a higher than previously tried billet temperature.

Result:

Four feet of beryllium extruded with gross tearing at the start and at the end. The outside surface of the entire extrusion was much rougher. Quite unsatisfactory.

Push No. 7

Conditions:

Same as No. 1 except for the use of a 10 inch long beryllium billet.

Result:

An extrusion 11 feet long without cracks or tears was obtained. Very satisfactory except for a rather progressive excessive roughness, particularly on the inside surface.

Push No. 8

Conditions:

Same as No. 7 with another 10 inch long beryllium billet.

Result:

Another 11 foot long section without cracks or tears. Fillets held very well but there were excessive drag marks in between the fillets on the inside surface.

Push No. 9

Conditions:

In order to try to eliminate the excessive drag marks inside, conditions for Push No. 9 were identical to Push No. 7 except that a short instead of a long beryllium billet was used, and it was preceded by a 1 inch thick copper nose plug.

Results:

No cracks but the surface quality was very poor with the copper being excessively smeared and uneven.

Push No. 10

Conditions:

Same as Push No. 7 with another 10 inch long billet being used. A three second dwell was deliberately allowed before pressing pressure was applied to encourage lubrication melting.

Results:

Another 11 foot long section without cracks or tears. The three second dwell appeared beneficial in that surface finish inside and out was the best of the group.

Push No. 11

Conditions:

Billet Material - 4" length, beryllium
Billet Temperature - 1750°F
Die Material - M-2 (new type)
Die Lubricant - Type G, one pad
Billet Lube - Type D-3 with B & F floss
Pressure - 550 tons
Ram Speed - in excess of 500 inches per min.

(The above billet temperature and lubes are the same as utilized in efforts which repetitively yielded uncracked sections).

Results:

Five foot length of fairly good extrusion except for a heavy tear six inches from the front. Die condition and inside of extrusion both appeared to be quite smooth.

Push No. 12

Conditions:

Billet Material - 10" length, beryllium
Die Material - EDS stellite, best x-ray quality.
Lubricants and billet temperatures same as Push No. 11.

Results:

First 1-1/2 feet were rattlesnaked, the next five feet whole, and then more rattlesnaking with one web broken off. The inside of the extrusion was grossly striated and was typical of previous die failures.

Push No. 13

Conditions:

Billet Material - 10" length, beryllium
Die Material - Stellite
Billet Temperatures same as Push No. 11.
Lubricants - new type glasses which were recommendations of Allegheny Ludlum Steel Co.

Results:

Ten foot length which was not torn but was rough and badly twisted. Inside and outside of extrusion were progressively rougher and clearly showed lubricant failure. Die failed severely, but unlike Push No. 12, the fillets were badly worn with minor damage in between.

Summary and Evaluation

Results on the 700 ton Loewy Press at Wolverine, when compared with experience on the older press at Nuclear Metals, yielded the following tentative conclusions:

- Higher Ram Speed More Favorable

General results of the high speed tests on the Wolverine Press were very encouraging. Ram speeds were in excess of 500 inches per minute compared with a top ram speed of 120 inches per minute for the NMI press. This faster and, particularly, more consistent speed very clearly contributed to the drastically improved results.

- Reproducibility Established

Efforts at NMI had previously yielded, on occasion, a crack free section; but at no time was it possible to duplicate the results at will. In this effort at Wolverine three maximum lengths (11 ft.) were produced without cracking or tearing defect that had characterized previous efforts. The important observation made during this session was that after a defective part was produced because changing one of the extruding variables a good one could again be made by returning to the original conditions.

- Temperature Variation Minimized

The very rapid speed and, perhaps more importantly, its consistency drastically minimized the billet temperature variation. In light of other findings, such as the criticalness of lubricant composition, the improvement of billet temperature variation would not help but have a profound effect on the chances of repeatability.

- Temperature is Critical

After having established an apparently satisfactory billet temperature of 1750°F on pushes #1 through #4, attempts were made to explore temperature limits. This was done by going to 1650°F on #5 and to 1775°F on #6. In each case the results were unsatisfactory. Return to 1750°F again yielded good extrusions.

- Lubrication is Critical

After three billets with the same temperature and the same billet and die lubes, the glass was changed to a lower melting point variety, and a bad rattlesnaking occurred. On the next attempt with the billet temperature substantially lowered, the lower melting point die lube was used with a lower melting point billet lube. A short section of extrusion came out, broke up, and the press stalled. A latter attempt to use a nose plug of copper as an added lubricant and was found to be detrimental.

These results, while not conclusive, do indicate a rather narrow lubricant tolerance. These results also demonstrate need for further experimentation and improvement. Figures 70 and 71 show

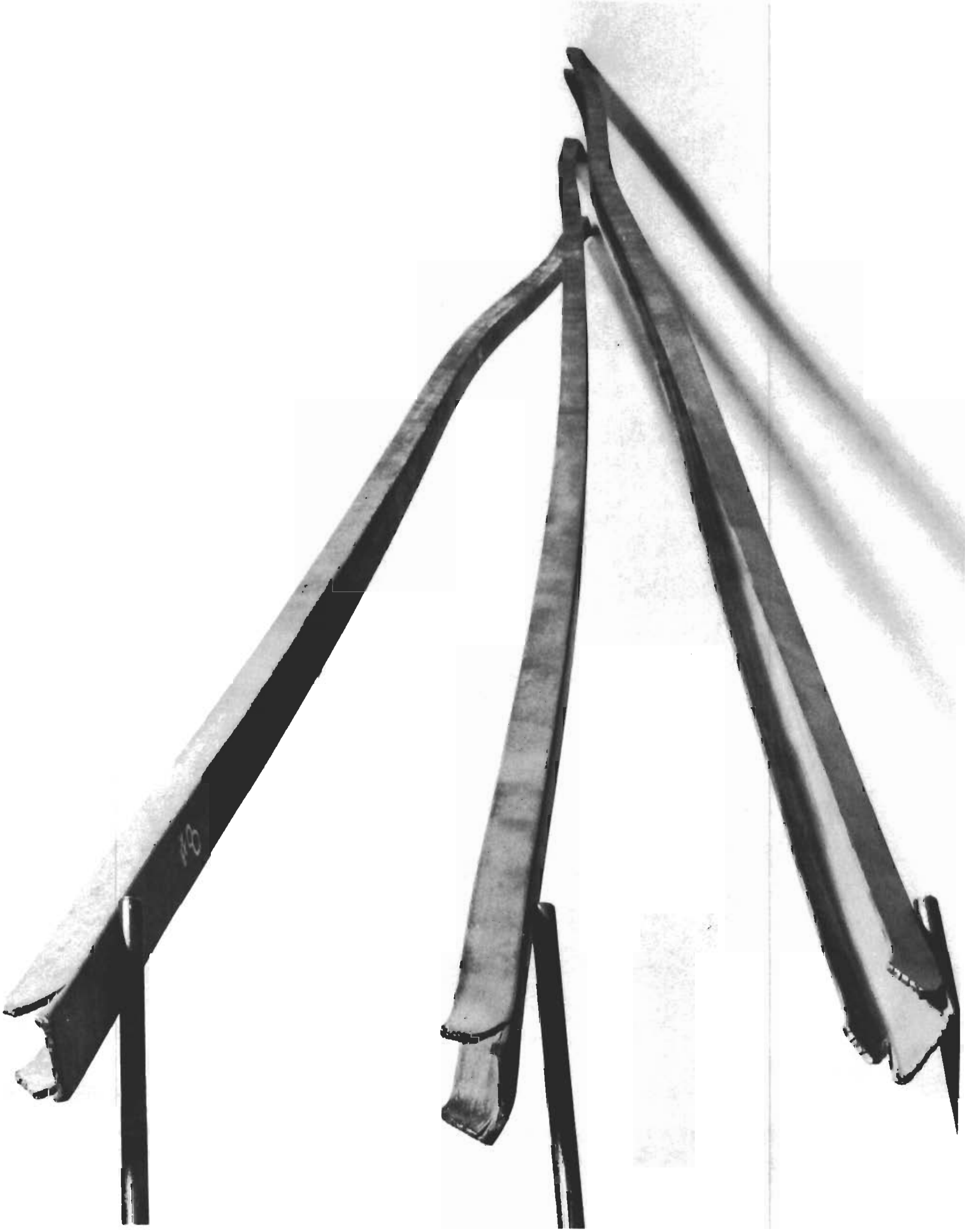


FIGURE 70 THREE BERYLLIUM EXTRUSIONS PRODUCED AT WOLVERINE TUBE.

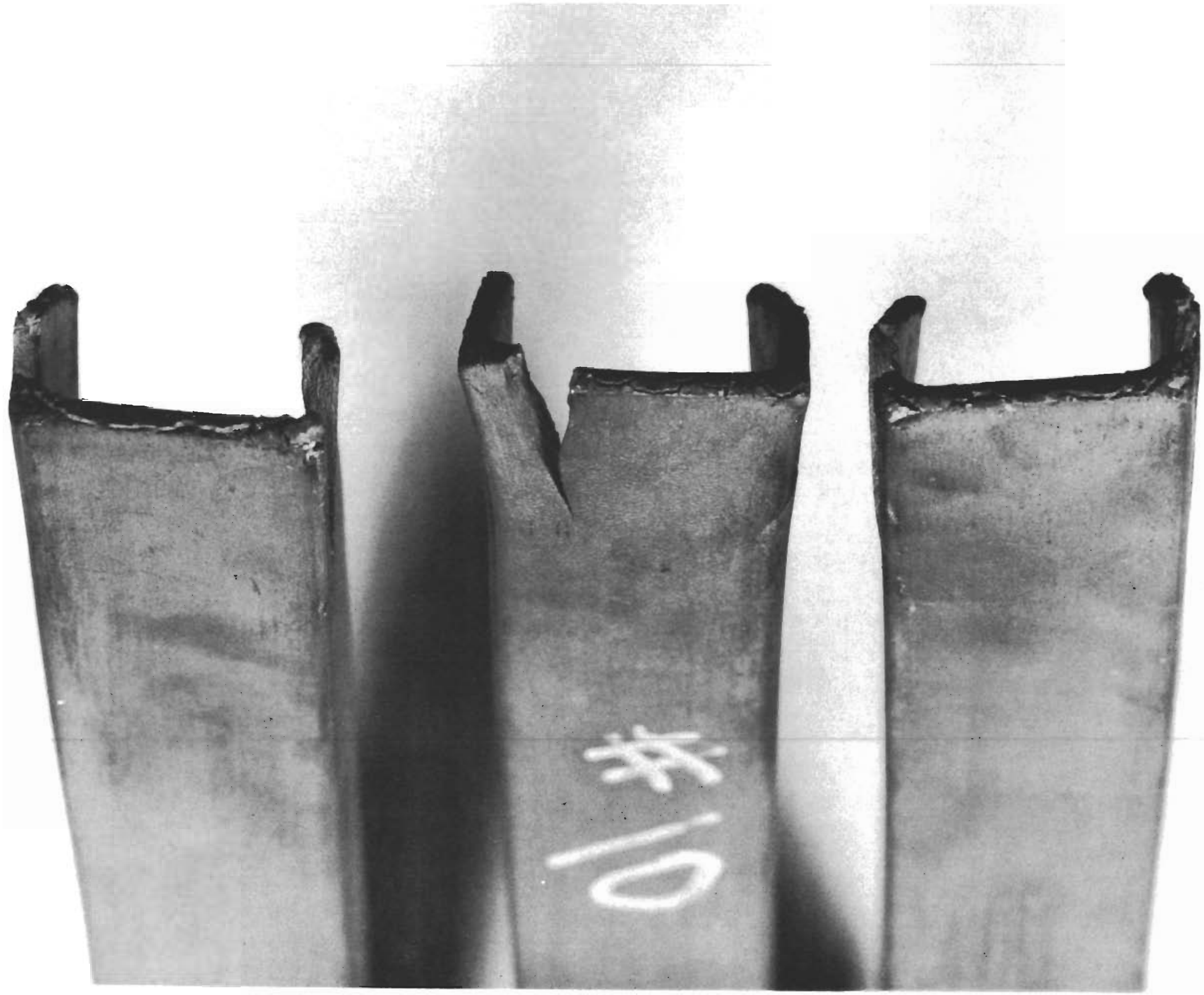


FIGURE 71 FORWARD END, BOTTOM VIEW, WOLVERINE BERYLLIUM EXTRUSIONS.

the good surface quality exhibited on the outside of all three 11 foot shapes. Condition of the inside surface, as shown in Figure 72, definitely shows a deficiency of lubrication. It should be noted, however, that in both Figures 72 and 73 the "piled up" metal at the extreme ends is due to extruding down to virtually no butt or discard. This lube deficiency could be due to composition, or quantity, or method of application of the lubricant. It could also be due to any one of numerous reasons that could cause or contribute to incorrect temperature. Also within the realm of possibility is the fact that the fault may have been either faulty composition or structure of the die. However, an analysis of the dies at Norair's research laboratories failed to reveal any basic defect in the dies. Since the temperature was believed to be very consistent, the composition and possibly the form of application of the lubricant should be considered as approaches to improve the inside surface quality.

- <u>Dwell Time Is Beneficial</u>

Experience with the Wolverine press indicated the desirability of intentionally waiting momentarily after the press has closed before beginning the extrusion (dwell time) in order to encourage melting of the lubricant before the extrusion is started. This conclusion has to be predicated on a number of reservations. Among these are that this is true with the present lubricant "G" and that it might or might not be true with other lubes.

- <u>Analysis of Die Failure</u>

Inasmuch as the dies from the last extrusions had a gross failure of an unusual type, micro and macrographic studies were made to attempt to determine the cause and mode of the failure. Figure 74 shows a typical die that has been broken in half. The upper half of the view shows the exposed bearing surface between the fillets of the channel section. Inspection shows that the fillets held up very well but that the flat area in between eroded badly. This leads to the suspicion that cast defects near the surface could cause local overheating and drastically hasten failure. A cross section of an unused die (See Figure 75) showed that cast defects of sufficient magnitude were present in an area not critically located. However, whether such defects were actually present in a critical location on the dies which had been used and eroded away, could be subject only to conjecture.

In line with the supposition made above, subsequent dies procured for the next effort were subjected to x-ray inspection. A 40 percent rejection rate was encountered at the foundry.

- <u>Straightener Not Used</u>

The 3 shapes shown in Figure 70 are as-extruded except for being vapor blasted to remove glass. The "on-press" straightener which had been very successfully used at Nuclear was not transferred to the new press. Neither were any supplementary straightening

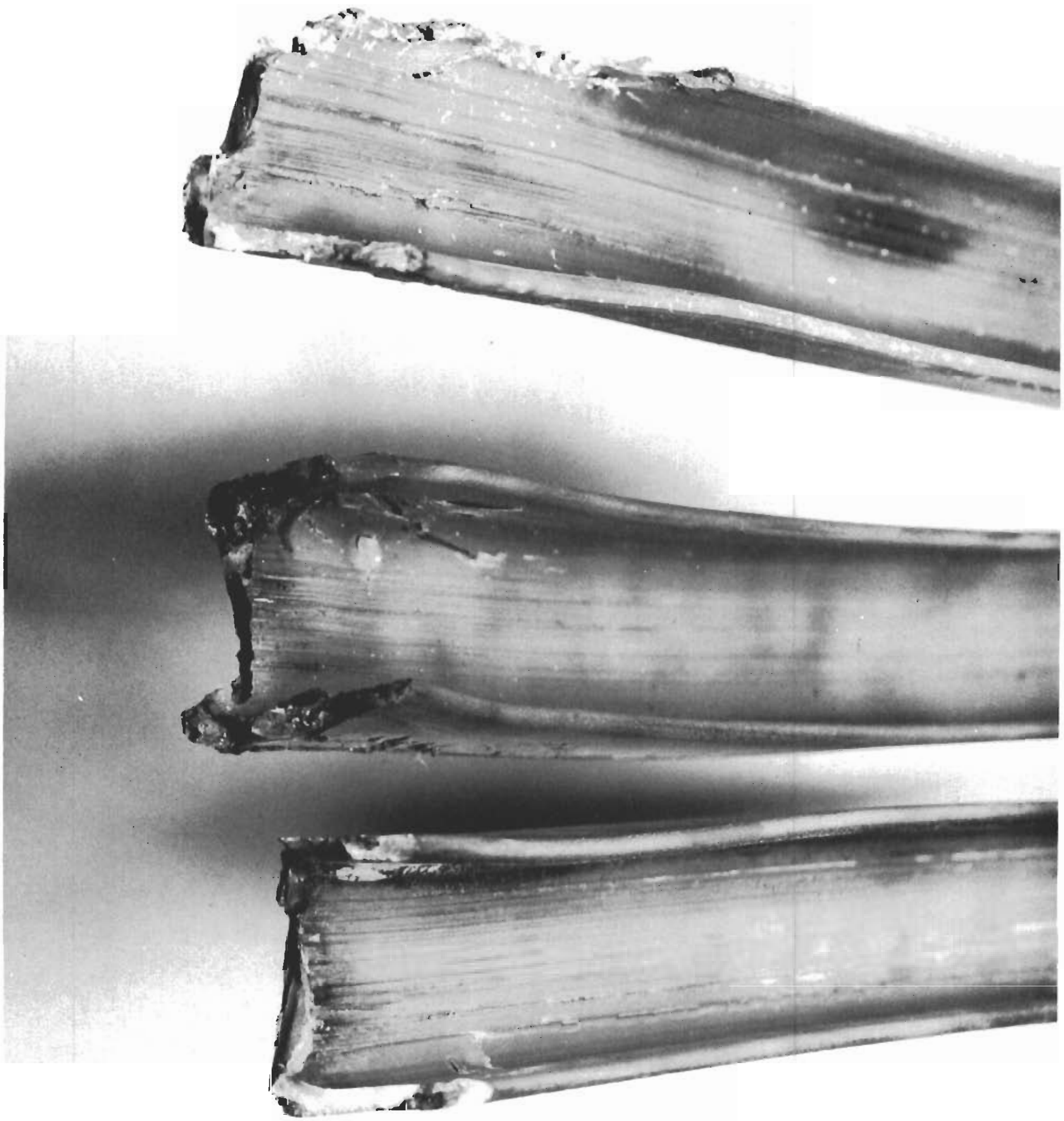


FIGURE 72 BUTT END, TOP VIEW, WOLVERINE BERYLLIUM EXTRUSIONS

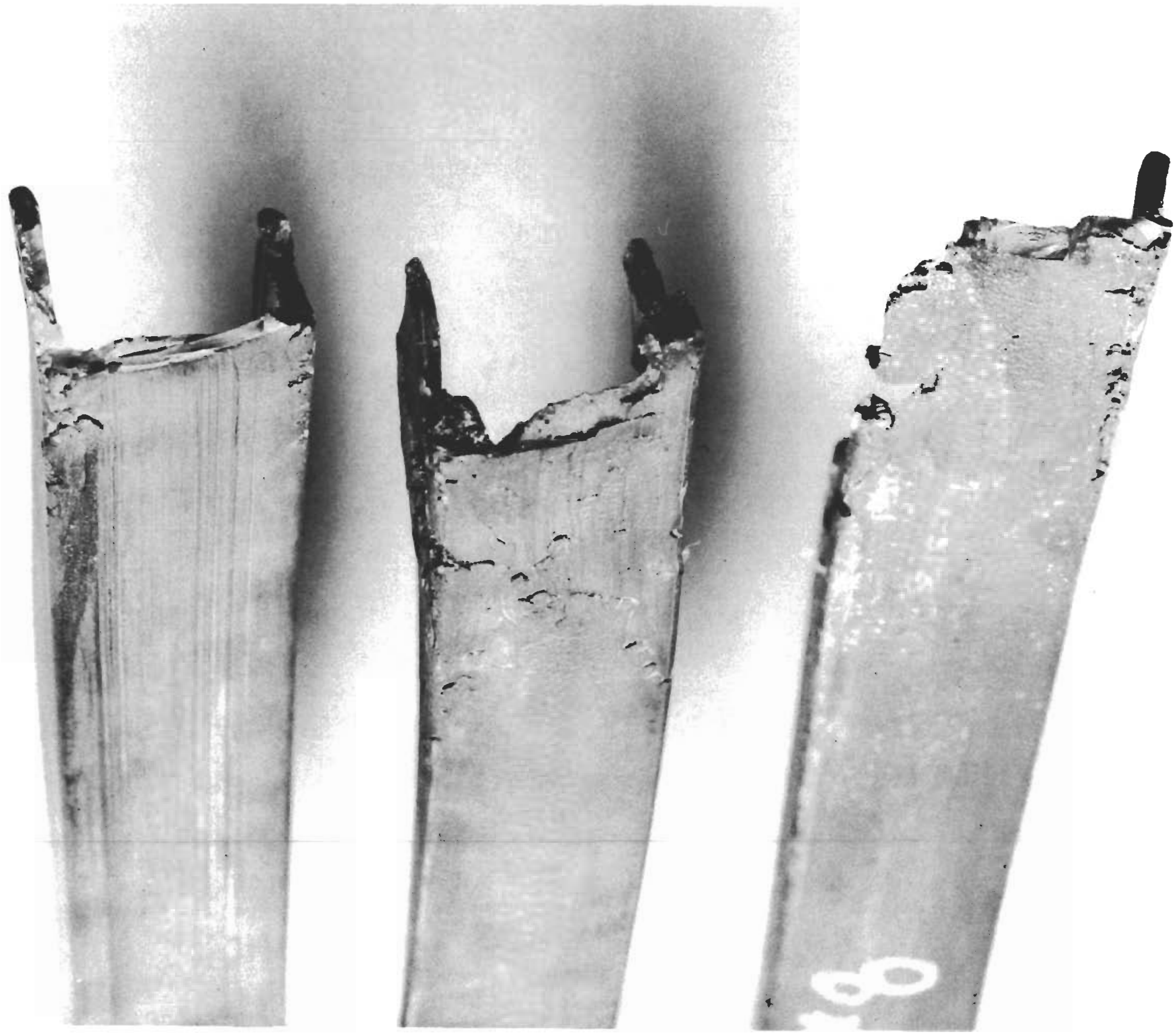


FIGURE 73 BUTT END, BOTTOM VIEW, WOLVERINE BERYLLIUM EXTRUSIONS

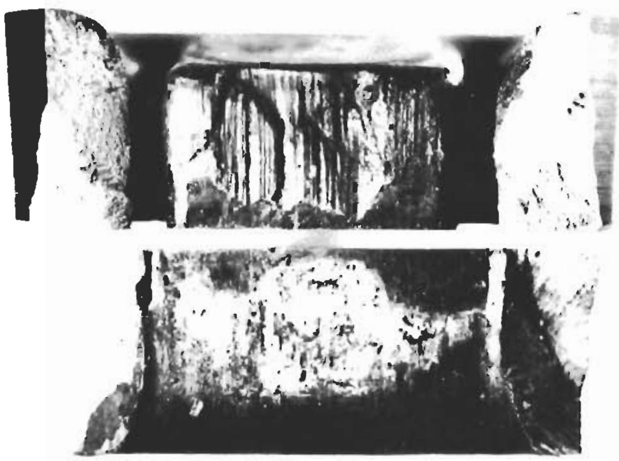


FIGURE 74 BEARING SURFACES OF DIE USED IN WOLVERINE WORK.

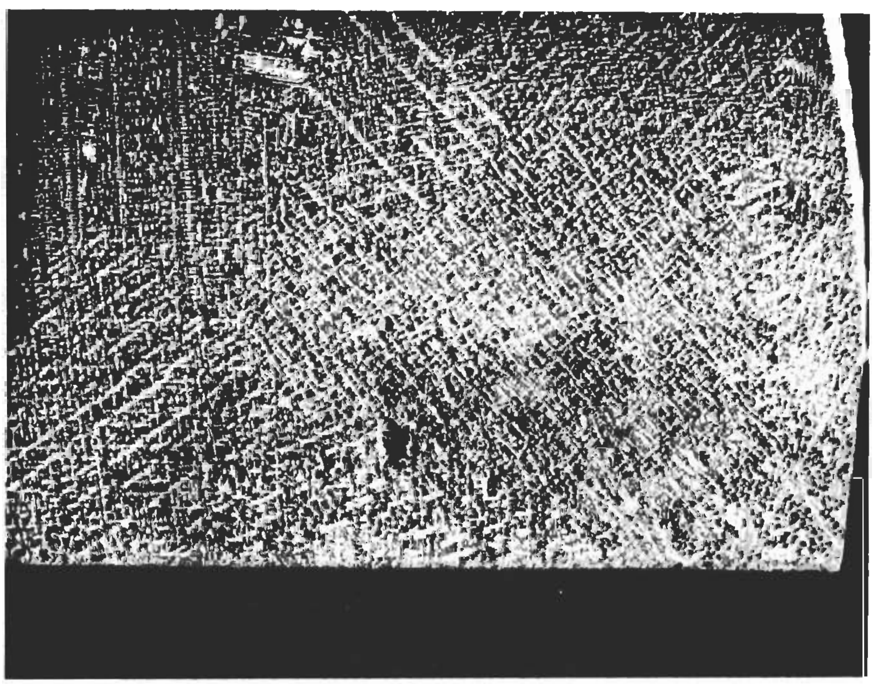


FIGURE 75 MACROGRAPH OF DIE USED IN WOLVERINE EXTRUDING.

operations employed. The extrusions are thus adjudged to be rather surprisingly straight.

REAPPRAISAL OF TECHNICAL APPROACH

Previous to this program, virtually all attempts to extrude beryllium had been to jacket the billet in an evacuated steel can which served not only to prevent oxidation and to minimize the toxicity hazard but also to keep the beryllium from direct contact with the die surfaces. In an attempt to make the process more economical and to generate complex beryllium shapes to closer tolerances, unclad beryllium extrusions were exclusively attempted under this program. As a substitute for the steel jacket, several alternatives were tried, predominently including the use of molten glass based on the Ugine-Sejournet process which Nuclear Metals, Inc., is authorized to employ as a licensee.

It was agreed by Nuclear Metals, by ASD and by Norair at the beginning of the program that this approach would provide maximum precision of dimensions in the extruded parts and would have the greatest applicability. Use of techniques involving canning or cladding of billets was felt to introduce a tolerance variable because of the resulting divergence in thickness of cladding. It was also conceived that certain complex shapes may not lend themselves to this process. However, recent work by Nuclear Metals using billets encapsulated in steel and copper had shown much promise with a finned tube for the atomic energy commission in 5 to 12 foot lengths. After the success of the finned tube became apparent, Nuclear Metals proposed that its technology be converted to this program. After a reevaluation of the results to that date, with particular emphasis on die wear and lubrication technology, and after discussions with ASD it was agreed that this newly refined approach would be incorporated. It was expected to offer the following certain advantages:

- It appeared that the press at Nuclear Metals facility would be adequate, thereby eliminating the need for two tiers of sub-contracting. Clad extrusion did not seem to require the precision of ram speeds beyond the capability of the Nuclear Metals Press.

- The tendency toward cracking and rattlesnaking would be greatly reduced.

- More conventional lubrication practice appeared to be adequate.

- Reverting to the Nuclear Metals press eliminated the need for a new container, liner, and stem which would have been required at Wolverine to achieve the 20 foot length capability.

IX COMPOSITE LUBRICANT EXTRUSION, PHASE I, AT NUCLEAR METALS

DISCUSSION

With the change over from bare beryllium extrusion using the Sejournet glass technique to a composite series of metallic and liquid lubes, the newly refined process was designated the "composite lubricant technique". The differentiation in terminology is deliverate to point up the high degree of precision obtainable compared with results associated with previous canned or clad efforts.

An extensive statistical study was made of all previous extrusion attempts at Nuclear Metals in order to furnish data to establish design parameters for the new technical approach. Previous efforts using glass as a lubricant had been replete with stalled billets and abnormal pressure patterns. It was essential, then, that in converting from bare beryllium with glass to a series of metallic and liquid lubes, an adequate specific pressure be established without jeopardizing other factors such as thickness of coatings and excessive billet length. This analysis resulted in a container diameter of 3.04 and a billet length of 17 inches.

The extrusion press is the same as was used for previous extruding efforts at Nuclear Metals and is shown in Figure 21. The billet heating facility is identical to that used at Wolverine and the earlier NMI pushes. Details of the special argon filled insert box for gas or electric furnace are shown in Figure 69. The difference in extrusion tooling is shown and described under "die design" which follows:

The billets of hot pressed-200 mesh QMV powder obtained from Brush Beryllium were turned down to a micro finish of approximately 32 RMS and encapsulated in a carbon steel tube of 0.115 thickness with end caps. Like the billet outside diameter, the inside diameter of the tube was finished to 32 RMS. This is considered to be the key to obtaining an extrusion of high quality surface finish. There was no attempt to seal or evacuate the steel envelope. To the exterior of the steel capsule was added a coating of electro-deposited copper of .030 thickness in order to provide additional lubricity. (See Figure 76)

All beryllium used in this program conformed to Brush S-100-B specifications. A typical analysis of the different lots of material purchased is shown below.

<u>Typical Analysis* in w/o of Beryllium Used in Program</u>

Assay	98.0
BeO	1.02
Fe	.116
Al	.070
Mg	.006
Si	.020
C	.100
Density	1.85 gm/cc

*By Brush Beryllium Corporation

DIE MATERIAL

The two die materials used interchangeably in this program were cast M-2 steel and EDS stellite. Each of these materials has its advantages and disadvantages under the extrusion conditions encountered in this program. Properly

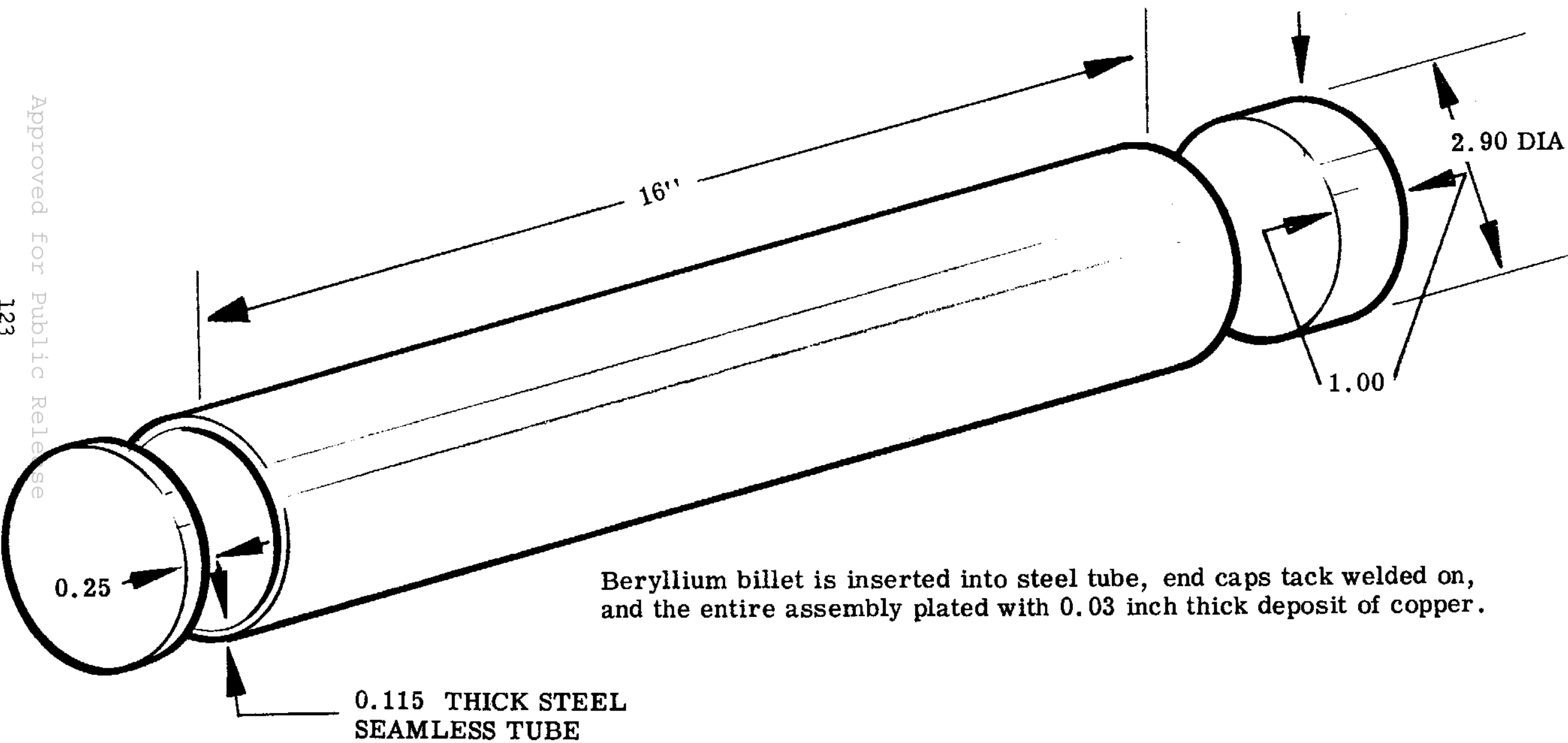


FIGURE 76 DETAILS OF COMPOSITE BILLET COATINGS.

heat treated M-2 steel in the R_c range of 54-57 does not exhibit washout. However, these dies cracked severely during extrusion, leaving jagged areas for the copperplated steel sheath to encounter and leading to possible clad breakthrough. The EDS stellite, which has a hardness of R_c 44, exhibits plastic deformation during extrusion and unless adequate support tooling is employed the die orifice changes dimensions drastically, affecting the extrusion configuration from front to rear. However, with adequate support tooling the plastic deformation of the die can be restrained considerably. The use of EDS stellite or an M-2 steel die depended upon numerous factors, such as lead time to acquire dies, support tooling, cost, etc.

Duplicast Die Company of Detroit cast the dies to shape by the Shaw process and the dies were finished to size at the Moczik Tool and Die company, also located in Detroit.

DIE DESIGN

It was apparent from past experience that the die design would have to be altered radically because of the complete change in type and method of application of lubricants. Under the Sejournet system of glass lubrication, flat faced design was a necessity to provide the reservoir of semi-molten glass which was gradually drawn off as the billet passed the so-called "dead zone." With the "composite lubricant technique" in which the beryllium never touches the die, the metallic and liquid lubes are applied over the entire billet surface prior to insertion into the container. This obviates the need of the reservoir provided by flat faced dies and, in fact, dictates the need for smoother, more streamlined flow. This was accomplished best by using a conical die approach.

To optimize the approach angle and entrance radii, three die variations were designed and cast. See Figures 77, 78 and 79 for details of these dies. Note the 28-1/2°, 32°, and 45° approach angles and substantially different faces on the tongue approach surfaces. See applicable extrusion data sheets Number 1 - 13 in Appendix VII for further detail of die design. Each subsequent design to the original MC-497-A was redesigned with a new letter designation and then cast and used in the next extruding effort. This redesigning was made only after careful analysis of the previous extrusions flow characteristics.

SUPPORT TOOLING

Figure 80 shows an exploded view of die and support tooling (bolster and straightener). Angular alignment between the die and bolster is maintained by a shoulder on the bolster which fits inside the liner with the die. A pin and slot provision in bolster and straightener provides lineal alignment. The straightener is placed immediately beyond the bolster and acts as a guide for the emerging extrusion. A railroad track type rail serves as a run-out table for the inverted extrusion. It also serves as a means to retain the straightness and shape during cooling. Two different run-out tables were used. One table consisted of fixed one-foot sections of Transite stationed end-to-end along a 30 foot I beam. The other run-out table was essentially the same except that the Transite was allowed rectilinear motion, to contract with the extrusion during cooling. Figure 81 shows the fixed Transite railroad type run-out table.

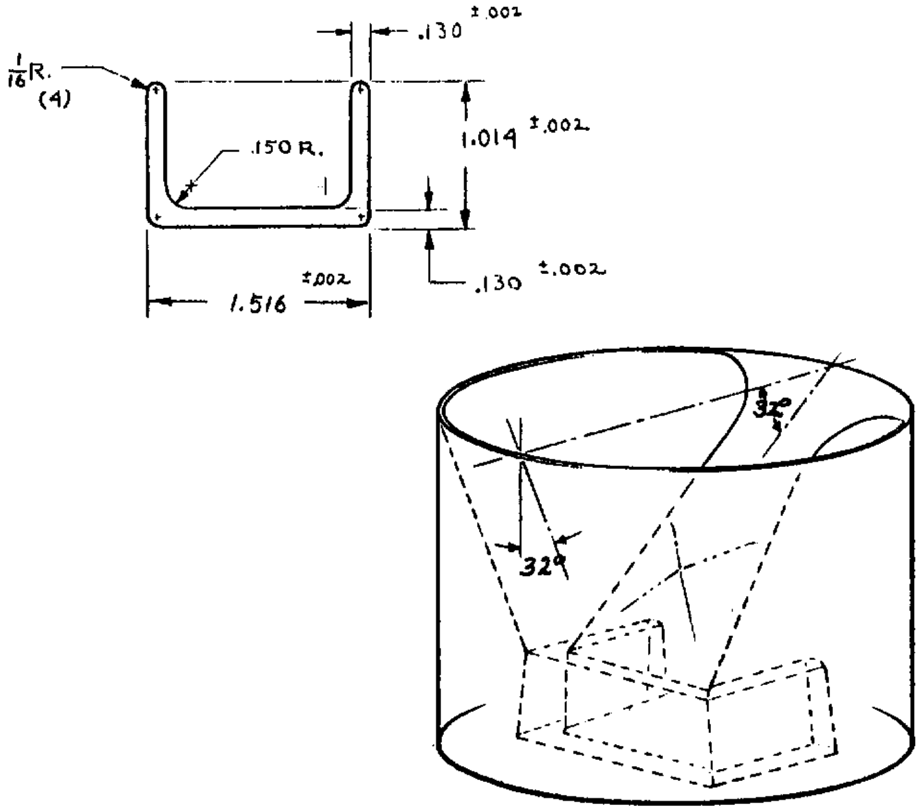


FIGURE 77   32° DIE DESIGN MC-497-A

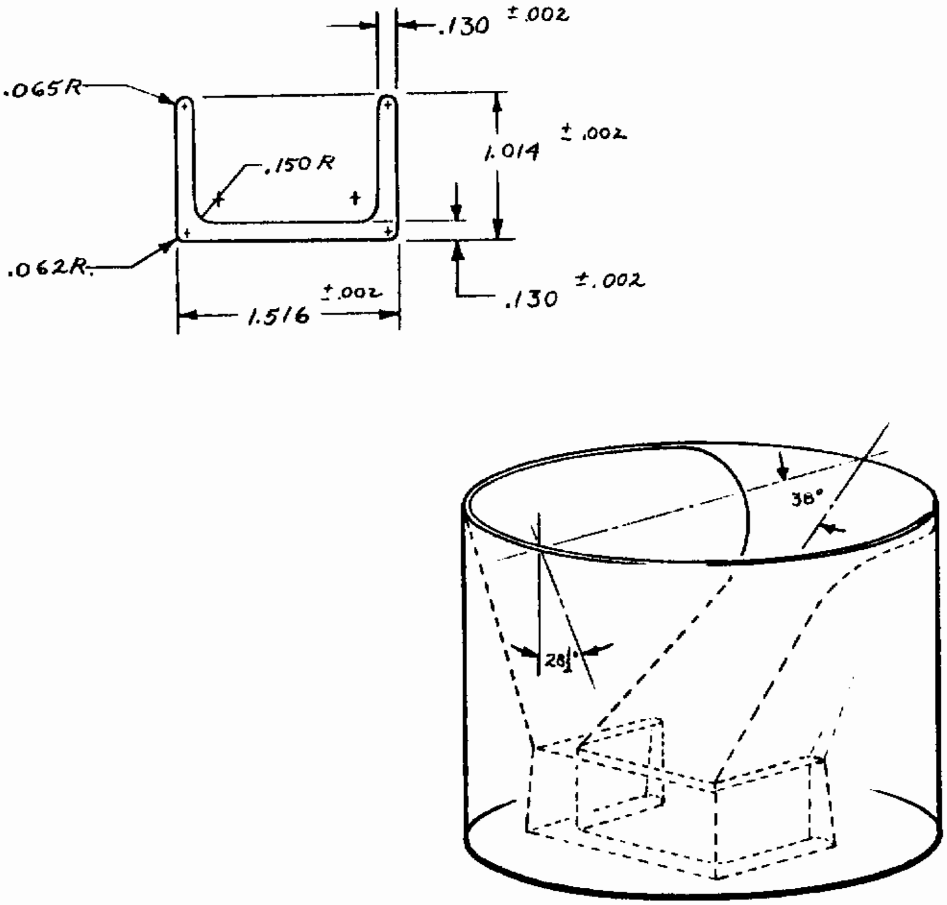


FIGURE 78 28 1/2° DIE DESIGN MC-497-B

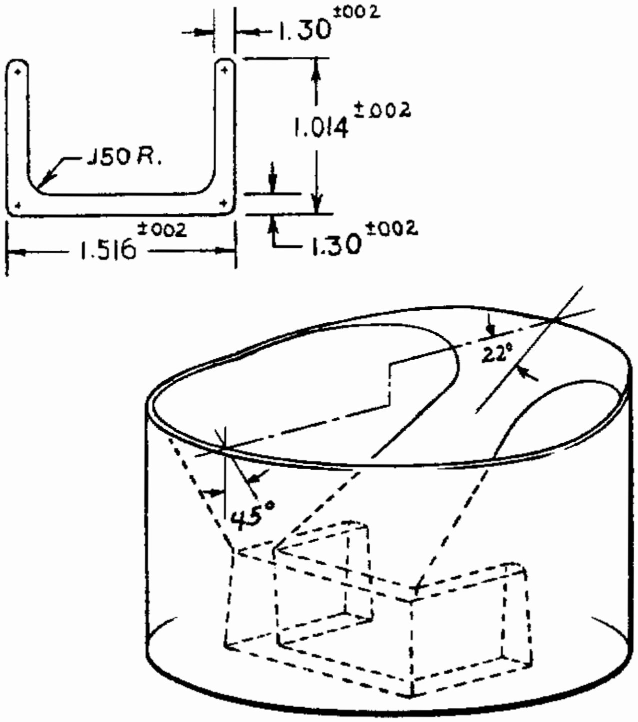


FIGURE 79 45° DIE DESIGN MC-497-C

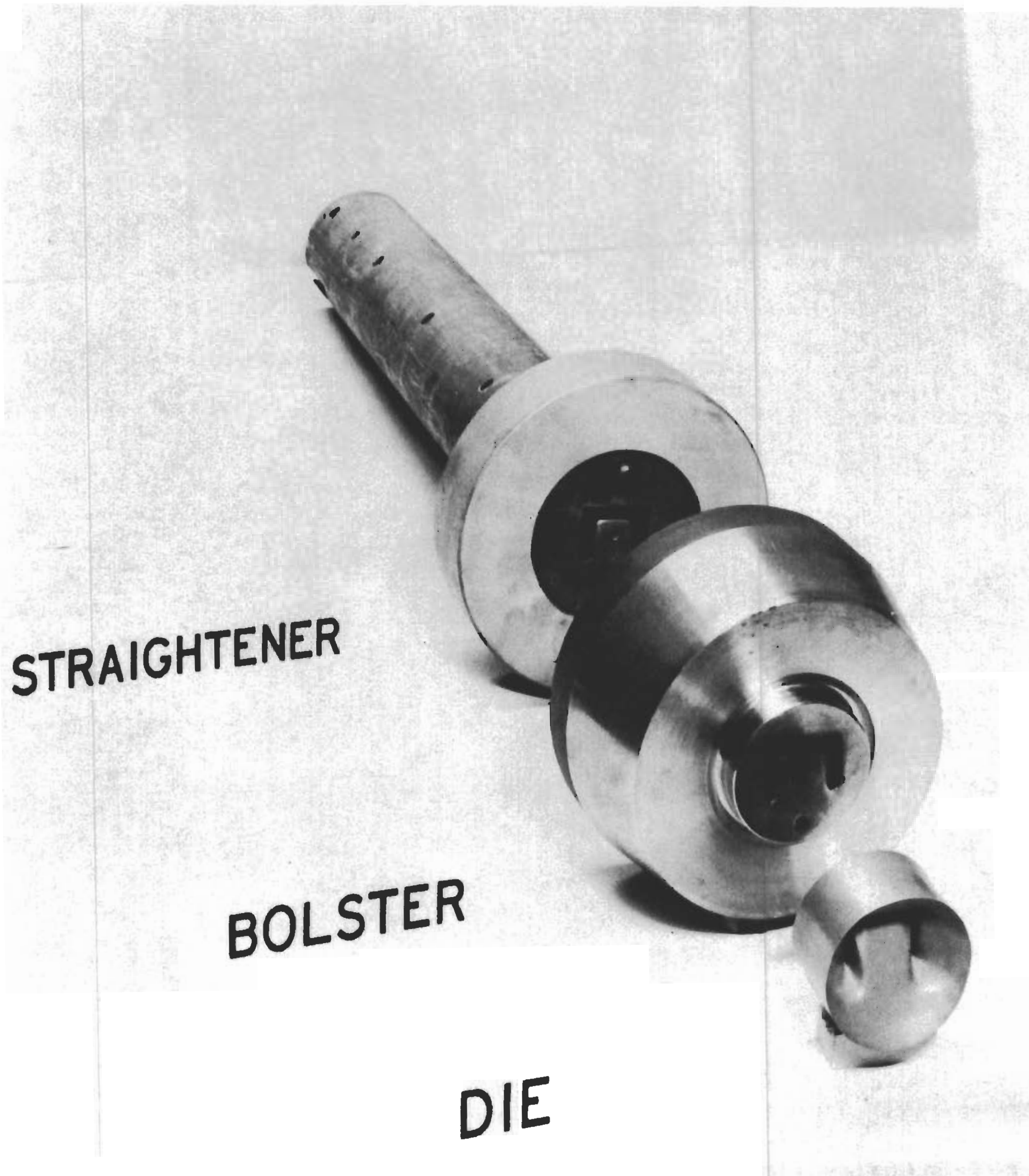


FIGURE 80 EXPLODED VIEW OF DIE, BOLSTER AND STRAIGHTENER ARRANGED IN SEQUENCE.

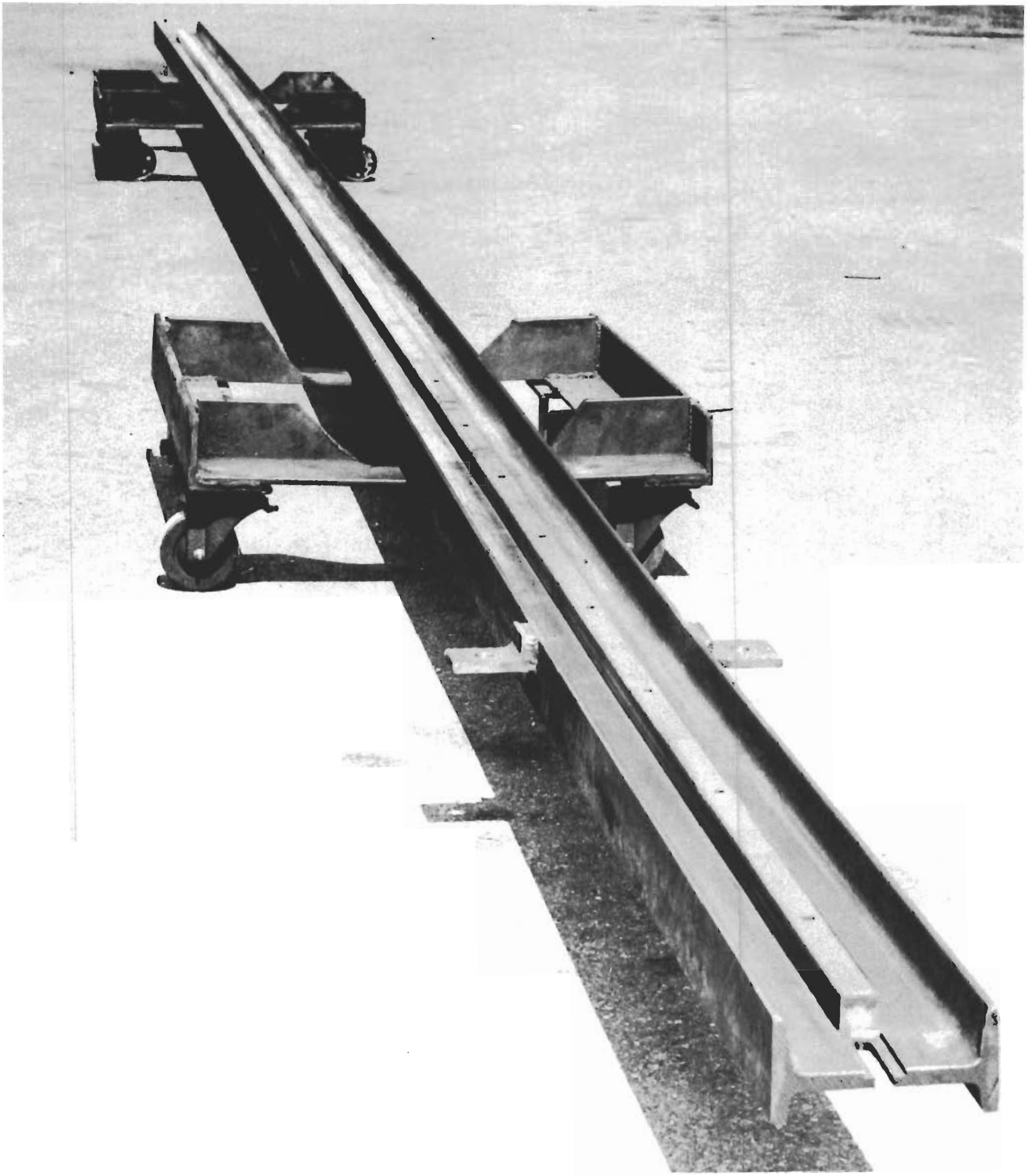


FIGURE 81 PHOTOGRAPH SHOWING THE FIXED TRANSITE RAILROAD-TYPE RAIL RUN-OUT TABLE.

LUBRICATION

Previous to this effort, virtually all extruding efforts were predicated on the Sejournet technique of utilizing molten glass to act both as a thermal barrier for the die and to provide a lubricant of adequate viscosity. From observation of product quality in the scores of extruding attempts under this process, it was obvious that technical contingencies exist in its application to beryllium. Other undesirable features were (1) the process of using glass was restricted to licensees, and (2) such important factors as glass composition could not be revealed to Norair or disseminated in reports. The latter complication is nonexistent with the composite lubricant technique because there is no glass utilized.

In addition to the 0.125 inch steel tube and the 0.03 inch thick electrodeposited copper mentioned in previous paragraphs, a container lube was used to provide further lubrication. This was a mica base lube called neorolene, manufactured by Crawford Emulsions of Pittsburgh, Pennsylvania, and was applied by swabbing the container.

EXTRUDING EFFORTS

With the decision to convert the technical approach from Sejournet glass lubrication to the composite lubrication system came the necessity of reestablishing come basic parameters. The most critical of these was that of die design since it was a foregone conclusion that flat faced dies would not be satisfactory for use with the new technique. The success or failure of the new approach appeared to hinge on development of a die design that would yield a smooth and relatively even flow about the periphery of the die aperture. The problem is quite extreme in the case of a channel because the outside surfaces have about 75 percent of the billet circumference to draw from while the inside of the U has only the remaining 25 percent. This obviously could easily lead to a "starved" condition on the internal surfaces, so a prime consideration was to shape the flow pattern to encourage as much as possible the peripheral flow of the billet to the inside and, in particular, to the fillets. Proper shaping of the flow pattern would establish the clad thickness of the inside relative to the outside, consistency along a surface, and amount of build up at the corners.

With this aim the extruding that followed was completed in five separate efforts with the first four being classified as experimental.

Appendix VII shows extrusion data sheets for each push with pertinent information such as heating time, temperatures, die design configuration, etc.

Effort 1 (Push 1)

To obtain a preliminary indication of flow characteristics with minimum time and cost, an adaptation was made with an existing flat faced glass lube die. An insert was machined with a conical approach and placed in front of the flat die to simulate the shape desired. One short beryllium billet was then extruded through this combination and the extruded section and the butt was sectioned and carefully analyzed. This experiment, although somewhat crude, did yield a good indication and constituted the basis of the die designs which followed.

Effort 2 (Push 2)

A definite die design was made based upon the results of effort 1, a pattern was fabricated, and a die was cast. A short beryllium billet was pushed through it with encouraging results. An important observation was the fact that the starting pressure was only 420 tons. Since the press was capable of 600 tons, this meant that Nuclear had ample pressure to spare. This tonnage was considerably less than that utilized with the flat faced dies. The flow was encouraging but not fully satisfactory, and the design was changed to improve the flow.

Effort 3 (Pushes 3, 4 and 5)

In addition to the modified design used in effort 2, two more designs were evolved and cast M-2 one-piece dies were procured. These three die variations are shown in Figures 77, 78 and 79.

The third extruding effort was made utilizing dies from all three designs. Short beryllium billets were pushed and the results compared and evaluated. The die design in Figure 80 showed the smoothest distribution of metal. The copper and steel sheathing extended the full length of the extrusion although there was a slight die pickup. The Figure 79 die pattern was altered slightly by smoothing the entrance radius in an attempt to eliminate the pickup.

Effort 4 (Pushes 6, 7 and 8)

The results of effort 3 were sufficiently encouraging to warrant proceeding with longer length billets. Five billets were prepared and made available in the following lengths: one five inch, two ten inch, and two seventeen inch. Sufficient dies in the Figure 79 configuration were procured.

The first attempt was with a 10 inch billet and resulted in a good 12 foot long secion. There was no indication of breaks, tears, or other defects. The metallic lube held up over the full 12 feet including the fillet area.

The results with the 10 inch billet were so satisfactory that a full length 17 inch billet was then extruded and these results were spectacularly successful. A full 24 foot length was obtained, thus leaving ample length for cropping off the two ends for the target length of 20 feet. Another 17 inch billet was then extruded and resulted in another 24 foot defect free section. (See Appendix VII for details of extruding conditions.)

With two apparently good 20 foot lengths, the important question was what the beryllium shape was like beneath the metallic lubes. Both the copper and steel were then stripped off with a 20 percent Nitric acid solution and the beryllium shapes were lightly etched in a 10 percent H_2SO_4 solution. The resultant beryllium core appeared excellent.

Effort 5 (Pushes 9 thru 13)

The analysis of the two 20 foot lengths from effort 4 showed that the technology and design parameters could be considered satisfactory. To fulfill the contract requirements of producing five 20 foot lengths for pilot production as representative of the state-of-the-art, six 17 inch long billets were prepared and the results were as follows:

Push 9

Conditions:

Die - M-2 tool steel per design configuration shown in Figure 79; no preheat.

Billet - 2.90 diameter, 17 inch long beryllium billet of 200 mesh QMV sintered power with 0.12 inch thick steel can covered with 0.03 inch thick electro-deposited copper; preheated to 1725°F.

Container - 3.045 inch diameter liner heated to 900F and swabbed with Necrolene mica lube: Extrusion ratio 20 -- 1.

Misc. - See appendix VII for further details.

Result:

Twenty four foot length of good product except for localized tearing of the left hand leg at the 18th foot. The last six foot length was again good. Figure 82 shows the tearing from the inside of the leg, and the upper extrusion in Figure 83 shows the tearing from the outside of the leg in the same area. Inspection of the die showed some erosion in the corresponding area.

Push 10

Conditions:

Same as Push 9.

Result:

Stalled. No extrusion because the graphite cut off slug which is placed between the billet and the dummy block was mishandled. This caused too much delay and chilling of the billet and therefore a stalled press.

Push 11

Conditions:

Same as Push 9.

Result:

Twenty four foot length of good product except for slight localized tearing on the left hand leg at the 21st foot. This defect is shown in the lower view of Figure 83. Inspection of the entire length showed that this defect could be cropped off and still give 20 feet of usable length.

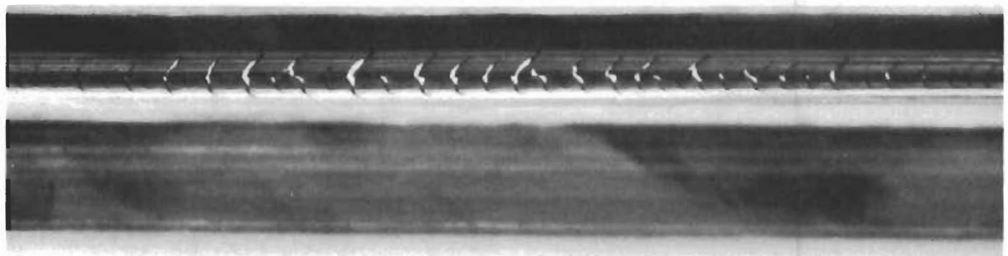


FIGURE 82 Local Tearing on inside of LH leg at the 18th foot of extrusion 9.

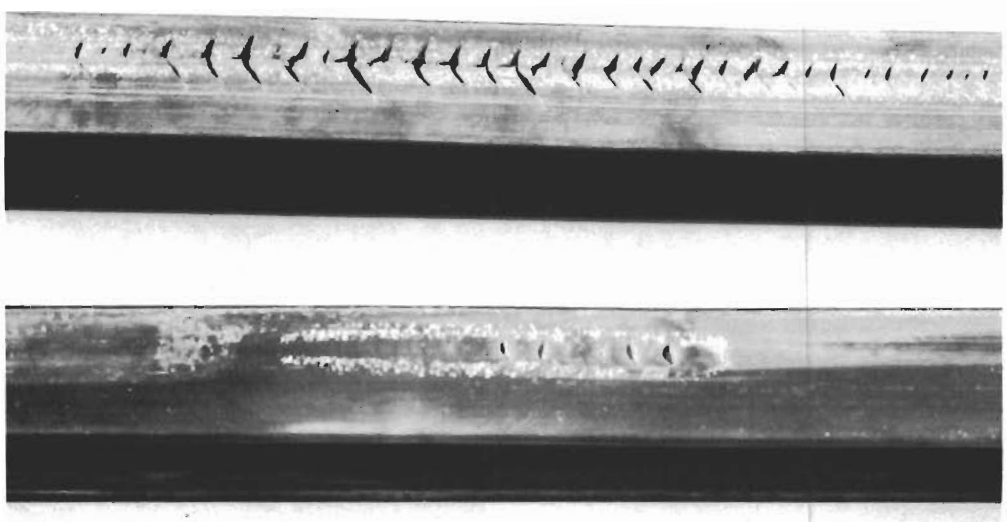


FIGURE 83 Upper: Local tearing outside of LH leg of extrusion 9.
Lower: Local tearing outside of LH leg at 21st foot of extrusion 11.

Push 12

Conditions:

Same as 9 except that EDS stellite die was used in place of previous M-2.

Result:

Twenty-four feet of totally good product from the visual standpoint. This resulted in the decision to return to the previously used EDS stellite cast dies. Stellite's one drawback is the tendency which has been repeatedly exhibited of closing down by 0.008 to 0.010 inch upon initial deformation. This action can be pre-estimated fairly reliably and thus is preferable to the die erosion experienced with several other types of die material.

Push 13

Conditions:

Identical to 12.

Result:

Again the billet yielded 24 feet of totally good product. The four full length sections of effort 5 together with the two excellent 24 foot sections from the previous extruding session constituted the Phase I pilot production requirement. Figure 84 shows the six shapes as they came from the press without supplementary straightening operations.

The five best extrusions of the six shown in Figure 84 that were selected for pilot production evaluation were pushes 7, 8, 11, 12 and 13. The 20th foot of each of these five was submitted to Mr. T. S. Felker, Project Engineer of the Manufacturing Technology Laboratory for consideration. Figure 85 shows the 20th foot specimen cut from extrusion 12. All extrusions exhibited a surface quality of approximately rms 32.

See Table X which shows a summary of the Phase I extruding effort.

POST EXTRUSION TREATMENT

Pickling

To remove the steel jacket from the extruded beryllium the best results were achieved with a 4:1 solution of H_2O (tap at 120°F) and HNO_3, using a sufficient volume of solution to prevent over-heating and changing the solution when the action at 120°F becomes minimized.

Dimensions

See Section X of this report for complete details and analysis of dimensional inspection.

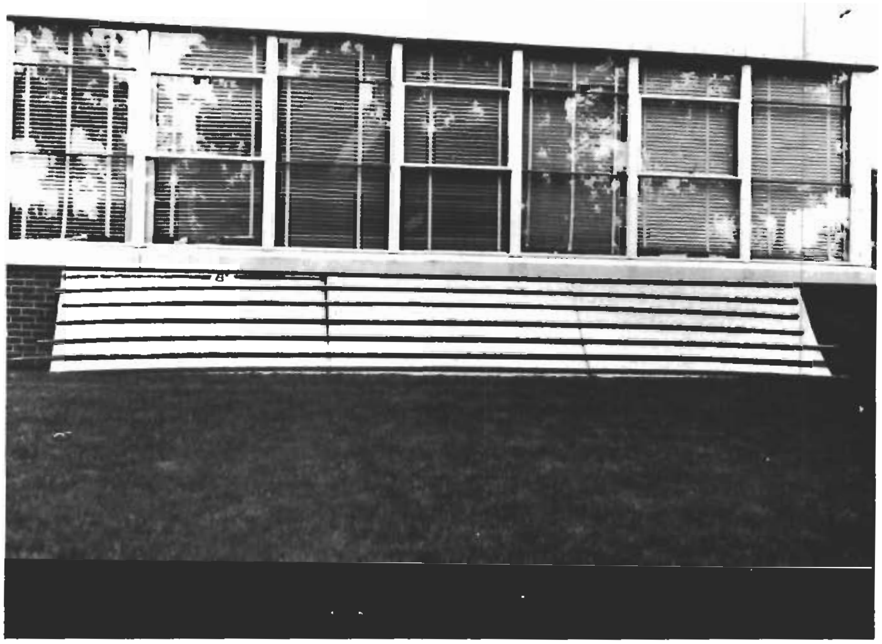


FIGURE 84 SIX 24 FOOT LONG BERYLLIUM EXTRUSIONS PRODUCED FOR PILOT PRODUCTION.

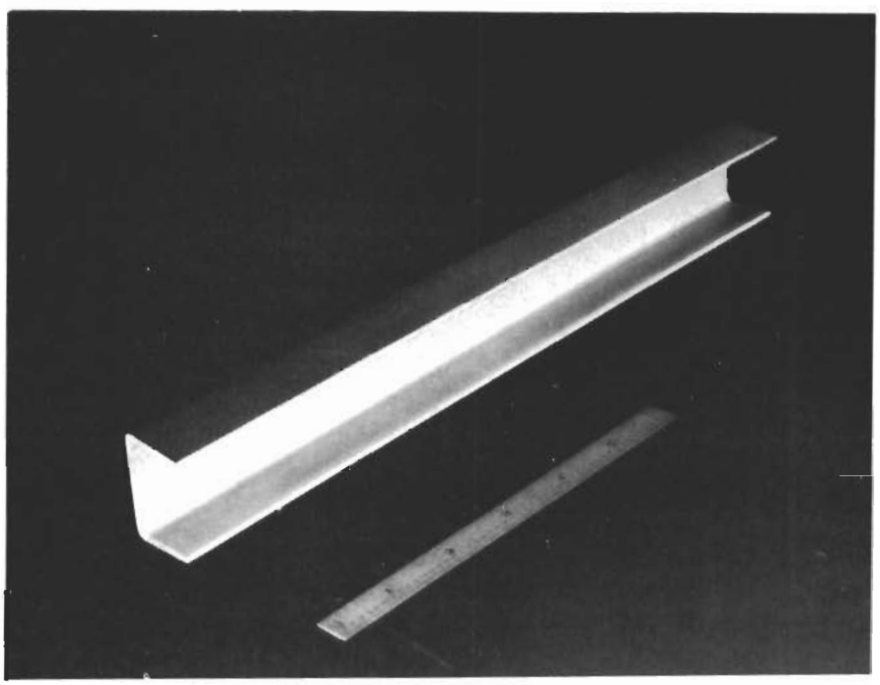


FIGURE 85 SHOWING THE 20th FOOT OF EXTRUSION 12. NOTE THE EXCELLENT SURFACE QUALITY OF RMS 32.

TABLE X

Summary of Extrusion Data
For Phase I Composite
Lubricant Extrusion

Ext. No.	Design	Die Orifice Opening (in.)	Material	Ext. Temp. (°F)	Reduction Ratio (Approx.)	Remarks
1	MC-497-A	.130	M-2(1)	1705	15:1	Extrusion successful; some clad breakthrough
2	MC-497-A	.130	"	1775	"	Extrusion successful
3	MC-497-B	.130	"	1775	"	" "
4	MC-497-C	.130	"	1750	"	" "
5	MC-497-C	.130	"	1750	"	" "
6	MC-497-C	.130	"	1750	"	" "
7	MC-497-C	.130	"	1750	"	" "
8	MC-497-C	.130	"	1710	"	" "
9	MC-497-C	.132	"	1735	"	Extrusion successful; clad breakthrough at the rear
10	MC-497-C	.134	"	1735	"	Stalled
11	MC-497-C	.134	"	1725	"	Extrusion successful
12	MC-497-C	.130	"	1725	"	" "
13	MC-497-C	.138	"	1725	"	" "

(1) Tool Steel

STUDY OF FLOW CHARACTERISTICS

The inspection data to follow shows the comparison of total steel and copper to that of beryllium, but does not show the relation of outside clad thickness to inside thickness, nor does it show clad thickness in the fillet area. In order to complete this information, which is of course necessary to a study of flow characteristics, sections were cut before pickle at the front, middle, and aft positions. These sections are shown in Figure 86 under a magnification of four power. This scale reproduction in coordination with dimensions shown in Section XI will give an accurate appraisal of individual thicknesses and relations. Each section shows that a portion of the steel is actually hanging loose from the beryllium.

This study was a prime requisite to evolution of die design in the experimental extruding.

X ADDITIONAL EXTRUDING REFINEMENTS, PHASES II & III

OBJECTIVES

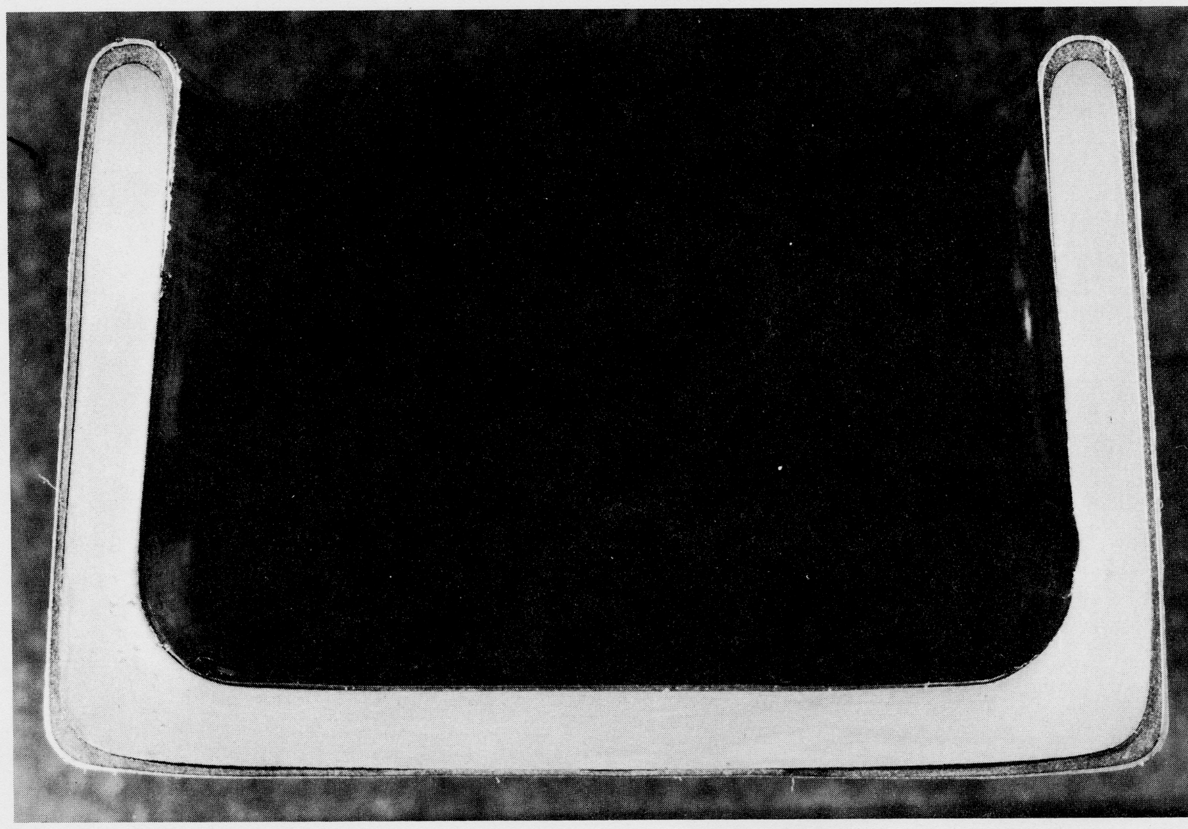
The objectives of Phases II and III were to extrude U-channels with sectional thicknesses of .09 and .06 respectively. During the tenure of the program, it was apparent that many authorities were desirous of observing the differential in mechanical properties for various thicknesses of extrusion. With this in mind it was decided to retain the same channel configuration for Phases II and III and simply reduce the sectional thickness for each. It was anticipated that the difference in flow patterns between different types of extrusions could put a variable into the results that could cloud the comparison.

BILLET PREPARATION

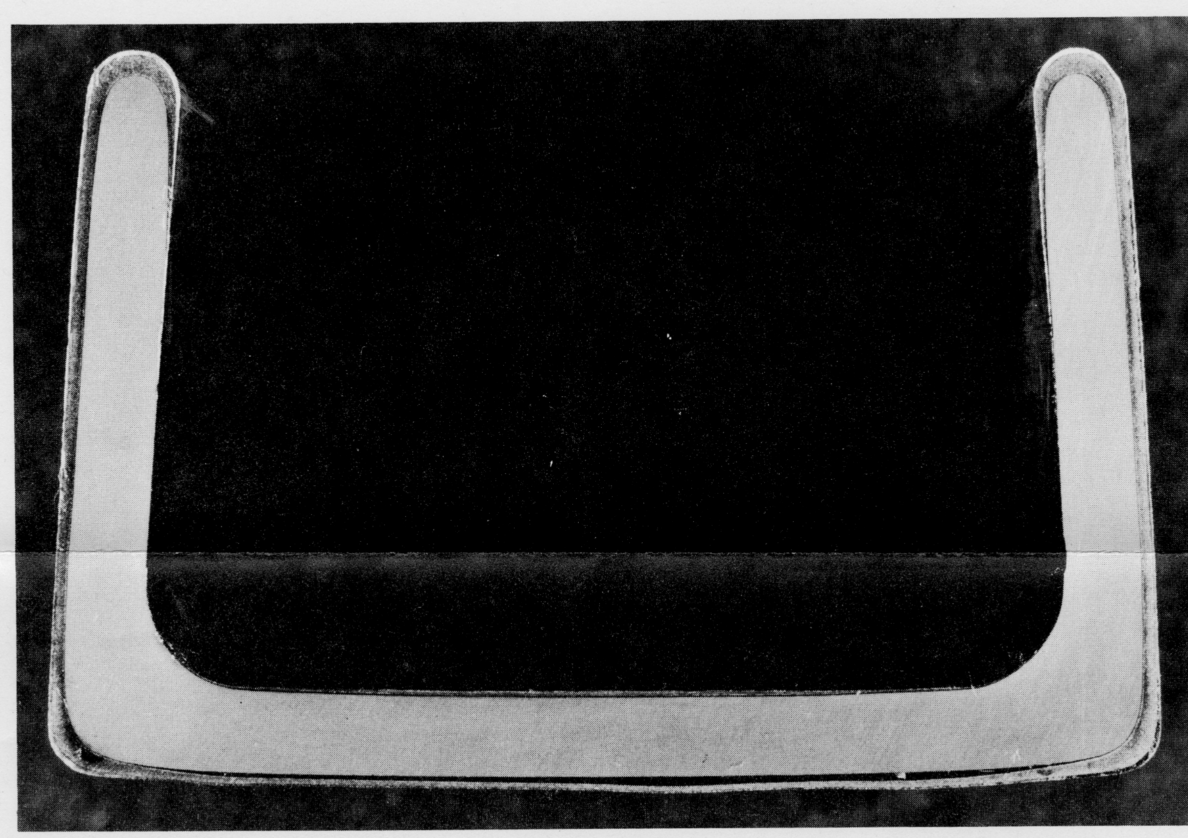
The hot-pressed beryllium core was turned down to about a 32-rms finish and encapsulated in a carbon steel sheath. The steel sheath is a piece of standard size seamless tubing with the ID lightly polished with a fine polishing paper. For the Phase I part of the program, the ID's of the carbon steel sheaths were ground to a 32-rms finish in order to assure an extrusion of high quality surface finish. Later in the program, this procedure was abandoned when it was found to be unnecessary. Wall thickness of the steel sheathing varied from 0.065 inch, used in early extrusions, to 0.115 inch used in most of the extrusions. A 20- to 30-mil copper electroplate was added to the exterior of the steel container on all but the last 10 extrusions. In these extrusions, (Extrusions Numbers 25 through 34) the steel container was placed within a copper container having a 50-mil wall thickness. No attempt was made to seal or evacuate the capsule containing the beryllium core.

A composite lubricant was provided by using a copper plate and a mica slurry (the mica in a liquid carrier was used between the copper plated sheath and the liner wall).

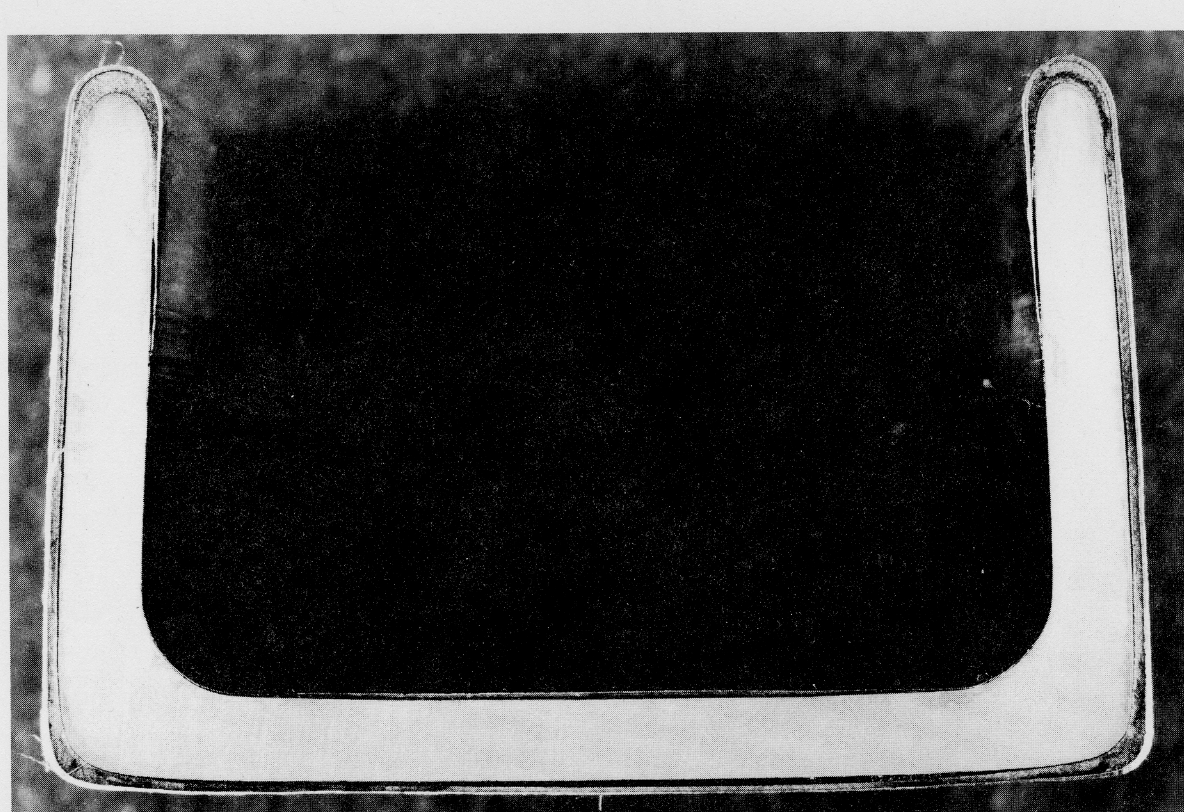
After the successful efforts of Phase I under the composite lube system, the billet for Push Number 18 was prepared without the steel and copper sheathing. This was to recheck glass extrusion with the latest parameters including a conical approach die. The result was totally unsuccessful with rattlesnaking occuring over most of the length.



AFT



CENTER



FRONT

FIGURE 86 CROSS-SECTIONAL VIEWS OF REPRESENTATIVE BERYLLIUM EXTRUSION, 4X MAGNIFICATION.

DIE DESIGN

As shown in the Phase I pilot production effort the basic die design utilizes a conical approach into the die orifice for the smoother, more streamlined flow which is desirable for this composite lubricant technique. The die was also designed to be internal or semi-internal. With the cooperation of the Duplicast Corporation, (who also cast the dies) and Moczik Tool and Die Company, both located in Detroit, many design modifications were made to determine the optimum die design for the desired metal flow conditions. Figure 87 is a photograph of four dies used during this extrusion development program. Close examination of these dies reveals the different die orifices, approach angles, lip extensions and surface contours which were tried. The die labeled "A" in Figure 87 is the design satisfying the requirements imposed by the extrusion shape.

An interesting technique for generating different die designs which would ordinarily be difficult to achieve by machining operations was developed during this program and is worthy of mention. The desire to achieve good metal flow conditions with a suitable die design and the limitations in maching contours in the conical approach to the die orifice led to sculpturing die prototypes in wax. This technique allowed unlimited flexibility in the design of contour shapes. Once the desired contour was attained, a permanent master pattern was made from the wax prototype. A die made by this technique is shown in Figure 87, (die design MC-497-K). Figure 88 is a cutaway of the MC-497-K type die (a rubber duplicate of "D" in Figure 87), showing the pertinent features (arrows). To machine these features into the die would have been extremely difficult since some of the surfaces are continuously changing curves.

Figures 89 and 90 show the die design used to extrude the Phase II 0.09 inch thick shape and Figures 91, 92 and 93 are for the Phase III 0.06 inch thick channel section. Of particular interest is Figure 92 which shows what is termed a "wing type die". It is designed to encourage flow to the inside of the channel which is very critical. The bolster used with the wing die is of special design to "iron out" the obtuse angle on each leg.

SUPPORT TOOLING

The track type straightener shown in Figure 81, which was beneficially used in Phase I, was redesigned and fabricated to incorporate compression springs between each of the foot long transite segments. The segments are bolt mounted to slotted holes in the base to allow the straightener to contract with the extrusion during cooling. The benefits of this apparatus are graphically shown by comparing the extrusion shown in Figure 94 which was pushed without a straightener with those extrusions of Figure 95 which did utilize the straightener.

EXTRUDING EFFORTS

Using the same basic technology which successfully consumated Phase I, dies were redesigned to accommodate the Phase II shape and experimental pushes were made. In order to achieve the desired development in the shortest time possible experimental pushes for both Phases II and III were made interchangeably. In order to do this ten billets were utilized to work out the

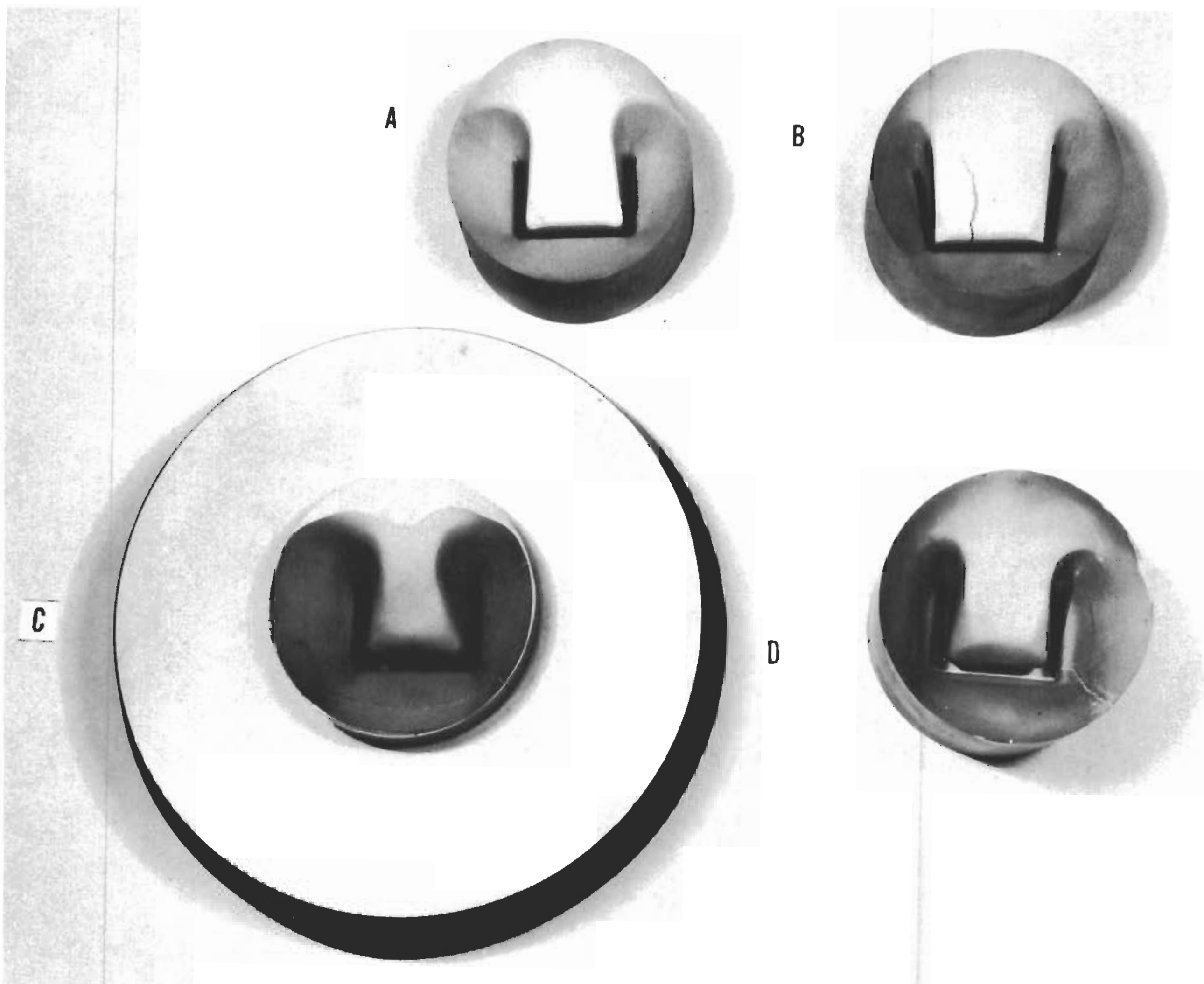
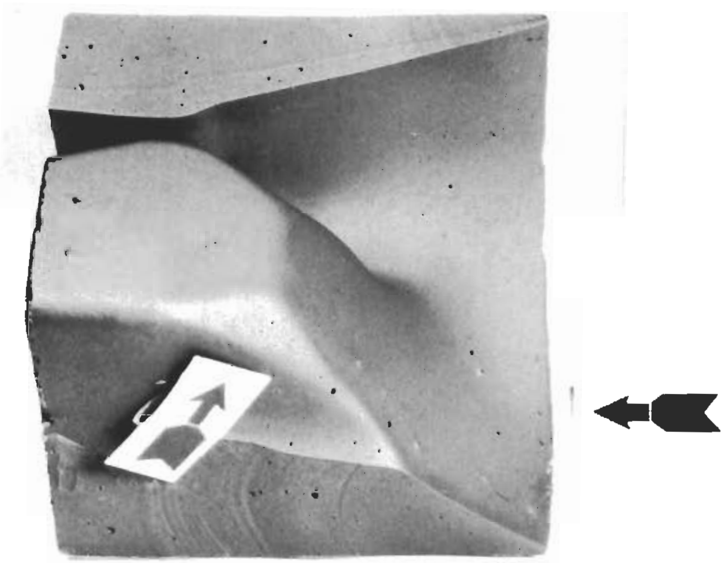
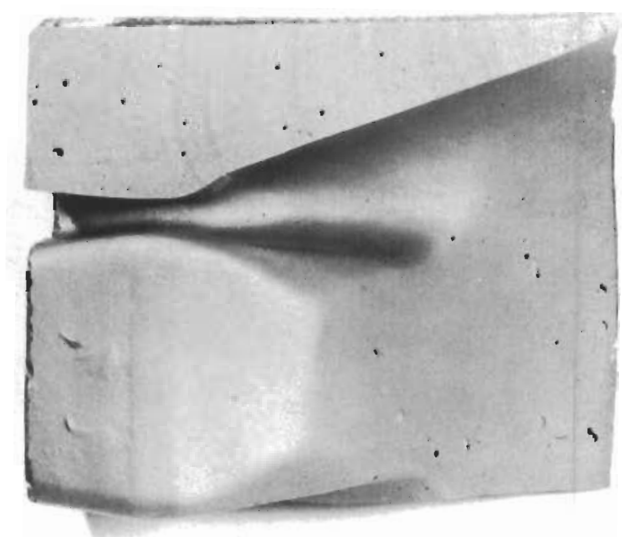


FIGURE 87 Die design modifications used during this program.

" A " was the finalized die used.
" B ", MC-497-L, was designed to improve the flow of lubrication into the inside cover radius.
" C " is a semi-internal die (design MC-497-B) shrunk into an external die holder.
" D " is the result of the sculptured wax technique (design MC-497-K).



a.



b.

FIGURE 88 Cutaways of the MC-497-K type die (the die in this photograph is made of rubber) showing the pertinent features.

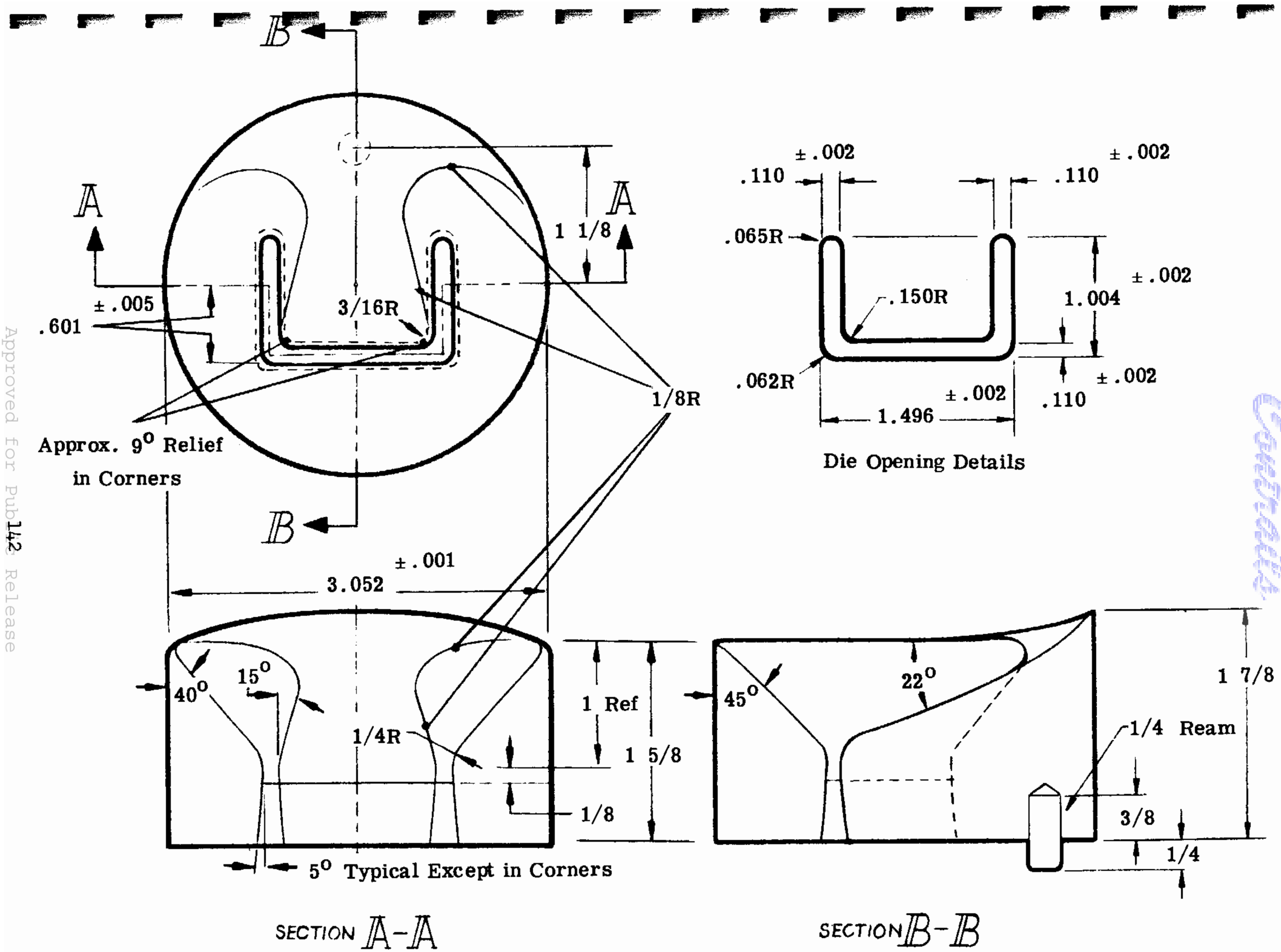


FIGURE 89 DIE DESIGN NO. MC-497-E

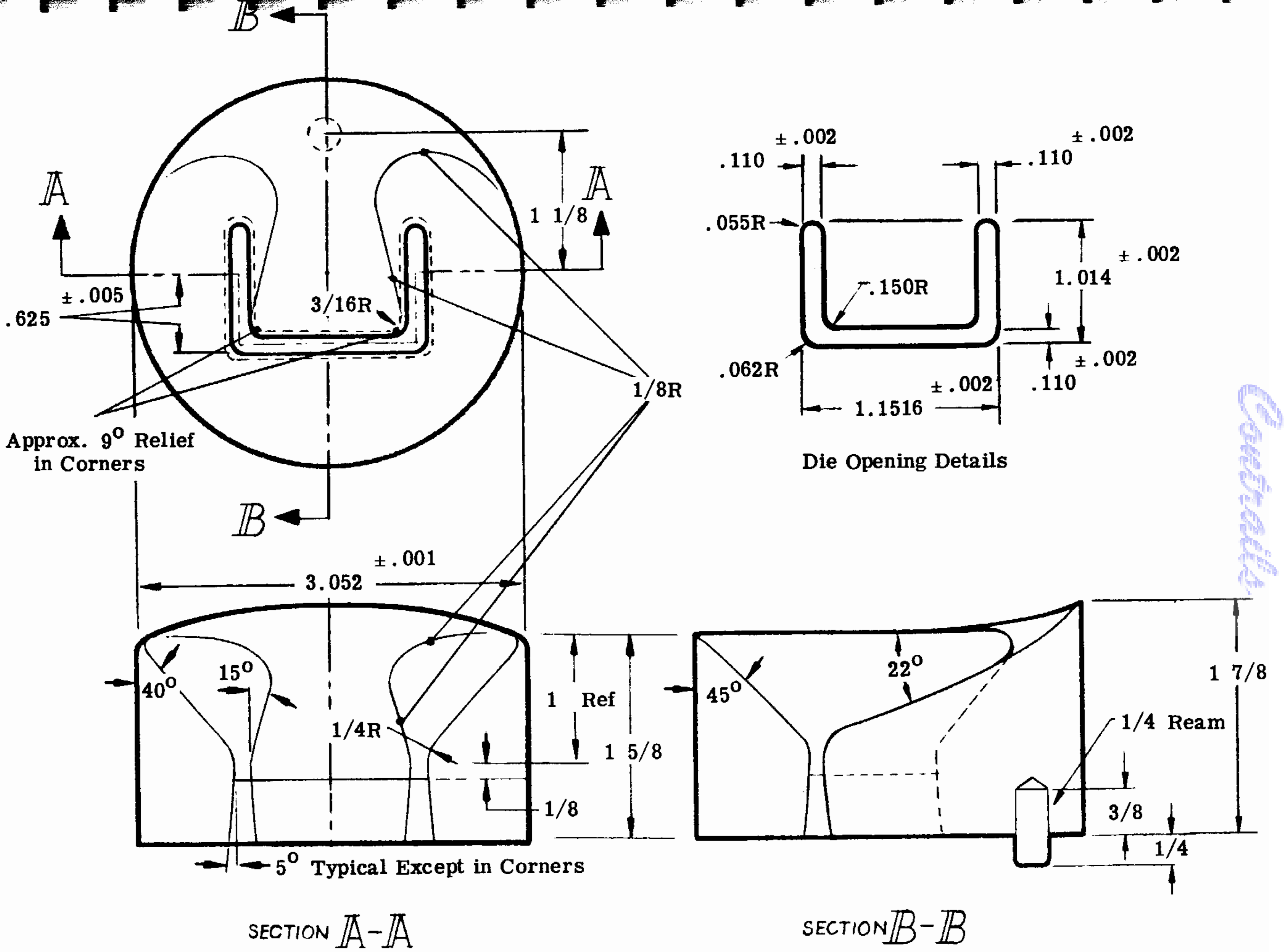


FIGURE 90 DIE DESIGN NO. MC-497-I

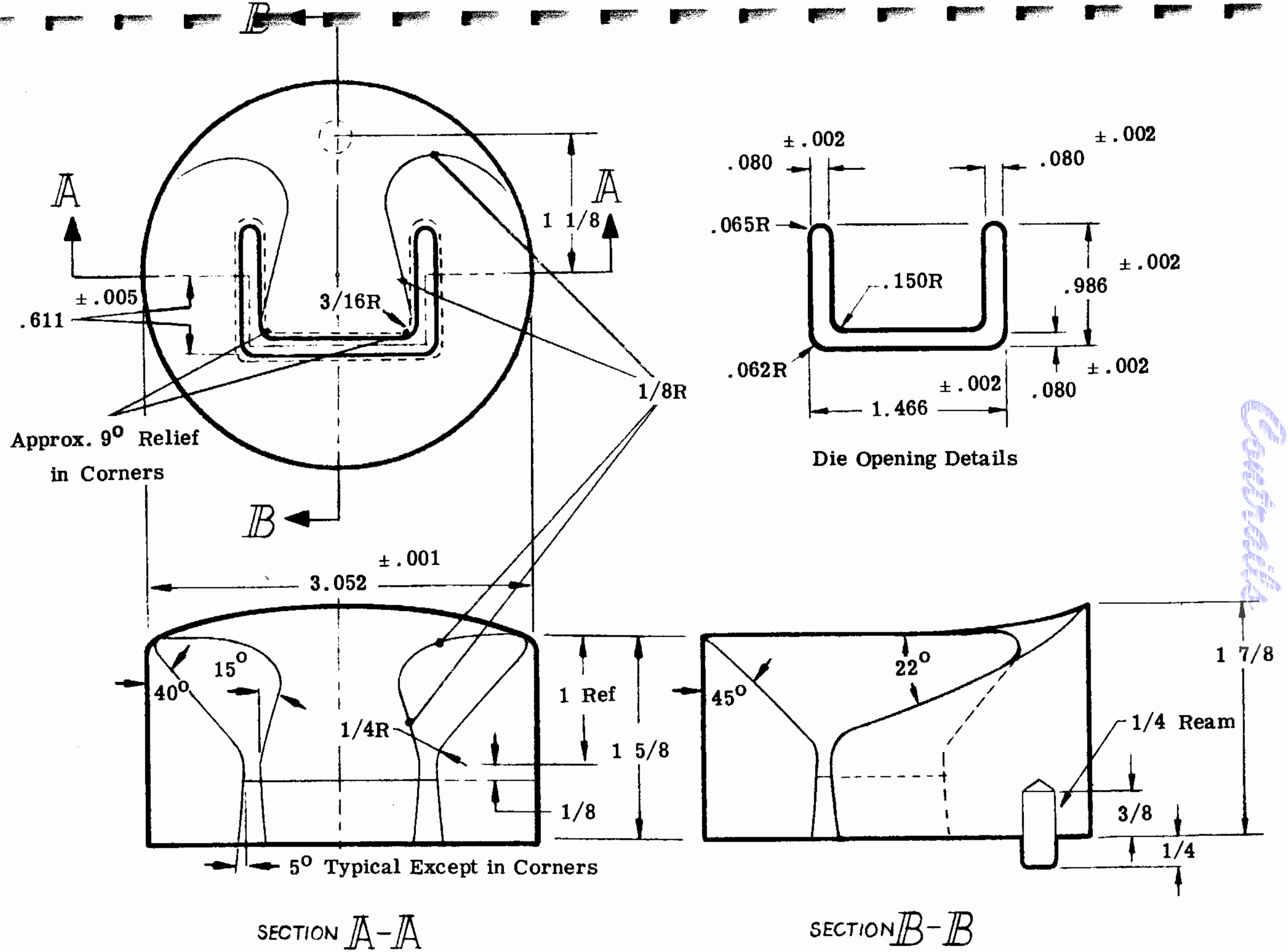


FIGURE 91 DIE DESIGN NO. MC-497-F

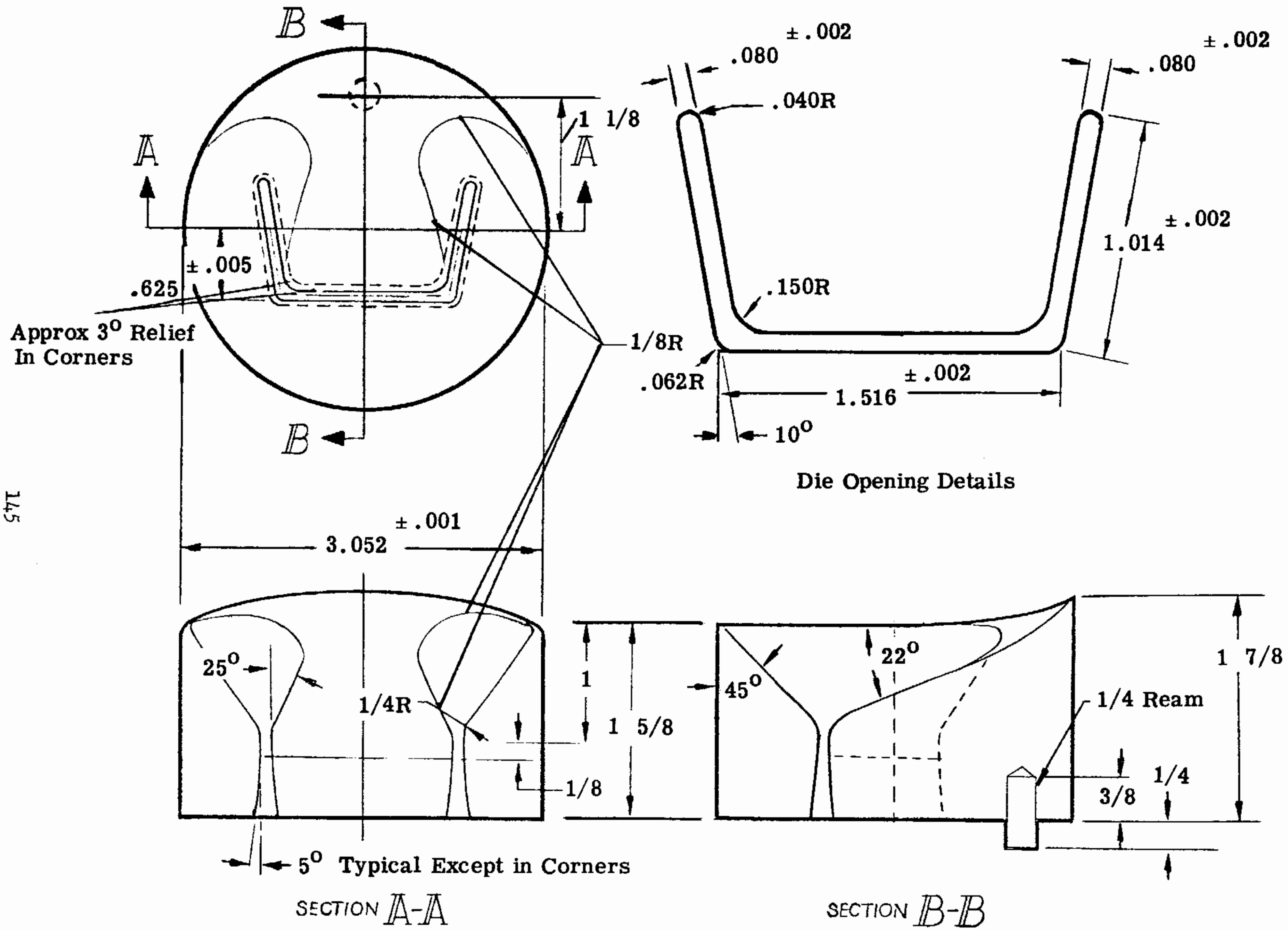


FIGURE 92 DIE DESIGN NO. MC-497-H

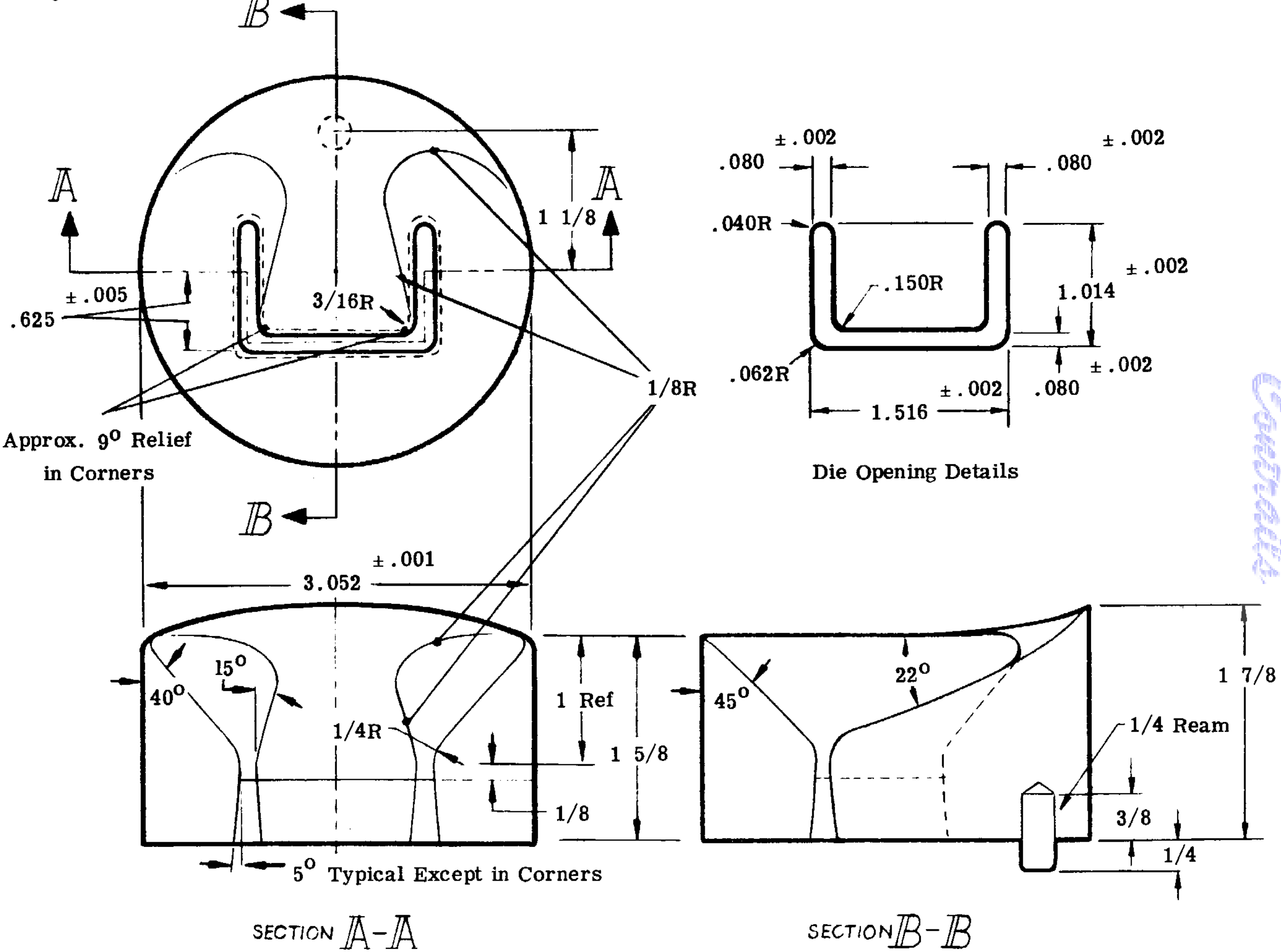


FIGURE 93 DIE DESIGN NO. MC-497-J

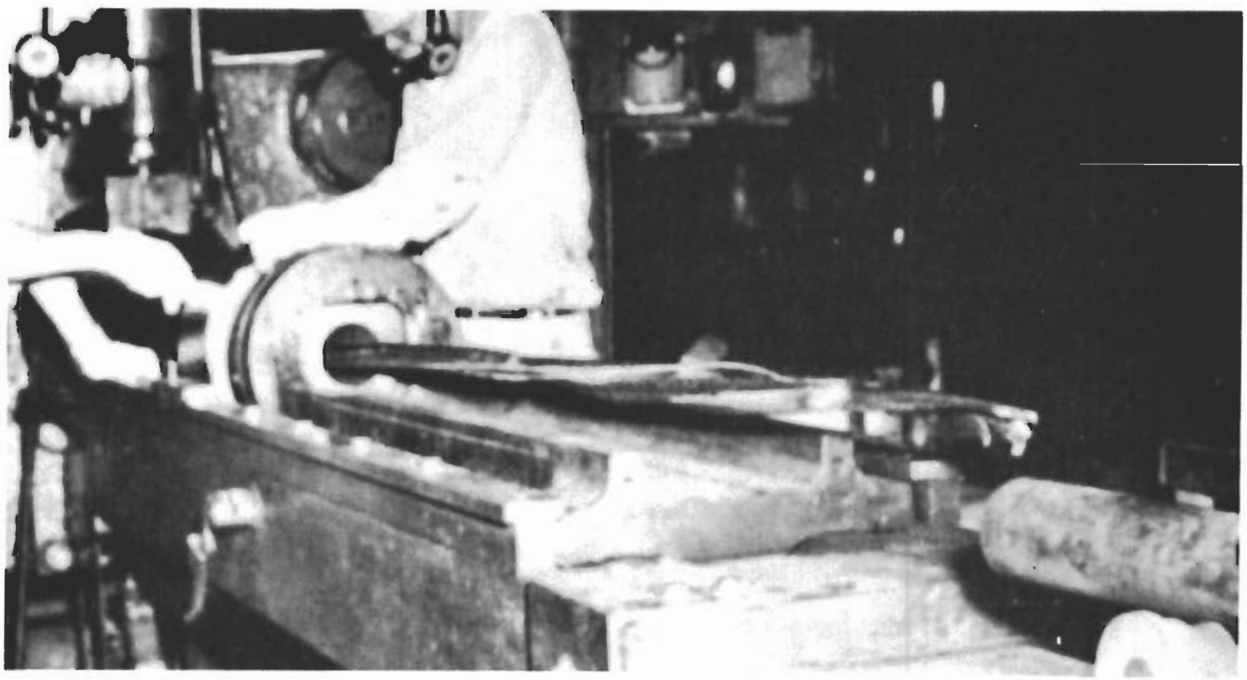


FIGURE 94 TWISTED, TORN, AND RATTLESNAKED BERYLLIUM EXTRUSION MADE WITHOUT STRAIGHTENER.

FIGURE 95 Photograph showing the Beryllium U-channels produced by the clad technique in Phases I, II, and III of this program for the development of extruded Beryllium shapes.

design and extruding parameters necessary to proceed with pilot production. During several of the extruding operations, there was a minor amount of clad breakthrough in the fillet areas. However, it was not sufficient to be injurious to the beryllium core. Summary details of the series of efforts are shown in Table XI. Complete detail data is compiled in Appendix VII under extrusion Numbers 15 through 34.

Of particular interest from the die design standpoint are pushes Number 19, 21, 22, and 23 which utilized the so called wing die, whereby the billet was extruded through the die with the legs flared open to encourage flow to the inside of the channel. The accompanying bolster was made to straighten the legs back up to a vertical position. Results were very promising, but not totally satisfactory due to the tendency for the deformation to be non-uniform. Rather than take the time to further develop the bolster design, it was decided to revert to the previous type of design for pilot production.

The redesigned track straightener worked very satisfactorily. See Figure 95 which shows the pilot production extrusions for all three phases. None of the sections in Figure 95 have had any supplementary straightening operations. The benefits are apparent when compared with Figure 94 which was pushed without a straightener.

See sections XI and XII for evaluation of dimensional inspection and mechanical tests respectively.

FILLET RADII STUDY

The sharpest inside corner radius extruded was 0.030 inch (Extrusion Nos. 22 and 23). The appearance of the inside corner radii may be compared in Figure 96 which shows the cross-sectional areas of two as extruded extrusions (the front sections of Numbers 12 and 23). The photograph at the top shows extrusion number 12 with the 0.120 inch inside corner radius. The bottom shows extrusion number 23 with the 0.03 inch corner radius.

XI DIMENSIONAL INSPECTION OF PILOT PRODUCTION EXTRUSION, PHASES I, II & III

Complete dimensional inspection was made on each extrusion, both before and after pickle over the full 20 feet of length. In this manner, the clad thickness in various segments of the cross section could be compared and its increase or decrease over the length compared with the increase or decrease of the beryllium sections. This study in combination with that shown under the sub-section entitled "Study of Flow Characteristics" is essential in conversion of design parameters to that of other shape variations. Figures 97 through 111 show the results of this inspection at front, center and aft sections of 5 extrusions from each of Phases I, II and III.

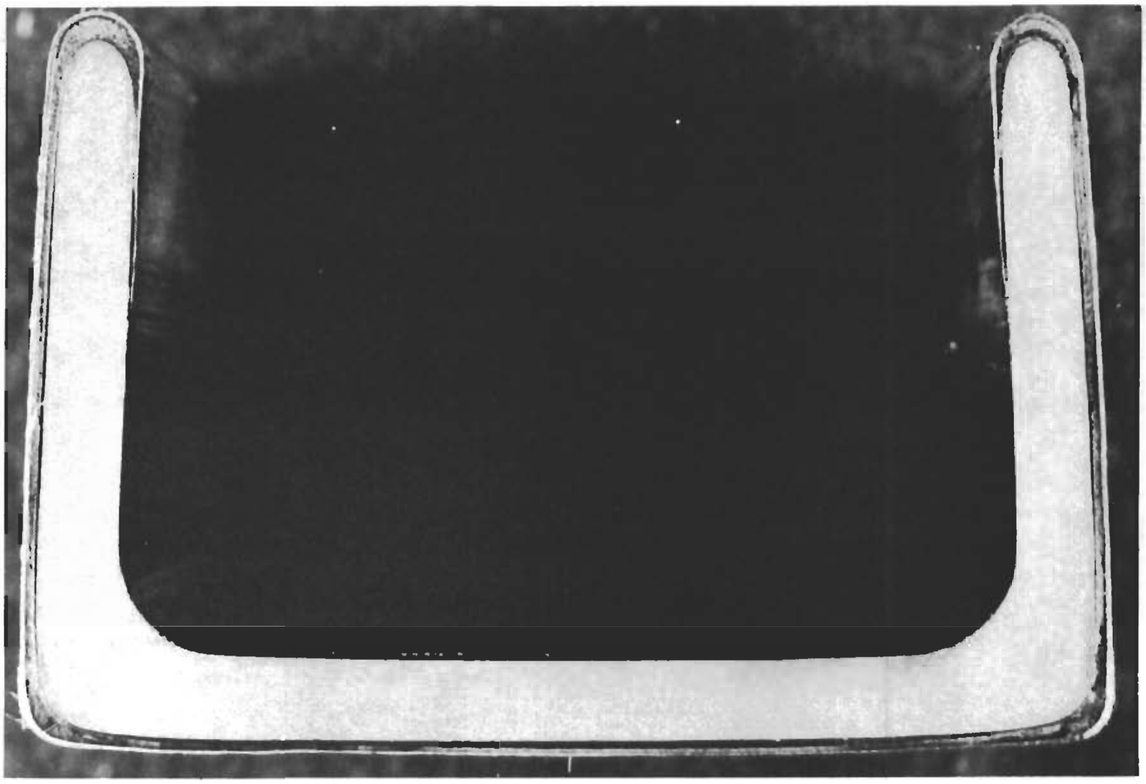
Table XII shows a composite in tabular form of the pilot production shapes to study their dimensional consistency not only over each length, but also from part to part. Included is the range of minima and maxima both over the lengths and from part to part.

Extrusion 13 is shown to be the most consistent shape particularly from the all important standpoint of leg thickness. Both the LH and RH legs varied only a total of 0.001 inch over the entire 20 feet of length. The largest

TABLE XI
Summary of Phases II & III
Composite Lubricant Extrusion Data

Ext. No.	Design	Die Orifice Opening (in.)	Material	Ext. Temp. (°F)	Reduction Ratio (approx.)	Remarks
14	------	------	------	------	------	Cancelled
15	MC-497-E	.116	EDS[2]	1805	21:1	Extrusion successful; some clad breakthrough
16	MC-497-F	.086	EDS	1810	25:1	" " " " "
17	MC-497-F	.075	EDS	1855	30:1	" " " " "
18	MC-497-G	.090	M-2[1]	1730	25:1	Glass-lubricated bare Be ext.; rattlesnaking entire length
19	MC-497-H	.080	EDS	1710	29:1	Extrusion successful
20	MC-497-K	.120	M-2	1775	17:1	" "
21	MC-497-H	.080	EDS	1760	29:1	" "
22	MC-497-L	.080	EDS	1845	29:1	Extrusion successful; clad breakthrough; rippling of one leg
23	MC-497-L	.079	M-2	1845	29:1	Extrusion successful; clad breakthrough
24	MC-497-I	.110	EDS	1715	23:1	" " " "
25	MC-497-I	.110	EDS	1800	23:1	" " " "
26	MC-497-I	.110	EDS	1735	23:1	" " " "
27	MC-497-I	.110	EDS	1800	23:1	" " " "
28	MC-497-I	.110	EDS	1790	23:1	" " " "
29	MC-497-J	.080	EDS	1800	29:1	Stalled
30	MC-497-J	.080	EDS	1825	29:1	Extrusion successful; clad breakthrough
31	MC-497-J	.080	EDS	1835	29:1	" " " "
32	MC-497-J	.080	EDS	1850	29:1	" " " "
33	MC-497-J	.080	EDS	1835	29:1	" " " "
34	MC-497-J	.080	EDS	1875	29:1	" " " "

(1) Tool Steel
(2) Stellite



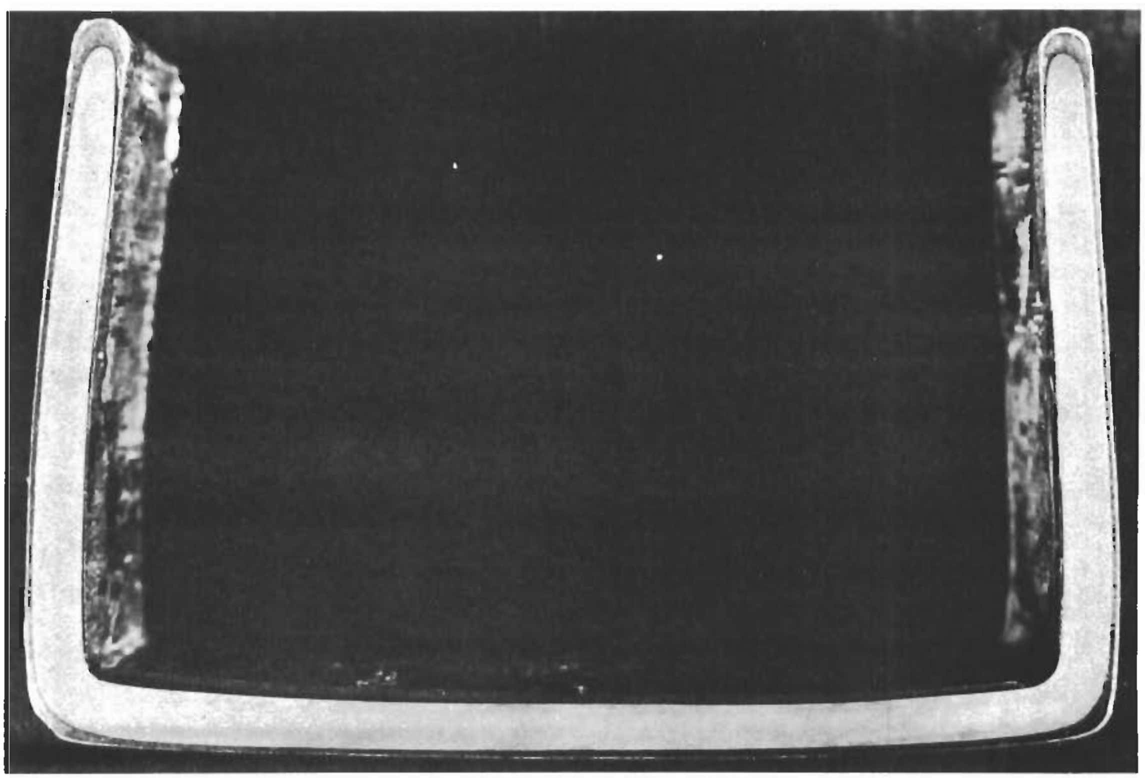
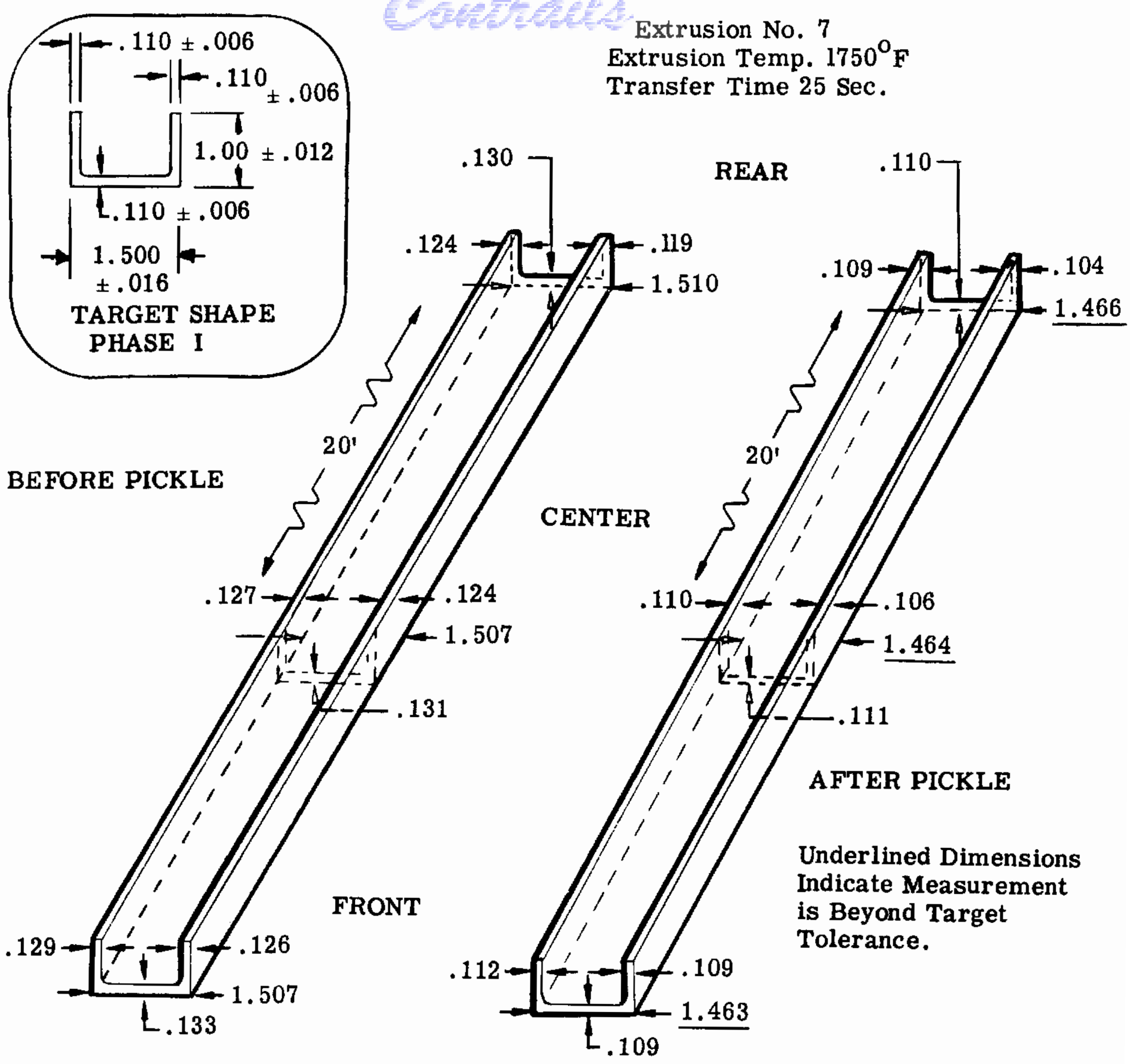


FIGURE 96 Cross-sectional areas of two extrusions (Ext. Nos. 12 above and 23 below) showing the 0.120" and 0.030" inside corner radii extruded during this program.

Extrusion No. 7
Extrusion Temp. 1750°F
Transfer Time 25 Sec.



LEG HEIGHT BEFORE PICKLE

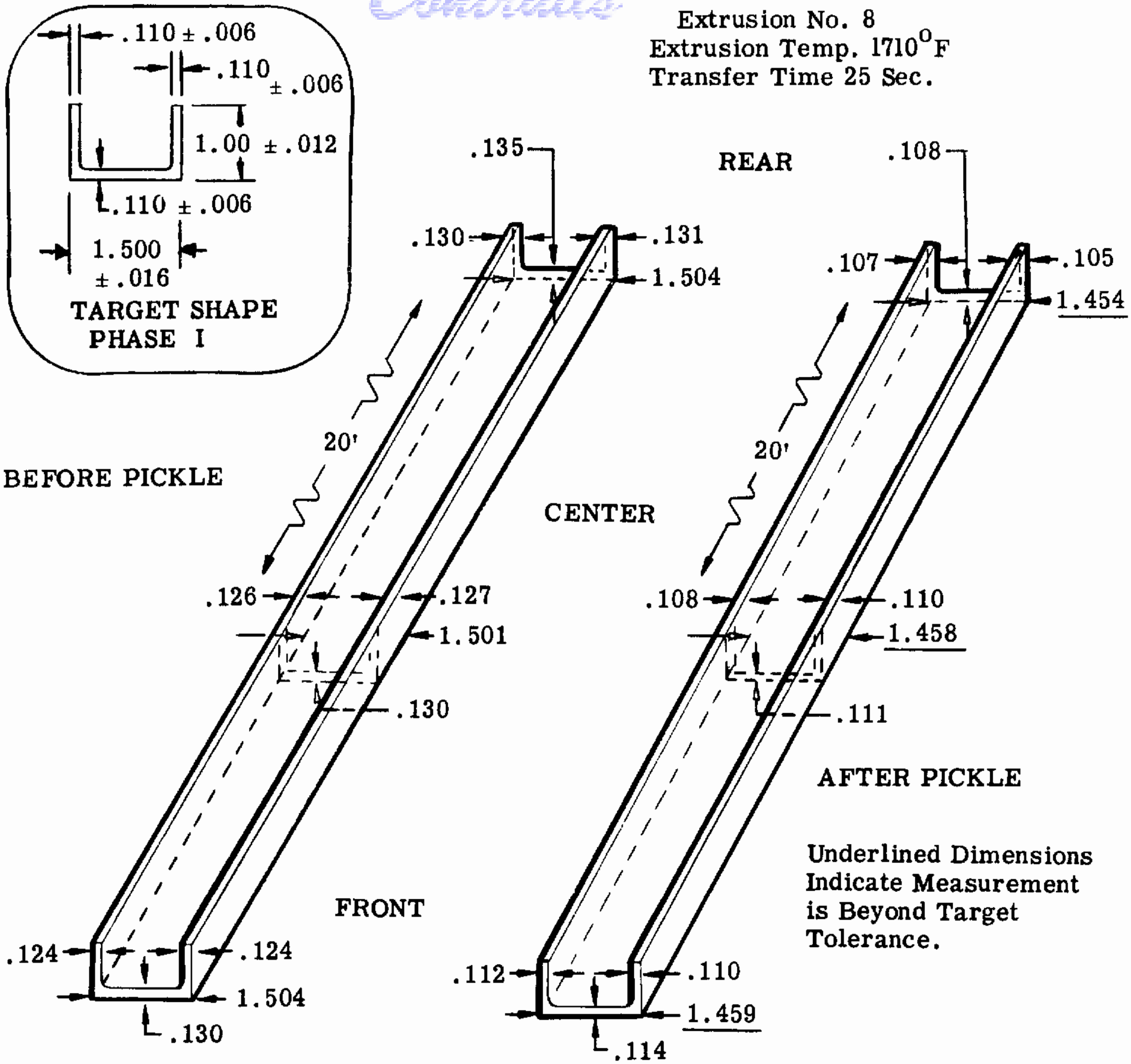
	LEFT	RIGHT
FRONT	—	1.009
CENTER	—	1.010
REAR	—	1.009

LEG HEIGHT AFTER PICKLE

	LEFT	RIGHT
FRONT	—	.950
CENTER	—	.949
REAR	—	.949

PHASE I

FIGURE 97 BERYLLIUM EXTRUSION INSPECTION DATA.



LEG HEIGHT BEFORE PICKLE

	LEFT	RIGHT
FRONT	—	.999
CENTER	—	.999
REAR	—	1.005

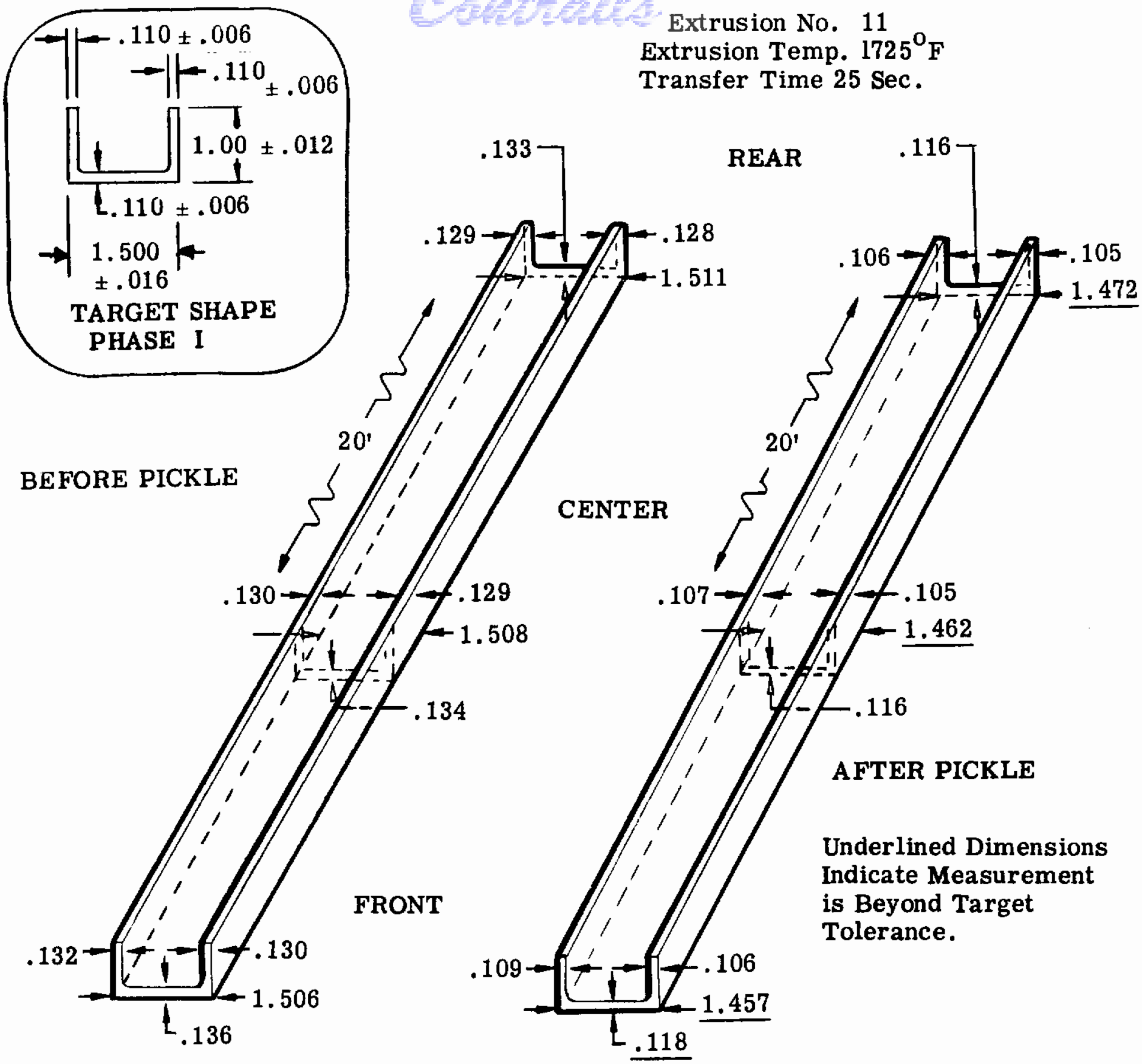
LEG HEIGHT AFTER PICKLE

	LEFT	RIGHT
FRONT	—	.950
CENTER	—	.949
REAR	—	.9525

PHASE I

FIGURE 98 BERYLLIUM EXTRUSION INSPECTION DATA.

Extrusion No. 11
Extrusion Temp. 1725°F
Transfer Time 25 Sec.



LEG HEIGHT BEFORE PICKLE

	LEFT	RIGHT
FRONT	1.013	1.006
CENTER	1.012	1.005
REAR	1.011	1.008

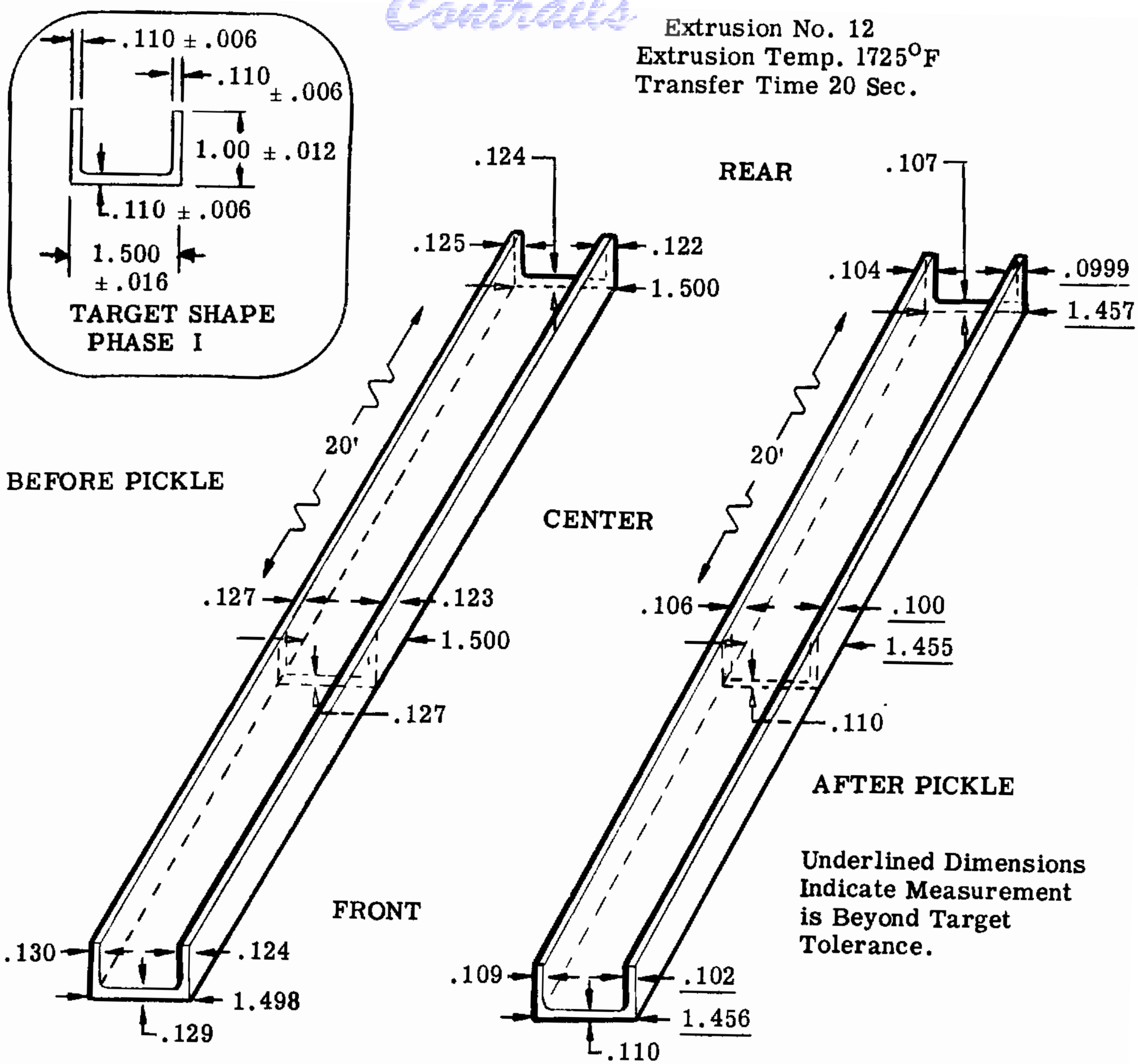
LEG HEIGHT AFTER PICKLE

	LEFT	RIGHT
FRONT	.952	.947
CENTER	.955	.949
REAR	.956	——

PHASE I

FIGURE 99 BERYLLIUM EXTRUSION INSPECTION DATA.

Extrusion No. 12
Extrusion Temp. 1725°F
Transfer Time 20 Sec.



LEG HEIGHT BEFORE PICKLE

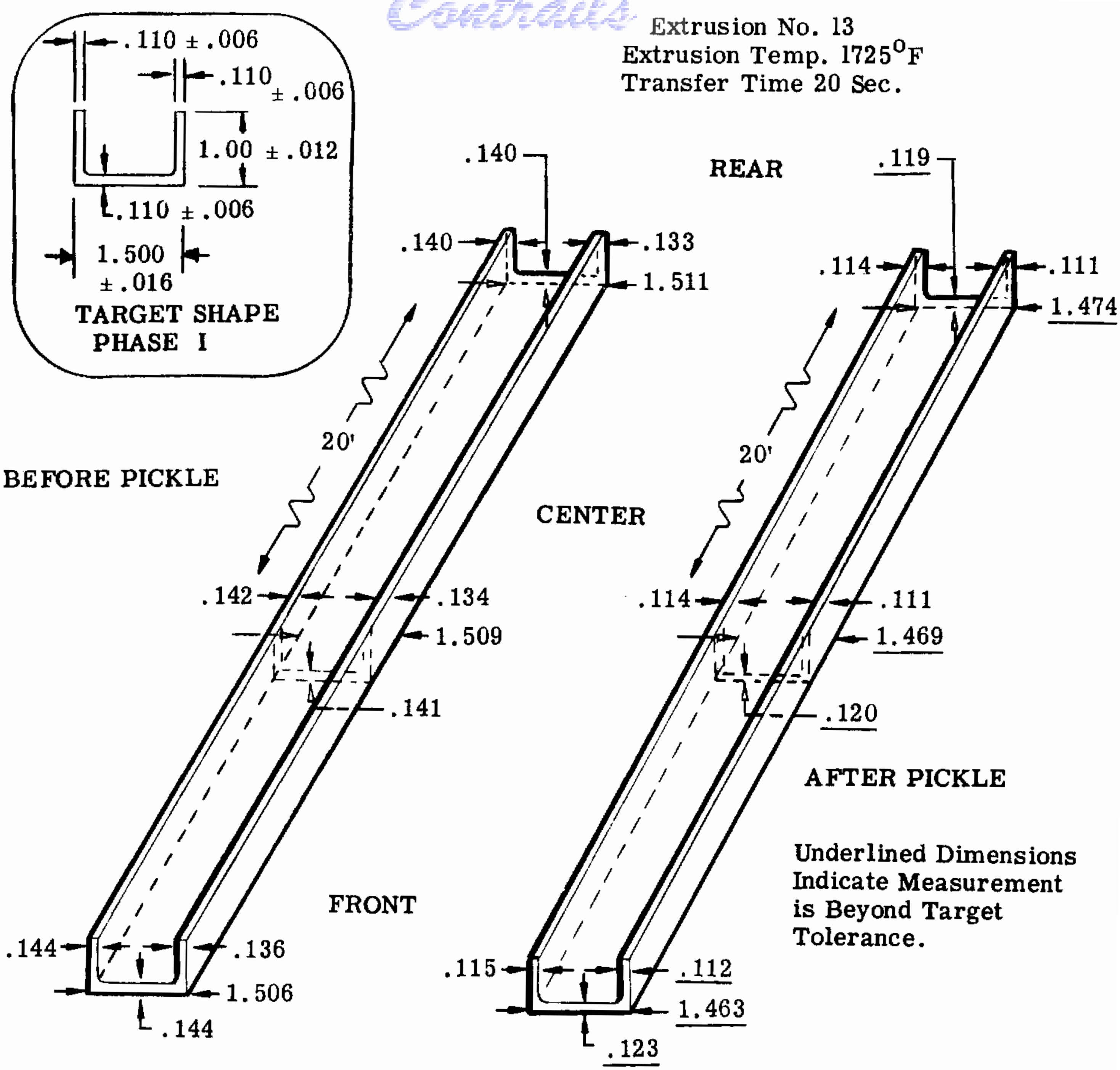
	LEFT	RIGHT
FRONT	1.002	.998
CENTER	1.000	1.001
REAR	1.000	1.000

LEG HEIGHT AFTER PICKLE

	LEFT	RIGHT
FRONT	.947	.942
CENTER	.949	.948
REAR	.952	.951

PHASE I

FIGURE 100 BERYLLIUM EXTRUSION INSPECTION DATA.



LEG HEIGHT BEFORE PICKLE

	LEFT	RIGHT
FRONT	1.019	1.008
CENTER	1.017	1.014
REAR	1.017	1.013

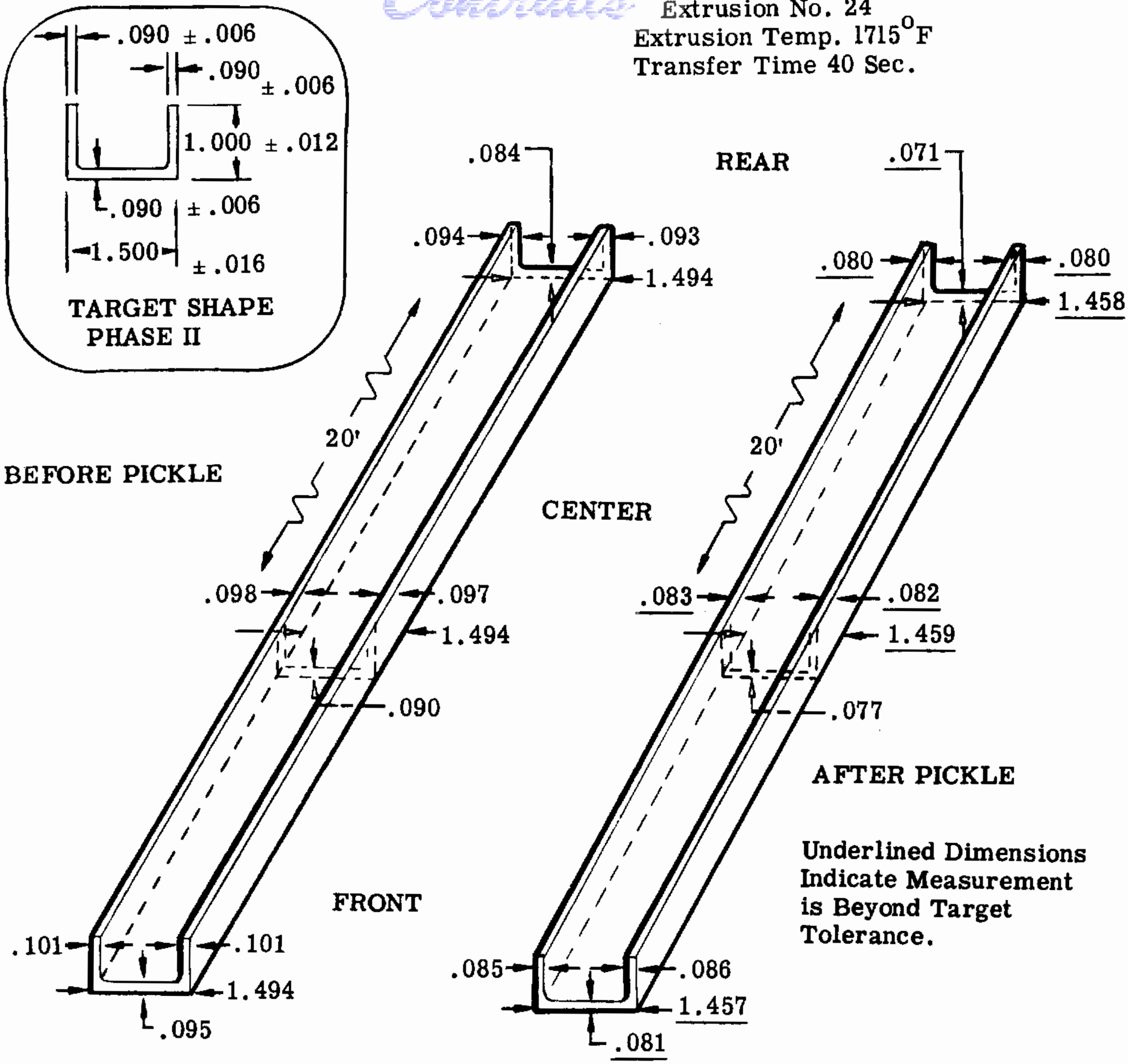
LEG HEIGHT AFTER PICKLE

	LEFT	RIGHT
FRONT	.960	.948
CENTER	.965	.953
REAR	.964	.956

PHASE I

FIGURE 101 BERYLLIUM EXTRUSION INSPECTION DATA.

Extrusion No. 24
Extrusion Temp. 1715°F
Transfer Time 40 Sec.



LEG HEIGHT BEFORE PICKLE

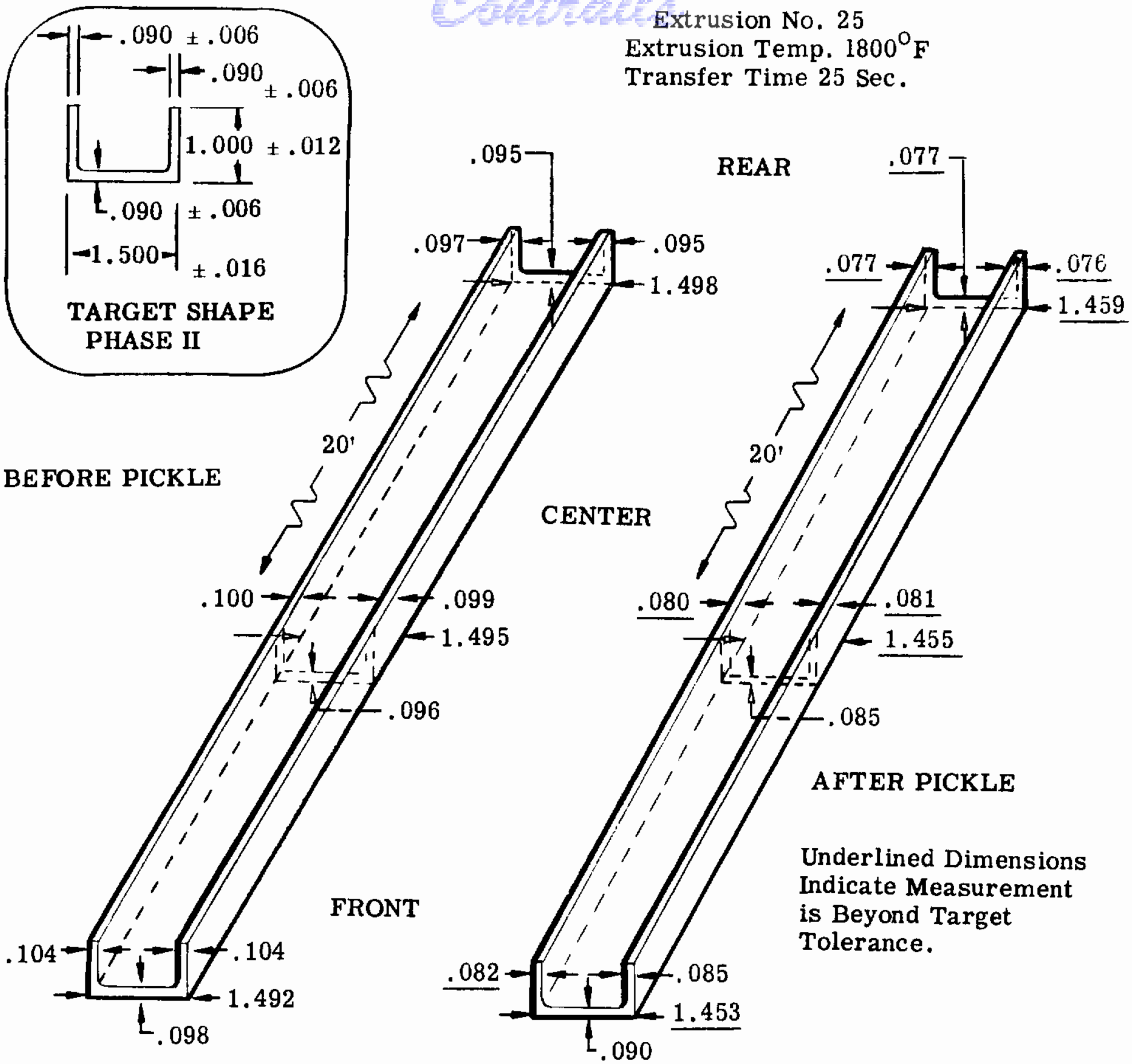
	LEFT	RIGHT
FRONT	——	1.000
CENTER	——	.997
REAR	——	.995

LEG HEIGHT AFTER PICKLE

	LEFT	RIGHT
FRONT	——	.945
CENTER	——	.945
REAR	——	.946

PHASE II

FIGURE 102 BERYLLIUM EXTRUSION INSPECTION DATA.



LEG HEIGHT BEFORE PICKLE

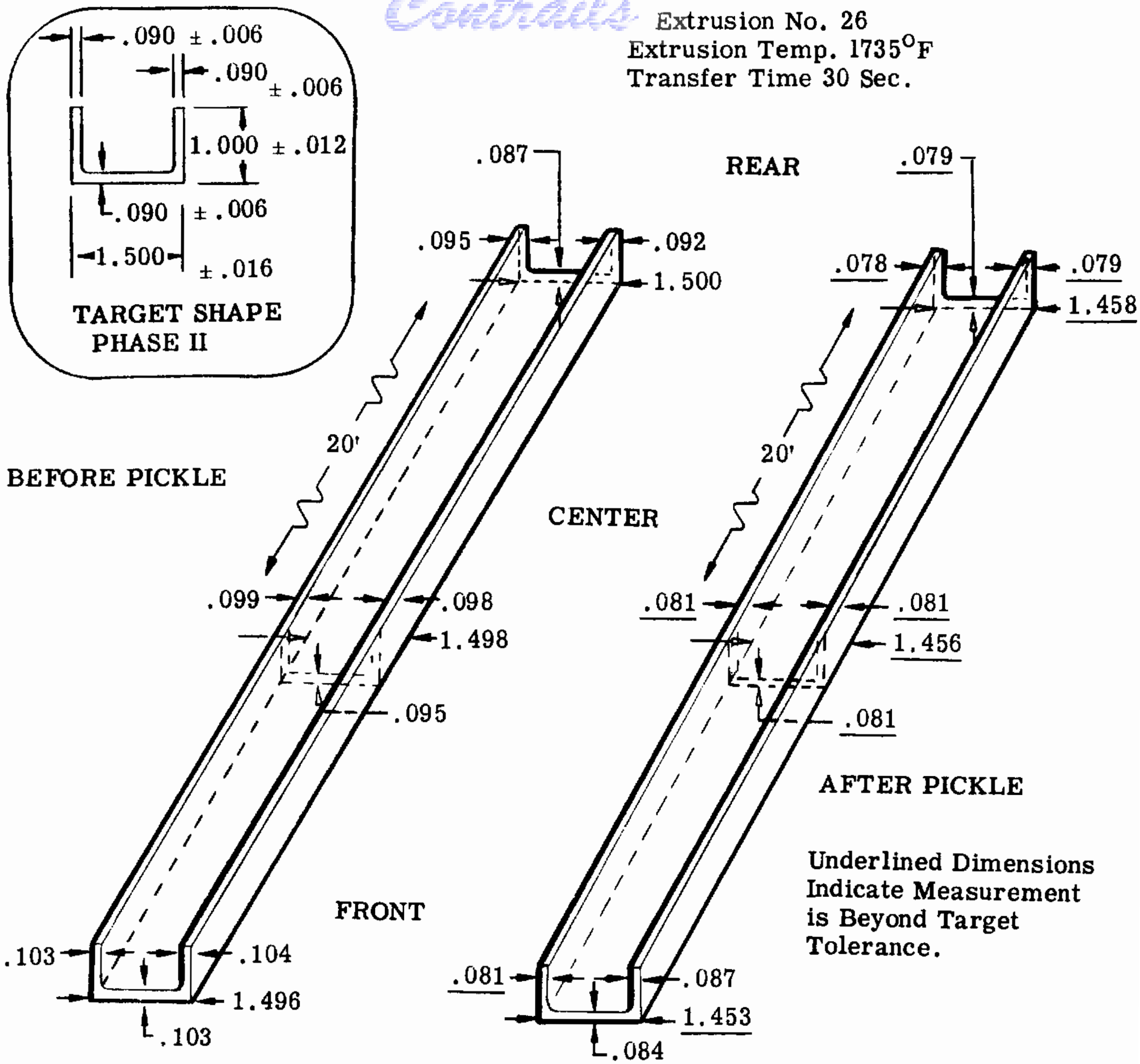
	LEFT	RIGHT
FRONT	—	1.005
CENTER	—	1.001
REAR	—	.997

LEG HEIGHT AFTER PICKLE

	LEFT	RIGHT
FRONT	—	.944
CENTER	—	.944
REAR	—	.944

PHASE II

FIGURE 103 BERYLLIUM EXTRUSION INSPECTION DATA.



LEG HEIGHT BEFORE PICKLE

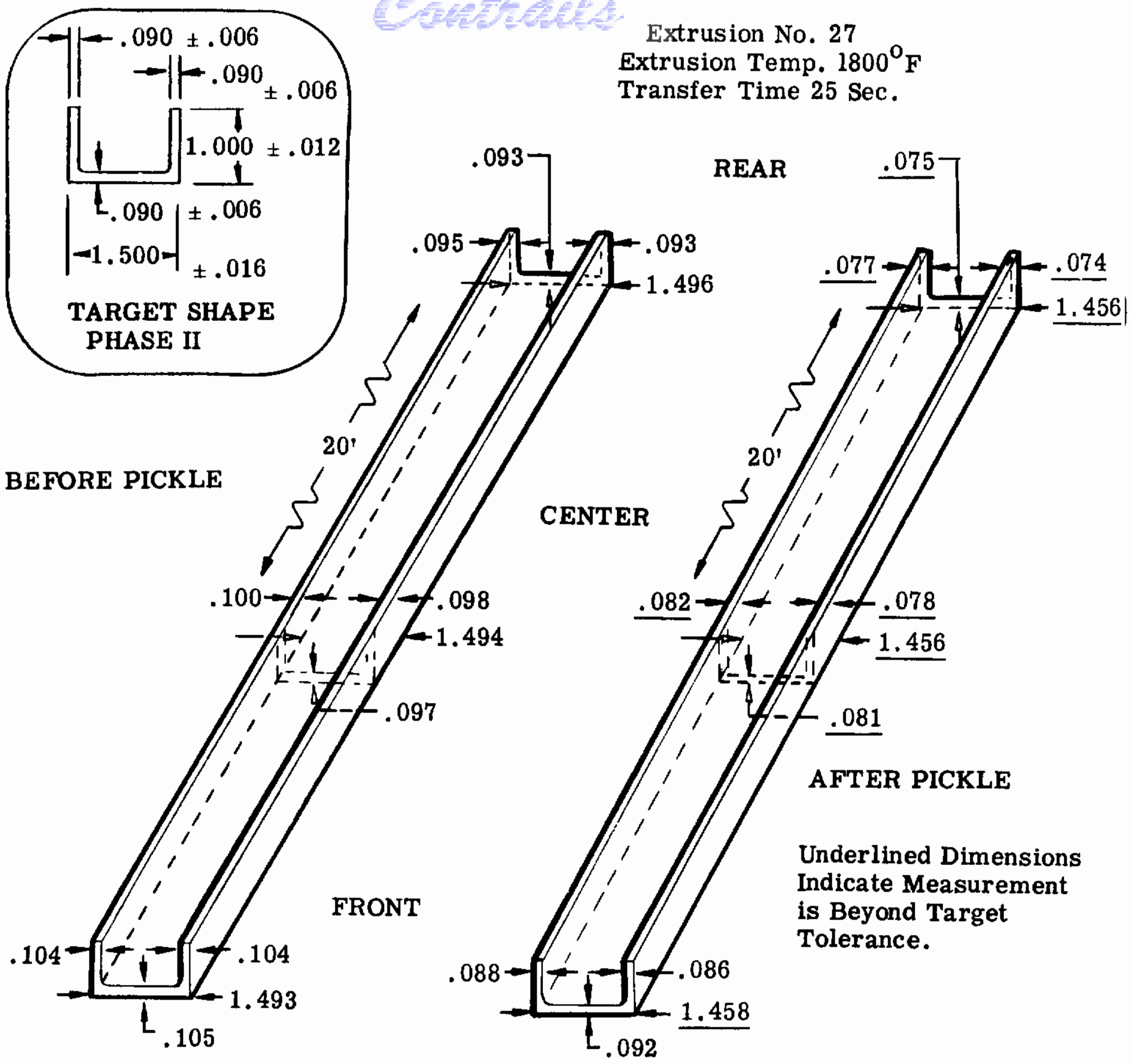
	LEFT	RIGHT
FRONT	——	1.001
CENTER	——	.997
REAR	——	.993

LEG HEIGHT AFTER PICKLE

	LEFT	RIGHT
FRONT	——	.944
CENTER	——	.949
REAR	——	.950

PHASE II

FIGURE 104 BERYLLIUM EXTRUSION INSPECTION DATA.



LEG HEIGHT BEFORE PICKLE

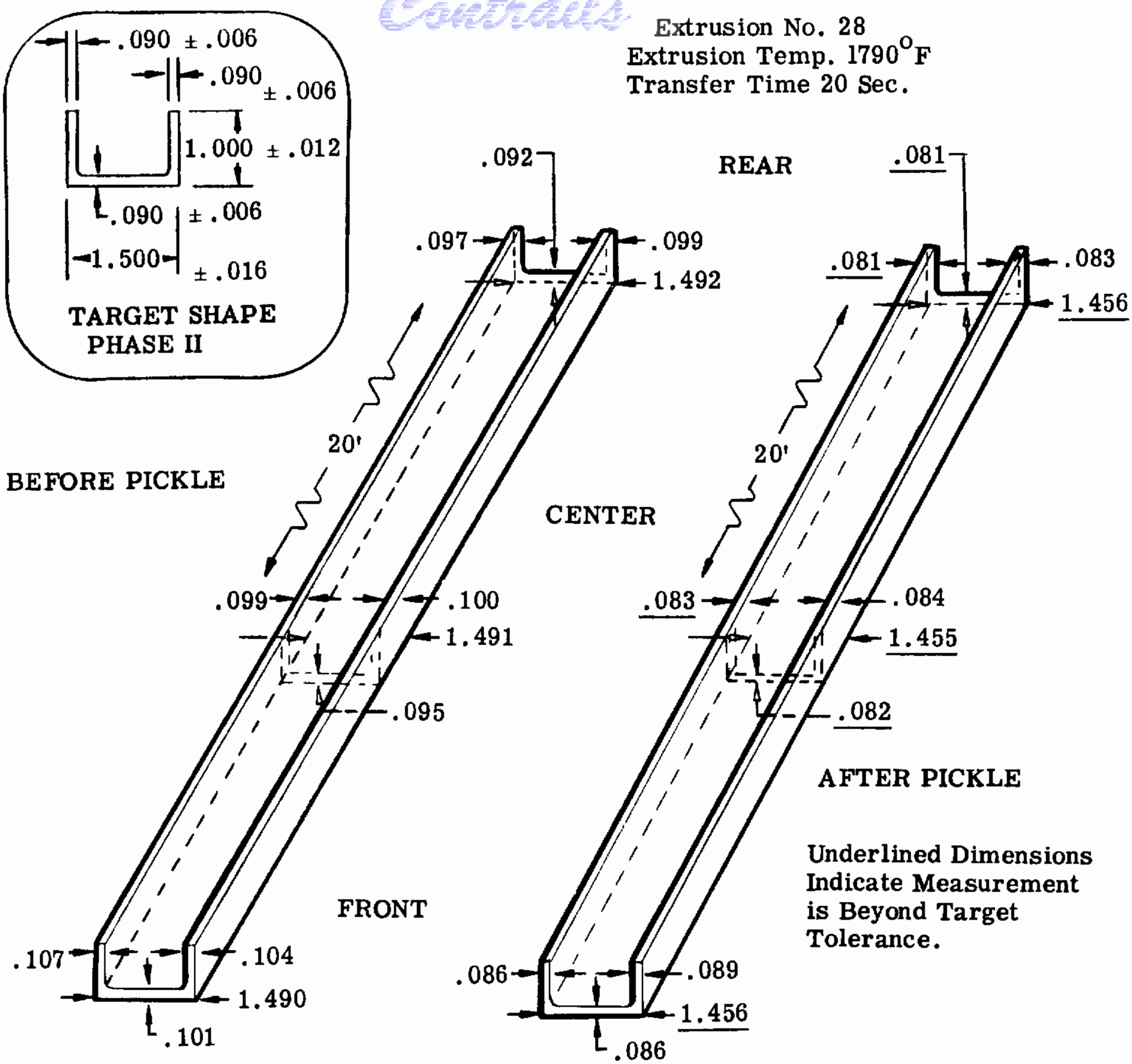
	LEFT	RIGHT
FRONT	—	.996
CENTER	—	.993
REAR	—	.990

LEG HEIGHT AFTER PICKLE

	LEFT	RIGHT
FRONT	—	.948
CENTER	—	.948
REAR	—	.939

PHASE II

FIGURE 105 BERYLLIUM EXTRUSION INSPECTION DATA.



LEG HEIGHT BEFORE PICKLE

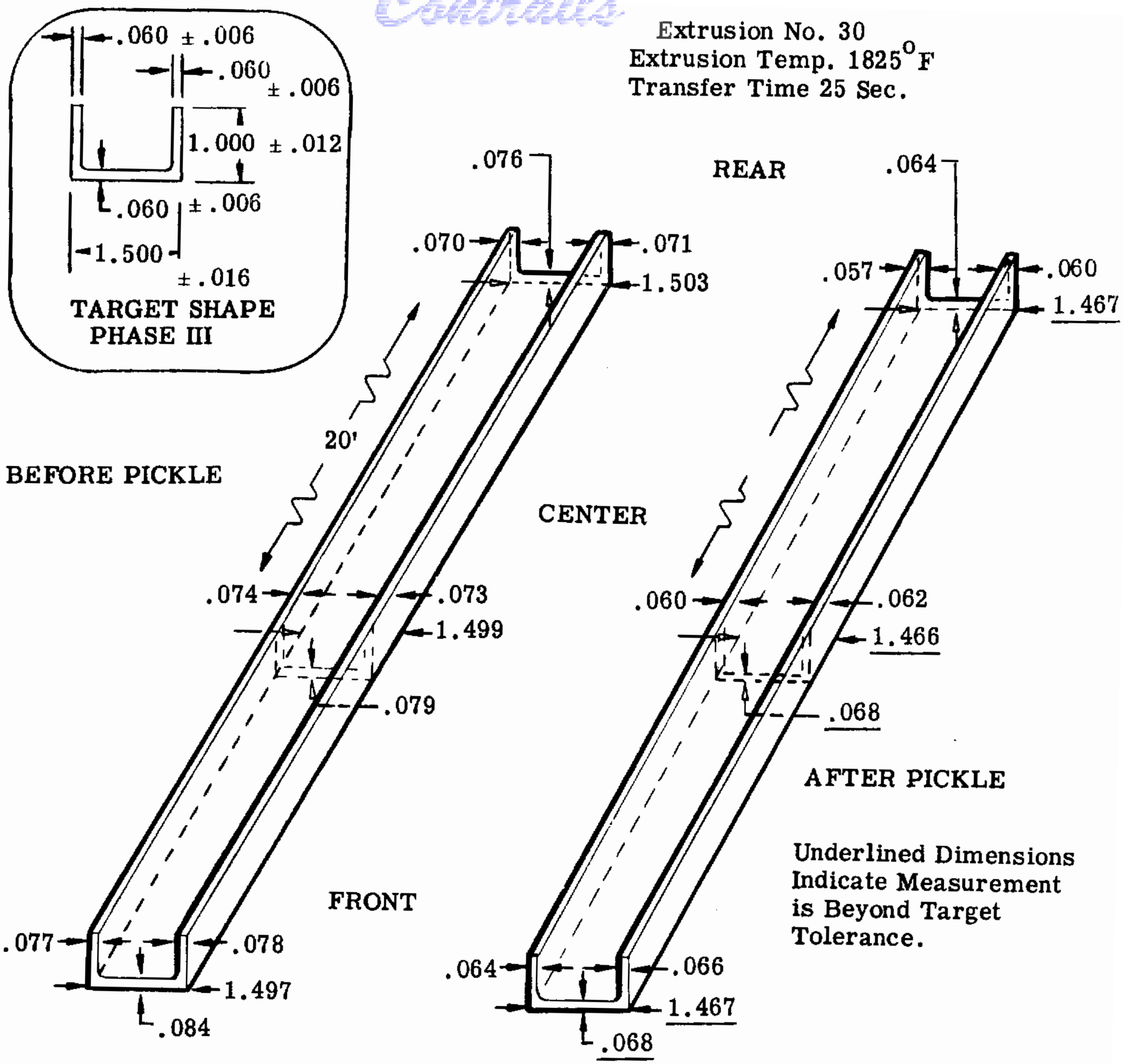
	LEFT	RIGHT
FRONT	——	1.000
CENTER	——	.996
REAR	——	.996

LEG HEIGHT AFTER PICKLE

	LEFT	RIGHT
FRONT	——	.943
CENTER	——	.949
REAR	——	.950

PHASE II

FIGURE 106 BERYLLIUM EXTRUSION INSPECTION DATA.



LEG HEIGHT BEFORE PICKLE

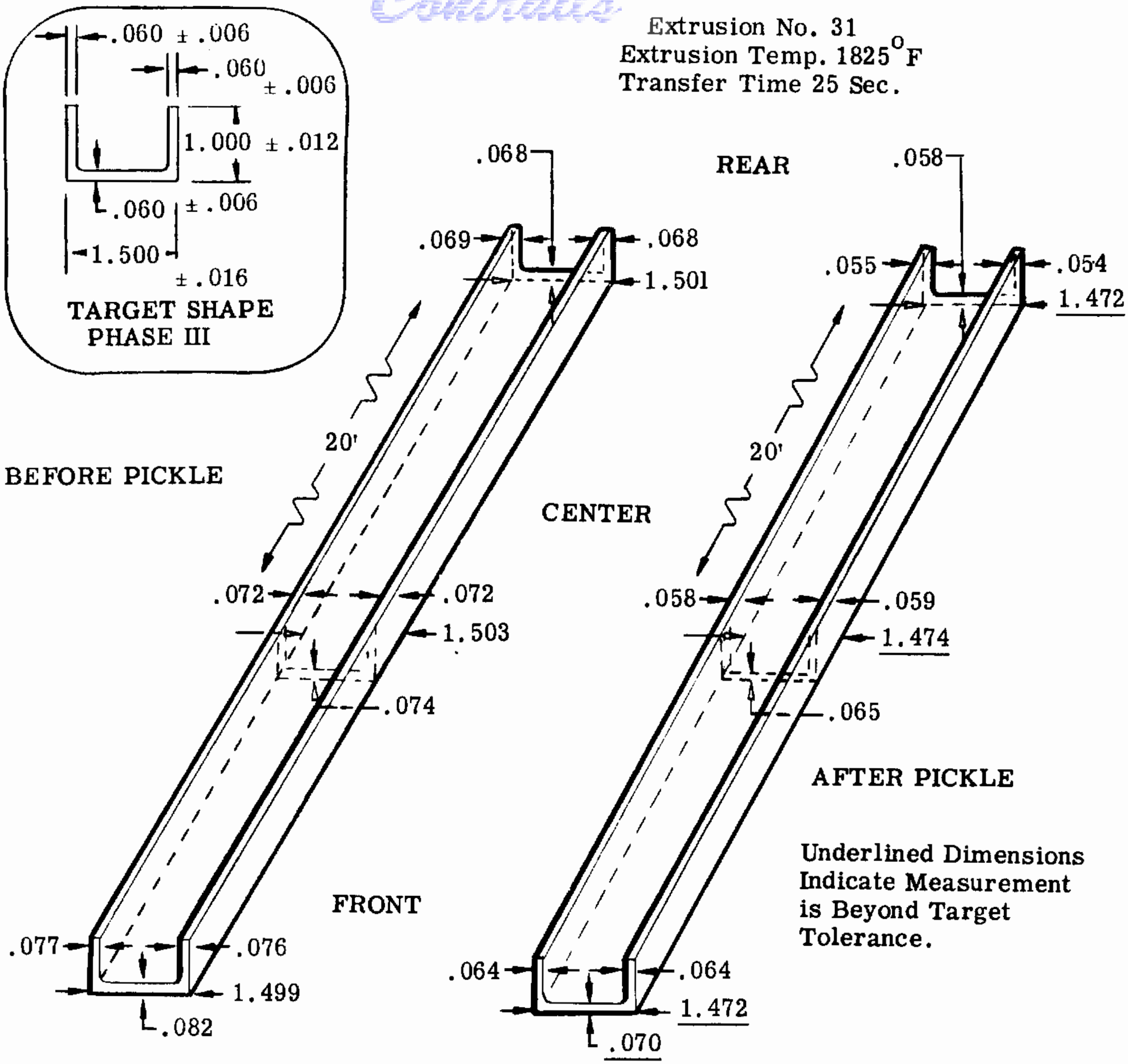
	LEFT	RIGHT
FRONT	—	1.002
CENTER	—	.998
REAR	—	.996

LEG HEIGHT AFTER PICKLE

	LEFT	RIGHT
FRONT	—	.948
CENTER	—	.946
REAR	—	.942

PHASE III

FIGURE 107 BERYLLIUM EXTRUSION INSPECTION DATA.



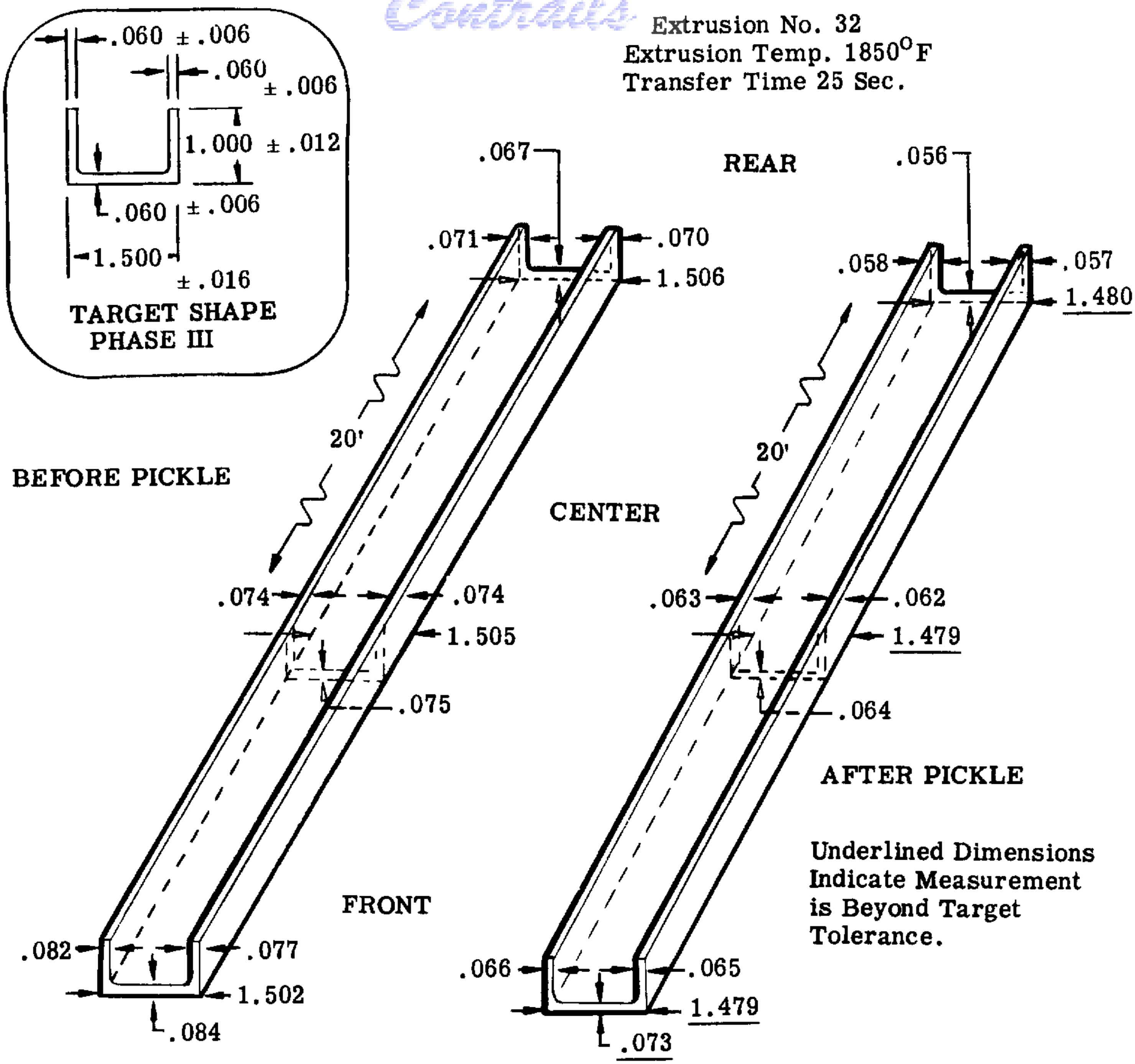
LEG HEIGHT BEFORE PICKLE	LEFT	RIGHT
FRONT	——	1.003
CENTER	——	1.002
REAR	——	1.000

LEG HEIGHT AFTER PICKLE	LEFT	RIGHT
FRONT	——	.947
CENTER	——	.950
REAR	——	.946

PHASE III

FIGURE 108 BERYLLIUM EXTRUSION INSPECTION DATA.

Extrusion No. 32
Extrusion Temp. 1850°F
Transfer Time 25 Sec.



LEG HEIGHT BEFORE PICKLE

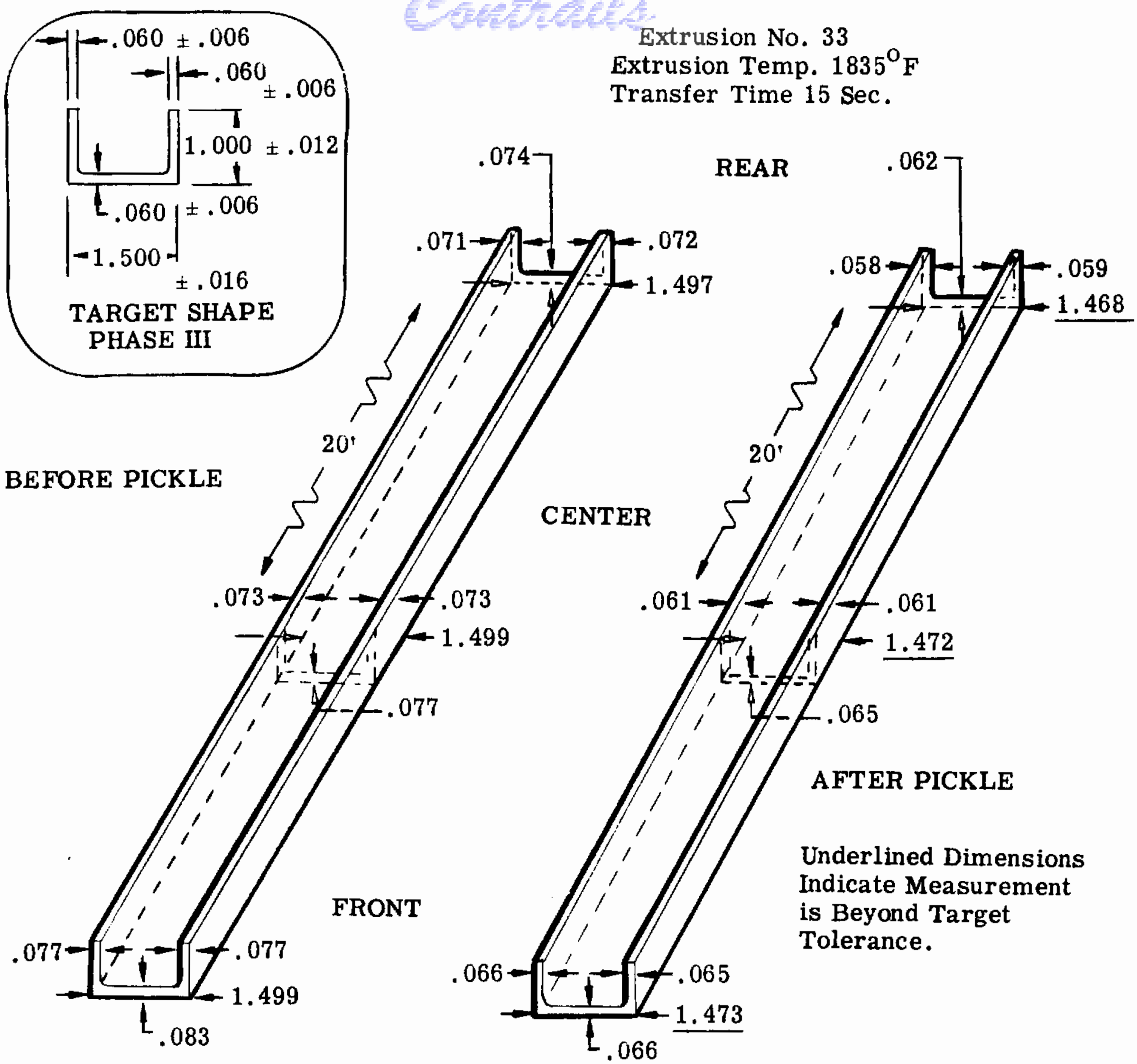
	LEFT	RIGHT
FRONT	——	1.006
CENTER	——	1.004
REAR	——	1.001

LEG HEIGHT AFTER PICKLE

	LEFT	RIGHT
FRONT	——	.966
CENTER	——	.954
REAR	——	.960

PHASE III

FIGURE 109 BERYLLIUM EXTRUSION INSPECTION DATA.



LEG HEIGHT BEFORE PICKLE

	LEFT	RIGHT
FRONT	—	1.007
CENTER	—	1.003
REAR	—	1.001

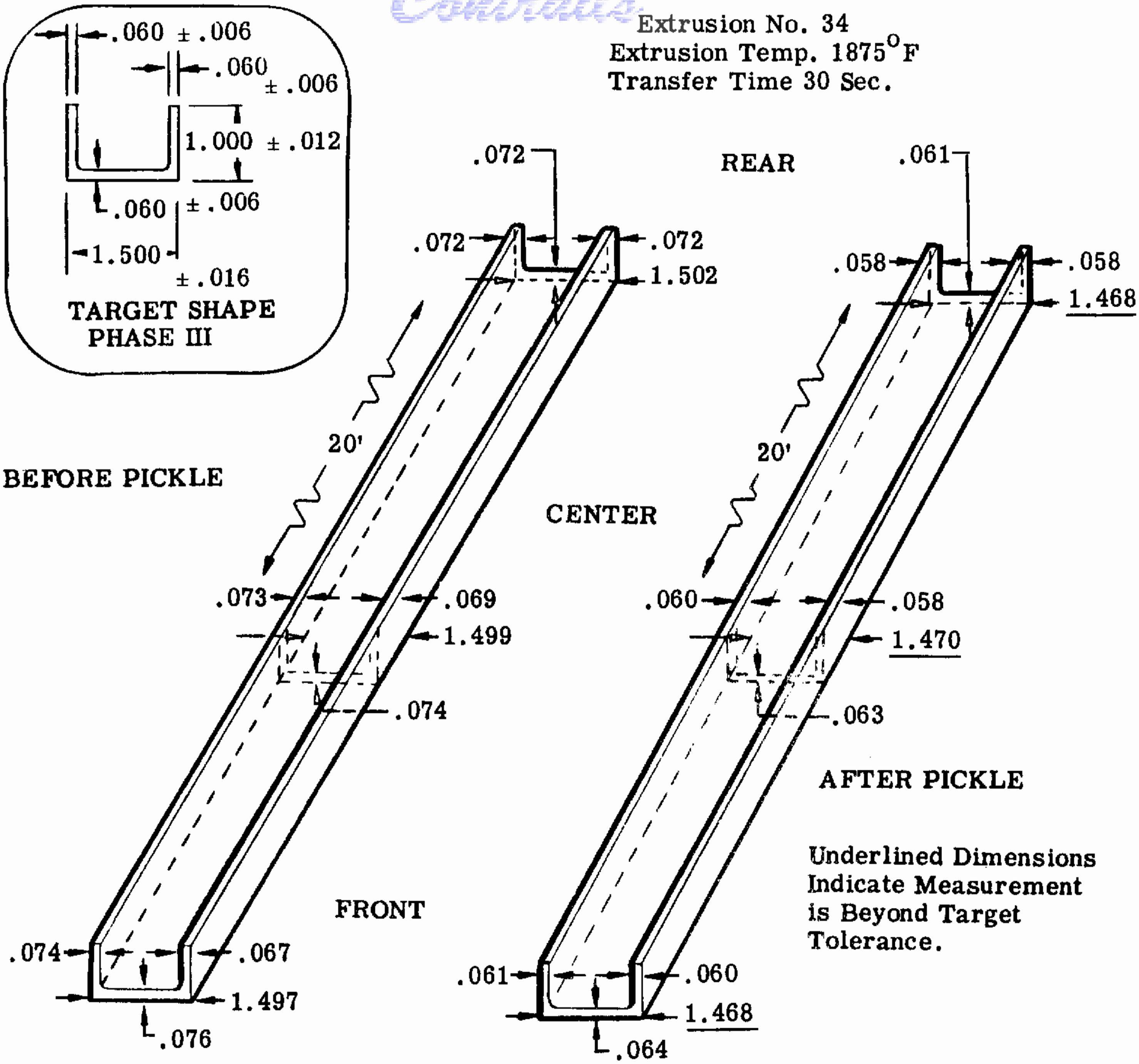
LEG HEIGHT AFTER PICKLE

	LEFT	RIGHT
FRONT	—	.956
CENTER	—	.954
REAR	—	.957

PHASE III

FIGURE 110 **BERYLLIUM EXTRUSION INSPECTION DATA.**

Extrusion No. 34
Extrusion Temp. 1875°F
Transfer Time 30 Sec.



LEG HEIGHT BEFORE PICKLE

	LEFT	RIGHT
FRONT	——	1.001
CENTER	——	1.001
REAR	——	1.000

LEG HEIGHT AFTER PICKLE

	LEFT	RIGHT
FRONT	——	.948
CENTER	——	.954
REAR	——	.957

PHASE III

FIGURE 111 BERYLLIUM EXTRUSION INSPECTION DATA.

Table XII Dimensional Analysis of Composite Lubricant Beryllium Extrusions

Phase No.	Extru. No.	Billet Temp. °F	L. H. Leg Thickness				R. H. Leg Thickness				Base Width				Leg Height (R. H.)			
			Front	℄	Aft	Variation	Front	℄	Aft	Variation	Front	℄	Aft	Variation	Front	℄	Aft	Variation
I	7	1750	.112	.110	.109	.003	.109	.106	.104	.005	1.463	1.465	1.466	.003	.950	.949	.949	.001
I	8	1710	.112	.108	.107	.005	.110	.110	.105	.005	1.458	1.458	1.454	.004	.950	.949	.952	.003
I	11	1725	.109	.107	.107	.002	.106	.105	.105	.001	1.457	1.462	1.472	.015	.947	.949	-	.002
I	12	1725	.109	.106	.106	.003	.102	.100	.099	.003	1.456	1.455	1.457	.002	.942	.948	.951	.009
I	13	1725	.115	.114	.114	.001	.112	.111	.111	.001	1.463	1.469	1.474	.011	.948	.953	.956	.008
	Variation		.006	.008	.008		.010	.011	.012		.007	.014	.020		.008	.005	.007	
II	24	1715	.085	.083	.080	.005	.086	.082	.080	.006	1.457	1.459	1.458	.002	.945	.945	.946	.001
II	25	1800	.082	.080	.077	.005	.085	.081	.076	.009	1.453	1.455	1.459	.006	.944	.944	.944	.000
II	26	1735	.081	.081	.078	.003	.087	.081	.079	.008	1.453	1.456	1.458	.005	.944	.949	.950	.006
II	27	1800	.088	.082	.077	.011	.086	.078	.074	.012	1.458	1.456	1.456	.002	.948	.948	.939	.009
II	28	1790	.086	.083	.081	.005	.089	.084	.083	.006	1.456	1.455	1.456	.001	.943	.949	.950	.007
	Variation		.007	.003	.004		.004	.006	.009		.005	.004	.003		.005	.005	.011	
III	30	1825	.064	.060	.057	.007	.066	.062	.060	.006	1.467	1.466	1.467	.001	.948	.946	.942	.006
III	31	1825	.064	.058	.055	.009	.064	.059	.054	.010	1.472	1.474	1.472	.002	.947	.950	.946	.004
III	32	1850	.066	.063	.058	.008	.065	.062	.057	.008	1.479	1.479	1.480	.001	.966	.954	.960	.012
III	33	1835	.066	.061	.058	.008	.065	.061	.059	.006	1.473	1.472	1.468	.005	.956	.954	.957	.003
III	34	1875	.061	.060	.058	.003	.060	.058	.058	.002	1.468	1.470	1.468	.002	.948	.954	.957	.009
	Variation		.005	.005	.003		.006	.004	.006		.012	.013	.013		.019	.008	.018	

9 Not sent to ASD because only 5 were required for pilot production.
10 Was a sticker

See Figures 97 thru 111 For More Detailed Dimensional Inspection Data variation that occurred was on extrusion Number 27 and was a total of 0.012 inch. About 85 percent of the shapes were within a maximum variation of 0.008 inch.

This inspection thus shows that the variation is sufficiently small to be adjudged feasible to predict, at least after an experimental push, to yield a product within the target thickness tolerance of plus or minus 0.006 inch. Appendix III gives complete dimensional and other requirements.

The reason that the base width and leg height dimensions were consistently beyond tolerance was because the 1.50 and 1.00 dimensions were deliberately shortened slightly for Phase I pressure requirements.

This was done in order to avoid a billet (3.00 dia.) longer than 17 inches and have an adequate margin of available pressure. The problem no longer existed for phases II and III but it was expeditious to keep the outside configuration the same and simply change the inside to reduce the thickness. This slight shortening of outside dimension did not make the part any easier to extrude and still yielded the desired answers.

The important point is how consistent are the extrusions along the 20 foot length and from shape to shape. This is shown to be very satisfactory in Table XII.

XII MECHANICAL PROPERTIES OF PILOT PRODUCTION, EXTRUSIONS PHASES I, II & III

The pilot production extrusions were prepared for mechanical property tests by removing specimen blanks from those areas shown in Figure 112 by selective chamical etching utilizing a 10 percent solution of H_2SO_4.

Specimens were machined by milling the blanks under filtered oil to the tensile specimen configurations illustrated in Figure 113. All specimens were encapsulated in an envelope that was evacuated to less than 10^{-4} mm Hg. The specimens were then annealed at 1500°F for two hours. Chemical etching in a 10 percent H_2SO_4 solution was employed to remove 0.002 to 0.010 inch of material from each side of each specimen after heat treatment.

Aluminum sheet tabs were bonded to the ends of the transverse tensile specimens to provide adequate gripping area.

A 1-inch gage length O.S. Peters B3M extensometer was used to measure strain on the longitudinal specimens. Extensometer strain measurement was not possible on the short transverse tensile specimens. Strain measurements were obtained by measuring head travel. Calibration runs using SR 4 strain gages and head travel measurements simultaneously on several samples indicated, that for a given load, the head travel movement measured was 1.6 times the strain measured with the SR 4 gages. Consequently, on subsequent tests employing head travel measurements only, the head travel movement was divided by a factor of 1.6 to give specimen strain. Head speeds employed for these tests were 0.05 in 1 minute. While strain rates were not accurately determined they did not exceed 0.005 in/in/min to the yield, nor 0.05 in/in/min between the yield and fracture.

Since longitudinal elongation was determined over a 1 inch gage length and transverse elongation was determined over a 1/2 inch gage length, direct comparison of these values might result in erroneous conclusions. However,

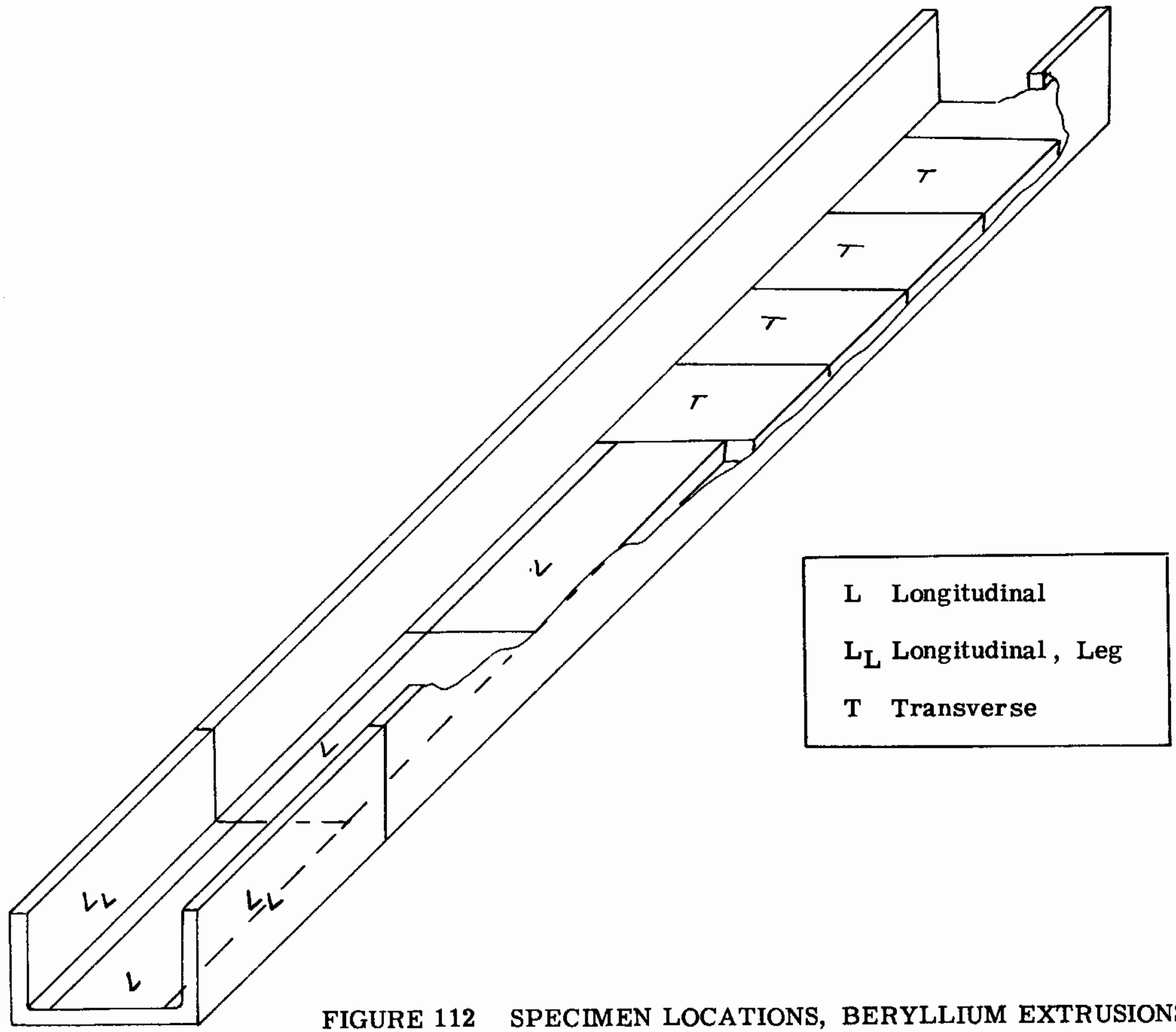
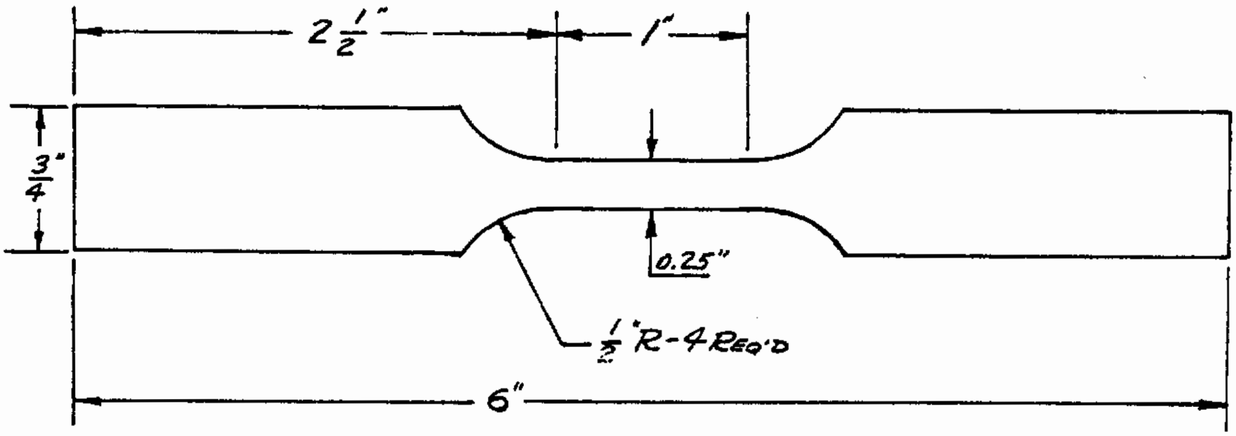
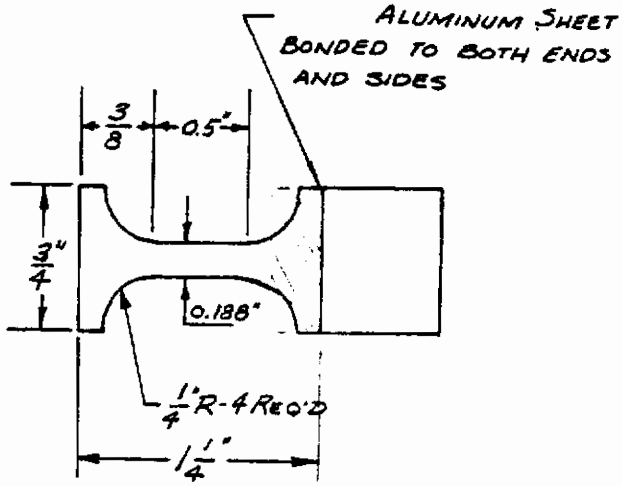


FIGURE 112 SPECIMEN LOCATIONS, BERYLLIUM EXTRUSIONS.



Longitudinal Beryllium
Tensile Specimen



Transverse Beryllium
Tensile Specimen

FIGURE 113 SPECIMEN CONFIGURATIONS, BERYLLIUM EXTRUSIONS in this particular case, the elongation took place in a fairly uniform manner over the entire gage length with little or no necking of the specimen. Thus, elongation measured in 1/2 inch and 1-inch gage lengths should be similar and direct comparison is possible without introducing serious error in the analysis.

Tensile properties of the 0.120 inch, 0.090 inch and 0.060 inch pilot production extrusions are presented in Tables XIII, XIV, and XV respectively. The variation of average ultimate and yield strength along the length of the extrusions are shown graphically in Figures 114 and 115.

As may be seen in these figures, the 0.120 inch and 0.090 inch extrusions are quite uniform in properties along the length of the extrusion in both the longitudinal and transverse direction. However, an increase of about 30,000 psi in the longitudinal ultimate tensile strength was found from the front to the back of the 0.060 inch extrusion (Figure 114). A corresponding change in longitudinal yield strength did not occur. Nor is a similar trend in the transverse direction statistically significant (Figures 14 and 115). Although there appears to be appreciable scatter of results from triplicate tests, the scatter is quite similar regardless of position or direction in a particular extrusion. The amount of scatter appears to be similar even when extrusions of different thicknesses are compared.

There is no consistent variation of elongation along the length of the extrusions, except for the longitudinal elongation of the 0.060 inch extrusion. In this extrusion, the longitudinal elongation increases as does the ultimate tensile strength from the front to the back of the extrusion, but the yield strength remains fairly constant.

The average mechanical properties of all the extrusions tested are summarized below:

Extrusion Thickness	Direction	Fty (ksi)	Range (ksi)	Ftu (ksi)	Range (ksi)	Elong. %	Range
0.120	Longitudinal	52.5	50.7-54.7	99.9	94.0-104.8	5.7	4.5-7.0
	Transverse	28.3	26.4-31.6	52.4	48.9-55.8	0.69	0.25-1.4
0.090	Longitudinal	50.3	47.6-54.1	96.2	88.0-101.4	7.2	3.5-9.5
	Transverse	28.0	23.2-31.7	56.4	53.4-59.5	2.0	1.0-3.0
0.060	Longitudinal	49.6	47.8-51.7	-	62.9-102.8	-	1.5-9.0
	Transverse	27.2	22.8-31.8	51.4	45.5-56.5	1.17	0.5-2.0

TABLE XIII

TENSILE PROPERTIES OF .120 INCH BERYLLIUM CHANNEL EXTRUSION NO. 12

Position	Direction	0.2% Offset Yield Strength (ksi)	Ultimate Tensile Strength (ksi)	Elongation (Percent) (1)
Front	Longitudinal (leg)	53.6	103.9	6.5
"	"	50.9	98.9	6.0
"	" (leg)	50.9	102.9	7.0
"	"	51.5	101.7	6.0
Average		51.7	101.8	6.4
Middle	Longitudinal (leg)	53.4	101.6	6.0
"	"	53.3	96.9	5.0
"	" (leg)	54.4	99.1	4.5
"	"	52.4	100.0	6.5
"	"	52.9	97.2	5.0
Average		53.3	98.9	5.4
Back	Longitudinal (leg)	50.7	94.0	4.5
"	"	51.7	99.8	4.5
"	" (leg)	54.7	104.8	6.0
"	"	52.5	98.9	7.0
"	"	53.2	96.3	4.5
Average		52.6	98.8	5.3
Front	Transverse	26.7	52.2	0.85
"	"	30.4	51.1	0.25
"	"	29.9	51.5	0.37
"	"	31.4	52.4	0.37
Average		29.6	51.8	0.46
Middle	Transverse	26.4	52.7	0.44
"	"	27.5	48.8	0.50
Average		26.8	50.8	0.52
Back	Transverse	31.6	55.0	0.75
"	"	27.8	53.2	1.0
"	"	27.0	55.9	1.4
"	"	27.4	53.8	1.25
Average		28.5	54.5	1.1

(1) Elongation in longitudinal direction in 1-inch; in transverse direction in 1/2-inch.

Test Conditions:
1. Tests were performed at R.T.
2. Crosshead travel was 0.050 inch/min.
3. All specimens were annealed in vacuum at 1500°F for two hours after machining.
4. At least 0.002 inches of specimen surface was removed by etching prior to testing.

TABLE XIV

TENSILE PROPERTIES OF 0.090

BERYLLIUM CHANNEL EXTRUSION NO. 28

Position	Direction	0.2% Offset Yield Strength (ksi)	Ultimate Tensile Strength (ksi)	Elongation (Percent) (1)
Front	Longitudinal (leg)	52.4	88.9	3.5
"	"	48.8	100.0	9.5
"	"	49.3	97.6	6.8
Average		50.2	95.5	6.6
Middle	Longitudinal	49.3	100.7	10.0
"	"	52.9	93.8	6.5
"	"	50.3	101.4	8.0
Average		50.8	98.6	8.2
Back	Longitudinal	47.6	88.0	7.0
"	"	48.2	96.6	8.5
"	" (leg)	54.1	100.0	5.0
Average		50.0	94.5	6.8
Front	Transverse	30.4	53.4	1.0
"	"	28.4	54.5	2.0
"	"	26.3	59.5	3.0
Average		28.4	55.8	2.0
Middle	Transverse	31.7	53.6	1.0
"	" *	23.2	57.7	
"	"	25.2	56.7	3.0
Average		26.7	55.6	2.0
Back	Transverse	30.9		
"	" **	30.0	56.6	
"	"	25.8	58.5	2.0
Average		28.9	57.6	

(1) Elongation in longitudinal direction in 1 inch; in transverse direction in 1/2 inch.

Test Conditions:
1. Tests were performed at R.T.
2. Crosshead travel was 0.050 inch/min except * 0.020 inch/min. ** 0.010 inch/min.
3. Specimens * and ** had Budd type C6-141-B strain gages mounted on each side of the specimen.
4. All specimens were annealed in vacuum at 1500°F for 2 hours after machining.
5. At least 0.002 inches of specimen surface was removed by etching prior to testing.

TABLE XV

TENSILE PROPERTIES OF 0.060

BERYLLIUM CHANNEL EXTRUSION NO. 30

Position	Direction	0.2% Offset Yield Strength (ksi)	Ultimate Tensile Strength (ksi)	Elongation (percent) (1)
Front	Longitudinal (leg)	48.7	62.9	2.0
"	"	47.8	74.1	3.0
"	"	48.0	67.0	1.5
Average		48.2	68.0	2.2
Middle	Longitudinal	5.7	78.7	3.0
"	"	49.5	82.8	3.0
Average		50.6	80.8	3.0
Back	Longitudinal	50.0	101.8	8.5
"	"	47.9	96.2	9.0
"	" (leg)	51.7	102.8	6.9
Average		49.9	100.3	8.1
Front	Transverse	22.8	47.9	2.0
"	"	24.3	45.5	1.0
"	"	28.1	55.3	0.5
Average		25.1	49.6	1.2
Middle	Transverse	25.1	48.0	2.0
"	"	29.9	53.3	0.5
Average		27.5	50.7	1.3
Back	Transverse	24.4	50.3	1.0
"	"	31.8	56.5	1.0
"	" *	30.5	54.7	---
Average		28.9	53.8	1.0

(1) Elongation in longitudinal direction in 1 inch; in transverse direction in 1/2 inch.

Test Conditions:
1. Tests were performed at R.T.
2. Crosshead travel was 0.050 inch/min. except *0.020 inch/min.
3. Specimen * had Budd type C6-141-B strain gages mounted on each side of the specimen.
4. All specimens were annealed in vacuum at 1500°F for two hours after machining.
5. At least 0.002 inches of specimen surface was removed by etching prior to testing.

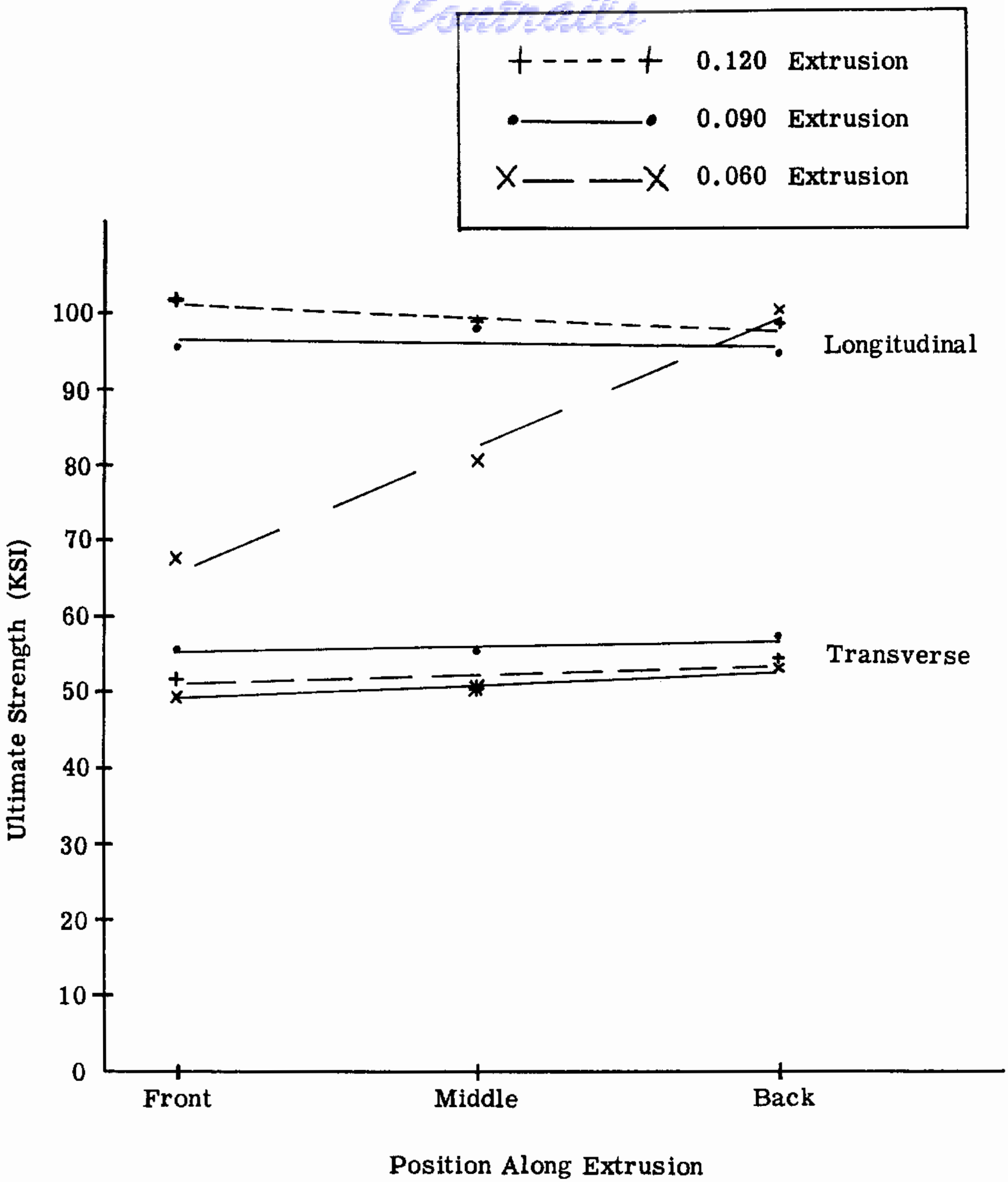


FIGURE 114 ULTIMATE STRENGTH ALONG THE EXTRUSIONS.

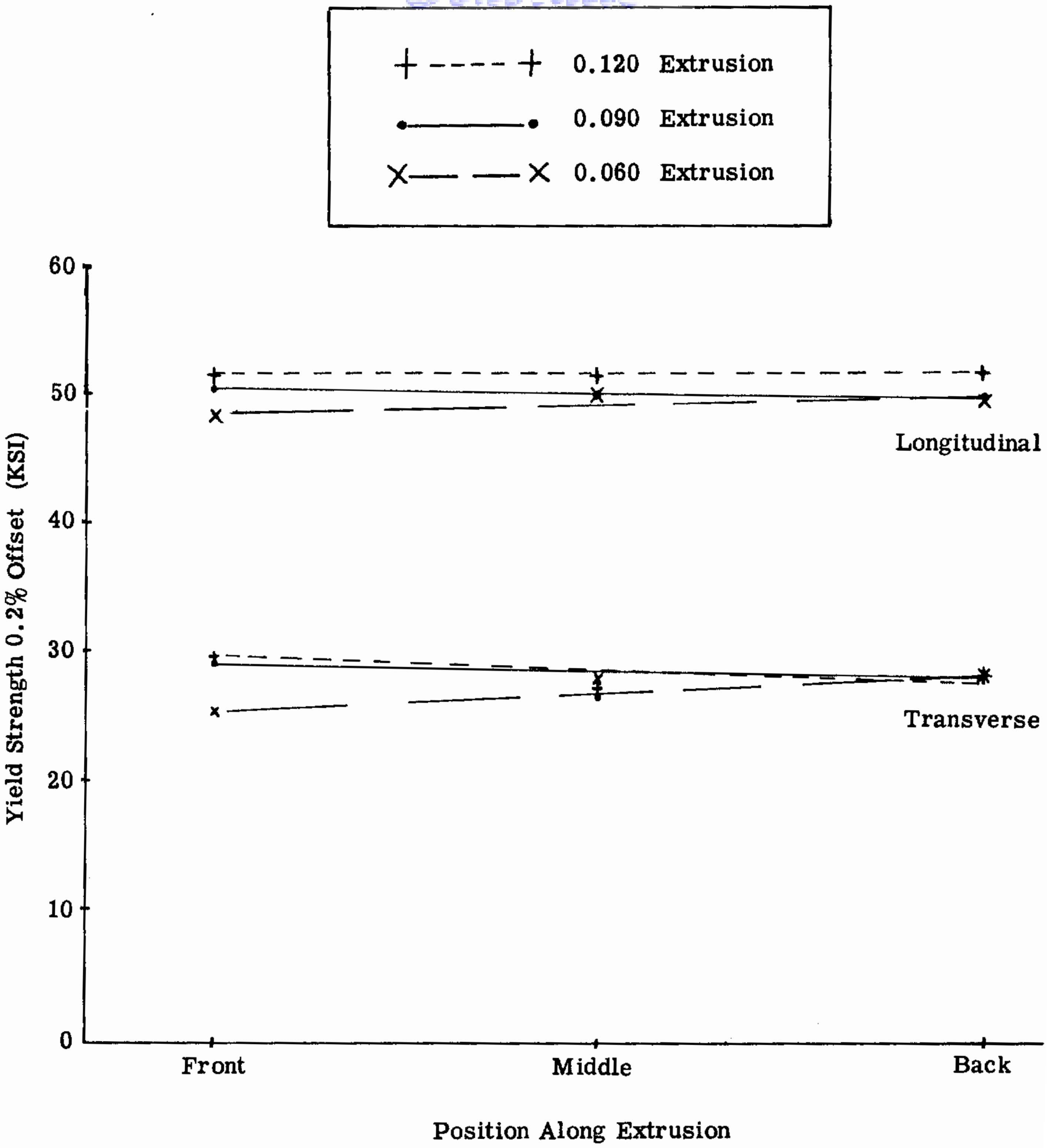


FIGURE 115 YIELD STRENGTH ALONG THE EXTRUSIONS.

It is believed that the large variation of the longitudinal ultimate tensile strength and elongation obtained from the 0.06 inch extrusions was caused by differences in preferred orientation along the length of the extrusion. It is probable that a heat treatment could be found to reduce the difference in preferred orientation and bring the ultimate tensile strength and elongation values up to acceptable limits, but a research program along this line was not within the scope of this contract.

In addition, the large variation in properties observed in the 0.060 inch extrusion may be decreased considerably by appropriate changes in the extruding parameters.

The relationship between elongation and ultimate strength and yield strength is shown in Figure 116. In this figure, the difference between ultimate tensile strength (Ftu) and 0.2% offset yield strength (Fty) is plotted against elongation. A reasonable relationship in the form of a band of values exists which illustrates the general increase of elongation with an increase in the difference between Ftu and Fty; $\Delta(F_{t_u} - F_{t_y})$.

The transverse specimens have smaller Δ(Ftu-Fty) values and correspondingly low values of elongation. In general, elongation in the longitudinal direction is considerably higher than that found in the transverse direction. However, elongation in the longitudinal direction at the front end of the 0.06 inch extrusion is low and the low elongation values are accompanied by low Δ(Ftu-Fty) values (see Figure 116).

The following significant points are derived from this data:

(A) Transverse yield and ultimate tensile strengths are about 50 percent of those found for the longitudinal direction.

(B) The tensile ultimate strength and elongation of the 0.06 inch extrusion increase from a low at the front of the extrusion to values similar to those found for the other extrusions at the back. Tensile properties are quite uniform in the 0.12 inch and 0.09 inch extrusions.

(C) The longitudinal elongation of the channel legs in the 0.09 inch extrusion were lower than that of the flat area for similar Δ(Ftu-Fty) values.

(D) As the difference between ultimate tensile strength and yield strength Δ (Ftu-Fty) increases, the elongation increases.

XIII RADIOGRAPHIC AND DIE PENETRANT INSPECTION

During the earlier stages of development several sections of extrusions were x-rayed to determine what correllation might be established. After several examinations, it became apparent that x-ray inspection was of little value, at least with present day commercially available methods. This was not too surprising in view of the fact that beryllium is sometimes used for x-ray windows. Consequently, this inspection technique was not employed in evaluating the subject pilot production shapes.

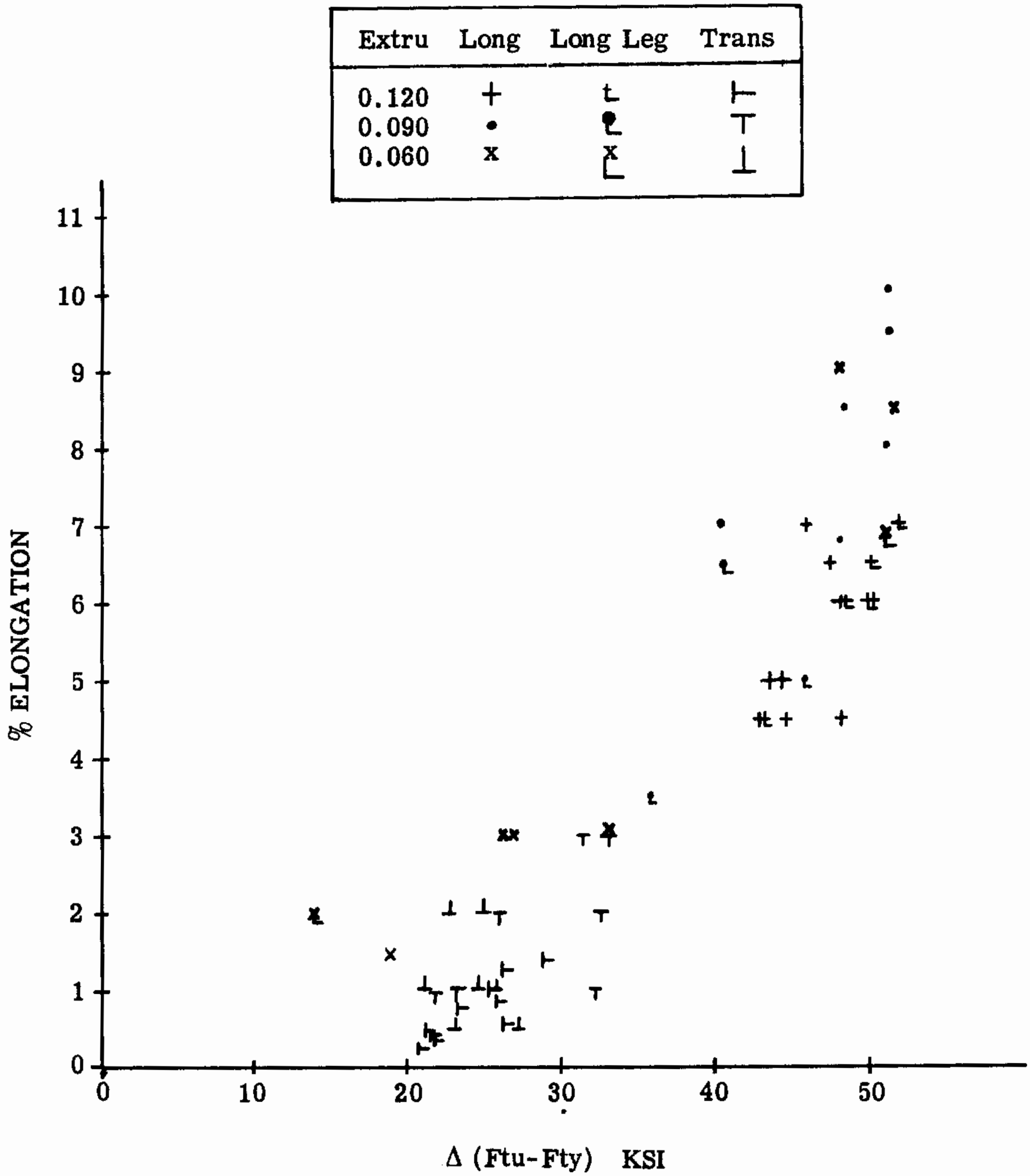


FIGURE 116 INFLUENCE OF THE SPREAD BETWEEN ULTIMATE TENSILE AND YIELD STRENGTH ON ELONGATION.

After removal of the cladding by pickling the extrusions were lightly etched in a 5 to 10 percent solution of sulfuric acid. This cleaned up discoloration, slightly smoothed the surface, and acted as a defect detection inspection. During the course of the development there was ample cross checking on suspect areas between etch inspection and die penetrant. As a result, etch inspection was adjudged to be adequate for the pilot production quantity and all were found to be completely defect free except for the tearing shown in Figures 82 and 83.

XIV APPLICABILITY OF THE EXTRUSION PROCESS TO OTHER AIRCRAFT SHAPES

The experience acquired in this program with the careful study of the variables encountered for successful extrusion of 20 foot beryllium U-channels poses the question of adaptability of the technique to other airframe shapes.

An analysis of external flow characteristics of the most common airframe sections is shown in Figure 117. The dotted lines in each of the configurations shows the boundries of the periphery of the billet which flow to the respective surface of the shape. It is obviously well distributed in T's, L's and V's which are by far the most commonly used in airframe construction.

The U-channel shows a great disparity in percent of OD of billet to the tongue surface versus the outside of the shape. This means more complicated flow, more differential in distribution of lubricant, and generally tougher extruding conditions. The channel is more difficult to extrude than any other shape except the H section which is simply a symetrical double U. The technology is therefore adjudged to be adaptable.

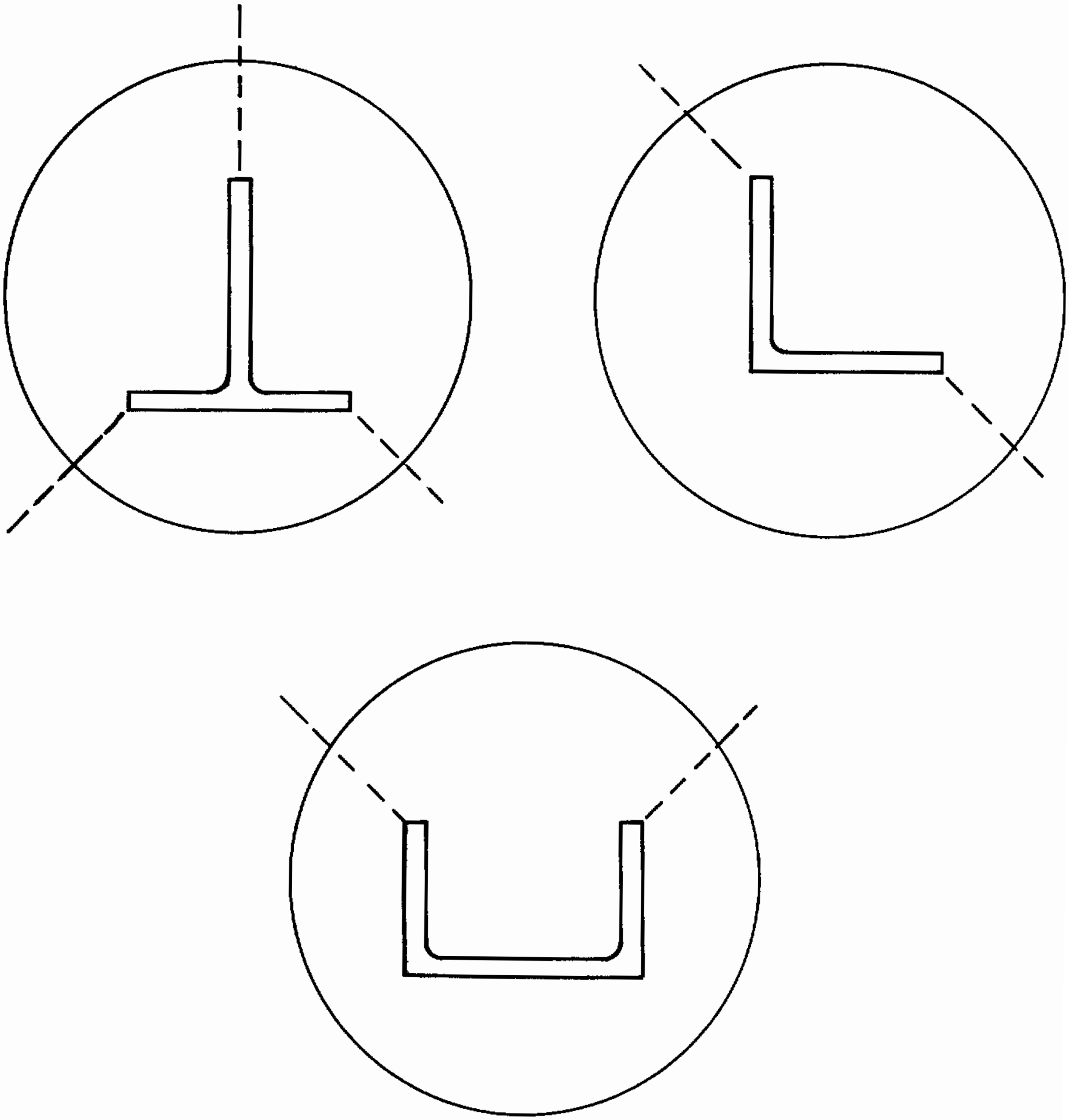


FIGURE 117 DIAGRAM OF COMPARATIVE FLOW FROM BILLET O.D. TO VARIOUS COMMON APERTURE CONFIGURATIONS

APPENDIX I

Airframe Industry Survey

Questionnaires were sent to the following companies:

Bell Aircraft
Boeing, Seattle
Boeing, Wichita
Chance Vought
Convair, Ft. Worth
Convair, Pomona
Convair, San Diego
Douglas, Santa Monica
General Electric
Grumman
Lockheed, Burbank
Lockheed, Marietta
Lockheed, Sunnyvale
Martin, Baltimore
Martin, Denver
McDonnell
North American, Columbus
North American, Los Angeles
Republic

All companies with one exception responded to the questionnaire. Three companies were unable because of their experience to complete the questionnaire and two others were able to give only partial replies.

BERYLLIUM EXTRUSION STUDY

CONTRACT AF 33(600)-36931

1. Do you envision the need for extruded beryllium metal shapes in the design and construction of your products during the next five years?

   Yes_12_ No_5_

   If your answer to question No. 1 was "No", how long before you anticipate a need for beryllium extrusions?

   Replies varied from "more than" five years to no reply whatsoever

2. What are the general anticipated areas of use of application for extruded beryllium shapes in your organization?

   a. Primary structures only? Yes_2_ No_11_

   b. Secondary structures only? Yes_0_ No_14_

   c. Both primary and Secondary structures? Yes_12_ No_2_

3. Do you anticipate the use of extruded beryllium shapes in:

   a. Flight vehicles in current production? Yes_0_ No_15_

   b. Flight vehicles currently being designed? Yes_3_ No_11_

   c. Flight vehicles in the preliminary or advanced design state?

   Yes_7_ No_8_

   d. Missiles only? Yes_2_ No_12_

   e. Manned flight vehicles only? Yes_1_ No_14_

   f. Both manned and unmanned flight vehicles? Yes_10_ No_4_

   g. Space vehicles? Yes_11_ No_1_

4. What is the approximate total quantity of extruded beryllium shapes, in pounds, that you company could use per flight vehicle? _(1) 50_ pounds; three producers stated 5%; another 3 to 4%; no data in 12 replies.

a. What approximate percentage of airframe weight? 3 to 60 percent (estimated by 4 companies).

b. How many pounds per month do you anticipate using? 100 pounds (estimated by 1 producer).

5. Will you submit three drawings (or cross-section sketches) of typical extruded beryllium shapes which you consider of relatively high potential usage, one drawing for each of the following categories:

   Shapes in all categories consisted of dimensionless sections of channels, I's, H's, angles, Z sections, etc.

6. What size circle would be required to circumscribe the largest extruded beryllium shape which you consider of relatively high potential usage, and for which you anticipate a requirement within the next five years?

   1 1/2 to 20 inches (average 4-5 inches).

7. What maximum ratio of leg or protuberance length to thickness would you expect to require in extruded beryllium shapes?

   3:1 to 65:1 (16:1 to 25:1 was the range specified in the majority of replies).

8. What minium fillet and corner radii do you expect to require in extuded beryllium shapes?

   a. In angles where no thickness change occurs? 0.1 to .03 inches.

   b. In angles where changes in thickness occurs? 0.125 to .031 inches.

   c. In outside corners? 0.031 to .125 inches.

9. Do you expect to require angles of other than 90° in extruded beryllium shapes?

   Yes 11 No 1

   If your answer was Yes, please specify angles 30, 60, 75, 160°

10. What do you consider the average minimum acceptable length for extruded beryllium shapes?

   4 to 60 Linear Feet; (12-16 feet average).

11. What length of extruded beryllium shapes would you like to see produced on a standard basis?

    10 to 40 Linear Feet; (20 feet indicated by majority).

12. What would be the maximum average price per pound you would be willing to pay for beryllium extrusions? $30 to 250 per pound.

13. Based upon the attributes of beryllium, at what price per pound do you believe that extruded beryllium shapes would become competitive with:

    a. Aluminum extrusions? $3.40 to 16.90 per pound.

    b. Magnesium extrusions? $3.00 to 34.90 per pound.

    c. Steel extrusions? $2.00 to 104.00 per pound.

    d. Titanium extrusions? $16.00 to 110.00 per pound.

14. What is the roughest surface finish which you would consider acceptable in as-received extruded beryllium shapes? 60 to 500 microinches (125 microinches average).

15. Would you consider using beryllium extrusions in corrosive environments?

    Yes 9 No 4

    a. If your answer was Yes, please specify anticipated conditions sodium chloride, dissimilar metals, air at 1200°F, and exhaust gases

16. Do you believe that surface protection will be required for beryllium extrusions?

    Yes 6 No 6

    a. If your answer was Yes, please state what type(s) of surface protection you consider feasible:

       Ceramic coatings, electroplates, anodic coatings, primers and paints

17. What operating or service temperatures are anticipated for extruded beryllium shapes:

    a. Lowest service temperature? -460°F

    b. Highest service temperature? +1400°F

18. What are the minimum section thicknesses desired in beryllium extrusions?

Range was from 0.010 up to 0.10-inches; .06-inch was most frequently mentioned.

19. What dimensional tolerances are desired in beryllium extrusions?

Majority specified "same as aluminum".

20. How would variations in mechanical properties in different directions affect your use of beryllium extrusions?

Replies included the following: "Depends on variations", "would limit use", "would restrict use", "limit forming and loading", "design to optimum properties", "anticipate problems", "no general problem", "do not know", "would affect only 1/4 of designs", "10% or less", and "the greater the difference the more difficult it would be to run it".

21. Would you be willing to sacrifice strength in extruded beryllium shapes for the sake of reducing directionality of mechanical properties?

Yes 12 No 1

a. If your answer was Yes, please state to what extent you would be willing to sacrifice strength to reduce directionality:

Relies included the following: "Depends on ductility", "yes, 20%", "Yes, up to 25%", "maximum of 25%", "maximum of 20%", "same as aluminum alloy", "yes, depends", "yes", "yes, 15%", and "5%".

22. Mechanical property requirement data. (Please fill applicable spaces):

Property	Service Temperature	Minimum Required	Minimum Desired
a. Ultimate Tensile Strength, psi	Room	60,000 to 115,000	80,000 to 120,000
	500°F	85,000	110,000
	600°F	-	60,000
	800°F	35,000	50,000
	1000°F	35,000-60,000	35,000-100,000
	1200°F	8,000-40,000	20,000- 45,000
	1500°F	10,000	8,000

	Service Temperature	Minimum Required	Minimum Desired
b. Yield Strength, 0.2% offset, psi	Room	35,000 to 90,000	60,000 to 105,000
	500°F	70,000	90,000
	600°F	-	50,000
	800°F	32,000	50,000
	1000°F	30,000-45,000	27,000-80,000
	1200°F	5,000-35,000	20,000
	1500°F	7,500	6,100
c. Percent Elongation	Room	No Data	4 to 10
	500°F	No Data	No Data
	600°F	No Data	6
	800°F	No Data	10
	1000°F	No Data	20
	1200°F	No Data	10 to 14
	1500°F	No Data	No Data
d. Shear Strength, psi	Room	55,000 to 75,000	48,000 to 95,000
	500°F	65,000	80,000
	600°F	-	36,000
	800°F	-	-
	1000°F	20,000-40,000	30,000-70,000
	1200°F	18,000-30,000	-
	1500°F	4,000	-
e. Miscellaneous Properties			
Ultimate Bearing Strength, psi	Room	150,000-240,000	150,000
	1000°F	No Data	220,000
Bearing Yield Strength, psi	Room	135,000	135,000-175,000
Impact Strength, pounds	No Data	No Data	No Data
Creep Strength, psi	450°F	1.0% stressed 500 hrs @ 70,000 psi	
	1200°F	1.0% stressed 50 hrs @ 14,000 psi	
Relaxation Strength, psi	No Data	No Data	No Data
Fatique Strength, psi	Room	24,000	27,000-60,000

NOTE: As can be observed from answers to all questions, particularly numbers 18 through 21, inclusive, some companies were much more familiar with the mechanical property characteristics of beryllium than others. For this reason replies in this category had to be "weighted" to the best ability of contractor. In question 22, for example, some companies had tentatively established beryllium extrusion property requirements which were wholly beyond the realm of reason. Since this is a "feasibility" project, it will be necessary to design to whatever mechanical properties are obtained. Also, in question 22, it will be noted that some spaces contain only a single number or value: this indicates that an aswer was supplied by only one company and should not necessarily be considered representative of industry.

APPENDIX II

Beryllium Extrusion Material Specification ND-161-A

This specification is an integral part of the Purchase Orders placed with the extruding sub-contractors and outlines the requirements for extruding material.

SPECIFICATION NUMBER ND-161 A

BERYLLIUM EXTRUSION MATERIAL SPECIFICATION

Introduction

This interim specification has been prepared to fulfill the need for such a document as specifically related to the Air Force Contract for the Production Method Development and Evaluation of Shaped Beryllium Extrusions (AF-33(600)36931). As is so often true with a relatively new aeronautical structural material, such as beryllium, this specification may require revision before final standardization is achieved.

The beryllium extrusions produced during Phase I of this project may not meet all of the material requirements specified herein; but this will be one of the criteria on which these extrusions can be judged.

1.0 Workmanship

The material shall be uniform in quality and condition; free from foreign material; clean, smooth, and free from buckles, cracks, seams, and other injurious defects.

2.0 Composition

Shaped beryllium extrusions shall fall within the material composition limits shown in Table I.

TABLE I

Material Composition Requirements for Extruded Beryllium Shapes

ELEMENT	QUANTITY
Carbon	0.15% maximum
*Iron	1500 parts per million maximum
Nickel	0.08% maximum
Copper	0.05% maximum
Aluminum	0.15% maximum
Manganese	0.03% maximum
Silicon	0.10% maximum
Chromium	0.05% maximum
Magnesium	0.05% maximum
Beryllium Oxide	1.50% maximum
Beryllium	Remainder

Total impurities (other than beryllium oxide) shall not exceed 0.50%.

*700 parts per million highly desirable.

2.1 Composition Determination

The composition of beryllium extrusions shall be determined by removing specimens from each end of the extrusion upon which composition determination(s) is to be made. Butts or scrapped beryllium composition determinations are not to be considered as representative of satisfactory extrusions.

2.2 Methods for Determining Composition

Methods (either chemical or spectrographic) for determining the composition of beryllium extrusions shall be those currently practiced and considered to be standard by:

The United States Atomic Energy Commission Laboratory, New Brunswick, New Jersey

Note: A subsequent revision to this specification will present standard methods for determining various elements in beryllium extrusions if such is found to be necessary.

3.0 Beryllium Extrusions Billet Material Requirements

Beryllium extrusions shall be made either from beryllium powder or from extrusion billets which were prepared from beryllium powder. This beryllium powder shall not exceed the particle size limits for that considered standard as minus two hundred (200) mesh. Powder composition shall be such that, subsequent to its conversion into a bare extrusion, said extrusion will fall within the position limits specified in Table I.

3.1 Beryllium Extrusion Billet Preparation Temperature Limitations

Beryllium extrusion billets shall not be subjected to temperatures exceeding 1260°C (2300°F) at any time during their preparation or processing. This includes the hot pressing of attritioned powder as a means of extrusion billet production.

4.0 Extrusion Density

Bare beryllium extrusions shall possess a density of not less than one and eighty-two hundredths gram per cubic centimeter (1.82 gm/cc).

5.0 Mechanical Properties

The mechanical properties of hot extruded bare beryllium shall conform to the requirements appearing in Table II. Mechanical property determinations shall be made after all extrusion processing or finishing operations have been completed (this includes probable processing such as straightening, removal of extrusion lubricant(s) surface etching, annealing, etc.) All specimens shall be taken from the beryllium extrusions after the scrap portions removed from each end.

TABLE II

Target Mechanical Property Requirements for Hot Extruded Bare Beryllium

DIRECTION	PROPERTY	VALUE
Longitudinal	Ultimate Tensile Strength	60,000 psi, min.
Longitudinal	Yield Strength (.2% offset)	35,000 psi, min.
Longitudinal	Elongation in 2 inches	10% minimum
Longitudinal	Reduction of Area	10% minimum
Longitudinal	Ratio to Long Transverse Ultimate Tensile Strength	*(1)
Longitudinal	Ratio to Short Transverse Ultimate Tensile Strength	*(1)
Long Transverse	Ultimate Tensile Strength	*(1)
Long Transverse	Yield Strength (.2* offset)	*(1)
Long Transverse	Elongation	*(1)
Long Transverse	Reduction of Area	*(1)
Short Transverse	Ultimate Tensile Strength	*(1)
Short Transverse	Yield Strength (.2% offset)	*(1)
Short Transverse	Elongation	*(1)
Short Transverse	Reduction of Area	*(1)

*To be added in a subsequent revision when more data is available.

(1) These properties will be determined only in instances where extrusion size and configuration make their measurement feasible.

5.1 Mechanical Property Determinations

Standard ASTM or equivalent test methods shall be employed in conducting tests to determine the mechanical properties of beryllium extrusions.

5.2 Test Specimens

Test specimens shall be taken from each end of experimental and/or pilot production beryllium extrusions. Specimens shall, whenever possible, be taken so that the longitudinal and long transverse mechanical properties can be determined.

5.2.1 Number of Specimens

One specimen from which each necessary mechanical property can be determined shall be taken from each end of each experimental (best effort) and pilot run extrusion in which the metal is sound.

5.2.2 Test Specimen Size

If the beryllium extrusion size and configuration permits, standard sized (ASTM) specimens of two-inch gage length shall be employed to determine mechanical properties. In the event that standard size test specimens cannot be obtained, because of beryllium extrusion size limitations, standard miniature specimens shall be prepared and tested.

5.2.3 Test Specimen Surface Preparation

After all specimen machining has been completed, and minimum of 0.008 and maximum of 0.012 inch of the surface of each mechanical property test specimen (including fatigue test) shall be removed from machined areas by etching. The etchant shall be that considered standard by beryllium producers and fabricators.

5.2.4 Miscellaneous Mechanical Property Test Specimens

Specimens taken from beryllium extrusions for the purpose of conducting "miscellaneous" tests such as impact, creep and relaxation test, shall, whenever possible, be of standard ASTM size and configuration. If the beryllium extrusion size and configuration make it impossible to obtain standard size test specimens, then standard sub-sized specimens, whenever applicable, shall be utilized.

6.0 Metallurgical Requirements and Considerations

6.1 Grain Orientation in Beryllium Extrusions

Grain orientation studies shall be conducted (either by contractor or sub-contractor on specimens taken from the grip ends of tensile specimens representing areas in both experimental and pilot run beryllium extrusions). Grain orientation studies include x-ray diffraction studies with resultant pole diagrams.

NOTE: At this time it is impossible to fully describe the grain orientation criteria which must eventually be considered. It is also highly desirable to evolve methods whereby maximum possible control of grain orientation in shaped beryllium extrusions can be achieved during production.

6.2 Metallurgical studies

Specimens for microscopic and/or macroscopic examination shall be taken from each end of each experimental and each pilot run beryllium extrusion. Correlation between metallurgical specimens and the results of mechanical property tests will be attempted in an effort to originate relatively simple, inexpensive methods for determining the relative quality of extruded beryllium shapes.

6.3.1 Grain Size Determination

The average grain size of specimens taken from the grip ends of tensile test coupons shall be determined. (This is also for the purpose of correlating mechanical properties with metallurgical observations.)

6.3 Hardness Tests

Hardness determinations shall be made on the grip ends of each flat mechanical test specimen taken from both experimental and pilot production beryllium extrusions. The "15T" and "30T" scales shall be utilized. The "Wilson" Rockwell instrument or equivalent shall be employed in conducting hardness tests.

6.3.1 Micro-Hardness Tests

One micro-hardness measurement shall be made on one specimen taken from end first leaving the die of each experimental and pilot run production extrusion. A "Tukon" or equivalent micro-hardness testing instrument shall be employed.

7.0 Finishing and Finish Requirements

The surface and surface finish required on bare beryllium extrusions shall be in accordance with those stipulated in the purchase order and/or drawing of the extrusion in question.

7.1 Annealing

Unless otherwise specified, beryllium extrusions shall be supplied in the fully annealed condition.

NOTE: Future evaluation may reveal that as-extruded beryllium is desirable from a standpoint of strength and other reasons. This will be covered later on in this project.

7.2 Straightening

The straightening of shaped beryllium extrusions after extruding shall be accomplished in such a manner that no detriment will result from the straightening operation:

NOTE: Hot straightening may be necessary to eliminate stresses induced by cold straightening. It may be found that post straightening annealing will be required regardless of the use of heat employed in straightening. Temperatures employed in either straightening or annealing shall not exceed 1100°C.

8.0 Inspection and Quality Control

8.1 Size, Configuration, Length, and Straightness

Extruded beryllium shapes shall meet the size, configuration, length, straightness, thickness, width, and surface finish requirements stipulated in the purchase order and the drawing(s) on which the purchase order is based.

8.2 X-ray Examination

Beryllium extrusions developed and produced to the Z-I shape and Phases II and III shapes, Contract AF-33(600)-36931, shall be subjected to 100% X-ray examination. Upon discovery of flaws revealed by studies of exposed X-ray film, the flaw areas and adjacent material shall be sectioned and subjected to metallurgical studies.

8.3 Die Penetrant Inspection

All beryllium extrusions referred to in Section 7.2 shall be subjected to 100% die penetrant examination. Any flaws located in die penetrant inspection shall be closely examined to determine their type and severity. If defects are found to be definitely detrimental to the integrity of the beryllium extrusion under consideration, a metallurgical study of the defect and its boundaries shall be made.

9.0 Shipping and Handling Requirements

Packaging, shipping and handling shall be in accordance with practices considered standard to the beryllium industry and shall meet all applicable requirements as established by the Atomic Energy Commission. All packaging, handling, and shipping shall be conducted in such a manner as to prevent all danger of beryllium contamination and shall insure delivery of completely undamaged extrusions.

9.1 Shipping and Handling

Unless otherwise specified, the material shall be separated by size, heat, and composition when packaged for shipment.

APPENDIX III

Beryllium Extrusion Specification NAI 215-1

This specification is an integral part of the Purchase Orders placed with the extruding sub-contractors and outlines the program requirements as well as the data reporting requirements.

Beryllium Extrusion Specification

NAI 215-1

1. The goal of this program is to develop bare beryllium extruding techniques, lubricants, optimum extrusion temperatures, and tooling to achieve the following objectives:

   a. Tolerances equal to aluminum extrusions.

   b. Surface quality equal to aluminum extrusions.

   c. Structural and metallurgical integrity of beryllium extrusions.

   d. Lowest possible tooling cost commensurate with acceptable extrusions.

   e. Consistant fillet and corner radii.

   f. Low scrap loss and high scrap recovery in achieving the above objectives to help keep beryllium extrusion prices at a minimum.

2. Subcontractor will use his best efforts to develop extruding techniques and to produce one 20 ft. length of extrusion per NAI Section, Drawing Z-1, and in accordance with the following tolerances:*

   Straightness: 0.0125-in per foot length.

   Twist: (Circle Size) 1/2° per foot of length; 5° total maximum.

   Angularity (Less than .188-in thick) ± 2° at any point of measurement.

   Length: ± 0.250-inch.

   Flatness: (Cross-wise Dimension): 0.004 inch per inch.

   Surface roughness: 100 microinch general; local drag or similar effects: 0.002 - inch.

3. Billets shall be hot pressed from QMV or equivalent sintered beryllium powder.

4. Cold drawing cannot be used to achieve the cross-section and tolerances specified. Delivered parts are to be "as-extruded."

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* Tolerances are in accordance with those used by the Aluminum Extruded Products Division of the Aluminum Association.

5. Extrusions are to be produced without cladding or "canning."

6. Subcontractor must comply with all safety provisions of T.O. 00-80BB-1, 10 January 1958.

7. Finished extrusions will be ready for delivery to Contractor for inspection and evaluation by 15 January 1959.

8. Monthly progress letters will be submitted to the Contractor no later than the 3rd of the month following end of the reporting period.

9. A final Engineering Report will be submitted to the Contractor by 15 February 1959.

10. The subcontractor will include in his final report and, as practical, in monthly status reports all pertinent information, State-of-the-Art advances, tooling data, photographs, and details of these relating to development carried on under this purchase order, including data regarding both positive and negative results. All photographs must be 8 x 10 glossy prints. Reports shall include data for all extruding attempts as well as the final result:

    a. Billet preparation

        - Size
        - Type and results of inspection
        - Type of billet surface preparation (turned, scalped, etc.)

    b. Dies

        - Material
        - Method of fabrication
        - Detail design drawing

    c. Lubricants

        - Type and composition
        - List separately for billet, container, and die lubricant, if different for each

    d. Press Setup

        - Type and size of press, with any features not common to other types
        - Stem size and material
        - Container size, shape, and material
        - Track

e. Extruding Operation

- Extrusion ratio
- Pre-heat details for billet container, and die, including method and temperature of pre-heating
- Billet handling from pre-heat to press, including time history
- Method of applying lubricant to billet
- Extruding pressure, temperature, and rate through the cycle
- Guiding and straightening during extruding
- Ram speed

f. Post Extruding Operation

- Removal of scale or lubricant
- Straightening and de-twisting

g. Inspection

- Section dimensions start, center, and end of extrusion
- Die condition
- Extrusion surface condition
- Test data from any metallurgical or physical property tests conducted

11. Pilot Production will be the subject of further negotiation and a change to this Purchase Order.

12. Subcontractor will allow Contractor personnel to have full access to his facilities during this program to monitor Research and Development activities on beryllium extrusions.

13. No changes are to be made in any of the elements of the Purchase Order without written authorization from Northrop's Purchasing Department.

APPENDIX IV

Beryllium Corporation
Extrusion Data Sheets

TABLE I

DETAILED SUMMARY

BERYLLIUM EXTRUSION TEST DATA

Work at: The Beryllium Corporation, Reading, Pennsylvania
Report: Interim Engineering Report No. 2
Report Period: 1 September through 30 November 1958

Item of Information	Test (Extrusion) Number 1	2	3	4	5
Push Number	1	2	3	4	5
Stem Diameter, Inches	5-3/16	5-3/15	5-3/16	5-3/16	5-3/16
Container Diameter, Inches	5-1/2	5-1/2	5-1/2	5-1/2	5-1/2
Extrusion Ratio	54:1	54:1	54:1	54:1	54:1
Billet Length, Inches	7-1/32	7-31/32	9-5/8	6-9/16	6-1/4
Billet Temperature, °F.	1750	1750	1750	1750	1750
Type of Billet Heating	*Electrical Resistance	*Electrical Resistance	*Electrical Resistance	*Electrical Resistance	*Electrical Resistance
Billet Heating Time	1450°-8 hrs. 1850°-2½ hrs.	1450°-8 hrs. 1850°-2½ hrs.	1450°-8 hrs. 1850°-2½ hrs.	1450°-8 hrs. 1850°-2½ hrs.	1450°-8 hrs. 1850°-2½ hrs.
Billet Lubricant	Glass	Glass	Glass	Glass	Glass
Die Lubricant	Calcium Base Soap with Graphite	Calcium Base Soap with Graphite	Calcium Base Soap with Graphite	Calcium Base Soap with Graphite	Calcium Base Soap with Graphite
Container Lubricant	Calcium Base Soap with Graphite	Calcium Base Soap with Graphite	Calcium Base Soap with Graphite	Calcium Base Soap with Graphite	Calcium Base Soap with Graphite
Die Material	Hard-faced Tool Steel	Hard-faced Tool Steel	Hard-faced Tool Steel	Hard-faced Tool Steel	Hard-faced Tool Steel
Type of Die Fabrication	Machined	Machined	Machined	Machined	Machined
Die Temperature, °F.	600	500	550	600	500
Container Temperature, °F.	675	675	675	675	675
Billet Transfer Time, Seconds	30	25	30	35	30
Starting Pressure Reading, PSIG	1700	1200	1400	1600	1500
End Pressure Reading, PSIG	2000	800	600	500	2550
Maximum Force on Billet, Tons	1625	1156	1000	1406	1600
Maximum Pressure on Billet, PSI	138,000	97,500	84,400	118,500	135,000
Extrusion Length, Inches	137	84	101	121	153
Number of Pushes through Same Die	1	2	1	2	3
Extrusion Speed Inches per Minute	21	20	21	14	36
Butt Length, Inches	3-1/4	4-1/8	3-1/2	3-1/4	3-3/8
Billet Hardness, Brinell:					
End	88	87	89	87	83
Middle	88	87	86	88	84
End	87	89	88	88	85

TABLE II
EXTRUSION DEVELOPMENT DETAILS
THE BERYLLIUM CORPORATION

Item of Information	EXPERIMENTAL EXTRUSION NUMBER 6 12-22-58	7 12-22-58	8 12-23-58	9 12-23-58	10 12-23-58
Push Number	6-B	7-C	8-C	9	10-D
Primary Purpose of This Experiment	Lubrication Study	Heating & Lead-in Angle Study	Billet Heating Study	Effort Duplication	Extrusion Speed
Press Capacity, Tons	1700	1700	1700	1700	1700
Stem Diameter in Inches	5 - 3/16	5 - 3/16	5 - 3/16	5 - 3/16	5 - 3/16
Container Diameter in Inches	5 - 1/2	5 - 1/2	5 - 1/2	5 - 1/2	5 - 1/2
Extrusion Ratio	54:1	54:1	54:1	54:1	54:1
Billet Material	Pure Be	Pure Be	Pure Be	Pure Be	Pure Be
Billet Size, Inches Diameter / Length	5 - 3/8 6 - 1/4	5 - 3/8 6 - 1/4	5 - 3/8 6 - 1/4	5 - 1/4 6 - 1/4	5 - 1/4 6 - 1/4
Billet Temperature, °F	1850	1850	1950	1950	1950
Type of Billet Heating	Salt Bath	Salt Bath	Salt Bath	Salt Bath	Salt Bath
Billet Heating Time in Minutes	20	20	20	20	20
Billet Lubricant	Boron Nitride	None	Glass	Glass	Glass
Die Lubricant	Bentonite Grease	Bentonite Grease	Calc. Base Soap	Calc. Base Soap	Calc. Base Soap
Container Lubricant	Bentonite Grease	Bentonite Grease	Calc. Base Soap	Calc. Base Soap	Calc. Base Soap
Die Design Number	2x-2DD Type 2	2x-2DD Type 2	2x-2DD Type 2	2x-2DD Type 2	2x-2DD Type II
Die Material	Hard Faced Die Steel	Hard Faced Die Steel	Hard Faced Die Steel	Hard Faced Die Steel	Hard Faced Die Steel
Type of Die	Flat Faced Insert	Flat Faced Insert	Flat Faced Insert	Flat Faced Insert	Flat Faced Insert
Die Temperature, °F	700	650	650	650	650
Container Temperature °F	650	650	650	650	650
Billet Transfer Time in Seconds	30	30	30	30	30
Starting Pressure Reading in PSI	2700	2725	1750	1900	2000
End Pressure Reading in PSI	2725	2725	2725	2725	2300
Maximum Force on Billet, Tons	1700	1700	1687.5	1421.8	1437.5
Maximum Pressure on Billet in PSI	143,100	143,100	140,800	119,800	120,000
Extrusion Length in Inches	135	120	213	233	219
Extrusion Surface Finish	Heavy Rupture & Striation	Heavy Rupture & Striation	Slight Rupture & Heavy Striations	Heavy Rupture & Striation	Slight Rupture & Heavy Striations
Die Condition	Light Striations	Medium Striation & Pickup	Collapsed & Heavily Eroded	Heavily Eroded	Collapsed & Heavily Eroded
Die Rework	Re-polish	Cleanup & polish	Minor cleanup & repolish	None	None
Number of Pushes Through Same Die	2	3	4	3	4
Extrusion Speed in Inches Per Second	3	4	20	19.5	40
Billet Hardness Rockwell "B" Front	86	86	87	85	84
Middle	87	84	85	85	85
Back	88	86	83	85	86

TABLE III
EXTRUSION DEVELOPMENT DETAILS
THE BERYLLIUM CORPORATION

Item of Information		EXPERIMENTAL EXTRUSION NUMBER 11 1-13-59	12 1-13-59	13 1-13-59	14 1-13-59
Push Number		11-E	12-F	13-F	14-F
Primary Purpose of This Experiment		Solid Round Effort Duplication	Rectangular Shape Development	Rectangular Shape Development	Oversize Channel Development
Press Capacity, Tons		1700	1700	1700	1700
Stem Diameter in Inches		5 - 3/16	5 - 3/16	5 - 3/16	5 - 3/16
Container Diameter in Inches		5 - 1/2	5 - 1/2	5 - 1/2	5 - 1/2
Extrusion Ratio		46:1	16:1	16:1	18:1
Billet Material		Pure Be	Pure Be	Pure Be	Pure Be
Billet Size, Inches	Diameter	5 - 1/4	5 - 1/4	5 - 1/4	5 - 1/4
	Length	6 - 1/4	6 - 1/4	6 - 1/4	6 - 1/4
Billet Temperature, °F		1950	1950	1950	1950
Type of Billet Heating		Salt Bath	Salt Bath	Salt Bath	Salt Bath
Billet Heating Time in Minutes		30	30	30	30
Billet Lubricant		Powdered Glass	Powdered Glass	Powdered Glass	Powdered Glass
Die Lubricant		Bentonite Grease	Bentonite Grease	Bentonite Grease	Bentonite Grease
Container Lubricant		Bentonite Grease	Bentonite Grease	Bentonite Grease	Bentonite Grease
Die Design Number		2x-2DD Type II	2x-26D Type II	2x-25D Type I	2x-28D Type IV
Die Material		Hard Faced Die Steel	Hard Faced Die Steel	Hard Faced Die Steel	Hard Faced Die Steel
Type of Die		Flat Faced Insert	20° Lead-in Insert Type	Flat Faced Insert	Split Flat Faced Insert
Die Temperature, °F		750	625	Not Given	Not Given
Container Temperature, °F		750	750	750	750
Billet Transfer Time in Seconds		30	30	30	30
Starting Pressure Reading in PSI		2150	1200	1650	1675
End Pressure Reading in PSI		2350	1500	2100	2375
Maximum Force on Billet, Tons		1468.7	937.5	1312.5	1500
Maximum Pressure on Billet in PSI		120,800	78,900	107,600	123,500
Extrusion Length in Inches		246	92	99	108
Extrusion Surface Finish		Severe Rupturing	Severe Rupturing	Severe Rupturing	Severe Rupturing
Die Condition		Good; No Pickup	Good; No Pickup	Good; No Pickup	Collapsed & Washed Out
Die Rework		Opened from 3/4" to 13/16"	None	None	None
Number of Pushes Through Same Die		4	1	1	1
Extrusion Speed in Inches Per Second		Not Obtained	5	4.5	2 to 10.5
Billet Hardness Rockwell "B"	Front	86	87	88	86
	Middle	85	87	87	87
	Back	85	88	88	86

TABLE IV
EXTRUSION DEVELOPMENT DETAILS
THE BERYLLIUM CORPORATION

Item of Information	EXPERIMENTAL EXTRUSION NUMBER 15 1-13-59	16 1-13-59	17 1-13-59	18 1-26-59
Push Number	15	16-F	17-F	18
Primary Purpose of This Experiment	Rectangular Shape Development	Z-1 Shape Development	Z-1 Shape Development	Lubrication Study
Press Capacity, Tons	1700	1700	1700	1700
Stem Diameter in Inches	5 - 3/16	5 - 3/16	5 - 3/16	5 - 3/16
Container Diameter in Inches	5 - 1/2	5 - 1/2	5 - 1/2	5 - 1/2
Extrusion Ratio	16:1	54:1	54:1	30.5:1
Billet Material	Pure Be	Pure Be	Pure Be	Pure Be
Billet Size, Inches Diameter	5 - 1/4	5 - 1/4	5 - 1/4	5 - 1/4
Billet Size, Inches Length	6 - 1/4	6 - 1/4	6 - 1/4	5 - 3/4
Billet Temperature, °F	1850	1850	1950	1700
Type of Billet Heating	Salt Bath	Salt Bath	Salt Bath	Salt Bath
Billet Heating Time in Minutes	30	30	30	30
Billet Lubricant	Powdered Glass	Powdered Glass	Powdered Glass	Lithium Carbonate
Die Lubricant	Bentonite Grease	Bentonite Grease	Bentonite Grease	Bentonite Grease
Container Lubricant	Bentonite Grease	Bentonite Grease	Bentonite Grease	Bentonite Grease
Die Design Number	2x-25D Type I	2x-30D Type V	2x-30D Type V	2x-2D
Die Material	Hard Faced Die Steel	Hard Faced Die Steel	Hard Faced Die Steel	Hard Faced Die Steel
Type of Die	Flat Faced Insert	Split Flat Faced Insert	Split Flat Faced Insert	Flat Faced Insert
Die Temperature, °F	700	700	700	700
Container Temperature, °F	725	725	750	750
Billet Transfer Time in Seconds	30	30	30	30
Starting Pressure Reading In PSI	1250	2725	Chart Broke	1950
End Pressure Reading in PSI	2650	2725	Chart Broke	2625
Maximum Force on Billet, Tons	1700	1700	Chart Broke	1640.6
Maximum Pressure on Billet in PSI	140,800	140,800	Chart Broke	138,400
Extrusion Length in Inches	81	Press Stalled	Broke in Pieces Not Measured	120
Extrusion Surface Finish	Severe Rupturing	No Extrusion	Severe Rupturing	Severe Rupturing
Die Condition	Collapsed & Washed Out	Good	Collapsed & Washed Out	Washout Behind Hard Facing
Die Rework	None	None	None	None
Number of Pushes Through Same Die	2	1	2	2
Extrusion Speed in Inches Per Second	1.94	Press Stalled	Chart Broke; No Record	5.5
Billet Hardness Rockwell "B" Front	85	86	84	91
Billet Hardness Rockwell "B" Middle	86	86	84	94
Billet Hardness Rockwell "B" Back	87	86	84	95

APPENDIX V

Nuclear Metals
Extrusion Data Sheets

Tests Conducted Using Sejournet
Glass Lubricant Technology

TABLE I
EXTRUSION DEVELOPMENT DETAILS
NUCLEAR METALS, INC.

Item of Information	EXPERIMENTAL EXTRUSION NUMBER 1	2	3	4	5
Primary Purpose of This Experiment	Lubrication Technique Development	Not Given	Not Given	Not Given	Flow and Lubrication Study
Press Capacity, Tons	1100	1100	1100	1100	1100
Stem Diameter, Inches	3 - 1/2	3 -1/2	3 - 1/2	3 - 1/2	3 - 1/2
Container Diameter, Inches	3 - 5/8	3 - 5/8	3 - 5/8	3 - 5/8	3 - 5/8
Extrusion Ratio	27:1	27:1	27:1	27:1	27:1
Billet Material	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder	Cold Rolled Steel
Billet Length, Inches	3	3	3	3	3
Billet Temperature, °F	1950	1950	1850	1780	1950
Type of Billet Heating	Resistance Furnace Argon Atmosphere	Resistance Furnace Argon Atmosphere	Resistance Furnace Argon Atmosphere	Resistance Furnace Argon Atmosphere	Resistance Furnace Argon Atmosphere
Billet Heating Time in Minutes	75	90	120	150	210
Billet Lubricant	Type C Glass	Glass, Types C & D-6	Types C & D-6 Glass	Type C & D-6 Glass	Types C & D-6 Glass
Die Lubricant	Type E Glass	Type G Glass	Type E Glass	Type E Glass	Type E Glass
Container Lubricant	Not Given	Type D-6 Glass	Type D-6 Glass	Type D-6 Glass	Type D-6 Glass
Die Design Designation	0.70-in Round Hole	0.70-in Round Hole	0.70-in Round Hole	0.70-in Round Hole	0.70-in Round Hole
Die Material	18-4-1 Tool Steel	18-4-1 Tool Steel	18-4-1 Tool Steel	18-4-1 Tool Steel	18-4-1 Tool Steel
Type of Die Fabrication	Machined & Hardened	Machined & Hardened	Machined & Hardened	Machined & Hardened	Machined & Hardened
Die Temperature, °F	900	900	900	900	900
Container Temperature, °F	900	900	900	900	900
Billet Transfer Time in Seconds	12	12	12	12	12
Maximum Force on Billet in Tons	Not Given	Not Given	474	559	457
Maximum Pressure on Billet in PSI	Not Given	Not Given	Not Given	Not Given	Not Given
Extrusion Length, Inches	Not Given	Not Given	Not Given	Not Given	72
Extrusion Surface Finish	Rattlesnaked	Poor	Poor	Fair	Good
Die Condition	Good	Good	Good	Good	Good
Die Rework	None	Not Given	Not Given	Not Given	Not Given
Number of Pushes Through Same Die	1	Not Given	Not Given	Not Given	Not Given
Ram Speed in Inches Per Minute	120	144	55	55	Not Given
Extrusion Configuration	Round Rod	Round Rod	Round Rod	Round Rod	Round Steel Rod

TABLE II
EXTRUSION DEVELOPMENT DETAILS
NUCLEAR METALS, INC.

Item of Information	EXPERIMENTAL EXTRUSION NUMBER 6	7	8	9	10
Primary Purpose of This Experiment	Not Given	Speed Evaluation	Speed & Temperature Evaluation	Selection of Variables	Not Given
Press Capacity, Tons	1100	1100	1100	1100	1100
Stem Diameter, Inches	3 - 1/2	3 - 1/2	3 - 1/2	3 - 1/2	3 - 1/2
Container Diameter, Inches	3 - 5/8	3 - 5/8	3 - 5/8	3 - 5/8	3 - 5/8
Extrusion Ratio	27:1	27:1	27:1	35:1	35:1
Billet Material	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder
Billet Length, Inches	3	3	3	3	3
Billet Temperature, °F	1750	1750	1950	1750	1750
Type of Billet Heating	Resistance Furnace Argon Atmosphere	Resistance Furnace Argon Atmosphere	Resistance Furnace Argon Atmosphere	Resistance Furnace Argon Atmosphere	Resistance Furnace Argon Atmosphere
Billet Heating Time in Minutes	80	90	150	90	105
Billet Lubricant	Glass, Types B, D-4 & F	Glass, Types B, D-5 & F	Glass, Types C, D-4 & F	Glass, Types B, F, & D-5	Glass, Types B, F, & D-5
Die Lubricant	Type E Glass	Type E Glass	Glass, Type G	Type E Glass	Type E Glass
Container Lubricant	Glass, Types D-4 & F	Glass, Types D-5 & F	Glass, Types D-4 & F	Type D-5 Glass	Type D-5 Glass
Die Design Designation	0.70 inch Round Hole	0.70 inch Round Hole	0.70 inch Round Hole	Z-1-A	Z-1-C
Die Material	18-4-1 Tool Steel	18-4-1 Tool Steel	18-4-1 Tool Steel	M-2	H-13 Steel
Type of Die Fabrication	Machined & Hardened	Machined & Hardened	Machined & Hardened	Forged, Machined & Hardened	Forged, Machined & Hardened
Die Temperature, °F	900	900	900	900	900
Container Temperature, °F	900	900	900	900	900
Billet Transfer Time in Seconds	12	12	12	12	12
Maximum Force on Billet in Tons	593	949	Not Given	848	Over 800
Maximum Pressure on Billet in PSI	Not Given	Not Given	Not Given	163,000	Not Given
Extrusion Length, Inches	72	72	72	None	Not Given
Extrusion Surface Finish	Good	Rattlesnaked	Good	Equipment Broke	Corners & Tongue Smeared
Die Condition	Good	Die Broke	Good	Die Broke	New Die Used
Die Rework	Not Given	None	Not Given	None	None
Number of Pushes Through Same Die	Not Given	Not Given	Not Given	1	1
Ram Speed in Inches Per Minute	Not Given	Not Given	Not Given	80	80
Extrusion Configuration	Round Rod	Round Rod	Round Rod	None Produced	Z-1 Channel

TABLE III
EXTRUSION DEVELOPMENT DETAILS
NUCLEAR METALS, INC.

Item of Information	EXPERIMENTAL EXTRUSION NUMBER 11	12	13	14	15
Primary Purpose of This Experiment	Temperature & Speed Increased	Temperature & Lubricant variation	Increase in Speed	Lower Temp. Glass Evaluation	Glass Combination Tried
Press Capacity, Tons	1100	1100	1100	1100	1100
Stem Diameter, Inches	3 - 1/2	3 - 1/2	3 - 1/2	3 - 1/2	3 - 1/2
Container Diameter, Inches	3 - 5/8	3 - 5/8	3 - 5/8	3 - 5/8	3 - 5/8
Extrusion Ratio	35:1	35:1	35:1	35:1	35:1
Billet Material	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder
Billet Length, Inches	3	3	3	3	3
Billet Temperature, °F	1800	1800	1800	1800	1800
Type of Billet Heating	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere
Billet Heating Time in Minutes	180	120	120	90	120
Billet Lubricant	Glass, Types B, F, & D-5	Glass, Types J, F, & D-6	Glass, Types J, F, & D-6	Glass, Types B, F, & D-4	Glass, Types B, F, & D-2
Die Lubricant	Type E Glass	Type G Glass	Type G Glass	Type E Glass	Type E Glass
Container Lubricant	Type D-5 Glass	Type D-6 Glass	Type D-6 Glass	Type D-4 Glass	Type D-2 Glass
Die Design Designation	Z-1-D	Z-1-C	Z-1-C	Z-1-C	Z-1-C
Die Material	M-2 Tool Steel	H-13 Tool Steel	H-13 Tool Steel	H-13 Tool Steel	H-13 Tool Steel
Type of Die Fabrication	Forged, Machined & Hardened	Forged, Machined & Hardened	Forged, Machined & Hardened	Forged, Machined & Hardened	Forged, Machined & Hardened
Die Temperature, °F	900	900	900	900	900
Container Temperature, °F	900	900	900	900	900
Billet Transfer Time in Seconds	12	12	12	12	12
Maximum Force on Billet in Tons	560	900	975	560	560
Maximum Pressure on Billet in PSI	108,000	Not Given	Press Stalled	108,000	108,000
Extrusion Length, Inches	Not Given	None, Press Stalled	Not Given	Not Given	Not Given
Extrusion Surface Finish	Not Given	None Produced	Smeared by Die	Not Given	Not Given
Die Condition	New Die Used	Die Tongue Smeared	Not Given	Tongue Smeared	Tongue Corners Smeared
Die Rework	None	None	None	None	Yes
Number of Pushes Through Same Dies	1	1	1	1	2
Ram Speed in Inches Per Minute	110	14	80	14	70
Extrusion Configuration	Z-1 Channel	None Channel	Z-1 Channel	Z-1 Channel	Z-1 Channel

TABLE IV
EXTRUSION DEVELOPMENT DETAILS
NUCLEAR METALS, INC.

EXPERIMENTAL EXTRUSION NUMBER

Item of Information	16	17	18	19	20
Primary Purpose of This Experiment	Test Glass Disc	Test Glass Disc	Not Given	Not Given	Test $LiCO_3$ Lubricant
Press Capacity, Tons	1100	1100	1100	1100	1100
Stem Diameter, Inches	3 - 1/2	3 - 1/2	3 - 1/2	3 - 1/2	3 - 1/2
Container Diameter, Inches	3 - 5/8	3 - 5/8	3 - 5/8	3 - 5/8	3 - 5/8
Extrusion Ratio	26:1	26:1	26:1	26:1	26:1
Billet Material	Machined Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder
Billet Length, Inches	3	3	3	3	3
Billet Temperature, °F	1800	1800	1800	1750	1800
Type of Billet Heating	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere
Billet Heating Time in Minutes	120	100	120	150	135
Billet Lubricant	Glass, Types C, F & D-2	Glass Types B, F, & D-2	Glass, Types B, F, & D-2	Glass, Types B, F, & D-2	Types D-2 Glass
Die Lubricant	Types E & D-4 Glass	Type E Glass	Type E Glass	Type E Glass	$LiCO_3$ Disc
Container Lubricant	Types C & D-2 Glass	Types F & D-2 Glass	Types F & D-2 Glass	Types F & D-2 Glass	Not Given
Die Design Designation	Z-1-D	Z-1-C Modified	Z-1-C Modified	Z-1-C	Z-1-C
Die Material	M-2 Tool Steel	H-13 Tool Steel	M-2 Tool Steel	H-13 Tool Steel	H-13 Tool Steel
Type of Die Fabrication	Forged, Machined & Hardened	Forged, Machined & Hardened	Forged, Machined & Hardened	Forged, Machined & Hardened	Forged, Machined & Hardened
Die Temperature, °F	900	900	60 (Approx)	Cold	Room (70)
Container Temperature °F	900	900	900	900	900
Billet Transfer Time in Seconds	12	12	12	12	12
Maximum Force on Billet in Tons	700	600	600	600	900
Maximum Pressure on Billet in PSI	Not Given	Not Given	Not Given	Not Given	Not Given
Extrusion Length, Inches	83	75	62	84	None, Press Stalled
Extrusion Surface Finish	Rattlesnaked	Hot Spots & Rattlesnaked	Rattlesnake Plus 18inch good channel	Mild Rattlesnake	No Extrusion
Die Condition	Die Tongue Corners washed Away	Bottom Corners of Tongue washed	Slight Wash of Lower Tongue Corners	Good	Good
Die Rework	None	None	Yes	None	None
Number of Pushes Through Same Die	1	1	3	1	1
Ram Speed in Inches Per Minute	70	70	Varied From 70 Down to 14	14 (Minimum)	70
Extrusion Configuration	Z-1 Channel	Z-1 Channel	Z-1 Channel	Z-1 Channel	None Produced

TABLE V
EXTRUSION DEVELOPMENT DETAILS
NUCLEAR METALS, INC.

Item of Information	EXPERIMENTAL EXTRUSION NUMBER				
	21	22	23	24	25
Primary Purpose of This Experiment	Test $LiCO_3$ Lubricant	Test Lead-in Cone	Test Lead-in Cone	Test Chrome Plated Die	Evaluate $LiCO_3$ Disc
Press Capacity, Tons	1100	1100	1100	1100	1100
Stem Diameter, Inches	3 - 1/2	3 - 1/2	3 - 1/2	3 - 1/2	3 - 1/2
Container Diameter, Inches	3 - 5/8	3 - 5/8	3 - 5/8	3 - 5/8	3 - 5/8
Extrusion Ratio	26:1	26:1	26:1	26:1	26:1
Billet Material	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder
Billet Length, Inches	3	4	6	3	3
Billet Temperature, ^{o}F	1800	1800	1850	1750	1750
Type of Billet Heating	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere
Billet Heating Time in Minutes	180	190	240	120	150
Billet Lubricant	Glass, Types B F, & D-2	Glass, Types B, F, & D-2	Glass, Types B, F, & D-2	Glass, Types B, F, & D-5	Type B Glass
Die Lubricant	$LiCO_3$ Disc	Type E Glass	Type E Glass	Type E Glass	$LiCO_3$ Disc
Container Lubricant	Types F & D-2 Glass	Types F & D-2 Glass	Types F & D-2 Glass	Type D-5 Glass Glass	Oil Dag
Die Design Designation	Z-1-C Modified	Z-1-C Modified	Z-1-C Modified	Z-1-C Modified	Z-1-C Modified
Die Material	H-13 Tool Steel	H-13 Tool Steel	H-13 Tool Steel	18-4-1 Plated Tool Steel	H-13 Tool Steel
Type of Die Fabrication	Forged, Machined,&Hardened	Forged, Machined,& Hardened	Forged, Machined,&Hardened	Forged, Machined,&Hardened	Forged, Machined,&Hardened
Die Temperature, ^{o}F	Room (70)	Room (70)	Room (70)	Room (70)	Room (70)
Container Temperature, ^{o}F	900	900	900	900	900
Billet Transfer Time in Seconds	12	22	30	12	12
Maximum Force on Billet in Tons	900	900	900	500	550
Maximum Pressure on Billet In PSI	Not Given	Not Given	Not Given	Not Given	Not Given
Extrusion Length, Inches	None, Press Stalled	Press Stalled	Not Given	94	90
Extrusion Surface Finish	No Extrusion	Press Stalled	Very Poor	Not Given	Rattlesnaked
Die Condition	Good	Good	Not Given	Poor	Not Given
Die Rework	None	None	Not Given	None	None
Number of Pushes Through Same Die	2	3	4	1	1
Ram Speed in Inches Per Minute	70	70	70	70	70
Extrusion Configuration	None Produced	None Produced	Z-1 Channel	Z-1 Channel	Z-1 Channel

TABLE VI
EXTRUSION DEVELOPMENT DETAILS
NUCLEAR METALS, INC.

Item of Information	EXPERIMENTAL EXTRUSION NUMBER 26	27	28	29	30
Primary Purpose of This Experiment	High Temp, High Speed Extrusion Test	Testing of Z-1-V Die	Testing of Z-1-V Die	Test Wide Flange Die	Repeat of Extrusion No. 29
Press Capacity, Tons	1100	1100	1100	1100	1100
Stem Diameter, Inches	3 - 1/2	3 - 1/2	3 - 1/2	3 - 1/2	3 - 1/2
Container Diameter, Inches	3 - 5/8	3 - 5/8	3 - 5/8	3 - 5/8	3 - 5/8
Extrusion Ratio	26:1	19:1	19:1	26:1	26:1
Billet Material	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder
Billet Length, Inches	3	3 - 1/2	3 - 1/2	3 - 1/2	3 - 1/2
Billet Temperature, °F	1900	1680	1735	1745	1745
Type of Billet Heating	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere
Billet Heating Time in Minutes	180	Not Given	Not Given	Not Given	Not Given
Billet Lubricant	Glass C & $LiCO_3$ Powder	Types B, F, & D-5 Glass	Types B, F, & D-5 Glass	Types B, F, & D-5 Glass	Types B, F, & D-5 Glass
Die Lubricant	$LiCO_3$ Disc	Type E Glass	Type E Glass	Type E Glass	Type E Glass
Container Lubricant	Oil Dag	Types F & D-5 Glass	Types F & D-5 Glass	Types F & D-5 Glass	Types F & D-5 Glass
Die Design Designation	Z-1-C Modified	Z-1-V	Z-1-DL	Z-1-C with Wide Flanges	Z-1-C with Wide Flanges
Die Material	18-4-1 Tool Steel	M-2 Tool Steel	M-2 Tool Steel	H-13 Tool Steel	H-13 Tool Steel
Type of Die Fabrication	Forged, Machined,&Hardened	Forged Machined,&Hardened	Forged Machined,&Hardened	Forged, Machined,&Hardened	Forged, Machined,&Hardened
Die Temperature, °F	Room (70)	Cold	Cold	Cold	Cold
Container Temperature, °F	900	800	800	800	800
Billet Transfer Time in Seconds	12	12	12	25	12
Maximum Force on Billet in Tons	525	550	600	Press Stalled	Press Stalled
Maximum Pressure on Billet in PSI	Not Given	Not Given	Not Given	Press Stalled	Press Stalled
Extrusion Length, Inches	93	72	69	None, Press Stalled	None, Press Stalled
Extrusion Surface Finish	Rattlesnaked	Partially Rattlesnaked	4 Minor Rattlesnakes	No Extrusion	No Extrusion
Die Condition	Not Given	Die Cracked	Slight Washout	Good	Good
Die Rework	None	None	None	Yes	Yes
Number of Pushes Through Same Die	1	1	1	3	4
Ram Speed in Inches Per Minute	144	70	70	70	70
Extrusion Configuration	Z-1 Channel	Z-1 Channel	Z-1 Channel	No Extrusion	No Extrusion

TABLE VII
EXTRUSION DEVELOPMENT DETAILS
NUCLEAR METALS, INC.

EXPERIMENTAL EXTRUSION NUMBER

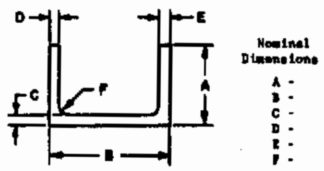
Item of Information	31	32	33	34	35
Primary Purpose of This Experiment	Test of Nitrided Die	Repeat Test of Extrusion No.28	Test Cast Stellite Insert Die	Test Metallic Lead-in Billet	Test Stellite Cast Insert Die
Press Capacity, Tons	1100	1100	1100	1100	1100
Stem Diameter, Inches	3 - 1/2	3 - 1/2	3 - 1/2	3 - 1/2	3 - 1/2
Container Diameter, In Inches	3 - 5/8	3 - 5/8	3 - 5/8	3 - 5/8	3 - 5/8
Extrusion Ratio	19:1	19:1	26:1	26:1	26:1
Billet Material	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder	Sintered Beryllium Powder
Billet Length, Inches	3 - 1/2	3 - 1/2	3 - 1/2	3 - 1/2	3 - 1/2
Billet Temperature, °F	1800	1755	1750	1750	1750
Type of Billet Heating	Molten Salt Bath	Resistance Furnace, Argon Atmosphere	Molten Salt Bath	Resistance Furnace, Argon Atmosphere	Resistance Furnace, Argon Atmosphere
Billet Heating Time in Minutes	15 Min Soak	210	60-Min Soak	240	270
Billet Lubricant	Types F & D-5 Glass	Types B, F, & D-5 Glass	Types F & D-5 Glass	Types B, F, & D-5 Glass	Types B, F, & D-5 Glass
Die Lubricant	Type E Glass	Type E Glass	Type E Glass	Type E Glass	Type E Glass
Container Lubricant	Types F & D-5 Glass	Types D-5 & F Glass	Types F & D-5 Glass	Types F & D-5 Glass	Types F & D-5 Glass
Die Design Designation	Z-1-V	Z-1-DL	PMD-1	PMD-1	PMD-2
Die Material	Nitrided H-13 Tool Steel	Nitrided H-13 Tool Steel	PMD Stellite Alloy	PMD Stellite Alloy	PMD Stellite Alloy
Type of Die Fabrication	Forged Machined & Hardened	Forged Machined & Hardened	Insert Shrunk Fit into Die Base	Hard Insert Shrunk Fit into Die Base	Hard Insert Shrunk Fit into Die Base
Die Temperature, °F	Cold	Cold	Not Given	900	900
Container Temperature °F	900	900	900	900	900
Billet Transfer Time in Seconds	12	12	12	12	12
Maximum Force on Billet in Tons	900	750	900	400	900
Maximum Pressure on Billet in PSI	Not Given	Not Given	Not Given	Not Given	Not Given
Extrusion Length, Inches	70	143	106	150	72
Extrusion Surface Finish	One Flange Heavily Rattlesnaked	Partially Rattlesnaked	On Side of Channel Rattlesnaked	No Rattlesnakes	Slivered into many pieces
Die Condition	Considerable washout	Considerable washout	Good	Good; no washout	Good
Die Rework	None	None	None	None	None
Number of Pushes Through Same Die	1	1	1	2	1
Ram Speed in Inches Per Minute	70	70	70	70	70
Extrusion Configuration	Z-1 Channel	Z-1 Channel	Z-1 Channel	Z-1 Channel	Z-1 Channel

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	36 (NMI-21065)	Die Temp., °F	900°F
Primary Purpose of this Experiment	Duplicate No. 34	Container Temp., °F	900°F
Press Capacity	1100 tons	Billet Transfer Time in Seconds	26
Stem Diameter	3.400	Starting Pressure Reading in psi	116,000
Container Diameter	3.625	End Pressure Reading in psi	195,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	900
Billet Material	Be sintered bar	Max Pressure on Billet in psi	198,000
Billet Length	3 inches	Extrusion Length in inches	70
Billet Temp., °F	1750°F	Extrusion Surface Finish	Good
Type of Billet Heating	Furnace (Argon atm)	Die Condition	Good
Billet Heating Time in Minutes	150	Die Rework	None
Billet Lubricant	NMI "B and F"	No. of Extrusions Through Same Die	1 before
Die Lubricant	NMI "E"	Lead-in billet	3 inches Cu-Ni
Container Lubricant	D-2		
Die Design No.	PMD-2 inverted		
Die Material	Stellite		

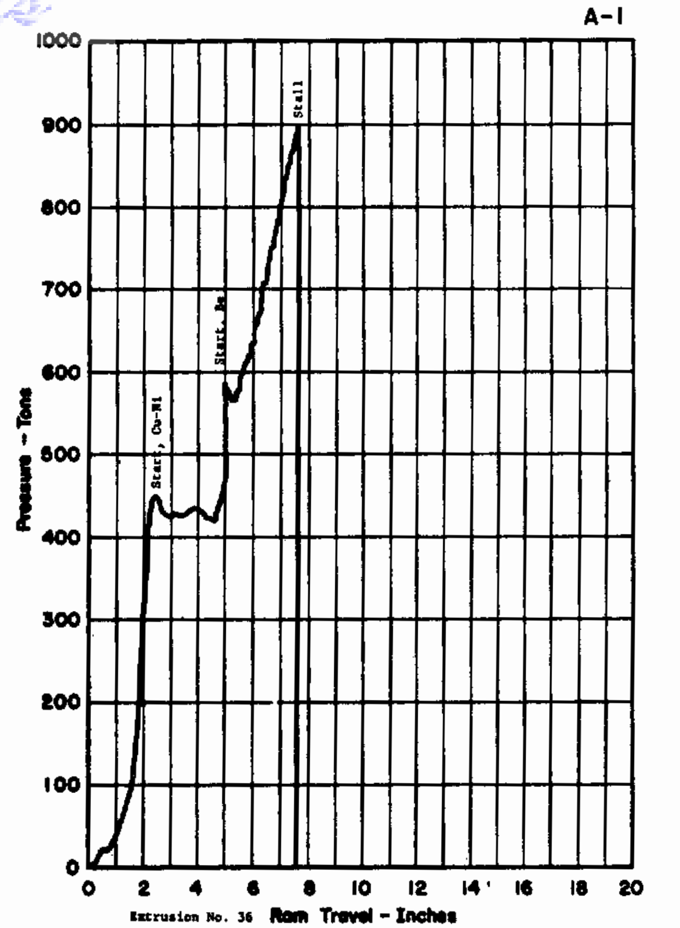
Extrusion Section Dimensions			
	Front	A	0.978
		B	1.377 (T) 1.491 (B)
		C	0.112
		D	0.114
		E	0.117
		F	0.150R
	Center	A	0.9865
		B	1.305 (T) 1.503 (B)
		C	0.106
		D	0.116
		E	0.115
		F	0.150R
	Rear	A	0.997
		B	1.324 (T) 1.521 (B)
		C	0.102
		D	0.113
		E	0.116
		F	0.150R

Extruded Shape Sketch:



REMARKS:

Channel free of rattlesnakes, last 1/2 inch of billet stalled.



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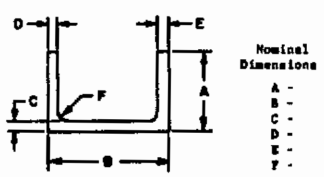
BERYLLIUM EXTRUSION TEST DATA

Task A, June 3, 1959

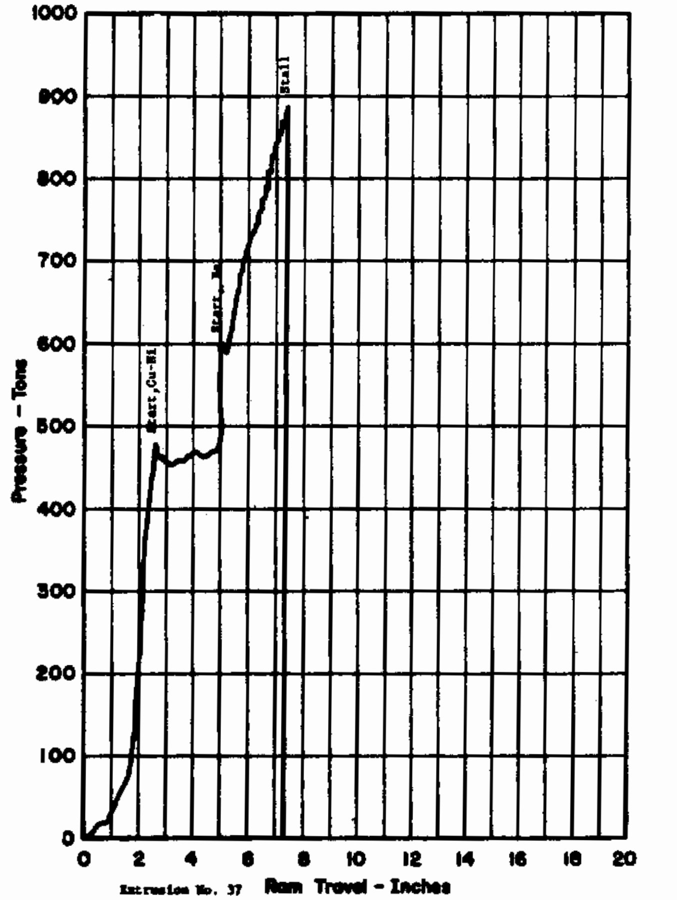
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	37 (NMI-21066)	Die Temp., °F	900°F
Primary Purpose of this Experiment	Duplicate No. 34	Container Temp., °F	900°F
Press Capacity	1100 Tons	Billet Transfer Time in Seconds	26
Stem Diameter	3.400	Starting Pressure Reading in psi	130,000
Container Diameter	3.625	End Pressure Reading in psi	193,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	880
Billet Material	Be sintered bar	Max Pressure on Billet in psi	193,000
Billet Length	3 inches	Extrusion Length in inches	70
Billet Temp., °F	1750°F	Extrusion Surface Finish	Good
Type of Billet Heating	Furnace (Argon atm)	Die Condition	Normal
Billet Heating Time in Minutes	180	Die Rework	None
Billet Lubricant	NMI "B and F"	No. of Extrusions Through Same Die	1 before
Die Lubricant	NMI "E"	Lead-in billet	3 inches Cu-Ni
Container Lubricant	D-2		
Die Design No.	PMD-1 inverted		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	0.959
		B	1.405(T) 1.508(B)
		C	0.1225
		D	0.114
		E	0.113
		F	0.100R
	Center	A	0.970
		B	1.529(T) 1.5155(B)
		C	0.091
		D	0.116
		E	0.115
		F	0.100R
	Rear	A	1.004
		B	1.5265(T) 1.511 (B)
		C	0.089
		D	0.113
		E	0.116
		F	0.100R

Extruded Shape Sketch:



REMARKS: Channel free of rattlesnakes, last 1/2 inch of billet stalled.



RA1102

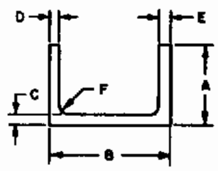
BERYLLIUM EXTRUSION TEST DATA

Task A, June [illegible], 1959

Subcontractor	NMI	Type of Die Fabrication	Hard faced
Extrusion No.	38 (NMI-21067)	Die Temp., °F	900°F
Primary Purpose of this Experiment	To duplicate No. 34	Container Temp., °F	900°F
Press Capacity	1100 Tons	Billet Transfer Time in Seconds	27
Stem Diameter	3.400	Starting Pressure Reading in psi	126,000
Container Diameter	3.625	End Pressure Reading in psi	191,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	870
Billet Material	Be sintered bar	Max Pressure on Billet in psi	191,000
Billet Length	3 inches	Extrusion Length in inches	59
Billet Temp., °F	1750°F	Extrusion Surface Finish	Good
Type of Billet Heating	Furnace (Argon atm)	Die Condition	Good
Billet Heating Time in Minutes	165	Die Rework	None
Billet Lubricant	NMI "B and F"	No. of Extrusions Through Same Die	None before
Die Lubricant	NMI "E"	Lead-in billet	3 inches Cu-Ni
Container Lubricant	D-2		
Die Design No.	MC-38 inverted		
Die Material	Steel, hard-faced		

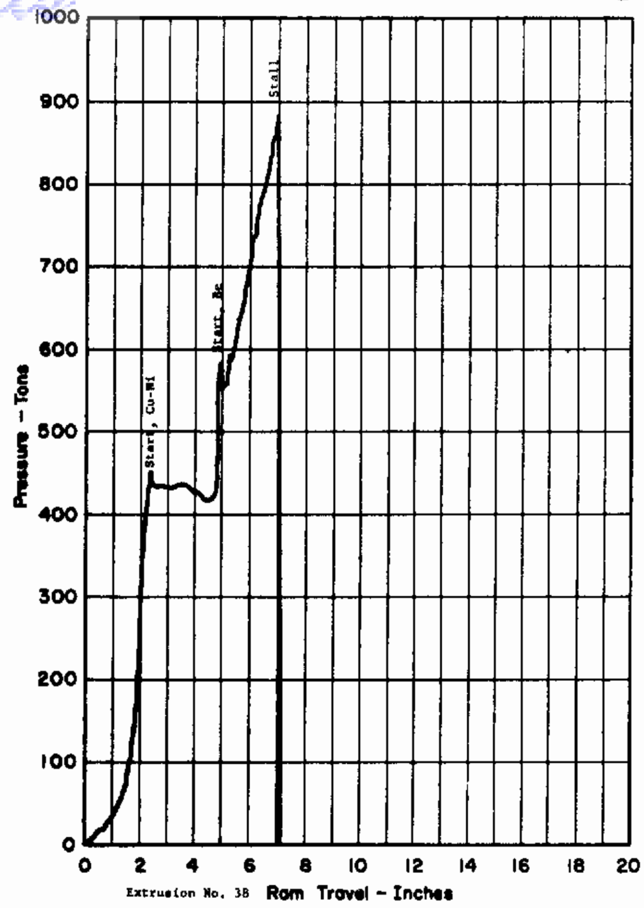
Extrusion Section Dimensions			
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: One side of channel rattle-snaked. Last 1/2 inch of billet stalled. No dimensions taken because channel was too distorted.



Extrusion No. 38

RA1102

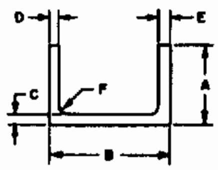
BERYLLIUM EXTRUSION TEST DATA

Task A, June 24, 1959

Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	39 (NMI-21195)	Die Temp., °F	900°F
Primary Purpose of this Experiment	To extrude without stalling	Container Temp., °F	900°F
Press Capacity	1000 Tons	Billet Transfer Time in Seconds	29
Stem Diameter	3.400	Starting Pressure Reading in psi	200,000
Container Diameter	3.625	End Pressure Reading in psi	200,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	910
Billet Material	Be	Max Pressure on Billet in psi	200,000
Billet Length	5 inches	Extrusion Length in inches	0 (stalled)
Billet Temp., °F	1950°F	Extrusion Surface Finish	None
Type of Billet Heating	Furnace (Argon atm)	Die Condition	Normal
Billet Heating Time in Minutes	270	Die Rework	None
Billet Lubricant	NMI "C"	No. of Extrusions Through Same Die	2 before
Die Lubricant	NMI "G"	Lead-in billet	3 inches Cu-Ni
Container Lubricant	NMI "F" and "D7"		
Die Design No.	PMD-1 inverted		
Die Material	Stellite		

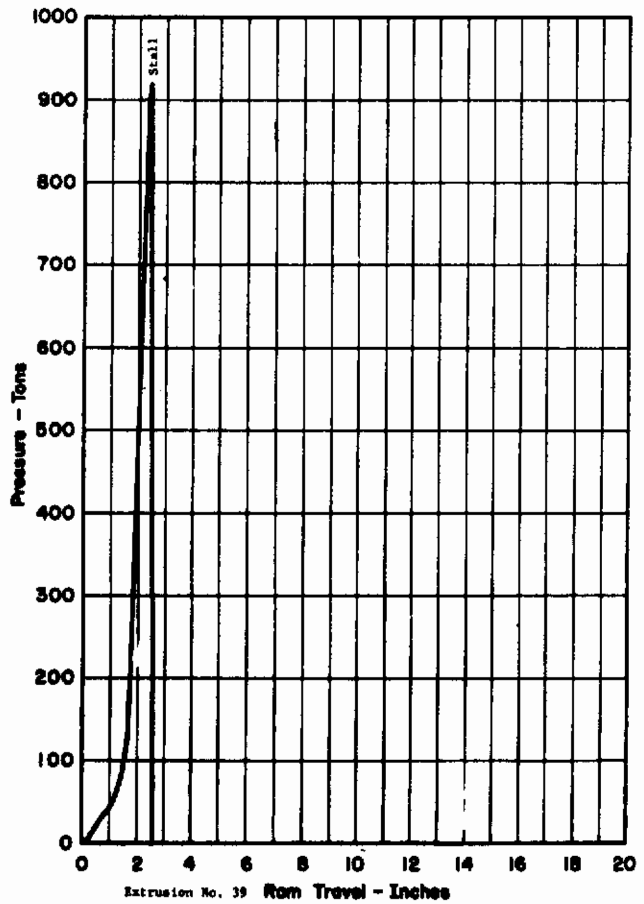
Extrusion Section Dimensions			
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Billet stalled since Cu-Ni lead-in billet was at too low a temperature. No channel was produced.



Extrusion No. 39

RA1102

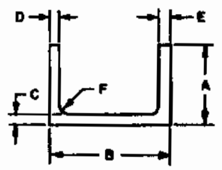
BERYLLIUM EXTRUSION TEST DATA

Task A, June 24, 1959

Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	40 (NMI-21196)	Die Temp., °F	900°F
Primary Purpose of this Experiment	To extrude without stalling	Container Temp., °F	900°F
Press Capacity	1000 Tons	Billet Transfer Time in Seconds	26
Stem Diameter	3.400	Starting Pressure Reading in psi	140,000
Container Diameter	3.625	End Pressure Reading in psi	200,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	910
Billet Material	Be	Max Pressure on Billet in psi	200,000
Billet Length	5inches	Extrusion Length in inches	139 inches (24 inches rattlesnaked)
Billet Temp., °F	1950°F	Extrusion Surface Finish	Good
Type of Billet Heating	Furnace (Argon atm)	Die Condition	Normal
Billet Heating Time in Minutes	290	Die Rework	None
Billet Lubricant	NMI "C"	No. of Extrusions Through Same Die	2 before
Die Lubricant	NMI "C"	Lead-in billet	3 inches Cu-Ni
Container Lubricant	NMI "F" and "D7"		
Die Design No.	FMD-1		
Die Material	Stellite		

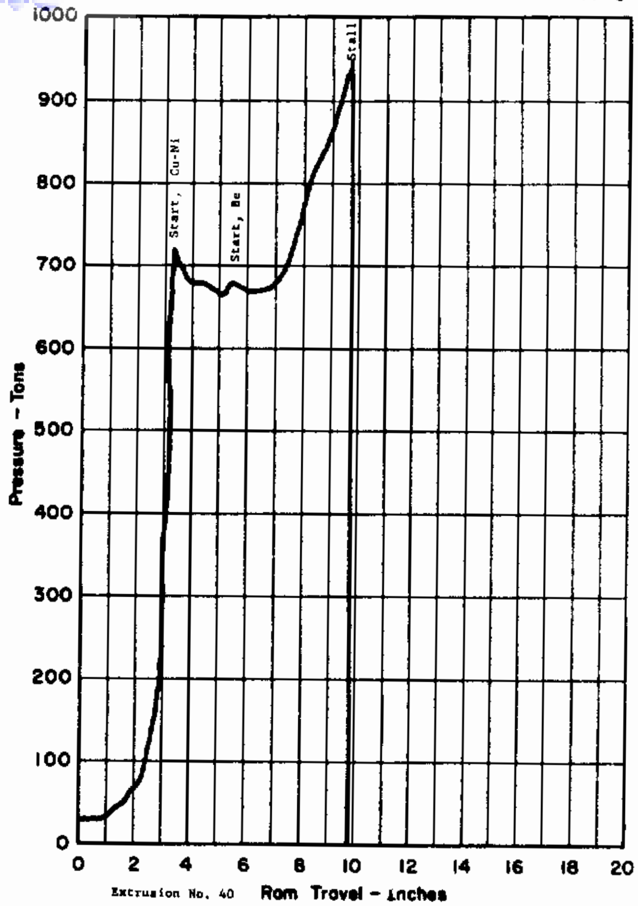
Extrusion Section Dimensions			
Front	A	0.991	
	B	1.508(B) 1.452(T)	
	C	0.103	
	D	0.111	
	E	0.109	
	F	0.150R	
Center	A	1.002	
	B	1.449(B) 1.379(T)	
	C	0.093	
	D	0.118	
	E	0.116	
	F	0.150R	
Rear	A	0.989	
	B	1.506(B) 1.326(T)	
	C	0.080	
	D	0.103	
	E	0.109	
	F	0.150R	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Longest length of unrattlesnaked channel to date. Pressure rose rapidly at end of run. The reasons for this are not fully understood. Last 1 inch of billet stalled.



Extrusion No. 40

RA1102

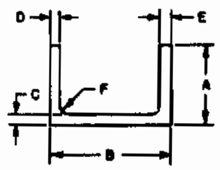
BERYLLIUM EXTRUSION TEST DATA

Task A, June 24, 1959

Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	41 (NMI-21197)	Die Temp., °F	900°F
Primary Purpose of this Experiment	To extrude a 20-foot length	Container Temp., °F	900°F
Press Capacity	1000 Tons	Billet Transfer Time in Seconds	30
Stem Diameter	3.400	Starting Pressure Reading in psi	189,000
Container Diameter	3.625	End Pressure Reading in psi	220,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	995
Billet Material	Be	Max Pressure on Billet in psi	220,000
Billet Length	11 inches	Extrusion Length in inches	None - stalled
Billet Temp., °F	1950°F	Extrusion Surface Finish	None
Type of Billet Heating	Furnace (Argon atm)	Die Condition	Normal
Billet Heating Time in Minutes	310	Die Rework	None
Billet Lubricant	NMI "C"	No. of Extrusions Through Same Die	2 before
Die Lubricant	NMI "C"	Lead-in billet	3 inches Cu-Ni
Container Lubricant	NMI "F" and "D7"		
Die Design No.	FMD-1		
Die Material	Stellite		

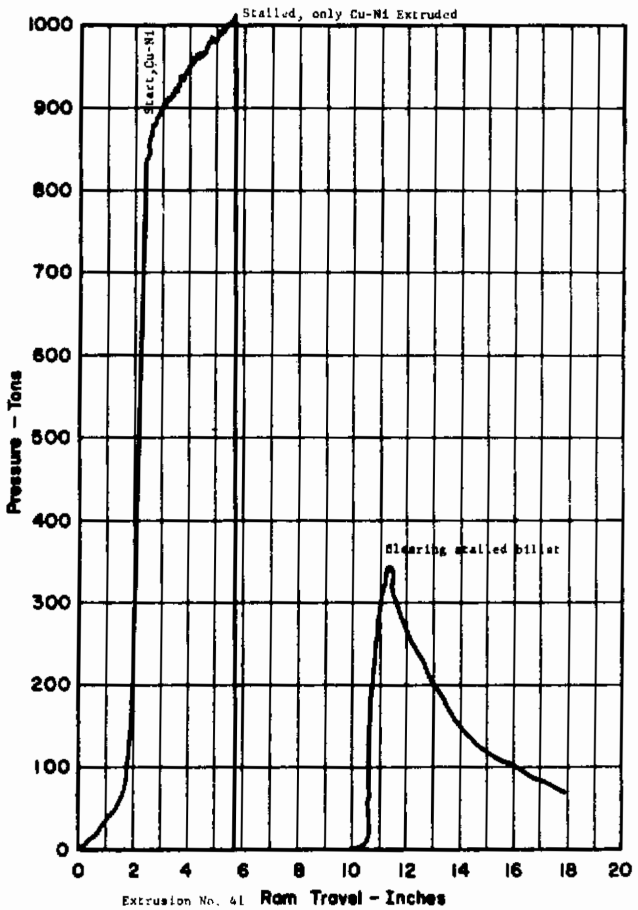
Extrusion Section Dimensions			
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Billet stalled, probably due to high friction between billet and liner because of long length of billet.



Extrusion No. 41

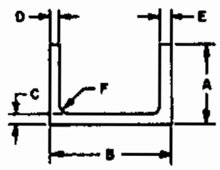
RA1102

BERYLLIUM EXTRUSION TEST DATA
Task D - July 10, 1959

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	Ext. 42 (NMI 21263)	Die Temp., °F	900
Primary Purpose of this Experiment	Attempt extrusion w/o Cu-Ni Lead in billet.	Container Temp., °F	900
Press Capacity	1000 tons	Billet Transfer Time in Seconds	31
Stem Diameter	3.400 inches	Starting Pressure Reading in psi	139,000
Container Diameter	3.625	End Pressure Reading in psi	202,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	820
Billet Material	Be sintered bar	Max Pressure on Billet in psi	202,000
Billet Length	3 inches	Extrusion Length in inches	80
Billet Temp., °F	1715	Extrusion Surface Finish	Good
Type of Billet Heating	Furnace in argon atm.	Die Condition	Good
Billet Heating Time in Minutes	405	Die Rework	None
Billet Lubricant	B, F, and D2	No. of Extrusions Through Same Die	None prior
Die Lubricant	G	Lead-in-billet	None
Container Lubricant	None		
Die Design No.	PMD-1 Die B		
Die Material	Stellite		

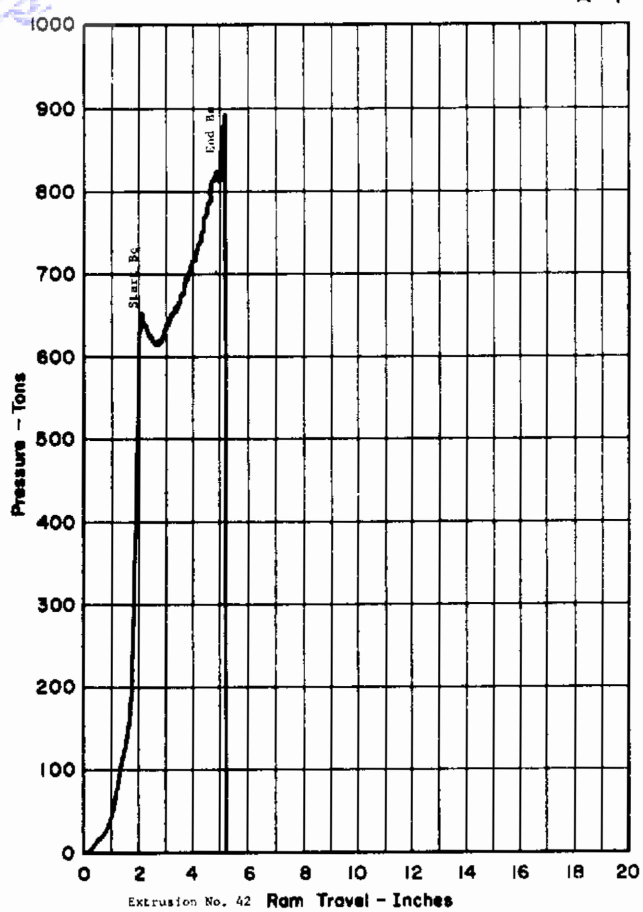
Extrusion Section Dimensions			
	Front	A	0.959
	Front	B	1.418 (T) 1.4665 (B)
	Front	C	0.110
	Front	D	0.114
	Front	E	0.114
	Front	F	0.100 (R)
	Center	A	0.9635
	Center	B	1.287 (T) 1.456 (B)
	Center	C	0.083
	Center	D	0.103
	Center	E	0.100
	Center	F	0.100 (R)
	Rear	A	0.9562
	Rear	B	1.300 (T) 1.461 (B)
	Rear	C	0.093
	Rear	D	0.102
	Rear	E	0.101
	Rear	F	0.100 (R)

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Best channel to date. No rattlesnake - much straighter than any before - entire billet was extruded.



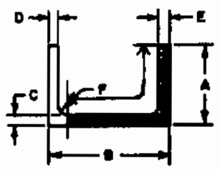
RA1102

BERYLLIUM EXTRUSION TEST DATA
Task D - July 10, 1959

Subcontractor	NMI	Type of Die Fabrication	Cas. insert
Extrusion No.	Ext. 43 (NMI-21264)	Die Temp., °F	900
Primary Purpose of this Experiment	Test extruded w/o Cu-Ni lead in billet	Container Temp., °F	900
Press Capacity	1000 tons	Billet Transfer Time in Seconds	25
Stem Diameter	3.400 inches	Starting Pressure Reading in psi	209,000
Container Diameter	3.625 inches	End Pressure Reading in psi	223,000
Extrusion Ratio	~80:1 (see remarks)	Max Force on Billet in Tons	1010
Billet Material	Be sintered bar	Max Pressure on Billet in psi	223,000
Billet Length	5 inches	Extrusion Length in Inches	Approximately 180-inch ribbon
Billet Temp., °F	1715	Extrusion Surface Finish	Good
Type of Billet Heating	Furnace in argon atm.	Die Condition	See remarks
Billet Heating Time in Minutes	420	Die Rework	None
Billet Lubricant	B, F and D2	No. of Extrusions Through Same Die	3 prior
Die Lubricant	G	Lead in billet	None
Container Lubricant	None		
Die Design No.	PMD 1 (A)		
Die Material	Stellite		

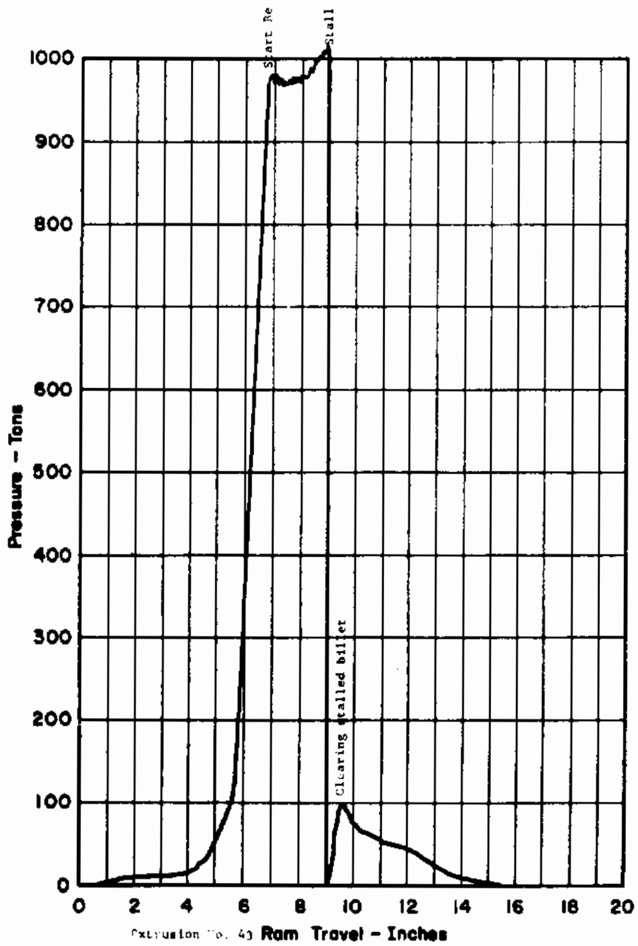
Extrusion Section Dimensions			
	Front	A	
	Front	B	
	Front	C	
	Front	D	0.101
	Front	E	
	Front	F	
	Center	A	
	Center	B	
	Center	C	
	Center	D	0.105
	Center	E	
	Center	F	
	Rear	A	
	Rear	B	
	Rear	C	
	Rear	D	0.090
	Rear	E	
	Rear	F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Die closed up and packed with glass in area shown above. About 15 foot of ribbon extruded before the press stalled, no rattlesnaking, apparently the metal of the die deformed plastically enough to close off part of the channel.



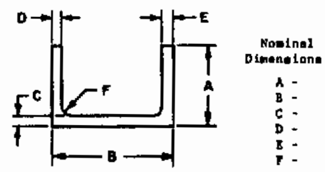
RA1102

BERYLLIUM EXTRUSION TEST DATA
Task C - July 15, 1959

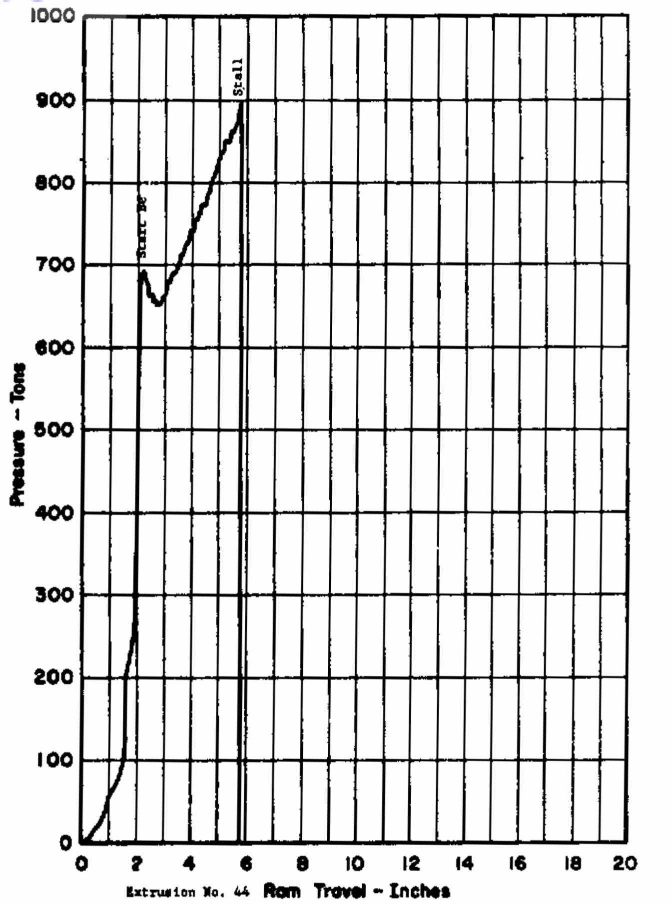
Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	Ext. 44 (NMI-21268)	Die Temp., °F	900
Primary Purpose of this Experiment	Extrude w/o Cu-Ni	Container Temp., °F	900
Press Capacity	1000 tons	Billet Transfer Time in Seconds	22
Stem Diameter	3.400 inches	Starting Pressure Reading in psi	151,000
Container Diameter	3.625 inches	End Pressure Reading in psi	196,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	920
Billet Material	Be sintered bar	Max Pressure on Billet in psi	196,000
Billet Length	5 inches	Extrusion Length in inches	111
Billet Temp., °F	1725	Extrusion Surface Finish	Good
Type of Billet Heating	Furnace in argon atm.	Die Condition	Good
Billet Heating Time in Minutes	230	Die Rework	None
Billet Lubricant	B, F and D2	No. of Extrusions Through Same Die	None prior
Die Lubricant	G		
Container Lubricant	None		
Die Design No.	PMD-1 Die B		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	0.962
		B	1.418 (T) 1.4655 (B)
		C	0.112
		D	0.112
		E	0.113
		F	0.100
	Center	A	0.955
		B	1.394 (T) 1.4565 (B)
		C	0.105
		D	0.1115
		E	0.109
		F	0.100
	Rear	A	0.977
		B	1.3535 (T) 1.471 (B)
		C	0.105
		D	0.109
		E	0.110
		F	0.100

Extruded Shape Sketch:



REMARKS: Same pressure pattern - channel twisted - section good - no rattlesnaking. ~One inch of billet did not extrude.



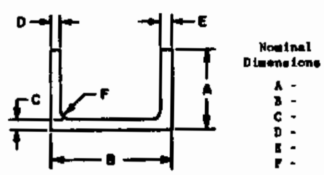
RA1102

BERYLLIUM EXTRUSION TEST DATA
Task C - July 15, 1959

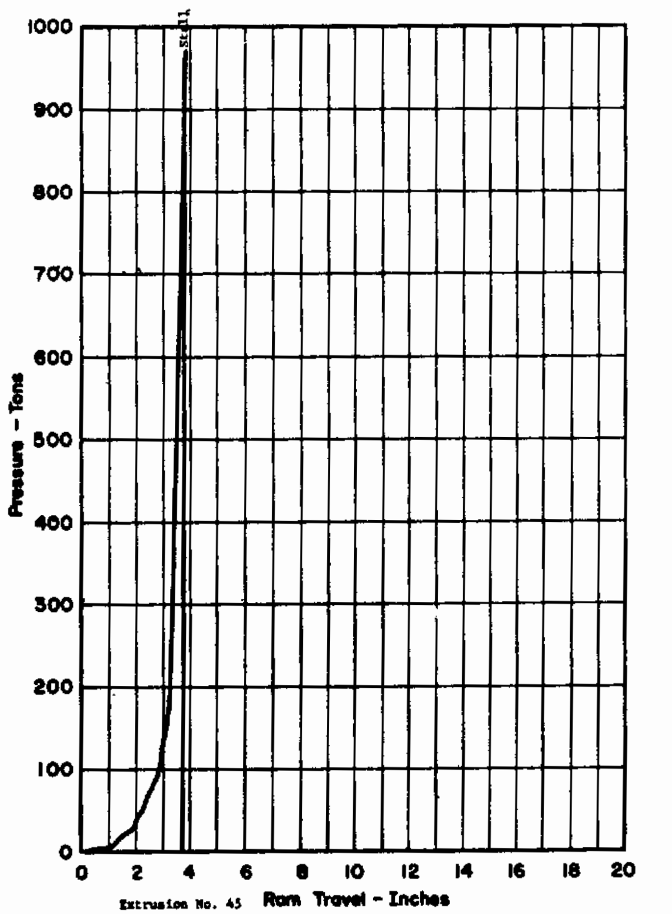
Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	Ext. 45 (NMI-21264)	Die Temp., °F	900
Primary Purpose of this Experiment	Investigate low temperature glasses	Container Temp., °F	900
Press Capacity	1000 tons	Billet Transfer Time in Seconds	40
Stem Diameter	3.400 inches	Starting Pressure Reading in psi	212,000
Container Diameter	3.625 inches	End Pressure Reading in psi	212,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	965
Billet Material	Be sintered bar	Max Pressure on Billet in psi	212,000
Billet Length	5 inches	Extrusion Length in Inches	0
Billet Temp., °F	1725	Extrusion Surface Finish	0
Type of Billet Heating	Furnace in argon atm.	Die Condition	Good
Billet Heating Time in Minutes	245	Die Rework	None
Billet Lubricant	B, H and J	No. of Extrusions Through Same Die	None prior
Die Lubricant	E		
Container Lubricant	None		
Die Design No.	PMD 1 (C)		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



REMARKS: Stall - different glass - different loading caused long transfer. Long transfer time caused glass to freeze in liner.



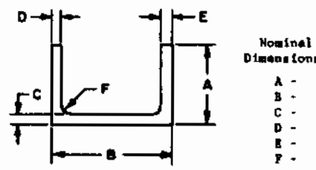
RA1102

BERYLLIUM EXTRUSION TEST DATA
Task B - July 15, 1959

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	Ext. 46 (NMI-21270)	Die Temp., °F	900
Primary Purpose of this Experiment	Test salt as lubricant	Container Temp., °F	900
Press Capacity	1000 tons	Billet Transfer Time in Seconds	20
Stem Diameter	3.400 inches	Starting Pressure Reading in psi	124,000
Container Diameter	3.625 inches	End Pressure Reading in psi	133,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	605
Billet Material	Sintered Be	Max Pressure on Billet in psi	133,000
Billet Length	3 inches	Extrusion Length in inches	85
Billet Temp., °F	1950	Extrusion Surface Finish	Good
Type of Billet Heating	Salt pot	Die Condition	Worn (see below)
Billet Heating Time in Minutes	30	Die Rework	None
Billet Lubricant	Salt	No. of Extrusions Through Same Die	None prior
Die Lubricant	G		
Container Lubricant	Mica		
Die Design No.	PS-1 Die A		
Die Material	Stellite		

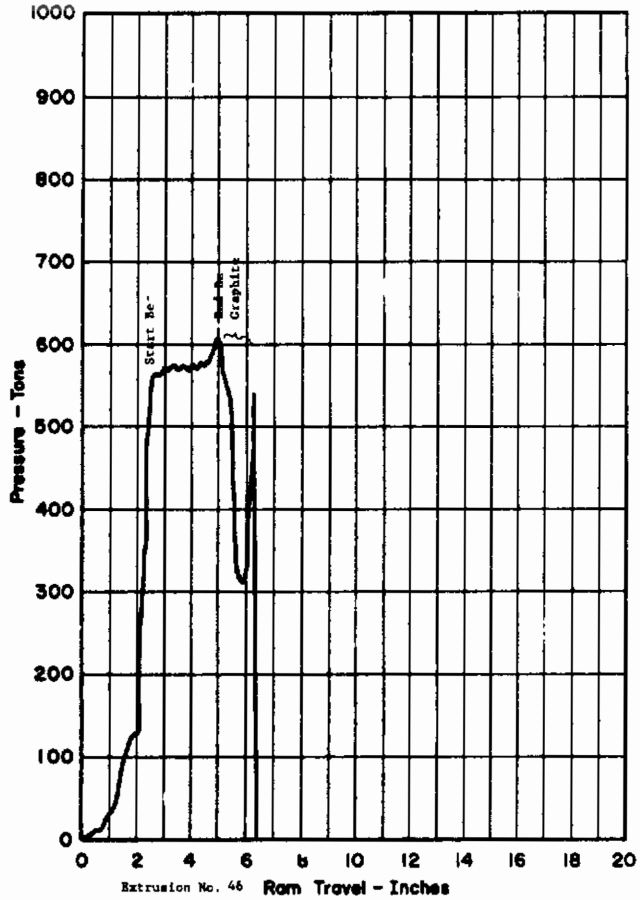
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Extrusion pressure did not rise rapidly, as it did during extrusions with glass as a lubricant. Lubrication was insufficient; the channel rattlesnaked in the front portion, and was split in the rear. Die wear was severe in the inside corners of the channel.



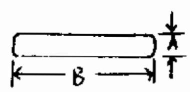
RA 1102

BERYLLIUM EXTRUSION TEST DATA
Task B - July 15, 1959

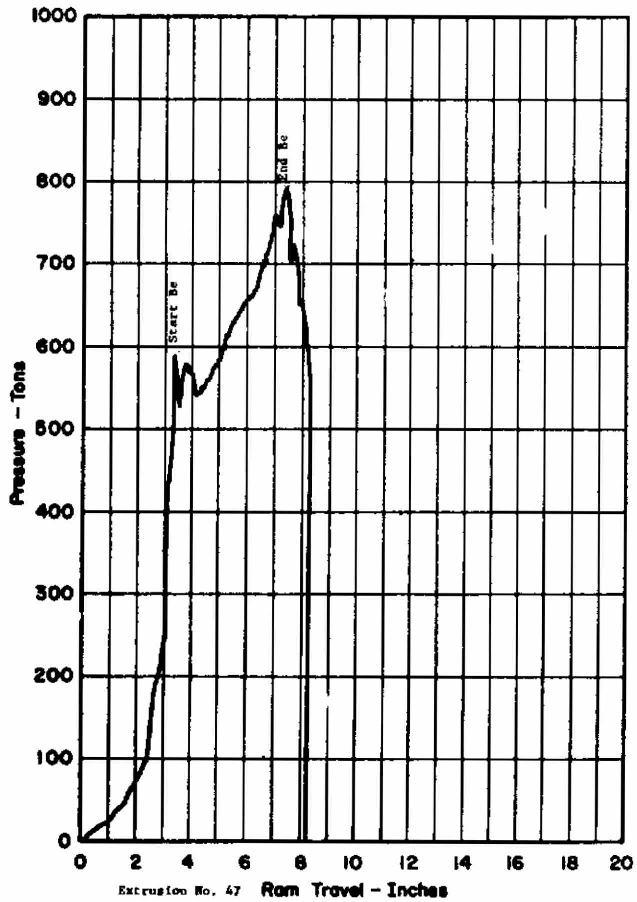
Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	Ext. 47 (NMI-21271)	Die Temp., °F	900
Primary Purpose of this Experiment	To push a flat	Container Temp., °F	900
Press Capacity	1000 tons	Billet Transfer Time in Seconds	19
Stem Diameter	3.400 inches	Starting Pressure Reading in psi	128,000
Container Diameter	3.625 inches	End Pressure Reading in psi	175,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	795
Billet Material	Be powder canned in Fe	Max Pressure on Billet in psi	175,000
Billet Length	5 inches	Extrusion Length in inches	100
Billet Temp., °F	1715	Extrusion Surface Finish	Good
Type of Billet Heating	Graphite	Die Condition	Scored
Billet Heating Time in Minutes	250	Die Rework	None
Billet Lubricant	F, 02	No. of Extrusions Through Same Die	None prior
Die Lubricant	G		
Container Lubricant	None		
Die Design No.	PS2 Die A		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	0.266
		B	1.461
		C	
		D	
		E	
		F	
	Center	A	0.269
		B	1.492
		C	
		D	
		E	
		F	
	Rear	A	0.268
		B	1.474
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



REMARKS: Entire billet was extruded. Portions of the extrusion were rattlesnaked; others were unrattlesnaked.



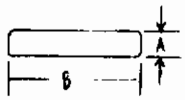
RA 1102

BERYLLIUM EXTRUSION TEST DATA
Task B - July 15, 1959

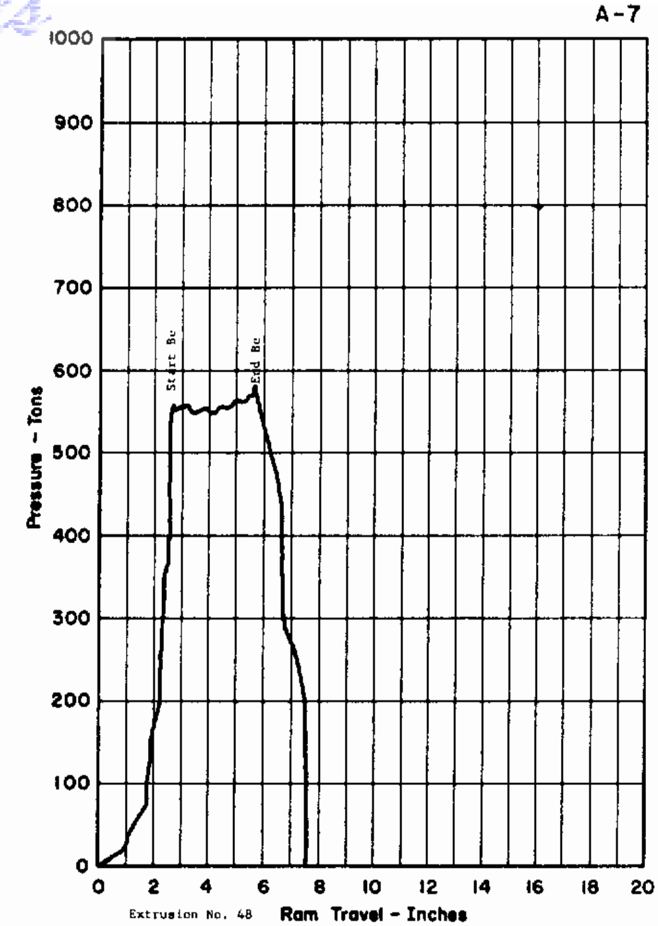
Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	Ext. 48 (NMI-21272)	Die Temp., °F	900
Primary Purpose of this Experiment	To push a flat	Container Temp., °F	900
Press Capacity	1000 tons	Billet Transfer Time in Seconds	20
Stem Diameter	3.400 inches	Starting Pressure Reading in psi	122,000
Container Diameter	3.625 inches	End Pressure Reading in psi	126,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	610
Billet Material	Be sintered bar - canned	Max Pressure on Billet in psi	126,000
Billet Length	3 inches	Extrusion Length in inches	97
Billet Temp., °F	1725	Extrusion Surface Finish	Good
Type of Billet Heating	Graphite	Die Condition	Scored
Billet Heating Time in Minutes	265	Die Rework	None
Billet Lubricant	None	No. of Extrusions Through Same Die	None
Die Lubricant	G		
Container Lubricant	Mica		
Die Design No.	FS 2 B		
Die Material	Stellite		

Extrusion Section Dimensions			
Front	A	0.264	
	B	1.469	
	C		
	D		
	E		
	F		
Center	A	0.261	
	B	1.4685	
	C		
	D		
	E		
	F		
Rear	A	0.2665	
	B	1.4695	
	C		
	D		
	E		
	F		

Extruded Shape Sketch:



REMARKS: Good - straight - no rattlesnake.



Extrusion No. 48

RA1102

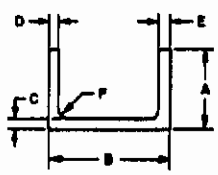
BERYLLIUM EXTRUSION TEST DATA
Task C - July 15, 1959

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	Ext. 49 (NMI-21273)	Die Temp., °F	900
Primary Purpose of this Experiment	Test D2 and salt as lubricant	Container Temp., °F	900
Press Capacity	1000 tons	Billet Transfer Time in Seconds	Not taken
Stem Diameter	3.400 inches	Starting Pressure Reading in psi	124,000
Container Diameter	3.625 inches	End Pressure Reading in psi	152,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	690
Billet Material	Be	Max Pressure on Billet in psi	152,000
Billet Length	3 inches	Extrusion Length in inches	99
Billet Temp., °F	1950	Extrusion Surface Finish	Good
Type of Billet Heating	Salt	Die Condition	Worn (see below)
Billet Heating Time in Minutes	30	Die Rework	None
Billet Lubricant	Salt and D2	No. of Extrusions Through Same Die	None
Die Lubricant	G		
Container Lubricant	Mica		
Die Design No.	PMD 2A		
Die Material	Stellite		

Extrusion Section Dimensions			
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

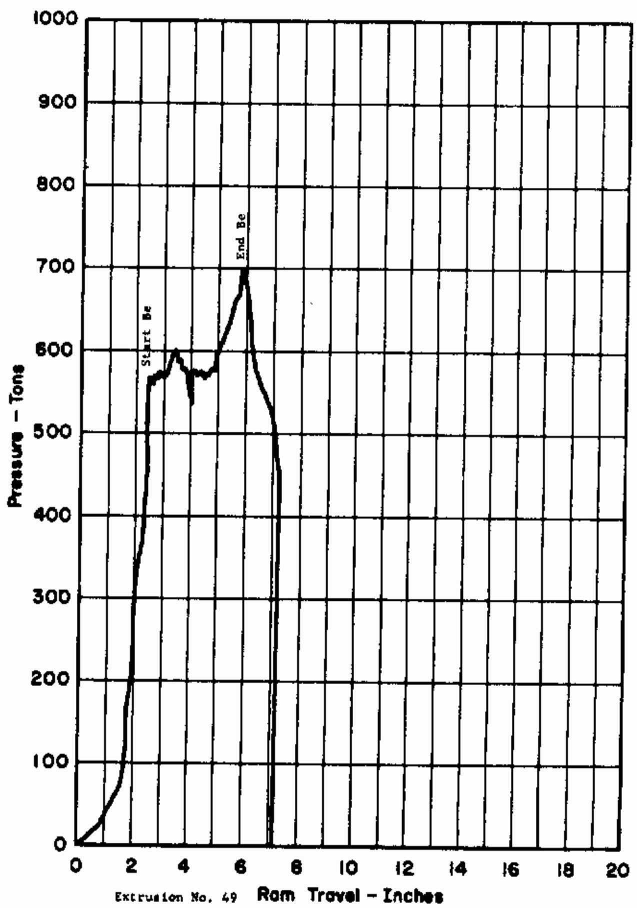
Extruded Shape Sketch:

Heavy die wear in this location



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Badly rattlesnaked.
Too torn up for micrometer readings.



Extrusion No. 49

RA1102

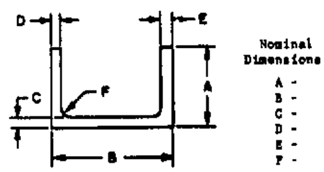
BERYLLIUM EXTRUSION TEST DATA

Task C - July 27, 1959

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	50	Die Temp., °F	900
Primary Purpose of this Experiment	Test glass disc as die lubricant	Container Temp., °F	900
Press Capacity	1000 tons	Billet Transfer Time in Seconds	24
Stem Diameter	3.400 inches	Starting Pressure Reading in psi	158,000
Container Diameter	3.625 inches	End Pressure Reading in psi	166,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	850
Billet Material	Be sintered bar	Max Pressure on Billet in psi	166,000
Billet Length	5 inches	Extrusion Length in inches	30
Billet Temp., °F	1775	Extrusion Surface Finish	Torn
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	33	Die Rework	None
Billet Lubricant	Salt	No. of Extrusions Through Same Die	None prior
Die Lubricant	Glass disc		
Container Lubricant	Mica		
Die Design No.	PS 1B		
Die Material	Stellite		

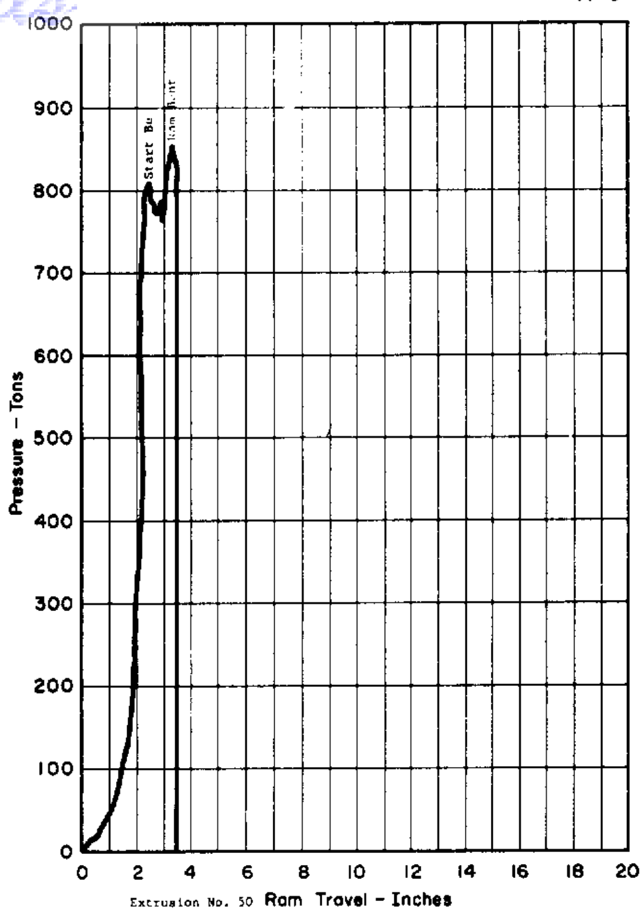
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: 2-1/2 feet extruded - badly snaked. Ram bent.



RA1102

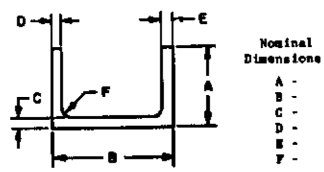
BERYLLIUM EXTRUSION TEST DATA

Task C - July 27, 1959

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	51	Die Temp., °F	900
Primary Purpose of this Experiment	Test salt as lubricant at 1775°F	Container Temp., °F	900
Press Capacity	1000 tons	Billet Transfer Time in Seconds	31
Stem Diameter	3.400 inches	Starting Pressure Reading in psi	142,000
Container Diameter	3.625	End Pressure Reading in psi	162,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	800
Billet Material	Be sintered bar	Max Pressure on Billet in psi	162,000
Billet Length	5 inches	Extrusion Length in inches	104
Billet Temp., °F	1775	Extrusion Surface Finish	Torn
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	30	Die Rework	None
Billet Lubricant	E	No. of Extrusions Through Same Die	one prior
Die Lubricant	E		
Container Lubricant	Mica		
Die Design No.	PS-1A		
Die Material	Stellite		

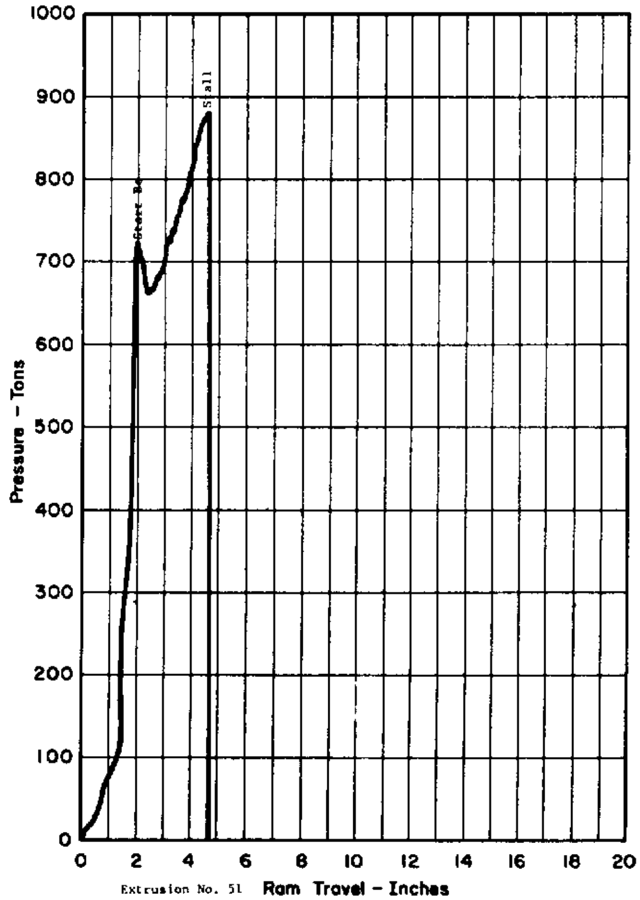
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: One-half inch butt. Torn and snaked badly.



RA1102

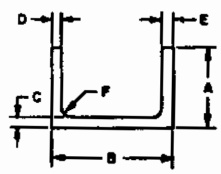
BERYLLIUM EXTRUSION TEST DATA

Task C - July 27, 1959

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	52	Die Temp., °F	900
Primary Purpose of this Experiment	Test salt - glass mixture as lubricant	Container Temp., °F	900
Press Capacity	1000 tons	Billet Transfer Time in Seconds	48
Stem Diameter	3.400 inches	Starting Pressure Reading in psi	136,000
Container Diameter	3.625	End Pressure Reading in psi	165,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	870
Billet Material	Be sintered bar	Max Pressure on Billet in psi	165,000
Billet Length	3 inches	Extrusion Length in inches	80
Billet Temp., °F	1800	Extrusion Surface Finish	Center good - ends torn
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	58	Die Rework	None
Billet Lubricant	Salt and D2 modified	No. of Extrusions Through Same Die	1 prior
Die Lubricant	E		
Container Lubricant	Mica		
Die Design No.	FMD-1C		
Die Material	Stellite		

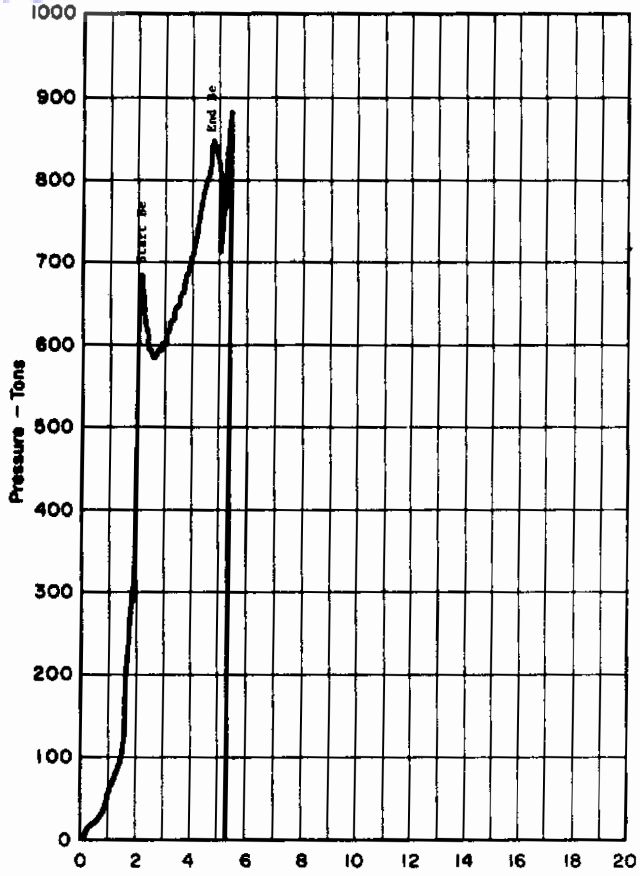
Extrusion Section Dimensions	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Entire billet extruded. Four feet at center straight and sound ends torn.



Extrusion No. 52 Ram Travel - Inches

RA1102

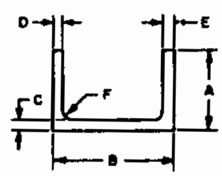
BERYLLIUM EXTRUSION TEST DATA

Task C - July 27, 1959

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	53	Die Temp., °F	900
Primary Purpose of this Experiment	Test salt - glass mixture as lubricant	Container Temp., °F	900
Press Capacity	1000 tons	Billet Transfer Time in Seconds	39
Stem Diameter	3.400 inches	Starting Pressure Reading in psi	124,000
Container Diameter	3.625 inches	End Pressure Reading in psi	161,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	830
Billet Material	Be sintered bar	Max Pressure on Billet in psi	161,000
Billet Length	3 inches	Extrusion Length in inches	80
Billet Temp., °F	1800	Extrusion Surface Finish	Torn
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	78	Die Rework	None
Billet Lubricant	Salt and D2 modified	No. of Extrusions Through Same Die	2 prior
Die Lubricant	G		
Container Lubricant	Mica		
Die Design No.	FMD-1B		
Die Material	Stellite		

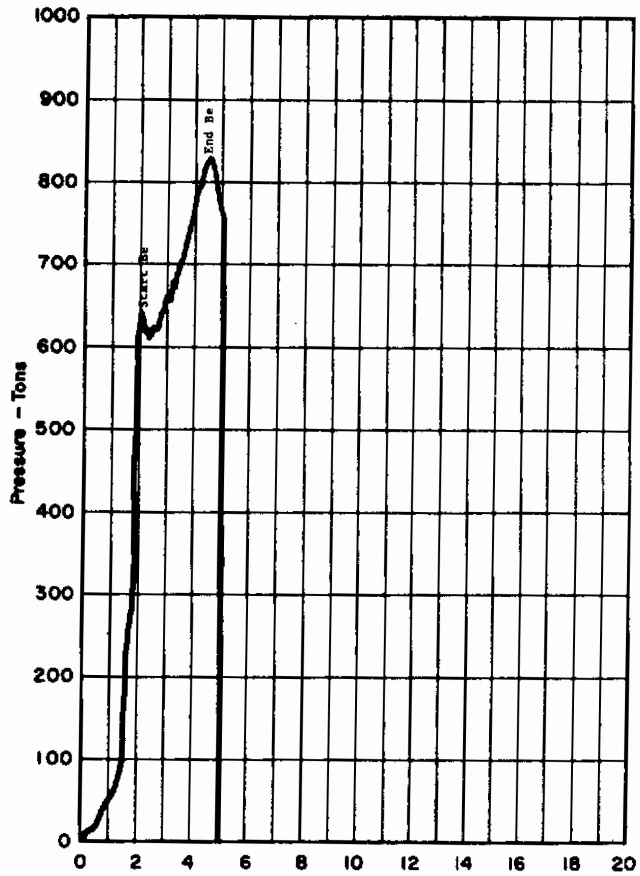
Extrusion Section Dimensions	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Entire billet extruded one side torn entire length, tearing less severe at center than at ends.



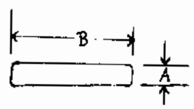
Extrusion No. 53 Ram Travel - Inches

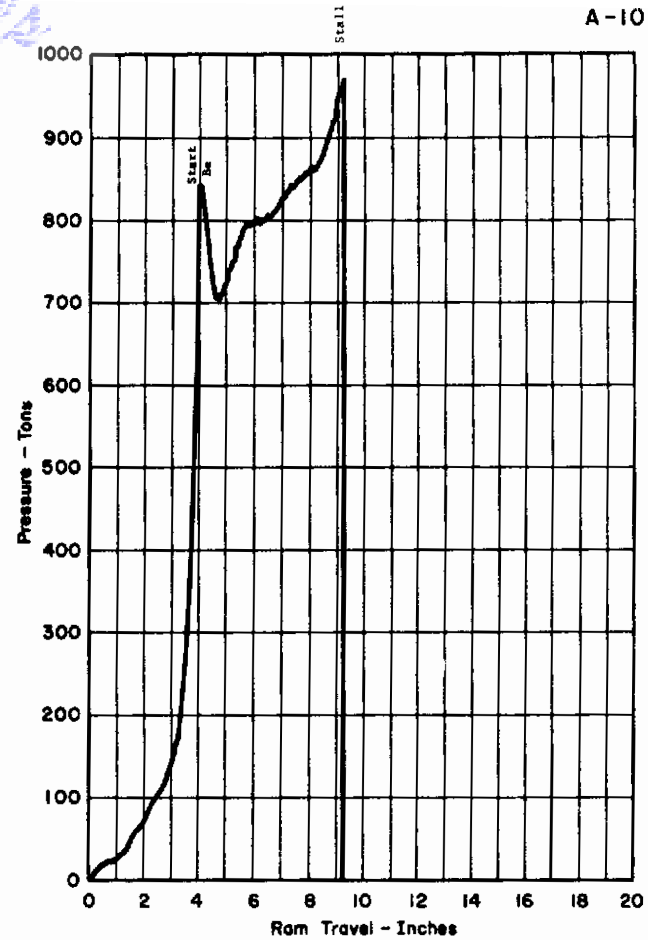
RA1102

BERYLLIUM EXTRUSION TEST DATA

Task B 8/4/59

Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	54 (NMI 21381)	Die Temp., °F	900
Primary Purpose of this Experiment	Produce flat stock for bend tests	Container Temp., °F	900
Press Capacity	1000T	Billet Transfer Time in Seconds	22
Stem Diameter	3.400	Starting Pressure Reading in psi	164,000
Container Diameter	3.625	End Pressure Reading in psi	188,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	970
Billet Material	Be powder in steel can	Max Pressure on Billet in psi	185,000
Billet Length	3"	Extrusion Length in inches	148"
Billet Temp., °F	1750	Extrusion Surface Finish	Good
Type of Billet Heating	Furnace in graphite	Die Condition	Normal
Billet Heating Time in Minutes	148	Die Rework	None
Billet Lubricant	None	No. of Extrusions Through Same Die	1 prior
Die Lubricant	None		
Container Lubricant	K		
Die Design No.	PS2B		
Die Material	Stellite		

Extrusion Section Dimensions	Front	A	.257"	Extruded Shape Sketch: 
		B	1.473"	
		C		
		D		
		E		
		F		
	Center	A	.246" - .249"	
		B	1.468"	
		C		
		D		
		E		
		F		
	Rear	A	.229" - .235"	REMARKS: stall - 1" butt straight - smooth
		B	1.458"	
		C		
		D		
		E		
		F		



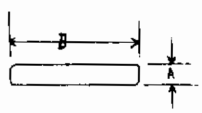
Extrusion No. 54

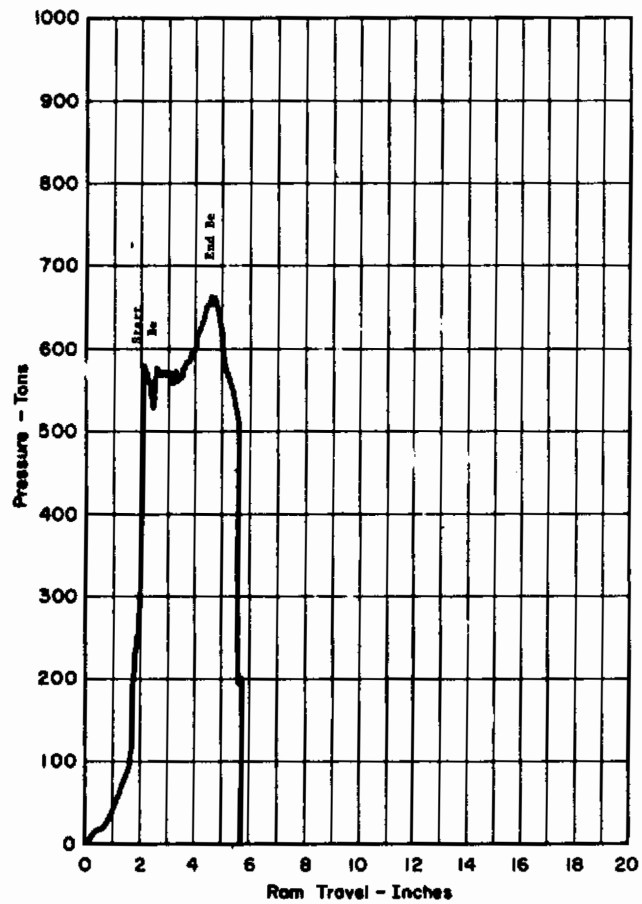
RA1102

BERYLLIUM EXTRUSION TEST DATA

Task C 8/4/59

Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	55 (NMI 21382)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	22
Stem Diameter	3.400	Starting Pressure Reading in psi	113,000
Container Diameter	3.625	End Pressure Reading in psi	--
Extrusion Ratio	26:1	Max Force on Billet in Tons	660
Billet Material	Be sintered bar	Max Pressure on Billet in psi	128,000
Billet Length	3"	Extrusion Length in inches	82"
Billet Temp., °F	1750	Extrusion Surface Finish	Poor
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	17	Die Rework	None
Billet Lubricant	Salt	No. of Extrusions Through Same Die	1 prior
Die Lubricant	G		
Container Lubricant	Mica - heavy		
Die Design No.	PS2A		
Die Material	Stellite		

Extrusion Section Dimensions	Front	A	.259" - .260"	Extruded Shape Sketch: 
		B	1.479"	
		C		
		D		
		E		
		F		
	Center	A	.250" - .254"	
		B	1.461"	
		C		
		D		
		E		
		F		
	Rear	A	.248" - .252"	REMARKS: all extruded - die in good shape - one side snaked - last 12" sound.
		B	1.449"	
		C		
		D		
		E		
		F		



Extrusion No. 55

RA1102

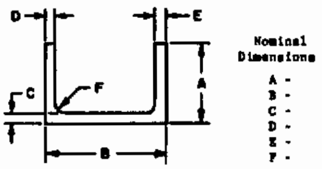
BERYLLIUM EXTRUSION TEST DATA

Task C 8/4/59

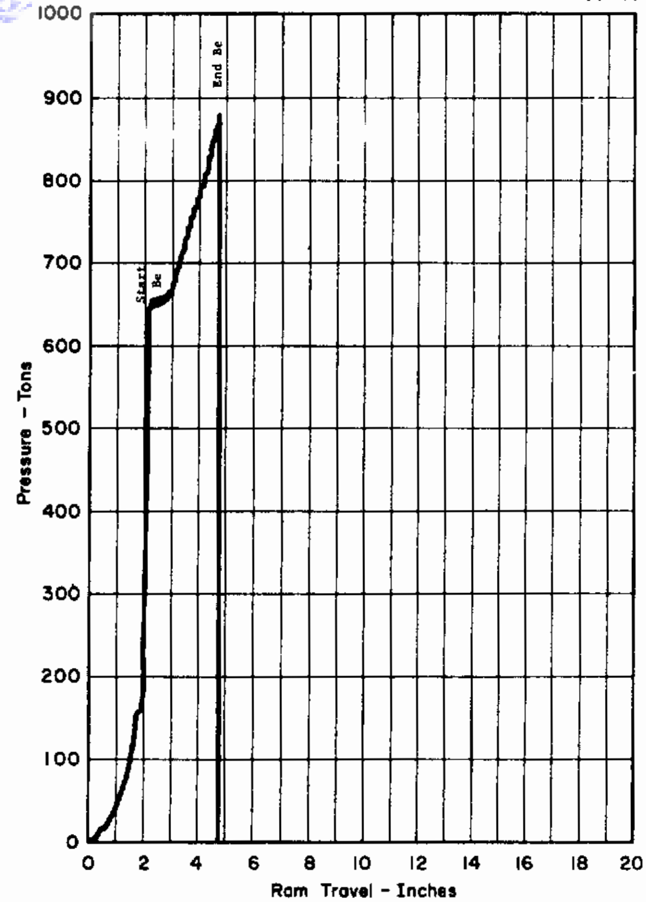
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	56 (NMI 21383)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	31
Stem Diameter	3.400	Starting Pressure Reading in psi	126,000
Container Diameter	3.625	End Pressure Reading in psi	171,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	880
Billet Material	Sintered bar	Max Pressure on Billet in psi	171,000
Billet Length	3"	Extrusion Length in inches	70"
Billet Temp., °F	1750	Extrusion Surface Finish	Good
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	20	Die Rework	None
Billet Lubricant	Salt	No. of Extrusions Through Same Die	None prior
Die Lubricant	G & E		
Container Lubricant	Mica		
Die Design No.	PMD2B		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	.998"
		B	1.475"
		C	.118"
		D	.123"
		E	.120"
		F	
	Center	A	.971"
		B	1.476"
		C	.103"
		D	.113"
		E	.112"
		F	
	Rear	A	.972"
		B	1.4785"
		C	.105"
		D	.109"
		E	.109"
		F	

Extruded Shape Sketch:



REMARKS: pressure rise pattern again -- stall with 1/8" butt -- slight twist -- small snake pattern at corners.



Extrusion No. 56

RA1102

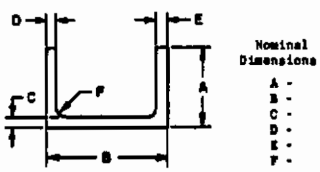
BERYLLIUM EXTRUSION TEST DATA

Task C 8/4/59

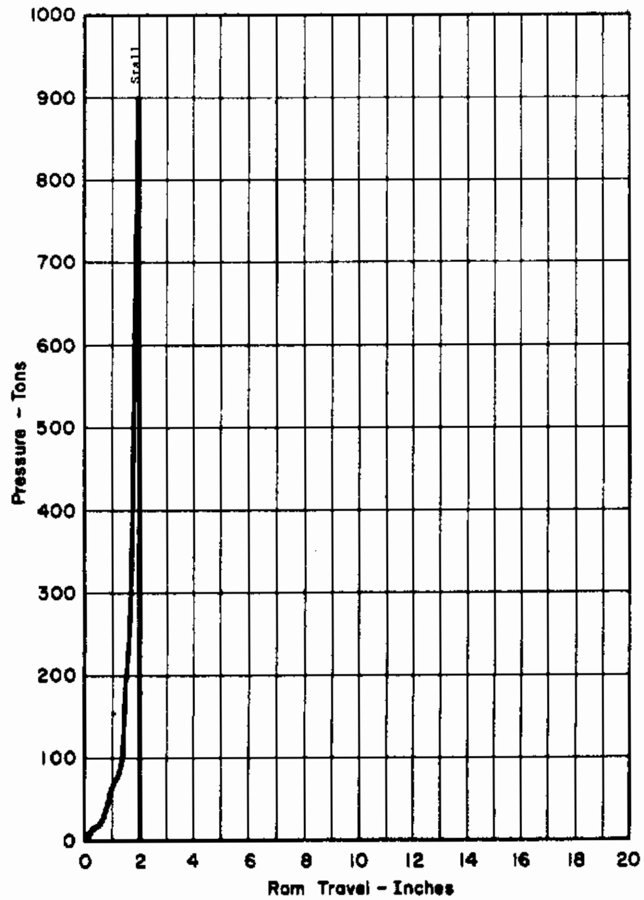
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	57 (NMI 21384)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	23
Stem Diameter	3.400	Starting Pressure Reading in psi	175,000
Container Diameter	3.625	End Pressure Reading in psi	
Extrusion Ratio	26:1	Max Force on Billet in Tons	900
Billet Material	Sintered bar	Max Pressure on Billet in psi	175,000
Billet Length	3"	Extrusion Length in inches	0
Billet Temp., °F	1750	Extrusion Surface Finish	
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	16	Die Rework	None
Billet Lubricant	Salt	No. of Extrusions Through Same Die	3 prior
Die Lubricant	G & E		
Container Lubricant	Mica		
Die Design No.	PMD1B		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



REMARKS: stall -- not billet, because liner cleared very easily.



Extrusion No. 57

RA1102

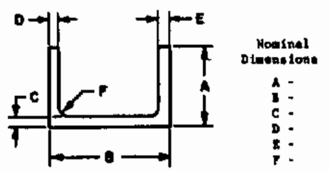
BERYLLIUM EXTRUSION TEST DATA

Task C 6/26/59

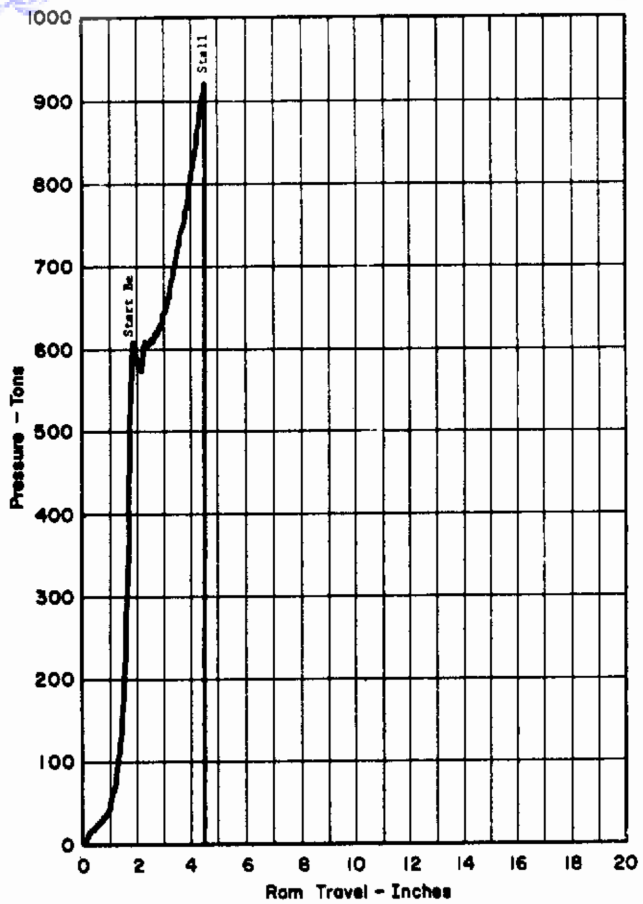
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	58 (NMI 21493)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	Not taken
Stem Diameter	3.400	Starting Pressure Reading in psi	118,000
Container Diameter	3.625	End Pressure Reading in psi	181,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	930
Billet Material	Be sintered bar	Max Pressure on Billet in psi	181,000
Billet Length	3"	Extrusion Length in inches	
Billet Temp., °F	1750	Extrusion Surface Finish	Good
Type of Billet Heating	Salt bath	Die Condition	Poor
Billet Heating Time in Minutes	15	Die Rework	None
Billet Lubricant	D	No. of Extrusions Through Same Die	None prior
Die Lubricant	G		
Container Lubricant	Mica		
Die Design No.	PS1A		
Die Material	Stellite		

Extrusion Section Dimensions			
Front	A	.096"	
	B	1.491"	
	C	.114"	
	D	.119"	
	E	.119"	
	F	.100R	
Center	A	.983"	
	B	1.493"	
	C	.096"	
	D	.115"	
	E	.110"	
	F	.100R	
Rear	A	.0983"	
	B	1.489"	
	C	.082"	
	D	.104"	
	E	.089"	
	F	.100R	

Extruded Shape Sketch:



REMARKS: quite twisted, but otherwise good.



Extrusion No. 58

RA1102

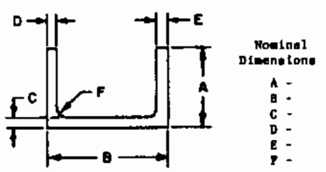
BERYLLIUM EXTRUSION TEST DATA

Task C 8/26/59

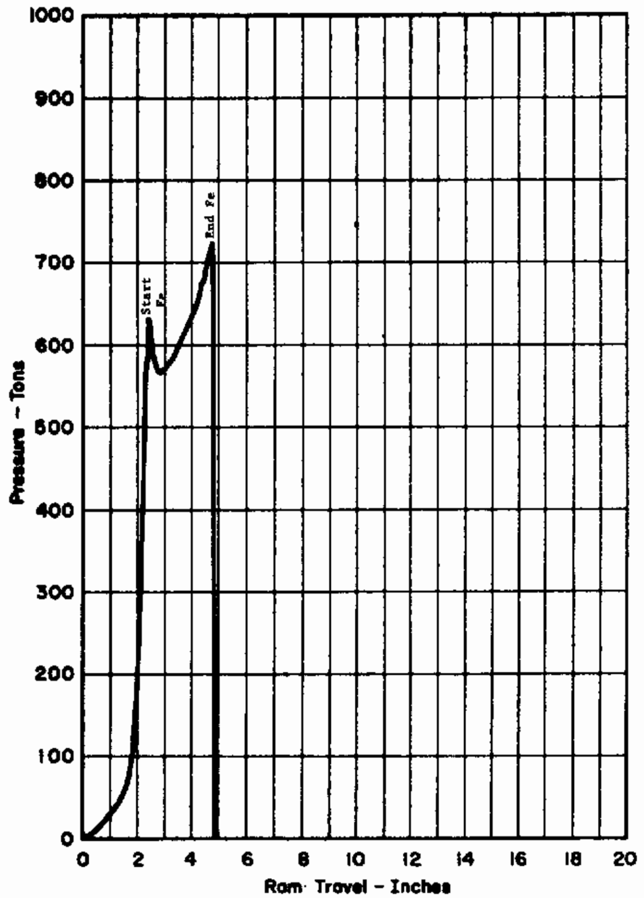
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	59 (NMI 21494)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	Not taken
Stem Diameter	3.400	Starting Pressure Reading in psi	122,000
Container Diameter	3.625	End Pressure Reading in psi	142,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	730
Billet Material	CR steel	Max Pressure on Billet in psi	142,000
Billet Length	3"	Extrusion Length in inches	
Billet Temp., °F	1750	Extrusion Surface Finish	Good
Type of Billet Heating	Salt bath	Die Condition	Poor
Billet Heating Time in Minutes	15	Die Rework	None
Billet Lubricant	J	No. of Extrusions Through Same Die	4 prior
Die Lubricant	K		
Container Lubricant	--		
Die Design No.	PMD1B		
Die Material	Stellite		

Extrusion Section Dimensions			
Front	A	.962"	
	B	1.464"	
	C	.091"	
	D	.109"	
	E	.111"	
	F	.100R	
Center	A	.9615"	
	B	1.465"	
	C	.087"	
	D	.104"	
	E	.106"	
	F	.100R	
Rear	A	.961"	
	B	1.4645"	
	C	.084"	
	D	.101"	
	E	.103"	
	F	.100R	

Extruded Shape Sketch:



REMARKS: straight channel best yet -- steel instead of "Be".



Extrusion No. 59

RA1102

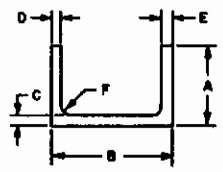
BERYLLIUM EXTRUSION TEST DATA

Task C 8/26/59

Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	60 (NMI 21495)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	Not taken
Stem Diameter	3.400	Starting Pressure Reading in psi	134,000
Container Diameter	3.625	End Pressure Reading in psi	175,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	900
Billet Material	Be sintered bar	Max Pressure on Billet in psi	175,000
Billet Length	3"	Extrusion Length in inches	
Billet Temp., °F	1750	Extrusion Surface Finish	Good
Type of Billet Heating	Salt bath	Die Condition	Poor
Billet Heating Time in Minutes	15	Die Rework	None
Billet Lubricant	J	No. of Extrusions Through Same Die	None prior
Die Lubricant	K		
Container Lubricant	--		
Die Design No.	PS1B		
Die Material	Stellite		

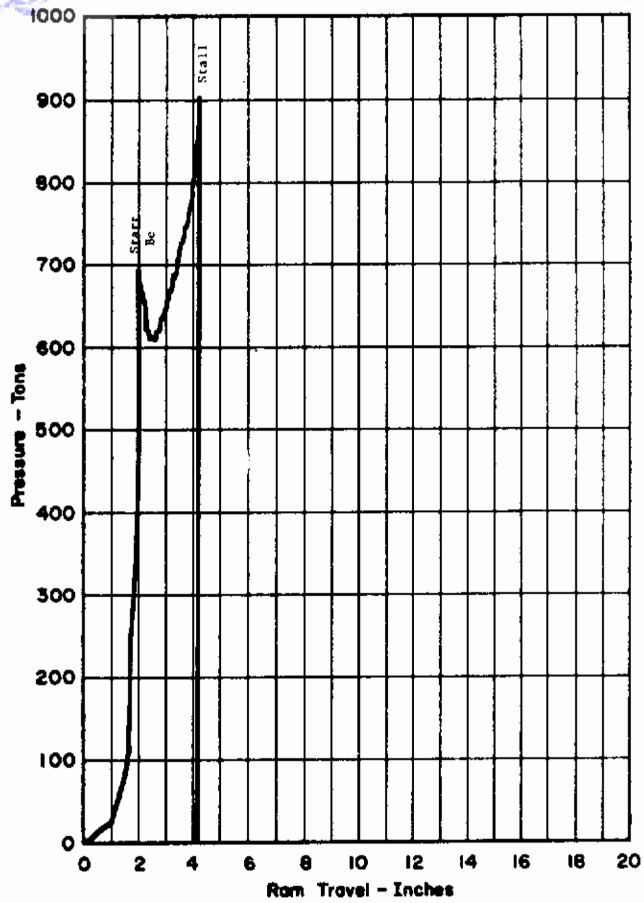
Extrusion Section Dimensions			
	Front	A	.990"
		B	1.483"
		C	.106"
		D	.115"
		E	.115"
		F	.100R
	Center	A	.982"
		B	1.470"
		C	.095"
		D	.106"
		E	.110"
		F	.100R
	Rear	A	.978"
		B	1.464"
		C	.067"
		D	.106"
		E	.100"
		F	.100R

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: channel twisted, but otherwise good.



Extrusion No. 60

RA1102

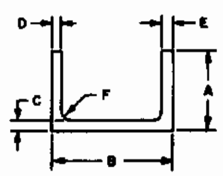
BERYLLIUM EXTRUSION TEST DATA

Task C 8/26/59

Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	61 (NMI 21496)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	Not taken
Stem Diameter	3.400	Starting Pressure Reading in psi	126,000
Container Diameter	3.625	End Pressure Reading in psi	150,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	770
Billet Material	Be sintered bar	Max Pressure on Billet in psi	150,000
Billet Length	3"	Extrusion Length in inches	
Billet Temp., °F	1750	Extrusion Surface Finish	Poor
Type of Billet Heating	Salt bath	Die Condition	Poor
Billet Heating Time in Minutes	15	Die Rework	None
Billet Lubricant	Fe plate .010"	No. of Extrusions Through Same Die	1 prior
Die Lubricant	--		
Container Lubricant	K		
Die Design No.	PMD2B		
Die Material	Stellite		

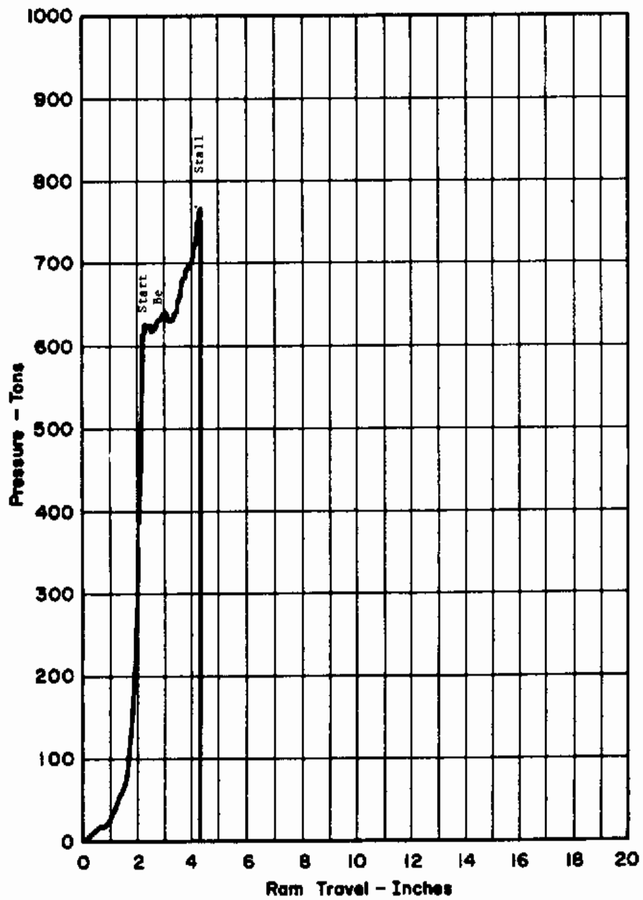
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: straight channel but rattlesnaked so badly, impossible to take dimensions.



Extrusion No. 61

RA1102

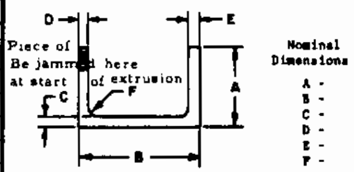
BERYLLIUM EXTRUSION TEST DATA

September 1, 1959

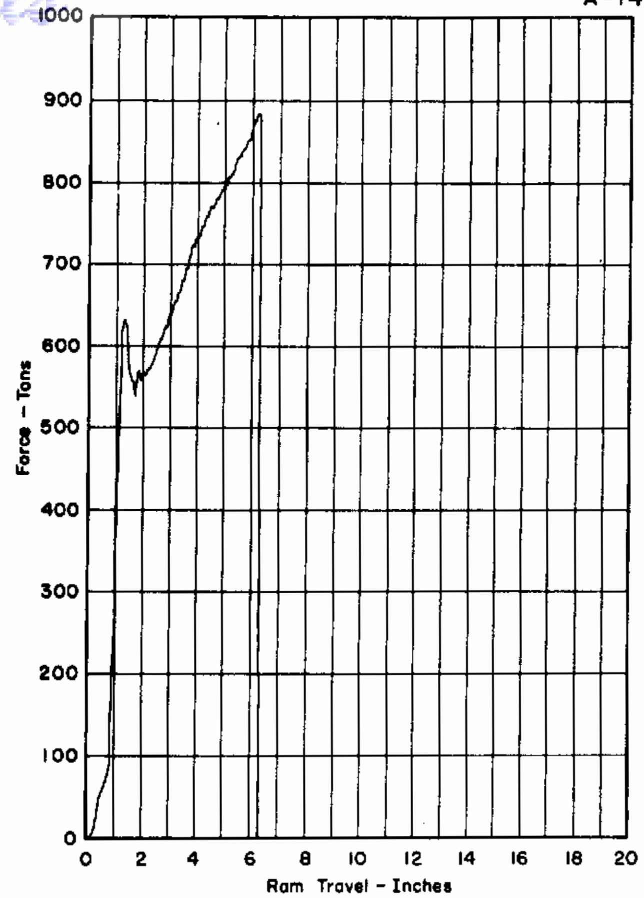
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	62 (NMI 21521)	Die Temp., °F	900°
Primary Purpose of this Experiment	Lube Experiment	Container Temp., °F	900°
Press Capacity	1000 T	Billet Transfer Time in Seconds	30
Stem Diameter	3.400"	Starting Pressure Reading in psi	109,000
Container Diameter	3.625"	End Pressure Reading in psi	172,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	880
Billet Material	Be sintered bar	Max Pressure on Billet in psi	172,000
Billet Length	7"	Extrusion Length in inches	137
Billet Temp., °F	1750	Extrusion Surface Finish	Good
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	21	Die Rework	--
Billet Lubricant	"D"	No. of Extrusions Through Same Die	None
Die Lubricant	"G"	Cut-off	Cu-Ni
Container Lubricant	"K"		
Die Design No.	PMD 1 A (new)		
Die Material	Stellite		

Extrusion Section Dimensions			
Front	A	.790	.976
	B	1.464	
	C	.111	
	D	.114	
	E	.113	
	F	.100R	
Center	A	.780	.976
	B	1.463	
	C	.099	
	D	.106	
	E	.103	
	F	.100R	
Rear	A	.778	.970
	B	1.462	
	C	.094	
	D	.102	
	E	.101	
	F	.100R	

Extruded Shape Sketch:



REMARKS: 2½" butt left - pressure rose to stall. Channel was straight and sound except 6" torn at front and 2½" torn one side at rear. Blocking of die caused one side to be 3/4" instead of 1".



Extrusion 62

RA 1102

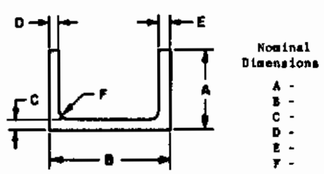
BERYLLIUM EXTRUSION TEST DATA

September 1, 1959

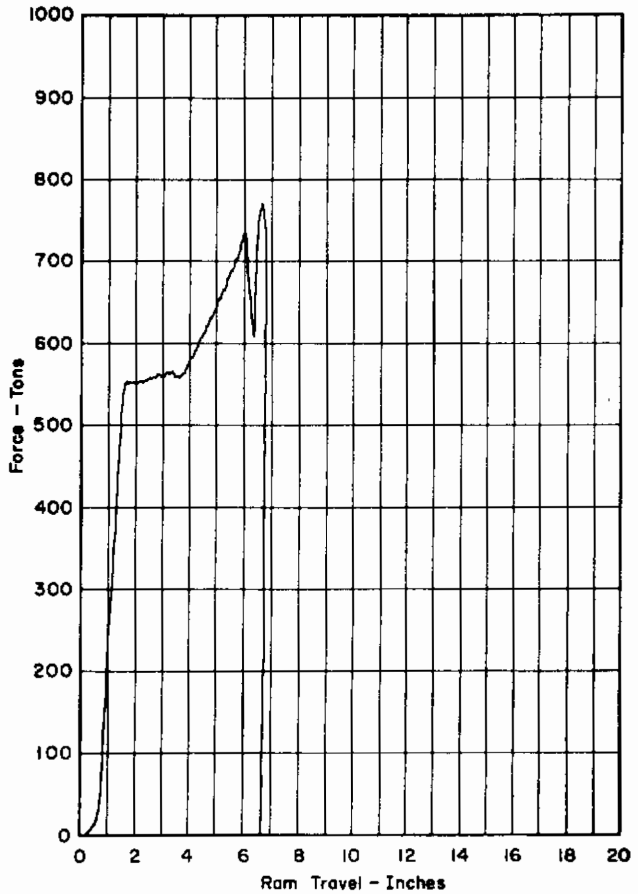
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	63 (NMI 21522)	Die Temp., °F	900°
Primary Purpose of this Experiment	Lube Experiment	Container Temp., °F	900°
Press Capacity	1000 T	Billet Transfer Time in Seconds	27
Stem Diameter	3.400"	Starting Pressure Reading in psi	107,000
Container Diameter	3.625"	End Pressure Reading in psi	141,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	735
Billet Material	Be sintered bar	Max Pressure on Billet in psi	141,000
Billet Length	5"	Extrusion Length in inches	130
Billet Temp., °F	1800	Extrusion Surface Finish	Good
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	23	Die Rework	None
Billet Lubricant	"D"	No. of Extrusions Through Same Die	None
Die Lubricant	"G"	Cut-off	Cu-Ni
Container Lubricant	"K"		
Die Design No.	PMD 1 B (new)		
Die Material	Stellite		

Extrusion Section Dimensions		
Front	A	.966
	B	1.467
	C	.111
	D	.109
	E	.109
	F	.100R
Center	A	.959
	B	1.460
	C	.107
	D	.109
	E	.109
	F	.100R
Rear	A	.966
	B	1.464
	C	.094
	D	.106
	E	.104
	F	.100R

Extruded Shape Sketch:



REMARKS: All Be pushed, but pressure rise occurred again. 10' of sound straight channel and 2½' of torn material.



Extrusion 63

RA 1102

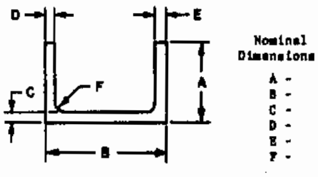
BERYLLIUM EXTRUSION TEST DATA

September 1, 1959

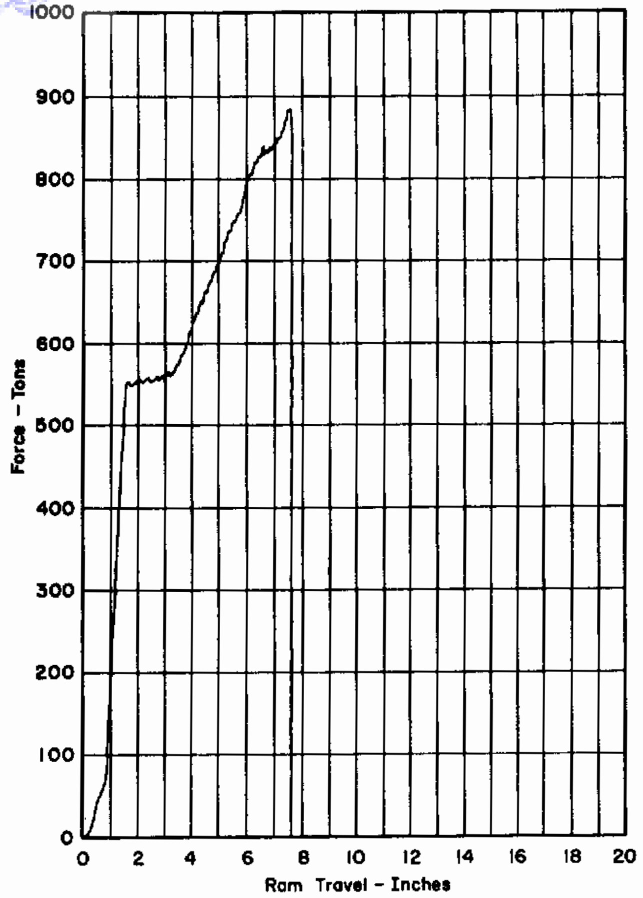
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	64 (NMI 21523)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube Experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	34
Stem Diameter	3.400"	Starting Pressure Reading in psi	107,000
Container Diameter	3.625"	End Pressure Reading in psi	172,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	884
Billet Material	Be sintered bar	Max Pressure on Billet in psi	172,000
Billet Length	10"	Extrusion Length in inches	168
Billet Temp., °F	1800	Extrusion Surface Finish	See remarks
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	28	Die Rework	None
Billet Lubricant	--	No. of Extrusions Through Same Die	None
Die Lubricant	"G"		
Container Lubricant	Mica		
Die Design No.	PMD 2 A (new)		
Die Material	Stellite		

Extrusion Section Dimensions			
Front	A	.972	
	B	1.469	
	C	.117	
	D	.117	
	E	--	
	F	.100R	
Center	A	.971	
	B	1.466	
	C	.105	
	D	.107	
	E	--	
	F	.100R	
Rear	A	.962	
	B	1.462	
	C	.097	
	D	.102	
	E	--	
	F	.100R	

Extruded Shape Sketch:



REMARKS: Pressure rise to stall
4" butt
14' of channel - one side sound
the other side badly torn.



Extrusion 64

RA1102

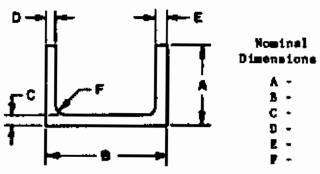
BERYLLIUM EXTRUSION TEST DATA

September 1, 1959

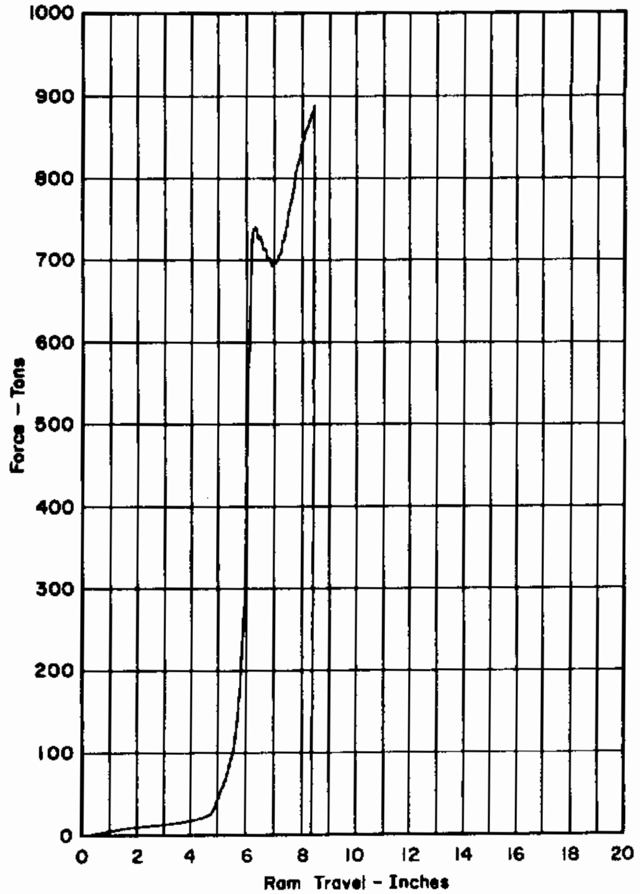
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	65 (NMI 21524)	Die Temp., °F	900
Primary Purpose of this Experiment	Coating Experiment	Container Temp., °F	900
Press Capacity	1000T	Billet Transfer Time in Seconds	26
Stem Diameter	3.400"	Starting Pressure Reading in psi	144,000
Container Diameter	3.625"	End Pressure Reading in psi	173,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	890
Billet Material	Be sintered bar	Max Pressure on Billet in psi	173,000
Billet Length	3" (.010" Fe plating)	Extrusion Length in inches	60
Billet Temp., °F	1750	Extrusion Surface Finish	See remarks
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	17	Die Rework	None
Billet Lubricant	--	No. of Extrusions Through Same Die	None
Die Lubricant	"L"		
Container Lubricant	"K"		
Die Design No.	PMD 2B (new)		
Die Material	Stellite		

Extrusion Section Dimensions			
Front	A	.980	
	B	1.481	
	C	.122	
	D	.118	
	E	.120	
	F	.100R	
Center	A	.997	
	B	1.481	
	C	.114	
	D	.116	
	E	.114	
	F	.100R	
Rear	A	.968	
	B	1.481	
	C	.108	
	D	.108	
	E	.108	
	F	.100R	

Extruded Shape Sketch:



REMARKS: 2" butt left at stall, deep
end defect with cut-off material
"sucked" in.
5' of channel - both sides torn.



Extrusion 65

RA1102

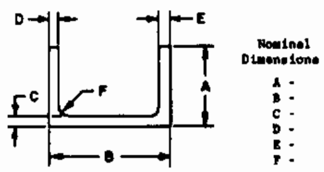
BERYLLIUM EXTRUSION TEST DATA

September 9, 1959

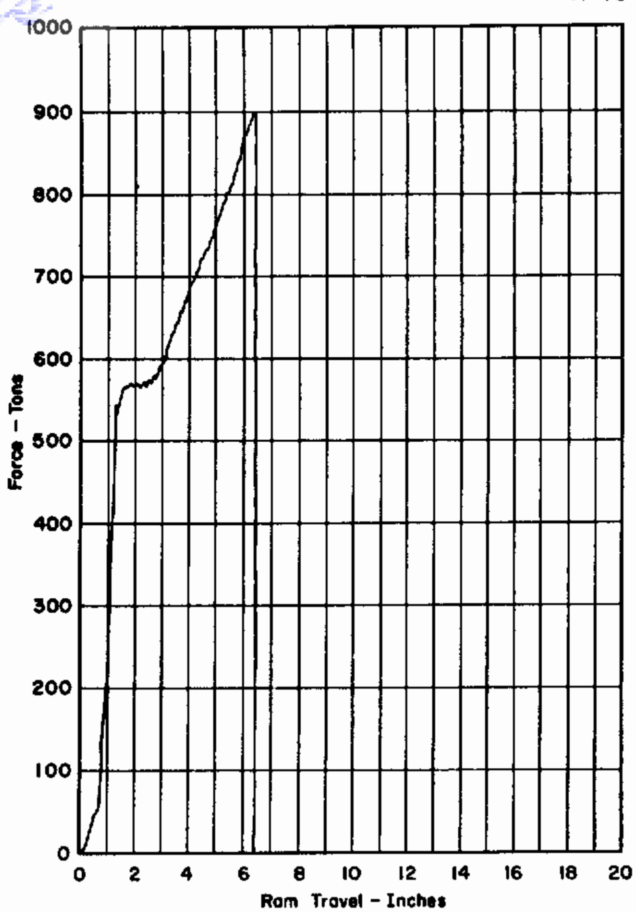
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	66 (NMI 21584)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	22
Stem Diameter	3.400"	Starting Pressure Reading in psi	109,000
Container Diameter	3.625"	End Pressure Reading in psi	175,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	900
Billet Material	Be sintered bar	Max Pressure on Billet in psi	175,000
Billet Length	7"	Extrusion Length in inches	165
Billet Temp., °F	1850	Extrusion Surface Finish	See remarks
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	17	Die Rework	None
Billet Lubricant	"D"	No. of Extrusions Through Same Die	1 prior
Die Lubricant	"G"		
Container Lubricant	Mica		
Die Design No.	PMD 1B		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	.969
		B	1.455
		C	
		D	
		E	
		F	.100R
	Center	A	.9685
		B	1.458
		C	
		D	
		E	
		F	.100R
	Rear	A	.968
		B	1.459
		C	
		D	
		E	
		F	.100R

Extruded Shape Sketch:



REMARKS: Pressure rise started after short run - left $1\frac{1}{2}$" butt at stall. Scattered small tears along entire length. See attached table for special dimension study made on this extrusion.



Extrusion 66

RA1102

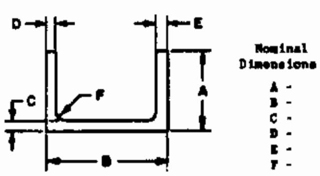
BERYLLIUM EXTRUSION TEST DATA

September 9, 1959

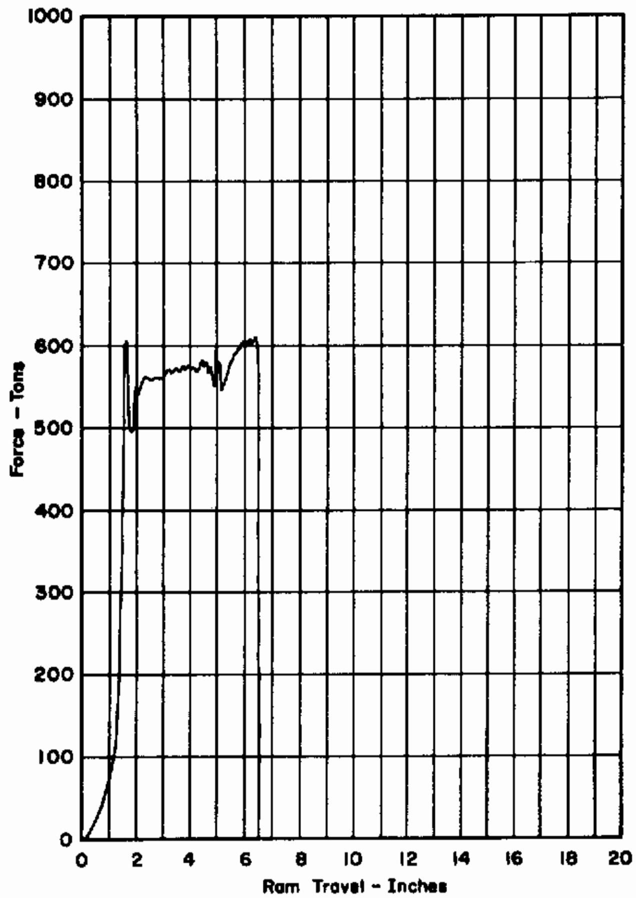
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	67 (NMI 21585)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	31
Stem Diameter	3.400"	Starting Pressure Reading in psi	107,000
Container Diameter	3.625"	End Pressure Reading in psi	114,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	590
Billet Material	CRS - 45° nose	Max Pressure on Billet in psi	114,000
Billet Length	4"	Extrusion Length in inches	100
Billet Temp., °F	1850	Extrusion Surface Finish	Good
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	19	Die Rework	None
Billet Lubricant	"D"	No. of Extrusions Through Same Die	1 prior
Die Lubricant	"H"		
Container Lubricant	Mica		
Die Design No.	PMD 1 A		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	.9675
		B	1.455
		C	.091
		D	.109
		E	.106
		F	.100R
	Center	A	.968
		B	1.460
		C	.091
		D	.109
		E	.105
		F	.100R
	Rear	A	.969
		B	1.464
		C	.091
		D	.105
		E	.101
		F	.100R

Extruded Shape Sketch:



REMARKS: Large volume of smoke emitted from die head. Explosion occurred near end of extrusion. Channel separated from cut-off, presumably by explosion.



Extrusion 67

RA1102

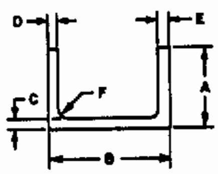
BERYLLIUM EXTRUSION TEST DATA

September 9, 1959

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	68 (NMI 21586)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	56
Stem Diameter	3.400"	Starting Pressure Reading in psi	173,000
Container Diameter	3.625:	End Pressure Reading in psi	173,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	890
Billet Material	Be sintered bar	Max Pressure on Billet in psi	173,000
Billet Length	5"	Extrusion Length in inches	--
Billet Temp., °F	1850	Extrusion Surface Finish	--
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	16	Die Rework	None
Billet Lubricant	"D"	No. of Extrusions Through Same Die	1 prior
Die Lubricant	"E"		
Container Lubricant	"K"		
Die Design No.	PMD 2A		
Die Material	Stellite		

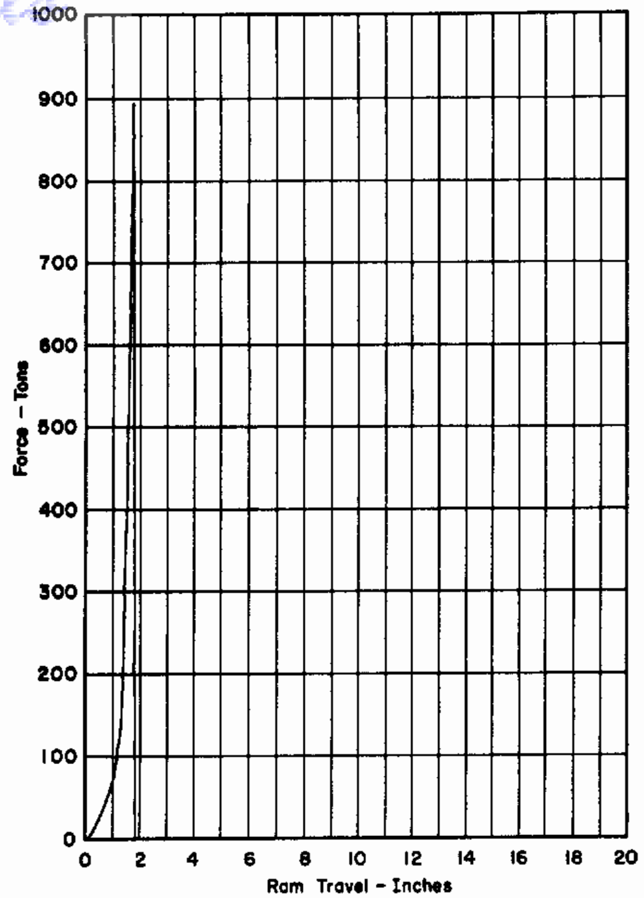
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Stall - glass scooped into die by billet and packed into die opening.



Extrusion 68

RA1102

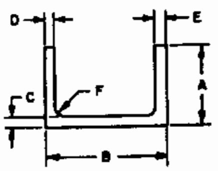
BERYLLIUM EXTRUSION TEST DATA

September 9, 1959

Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	69 (NMI 21587)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube Experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	37
Stem Diameter	3.400"	Starting Pressure Reading in psi	160,000
Container Diameter	3.625"	End Pressure Reading in psi	160,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	880
Billet Material	Be sintered bar	Max Pressure on Billet in psi	160,000
Billet Length	5"	Extrusion Length in inches	--
Billet Temp., °F	1850	Extrusion Surface Finish	--
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	17	Die Rework	None
Billet Lubricant	"D"	No. of Extrusions Through Same Die	1 prior
Die Lubricant	"E"		
Container Lubricant	"K"		
Die Design No.	PMD 2B		
Die Material	Stellite		

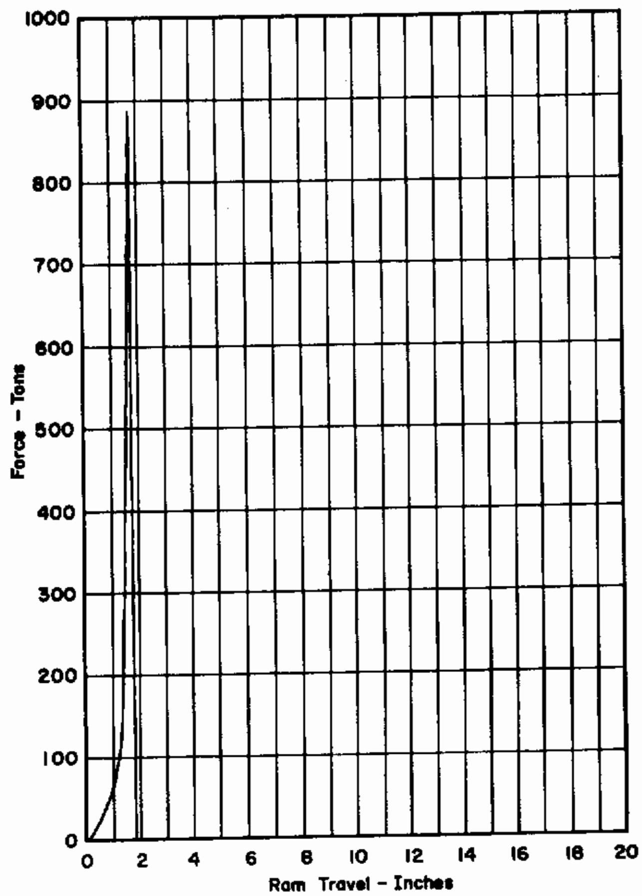
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Stall - Same as #68



Extrusion 69

RA1102

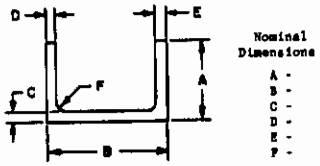
BERYLLIUM EXTRUSION TEST DATA

September 15, 1959

Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	70 (NMI 21657)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	1000
Press Capacity	1000 T	Billet Transfer Time in Seconds	28
Stem Diameter	3.400"	Starting Pressure Reading in psi	115,000
Container Diameter	3.625"	End Pressure Reading in psi	181,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	930
Billet Material	Be sintered bar	Max Pressure on Billet in psi	181,000
Billet Length	7"	Extrusion Length in inches	--
Billet Temp., °F	1850	Extrusion Surface Finish	See remarks
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	22	Die Rework	None
Billet Lubricant	"D"	No. of Extrusions Through Same Die	5
Die Lubricant	"G" ½ usual amount	Cut-off	Cu-Ni
Container Lubricant	Mica		
Die Design No.	PMD 1		
Die Material	Stellite		

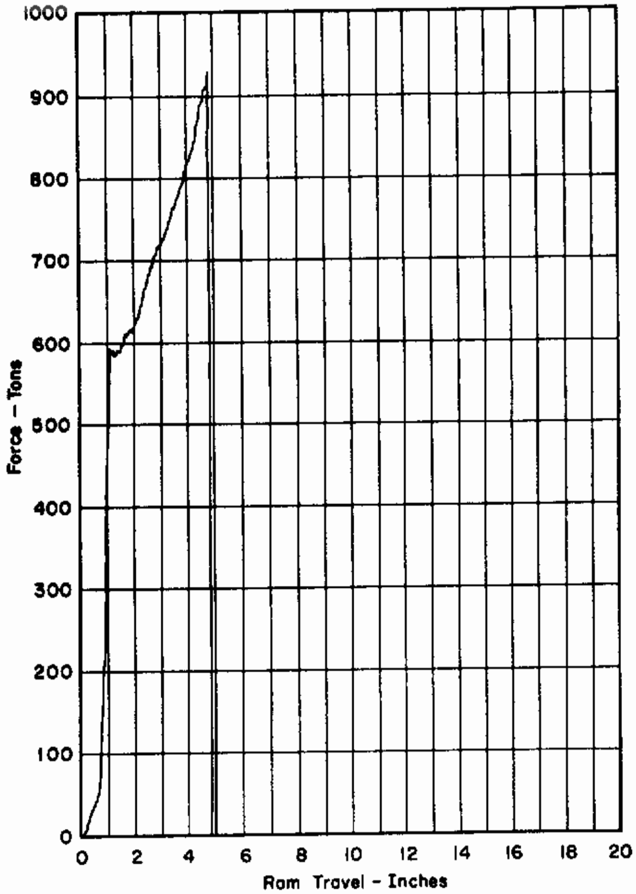
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Stalled after pressure rise - 4" butt. Glass on OD was still soft. Sides of channel rippled toward end. Bottom tore.



Extrusion 70

RA1102

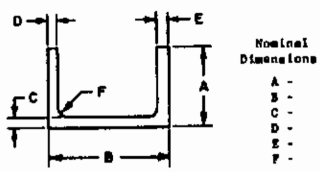
BERYLLIUM EXTRUSION TEST DATA

September 15, 1959

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	71 (NMI 21658)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube Experiment	Container Temp., °F	1000
Press Capacity	1000 T	Billet Transfer Time in Seconds	26
Stem Diameter	3.400"	Starting Pressure Reading in psi	110,000
Container Diameter	3.625"	End Pressure Reading in psi	179,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	920
Billet Material	Be sintered bar	Max Pressure on Billet in psi	179,000
Billet Length	5"	Extrusion Length in inches	110
Billet Temp., °F	1850	Extrusion Surface Finish	Fair
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	15	Die Rework	None
Billet Lubricant	"D"	No. of Extrusions Through Same Die	2 prior
Die Lubricant	"G"	Cut-off	Graphite
Container Lubricant	Mica		
Die Design No.	PMD 1A		
Die Material	Stellite		

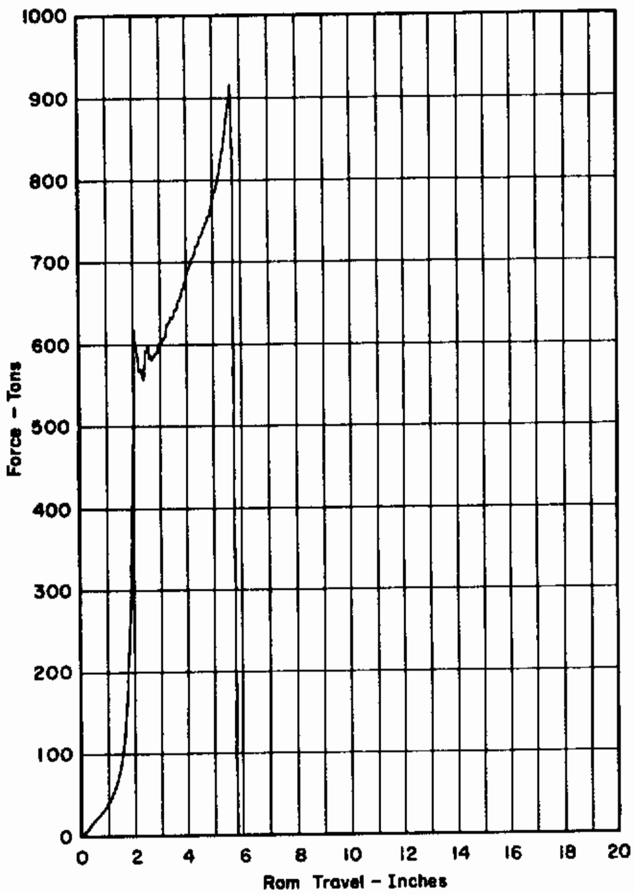
Extrusion Section Dimensions			
	Front	A	.955
		B	1.455
		C	.087
		D	.104
		E	.104
		F	.100R
	Center	A	.955
		B	1.458
		C	.083
		D	.101
		E	.101
		F	.100R
	Rear	A	.952
		B	1.450
		C	.074
		D	.098
		E	.098
		F	.100R

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Stall at end of pressure rise 1½" butt. Channel straight - slight tearing.



Extrusion 71

RA1102

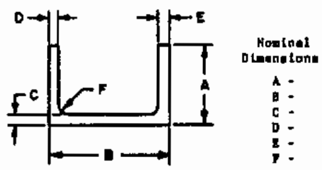
BERYLLIUM EXTRUSION TEST DATA

September 15, 1959

Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	72 (NMI 21659)	Die Temp., °F	900
Primary Purpose of this Experiment	Coating experiment	Container Temp., °F	1000
Press Capacity	1000 T	Billet Transfer Time in Seconds	22
Stem Diameter	3.400"	Starting Pressure Reading in psi	107,000
Container Diameter	3.625"	End Pressure Reading in psi	134,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	690
Billet Material	Be sintered bar	Max Pressure on Billet in psi	134,000
Billet Length	3" (.010" Ni coating)	Extrusion Length in inches	80
Billet Temp., °F	1850	Extrusion Surface Finish	Fair - see remark
Type of Billet Heating	Furnace under graphite	Die Condition	Normal
Billet Heating Time in Minutes	277	Die Rework	None
Billet Lubricant	--	No. of Extrusions Through Same Die	3 prior
Die Lubricant	"G"	Cut-off	Graphite
Container Lubricant	"K"		
Die Design No.	PMD 1B		
Die Material	Stellite		

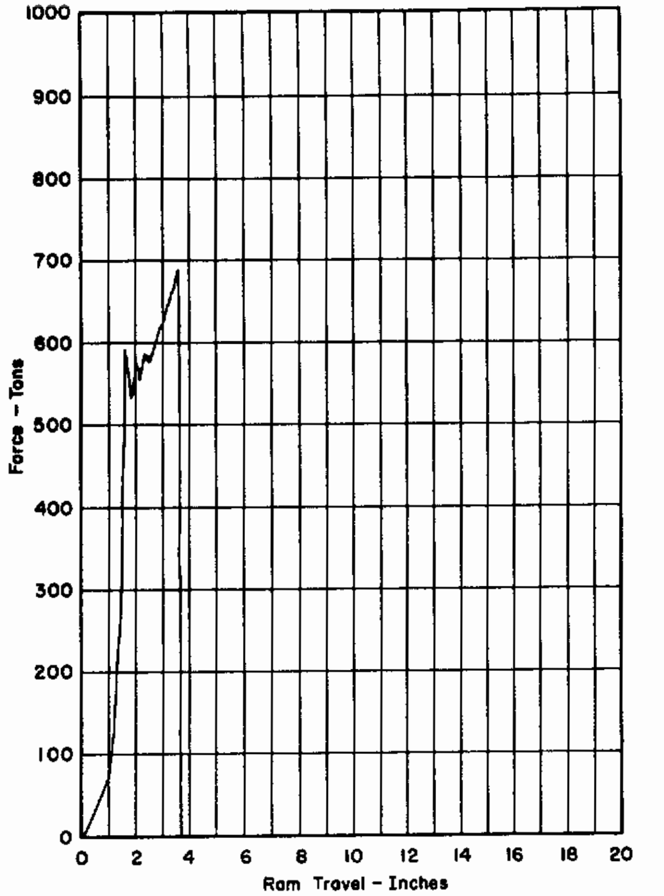
Extrusion Section Dimensions			
Front	A	.965	
	B	1.460	
	C	.097	
	D	.105	
	E	.106	
	F	.100R	
Center	A	.967	
	B	1.466	
	C	.095	
	D	.102	
	E	.102	
	F	.100R	
Rear	A	.964	
	B	1.464	
	C	.088	
	D	.101	
	E	.100	
	F	.100R	

Extruded Shape Sketch:



REMARKS: Limit switch set incorrectly stopped ram with 3/4" of Be still in liner. Pressure rise occurred.

One side of channel torn, the other sound.



Extrusion 72

RA1102

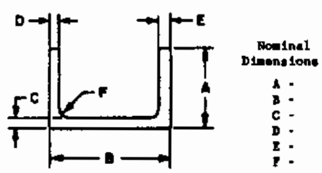
BERYLLIUM EXTRUSION TEST DATA

September 15, 1959

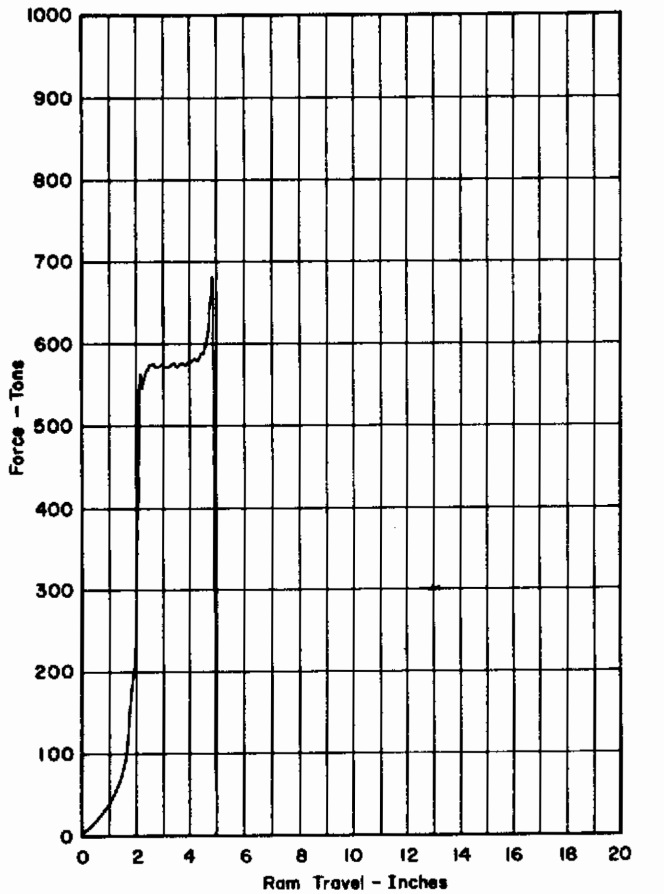
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	73 (NMI 21660)	Die Temp., °F	900
Primary Purpose of this Experiment	Coating experiment	Container Temp., °F	1000
Press Capacity	1000 T	Billet Transfer Time in Seconds	27
Stem Diameter	3.400"	Starting Pressure Reading in psi	109,000
Container Diameter	3.625"	End Pressure Reading in psi	132,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	680
Billet Material	Be sintered bar	Max Pressure on Billet in psi	132,000
Billet Length	3" (.010" Fe coating)	Extrusion Length in inches	90
Billet Temp., °F	1850	Extrusion Surface Finish	Fair-see remarks
Type of Billet Heating	Furnace in graphite	Die Condition	Normal
Billet Heating Time in Minutes	292	Die Rework	Yes
Billet Lubricant	--	No. of Extrusions Through Same Die	3
Die Lubricant	"G"	Cut-off	Graphite
Container Lubricant	"K"		
Die Design No.	PMD 2		
Die Material	Stellite		

Extrusion Section Dimensions			
Front	A	1.109	
	B	1.509	
	C	.126	
	D	.125	
	E	.125	
	F	.100R	
Center	A	1.108	
	B	1.508	
	C	.122	
	D	.120	
	E	.120	
	F	.100R	
Rear	A	1.104	
	B	1.507	
	C	.120	
	D	.119	
	E	.119	
	F	.100R	

Extruded Shape Sketch:



REMARKS: One side torn, other sound.



Extrusion 73

RA1102

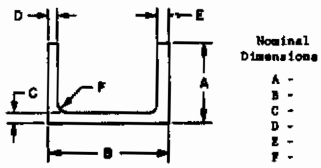
BERYLLIUM EXTRUSION TEST DATA

September 28, 1959

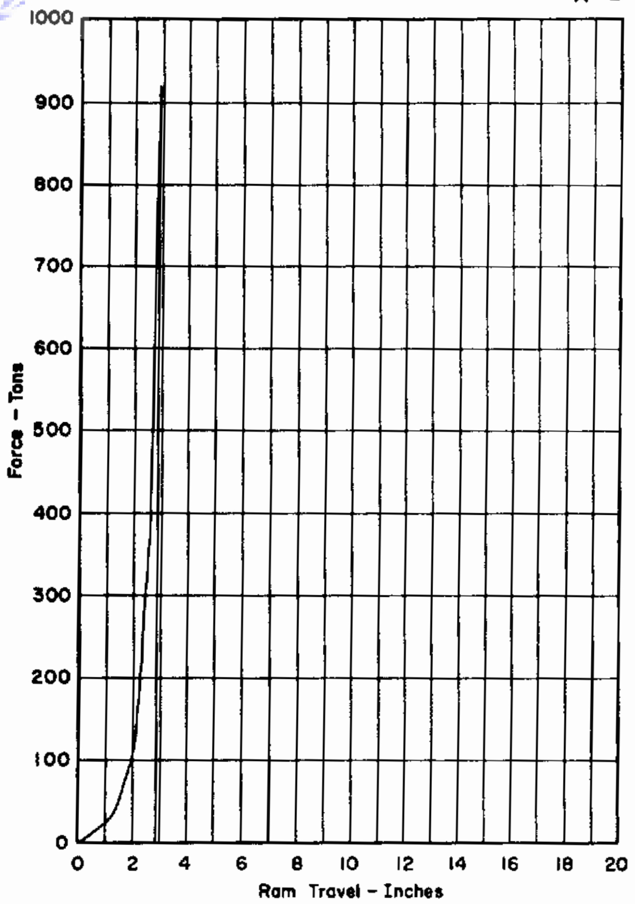
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	74 (NMI 21729)	Die Temp., °F	900
Primary Purpose of this Experiment	Flow Pattern Experiment	Container Temp., °F	1000
Press Capacity	1000 T	Billet Transfer Time in Seconds	27
Stem Diameter	3.400"	Starting Pressure Reading in psi	178,000
Container Diameter	3.625"	End Pressure Reading in psi	178,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	920
Billet Material	Be sintered bar	Max Pressure on Billet in psi	178,000
Billet Length	4" - 1"R nose wired	Extrusion Length in inches	--
Billet Temp., °F	1750	Extrusion Surface Finish	--
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	18	Die Rework	None
Billet Lubricant	--	No. of Extrusions Through Same Die	None
Die Lubricant	"G" 3 pad	Cut-off	Graphite
Container Lubricant	Mica		
Die Design No.	PMD 1E		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



REMARKS: Stall - glass fused at billet and powdered at die - packed into die opening.



Extrusion 74

RA1102

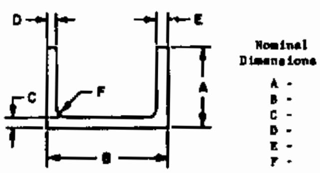
BERYLLIUM EXTRUSION TEST DATA

September 28, 1959

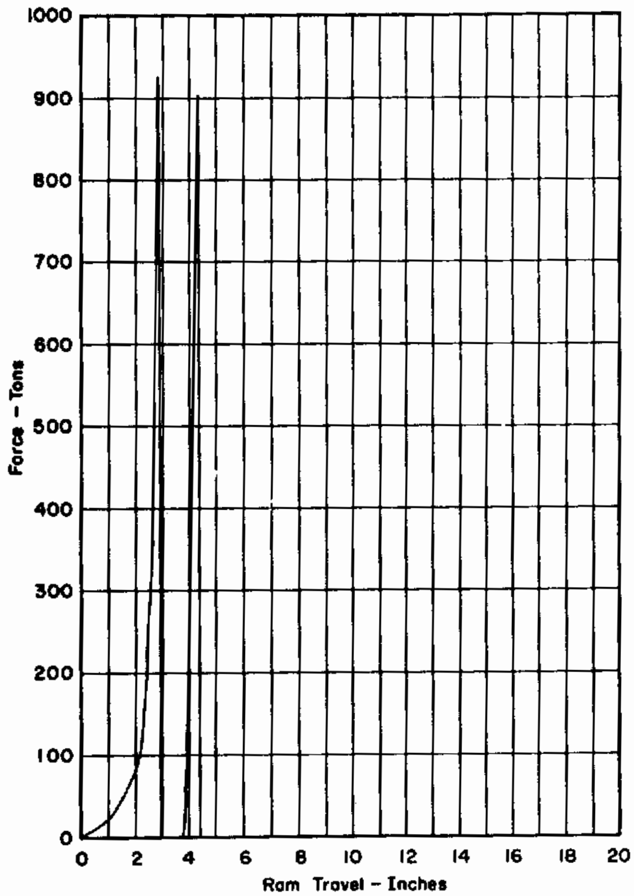
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	75 (NMI 21730)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube Experiment	Container Temp., °F	1000
Press Capacity	1000 T	Billet Transfer Time in Seconds	32
Stem Diameter	3.400"	Starting Pressure Reading in psi	180,000-176,000
Container Diameter	3.625"	End Pressure Reading in psi	180,000-176,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	925-905
Billet Material	Be sintered bar	Max Pressure on Billet in psi	180,000-176,000
Billet Length	5" (45° nose)	Extrusion Length in inches	--
Billet Temp., °F	1750	Extrusion Surface Finish	--
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	26	Die Rework	None
Billet Lubricant	--	No. of Extrusions Through Same Die	None
Die Lubricant	"G" (3 pad)		
Container Lubricant	Mica		
Die Design No.	PMD 1F		
Die Material	Stellite (EDS)		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



REMARKS: Stall - hit twice



RA1102

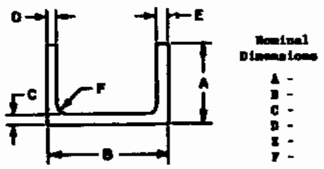
BERYLLIUM EXTRUSION TEST DATA

September 28, 1959

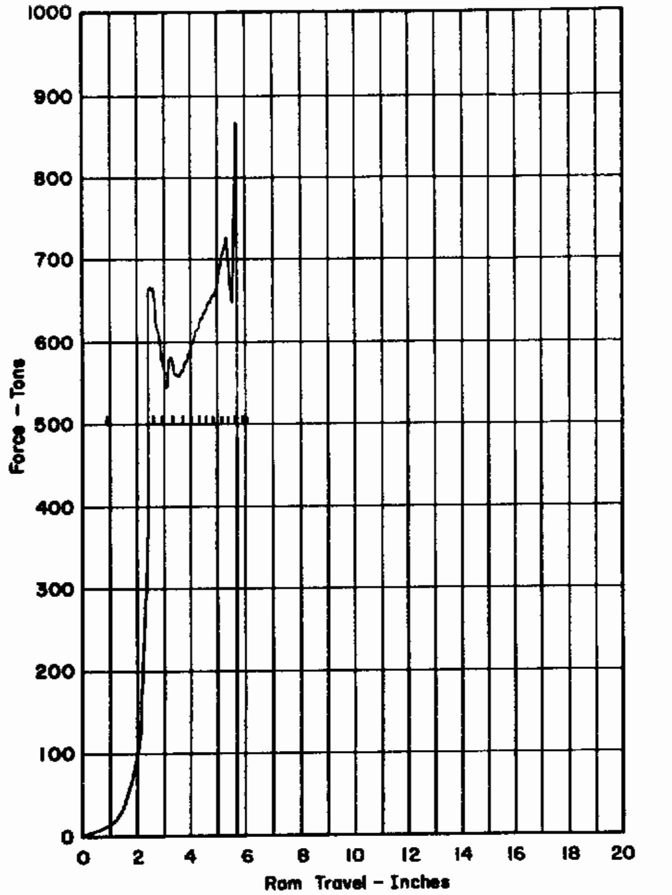
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	76 (NMI 21731)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	1000
Press Capacity	1000 T	Billet Transfer Time in Seconds	24
Stem Diameter	3.400"	Starting Pressure Reading in psi	128,000
Container Diameter	3.625"	End Pressure Reading in psi	141,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	725
Billet Material	Be sintered bar	Max Pressure on Billet in psi	141,000
Billet Length	3" (3/4R nose)	Extrusion Length in inches	80
Billet Temp., °F	1850	Extrusion Surface Finish	Good
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	18	Die Rework	None
Billet Lubricant	--	No. of Extrusions Through Same Die	1 prior
Die Lubricant	"G"		
Container Lubricant	Mica		
Die Design No.	PMD 1E		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



REMARKS: Pushed entire billet - pressure rose. Tearing occurred at front - otherwise the channel was straight and sound.



Extrusion 76

RA1102

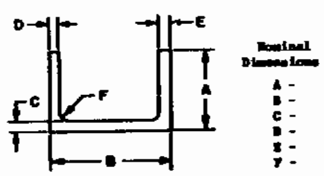
BERYLLIUM EXTRUSION TEST DATA

September 28, 1959

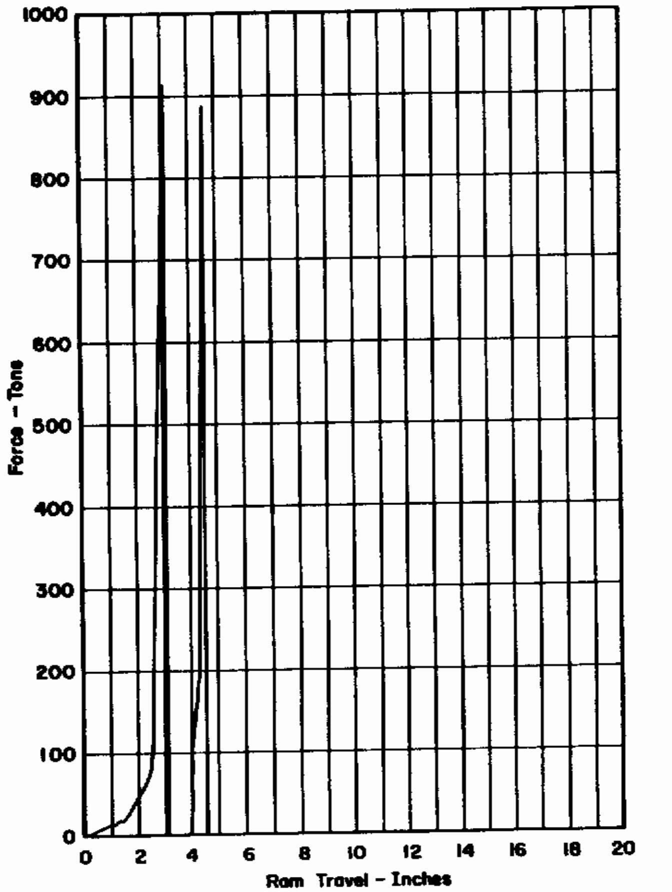
Subcontractor	NMI	Type of Die Fabrication	Cast Insert
Extrusion No.	77 (NMI 21732)	Die Temp., °F	900
Primary Purpose of this Experiment	Die design experiment	Container Temp., °F	1000
Press Capacity	1000 T	Billet Transfer Time in Seconds	22
Stem Diameter	3.400"	Starting Pressure Reading in psi	177,000-173,000
Container Diameter	3.625"	End Pressure Reading in psi	177,000-173,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	910-890
Billet Material	Be sintered bar	Max Pressure on Billet in psi	177,000-173,000
Billet Length	3" (5/8R nose)	Extrusion Length in inches	--
Billet Temp., °F	1850	Extrusion Surface Finish	--
Type of Billet Heating	Salt bath	Die Condition	Normal
Billet Heating Time in Minutes	21	Die Rework	None
Billet Lubricant	--	No. of Extrusions Through Same Die	None
Die Lubricant	"G"		
Container Lubricant	Mica		
Die Design No.	DC 1		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



REMARKS: Stalled as Be entered die. Hit twice with ram.



Extrusion 77

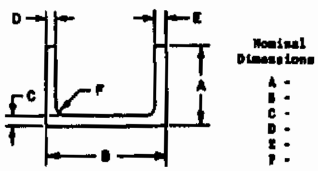
RA1102

BERYLLIUM EXTRUSION TEST DATA
Task C 10/5/59

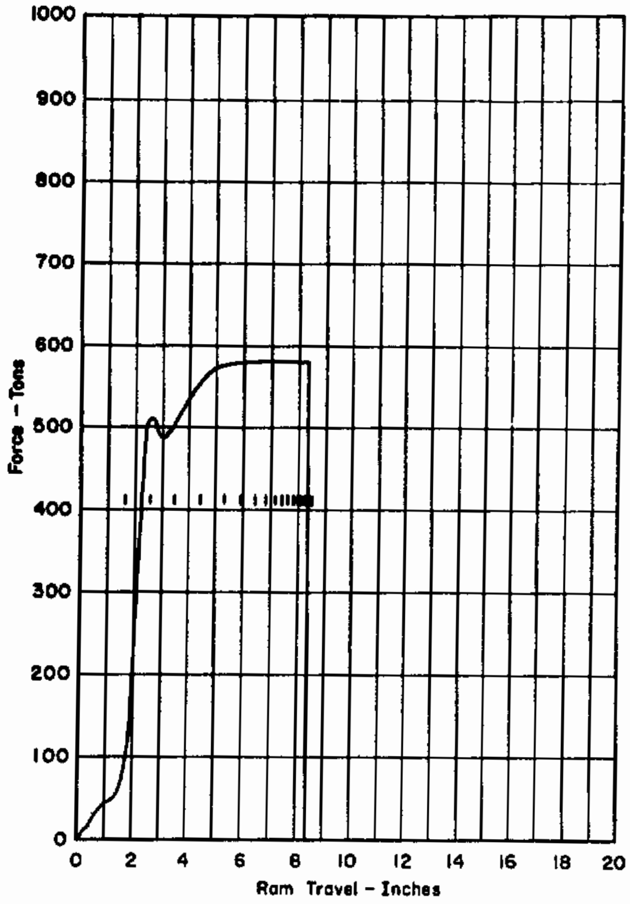
Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	78 (21811)	Die Temp., °F	900°
Primary Purpose of this Experiment	Pressure Experiment	Container Temp., °F	900°
Press Capacity	600 T	Billet Transfer Time in Seconds	30
Stem Diameter	3"	Starting Pressure Reading in psi	137,000
Container Diameter	3.050	End Pressure Reading in psi	164,000
Extrusion Ratio	18½ to 1	Max Force on Billet in Tons	600T
Billet Material	Be sintered bar	Max Pressure on Billet in psi	164,000
Billet Length	10" (2.925" diam)	Extrusion Length in inches	106
Billet Temp., °F	1800°	Extrusion Surface Finish	Fair
Type of Billet Heating	Salt bath	Die Condition	Poor
Billet Heating Time in Minutes	36	Die Rework	None
Billet Lubricant	D	No. of Extrusions Through Same Die	None prior
Die Lubricant	G		
Container Lubricant	K		
Die Design No.	FMD1D		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	.979"
		B	1.474"
		C	.108"
		D	.120"
		E	.118"
		F	.100R
	Center	A	.967"
		B	1.472"
		C	.098"
		D	.110"
		E	.110"
		F	.100R
	Rear	A	.961"
		B	1.464"
		C	.083"
		D	.101"
		E	.105"
		F	.100R

Extruded Shape Sketch:



REMARKS:
4-inch butt - straight channel-started sound - tearing in last 2/3 - ran out of lube. Die closed on corners.



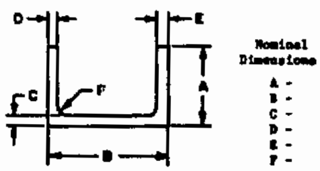
Extrusion No. 78

BERYLLIUM EXTRUSION TEST DATA

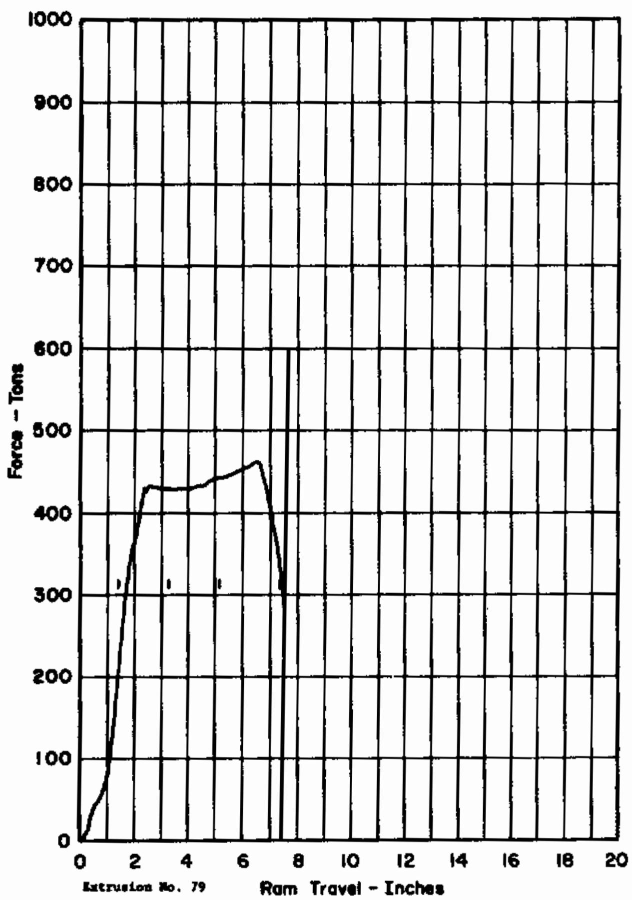
Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	79 (22002)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	29
Stem Diameter	2.850	Starting Pressure Reading in psi	117,000
Container Diameter	3.050	End Pressure Reading in psi	127,000
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	465
Billet Material	Be sintered bar	Max Pressure on Billet in psi	127,000
Billet Length	6 inches	Extrusion Length in inches	104
Billet Temp., °F	1850	Extrusion Surface Finish	Poor
Type of Billet Heating	Salt	Die Condition	New insert
Billet Heating Time in Minutes	31	Die Rework	Die scrapped
Billet Lubricant	D1	No. of Extrusions Through Same Die	One
Die Lubricant	K (cone)	Cone	Glass 45°
Container Lubricant	K	Scheduled speed	140 ipm
Die Design No.	FMD-1A		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	0.978
		B	1.472
		C	0.105
		D	0.120
		E	0.118
		F	0.100R
	Center	A	0.977
		B	1.480
		C	0.101
		D	0.119
		E	0.115
		F	0.100R
	Rear	A	0.975
		B	1.501
		C	0.099
		D	0.117
		E	0.120
		F	0.100R

Extruded Shape Sketch:



REMARKS:
Rattlesnaked throughout - breakthrough of "U".



Extrusion No. 79

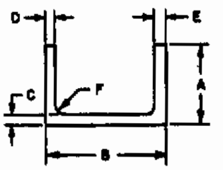
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	80 (22003)	Die Temp., °F	950
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	25
Stem Diameter	2.850	Starting Pressure Reading in psi	115,000
Container Diameter	3.050	End Pressure Reading in psi	131,000
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	480
Billet Material	Be sintered bar	Max Pressure on Billet in psi	131,000
Billet Length	4 inches	Extrusion Length in inches	88-1/2
Billet Temp., °F	1850	Extrusion Surface Finish	Good
Type of Billet Heating	Salt	Die Condition	New insert
Billet Heating Time in Minutes	34	Die Rework	Needed
Billet Lubricant	D1	No. of Extrusions Through Same Die	One
Die Lubricant	G	Cone	None
Container Lubricant	K	Scheduled speed	140 ipm
Die Design No.	FMD-1C	Actual speed	140
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	0.970
		B	1.461
		C	0.110
		D	0.975
		E	0.974
		F	0.100R
	Center	A	0.966
		B	1.461
		C	0.098
		D	0.966
		E	0.967
		F	0.100R
	Rear	A	0.968
		B	1.456
		C	0.087
		D	0.966
		E	0.969
		F	0.100R

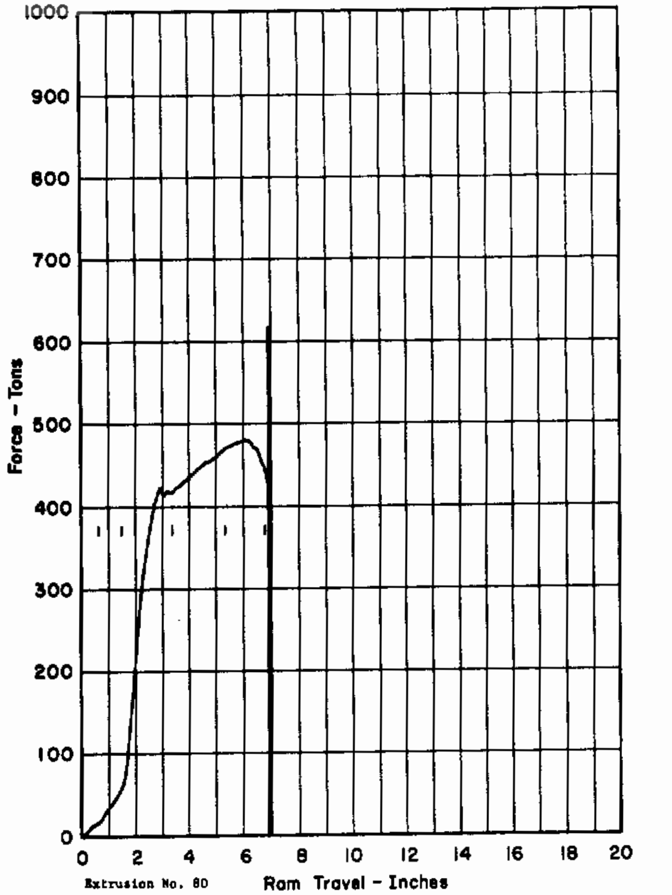
Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

Good and straight - sides with no rattlesnake. Last 4 inches of extrusion started to rattlesnake.



Extrusion No. 80

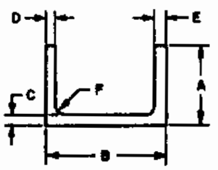
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	81 (22004)	Die Temp., °F	900
Primary Purpose of this Experiment	Repeat 80	Container Temp., °F	900
Press Capacity	600T	Billet Transfer Time in Seconds	25
Stem Diameter	2.850	Starting Pressure Reading in psi	164,000
Container Diameter	3.050	End Pressure Reading in psi	164,000
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	600
Billet Material	Be sintered bar	Max Pressure on Billet in psi	164,000
Billet Length	4 inches	Extrusion Length in inches	0
Billet Temp., °F	1850	Extrusion Surface Finish	N/A
Type of Billet Heating	Salt	Die Condition	Used not repolished
Billet Heating Time in Minutes	30	Die Rework	Needed
Billet Lubricant	D1	No. of Extrusions Through Same Die	One prior
Die Lubricant	G	Cone	None
Container Lubricant	K	Speed	N/A
Die Design No.	FMD-1C		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

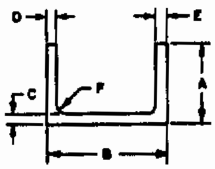
Tried to use same die twice without full cleaning procedure. Billet stalled.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	82 (22080)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	22
Stem Diameter	3.400	Starting Pressure Reading in psi	113,000
Container Diameter	3.625	End Pressure Reading in psi	177,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	910
Billet Material	Be sintered bar	Max Pressure on Billet in psi	177,000
Billet Length	4 inches 45° nose	Extrusion Length in inches	97
Billet Temp., °F	1850	Extrusion Surface Finish	Poor
Type of Billet Heating	Salt	Die Condition	New
Billet Heating Time in Minutes	36	Die Rework	None
Billet Lubricant	D1	No. of Extrusions Through Same Die	None prior
Die Lubricant	"N" cone and G in center	Cone	Glass
Container Lubricant	K	Speed	Slowed to 13 ipm
Die Design No.	PMD-1D		
Die Material	Stellite		

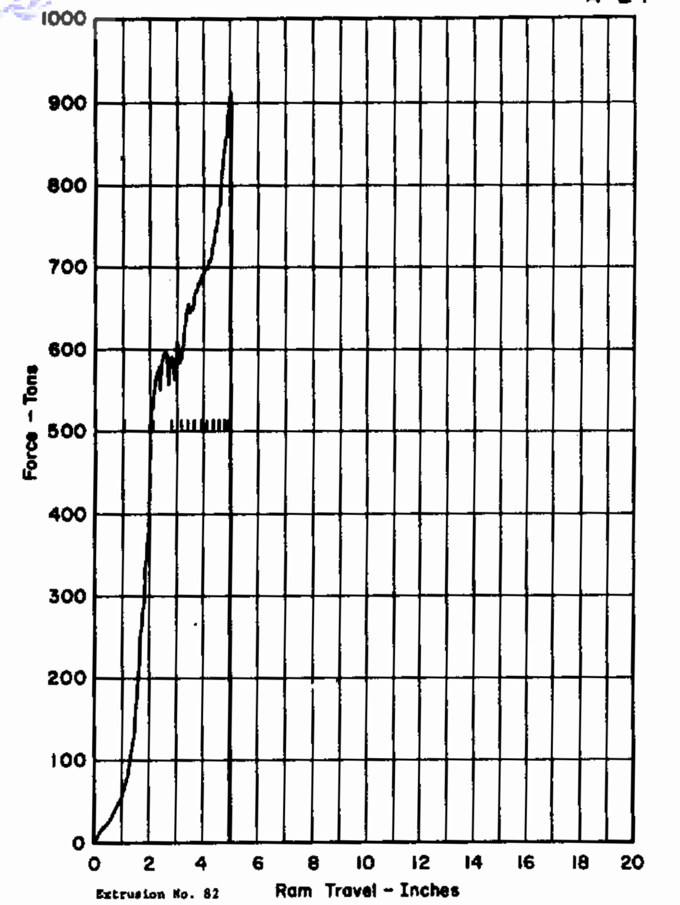
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: ~ 1/2-inch butt - entire length of extrusion too torn for measurement - glass fed through die too fast - in thick gobs on metal - die damaged.



Extrusion No. 82

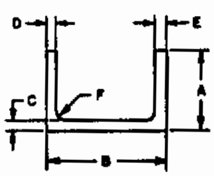
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	83 (22081)	Die Temp., °F	900
Primary Purpose of this Experiment	Cone experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	33
Stem Diameter	3.400	Starting Pressure Reading in psi	113,000
Container Diameter	3.625	End Pressure Reading in psi	177,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	910
Billet Material	Be sintered bar	Max Pressure on Billet in psi	177,000
Billet Length	4 inches - 3/8 R nose	Extrusion Length in inches	110
Billet Temp., °F	1850	Extrusion Surface Finish	Excellent
Type of Billet Heating	Salt	Die Condition	New
Billet Heating Time in Minutes	32	Die Rework	None
Billet Lubricant	N	No. of Extrusions Through Same Die	None prior
Die Lubricant	G	Entry cone	70°
Container Lubricant	K	Speed	Slowed to 13 ipm
Die Design No.	PMD-1E		
Die Material	Stellite		

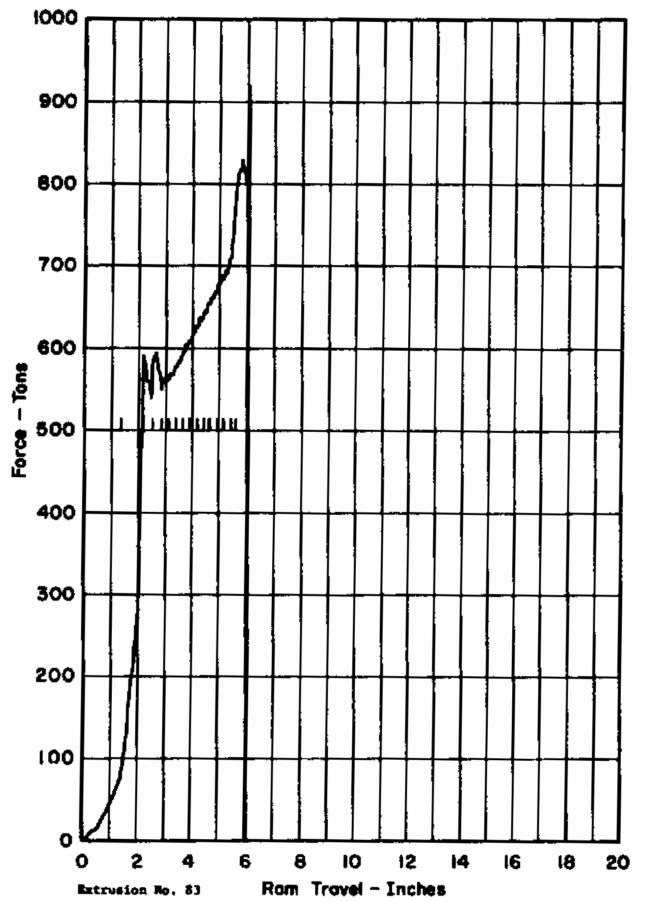
Extrusion Section Dimensions			
	Front	A	0.979
		B	1.475
		C	0.101
		D	0.116
		E	0.116
		F	0.100R
	Center	A	0.976
		B	1.470
		C	0.095
		D	0.106
		E	0.106
		F	0.100R
	Rear	A	0.966
		B	1.475
		C	0.090
		D	0.103
		E	0.101
		F	0.100R

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Pressure rise - all pushed - little tearing at end. Die ? - cone in good shape - some glass on it.



Extrusion No. 83

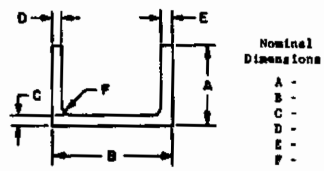
RA1102

BERYLLIUM EXTRUSION TEST DATA

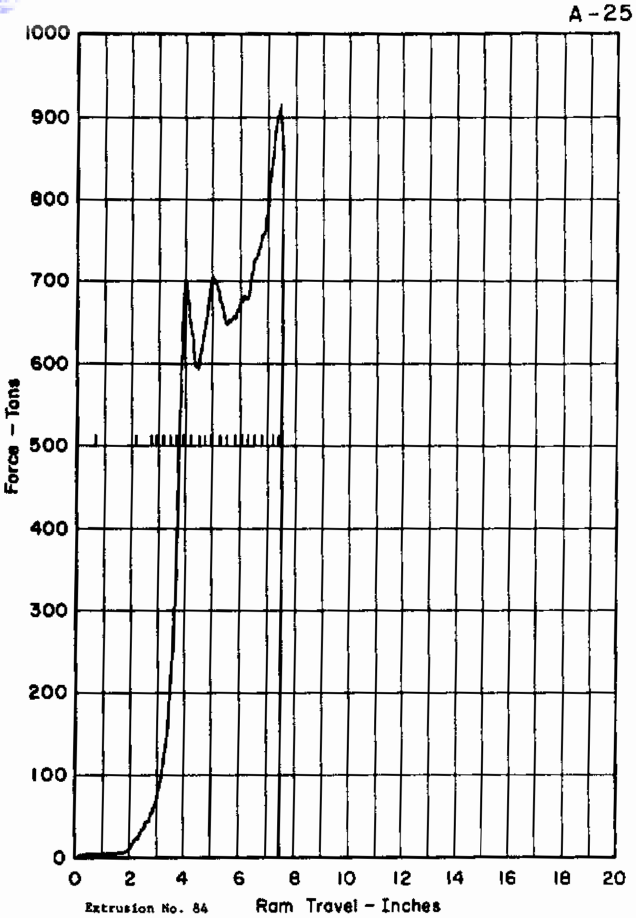
Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	84 (22082)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	50
Stem Diameter	3.400	Starting Pressure Reading in psi	136,000
Container Diameter	3.625	End Pressure Reading in psi	177,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	910
Billet Material	Be sintered bar	Max Pressure on Billet in psi	177,000
Billet Length	4 inches - 45° nose	Extrusion Length in inches	108-1/2
Billet Temp., °F	1850	Extrusion Surface Finish	Rough
Type of Billet Heating	Salt	Die Condition	New
Billet Heating Time in Minutes	39	Die Rework	None
Billet Lubricant	N	No. of Extrusions Through Same Die	None prior
Die Lubricant	N core and G	Cone	Glass
Container Lubricant	K	Speed	13 ipm
Die Design No.	PMD-1		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	0.966
		B	1.466
		C	0.066
		D	0.107
		E	0.105
		F	0.100R

Extruded Shape Sketch:



REMARKS: Tearing good - all pushed. Rattlesnaked "E" side very bad "D" side very irregular. Front and center too torn for measurements.



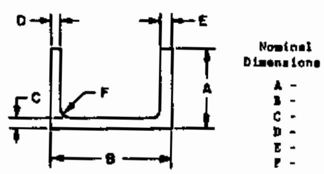
RA1102

BERYLLIUM EXTRUSION TEST DATA

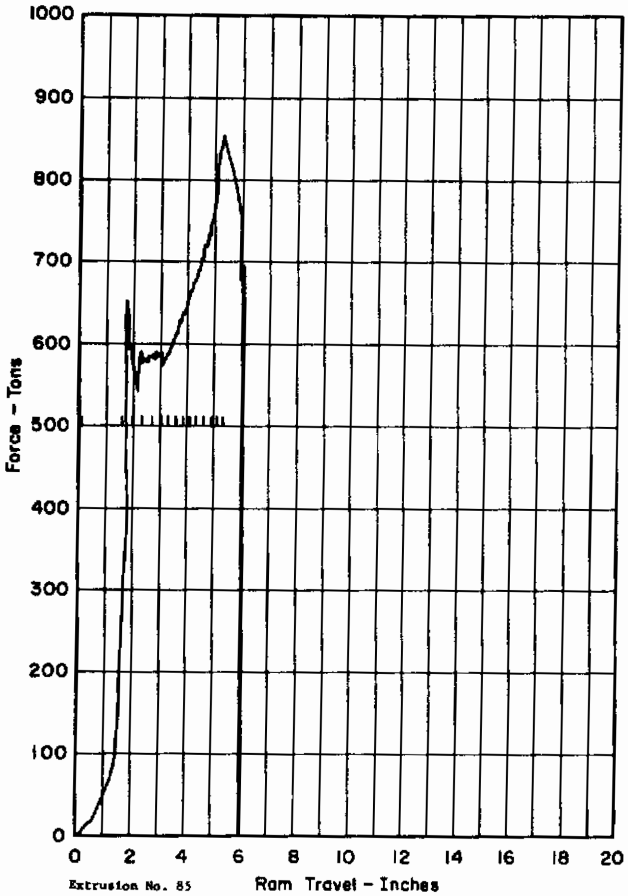
Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	85 (22083)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	35
Stem Diameter	3.400	Starting Pressure Reading in psi	126,000
Container Diameter	3.625	End Pressure Reading in psi	165,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	850
Billet Material	Be sintered bar	Max Pressure on Billet in psi	165,000
Billet Length	4 inches 45° nose	Extrusion Length in inches	117
Billet Temp., °F	1850	Extrusion Surface Finish	Poor
Type of Billet Heating	Salt	Die Condition	New
Billet Heating Time in Minutes	30	Die Rework	None
Billet Lubricant	N	No. of Extrusions Through Same Die	None prior
Die Lubricant	G	Entry cone	90° steel
Container Lubricant	G	Speed	13 ipm
Die Design No.	PMD-1F		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	0.970
		B	1.466
		C	0.101
		D	0.113
		E	0.106
		F	0.100R
	Center	A	0.939
		B	1.457
		C	0.085
		D	0.106
		E	0.086
		F	0.100R
	Rear	A	0.926
		B	1.459
		C	0.080
		D	0.091
		E	0.086
		F	0.100R

Extruded Shape Sketch:



REMARKS: All extruded but pressure rise occurred after short run - cone in good condition - one bad tear one side ~2-1/2 feet from front.



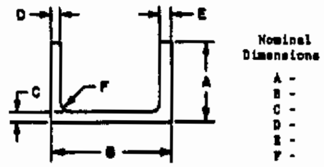
RA1102

BERYLLIUM EXTRUSION TEST DATA

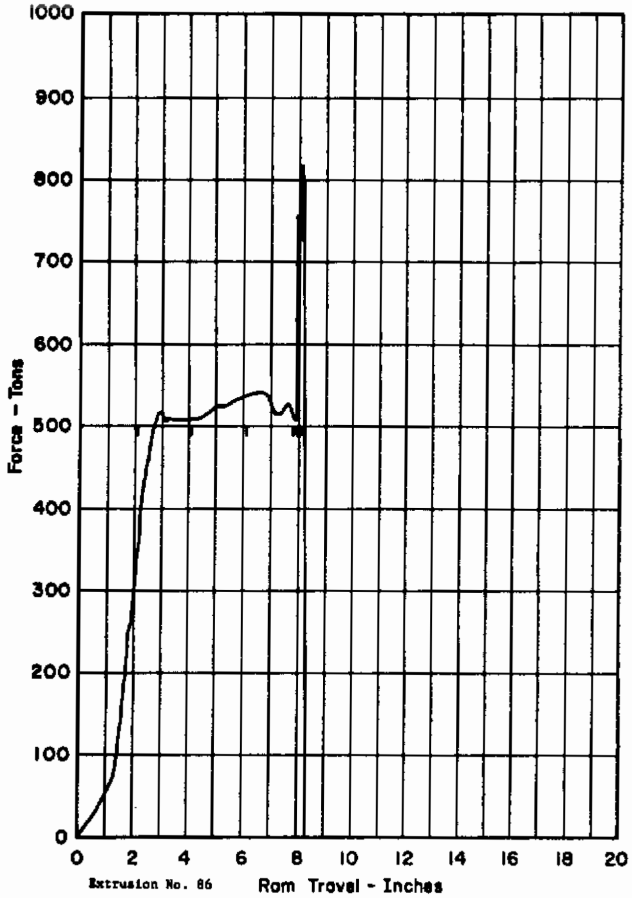
Subcontractor	NMI	Type of Die Fabrication	Machined and Hardened
Extrusion No.	86 (22103)	Die Temp., °F	900
Primary Purpose of this Experiment	Cone experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	30
Stem Diameter	3.400	Starting Pressure Reading in psi	99,000
Container Diameter	3.625	End Pressure Reading in psi	100,000
Extrusion Ratio	30:1	Max Force on Billet in Tons	540
Billet Material	CRS	Max Pressure on Billet in psi	105,000
Billet Length	6 inches	Extrusion Length in inches	180
Billet Temp., °F	1850	Extrusion Surface Finish	Good
Type of Billet Heating	Salt	Die Condition	Good
Billet Heating Time in Minutes	40	Die Rework	None
Billet Lubricant	D	No. of Extrusions Through Same Die	None prior
Die Lubricant	G	Cone	90° CRS
Container Lubricant		Speed	140 ipm
Die Design No.			
Die Material	Steel		

Extrusion Section Dimensions	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



REMARKS: Went fast - shot out of catch tube - straight - smooth. Cone and die clean - unworn - except small pits in cone surface.



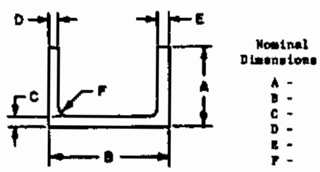
RA1102

BERYLLIUM EXTRUSION TEST DATA

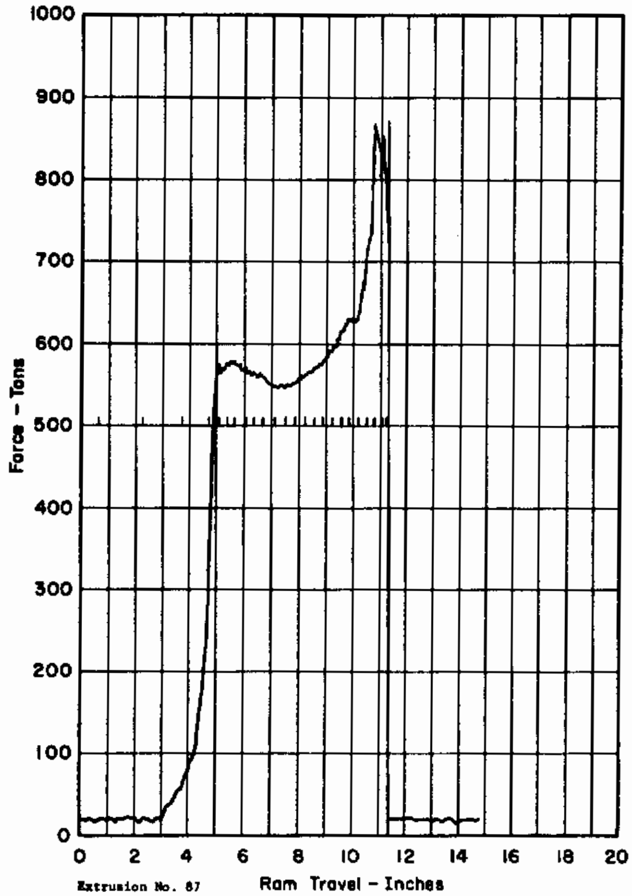
Subcontractor	NMI	Type of Die Fabrication	Machined and hardened
Extrusion No.	87 (22104)	Die Temp., °F	900
Primary Purpose of this Experiment	Cone experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	
Stem Diameter	3.400	Starting Pressure Reading in psi	111,000
Container Diameter	3.625	End Pressure Reading in psi	167,000
Extrusion Ratio	30:1	Max Force on Billet in Tons	860
Billet Material	CRS	Max Pressure on Billet in psi	167,000
Billet Length	6 inches	Extrusion Length in inches	180
Billet Temp., °F	1850	Extrusion Surface Finish	Fair
Type of Billet Heating	Salt	Die Condition	Washed
Billet Heating Time in Minutes	29	Die Rework	N/A
Billet Lubricant	D	No. of Extrusions Through Same Die	None prior
Die Lubricant	G	Cone	90° CRS
Container Lubricant		Speed	13 ipm
Die Design No.			
Die Material	Steel		

Extrusion Section Dimensions	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



REMARKS: Pressure rise occurred. Cone washed into die - die sloughed - rod surface slightly scored.



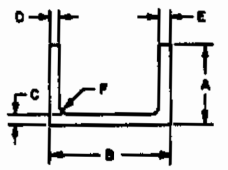
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined and hardened
Extrusion No.	88 (22105)	Die Temp., °F	900
Primary Purpose of this Experiment	Core and lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	20
Stem Diameter	3.400	Starting Pressure Reading in psi	113,000
Container Diameter	3.625	End Pressure Reading in psi	128,000
Extrusion Ratio	30:1	Max Force on Billet in Tons	660
Billet Material	CRS	Max Pressure on Billet in psi	128,000
Billet Length	6 inches	Extrusion Length in inches	180
Billet Temp., °F	1850	Extrusion Surface Finish	Good
Type of Billet Heating	Furnace - graphite	Die Condition	Fair
Billet Heating Time in Minutes	121	Die Rework	None
Billet Lubricant		No. of Extrusions Through Same Die	None prior
Die Lubricant		Cone	90° CRS
Container Lubricant	P	Speed	13 ipm
Die Design No.			
Die Material	Steel		

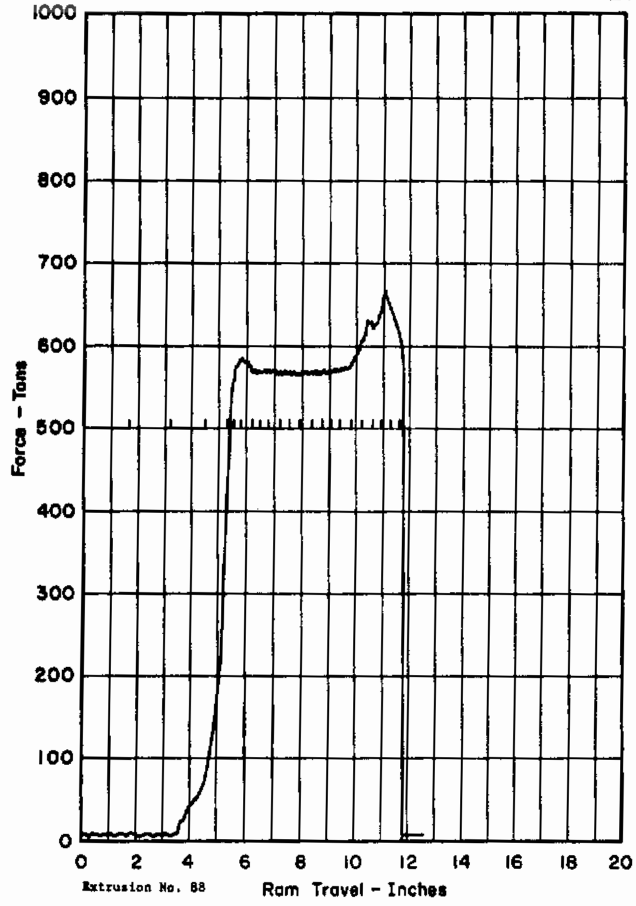
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Flat pressure pattern - no die damage - cone washed slightly - rod left die at high speed - much smoke and flame.



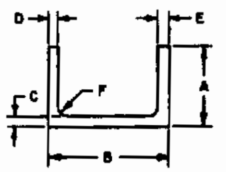
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined and hardened
Extrusion No.	89	Die Temp., °F	900
Primary Purpose of this Experiment	Duplicate No. 88	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	20
Stem Diameter	3.400	Starting Pressure Reading in psi	112,000
Container Diameter	3.625	End Pressure Reading in psi	130,000
Extrusion Ratio	30:1	Max Force on Billet in Tons	670
Billet Material	CRS	Max Pressure on Billet in psi	130,000
Billet Length	6 inches	Extrusion Length in inches	180
Billet Temp., °F	1850	Extrusion Surface Finish	Good
Type of Billet Heating	Furnace	Die Condition	Good
Billet Heating Time in Minutes	130	Die Rework	None
Billet Lubricant		No. of Extrusions Through Same Die	None prior
Die Lubricant		Cone	90° CRS
Container Lubricant	P	Speed	13 ipm
Die Design No.			
Die Material	Steel		

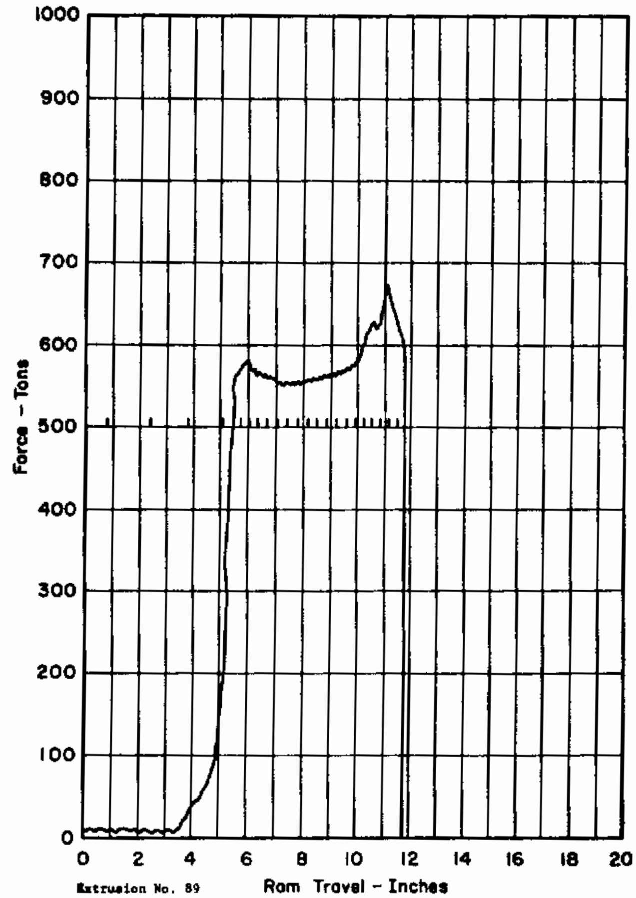
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Results same as No. 88.



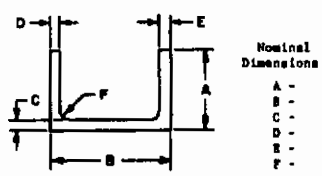
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined and hardened
Extrusion No.	90 (22107)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube Cone experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	24
Stem Diameter	3.400	Starting Pressure Reading in psi	99,000
Container Diameter	3.625	End Pressure Reading in psi	141,000
Extrusion Ratio	30:1	Max Force on Billet in Tons	725
Billet Material	Beryllium	Max Pressure on Billet in psi	141,000
Billet Length	3 inches	Extrusion Length in inches	90
Billet Temp., °F	1850	Extrusion Surface Finish	Good some tears
Type of Billet Heating	Salt	Die Condition	Cracked
Billet Heating Time in Minutes	45	Die Rework	None
Billet Lubricant	D	No. of Extrusions Through Same Die	None prior
Die Lubricant	G	Cone	90° CRS
Container Lubricant		Speed	13 ipm
Die Design No.			
Die Material	Steel		

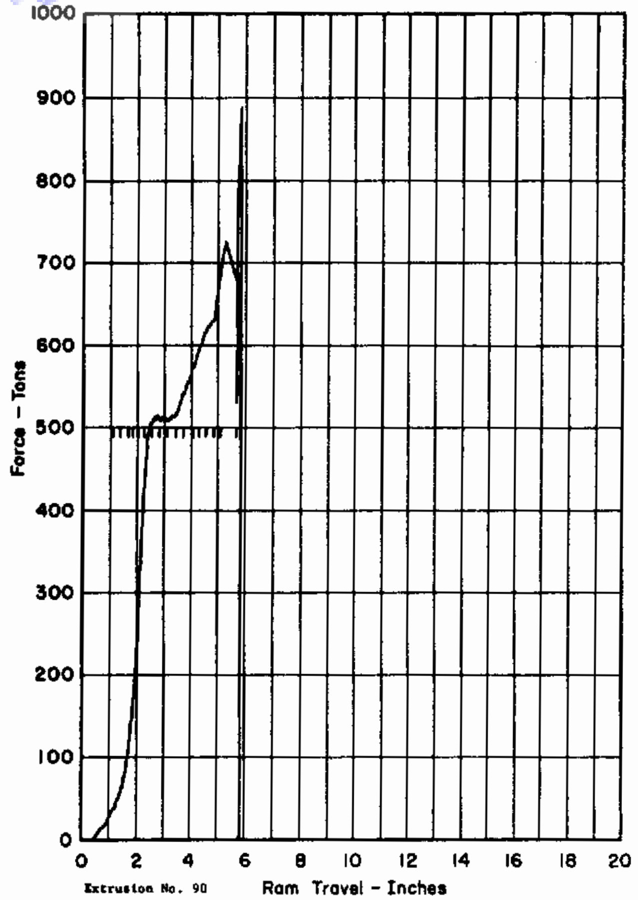
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Pressure rise occurred. Die cracked -cone OK.



Extrusion No. 90

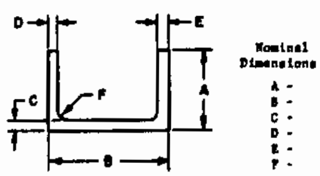
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined and hardened
Extrusion No.	91 (22108)	Die Temp., °F	900
Primary Purpose of this Experiment	Cone experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	19
Stem Diameter	3.400	Starting Pressure Reading in psi	100,000
Container Diameter	3.625	End Pressure Reading in psi	120,000
Extrusion Ratio	30:1	Max Force on Billet in Tons	620
Billet Material	CRS	Max Pressure on Billet in psi	120,000
Billet Length	6 inches	Extrusion Length in inches	170
Billet Temp., °F	1850	Extrusion Surface Finish	Good
Type of Billet Heating	Salt	Die Condition	Cracked
Billet Heating Time in Minutes	22	Die Rework	None
Billet Lubricant	D	No. of Extrusions Through Same Die	None prior
Die Lubricant	G	Cone	Omitted
Container Lubricant		Speed	13 ipm
Die Design No.			
Die Material	Steel		

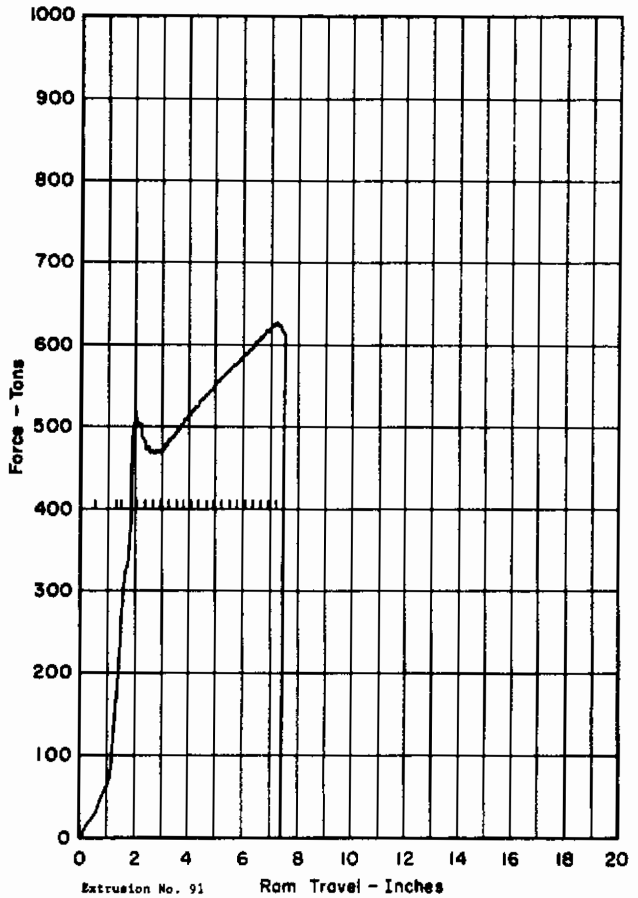
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS: Pressure rise - stalled with small butt - die cracked - some glass left between die and butt.



Extrusion No. 91

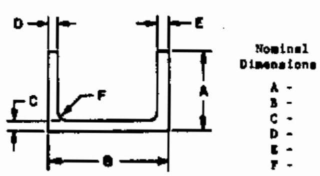
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined and hardened
Extrusion No.	92 (23022)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	30
Stem Diameter	3.400	Starting Pressure Reading in psi	109,000
Container Diameter	3.625	End Pressure Reading in psi	140,000
Extrusion Ratio	36:1	Max Force on Billet in Tons	720
Billet Material	CRS	Max Pressure on Billet in psi	140,000
Billet Length	6 inches	Extrusion Length in inches	215
Billet Temp., °F	1850	Extrusion Surface Finish	good
Type of Billet Heating	salt bath	Die Condition	---
Billet Heating Time in Minutes	45	Die Rework	---
Billet Lubricant	D	No. of Extrusions Through Same Die	none prior
Die Lubricant	F	Core	150° SS
Container Lubricant	F	Speed	15ipm
Die Design No.	.600" round	Cut-off	Graphite
Die Material	steel		

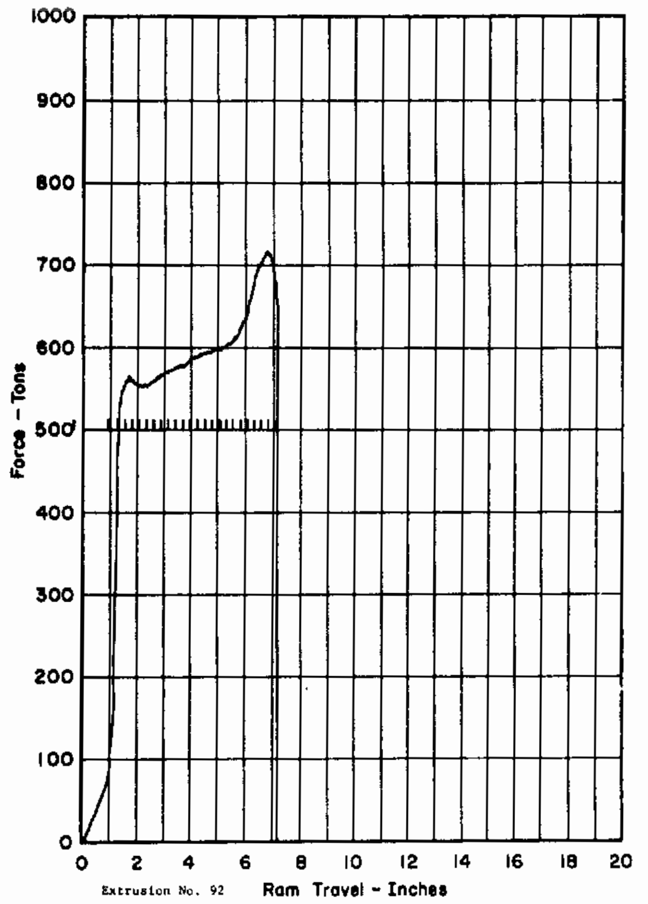
Extrusion Section Dimensions			
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Extruded Shape Sketch:



REMARKS:

Pressure rise occurred. Long end defect - rod shot out of die head, but some steel left in die opening.



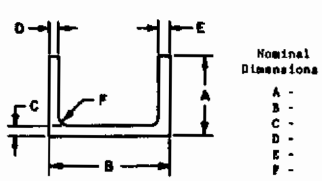
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined & hardened
Extrusion No.	93 (23023)	Die Temp., °F	900
Primary Purpose of this Experiment	Repeat No. 91	Container Temp., °F	900
Press Capacity	1000T	Billet Transfer Time in Seconds	25
Stem Diameter	3.400	Starting Pressure Reading in psi	126,000
Container Diameter	3.625	End Pressure Reading in psi	158,000
Extrusion Ratio	36:1	Max Force on Billet in Tons	815
Billet Material	CRS	Max Pressure on Billet in psi	158,000
Billet Length	6 inches	Extrusion Length in inches	200
Billet Temp., °F	1850	Extrusion Surface Finish	good
Type of Billet Heating	salt bath	Die Condition	good
Billet Heating Time in Minutes	55	Die Rework	---
Billet Lubricant	D	No. of Extrusions Through Same Die	none prior
Die Lubricant	G	Cone	none
Container Lubricant	---	Speed	15 ipm
Die Design No.	.600" round		
Die Material	steel		

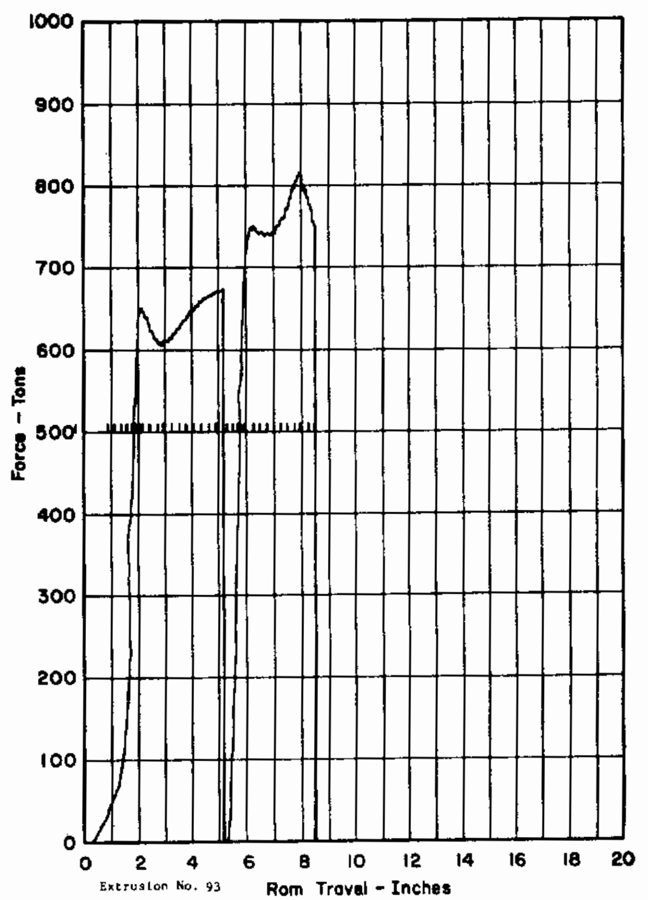
Extrusion Section Dimensions			
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Extruded Shape Sketch:



REMARKS:

Operator stopped ram in middle of extrusion for 5-10 seconds, then started again. Pressure rise occurred. Second portion of curve coincides with extrusion of first portion.



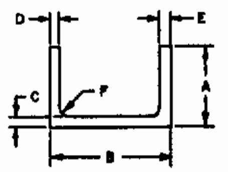
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined & hardened
Extrusion No.	94 (23024)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	35
Stem Diameter	3.400	Starting Pressure Reading in psi	118,000
Container Diameter	3.625	End Pressure Reading in psi	150,000
Extrusion Ratio	36:1	Max Force on Billet in Tons	770
Billet Material	Be-(Fe coated)	Max Pressure on Billet in psi	150,000
Billet Length	3 inches	Extrusion Length in inches	108
Billet Temp., °F	1850°	Extrusion Surface Finish	see notes
Type of Billet Heating	Furnace-under graph	Die Condition	good
Billet Heating Time in Minutes	270	Die Rework	---
Billet Lubricant	---	No. of Extrusions Through Same Die	none prior
Die Lubricant	P	Speed	set fast, but varied
Container Lubricant	P		from 120 to 15 as
Die Design	.600" round		force changed
Die Material	steel	Cone	90° CRS

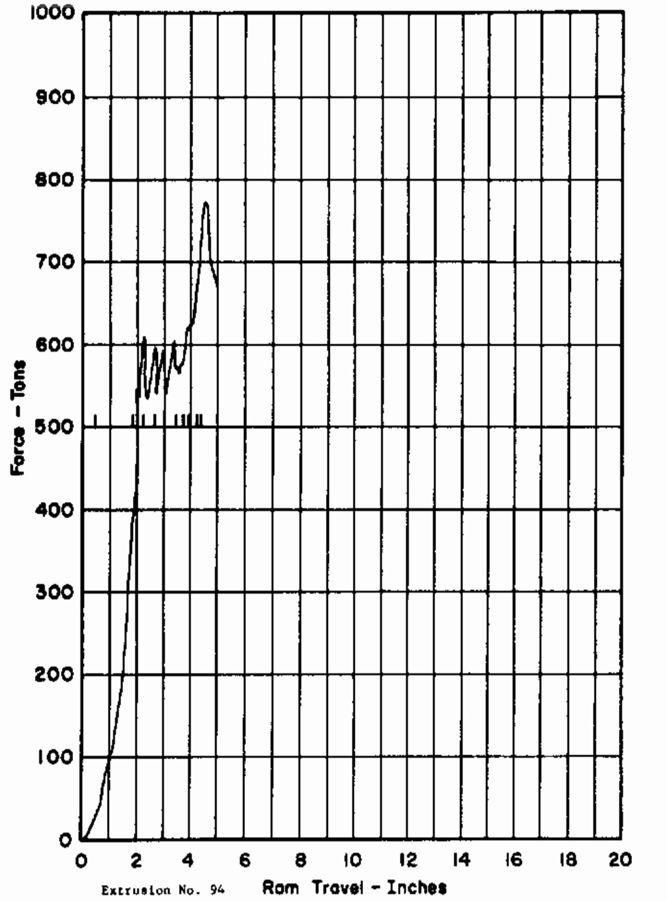
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:
Pressure rise obscured by large fluctuations associated with pump changeover.
Rod rattlesnaked full length.



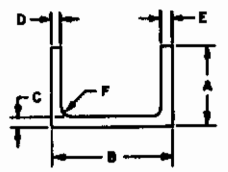
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined & hardened
Extrusion No.	95 (23025)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	31
Stem Diameter	3.400	Starting Pressure Reading in psi	116,000
Container Diameter	3.625	End Pressure Reading in psi	154,000
Extrusion Ratio	36:1	Max Force on Billet in Tons	790
Billet Material	CRS	Max Pressure on Billet in psi	154,000
Billet Length	6 inches	Extrusion Length in inches	200
Billet Temp., °F	1850	Extrusion Surface Finish	good
Type of Billet Heating	furnace - graphite	Die Condition	good
Billet Heating Time in Minutes	279	Die Rework	---
Billet Lubricant	---	No. of Extrusions Through Same Die	none prior
Die Lubricant	P	Cone	150° SS
Container Lubricant	P	Speed	15 ipm
Die Design	.600 round		
Die Material	steel		

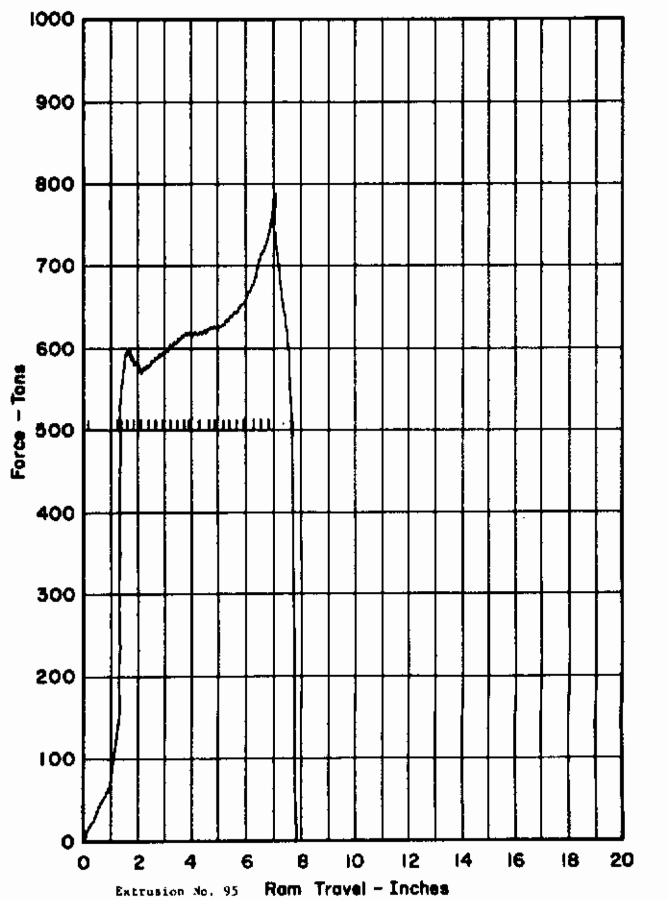
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:
Pressure rise occurred.



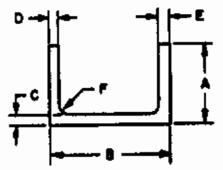
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined & hardened
Extrusion No.	96 (23026)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	35
Stem Diameter	3.400	Starting Pressure Reading in psi	126,000
Container Diameter	3.625	End Pressure Reading in psi	144,000
Extrusion Ratio	36:1	Max Force on Billet in Tons	740
Billet Material	CRS	Max Pressure on Billet in psi	144,000
Billet Length	6 inches	Extrusion Length in inches	200
Billet Temp., °F	1850	Extrusion Surface Finish	excellent
Type of Billet Heating	Furnace-graphite	Die Condition	good
Billet Heating Time in Minutes	295	Die Rework	none
Billet Lubricant	---	No. of Extrusions Through Same Die	none prior
Die Lubricant	R	Cone	150° SS
Container Lubricant	R	Speed	15 ipm
Die Design	.600 round		
Die Material	steel		

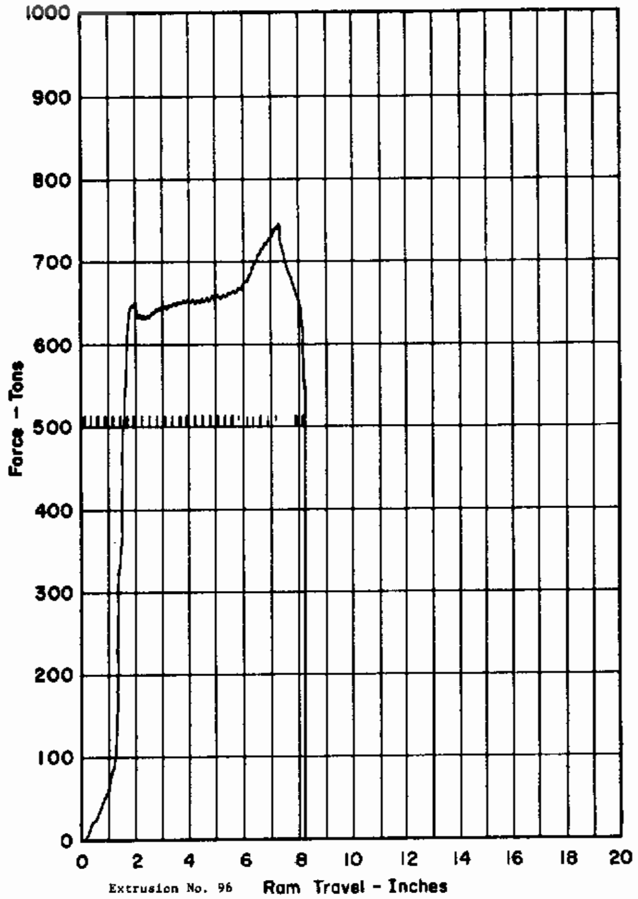
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:
Excellent finish on extruded rod.
Pressure pattern essentially flat.



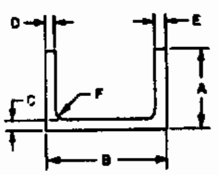
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined & hardened
Extrusion No.	97 (23027)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	29
Stem Diameter	3.400	Starting Pressure Reading in psi	110,000
Container Diameter	3.625	End Pressure Reading in psi	126,000
Extrusion Ratio	36:1	Max Force on Billet in Tons	650
Billet Material	CRS	Max Pressure on Billet in psi	126,000
Billet Length	6 inches	Extrusion Length in inches	200
Billet Temp., °F	1850	Extrusion Surface Finish	good
Type of Billet Heating	salt bath	Die Condition	good
Billet Heating Time in Minutes	33	Die Rework	none
Billet Lubricant	D	No. of Extrusions Through Same Die	none prior
Die Lubricant	G	Speed	
Container Lubricant	---	Cone	none
Die Design	Round .600 in.		
Die Material	Steel		

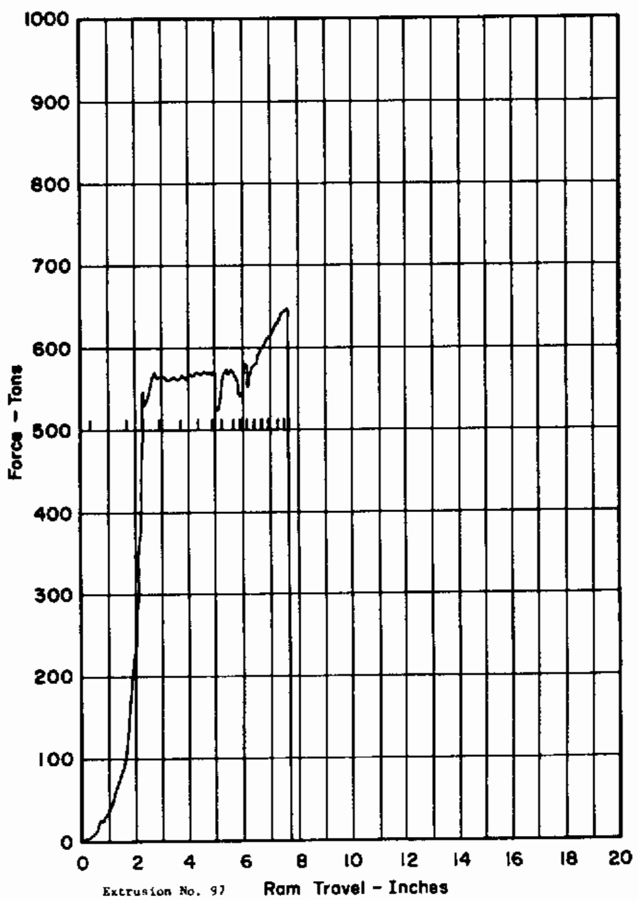
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:



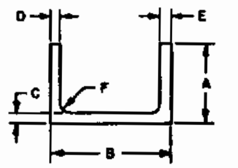
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined & hardened
Extrusion No.	98 (23028)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	28
Stem Diameter	3.400	Starting Pressure Reading in psi	105,000
Container Diameter	3.625	End Pressure Reading in psi	151,000
Extrusion Ratio	36:1	Max Force on Billet in Tons	780
Billet Material	CRS	Max Pressure on Billet in psi	151,000
Billet Length	6 inches	Extrusion Length in inches	200
Billet Temp., °F	1850	Extrusion Surface Finish	good
Type of Billet Heating	salt bath	Die Condition	good
Billet Heating Time in Minutes	27	Die Rework	none
Billet Lubricant	D	No. of Extrusions Through Same Die	none prior
Die Lubricant	M (pad)	Cone	glass - flat
Container Lubricant	---	Speed	15 ipm
Die Design	Round .600 in.		
Die Material	steel		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

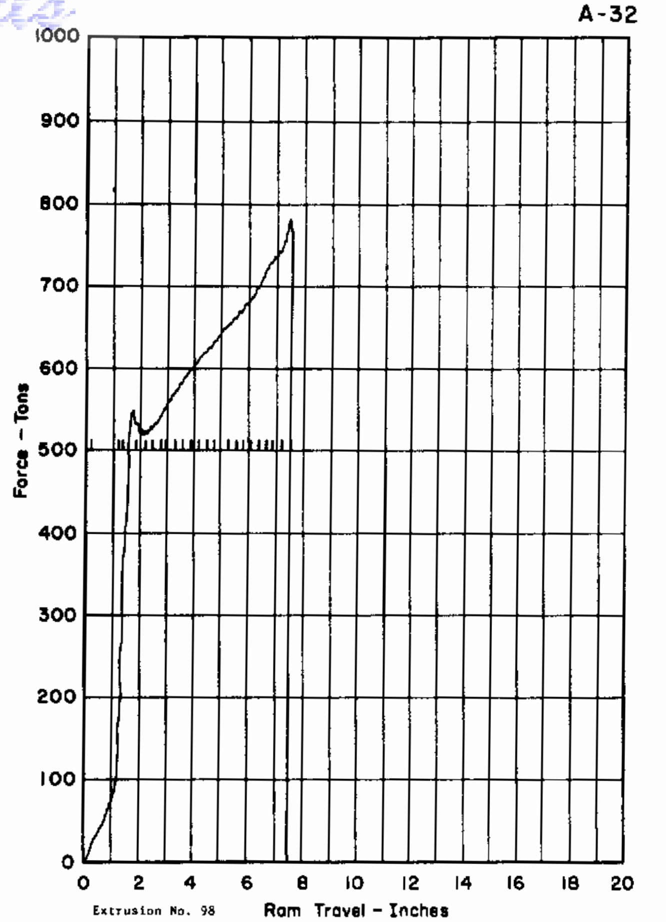
Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

Pressure rise occurred.



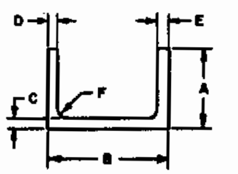
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined & hardened
Extrusion No.	99 (23029)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	27
Stem Diameter	3.400	Starting Pressure Reading in psi	130,000
Container Diameter	3.625	End Pressure Reading in psi	146,000
Extrusion Ratio	36:1	Max Force on Billet in Tons	750
Billet Material	CRS	Max Pressure on Billet in psi	146,000
Billet Length	6 inches	Extrusion Length in inches	200
Billet Temp., °F	1850	Extrusion Surface Finish	good
Type of Billet Heating	salt bath	Die Condition	good
Billet Heating Time in Minutes	37	Die Rework	none
Billet Lubricant	D	No. of Extrusions Through Same Die	none prior
Die Lubricant	---	Cone	90° CRS
Container Lubricant	---	Speed	15 ipm
Die Design	Round .600 in.		
Die Material	steel		

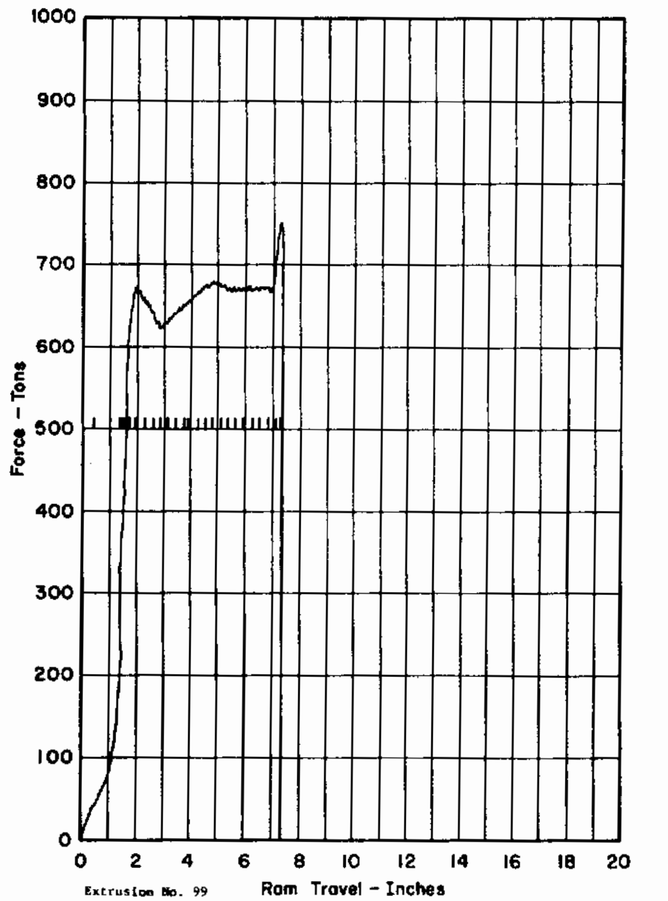
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:



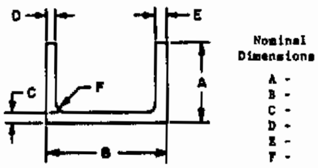
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined & hardened
Extrusion No.	100 (23030)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	32
Stem Diameter	3.400	Starting Pressure Reading in psi	116,000
Container Diameter	3.625	End Pressure Reading in psi	139,000
Extrusion Ratio	36:1	Max Force on Billet in Tons	720
Billet Material	CRS	Max Pressure on Billet in psi	139,000
Billet Length	6 inches	Extrusion Length in inches	200
Billet Temp., °F	1850	Extrusion Surface Finish	good
Type of Billet Heating	salt bath	Die Condition	good
Billet Heating Time in Minutes	30	Die Rework	none
Billet Lubricant	---	No. of Extrusions Through Same Die	none prior
Die Lubricant	G	Cone	none
Container Lubricant	P	Speed	15 ipm
Die Design	Round .600		
Die Material	steel		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

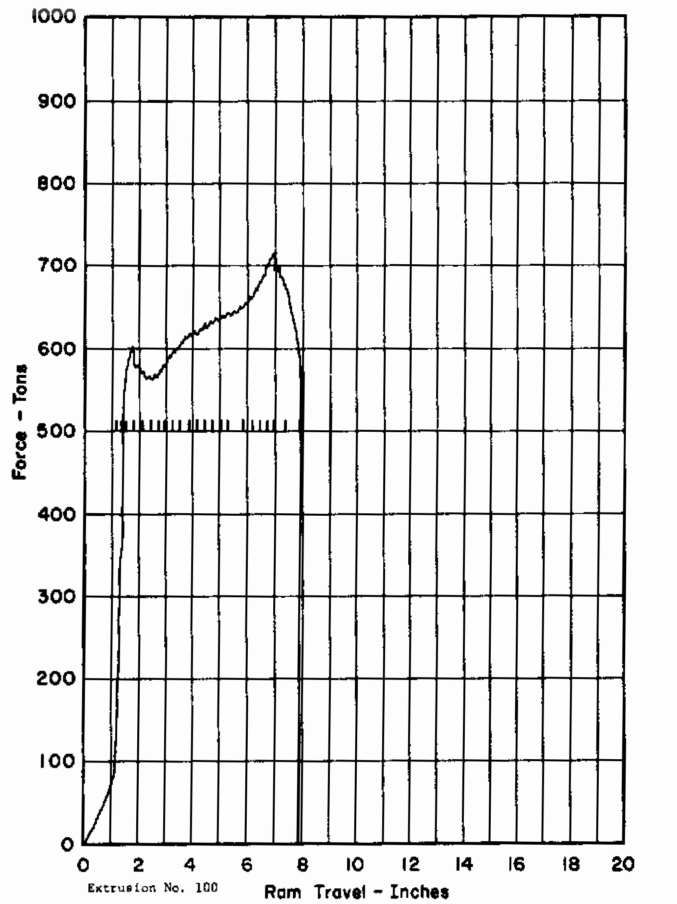
Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

Pressure rise occurred.



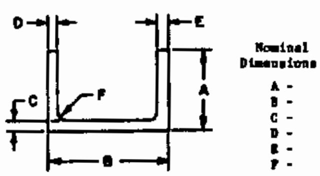
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined & hardened
Extrusion No.	101 (23031)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	21
Stem Diameter	3.400	Starting Pressure Reading in psi	107,000
Container Diameter	3.625	End Pressure Reading in psi	140,000
Extrusion Ratio	36:1	Max Force on Billet in Tons	720
Billet Material	Be	Max Pressure on Billet in psi	140,000
Billet Length	3 inches	Extrusion Length in inches	108
Billet Temp., °F	1850	Extrusion Surface Finish	see remarks
Type of Billet Heating	Furnace - graphite + A	Die Condition	good
Billet Heating Time in Minutes	140	Die Rework	none
Billet Lubricant	---	No. of Extrusions Through Same Die	none prior
Die Lubricant	P	Cone	90° CRS
Container Lubricant	P	Speed	15 ipm
Die Design	Round - .600		
Die Material	Steel		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

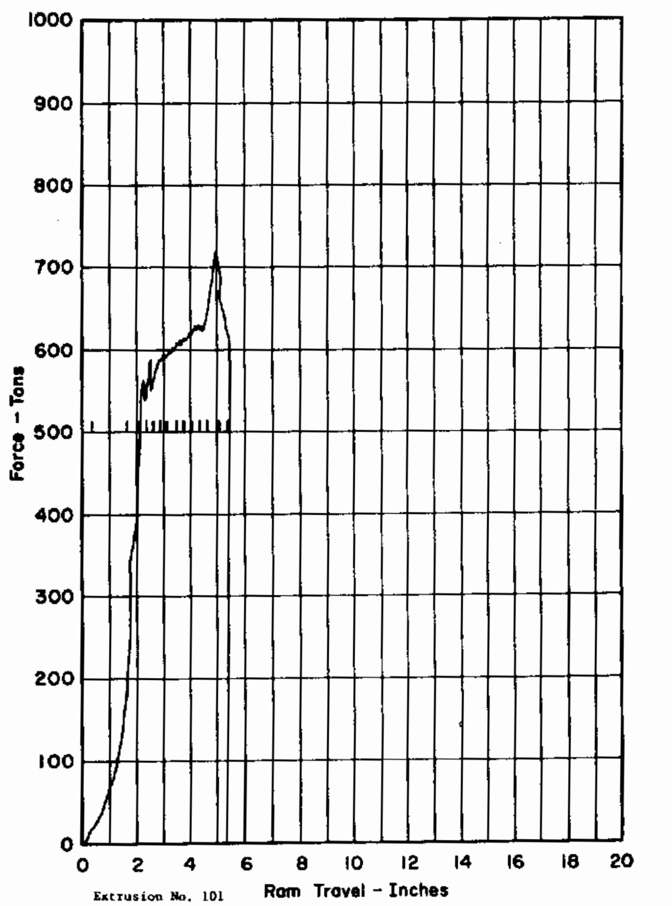
Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

Pressure rise occurred. Rod rattlesnaked badly full length.



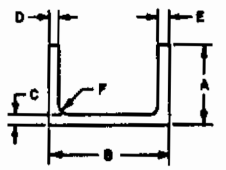
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	cast insert
Extrusion No.	102 (23032)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	28
Stem Diameter	3.400	Starting Pressure Reading in psi	116,000
Container Diameter	3.625	End Pressure Reading in psi	172,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	890
Billet Material	Be	Max Pressure on Billet in psi	172,000
Billet Length	4" - 45° Nose	Extrusion Length in inches	60
Billet Temp., °F	1850	Extrusion Surface Finish	poor
Type of Billet Heating	salt bath	Die Condition	good
Billet Heating Time in Minutes	35	Die Rework	none
Billet Lubricant	D	No. of Extrusions Through Same Die	none prior
Die Lubricant	M Cone	Cone	90° - glass
Container Lubricant	---	Speed	15 ipm
Die Design No.	PMDI		
Die Material	Stellite		

Extrusion Section Dimensions			
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

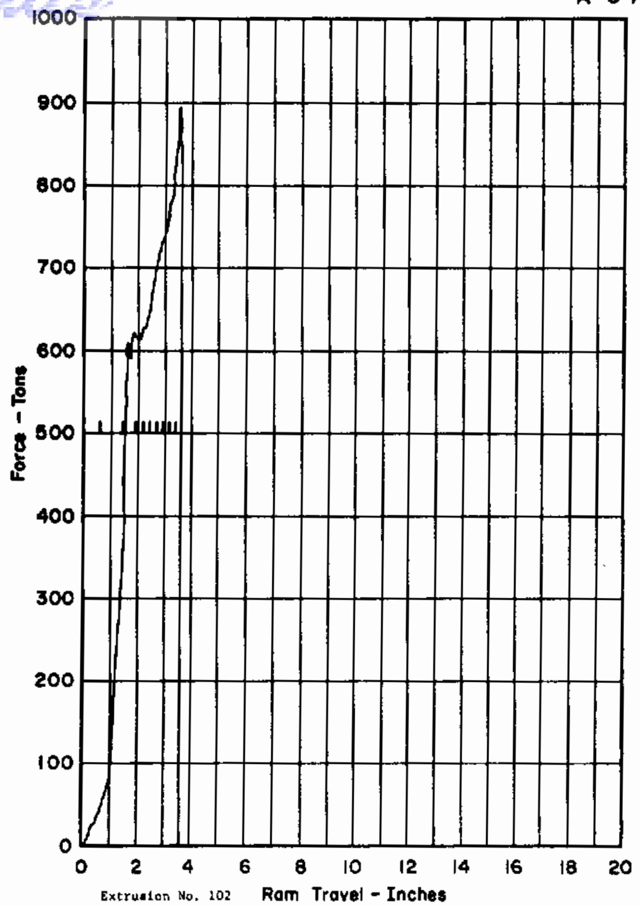
Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

Pressure rise occurred - stalled with 2 inch of billet pushed. Cone intact - only slightly deformed.



Extrusion No. 102

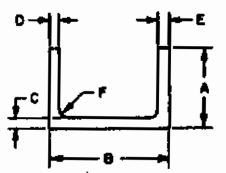
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	cast insert
Extrusion No.	103 (23033)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	35
Stem Diameter	3.400	Starting Pressure Reading in psi	85,500
Container Diameter	3.625	End Pressure Reading in psi	107,000
Extrusion Ratio	26:1	Max Force on Billet in Tons	550
Billet Material	Be	Max Pressure on Billet in psi	107,000
Billet Length	3 inches	Extrusion Length in inches	80
Billet Temp., °F	2100	Extrusion Surface Finish	poor
Type of Billet Heating	salt bath	Die Condition	good
Billet Heating Time in Minutes	32	Die Rework	none
Billet Lubricant	D	No. of Extrusions Through Same Die	none prior
Die Lubricant	C	Cone	none
Container Lubricant	---	Speed	75 ipm
Die Design No.	PMDI-A		
Die Material	Stellite		

Extrusion Section Dimensions			
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Extruded Shape Sketch:

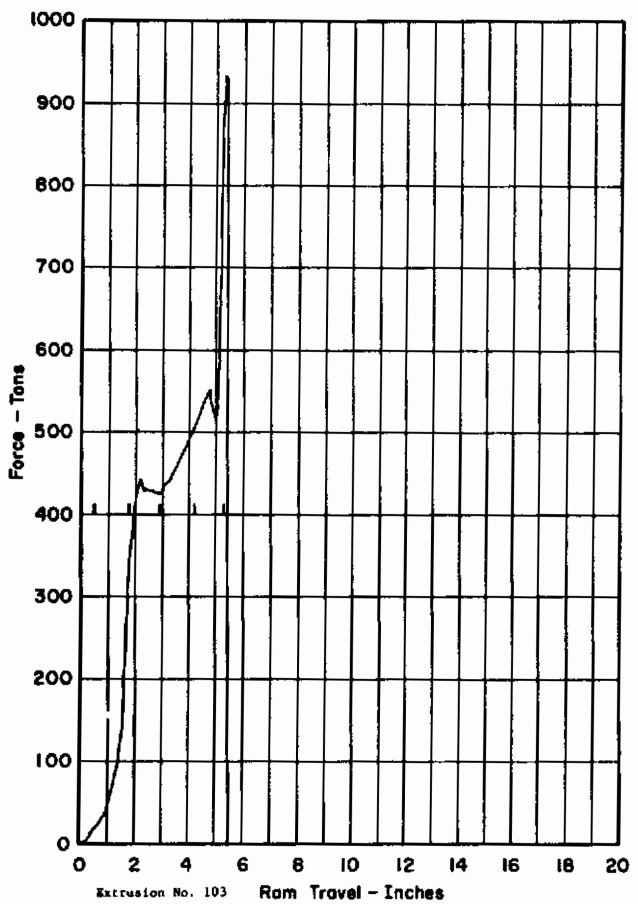


Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

Rattlesnaked full length.

Pressure rise occurred.



Extrusion No. 103

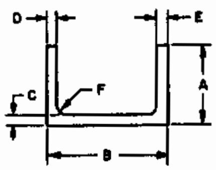
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined &hardened
Extrusion No.	104 (23034)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	1000 T	Billet Transfer Time in Seconds	
Stem Diameter	3.400	Starting Pressure Reading in psi	
Container Diameter	3.625	End Pressure Reading in psi	
Extrusion Ratio	36:1	Max Force on Billet in Tons	
Billet Material	CRS	Max Pressure on Billet in psi	
Billet Length	6 inches	Extrusion Length in inches	
Billet Temp., °F	2100	Extrusion Surface Finish	
Type of Billet Heating	salt bath	Die Condition	
Billet Heating Time in Minutes	30	Die Rework	
Billet Lubricant	D	No. of Extrusions Through Same Die	
Die Lubricant	G	Cone	none
Container Lubricant	---	Speed	
Die Design	.600" round		
Die Material	steel		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

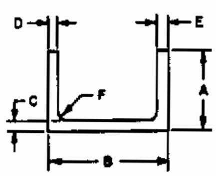
Loading stopped by frozen glass on liner. Attempt stopped.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	cast insert
Extrusion No.	105	Die Temp., °F	900
Primary Purpose of this Experiment	Extrude 20' channel	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	40
Stem Diameter	2.950	Starting Pressure Reading in psi	120,000
Container Diameter	3.045	End Pressure Reading in psi	158,000
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	575
Billet Material	Be	Max Pressure on Billet in psi	158,000
Billet Length	14" (9/16"R nose)	Extrusion Length in inches	312
Billet Temp., °F	1950°	Extrusion Surface Finish	poor
Type of Billet Heating	salt bath	Die Condition	washed
Billet Heating Time in Minutes	30	Die Rework	---
Billet Lubricant	D (fine)	No. of Extrusions Through Same Die	none prior
Die Lubricant	G	Cone	5/16" R
Container Lubricant	---	Speed	120 ipm
Die Design No.	PMDI (new)		
Die Material	stellite		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

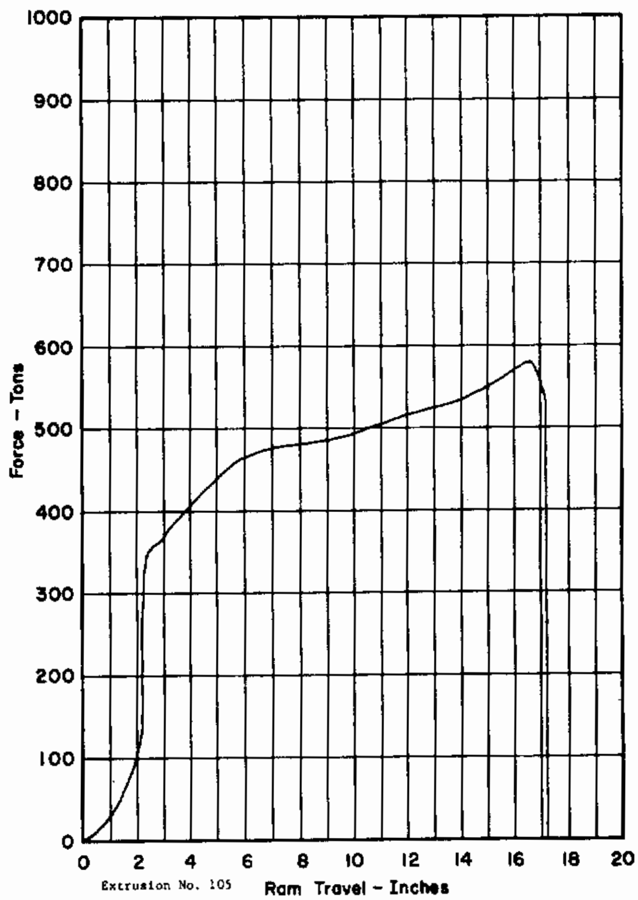
Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

Entire billet extruded at 120 ipm. Some pressure rise occurred. One side of channel torn for ~10 feet. Last 7' of channel rippled and separated.



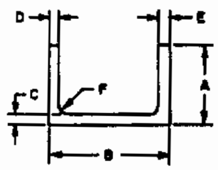
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	cast insert
Extrusion No.	106	Die Temp., °F	900
Primary Purpose of this Experiment	Ext. 20' channel	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	35
Stem Diameter	2.950	Starting Pressure Reading in psi	132,000
Container Diameter	3.045	End Pressure Reading in psi	176,000
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	680
Billet Material	Be	Max Pressure on Billet in psi	176,000
Billet Length	13" (9/16"R nose)	Extrusion Length in inches	330
Billet Temp., °F	1850	Extrusion Surface Finish	poor
Type of Billet Heating	salt pot	Die Condition	poor
Billet Heating Time in Minutes	42	Die Rework	---
Billet Lubricant	D (fine)	No. of Extrusions Through Same Die	one prior
Die Lubricant	G	Cone	5/16" R
Container Lubricant	---	Speed	120 ipm
Die Design No.	PMDI		
Die Material	stellite		

Extrusion Section Dimensions		
Front	A	
	B	
	C	
	D	
	E	
	F	
Center	A	
	B	
	C	
	D	
	E	
	F	
Rear	A	
	B	
	C	
	D	
	E	
	F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

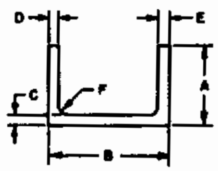
All pushed - Tearing in center third, slight ripple at rear. Die washed at corners.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined & hardened
Extrusion No.	107	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	33
Stem Diameter	2.950	Starting Pressure Reading in psi	115,000
Container Diameter	3.045	End Pressure Reading in psi	145,000
Extrusion Ratio	25:1	Max Force on Billet in Tons	530
Billet Material	CRS	Max Pressure on Billet in psi	145,000
Billet Length	10"	Extrusion Length in inches	250
Billet Temp., °F	1850	Extrusion Surface Finish	fair
Type of Billet Heating	salt bath	Die Condition	good
Billet Heating Time in Minutes	23	Die Rework	none
Billet Lubricant	---	No. of Extrusions Through Same Die	none prior
Die Lubricant	P	Cone	150° SS
Container Lubricant	P	Speed	120 ipm
Die Design No.	Round .600"		
Die Material	steel		

Extrusion Section Dimensions		
Front	A	
	B	
	C	
	D	
	E	
	F	
Center	A	
	B	
	C	
	D	
	E	
	F	
Rear	A	
	B	
	C	
	D	
	E	
	F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

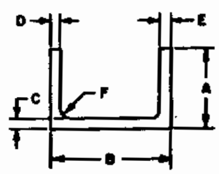
Rod scored slightly.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined & hardened
Extrusion No.	108	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	21
Stem Diameter	2.950	Starting Pressure Reading in psi	115,000
Container Diameter	3.045	End Pressure Reading in psi	115,000
Extrusion Ratio	25:1	Max Force on Billet in Tons	420
Billet Material	Be	Max Pressure on Billet in psi	115,000
Billet Length	3"(9/16"R nose)	Extrusion Length in inches	75
Billet Temp., °F	1850	Extrusion Surface Finish	poor
Type of Billet Heating	salt bath	Die Condition	good
Billet Heating Time in Minutes	36	Die Rework	---
Billet Lubricant	---	No. of Extrusions Through Same Die	none prior
Die Lubricant	---	Cone	90° CRS
Container Lubricant	R	Speed	120 ipm
Die Design No.	Round .600"		
Die Material	steel		

Extrusion Section Dimensions		
Front	A	
	B	
	C	
	D	
	E	
	F	
Center	A	
	B	
	C	
	D	
	E	
	F	
Rear	A	
	B	
	C	
	D	
	E	
	F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

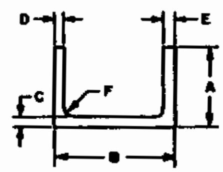
Rod rattlesnaked. No pressure rise.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	cast insert
Extrusion No.	109 (23167)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	not taken
Stem Diameter	2.950	Starting Pressure Reading in psi	142,000
Container Diameter	3.045	End Pressure Reading in psi	173,000
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	630
Billet Material	Be + CRS	Max Pressure on Billet in psi	173,000
Billet Length	3"(Be) + 6"(CRS)	Extrusion Length in inches	65-Be, 111 CRS
Billet Temp., °F	1850	Extrusion Surface Finish	scored
Type of Billet Heating	salt bath	Die Condition	fair
Billet Heating Time in Minutes	30	Die Rework	no
Billet Lubricant	---	No. of Extrusions Through Same Die	none prior
Die Lubricant	G	Cone	9/16" R
Container Lubricant	B - precoated	Speed	120 ipm
Die Design No.	PMDI (new)		
Die Material	stellite		

Extrusion Section Dimensions		Be	CRS
Front	A	.976	.976
	B	1.473	1.475
	C	.108	.104
	D	----	.120
	E	.118	.118
	F	.100R	.100
Center	A	.976	.976
	B	1.477	1.476
	C	.106	.104
	D	-----	.120
	E	.118	.118
	F	.100R	.100
Rear	A	.976	.976
	B	1.479	1.476
	C	.101	.104
	D	-----	.118
	E	.118	.118
	F	.100R	.100

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

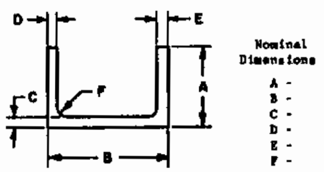
"D" side of CRS channel 3/4 inch high. Be tore one side-piece from this jammed in die. Die washed at corners - but only in Be portion - CRS caused no further washing of die.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined & hardened
Extrusion No.	110 (23168)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	31 (for Be)
Stem Diameter	2.950	Starting Pressure Reading in psi	146,000
Container Diameter	3.045	End Pressure Reading in psi	159,000
Extrusion Ratio	25:1	Max Force on Billet in Tons	580
Billet Material	Be + CRS	Max Pressure on Billet in psi	159,000
Billet Length	3" Be + 6" CRS	Extrusion Length in inches	Be-70, CRS 114-1/2
Billet Temp., °F	1850	Extrusion Surface Finish	Be-poor, CRS-good
Type of Billet Heating	salt bath	Die Condition	----
Billet Heating Time in Minutes	35	Die Rework	----
Billet Lubricant	A	No. of Extrusions Through Same Die	one prior
Die Lubricant	A (pad)	Cone	flat glass
Container Lubricant	---	Speed	120 ipm
Die Design	.600" round		
Die Material	steel		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



REMARKS:

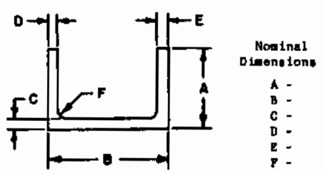
Be rattlesnaked - CRS surface good.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined & hardened
Extrusion No.	111 (23169)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	58
Stem Diameter	2.950	Starting Pressure Reading in psi	153,000
Container Diameter	3.045	End Pressure Reading in psi	137,000
Extrusion Ratio	25:1	Max Force on Billet in Tons	500
Billet Material	CRS	Max Pressure on Billet in psi	153,000
Billet Length	10 inches	Extrusion Length in inches	200
Billet Temp., °F	1850	Extrusion Surface Finish	good
Type of Billet Heating	salt bath	Die Condition	good
Billet Heating Time in Minutes	30	Die Rework	---
Billet Lubricant	S-(3 layers)	No. of Extrusions Through Same Die	one prior
Die Lubricant	C	Cone	8/16" R
Container Lubricant	---	Speed	120 ipm
Die Design	.600" round		
Die Material	steel		

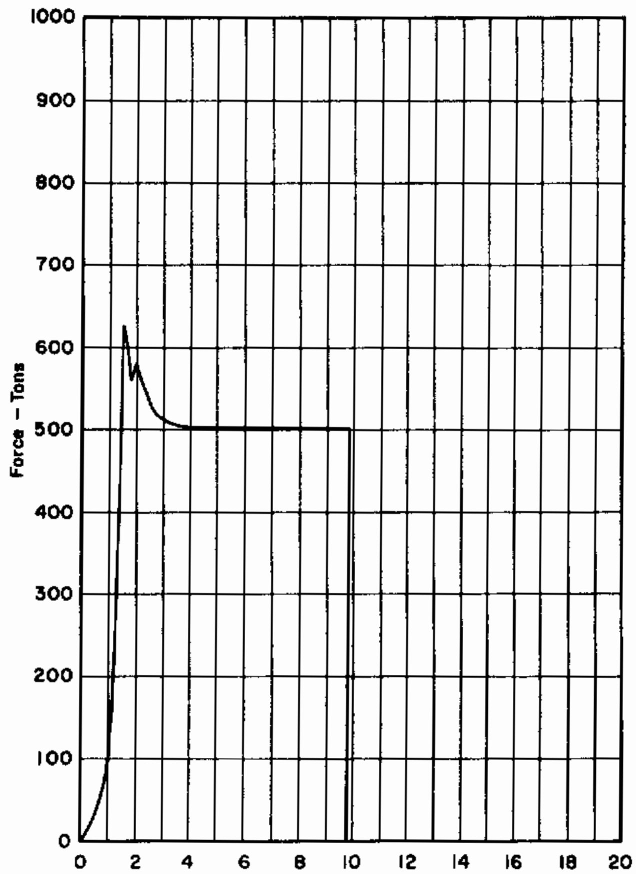
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



REMARKS:

Load remarkably constant at 500 T after initial peak of 560 T.



Extrusion No. 111

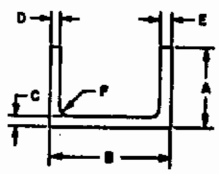
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Machined & hardened
Extrusion No.	112 (23170)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	61
Stem Diameter	2.950	Starting Pressure Reading in psi	126,000
Container Diameter	3.045	End Pressure Reading in psi	138,000
Extrusion Ratio	25:1	Max Force on Billet in Tons	510
Billet Material	CRS	Max Pressure on Billet in psi	138,000
Billet Length	10 inches	Extrusion Length in inches	209
Billet Temp., °F	1850	Extrusion Surface Finish	good
Type of Billet Heating	salt bath	Die Condition	good
Billet Heating Time in Minutes	30	Die Rework	---
Billet Lubricant	T	No. of Extrusions Through Same Die	two prior
Die Lubricant	G	Cone	90° CRS
Container Lubricant	---	Speed	120 ipm
Die Design	Round .600"		
Die Material	steel		

Extrusion Section Dimensions			
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

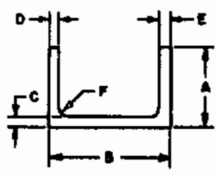
Very slight pressure rise during extrusion.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	113 (23171)	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	75
Stem Diameter	2.950	Starting Pressure Reading in psi	
Container Diameter	3.045	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	
Billet Material	CRS	Max Pressure on Billet in psi	
Billet Length	14 inches	Extrusion Length in inches	
Billet Temp., °F	1850	Extrusion Surface Finish	
Type of Billet Heating	salt bath	Die Condition	
Billet Heating Time in Minutes	32	Die Rework	
Billet Lubricant	T	No. of Extrusions Through Same Die	none prior
Die Lubricant	G	Cone	none
Container Lubricant	---	Speed	---
Die Design No.	PMDI		
Die Material	Stellite		

Extrusion Section Dimensions			
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

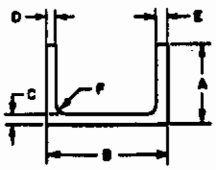
Stalled - loading slow

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	114	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	Not taken
Stem Diameter	2.950 inches	Starting Pressure Reading in psi	See remarks
Container Diameter	3.045 inches	End Pressure Reading in psi	See remarks
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	See remarks
Billet Material	Be	Max Pressure on Billet in psi	See remarks
Billet Length	13 inches	Extrusion Length in inches	250
Billet Temp., °F	1850	Extrusion Surface Finish	Fair - see remarks
Type of Billet Heating	salt bath	Die Condition	Poor
Billet Heating Time in Minutes	33	Die Rework	-
Billet Lubricant	-	No. of Extrusions Through Same Die	None prior
Die Lubricant	G	Cone	None
Container Lubricant	B	Speed	120 ipm
Die Design No.	PMD-I		
Die Material	Stellite		

Extrusion Section Dimensions			
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

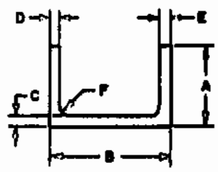
Recorder malfunction. Pressure chart not obtained. Extrusion was almost free of rattlesnakes but severe die damage caused separation and rippling.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	115	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 tons	Billet Transfer Time in Seconds	42
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.045 inches	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	600
Billet Material	CRS	Max Pressure on Billet in psi	
Billet Length	12 inches	Extrusion Length in inches	
Billet Temp., °F	1850	Extrusion Surface Finish	
Type of Billet Heating	Salt bath	Die Condition	
Billet Heating Time in Minutes	20	Die Rework	
Billet Lubricant	B	No. of Extrusions Through Same Die	1 prior
Die Lubricant	G	Cone	None
Container Lubricant		Speed	Full
Die Design No.	PMD-1		
Die Material	Stellite		

Extrusion Section Dimensions			
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

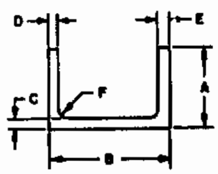
Stalled; slow load; also rear of billet cooler than salt bath.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	116	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 tons	Billet Transfer Time in Seconds	52
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.045 inches	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	
Billet Material	CRS	Max Pressure on Billet in psi	
Billet Length	10 inches	Extrusion Length in inches	
Billet Temp., °F	1850	Extrusion Surface Finish	Fair
Type of Billet Heating	Salt bath	Die Condition	Good
Billet Heating Time in Minutes	18	Die Rework	None
Billet Lubricant	S and T	No. of Extrusions Through Same Die	
Die Lubricant	G		
Container Lubricant			
Die Design No.	PMD-1		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	0.978
		B	1.487
		C	0.104
		D	0.122
		E	0.122
		F	0.100 R
	Center	A	0.975
		B	1.478
		C	0.099
		D	0.115
		E	0.115
		F	0.100 R
	Rear	A	0.975
		B	1.481
		C	0.096
		D	0.113
		E	0.113
		F	0.100 R

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

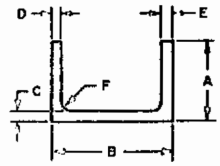
Pressure rise occured; channel sound; no die damage.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	117	Die Temp., °F	900
Primary Purpose of this Experiment		Container Temp., °F	900
Press Capacity	600 tons	Billet Transfer Time in Seconds	32
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.045	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	
Billet Material	Beryllium	Max Pressure on Billet in psi	
Billet Length	7 inches	Extrusion Length in inches	80
Billet Temp., °F	1750	Extrusion Surface Finish	Poor
Type of Billet Heating	Salt bath	Die Condition	Fair
Billet Heating Time in Minutes	16	Die Rework	None
Billet Lubricant	S and T	No. of Extrusions Through Same Die	
Die Lubricant	G (2)	Lead-in billet	
Container Lubricant			
Die Design No.	PMD-1		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	0.971
		B	1.463
		C	0.108
		D	0.117
		E	0.116
		F	0.100 R
	Center	A	0.968
		B	1.467
		C	0.101
		D	0.114
		E	0.112
		F	0.100 R
	Rear	A	0.971
		B	1.469
		C	0.098
		D	0.108
		E	0.106
		F	0.100 R

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

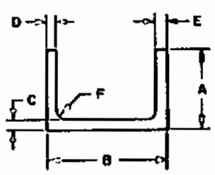
Surface rough. Tearing in first half.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	118	Die Temp., °F	900
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 tons	Billet Transfer Time in Seconds	30
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.045 inches	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	
Billet Material	Beryllium	Max Pressure on Billet in psi	
Billet Length	10 inches	Extrusion Length in inches	209
Billet Temp., °F	1800	Extrusion Surface Finish	Fair
Type of Billet Heating	Salt bath	Die Condition	Good
Billet Heating Time in Minutes	25	Die Rework	None
Billet Lubricant	S and T	No. of Extrusions Through Same Die	None prior
Die Lubricant	G		
Container Lubricant			
Die Design No.	PMD-1		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	0.982
		B	1.479
		C	0.112
		D	0.122
		E	0.122
		F	0.100 R
	Center	A	0.967
		B	1.470
		C	0.103
		D	0.111
		E	0.116
		F	0.100 R
	Rear	A	0.974
		B	1.477
		C	0.093
		D	0.108
		E	0.108
		F	0.100 R

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

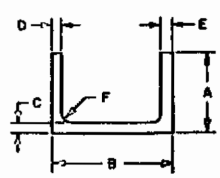
Several tears widely spaced on left side; no die damage; over-all one of best channels made to date.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	119	Die Temp., °F	900
Primary Purpose of this Experiment	Flowshape experiment	Container Temp., °F	900
Press Capacity	600 tons	Billet Transfer Time in Seconds	36
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.045	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	
Billet Material	Beryllium (wired)	Max Pressure on Billet in psi	
Billet Length	4 inches	Extrusion Length in inches	40
Billet Temp., °F	1900	Extrusion Surface Finish	Poor
Type of Billet Heating	Salt bath	Die Condition	Good
Billet Heating Time in Minutes	24	Die Rework	None
Billet Lubricant	S and T	No. of Extrusions Through Same Die	2 Prior
Die Lubricant	G	Cone	None
Container Lubricant		Speed	Full
Die Design No.	PMD-2		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	0.975
		B	1.471
		C	0.106
		D	0.115
		E	0.110
		F	0.100 R
	Center	A	0.974
		B	1.459
		C	0.100
		D	0.111
		E	0.108
		F	0.100 R
	Rear	A	0.967
		B	1.458
		C	0.094
		D	0.105
		E	0.102
		F	0.100 R

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

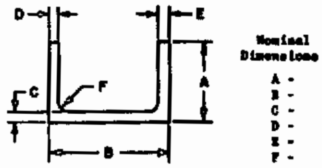
Stalled with 2-1/2 inch butt for study of flow pattern. Tearing occurred on left side of channel.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	120	Die Temp., °F	900
Primary Purpose of this Experiment	20-foot channel	Container Temp., °F	900
Press Capacity	600 tons	Billet Transfer Time in Seconds	35
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.045 inches	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	
Billet Material	Beryllium (radius nose)	Max Pressure on Billet in psi	
Billet Length	13 inches	Extrusion Length in inches	229-1/4
Billet Temp., °F	1850	Extrusion Surface Finish	Rough
Type of Billet Heating	Salt bath	Die Condition	Washed slightly
Billet Heating Time in Minutes	31	Die Rework	None
Billet Lubricant	S and T	No. of Extrusions Through Same Die	None prior
Die Lubricant	G (2)	Cone	Radius
Container Lubricant		Speed	120 ipm
Die Design No.	FMD-1 (.130)		
Die Material	Stellite		

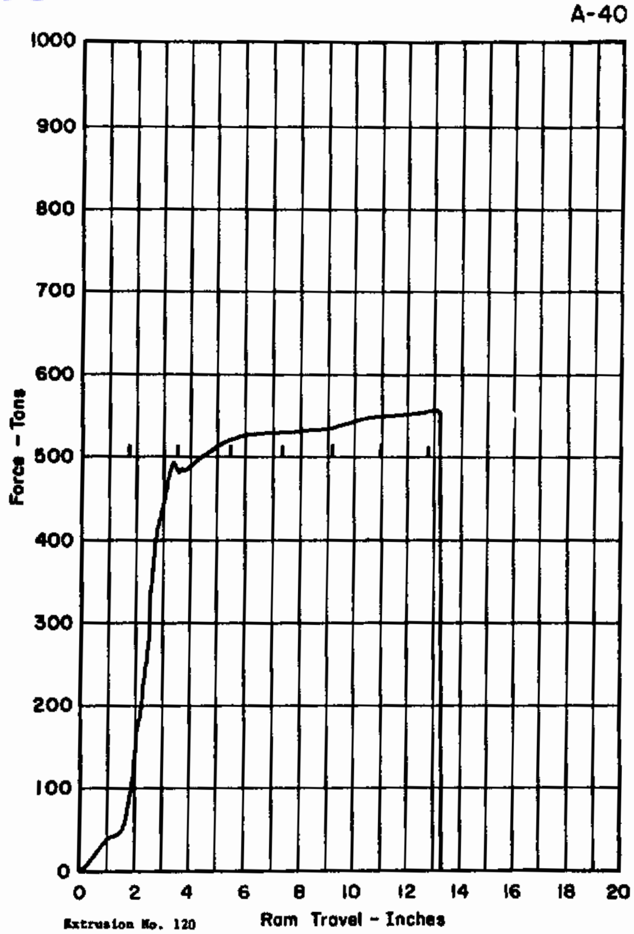
Extrusion Section Dimensions			
Front	A	0.973	
	B	1.475	
	C	0.107	
	D	0.120	
	E	0.121	
	F	0.100 R	
Center	A	0.973	
	B	1.475	
	C	0.107	
	D	0.120	
	E	0.121	
	F	0.100 R	
Rear	A	0.973	
	B	1.475	
	C	0.107	
	D	0.119	
	E	0.120	
	F	0.100 R	

Extruded Shape Sketch:



REMARKS:

Die opening rotated 60° clockwise. 19-1/2 feet of channel slight tearing both sides.



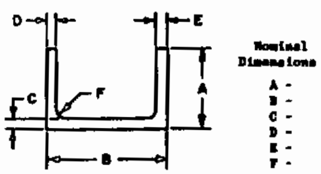
Extrusion No. 120

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	121	Die Temp., °F	900
Primary Purpose of this Experiment	20-foot channel	Container Temp., °F	900
Press Capacity	600 tons	Billet Transfer Time in Seconds	35
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.045 inches	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	
Billet Material	Beryllium	Max Pressure on Billet in psi	
Billet Length	13 inches	Extrusion Length in inches	
Billet Temp., °F	1750	Extrusion Surface Finish	
Type of Billet Heating	Salt bath	Die Condition	
Billet Heating Time in Minutes	26	Die Rework	
Billet Lubricant	S and T	No. of Extrusions Through Same Die	
Die Lubricant	G (2)		
Container Lubricant			
Die Design No.	FMD-1 (0.130)		
Die Material	Rex alloy 33		

Extrusion Section Dimensions			
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Extruded Shape Sketch:



REMARKS:

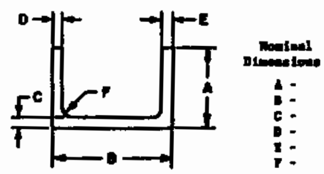
Stalled; beryllium passed through land of die, caught on bolster and upset to fill the relief, die destroyed in disassembly.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	
Extrusion No.	122	Die Temp., °F	
Primary Purpose of this Experiment	Check alignment	Container Temp., °F	900
Press Capacity	600 tons	Billet Transfer Time in Seconds	
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.045 inches	End Pressure Reading in psi	
Extrusion Ratio		Max Force on Billet in Tons	600
Billet Material	Cu - 45 Ni	Max Pressure on Billet in psi	
Billet Length	3 inches	Extrusion Length in inches	
Billet Temp., °F	1450	Extrusion Surface Finish	
Type of Billet Heating	Furnace	Die Condition	
Billet Heating Time in Minutes	80	Die Rework	
Billet Lubricant	None	No. of Extrusions Through Same Die	
Die Lubricant	None		
Container Lubricant	None		
Die Design No.	None		
Die Material			

Extrusion Section Dimensions			
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Extruded Shape Sketch:



REMARKS:

Cu-Ni piece was upset against a flat plate to see if flash could be measured to show degree of misalignment between container and die.

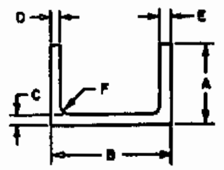
BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	123	Die Temp., °F	900
Primary Purpose of this Experiment	Alignment checks	Container Temp., °F	900
Press Capacity	600 tons	Billet Transfer Time in Seconds	60
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.045	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	
Billet Material	Beryllium	Max Pressure on Billet in psi	
Billet Length	3 inches	Extrusion Length in inches	64-1/2
Billet Temp., °F	1750	Extrusion Surface Finish	Rough
Type of Billet Heating	Salt bath	Die Condition	Washed
Billet Heating Time in Minutes	27	Die Rework	
Billet Lubricant	S and T	No. of Extrusions Through Same Die	None prior
Die Lubricant	G		
Container Lubricant			
Die Design No.	PMD-1		
Die Material	Stellite		

Extrusion Section Dimensions

Front	A	0.975
	B	1.468
	C	0.117
	D	0.110
	E	0.110
	F	0.100 R
Center	A	0.974
	B	1.470
	C	0.099
	D	0.104
	E	0.106
	F	0.100 R
Rear	A	0.973
	B	1.472
	C	0.085
	D	0.104
	E	0.104
	F	0.100 R

Extruded Shape Sketch:



Nominal Dimension
A -
B -
C -
D -
E -
F -

REMARKS:
Channel straight and sound; badly scored.

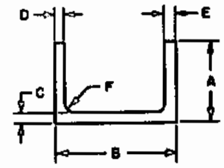
BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	124	Die Temp., °F	900
Primary Purpose of this Experiment	20-foot channel	Container Temp., °F	950
Press Capacity	600 tons	Billet Transfer Time in Seconds	44
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.047 inches	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	600 tons
Billet Material	Beryllium	Max Pressure on Billet in psi	
Billet Length	16 inches	Extrusion Length in inches	
Billet Temp., °F	1800	Extrusion Surface Finish	
Type of Billet Heating	Salt bath	Die Condition	
Billet Heating Time in Minutes	33	Die Rework	
Billet Lubricant	S and T	No. of Extrusions Through Same Die	
Die Lubricant	G		
Container Lubricant	PMD-1		
Die Design No.	Stellite		
Die Material			

Extrusion Section Dimensions

Front	A	
	B	
	C	
	D	
	E	
	F	
Center	A	
	B	
	C	
	D	
	E	
	F	
Rear	A	
	B	
	C	
	D	
	E	
	F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:
Stall; die packed full of glass.

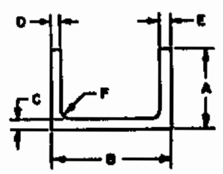
BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	125	Die Temp., °F	900
Primary Purpose of this Experiment	20-foot channel	Container Temp., °F	950
Press Capacity	600 tons	Billet Transfer Time in Seconds	32
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.047 inches	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	
Billet Material	Beryllium	Max Pressure on Billet in psi	
Billet Length	16 inches	Extrusion Length in inches	348
Billet Temp., °F	1800	Extrusion Surface Finish	Poor
Type of Billet Heating	Salt bath	Die Condition	Good
Billet Heating Time in Minutes	31	Die Rework	
Billet Lubricant	S and T	No. of Extrusions Through Same Die	None prior
Die Lubricant	G		
Container Lubricant			
Die Design No.	PMD-2		
Die Material	Stellite		

Extrusion Section Dimensions

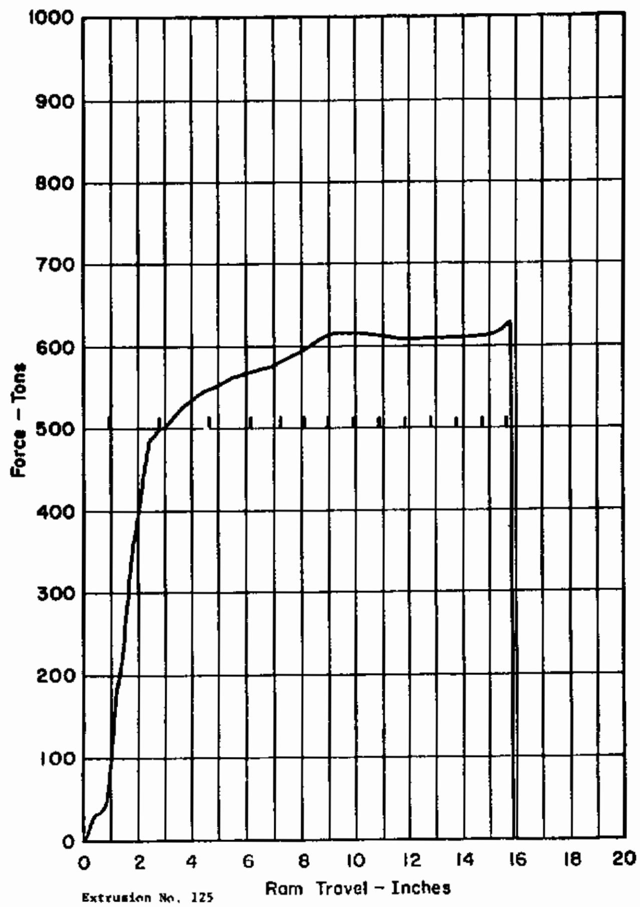
Front	A	
	B	
	C	
	D	
	E	
	F	
Center	A	
	B	
	C	
	D	
	E	
	F	
Rear	A	
	B	
	C	
	D	
	E	
	F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:
Load went up to 600 tons; ram slowed but did not stall. 20-foot channel extruded, torn left side last half; die O.K.



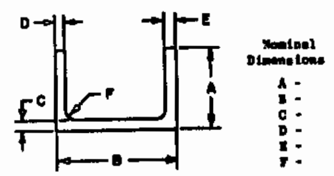
Extrusion No. 125

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	126	Die Temp., °F	900
Primary Purpose of this Experiment	20-foot channel	Container Temp., °F	950
Press Capacity	600 tons	Billet Transfer Time in Seconds	36
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.047 inches	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	
Billet Material	Beryllium	Max Pressure on Billet in psi	
Billet Length	16 inches	Extrusion Length in inches	
Billet Temp., °F	1800	Extrusion Surface Finish	
Type of Billet Heating	Salt bath	Die Condition	Good
Billet Heating Time in Minutes	32	Die Rework	None
Billet Lubricant	S and T	No. of Extrusions Through Same Die	One prior
Die Lubricant	G - cone	Cone	Glass
Container Lubricant		Speed	Full
Die Design No.	PMD-1		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



REMARKS:

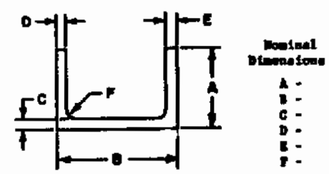
Stalled with 5 feet of channel extruded. Billet lube sheared off during loading.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	127	Die Temp., °F	900
Primary Purpose of this Experiment	20-foot channel	Container Temp., °F	950
Press Capacity	600 tons	Billet Transfer Time in Seconds	To liner - 15
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.047 inches	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	
Billet Material	Beryllium	Max Pressure on Billet in psi	
Billet Length	16 inches	Extrusion Length in inches	
Billet Temp., °F	1800	Extrusion Surface Finish	
Type of Billet Heating	Furnace (A atmos)	Die Condition	
Billet Heating Time in Minutes	189	Die Rework	
Billet Lubricant	B, S and T	No. of Extrusions Through Same Die	
Die Lubricant	G (1/2)		
Container Lubricant			
Die Design No.	PMD-1 (0.130)		
Die Material	EDS		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



REMARKS:

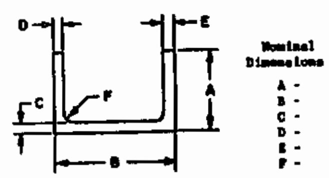
Billet jammed going into liner.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	128	Die Temp., °F	900
Primary Purpose of this Experiment	20-foot channel	Container Temp., °F	950
Press Capacity	600 tons	Billet Transfer Time in Seconds	34
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.047 inches	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	
Billet Material	Beryllium (reworked)	Max Pressure on Billet in psi	
Billet Length	11 inches	Extrusion Length in inches	~100
Billet Temp., °F	1810	Extrusion Surface Finish	Poor
Type of Billet Heating	Salt bath	Die Condition	Fair
Billet Heating Time in Minutes	30	Die Rework	None
Billet Lubricant	S and T	No. of Extrusions Through Same Die	2 prior
Die Lubricant	G - cone		
Container Lubricant			
Die Design No.	PMD-1		
Die Material	Stellite		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



REMARKS:

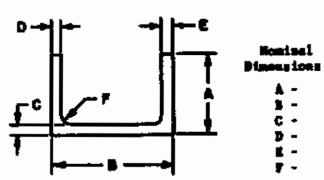
Pressure rise occurred, left side torn.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	
Extrusion No.	129	Die Temp., °F	Cold (in liner for 1 hr)
Primary Purpose of this Experiment	Alignment check	Container Temp., °F	650
Press Capacity	600 tons	Billet Transfer Time in Seconds	
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.047	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	
Billet Material	2S Aluminum	Max Pressure on Billet in psi	
Billet Length	8 inches	Extrusion Length in inches	
Billet Temp., °F	650	Extrusion Surface Finish	
Type of Billet Heating	Furnace bare (dag)	Die Condition	
Billet Heating Time in Minutes	7:30 - 10:35	Die Rework	
Billet Lubricant	Dag	No. of Extrusions Through Same Die	1 prior
Die Lubricant	blue dy-kem	Cone	45°
Container Lubricant	lead	Speed	slow
Die Design No.	PMD-1 (130)		
Die Material	EDS		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



REMARKS:

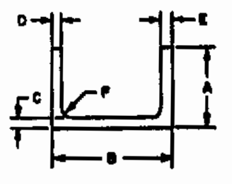
2-1/2 inch butt; left intentionally. "Beautiful" - J.M.S.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	
Extrusion No.	130	Die Temp., °F	650
Primary Purpose of this Experiment	Alignment check	Container Temp., °F	650
Press Capacity	600 tons	Billet Transfer Time in Seconds	
Stem Diameter	2.900 inches	Starting Pressure Reading in psi	
Container Diameter	3.047	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	
Billet Material	2S aluminum	Max Pressure on Billet in psi	
Billet Length	8 inches	Extrusion Length in inches	
Billet Temp., °F	650	Extrusion Surface Finish	
Type of Billet Heating	Furnace	Die Condition	
Billet Heating Time in Minutes	7:30 - 10:55	Die Rework	
Billet Lubricant	Dag	No. of Extrusions Through Same Die	
Die Lubricant			
Container Lubricant	Pb		
Die Design No.	PMD-2		
Die Material	EDS		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

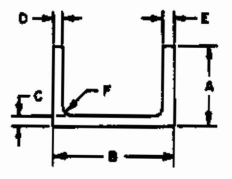
Scored both sides; longer than first one.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	131	Die Temp., °F	Room temp.
Primary Purpose of this Experiment	Lube Experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	15
Stem Diameter	2.900	Starting Pressure Reading in psi	
Container Diameter	3.047	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	600
Billet Material	Be	Max Pressure on Billet in psi	
Billet Length	16 inches	Extrusion Length in inches	0
Billet Temp., °F	[illegible]	Extrusion Surface Finish	
Type of Billet Heating	Furnace in A atm.	Die Condition	
Billet Heating Time in Minutes	169	Die Rework	
Billet Lubricant	B	No. of Extrusions Through Same Die	
Die Lubricant	C (2)	Cone	Radius
Container Lubricant		Speed	Full
Die Design No.	PMD-1	Nose	45°
Die Material	EDS		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

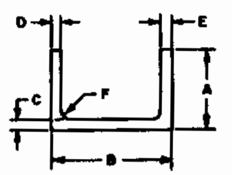
Filled die and stalled.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	132	Die Temp., °F	Room temp.
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	12
Stem Diameter	2.900	Starting Pressure Reading in psi	
Container Diameter	3.047	End Pressure Reading in psi	
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	600
Billet Material	Be	Max Pressure on Billet in psi	
Billet Length	16 inches	Extrusion Length in inches	0
Billet Temp., °F	1850	Extrusion Surface Finish	
Type of Billet Heating	Furnace in A atm.	Die Condition	
Billet Heating Time in Minutes	156	Die Rework	
Billet Lubricant	D slurry	No. of Extrusions Through Same Die	
Die Lubricant	C (2)	Cone	Radius
Container Lubricant		Speed	Full
Die Design No.	PMD-1	Nose	Conical
Die Material	EDS		

Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:

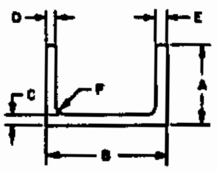
Stalled.

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	133	Die Temp., °F	Room temp.
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	22
Stem Diameter	2.900	Starting Pressure Reading in psi	140,000
Container Diameter	3.047	End Pressure Reading in psi	148,000
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	540
Billet Material	Be	Max Pressure on Billet in psi	148,000
Billet Length	16 inches	Extrusion Length in inches	245
Billet Temp., °F	1850	Extrusion Surface Finish	Rough
Type of Billet Heating	Salt bath	Die Condition	Good
Billet Heating Time in Minutes	32	Die Rework	None
Billet Lubricant	S + T	No. of Extrusions Through Same Die	None prior
Die Lubricant	G (1)	Cone	Radius
Container Lubricant		Speed	Full
Die Design No.	FMD-1	Nose	45°
Die Material	XDS		

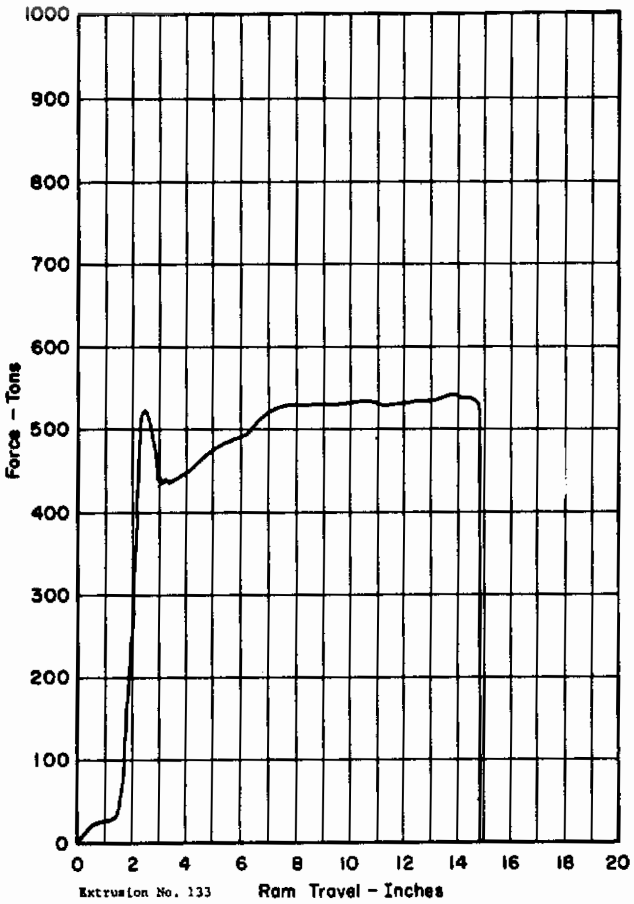
Extrusion Section Dimensions			
	Front	A	0.985
		B	1.514
		C	0.107
		D	0.129
		E	0.126
		F	0.100R
	Center	A	0.970
		B	1.469
		C	0.075
		D	0.122
		E	0.113
		F	
	Rear	A	0.970
		B	1.476
		C	0.090
		D	0.116
		E	0.114
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:
2½" butt left; cut-off set too far back. Both sides torn in last third of channel, otherwise sound.



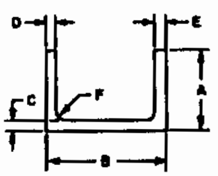
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	134	Die Temp., °F	Room temp.
Primary Purpose of this Experiment	Tooling experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	30
Stem Diameter	2.900	Starting Pressure Reading in psi	129,000
Container Diameter	3.047	End Pressure Reading in psi	136,000
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	580
Billet Material	Be	Max Pressure on Billet in psi	159,000
Billet Length	10 inches	Extrusion Length in inches	274
Billet Temp., °F	1900	Extrusion Surface Finish	Rough (see notes)
Type of Billet Heating	Salt bath	Die Condition	Good
Billet Heating Time in Minutes	40	Die Rework	None
Billet Lubricant	S + G (pwdr)	No. of Extrusions Through Same Die	None prior
Die Lubricant	G (1)	Cone	Radius
Container Lubricant		Speed	Full
Die Design No.	FMD-1	Nose	Radius
Die Material	Rexalloy		

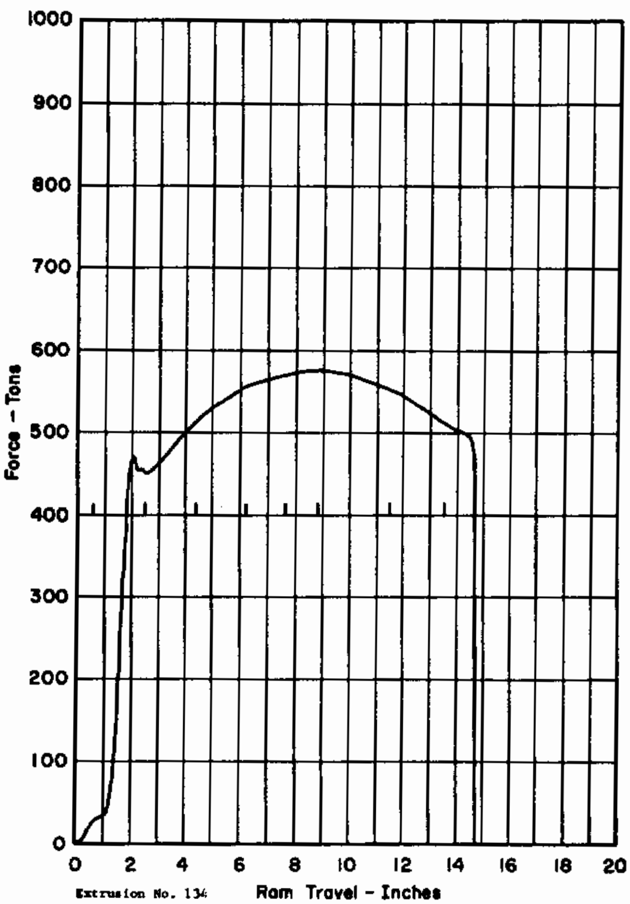
Extrusion Section Dimensions			
	Front	A	0.966
		B	1.475
		C	0.108
		D	0.121
		E	0.121
		F	0.125R
	Center	A	0.960
		B	1.474
		C	0.101
		D	0.113
		E	0.104
		F	
	Rear	A	0.960
		B	1.460
		C	0.095
		D	0.111
		E	0.105
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:
Straightener and catch tube omitted - extrusion passed from bolster into open air - center third torn both sides, both ends sound - pressure rose at middle of extrusion, then fell again.



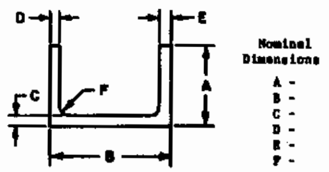
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	135	Die Temp., °F	Room temp.
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	29
Stem Diameter	2.900	Starting Pressure Reading in psi	124,000
Container Diameter	3.047	End Pressure Reading in psi	152,000
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	555
Billet Material	Be	Max Pressure on Billet in psi	152,000
Billet Length	16 inches	Extrusion Length in inches	356
Billet Temp., °F	1900	Extrusion Surface Finish	Rough
Type of Billet Heating	Salt bath	Die Condition	Good
Billet Heating Time in Minutes	30	Die Rework	None
Billet Lubricant	S + G (pwdr)	No. of Extrusions Through Same Die	None prior
Die Lubricant	M (cone)	Cone	Glass
Container Lubricant		Speed	Full
Die Design No.	PMD-1	Nose	Conical
Die Material	98M2		

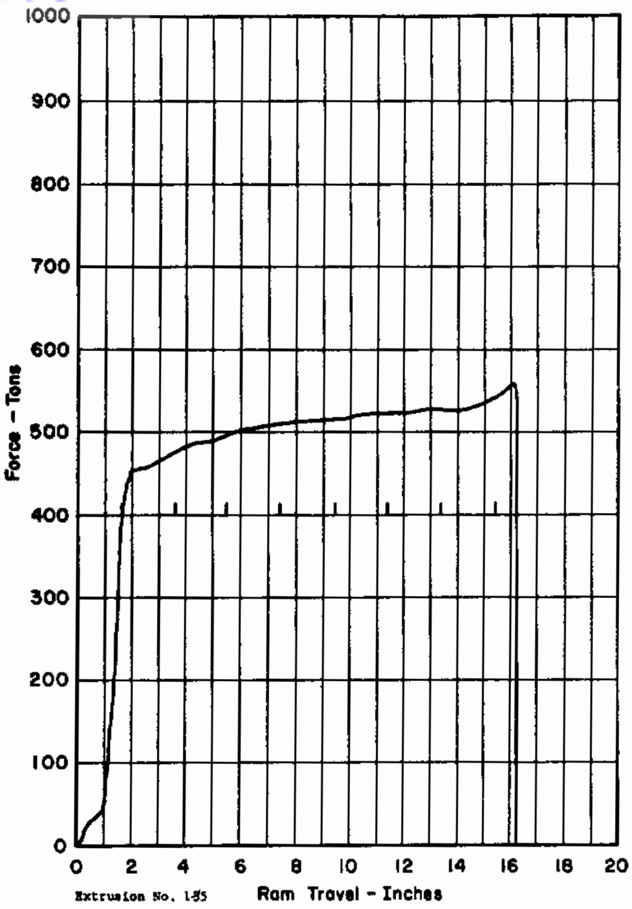
Extrusion Section Dimensions			
	Front	A	0.945
		B	1.431
		C	0.076
		D	0.091
		E	0.090
		F	0.100R
	Center	A	0.965
		B	1.455
		C	0.080
		D	0.091
		E	0.091
		F	0.100R
	Rear	A	0.965
		B	1.480
		C	0.090
		D	0.103
		E	0.107
		F	0.100R

Extruded Shape Sketch:



REMARKS:

Slight pressure rise - 4 minute tears on left side - widely spaced.



Extrusion No. 135

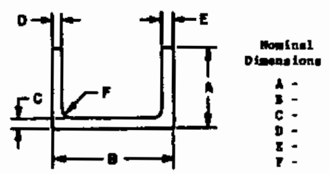
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	136	Die Temp., °F	Room temp.
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	30
Stem Diameter	2.900	Starting Pressure Reading in psi	137,000
Container Diameter	3.047	End Pressure Reading in psi	151,000
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	615
Billet Material	Be	Max Pressure on Billet in psi	169,000
Billet Length	15 inches	Extrusion Length in inches	300
Billet Temp., °F	1900	Extrusion Surface Finish	Rough
Type of Billet Heating	Salt bath	Die Condition	Washed
Billet Heating Time in Minutes	55	Die Rework	None
Billet Lubricant	S + G (pwdr)	No. of Extrusions Through Same Die	One prior
Die Lubricant	M (cone)	Cone	Glass
Container Lubricant		Speed	Full
Die Design No.	PMD-1	Nose	Radius
Die Material	EDS		

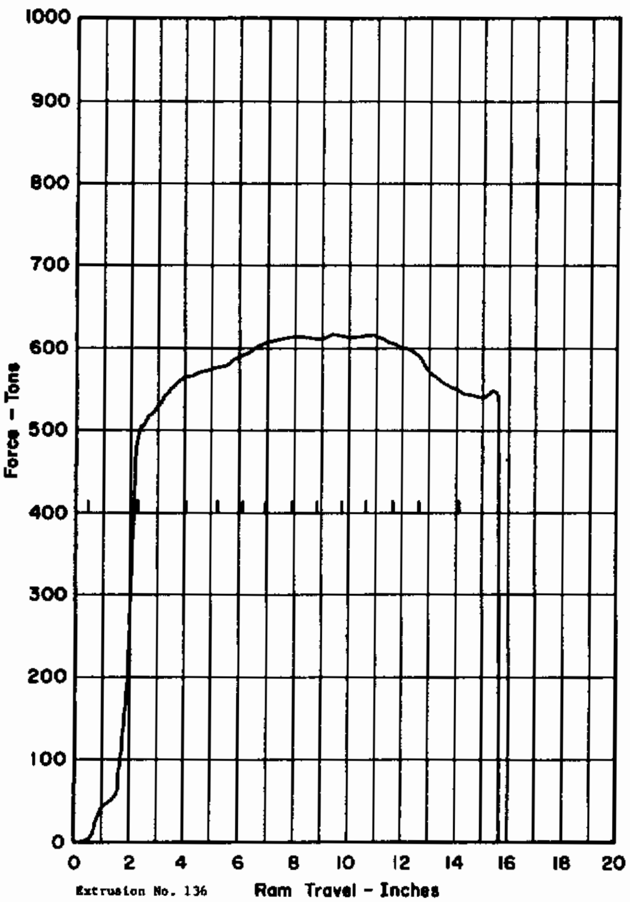
Extrusion Section Dimensions			
	Front	A	0.935
		B	1.477
		C	0.081
		D	0.109
		E	0.106
		F	
	Center	A	0.980
		B	1.468
		C	0.084
		D	0.107
		E	0.107
		F	~0.125R
	Rear	A	0.980
		B	1.466
		C	0.093
		D	0.109
		E	0.111
		F	

Extruded Shape Sketch:



REMARKS:

Die opening inverted - pressure pattern same as 134 - die washed - last third of channel separated and rippled - tearing occurred on left side.



Extrusion No. 136

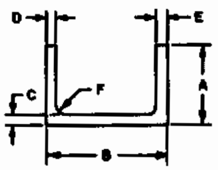
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	137	Die Temp., °F	Room temp.
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	31
Stem Diameter	2.900	Starting Pressure Reading in psi	150,000
Container Diameter	3.047	End Pressure Reading in psi	134,000
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	550
Billet Material	Be (reworked)	Max Pressure on Billet in psi	150,000
Billet Length	~14 inches	Extrusion Length in inches	215
Billet Temp., °F	1850	Extrusion Surface Finish	Poor
Type of Billet Heating	Furnace in A atm.	Die Condition	Washed
Billet Heating Time in Minutes	137	Die Rework	None
Billet Lubricant	B, F + T	No. of Extrusions Through Same Die	None prior
Die Lubricant	G (1)	Cone	Radius
Container Lubricant		Speed	Full
Die Design No.	PMD-1	Nose	45°
Die Material	KDS		

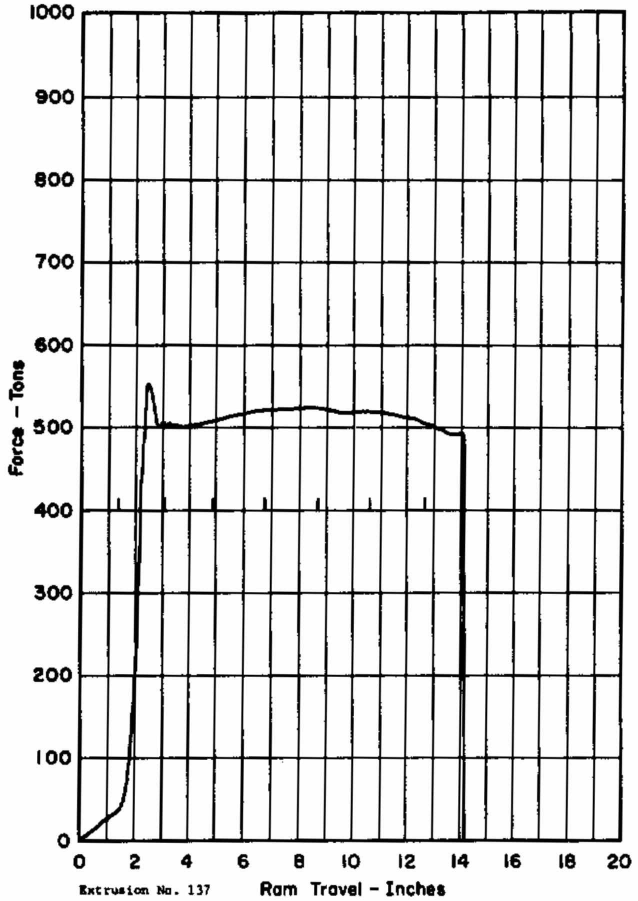
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:
Cone coextruded with Be near end of extrusion - several small tears near end.



Extrusion No. 137

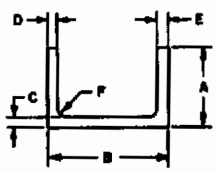
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	138	Die Temp., °F	Room temp.
Primary Purpose of this Experiment	Flow shape	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	31
Stem Diameter	2.900	Starting Pressure Reading in psi	136,000
Container Diameter	3.047	End Pressure Reading in psi	142,000
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	515
Billet Material	Be (w/.020" Fe insert)	Max Pressure on Billet in psi	142,000
Billet Length	6 inches	Extrusion Length in inches	86
Billet Temp., °F	1900	Extrusion Surface Finish	Poor
Type of Billet Heating	Salt bath	Die Condition	Fair
Billet Heating Time in Minutes	30	Die Rework	None
Billet Lubricant	S + T	No. of Extrusions Through Same Die	One prior
Die Lubricant	G (1)	Cone	None
Container Lubricant		Speed	Full
Die Design No.	PMD-1	Nose	Radius
Die Material	KDS		

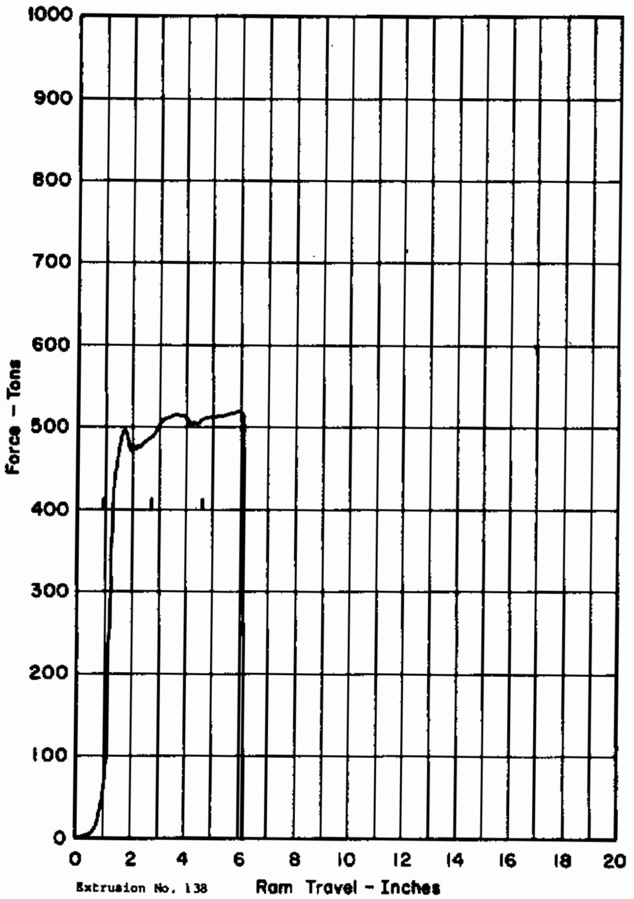
Extrusion Section Dimensions			
	Front	A	
		B	
		C	
		D	
		E	
		F	
	Center	A	
		B	
		C	
		D	
		E	
		F	
	Rear	A	
		B	
		C	
		D	
		E	
		F	

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:
Billet made by fastening two 3" billets with a .020" Fe disc between them - tearing occurred on both sides.



Extrusion No. 138

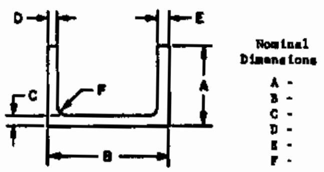
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	139	Die Temp., °F	Room temp.
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	32
Stem Diameter	2.900	Starting Pressure Reading in psi	131,000
Container Diameter	3.047	End Pressure Reading in psi	128,000
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	470
Billet Material	Be	Max Pressure on Billet in psi	131,000
Billet Length	10 inches	Extrusion Length in inches	153
Billet Temp., °F	1900	Extrusion Surface Finish	Fair
Type of Billet Heating	Salt bath	Die Condition	Good
Billet Heating Time in Minutes	30	Die Rework	None
Billet Lubricant	F + D4	No. of Extrusions Through Same Die	Two prior
Die Lubricant	G (1)	Cone	None
Container Lubricant		Speed	Full
Die Design No.	PMD-1	Nose	Cone
Die Material	EDS		

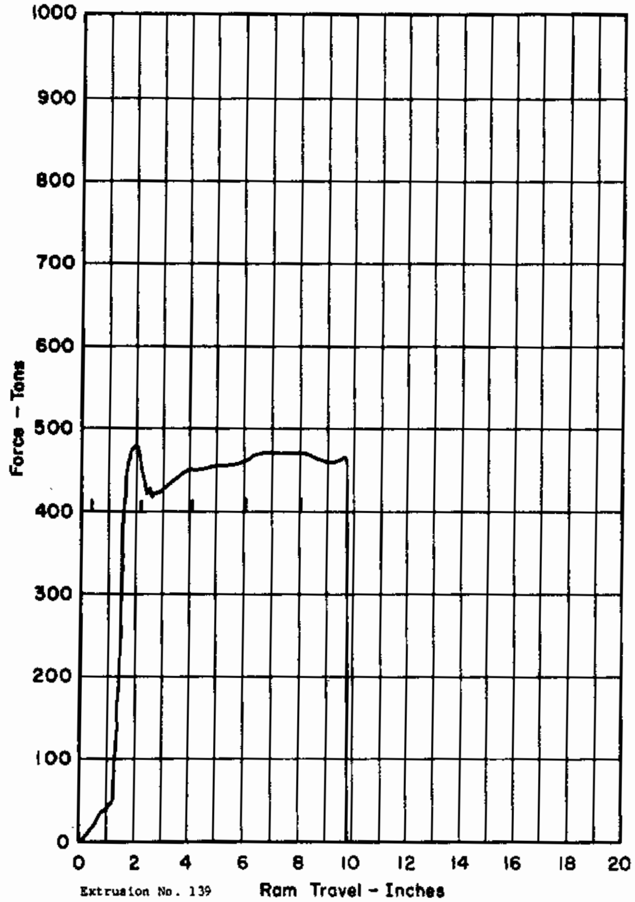
Extrusion Section Dimensions			
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:
Sides separated from base in middle third of channel.



Extrusion No. 139

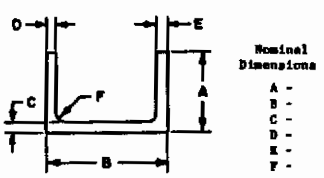
RA1102

BERYLLIUM EXTRUSION TEST DATA

Subcontractor	NMI	Type of Die Fabrication	Cast insert
Extrusion No.	140	Die Temp., °F	Room temp.
Primary Purpose of this Experiment	Lube experiment	Container Temp., °F	900
Press Capacity	600 T	Billet Transfer Time in Seconds	29
Stem Diameter	2.900	Starting Pressure Reading in psi	118,000
Container Diameter	3.047	End Pressure Reading in psi	141,000
Extrusion Ratio	18.5:1	Max Force on Billet in Tons	515
Billet Material	Be (reworked)	Max Pressure on Billet in psi	141,000
Billet Length	14 inches	Extrusion Length in inches	235
Billet Temp., °F	1900	Extrusion Surface Finish	Rough
Type of Billet Heating	Salt bath	Die Condition	Fair
Billet Heating Time in Minutes	28	Die Rework	None
Billet Lubricant	F + D4	No. of Extrusions Through Same Die	None prior
Die Lubricant	K (cone)	Cone	Glass
Container Lubricant		Speed	Full
Die Design No.	PMD-1	Nose	Radius
Die Material	98M2		

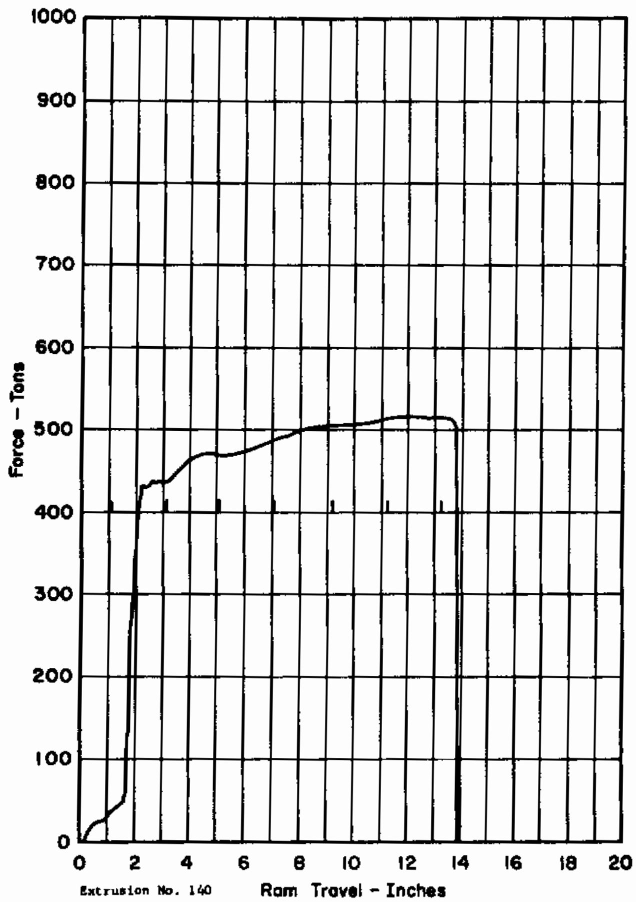
Extrusion Section Dimensions			
Front	A	0.959	
	B	1.470	
	C	0.098	
	D	0.088	
	E	0.097	
	F		
Center	A	0.957	
	B	1.477	
	C	0.101	
	D	0.090	
	E	0.096	
	F	-0.125R	
Rear	A	0.959	
	B	1.466	
	C	0.101	
	D	0.095	
	E	0.100	
	F		

Extruded Shape Sketch:



Nominal Dimensions
A -
B -
C -
D -
E -
F -

REMARKS:
Right side rippled and separated - large amount of glass left around butt (billet had tapered rear at start) - both sides torn.



Extrusion No. 140

RA1102

APPENDIX VI

Wolverine Glass
Extrusion Data Sheets

Efforts Conducted Under Technical Direction of Nuclear Metals Personel.

The following efforts were made at Wolverine Tube, Detroit, Michigan, under the direction of Nuclear Metals in order to evaluate the possible benefits of a faster acting press at ram speeds to 500 inches per minute or more.

EXTR. NO.	BILLET MAT'L.	BILLET LENGTH	DIE	BILLET TEMP.	BILLET LUBE	DIE LUBE	RESULTS
1	Steel	5"	O	1750°F	Glass B,F,&D_3	Glass G	Good lube coverage, good surface
2	Steel	10"	U	1750°F	Same as #1	Glass G	Same as above. Yielded 11-foot length
3	Beryl	4" Be 4" Fe	U	1750°F	Same as #1	Glass G	Be pushed first and was intact but rough
4	Beryl	4"	U	1750°F	Same as #1	Glass E	Bad rattlesnake
5	Beryl	3-1/2"	U	1650°F	Glass B & T	Glass E	Temperature to low; stalled
6	Beryl	3-1/2"	U	1775°F	Same as #1	Glass G	Better surface but some cracking present
7	Beryl	10"	U	1750°F	Same as #1	Glass G	11 Ft. crack free. Rough surface on inside. Die worn.
8	Beryl	10"	U	1750°F	Same as #1	Glass G	11 Ft. crack free. Slightly improved surface.
9	Beryl	3-1/2"	U	1750°F	Same as #1	CuDisc +Glass G	Cu not beneficial. Excessive die wear.
10	Beryl	10"	U	1750°F	Same as #1	Glass G	11 Ft. crack free. 3 second dwell on upset. Best surface quality.
11	Beryl	4"	U	1750°F	Same as #1	Glass G	Type M-2 die material. 5 Ft. fairly good. Surface quality and die condition good.
12	Beryl	10"	U	1750°F	Same as #1	Glass G	EDS stellite die. Rattlesnaking on all except about 5 Ft. surface of extrusion striated
13	Beryl	10"	U	1750°F	Glass	Glass	10 Ft. length rough and badly twisted. Die failed severely.

Push No. 11

CONDITIONS:

Billet Material - 4" length, beryllium
Billet Temperature - 1750°F
Die Material - M-2(new type)
Die Lubricant - Type G, one pad
Billet Lube - Type D-3 with B & F floss
Pressure - 550 tons
Ram Speed - in excess of 500 inches per min.

(The above billet temperature and lubes are the same as utilized in efforts covered by Interim Report Nr. 10 and which repetitively yielded uncracked sections.)

RESULT: Five foot length of fairly good extrusion except for a heavy tear six inches from the front. Die condition and inside of extrusion both appeared to be quite smooth.

Push No. 12

CONDITIONS:

Billet Material - 10" length, beryllium
Die Material - EDS stellite, best x-ray quality.

Lubricants and billet temperatures same as Push No. 1.

RESULTS: First 1-1/2 feet were rattlesnaked, the next five feet whole, and then more rattlesnaking with one web broken off. The inside of the extrusion was grossly striated and was typical of previous die failures.

Push No. 13

CONDITIONS:

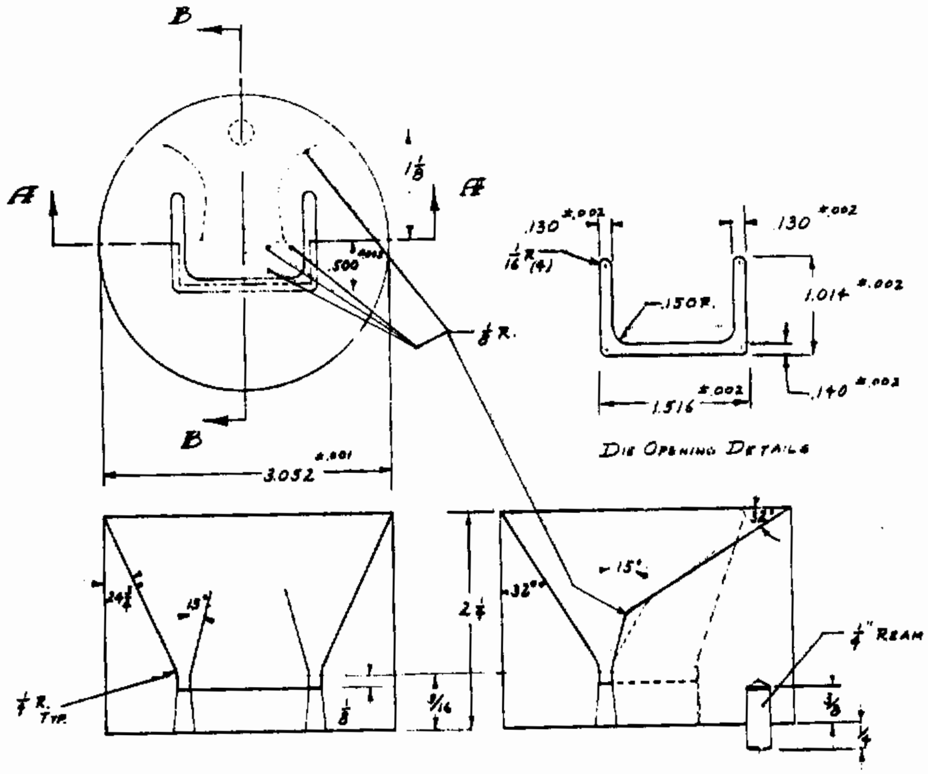
Billet Material - 10" length, beryllium
Die Material - stellite
Billet Temperature same as Push No. 1.

Lubricants - new type glasses which were recommendations of Allegheny.

RESULTS: Ten foot length which was not torn but was rough and badly twisted. Inside and outside of extrusion were progressively rougher and clearly showed lubricant failure. Die failed severely, but unlike Push No. 2 the fillets were badly worn with minor damage in-between.

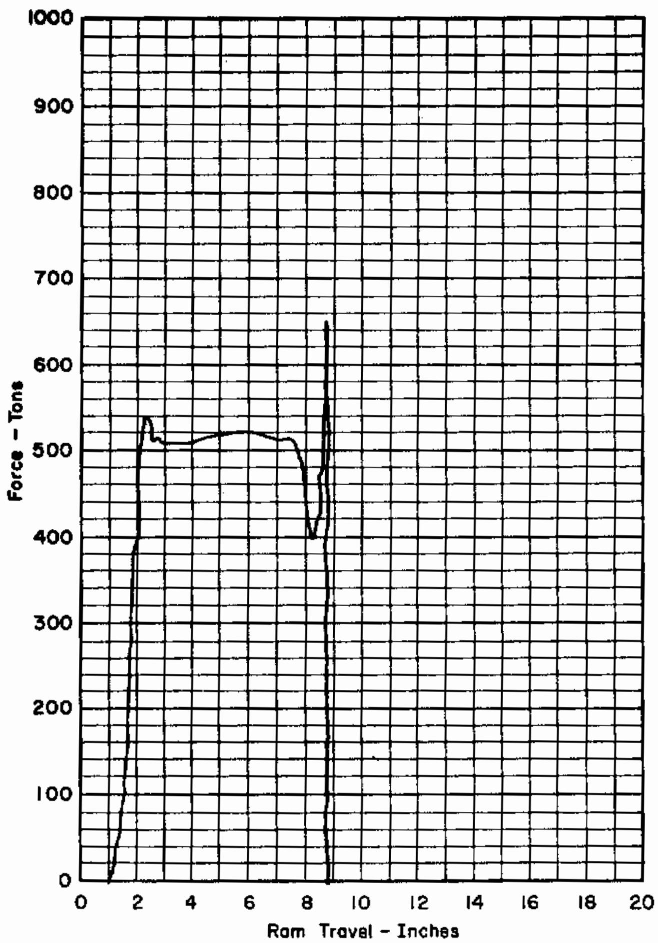
APPENDIX VII

Nuclear Metals Composite Lubricant Extrusion Data Sheets



SECTION A-A   MC-497-A   SECTION B-B

Extrusion 1



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

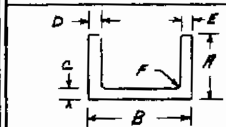
Type of Extrusion Development   Job No. 2567   Extrusion No. 1

NMI Extrusion No. 32059   Be Chem Lot No. 8661   Extrusion Date 5/29/61

Primary purpose of this extrusion: Evaluate die design having 0.130" orifice

Liner	ID (in.) 3.050	Length (in.) 13
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	--------------
Billet	Material	Be canned in steel
	Can Thickness	0.100"
	Length (in.)	Be Billet 5 1/2
	Temp. (°F)	1705
	Lubrication	Aqua deg
	Electroplate	0.015" cu
	Heating	Under graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 210
	Transfer Time (sec)	25
Die	Material	M-2
	Fabrication	Cast
	Type	Cenessed U/deep approach
	Design No.	MC-497-A
	Identification No.	A-1
	Temp. (°F)	300
	Lubrication	Aqua deg and mica coat
	Condition	New (check cracks)
	Rework	Diamond polish
	No. of Extrusions/Die	First
	Extrusion Ratio	15 to 1

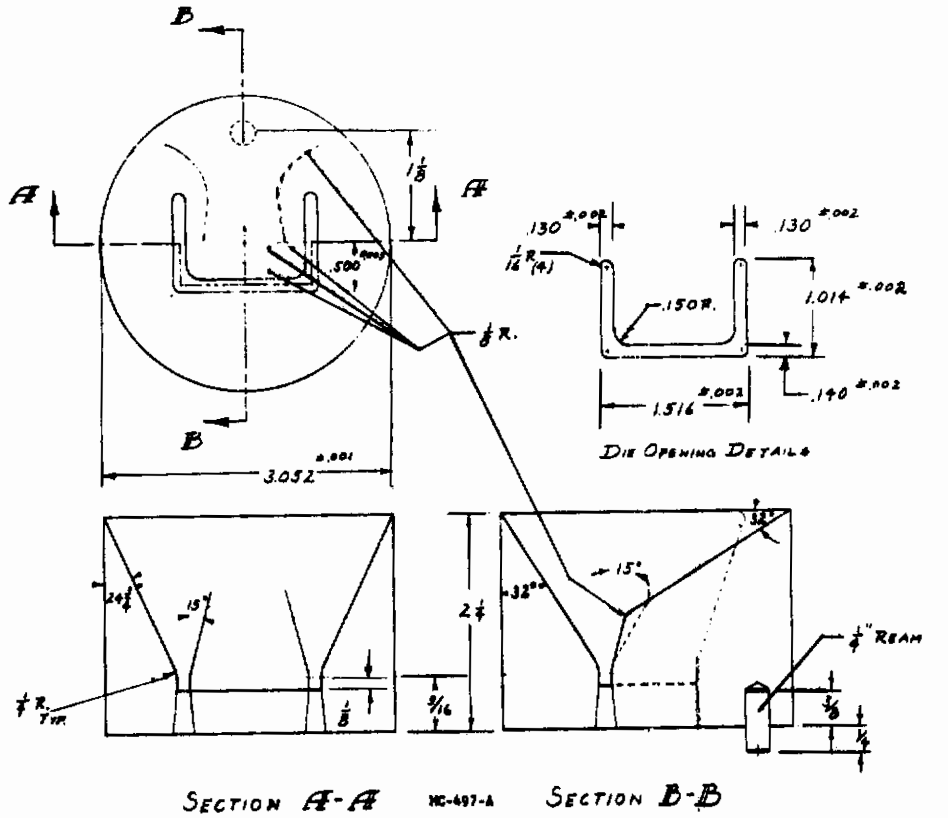
Extrusion Section Dimensions

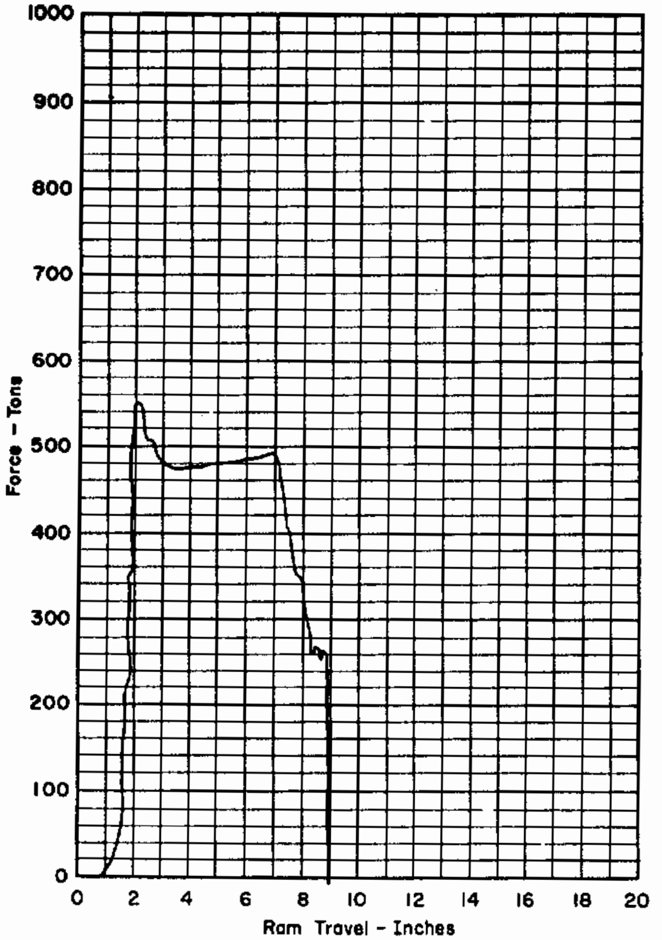


		Before Pickle	After Pickle
Front	A	Not Recorded	
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Remarks: Clad breakthrough on inside corners of channel, die cracked; rear of extrusion stuck in straightener

Extrusion 2





DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

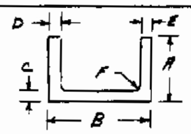
Type of Extrusion Development Job No. 2567 Extrusion No. 2

NMI Extrusion No. 32060 Be Chem Lot No. 8661 Extrusion Date 5/29/61

Primary purpose of this extrusion: Evaluate die design having 0.120" orifice

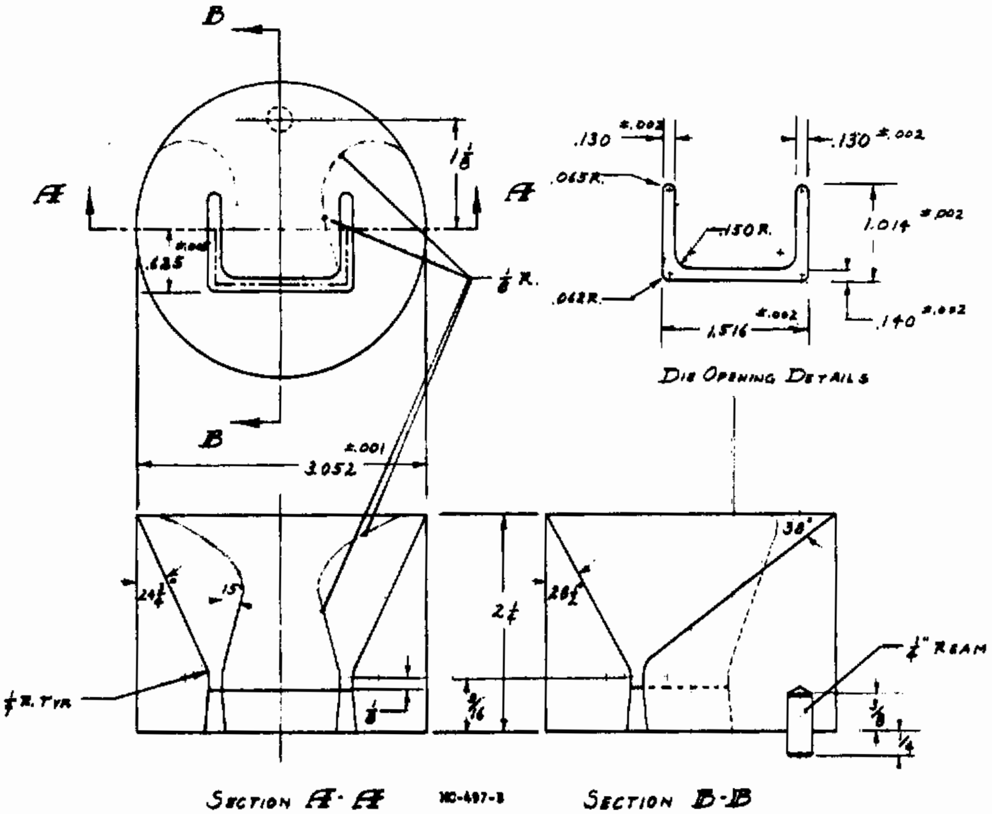
Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	---------------
Billet	Material	Be canned in steel
	Can Thickness	0.100"
	Length (in.)	Be 5 Billet 6 1/2
	Temp. (°F)	1775
	Lubrication	Aqua dag
	Electroplate	0.015" cu
	Heating	Under graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 307
	Transfer Time (sec)	25
Die	Material	M-2
	Fabrication	Cast
	Type	Offset U/deep approach
	Design No.	MC-497-A
	Identification No.	A-2
	Temp. (°F)	Room
	Lubrication	Aqua dag and mica coated
	Condition	New (check cracks)
	Rework	None
	No. of Extrusions/Die	First
	Extrusion Ratio	15 to 1

Extrusion Section Dimensions

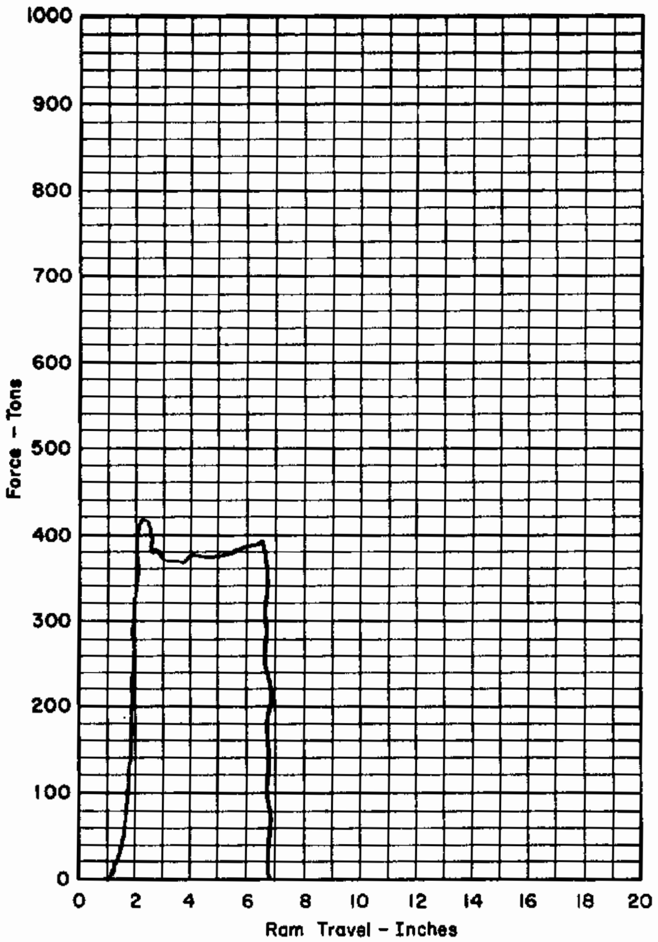


		Before Pickle	After Pickle
Front	A	Not Recorded	
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Remarks: Die cracked; rear of extrusion stuck in straightener



Extrusion 3



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

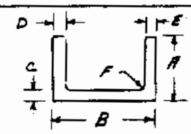
Type of Extrusion Development Job No. 2567 Extrusion No. 3

NMI Extrusion No. 32061 Be Chem Lot No. 8661 Extrusion Date 5/29/61

Primary purpose of this extrusion: Evaluate die design having 0.120" orifice and transite striaghtener

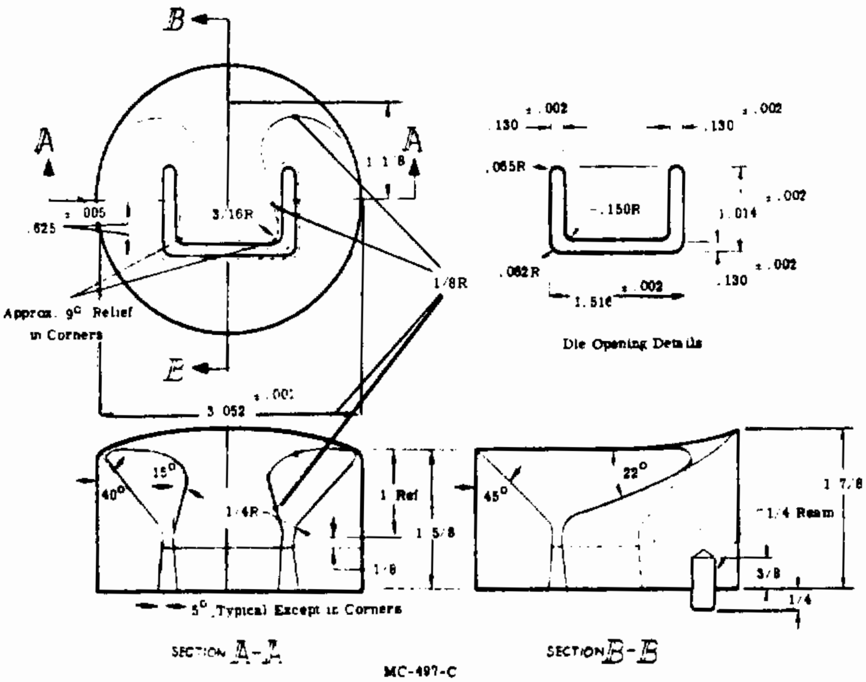
Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	----------------
Billet	Material	Be canned in steel
	Can Thickness	0.100"
	Length (in.)	Be 5 Billet 6 1/2
	Temp. (°F)	1775
	Lubrication	Aqua dag
	Electroplate	0.015 Cu
	Heating	Under graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 180
	Transfer Time (sec)	25
Die	Material	M-2
	Fabrication	Cast
	Type	Offset U-Sahllow approach
	Design No.	MC-497-B
	Identification No.	A-3
	Temp. (°F)	Room
	Lubrication	Aqua dag and mica coated
	Condition	New (check cracks)
	Rework	None
	No. of Extrusions/Die	First
	Extrusion Ratio	15 to 1

Extrusion Section Dimensions

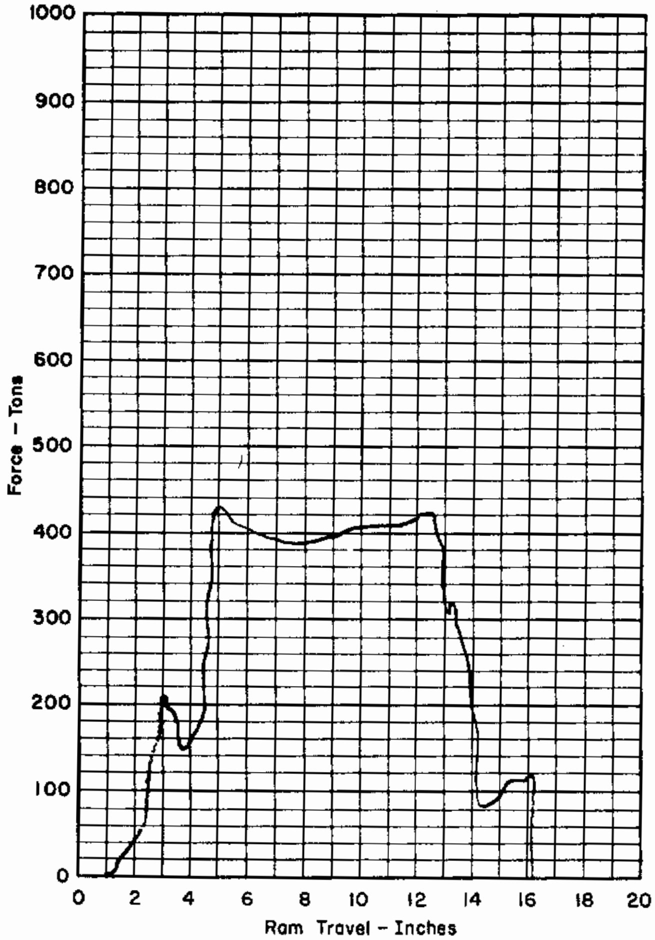


		Before Pickle	After Pickle
Front	A	Not Recorded	
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Remarks: Die cracked; extrusion good; transite straightener too wide to accomodate be channel after contraction, rear of extrusion stuck in straightener



Extrusion 4



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

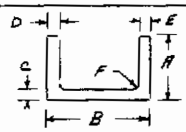
Type of Extrusion Development   Job No. 2567   Extrusion No. 4

NMI Extrusion No. 32214   Be Chem Lot No. 8661   Extrusion Date 6/9/61

Primary purpose of this extrusion: Obtain extrusion data

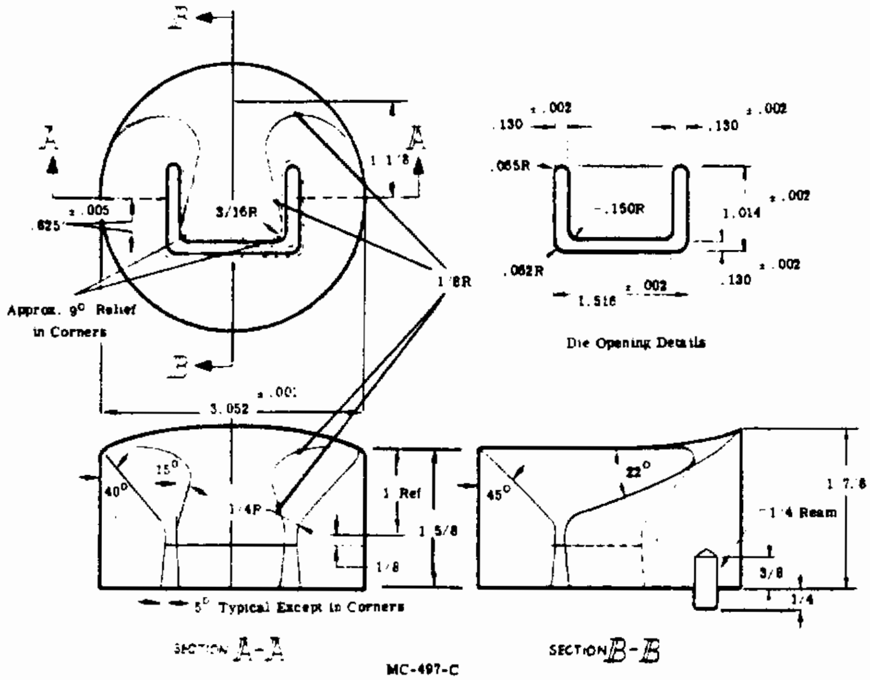
Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	New
Billet	Material	Be canned in steel
	Can Thickness	.116"
	Length (in.)	Be 11 Billet 12
	Temp. (°F)	1750
	Lubrication	Aqua dag
	Electroplate	Cu(25 mils thick)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 220
	Transfer Time (sec)	20
Die	Material	M-2 steel/Rc 40
	Fabrication	Casting
	Type	Offset/blunt
	Design No.	MC-497-C
	Identification No.	A-4
	Temp. (°F)	900
	Lubrication	Aqua dag and mica coated
	Condition	New
	Rework	Diamond polish
	No. of Extrusions/Die	None
	Extrusion Ratio	15 to 1

Extrusion Section Dimensions

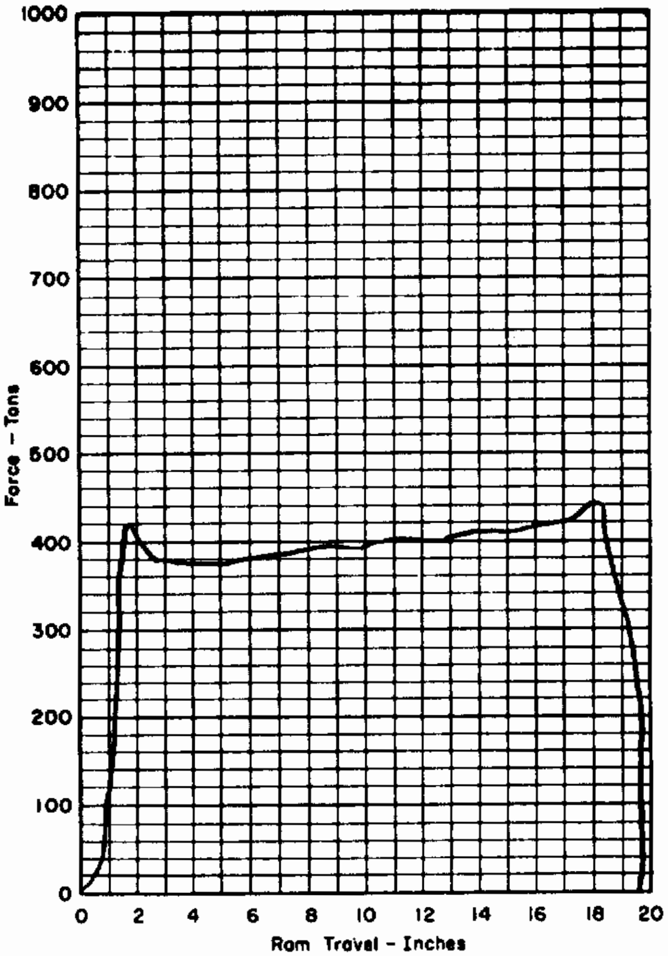


		Before Pickle	After Pickle
Front	A	Not Recorded	
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Remarks: Part of extrusion was ok the rest failed to materialize because of support tooling breakdown; rear of extrusion stuck in straightener



Extrusion 5



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

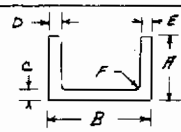
Type of Extrusion Development Job No. 2567 Extrusion No. 5

NMI Extrusion No. 32215 Be Chem Lot No. 8661 Extrusion Date 6/9/61

Primary purpose of this extrusion: Obtain extrusion data

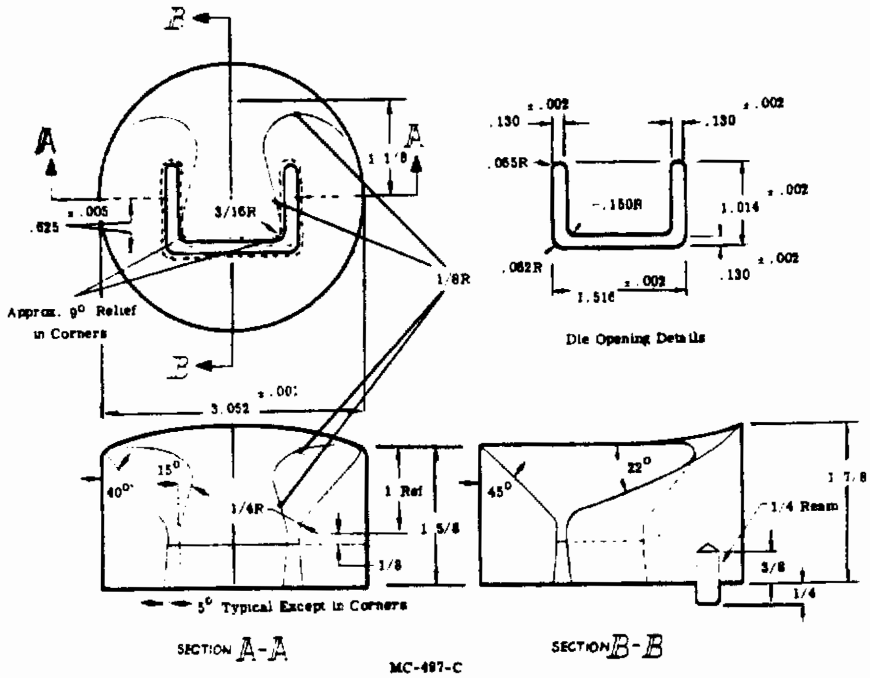
Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	New
Billet	Material	Be canned in steel
	Can Thickness	.112"
	Length (in.)	Be 16 Billet 17
	Temp. (°F)	1750
	Lubrication	Aqua dag
	Electroplate	Cu (25 mils thick)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 325
	Transfer Time (sec)	25
Die	Material	M-2 steel/Rc 42
	Fabrication	Casting
	Type	Offset/blunt
	Design No.	MC-497-C
	Identification No.	A-5
	Temp. (°F)	900
	Lubrication	Aqua dag and mica coated
	Condition	New
	Rework	Diamond polish
	No. of Extrusions/Die	None
	Extrusion Ratio	15 to 1

Extrusion Section Dimensions

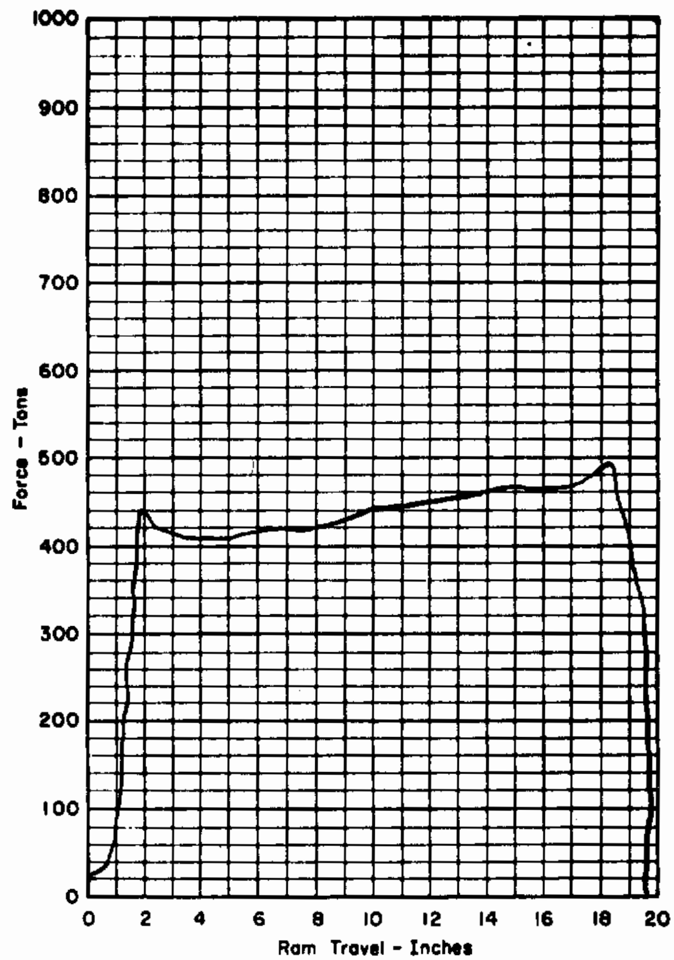


		Before Pickle	After Pickle
Front	A	1.009"	0.950"
	B	1.507"	1.463"
	C	0.133"	0.109"
	D	0.129"	0.112"
	E	0.126"	0.109"
	F	0.150"R	
Center	A	1.010"	0.949"
	B	1.5075"	1.4645"
	C	0.131"	0.111"
	D	0.127"	0.110"
	E	0.124"	0.106"
	F	0.150"R	
Rear	A	1.009"	0.949"
	B	1.510"	1.466"
	C	0.130"	0.110"
	D	0.124"	0.109"
	E	0.119"	0.104"
	F	0.150"R	

Remarks: Extrusion ok; extrusion cleared straightener



Extrusion 6



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

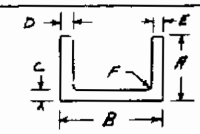
Type of Extrusion Development Job No. 2567 Extrusion No. 6

NMI Extrusion No. 32216 Be Chem Lot No. 8661 Extrusion Date 6/9/61

Primary purpose of this extrusion: Obtain extrusion data

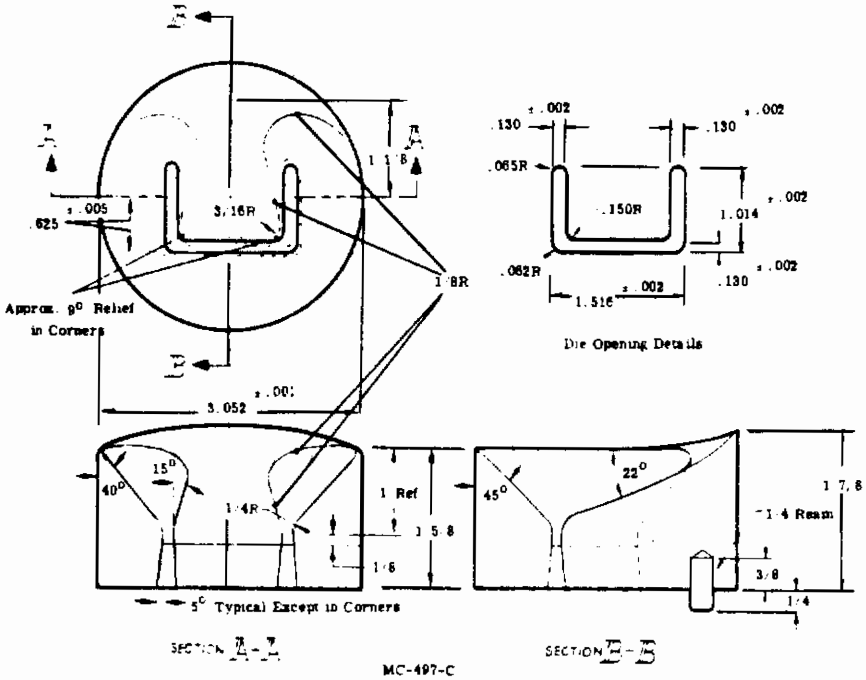
Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	New
Billet	Material	Be canned in steel
	Can Thickness	.116"
	Length (in.)	Be 16 / Billet 17
	Temp. (°F)	1710
	Lubrication	Aqua dag
	Electroplate	Cu(25 mils thick)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 / b. Actual 265
	Transfer Time (sec)	25
Die	Material	M-2 steel / Rc
	Fabrication	Casting
	Type	Offset/blunt
	Design No.	MC-497-C
	Identification No.	A-6 (H)
	Temp. (°F)	900
	Lubrication	Aqua dag and mica coated
	Condition	New
	Rework	Diamond polish
	No. of Extrusions/Die	None
	Extrusion Ratio	15 to 1

Extrusion Section Dimensions

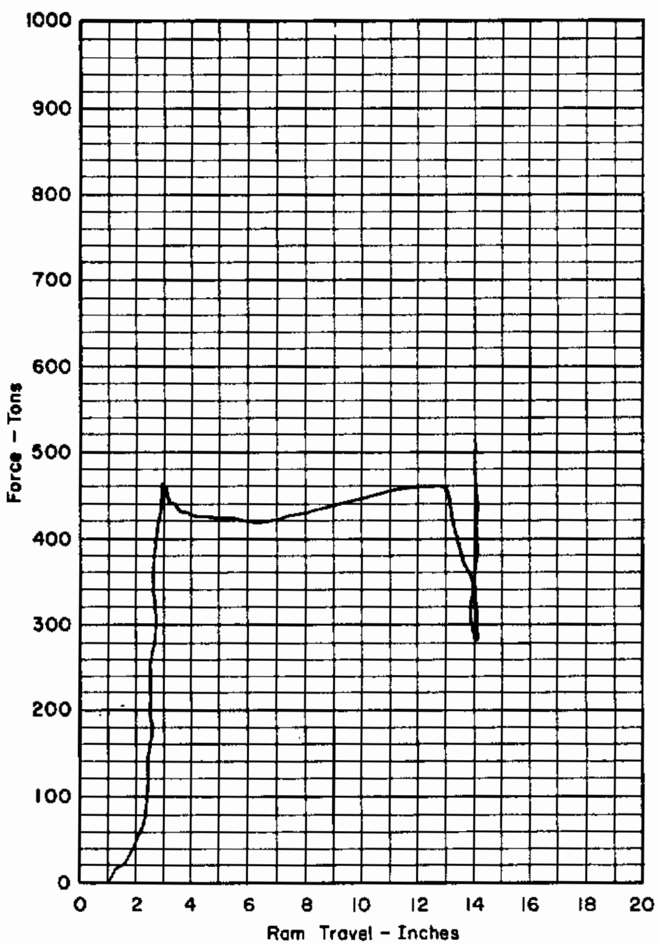


		Before Pickle	After Pickle
Front	A	0.999"	0.950"
	B	1.504"	1.459"
	C	0.130"	0.114"
	D	0.126"	0.112"
	E	0.126"	0.110"
	F	0.150"R	
Center	A	0.999"	0.949"
	B	1.501"	1.458"
	C	0.130"	0.111"
	D	0.126"	0.110"
	E	0.127"	0.110"
	F	0.150"R	
Rear	A	1.005"	0.9525"
	B	1.504"	1.4545
	C	0.135"	0.108"
	D	0.130"	0.107"
	E	0.133"	0.105"
	F	0.150"R	

Remarks: Extrusion ok; rear of extrusion did not clear straightener.



Extrusion 7



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

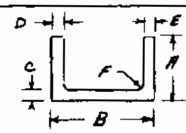
Type of Extrusion Development   Job No. 2567   Extrusion No. 7

NMI Extrusion No. 32217   Be Chem Lot No. 8661   Extrusion Date 6/9/61

Primary purpose of this extrusion: Obtain extrusion data

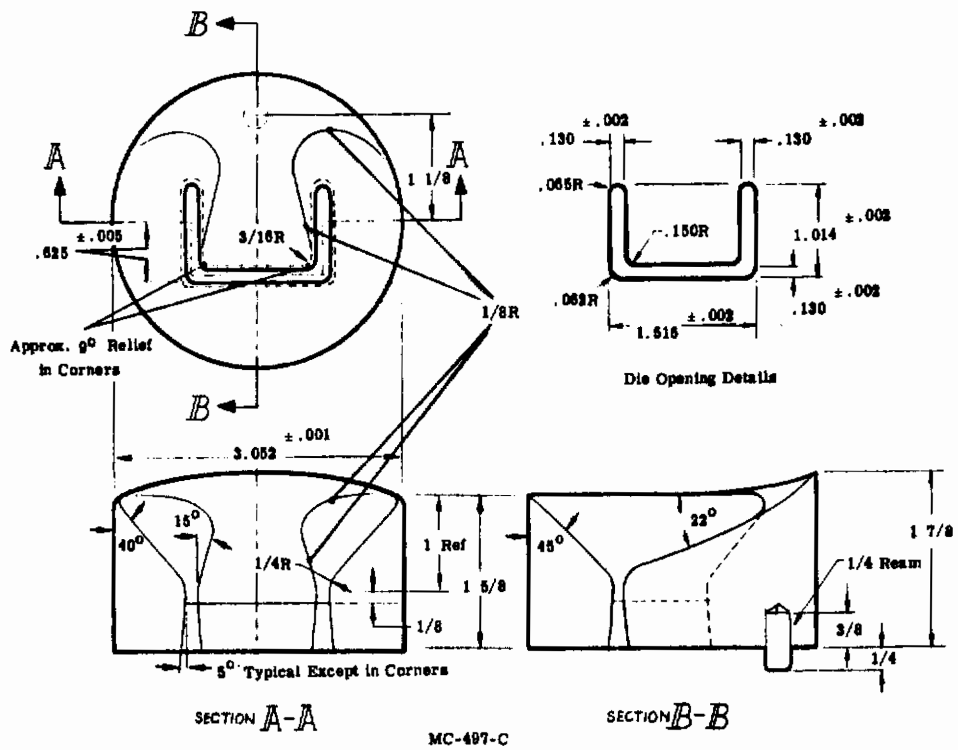
Liner	ID (in.) 3.050"	Length (in.) 26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	New
Billet	Material	Be canned in steel
	Can Thickness	.119"
	Length (in.)	Be 9 Billet 10
	Temp. (°F)	1710
	Lubrication	Aqua dag
	Electroplate	Cu(25 mils thick)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 295
	Transfer Time (sec)	25
Die	Material	M-2 steel/Rc 54
	Fabrication	Casting
	Type	Offset/blunt
	Design No.	MC-497-C
	Identification No.	A-7(E)
	Temp. (°F)	900
	Lubrication	Aqua dag and mica coat
	Condition	New
	Rework	Diamond polish
	No. of Extrusions/Die	None
	Extrusion Ratio	15 to 1

Extrusion Section Dimensions

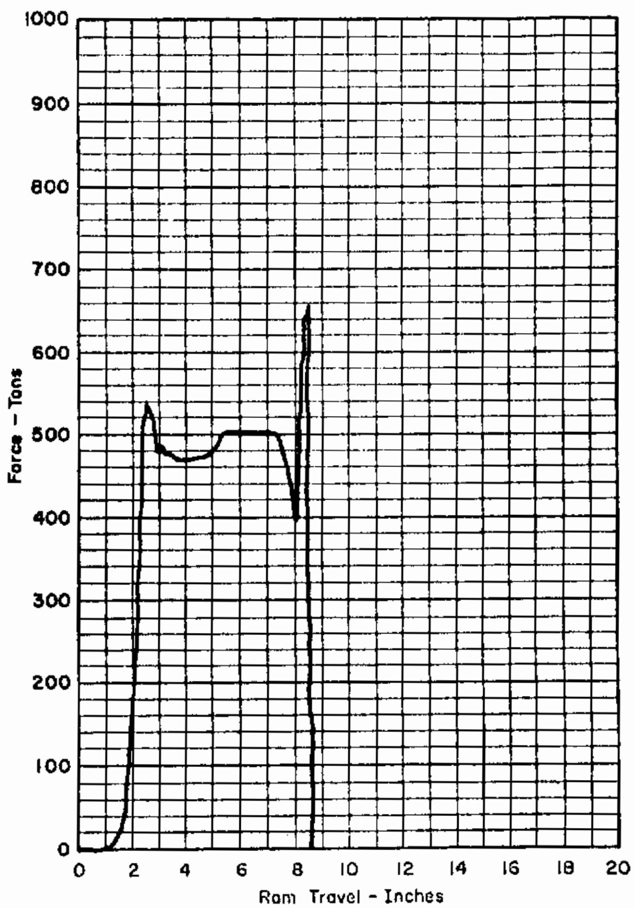


		Before Pickle	After Pickle
Front	A	1.009"	0.954"
	B	1.507"	1.472"
	C	.133"	0.115"
	D	.129"	0.116"
	E	.126"	0.110"
	F		
Center	A	1.010"	
	B	1.507"	
	C	.131"	0.111"
	D	.127"	0.111"
	E	.124"	0.107"
	F		
Rear	A	1.009"	0.953"
	B	1.510"	1.466"
	C	.130"	0.110"
	D	.124"	0.107"
	E	.119"	0.104"
	F		

Remarks: Extrusion ok



Extrusion 8



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

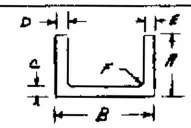
Type of Extrusion Development   Job No. 2567   Extrusion No. 8

NMI Extrusion No. ______   Be Chem Lot No. 8661   Extrusion Date 6/9/61

Primary purpose of this extrusion: Obtain Extrusion Data

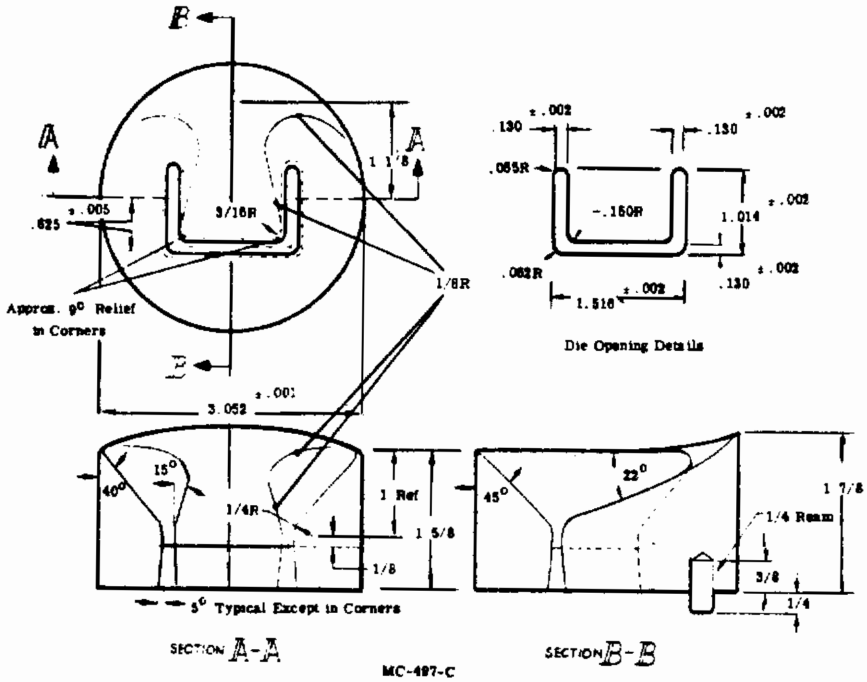
Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	New
Billet	Material	Be canned in steel
	Can Thickness	.119"
	Length (in.)	Be 5 Billet 7
	Temp. (°F)	1710
	Lubrication	Aqua dag
	Electroplate	Cu (25 mils thick)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 180
	Transfer Time (sec)	
Die	Material	M-2 steel
	Fabrication	Casting
	Type	Off-set/blunt
	Design No.	MC-497-C
	Identification No.	A-8
	Temp. (°F)	Liner temperature
	Lubrication	Mica
	Condition	New
	Rework	Diamond polish
	No. of Extrusions/Die	None
	Extrusion Ratio	15 to 1

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A	.999	0.950
	B	1.504	1.459
	C	.130	.114
	D	.124	.112
	E	.124	.110
	F		
Center	A	.999	.999
	B	1.501	1.458
	C	.130	.111
	D	.126	.108
	E	.127	.110
	F		
Rear	A	1.005	.9525
	B	1.504	1.454
	C	.135	.108
	D	.130	.107
	E	.131	.105
	F		

Remarks:



Extrusion 9

DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

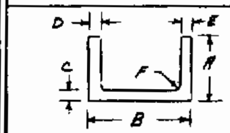
Type of Extrusion Pilot Production Job No. 2568 Extrusion No. 9

NMI Extrusion No. 32347 Be Chem Lot No. ______ Extrusion Date 7/6/61

Primary purpose of this extrusion: Produce 20' lengths

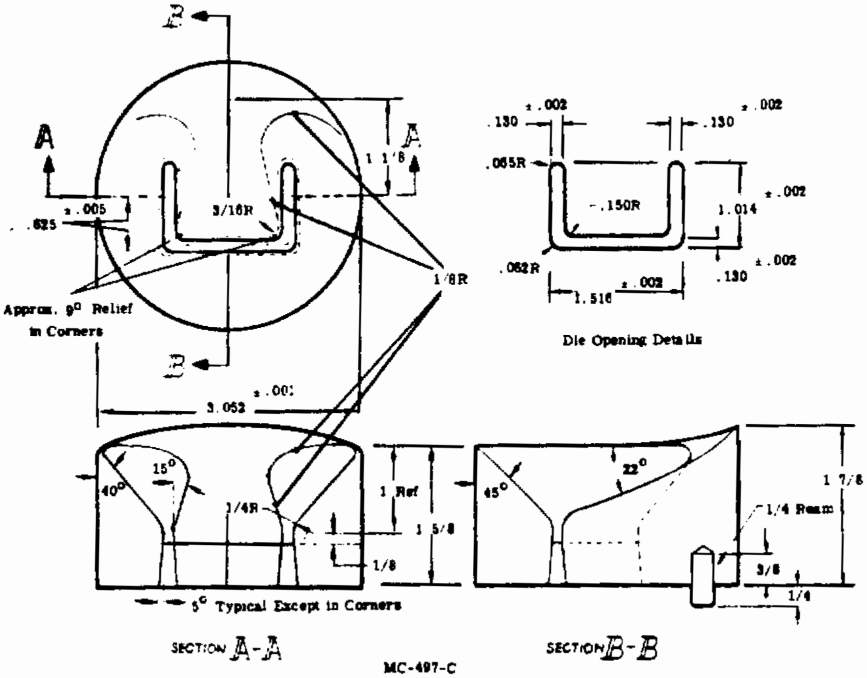
Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	New
Billet	Material	Be canned in steel
	Can Thickness	.100"
	Length (in.)	Be 17" Billet 18"
	Temp. (°F)	1735
	Lubrication	Aqua dag
	Electroplate	Cu(35 mils thick)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 215
	Transfer Time (sec)	25
Die	Material	M-2/RC 54
	Fabrication	Cast
	Type	Blunt tongue/scoop cone
	Design No.	MC-497-C
	Identification No.	A-9 (R)
	Temp. (°F)	900
	Lubrication	Aqua dag and mica coated
	Condition	New
	Rework	Diamond polish and radius increase on relief
	No. of Extrusions/Die	None
	Extrusion Ratio	~ 15 to 1

Extrusion Section Dimensions

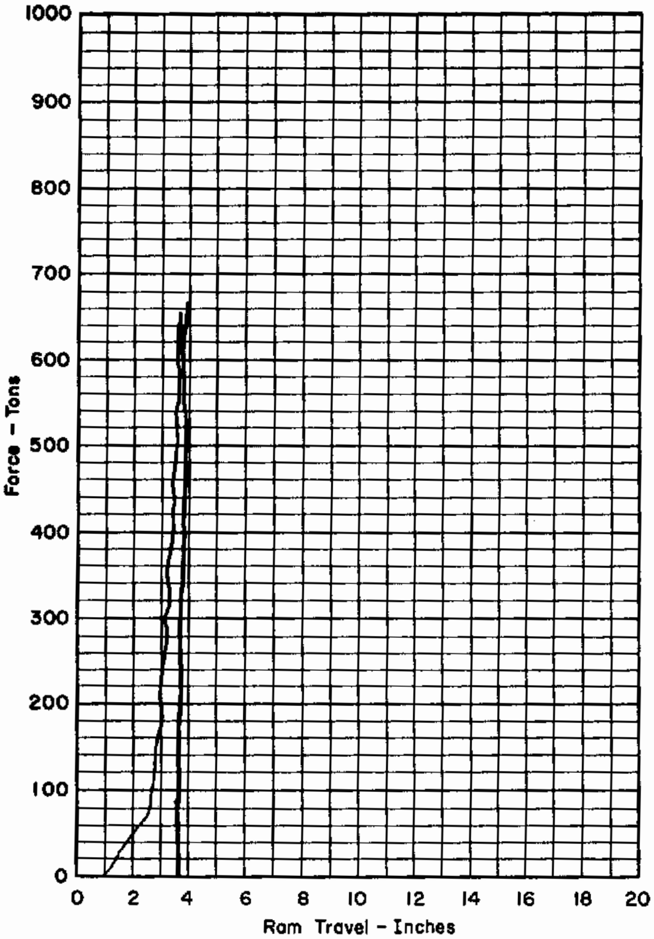


		Before Pickle	After Pickle
Front	A	1.001"	0.936"
	B	1.496"	1.451"
	C	0.133"	0.113"
	D	01132"	0.113"
	E	0.132"	0.113"
	F		
Center	A	1.006"	0.946"
	B	1.501"	1.459"
	C	0.131"	0.112"
	D	0.128"	0.108"
	E	0.130"	0.108"
	F		
Rear	A	1.004"	0.946"
	B	1.506"	1.4681"
	C	0.128"	0.110"
	D	0.127"	0.102"
	E	0.129"	0.107"
	F		

Remarks: Die washout; tearing of extrusion 6' from rear; press load not recorded.



Extrusion 10



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

Type of Extrusion Pilot Production Job No. 2568 Extrusion No. 10

NMI Extrusion No. 3234B Be Chem Lot No. ______ Extrusion Date 7/6/61

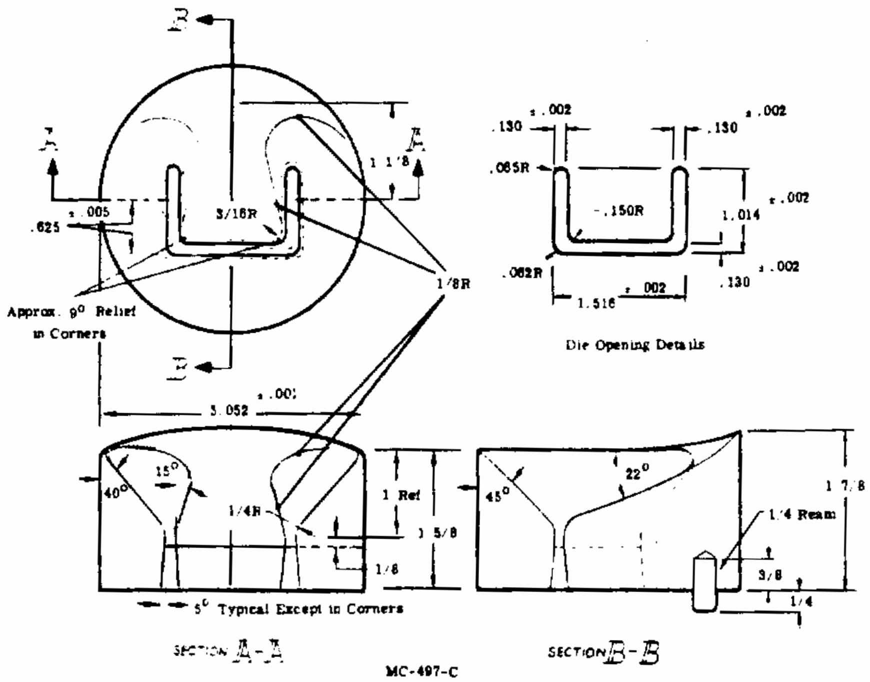
Primary purpose of this extrusion: Produce 20' lengths

Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	New
Billet	Material	Be canned in steel
	Can Thickness	.100"
	Length (in.)	Be 17" Billet 18"
	Temp. (°F)	1735
	Lubrication	Aqua dag
	Electroplate	Cu(35 mils thick)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 185
	Transfer Time (sec)	45
Die	Material	M-2/Rc 54
	Fabrication	Cast
	Type	Blunt tongue/scoop cone
	Design No.	MC-497-C
	Identification No.	A-10 (8)
	Temp. (°F)	900
	Lubrication	Aqua dag and mica coated
	Condition	New
	Rework	Diamond polish and radius increased on relief
	No. of Extrusions/Die	None
	Extrusion Ratio	~ 15 to 1

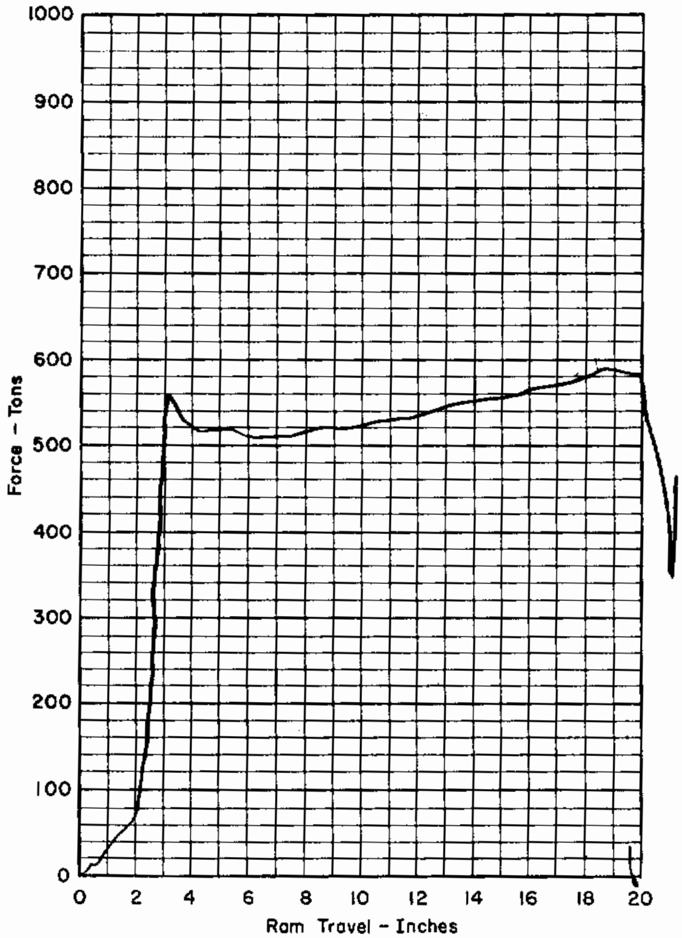
Extrusion Section Dimensions

		Before Pickle	After Pickle
Front	A	Not Recorded	
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Remarks: Stalled



Extrusion 11



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

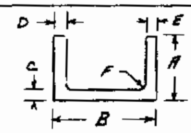
Type of Extrusion Pilot Production   Job No. 2568   Extrusion No. 11

NMI Extrusion No. 32349   Be Chem Lot No. ______   Extrusion Date 7/6/61

Primary purpose of this extrusion: Produce 20' lengths

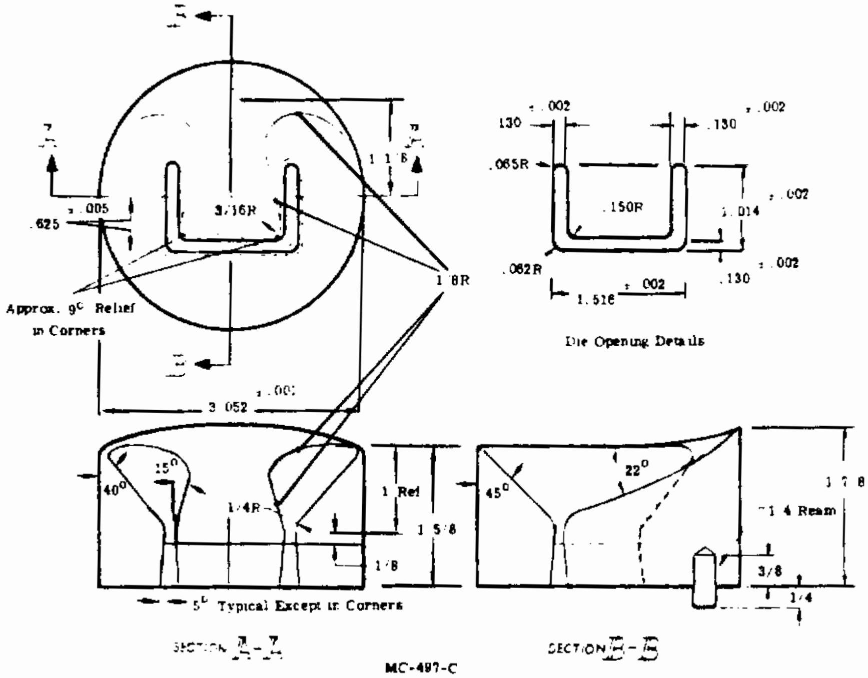
Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	New
Billet	Material	Be canned in steel
	Can Thickness	.100"
	Length (in.)	Be 17" Billet 18"
	Temp. (°F)	1725
	Lubrication	Aqua dag
	Electroplate	Cu (35 mils thick)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 180
	Transfer Time (sec)	25
Die	Material	M-2 /Rc 53
	Fabrication	Cast
	Type	Blunt tongue/scoop cone
	Design No.	MC-497-C
	Identification No.	A-11(T)
	Temp. (°F)	900
	Lubrication	Aqua dag and mica coated
	Condition	New
	Rework	Diamond polish and radius increased on relief
	No. of Extrusions/Die	None
	Extrusion Ratio	~ 15 to 1

Extrusion Section Dimensions

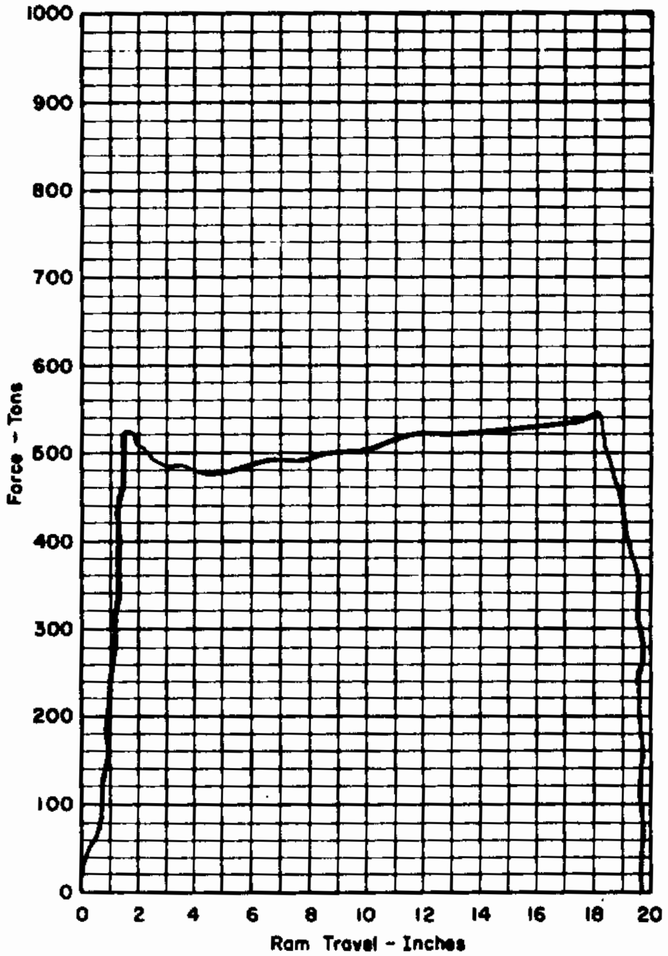


		Before Pickle	After Pickle
Front	A	1.006"	0.947"
	B	1.506"	1.457"
	C	0.136"	0.118"
	D	0.134"	0.114"
	E	0.133"	0.114"
	F		
Center	A	1.005"	0.949"
	B	1.508"	1.463"
	C	0.134"	0.116"
	D	0.130"	0.107"
	E	0.129"	0.108"
	F		
Rear	A	1.008"	
	B	1.511"	1.472"
	C	0.133"	0.116"
	D	0.129"	0.106"
	E	0.128"	0.105"
	F		

Remarks: Slight die washout; extrusion did not clear straightener; extrusion ok.



Extrusion 12



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

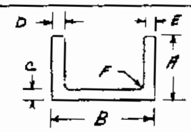
Type of Extrusion Pilot Production Job No. 2568 Extrusion No. 12

NMI Extrusion No. 32350 Be Chem Lot No. ______ Extrusion Date 7/6/61

Primary purpose of this extrusion: Produce 20' lengths

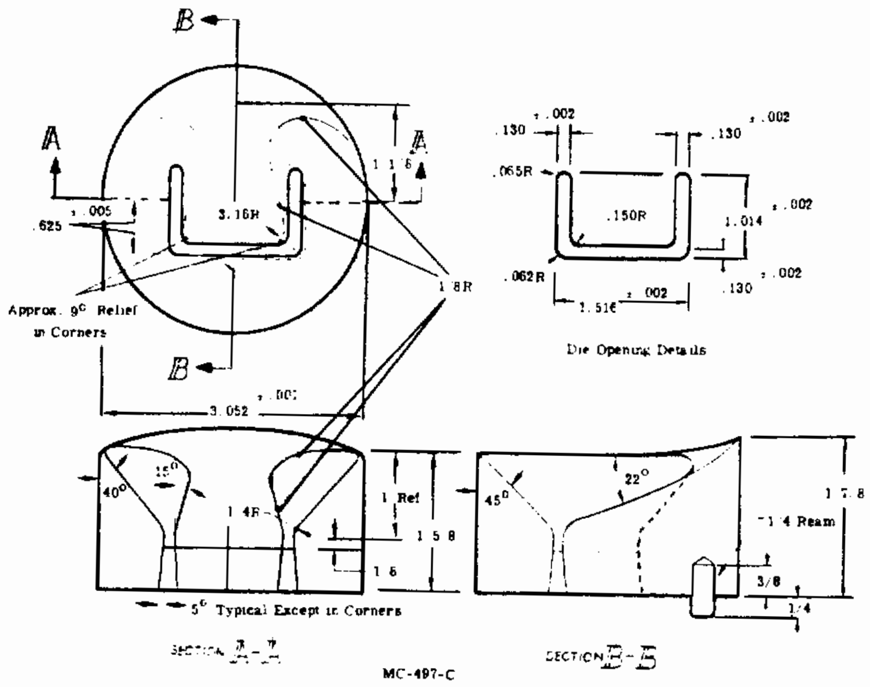
Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	New
Billet	Material	Be canned in steel
	Can Thickness	.100"
	Length (in.)	Be 17" Billet 18"
	Temp. (°F)	1725
	Lubrication	Aqua dag
	Electroplate	Cu(35 mils thick)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 250
	Transfer Time (sec)	20
Die	Material	M-2 /Rc 43
	Fabrication	Cast
	Type	Blunt tongue
	Design No.	MC-497-C
	Identification No.	A-12 (G)
	Temp. (°F)	Liner temp.
	Lubrication	Aqua dag and mica coated
	Condition	New
	Rework	Diamond polish and radius increased on relief
	No. of Extrusions/Die	None
	Extrusion Ratio	~ 15 to 1

Extrusion Section Dimensions

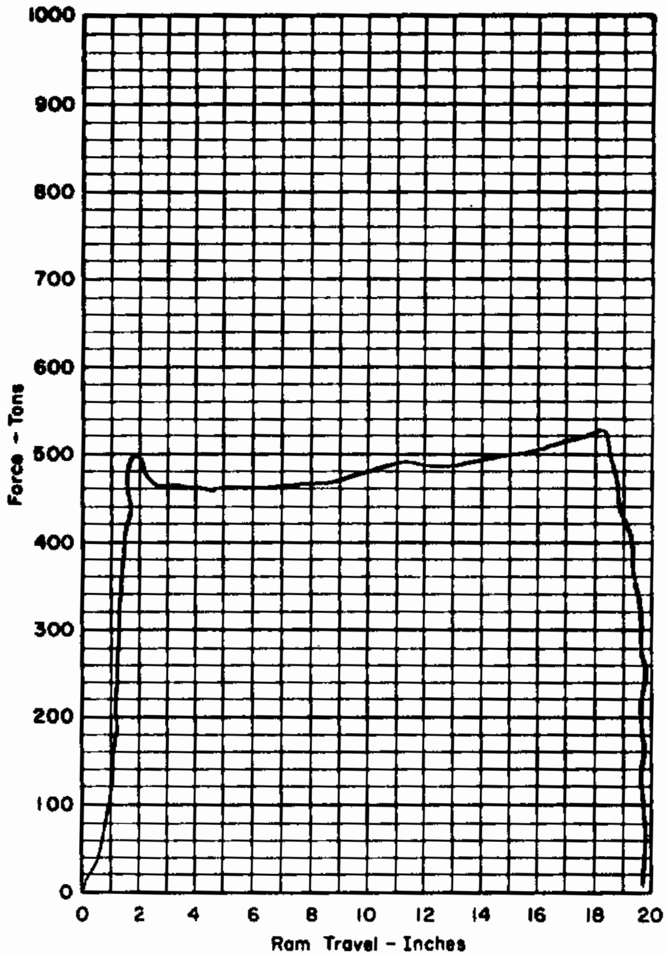


		Before Pickle	After Pickle
Front	A	0.998"	0.942"
	B	1.498"	1.456"
	C	0.129"	0.110"
	D	0.130"	0.111"
	E	0.124"	0.105"
	F		
Center	A	1.001"	0.948"
	B	1.500"	1.455"
	C	0.127"	0.110"
	D	0.127"	0.109"
	E	0.123"	0.103"
	F		
Rear	A	1.000"	0.951"
	B	1.500"	1.457"
	C	0.124"	0.107"
	D	0.125"	0.104"
	E	0.122"	0.099"
	F		

Remarks: Extrusion ok; extrusion did not clear straightener



Extrusion 13



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

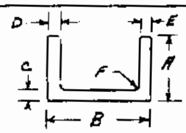
Type of Extrusion Pilot Production Job No. 2568 Extrusion No. 13

NMI Extrusion No. 32351 Be Chem Lot No. ______ Extrusion Date 7/6/61

Primary purpose of this extrusion: Produce 20' lengths

Liner	ID (in.)	3.050
	Length (in.)	26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	New
Billet	Material	Be canned in steel
	Can Thickness	100"
	Length (in.)	Be 17" Billet 18"
	Temp. (°F)	1725
	Lubrication	Aqua dag
	Electroplate	Cu(35 mils thick)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 180
	Transfer Time (sec)	20
Die	Material	M-2/Rc 57
	Fabrication	Cast
	Type	Blunt tongue
	Design No.	MC-497-C
	Identification No.	A-13 (P)
	Temp. (°F)	Room
	Lubrication	Aqua dag and mica coated
	Condition	New
	Rework	Diamond polish and relief radius increased on relief
	No. of Extrusions/Die	None
	Extrusion Ratio	~ 20 to 1

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A	1.008"	0.948"
	B	1.506"	1.463"
	C	0.144"	0.123"
	D	0.144"	0.115"
	E	0.136"	0.117"
	F		
Center	A	1.014"	0.953"
	B	1.509"	1.469"
	C	0.141"	0.120"
	D	0.142"	0.114"
	E	0.134"	0.114"
	F		
Rear	A	1.013"	0.956"
	B	1.511"	1.474"
	C	0.140"	0.119"
	D	0.142"	0.114"
	E	0.133"	0.111"
	F		

Remarks: Extrusion ok; die cracked

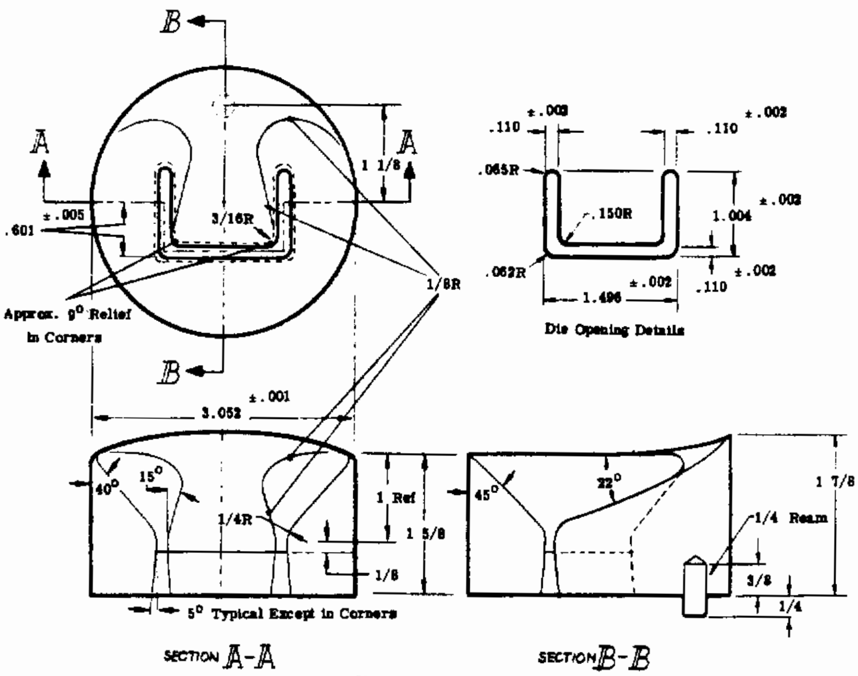


FIGURE 89 DIE DESIGN NO. MC-497-E

Extrusion 15

DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

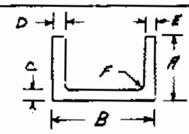
Type of Extrusion Development   Job No. 2568   Extrusion No. 15

NMI Extrusion No. 32984   Be Chem Lot No. ______   Extrusion Date 8/24/61

Primary purpose of this extrusion: Evaluate die design having 0.100" orifice

Liner	ID (in.)	3.050
	Length (in.)	26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	Liner slightly scored
Billet	Material	Be canned in steel
	Can Thickness	.115"
	Length (in.)	Be 14 Billet 15-1/2
	Temp. (°F)	1805
	Lubrication	Aqua dag
	Electroplate	Cu(30 mils thick on side)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 215
	Transfer Time (sec)	30
Die	Material	EDS/Rc 44-45(OD)
	Fabrication	Cast
	Type	Blunt tongue/scoop cone
	Design No.	MC-497-E
	Identification No.	A-15
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New
	Rework	Diamond polish
	No. of Extrusions/Die	None
	Extrusion Ratio	~ 21 to 1

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A	0.993"	.932"
	B	1.472"	1.430"
	C	.117"	.099"
	D	.112"	.095"
	E	.111"	.094"
	F		
Center	A	0.993"	0.934"
	B	1.472"	1.432"
	C	.111"	.094"
	D	.107"	.091"
	E	.109"	.090"
	F		
Rear	A	0.991"	0.933"
	B	1.471"	1.431"
	C	.108"	.091"
	D	.106"	.091"
	E	.107"	.088"
	F		

Remarks: Die cracked; slight tearing at inside channel corners

Extrusion 16

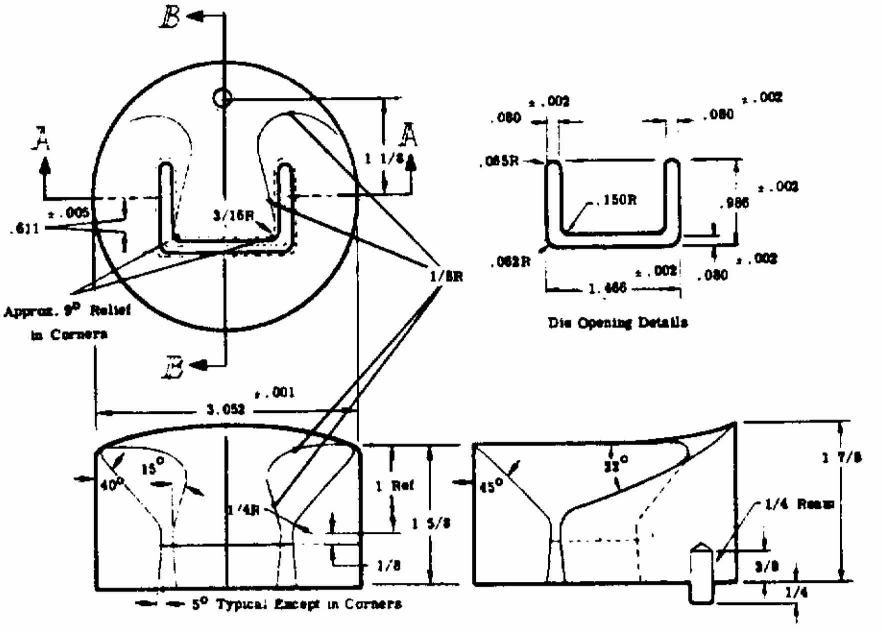
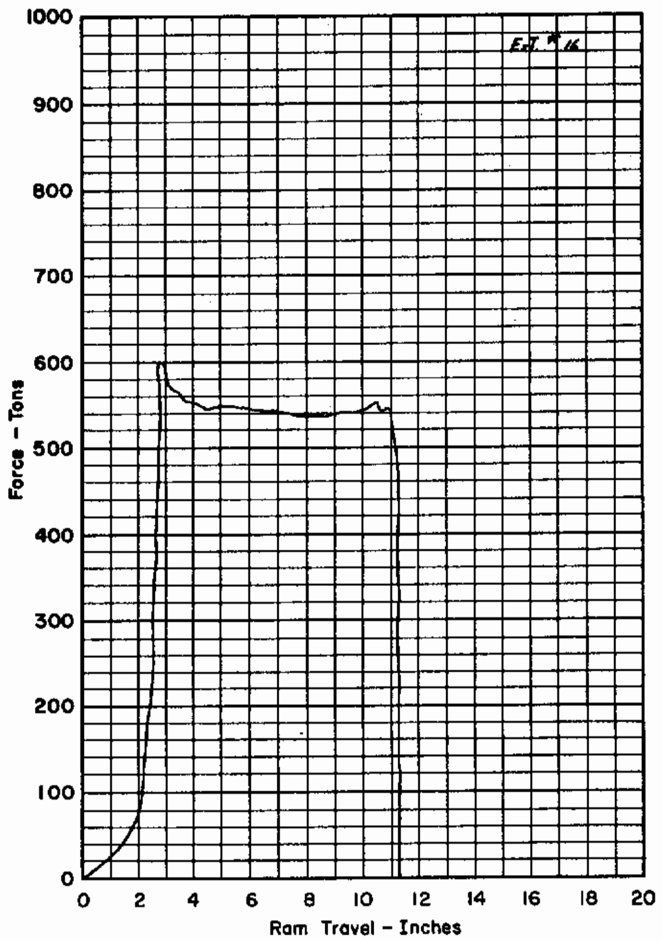


FIGURE 91 DIE DESIGN NO. MC-497-F



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

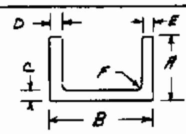
Type of Extrusion Development Job No. 2571 Extrusion No. 16

NMI Extrusion No. 32985 Be Chem Lot No. 8756 Extrusion Date 8/24/61

Primary purpose of this extrusion: Evaluate die design having 0.080" orifice

Liner	ID (in.)	3.050
	Length (in.)	26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	Slightly scored
Billet	Material	Be canned in steel
	Can Thickness	.115"
	Length (in.)	Be 7-1/2 Billet 9-1/2
	Temp. (°F)	1810
	Lubrication	Aqua dag
	Electroplate	Cu(30 mils on a side)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 210
	Transfer Time (sec)	25
Die	Material	EDS/Rc 41-1/2-42-1/2 (OD)
	Fabrication	Casting
	Type	Blunt tongue/ scoop cone
	Design No.	MC-497-F
	Identification No.	A-16
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New
	Rework	Diamond polish
	No. of Extrusions/Die	None
	Extrusion Ratio	~/25 to 1

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A	0.963"	0.913"
	B	1.435"	1.408
	C	.083"	.062"
	D	.080"	.068"
	E	.083	.068"
	F		
Center	A	0.961"	0.911"
	B	1.431"	1.502"
	C	.077"	.068"
	D	.076"	.063"
	E	.079"	.063"
	F		
Rear	A	0.963"	0.916"
	B	1.429"	1.402"
	C	.074"	.065"
	D	.075"	.062"
	E	.079"	.063"
	F		

Remarks: Slight tearing at both inside channel corners

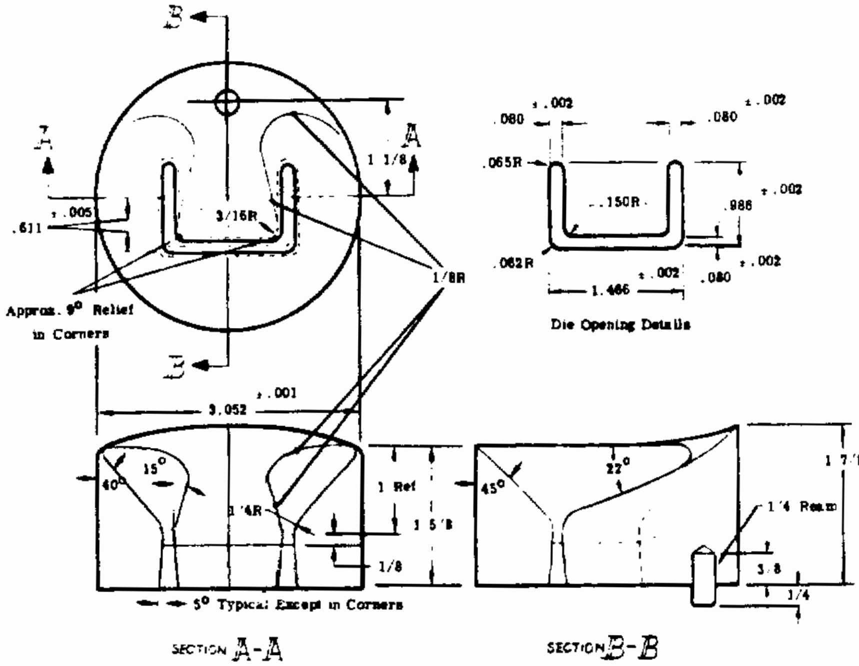
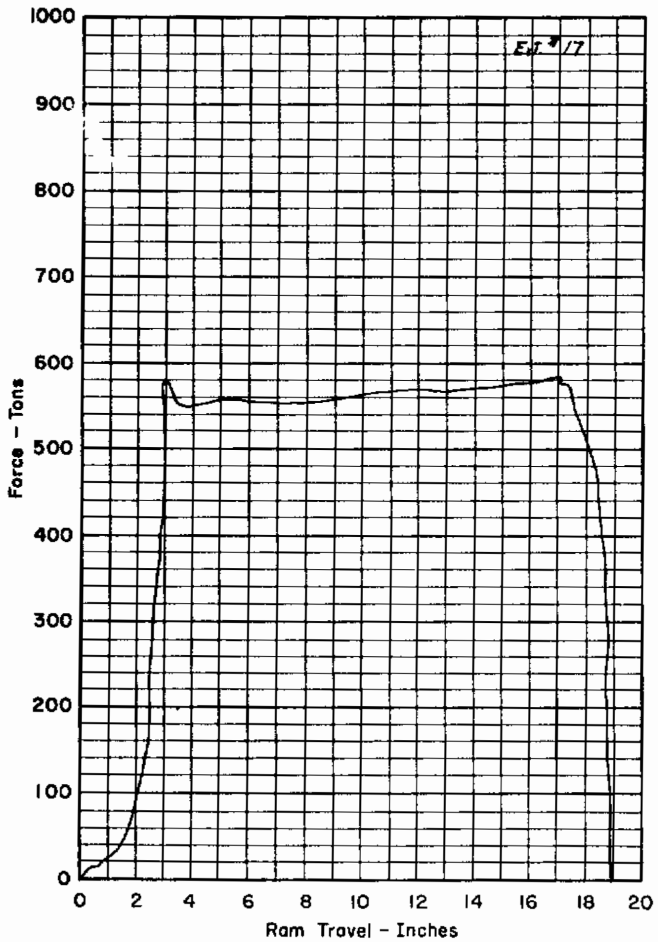


FIGURE 91 DIE DESIGN NO. MC-497-F

Extrusion 17



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

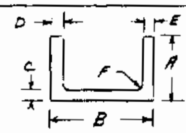
Type of Extrusion Development Job No. 2571 Extrusion No. 17

NMI Extrusion No. 32986 Be Chem Lot No. 8754 Extrusion Date 8/24/61

Primary purpose of this extrusion: To obtain extrusion data

Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	Slightly scored
Billet	Material	Be canned in steel
	Can Thickness	.115"
	Length (in.)	Be 14 Billet 15-1/2
	Temp. (°F)	1855
	Lubrication	Aqua dag
	Electroplate	Cu(30 mils on a side)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 210
	Transfer Time (sec)	20
Die	Material	EDS / Rc 41-1/2-42-1/2(OD)
	Fabrication	Cast
	Type	Blunt tongue/scoop cone
	Design No.	MC-497-F
	Identification No.	A-16
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	Cracked (5 places)
	Rework	Cleaned and dagged
	No. of Extrusions/Die	1 (previously 16)
	Extrusion Ratio	~ 31 to 1

Extrusion Section Dimensions

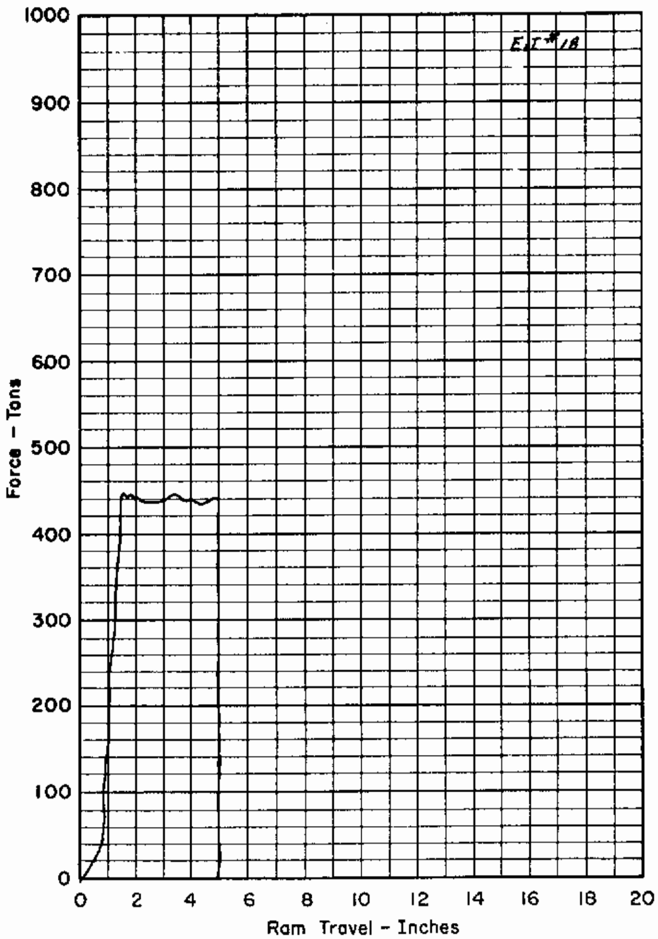


		Before Pickle	After Pickle
Front	A	0.957"	0.920"
	B	1.430"	1.392"
	C	.068"	.055"
	D	.083"	.060"
	E	.070"	.060"
	F		
Center	A	0.963"	0.924"
	B	1.424"	1.393"
	C	.064"	.052"
	D	.070"	.057"
	E	.068"	.058"
	F		
Rear	A	0.961"	0.925"
	B	1.420"	1.393"
	C	.063"	.050"
	D	.086"	.055"
	E	.068"	.057"
	F		

Remarks: Slight tearing at one corner inside the channel

Die Design Identical to MC-497-F
Except that O.D. is 2.800"

Extrusion 18



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

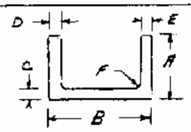
Type of Extrusion Development Job No. 2571 Extrusion No. 18

NMI Extrusion No. 33278 Be Chem Lot No. 8904 Extrusion Date 9/19/61

Primary purpose of this extrusion: To evaluate bare extrusion through conical approach die using glass lubricant

Liner	ID (in.)	2.800
	Length (in.)	13
	Temp. (°F)	900
	Lubrication	None
	Condition	-----------
Billet	Material	Bare Beryllium
	Can Thickness	-----------
	Length (in.)	Be 5 Billet 5
	Temp. (°F)	1730
	Lubrication	Glass
	Electroplate	None
	Heating	Graphite container with argon flow
	Heating Time (min)	a. Scheduled 180 b. Actual 205
	Transfer Time (sec)	35
Die	Material	M-2/Rc 52
	Fabrication	Casting
	Type	.093" die orifice
	Design No.	MC-497-G
	Identification No.	18
	Temp. (°F)	Room
	Lubrication	Aqua dag and glass
	Condition	New
	Rework	None
	No. of Extrusions/Die	None
	Extrusion Ratio	~25 to 1

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A	Not Recorded	
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Remarks: Die broke into 4 pieces; channel rattlesnaked nearly entire length

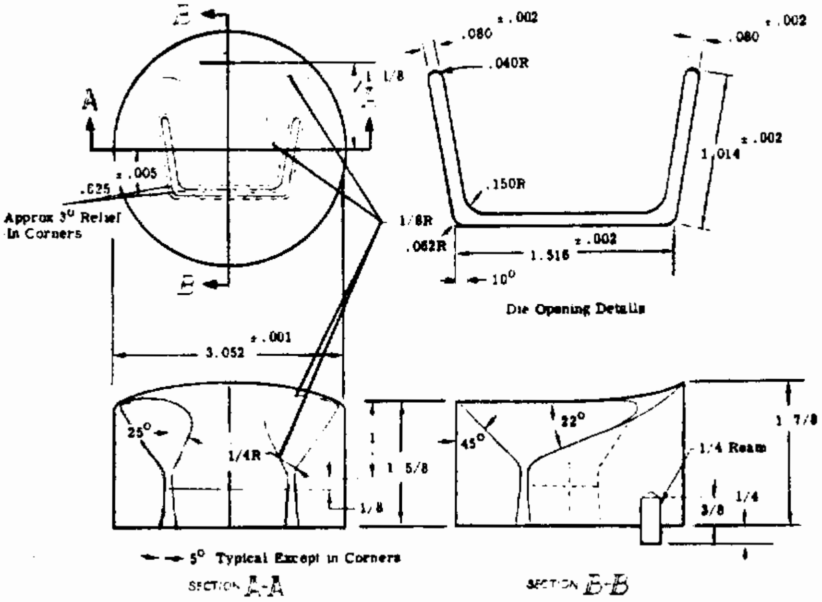
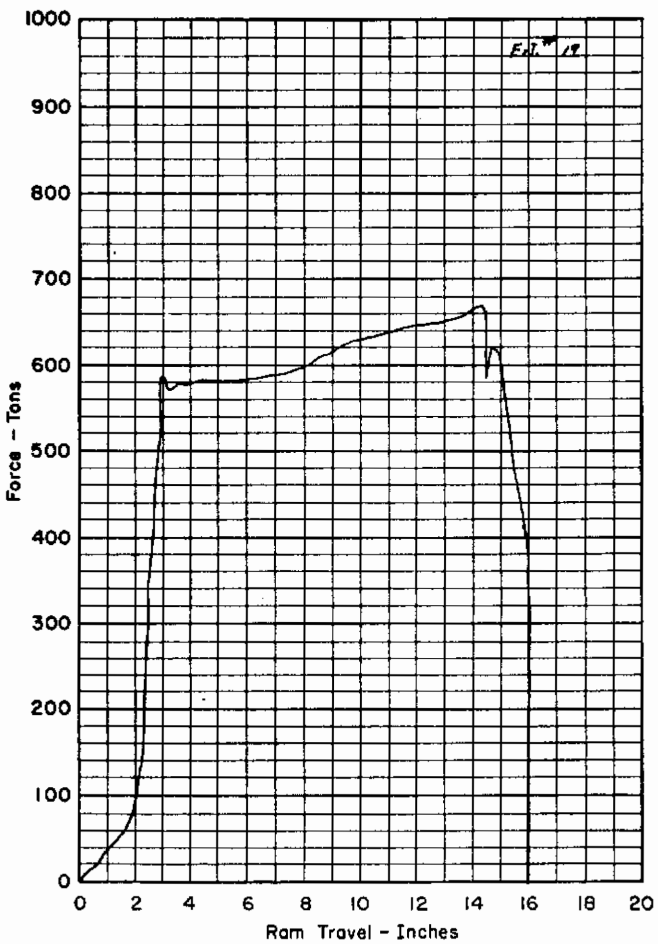


FIGURE 82 DIE DESIGN NO. MC-497-H

Extrusion 19



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

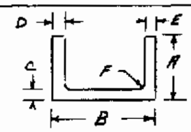
Type of Extrusion Development Job No. 2571 Extrusion No. 19

NMI Extrusion No. 33279 Be Chem Lot No. 8904 Extrusion Date 9/19/61

Primary purpose of this extrusion: To evaluate wing die design with .080" orifice

Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	----------------
Billet	Material	Be canned in steel
	Can Thickness	.115"
	Length (in.)	Be 11-1/2 Billet 12-1/2
	Temp. (°F)	1710
	Lubrication	Aqua dag
	Electroplate	Cu(30 mils on side)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 190
	Transfer Time (sec)	30
Die	Material	Rc 44 EDS alloy, Med. C stellite
	Fabrication	Casting
	Type	Wing die .080" die orifice
	Design No.	MC-497-H
	Identification No.	A-19
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New
	Rework	None
	No. of Extrusions/Die	None
	Extrusion Ratio	29:1

Extrusion Section Dimensions

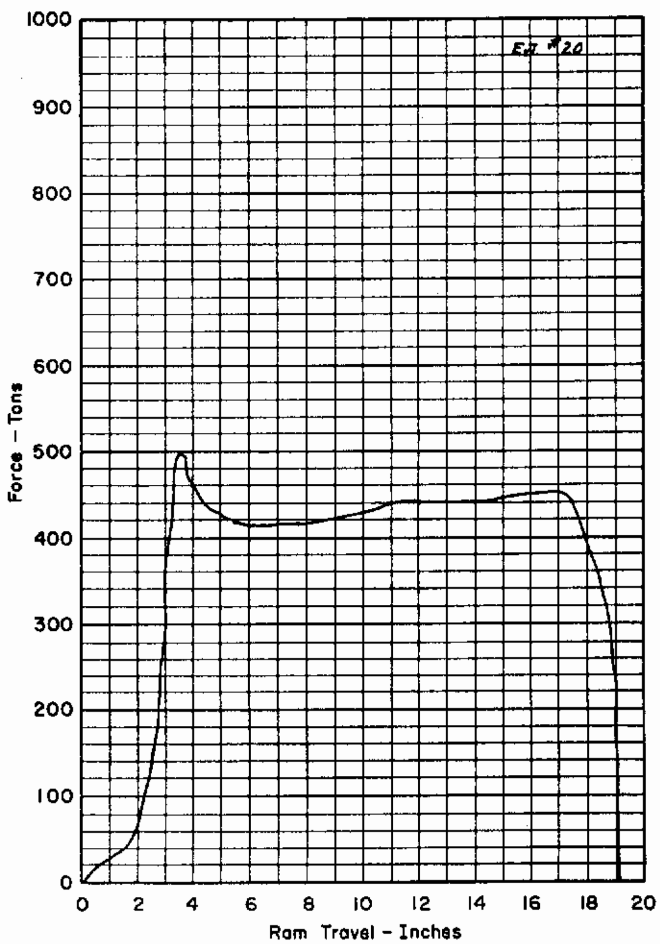


		Before Pickle	After Pickle
Front	A	1.015"	.972"
	B	1.532"	1.505"
	C	.081"	.060"
	D	.076"	.062"
	E	.071"	.059"
	F		
Center	A	1.018"	.975"
	B	1.511"	1.493"
	C	.074"	.062"
	D	.071"	.054"
	E		
	F	1.021"	.975"
Rear	A	1.508"	1.491"
	B	.063"	.053"
	C	.063"	.053"
	D	.064"	.053"
	E	.060"	.048"
	F		

Remarks: Die showed plastic deformation and cracking; no breakthru at inside corners of u-channel

Die Design MC-497-K
See Text

Extrusion 20



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

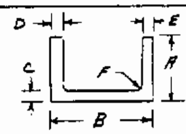
Type of Extrusion Development　Job No. 2571　Extrusion No. 20

NMI Extrusion No. 33280　Be Chem Lot No. 8904　Extrusion Date 9/19/61

Primary purpose of this extrusion: To obtain extrusion data and evaluate sculpture die design

Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	-----------------
Billet	Material	Be canned in steel
	Can Thickness	.115"
	Length (in.)	Be 14 Billet 15
	Temp. (°F)	1725
	Lubrication	Aqua dag
	Electroplate	Cu(30 mils thick)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 255
	Transfer Time (sec)	20
Die	Material	M-2/Rc 57
	Fabrication	Casting
	Type	Deep throat .120" die orifice
	Design No.	MC-497-K
	Identification No.	A-20
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New (deep approach)
	Rework	Diamond polish
	No. of Extrusions/Die	None
	Extrusion Ratio	17:1

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A	1.007"	.950"
	B	1.500"	1.450"
	C	.134"	.113"
	D	.120"	.100"
	E	.119"	.099"
	F		
Center	A	1.007"	.970"
	B	1.500"	1.451"
	C	.130"	.109"
	D	.118"	.098"
	E	.119"	.098"
	F		
Rear	A	1.007"	.957"
	B	1.501"	1.453"
	C	.128"	.111"
	D	.117"	.100
	E	.116"	.097"
	F		

Remarks: Die cracked; no break-through at inside of "U"

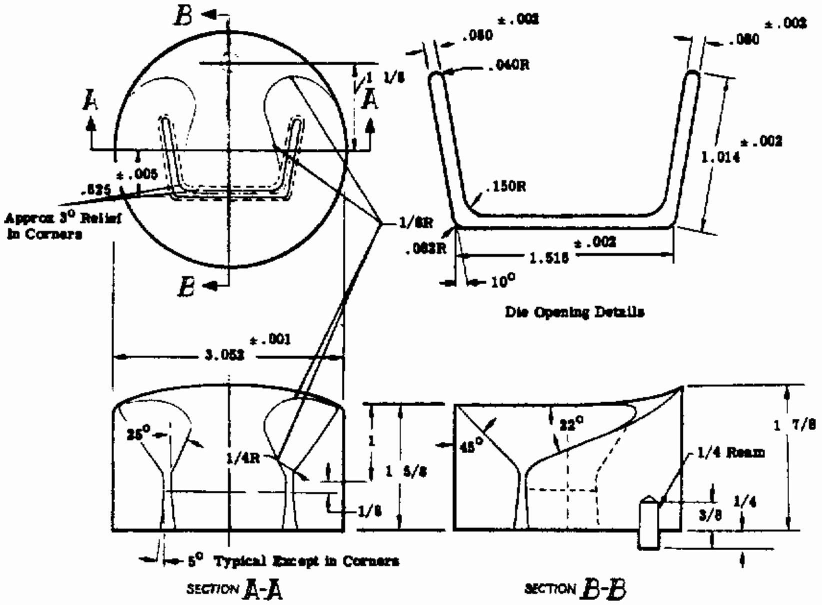
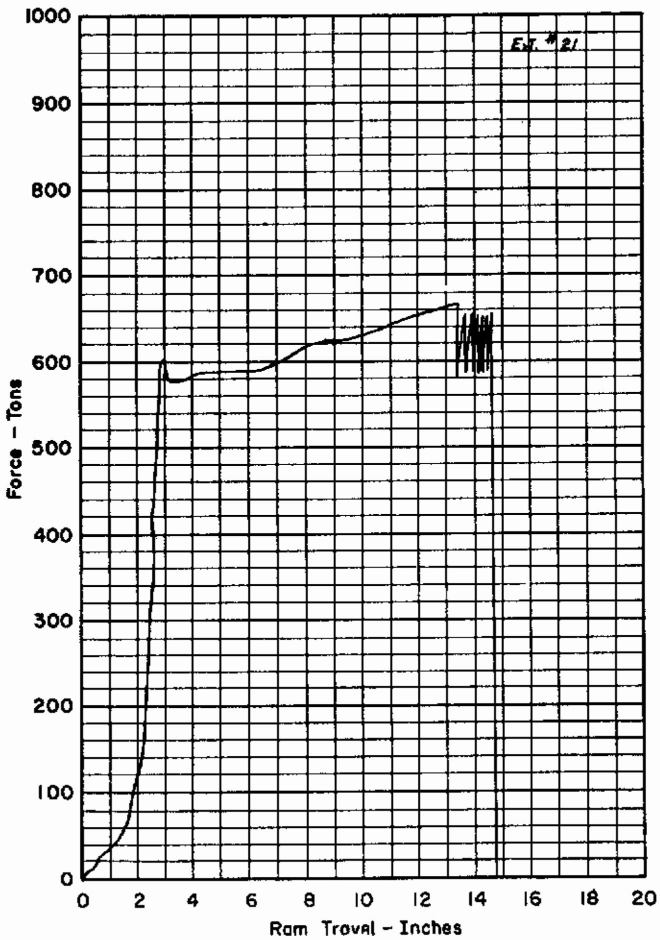


FIGURE 82 DIE DESIGN NO. MC-497-H

Extrusion 21



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

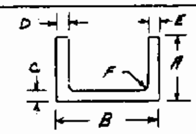
Type of Extrusion Development Job No. 2571 Extrusion No. 21

NMI Extrusion No. 33281 Be Chem Lot No. 8904 Extrusion Date 9/19/61

Primary purpose of this extrusion: To obtain extrusion data

Liner	ID (in.)	3.050
	Length (in.)	26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	----------------
Billet	Material	Be canned in steel
	Can Thickness	.115"
	Length (in.)	Be 11-1/2 Billet 12-1/2
	Temp. (°F)	1760
	Lubrication	Aqua dag
	Electroplate	Cu (30mils on a side)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 180
	Transfer Time (sec)	25
Die	Material	Rc 44 EDS alloy-~~Hi~~-Mod. C Stellite
	Fabrication	Casting
	Type	Wing die- .080" die orifice
	Design No.	MC-497-H
	Identification No.	21
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New
	Rework	None
	No. of Extrusions/Die	None
	Extrusion Ratio ~ 30 to 1	

Extrusion Section Dimensions

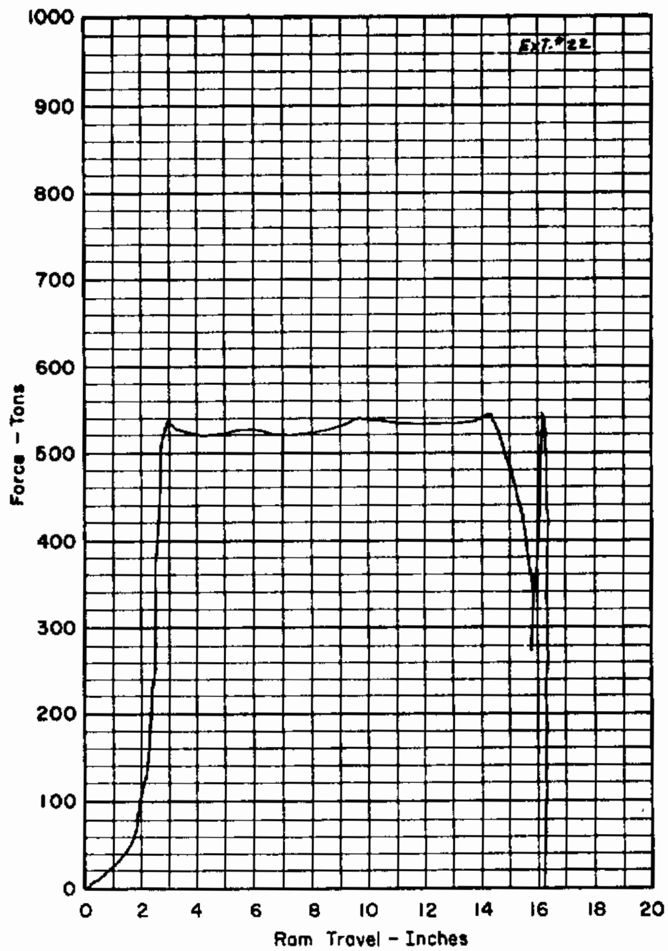


		Before Pickle	After Pickle
Front	A	1.019"	.975"
	B	1.533"	1.510"
	C	.081"	.064"
	D	.073"	.049"
	E	.070"	.057"
	F		
Center	A	1.026"	.975"
	B	1.514"	1.497"
	C	.072"	.063"
	D	.068"	.055"
	E	.066"	.051"
	F		
Rear	A	1.028"	.983"
	B	1.508"	1.492"
	C	.064"	.056"
	D	.061"	.050"
	E	.082"	.047"
	F		

Remarks: Die cracked and plastically deformed; no breakthrough at inside corners

Extrusion 22

Die Design Identical to MC-497-H
Except that Inside Corner Radius is .030"



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

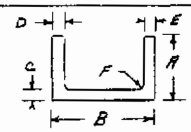
Type of Extrusion Development Job No. 2571 Extrusion No. 22

NMI Extrusion No. 33557 Be Chem Lot No. 8904 Extrusion Date 10/10/61

Primary purpose of this extrusion: To obtain extrusion data and evaluate sharp tongue corner winged die design with .080" orifice

Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	---------------
Billet	Material	Be canned in steel
	Can Thickness	.115"
	Length (in.)	Be 11-1/2 Billet 12-1/2
	Temp. (°F)	1845
	Lubrication	Aqua dag
	Electroplate	Cu(30 mils thick)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 210
	Transfer Time (sec)	30
Die	Material	EDS/Rc 46
	Fabrication	Casting
	Type	Winged sharp tongue corners
	Design No.	MC-497-L
	Identification No.	22
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New
	Rework	Diamond polish
	No. of Extrusions/Die	None
	Extrusion Ratio	30 to 1

Extrusion Section Dimensions

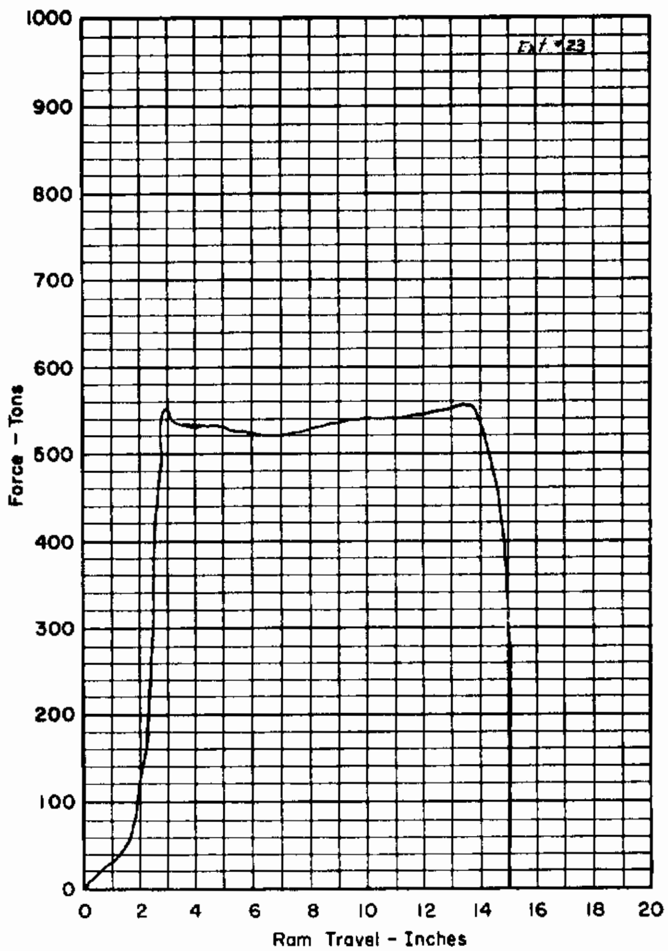


		Before Pickle	After Pickle
Front	A	0.998"	0.952"
	B	1.507"	1.484"
	C	0.083"	0.073"
	D	0.080"	0.065"
	E	0.082"	0.067"
	F		
Center	A	0.998"	0.955"
	B	1.508"	1.478"
	C	0.079"	0.069"
	D	0.075"	0.065"
	E	0.074	0.064"
	F		
Rear	A	0.999	0.954
	B	1.509	1.490
	C	0.075"	0.066"
	D	0.072"	0.064"
	E	0.072"	0.064"
	F		

Remarks: Die dowel pin slipped from the bolster slot and twisted out of alignment causing the channel to extrude with a ripple along its entire length.

Extrusion 23

Die Design Identical to MC-497-H
Except that Inside Corner Radius is .030"



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

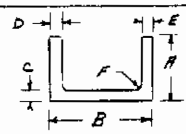
Type of Extrusion Development   Job No. 2571   Extrusion No. 23

NMI Extrusion No. 33558   Be Chem Lot No. 8904   Extrusion Date 10/10/61

Primary purpose of this extrusion: To obtain extrusion data and evaluate sharp tongue corner winged die design with .080" die orifice.

Liner	ID (in.)	3.050
	Length (in.)	26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	----------------
Billet	Material	Be canned in steel
	Can Thickness	.115"
	Length (in.)	Be 11 Billet 13
	Temp. (°F)	1850 (1845)
	Lubrication	Aqua dag
	Electroplate	Cu(30 mils thick)
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 190
	Transfer Time (sec)	35
Die	Material	M-2/Rc 53
	Fabrication	Casting
	Type	Winged sharp tongue corner
	Design No.	MC-497-L
	Identification No.	23
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New
	Rework	Diamond polish
	No. of Extrusions/Die	None
	Extrusion Ratio	30 to 1

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A	1.017"	0.973"
	B	1.541"	1.512"
	C	0.090"	0.075"
	D	0.080"	0.069"
	E	0.082"	0.068"
	F		
Center	A	1.017"	0.977"
	B	1.536"	1.512"
	C	0.085"	0.073"
	D	0.077"	0.065"
	E	0.078"	0.066"
	F		
Rear	A	1.018"	0.976"
	B	1.534"	1.512"
	C	0.084"	0.071"
	D	0.075"	0.062"
	E	0.075"	0.062"
	F		

Remarks: Extrusion was good except for clad breakthrough at the filled corners of the inside channel corners

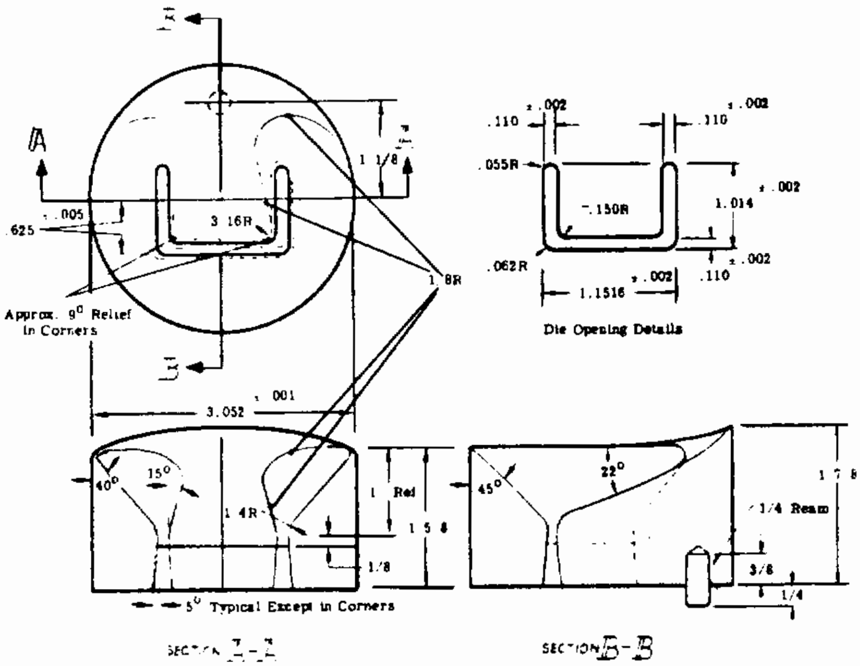
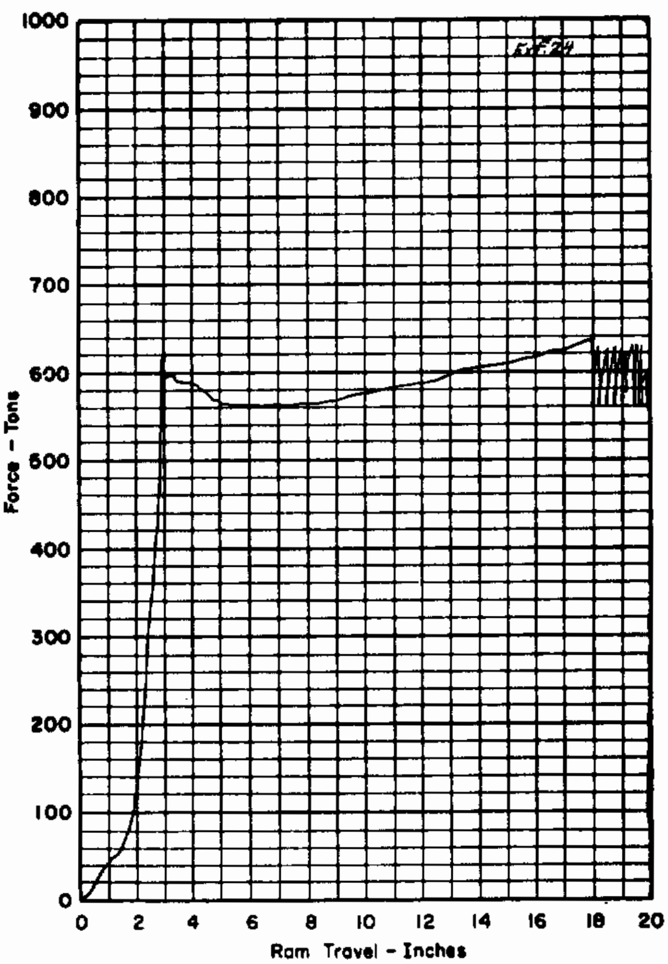


FIGURE 90 DIE DESIGN NO. MC-497-I

Extrusion 24



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

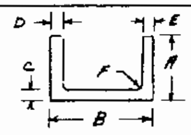
Type of Extrusion Pilot Production Job No. 2571 Extrusion No. 24

NMI Extrusion No. 33559 Be Chem Lot No. ______ Extrusion Date 10/10/61

Primary purpose of this extrusion: To evaluate new straightener designed to contract with extrusion

Liner	ID (in.)	3.050
	Length (in.)	26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	------------------
Billet	Material	Be canned in steel
	Can Thickness	.115"
	Length (in.)	Be 17, Billet 18
	Temp. (°F)	1715
	Lubrication	Aqua dag
	Electroplate	Cu (30 mils thick)
	Heating	Under convered graphite
	Heating Time (min)	a. Scheduled 180; b. Actual 200
	Transfer Time (sec)	40
Die	Material	EDS/Rc 44
	Fabrication	Casting
	Type	.110" orifice
	Design No.	MC-497-I
	Identification No.	24
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New
	Rework	Diamond polish
	No. of Extrusions/Die	None
	Extrusion Ratio	~ 25 to 1

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A	1.000"	0.945"
	B	1.494"	1.457"
	C	0.095"	0.081"
	D	0.101"	0.085"
	E	0.101"	0.086"
	F		
Center	A	0.997"	0.945"
	B	1.494"	1.459"
	C	0.090"	0.077"
	D	0.098"	0.083"
	E	0.097"	0.082"
	F		
Rear	A	0.995"	0.946"
	B	1.494"	1.458"
	C	0.084"	0.071"
	D	0.094"	0.080"
	E	0.093"	0.080"
	F		

Remarks: Extrusion ok

Extrusion 25

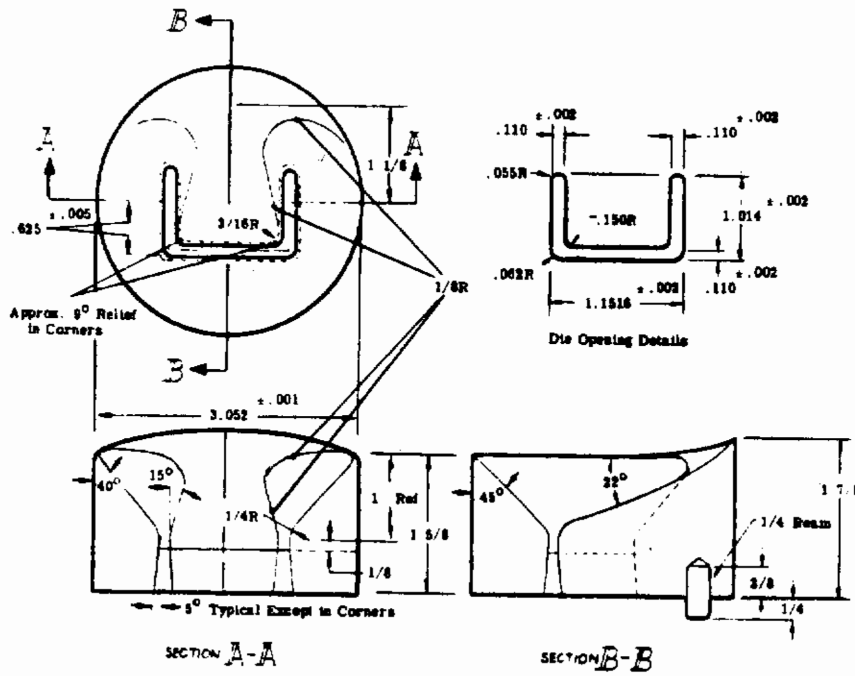
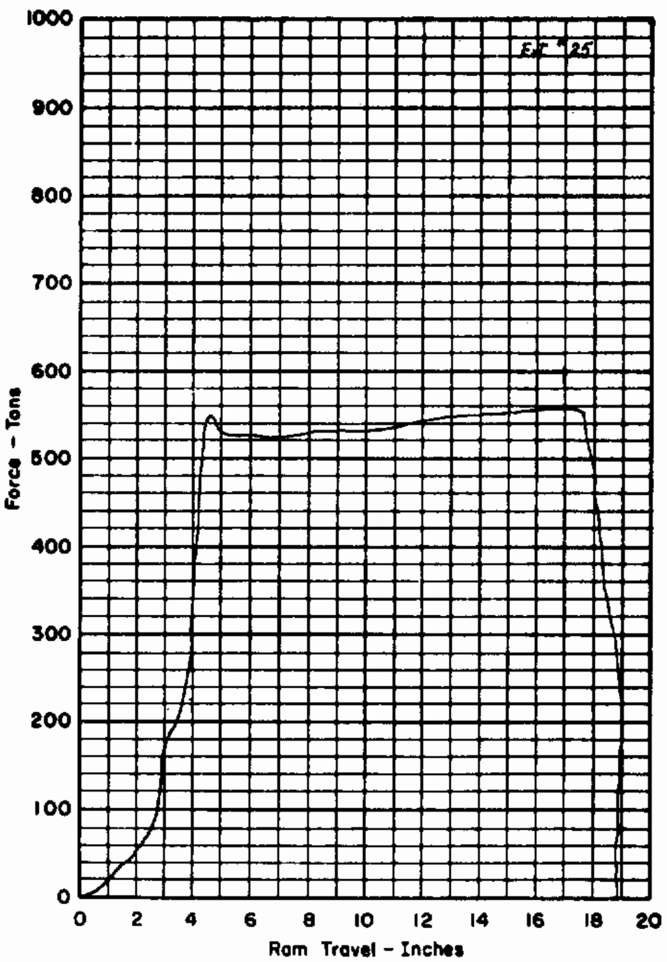


FIGURE 90 DIE DESIGN NO. MC-497-1



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

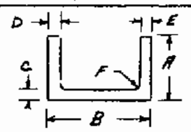
Type of Extrusion Pilot Production Job No. 2571 Extrusion No. 25

NMI Extrusion No. 34673 Be Chem Lot No. 8904 Extrusion Date 10/17/61

Primary purpose of this extrusion: Produce 20' extrusions

Liner	ID (in.)	3.050
	Length (in.)	26
	Temp. (°F)	900
	Lubrication	Heavy mica coated
	Condition	----------------
Billet	Material	Be canned in (.095") steel and copper (.045")
	Can Thickness	----------------
	Length (in.)	Be 14 Billet 15-1/2
	Temp. (°F)	1800
	Lubrication	Aqua dag
	Electroplate	No
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 220
	Transfer Time (sec)	25
Die	Material	EDS/Rc 44
	Fabrication	Casting
	Type	.110" orifice
	Design No.	MC-497-I
	Identification No.	A-25
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New
	Rework	None
	No. of Extrusions/Die	None
	Extrusion Ratio	∿ 25 to 1

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A	1.005"	.944"
	B	1.492"	1.453"
	C	.098"	.090"
	D	.104"	.082"
	E	.104"	.085"
	F		
Center	A	1.001"	.944"
	B	1.495"	1.455
	C	.096"	.085"
	D	.100"	.080"
	E	.099"	.081:
	F		
Rear	A	.997"	.944"
	B	1.498"	1.459"
	C	.095"	.077"
	D	.097"	.077"
	E	.095"	.076"
	F		

Remarks: Contracting straight used; slight scraping at inside channel corner along 1/2 the extrusion

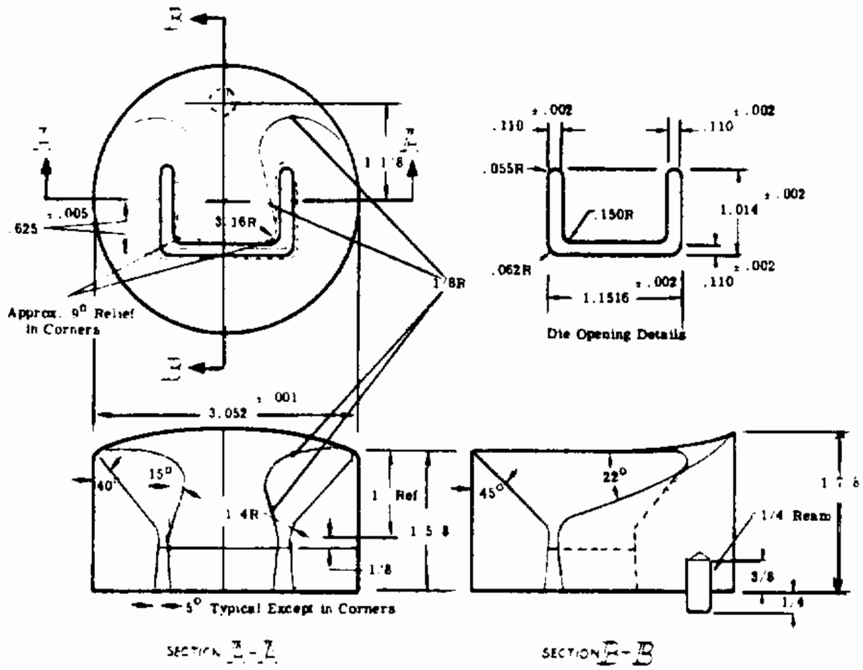
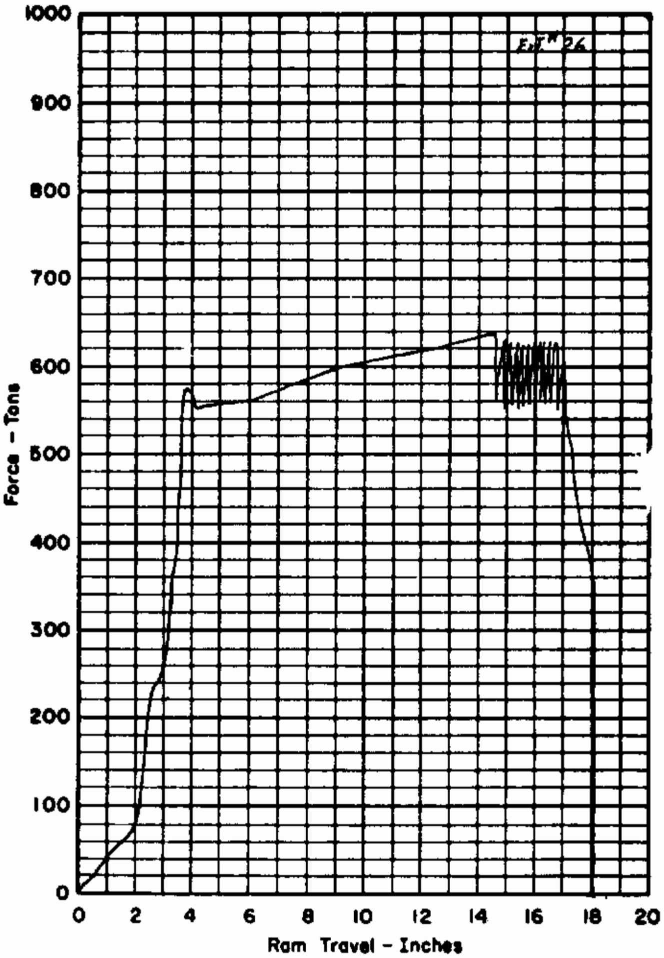


FIGURE 90 DIE DESIGN NO. MC-497-I

Extrusion 26



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

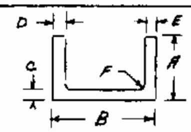
Type of Extrusion Pilot Production Job No. 2571 Extrusion No. 26

NMI Extrusion No. 34674 Be Chem Lot No. 8904 Extrusion Date 10/17/61

Primary purpose of this extrusion: Produce 20' extrusions

Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	875
	Lubrication	Heavy mica coated
	Condition	----------------
Billet	Material	Be canned in steel (.095") and copper (.045")
	Can Thickness	----------------
	Length (in.)	Be 14 Billet 15-1/2
	Temp. (°F)	1735
	Lubrication	Aqua dag
	Electroplate	No
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 205
	Transfer Time (sec)	30
Die	Material	EDS/Rc 44
	Fabrication	Casting
	Type	.110" orifice
	Design No.	MC-497-I
	Identification No.	A-26
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New
	Rework	None
	No. of Extrusions/Die	None
	Extrusion Ratio	~ 25 to 1

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A	1.001"	.944"
	B	1.496"	1.453"
	C	.103"	.086"
	D	.103"	.081"
	E	.104"	.087"
	F		
Center	A	.997"	.949"
	B	1.498"	1.456"
	C	.095"	.081"
	D	.099"	.081"
	E	.098"	.081"
	F		
Rear	A	.993"	.950"
	B	1.500"	1.458"
	C	.087"	.079"
	D	.095"	.078"
	E	.092"	.079"
	F		

Remarks: Slight scraping at inside corner of one leg along 3/4 of the extruded length. Contracting straightener used

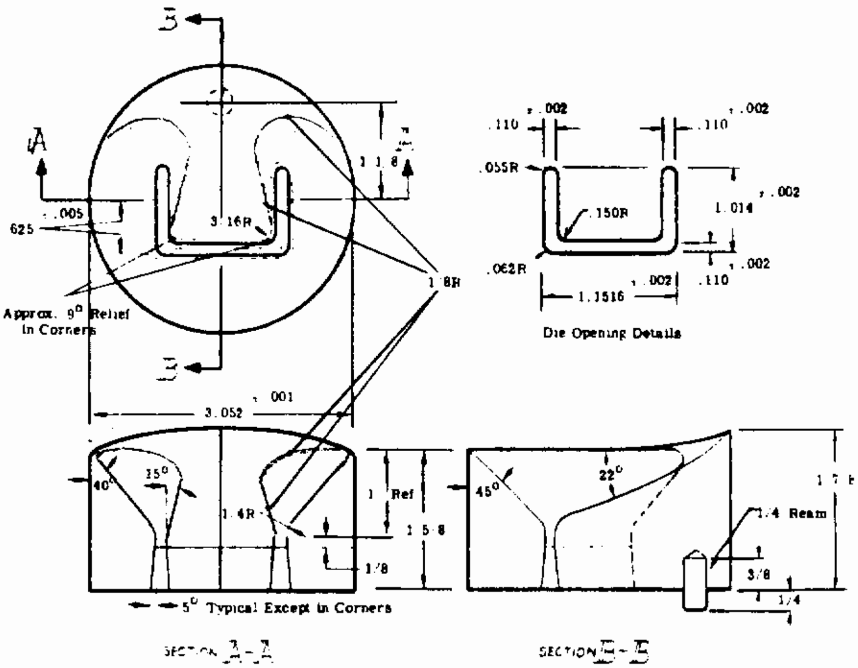
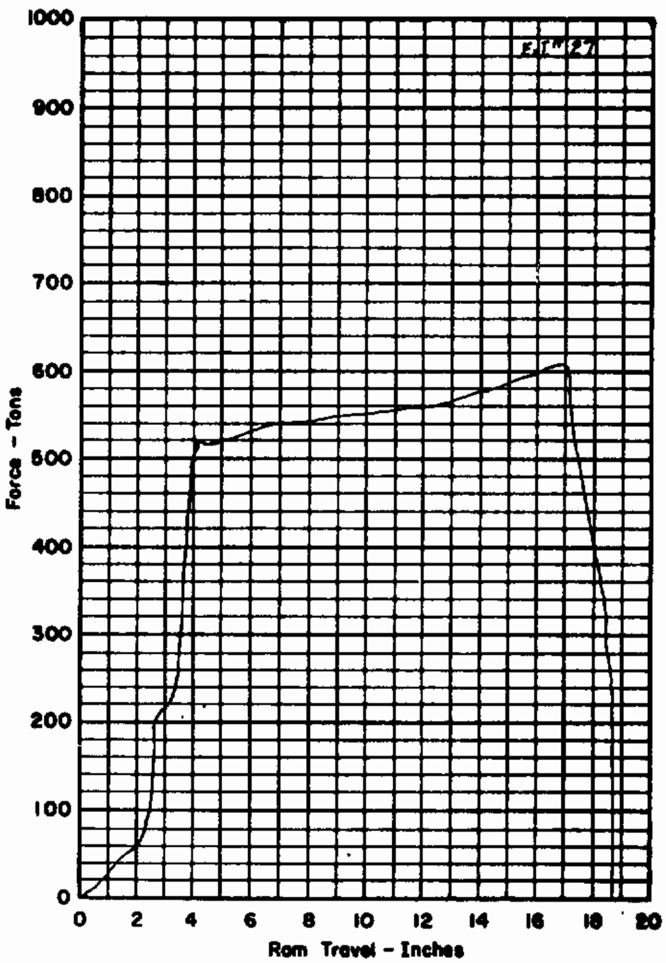


FIGURE 90 DIE DESIGN NO. MC-497-1

Extrusion 27



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

Type of Extrusion Pilot Production Job No. 2571 Extrusion No. 27

NMI Extrusion No. 34675 Be Chem Lot No. 8904 Extrusion Date 10/17/61

Primary purpose of this extrusion: Produce 20' extrusions

Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	850
	Lubrication	Heavy mica coated
	Condition	----------------
Billet	Material	Be canned in steel and copper (.045")
	Can Thickness	----------------
	Length (in.)	Be 14, Billet 15-1/2
	Temp. (°F)	1800
	Lubrication	Aqua dag
	Electroplate	None
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180; b. Actual 215
	Transfer Time (sec)	25
Die	Material	EDS/Rc 44
	Fabrication	Casting
	Type	.110" orifice
	Design No.	MC-497-I
	Identification No.	A-27
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New
	Rework	None
	No. of Extrusions/Die	None
	Extrusion Ratio	25 to 1

Extrusion Section Dimensions

		Before Pickle	After Pickle
Front	A	.996"	.948"
	B	1.493"	1.458"
	C	.105"	.092"
	D	.104"	.088"
	E	.104"	.086"
	F		
Center	A	.993"	.948"
	B	1.494"	1.456"
	C	.097"	.081"
	D	.100"	.082"
	E	.098"	.078"
	F		
Rear	A	.990	.939
	B	1.496"	1.456"
	C	.093"	.075"
	D	.095"	.077"
	E	.093"	.074"
	F		

Remarks: Slight scraping at inside corner of one channel leg; contracting straightener used

Extrusion 28

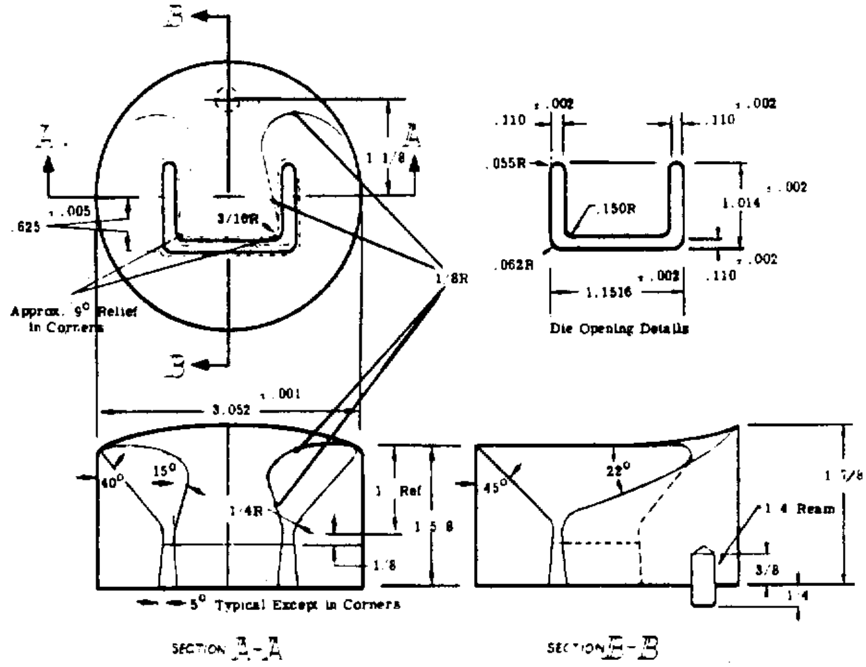
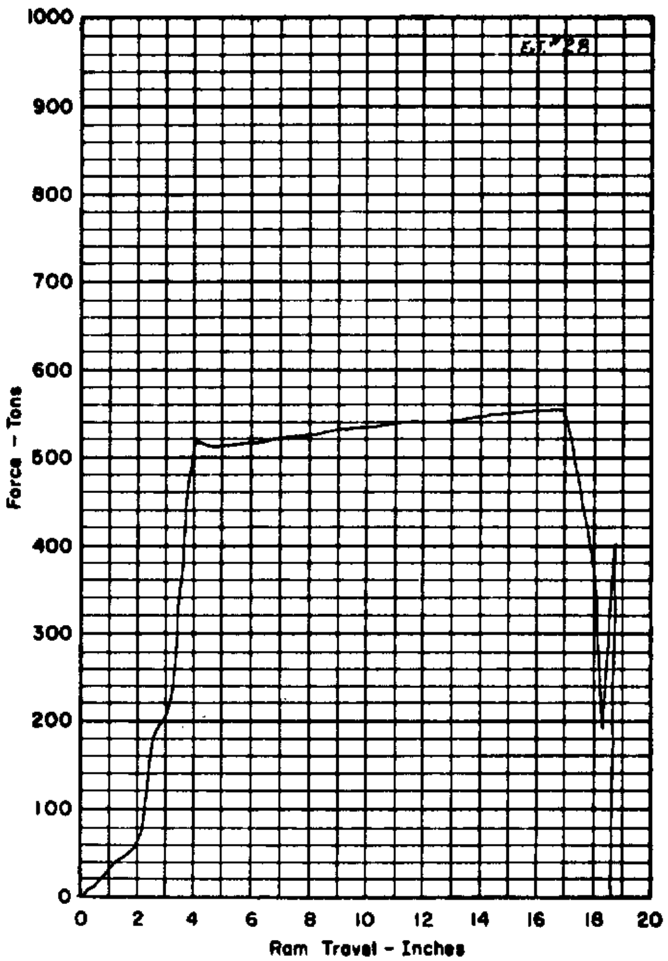


FIGURE 90 DIE DESIGN NO. MC-497-1



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

Type of Extrusion Pilot Production Job No. 2571 Extrusion No. 28

NMI Extrusion No. 34676 Be Chem Lot No. 8904 Extrusion Date 10/17/61

Primary purpose of this extrusion: Produce 20' extrusions

Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	800
	Lubrication	Heavy mica coated
	Condition	-----------------
Billet	Material	Be canned in steel (.095) and copper (.045")
	Can Thickness	---------------
	Length (in.)	Be 14" Billet 15-1/2"
	Temp. (°F)	1790
	Lubrication	Aqua dag
	Electroplate	None
	Heating	Under covered graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 196
	Transfer Time (sec)	20
Die	Material	EDS/Rc 44
	Fabrication	Casting
	Type	.110" orifice
	Design No.	MC-497-I
	Identification No.	A-28
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New
	Rework	None
	No. of Extrusions/Die	None
	Extrusion Ratio	25 to 1

Extrusion Section Dimensions

		Before Pickle	After Pickle
Front	A	1.000"	.943"
	B	1.490"	1.456"
	C	.101"	.086"
	D	.107"	.086"
	E	.104"	.089"
	F		
Center	A	.996"	.949"
	B	1.491"	1.455"
	C	.095"	.082"
	D	.099"	.083"
	E	.100"	.084"
	F		
Rear	A	.996"	.950"
	B	1.492"	1.456"
	C	.092"	.081"
	D	.097"	.081"
	E	.099"	.083"
	F		

Remarks: Slight scraping entire length at inside corner of one leg

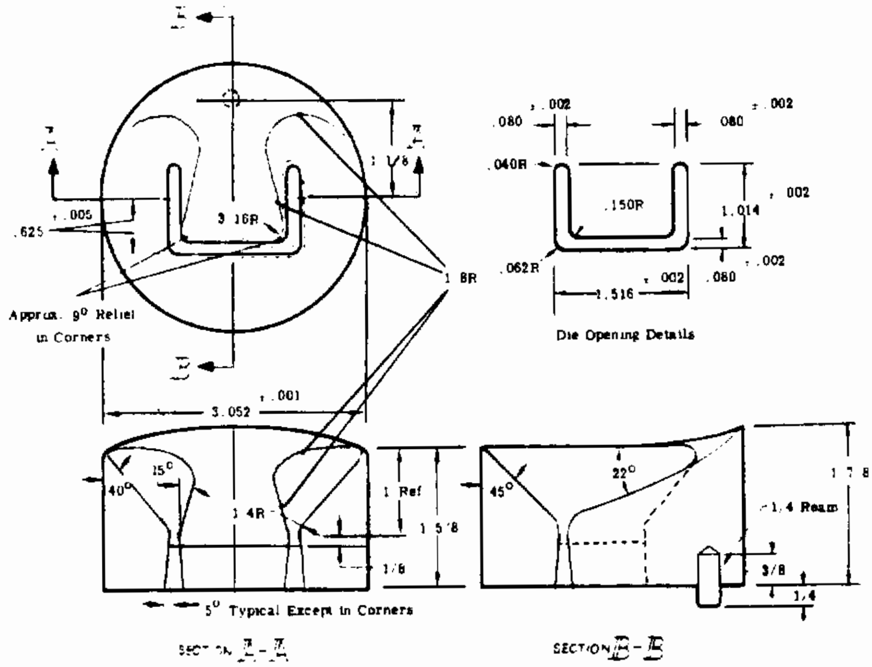
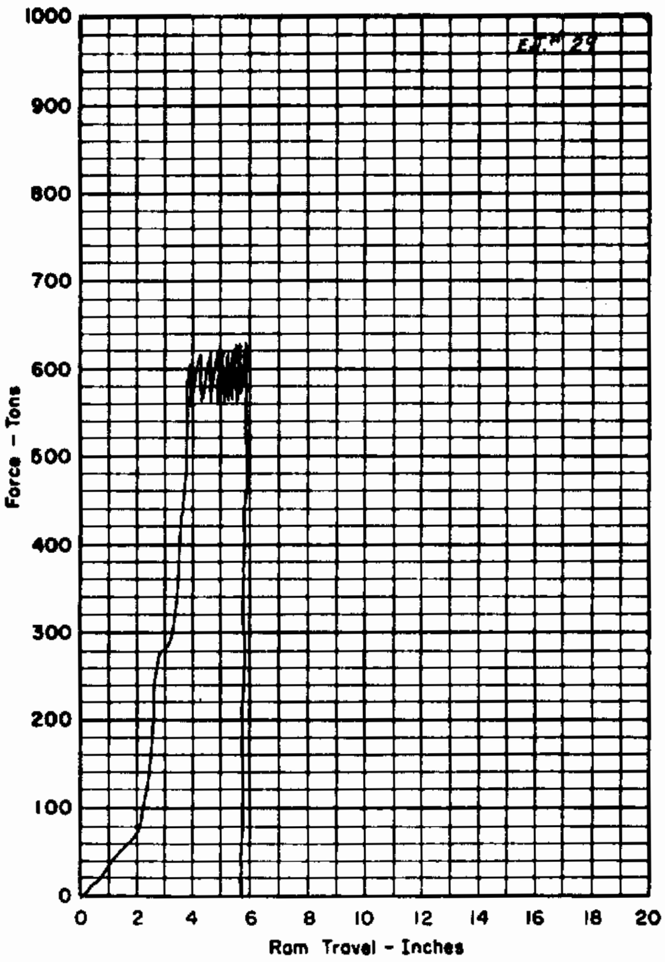


FIGURE 93 DIE DESIGN NO. MC-497-J

Extrusion 29



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

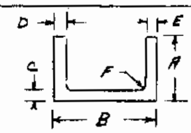
Type of Extrusion Pilot Production Job No. 2571 Extrusion No. 29

NMI Extrusion No. 34677 Be Chem Lot No. 8904 Extrusion Date 10/17/61

Primary purpose of this extrusion: Produce 20' extrusions

Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	750
	Lubrication	Heavy mica coated
	Condition	---------------
Billet	Material	Be canned in .095" steel and copper .045"
	Can Thickness	---------------
	Length (in.)	Be 10-3/4 Billet 12-1/4
	Temp. (°F)	1800
	Lubrication	Aqua dag
	Electroplate	None
	Heating	Under graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 175
	Transfer Time (sec)	20
Die	Material	EDS/Rc 44
	Fabrication	Casting
	Type	.080" orifice
	Design No.	MC-497-J
	Identification No.	A-29
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New
	Rework	None
	No. of Extrusions/Die	None
	Extrusion Ratio	30 to 1

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A		
	B		
	C		
	D		
	E		
	F		
Center	A		
	B		
	C		
	D		
	E		
	F		
Rear	A		
	B		
	C		
	D		
	E		
	F		

Remarks: Stalled

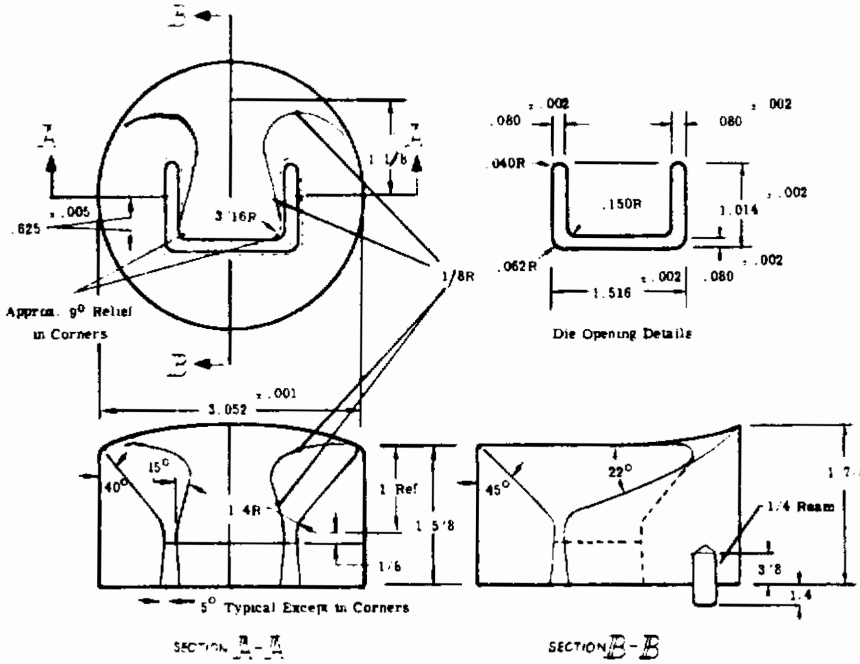
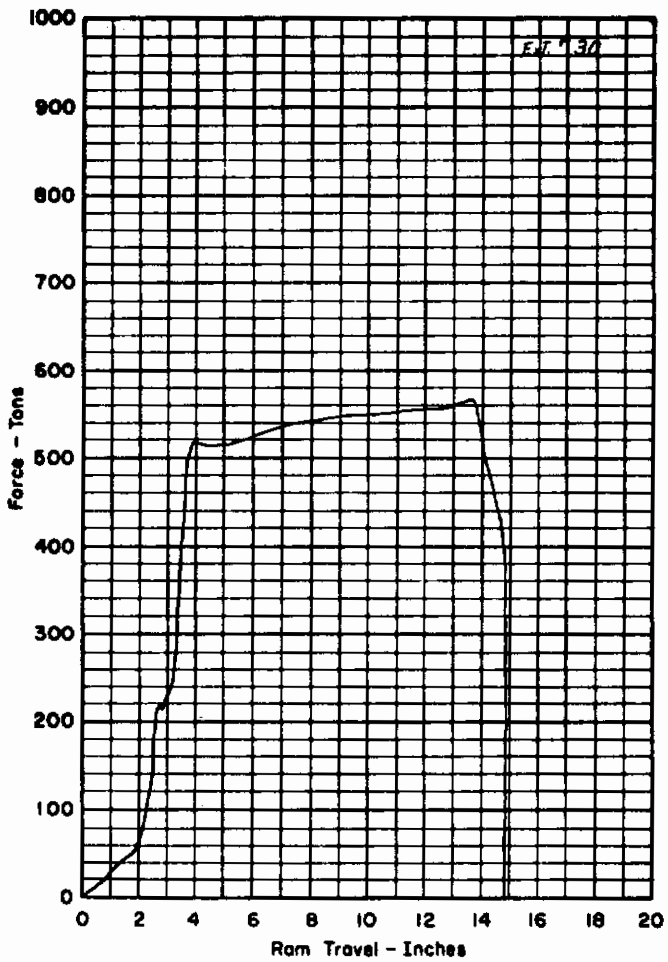


FIGURE 93 DIE DESIGN NO. MC-497-J

Extrusion 30



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

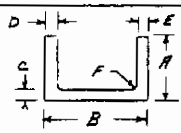
Type of Extrusion Pilot Production Job No. 2571 Extrusion No. 30

NMI Extrusion No. 34678 Be Chem Lot No. 8904 Extrusion Date 10/17/61

Primary purpose of this extrusion: Pilot production

Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	800
	Lubrication	Heavy mica coated
	Condition	-------------
Billet	Material	Be canned in steel .095" and copper .045"
	Can Thickness	-------------
	Length (in.)	Be 10-3/4 Billet 12-1/4
	Temp. (°F)	1825
	Lubrication	Aqua dag
	Electroplate	None
	Heating	Under graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 182
	Transfer Time (sec) 25	
Die	Material	EDS/Rc 44
	Fabrication	Casting
	Type	.080" orifice
	Design No.	MC-497-J
	Identification No. 30	
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New
	Rework	None
	No. of Extrusions/Die None	
	Extrusion Ratio	30 to 1

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A	1.002"	.948"
	B	1.497"	1.467"
	C	.084"	.068"
	D	.077"	.064
	E	.078"	.066"
	F		
Center	A	.998"	.946"
	B	1.499"	1.466"
	C	.079"	.068"
	D	.074"	.060"
	E	.073"	.062"
	F		
Rear	A	.996"	.962"
	B	1.503"	1.467"
	C	.076"	.064"
	D	.070"	.057"
	E	.071"	.060"
	F		

Remarks: Scraping inside, both legs, entire length

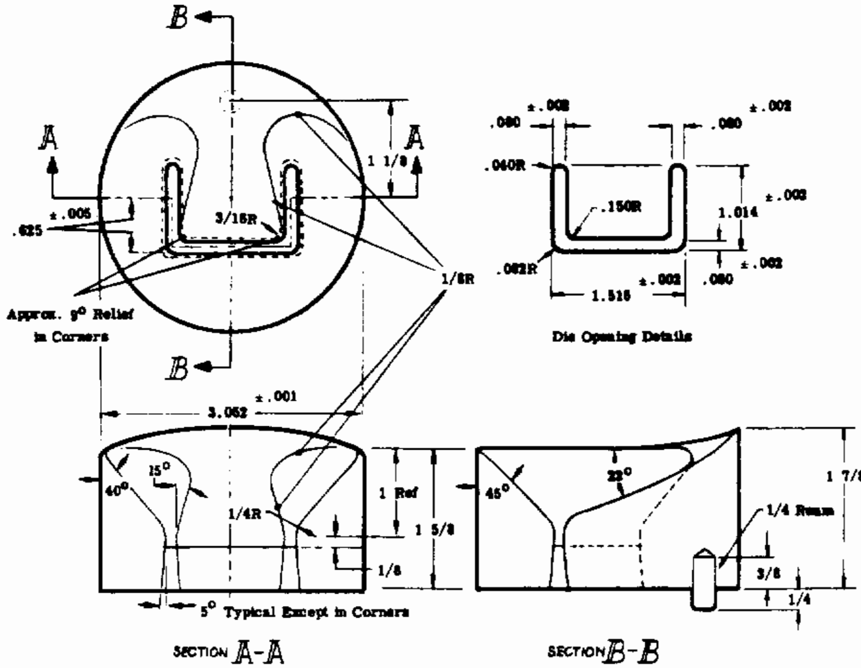
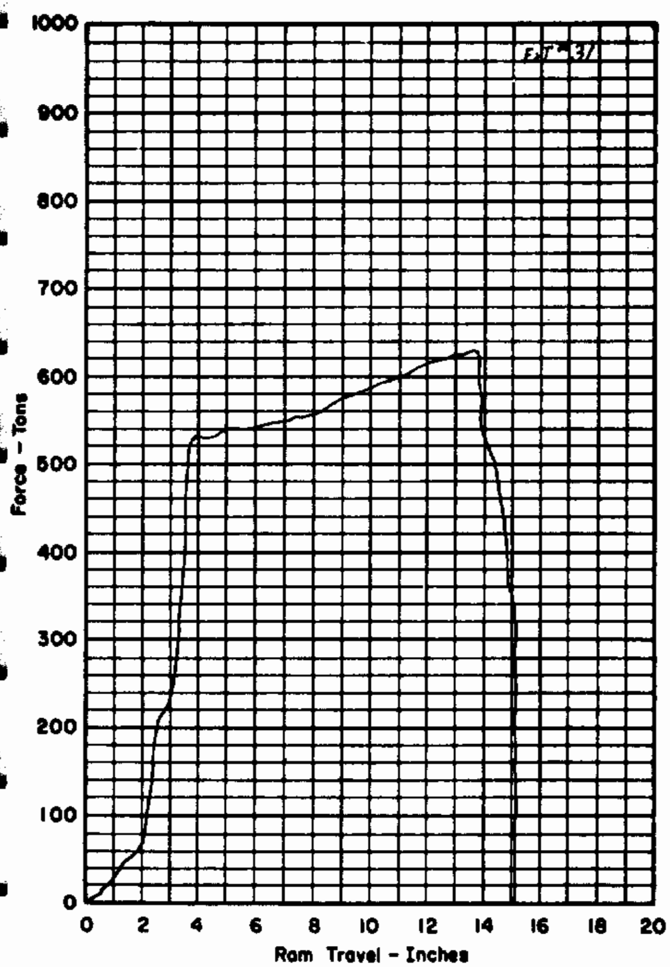


FIGURE 93 DIE DESIGN NO. MC-497-J

Extrusion 31



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

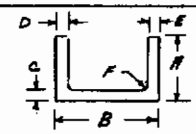
Type of Extrusion Pilot Production Job No. 2571 Extrusion No. 31

NMI Extrusion No. 34679 Be Chem Lot No. 8916 Extrusion Date 10/17/61

Primary purpose of this extrusion: Produce 20' extrusions

Liner	ID (in.)	3.050
	Length (in.)	26
	Temp. (°F)	800
	Lubrication	Heavy mica coated
	Condition	----------------
Billet	Material	Be canned in steel (.095") copper (.045")
	Can Thickness	----------------
	Length (in.)	Be 180 Billet 195
	Temp. (°F)	1825
	Lubrication	Aqua dag
	Electroplate	None
	Heating	Under graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 195
	Transfer Time (sec)	25
Die	Material	HDS/Rc 44
	Fabrication	Casting
	Type	.080" orifice
	Design No.	MC-497-J
	Identification No.	31
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New
	Rework	None
	No. of Extrusions/Die	None
	Extrusion Ratio	30 to 1

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A	1.008"	.947"
	B	1.499"	1.472"
	C	.082"	.070"
	D	.077"	.064"
	E	.076"	.064"
	F		
Center	A	1.002"	.950"
	B	1.503"	1.474"
	C	.074"	.065"
	D	.072"	.058"
	E	.072"	.059"
	F		
Rear	A	1.000"	.946"
	B	1.501"	1.472"
	C	.068"	.058"
	D	.069"	.055"
	E	.068"	.054"
	F		

Remarks: Scraping inside corner one leg, entire length

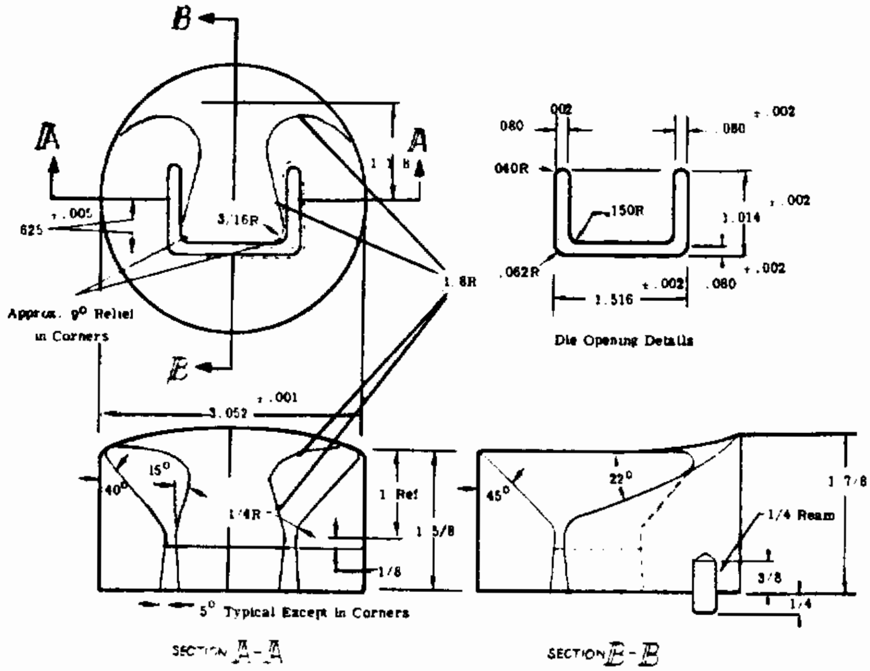
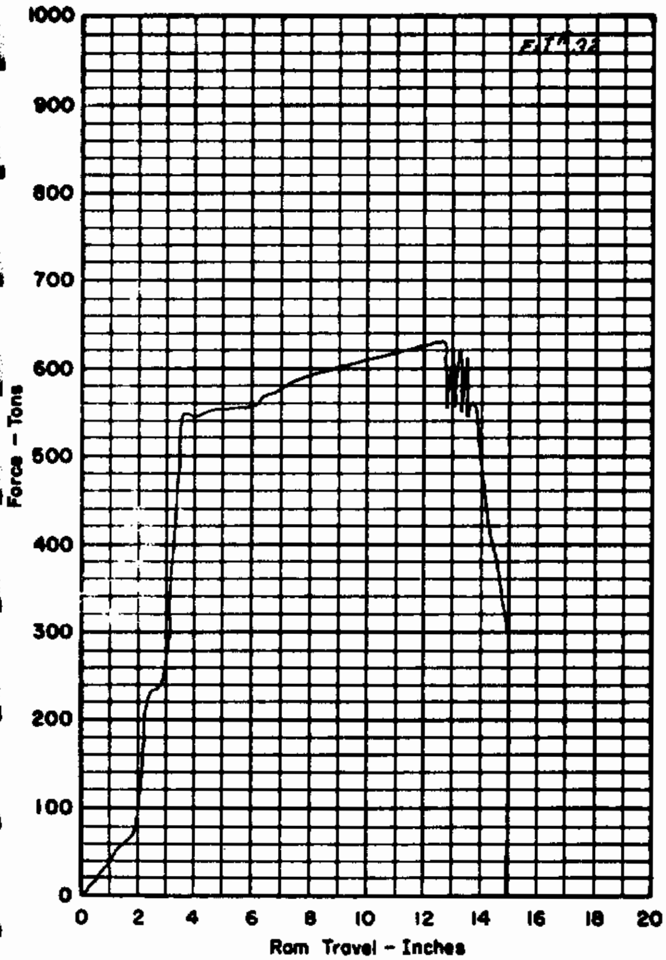


FIGURE 93 DIE DESIGN NO. MC-497-J

Extrusion 32



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

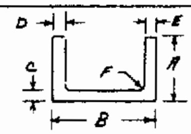
Type of Extrusion Pilot Production Job No. 2571 Extrusion No. 32

NMI Extrusion No. 34680 Be Chem Lot No. 8916 Extrusion Date 10/17/61

Primary purpose of this extrusion: Produce 20' extrusions

Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	825
	Lubrication	Heavy mica coated
	Condition	----------------
Billet	Material	Be canned in steel (.095") and copper (.045")
	Can Thickness	----------------
	Length (in.)	Be 10-3/4 Billet 12-1/4
	Temp. (°F)	1850
	Lubrication	Aqua dag
	Electroplate	None
	Heating	Under graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 180
	Transfer Time (sec)	25
Die	Material	EDS/Rc 44
	Fabrication	Casting
	Type	.080" orifice
	Design No.	MC-497-J
	Identification No.	32
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	New
	Rework	None
	No. of Extrusions/Die	None
	Extrusion Ratio	30 to 1

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A	1.006"	0.966"
	B	1.502"	1.479"
	C	.084"	.073"
	D	.082"	.066"
	E	.077"	.065"
	F		
Center	A	1.004"	0.954"
	B	1.505"	1.479"
	C	.075"	.064"
	D	.074"	.063"
	E	.074"	.062"
	F		
Rear	A	1.001"	0.960"
	B	1.506"	1.480"
	C	.067"	.056"
	D	.071"	.058"
	E	.070"	.057"
	F		

Remarks: Scraping inside at one corner, entire length

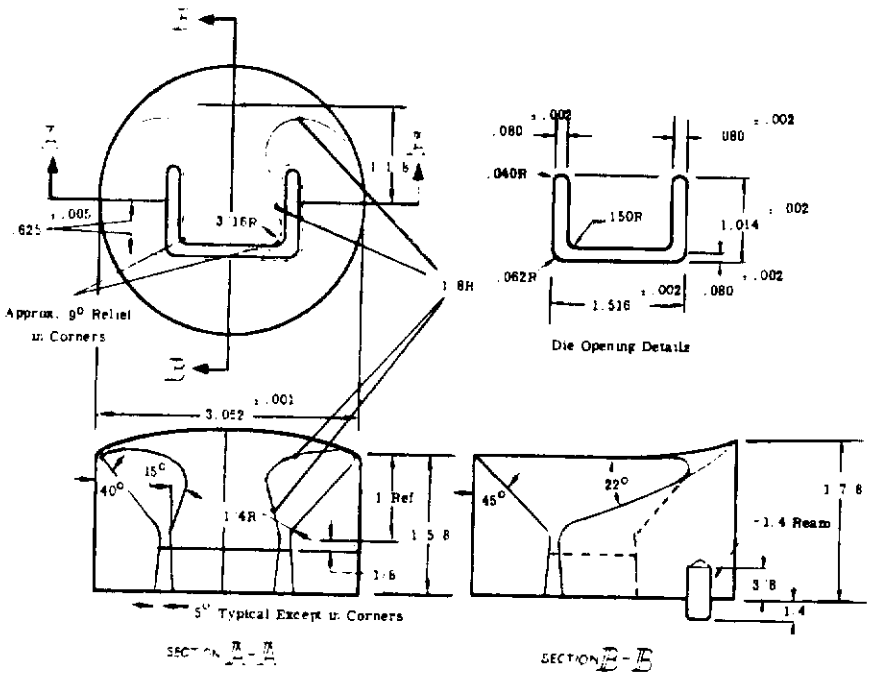
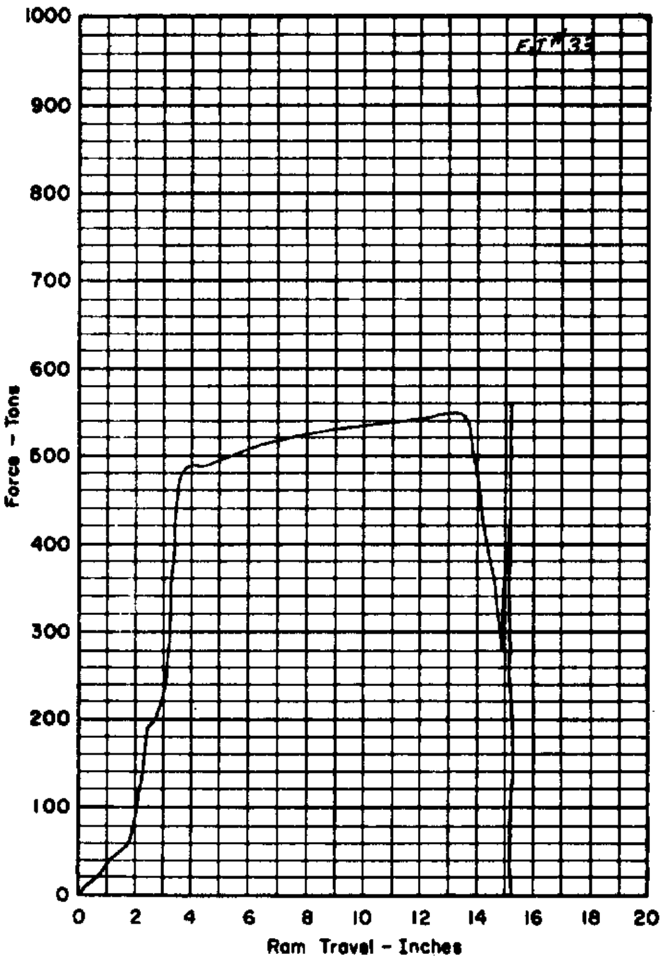


FIGURE 93 DIE DESIGN NO. MC-497-J

Extrusion 33



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

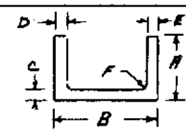
Type of Extrusion Pilot Production Job No. 2571 Extrusion No. 33

NMI Extrusion No. 34681 Be Chem Lot No. 8916 Extrusion Date 10/17/61

Primary purpose of this extrusion: Produce 20' extrusions

Liner	ID (in.) 3.050	Length (in.) 26	
	Temp. (°F)	825	
	Lubrication	Heavy mica coated	
	Condition	----------------	
Billet	Material	Be canned in steel (.095") and copper (.065")	
	Can Thickness	----------------	
	Length (in.)	Be 180 Billet 185	
	Temp. (°F)	1835	
	Lubrication	Aqua dag	
	Electroplate	None	
	Heating	Under graphite	
	Heating Time (min)	a. Scheduled 180	b. Actual 185
	Transfer Time (sec)	15	
Die	Material	HDS/Rc 44	
	Fabrication	Casting	
	Type	.080" orifice	
	Design No.	MC-497-J	
	Identification No.	33	
	Temp. (°F)	Room	
	Lubrication	Aqua dag	
	Condition	New	
	Rework	None	
	No. of Extrusions/Die	None	
	Extrusion Ratio	30 to 1	

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A	1.007"	0.956"
	B	1.499"	1.473"
	C	.083"	.066"
	D	.077"	.066"
	E	.077"	.065"
	F		
Center	A	1.003"	0.954"
	B	1.499"	1.472"
	C	.077"	.065"
	D	.073"	.061"
	E	.073"	.061"
	F		
Rear	A	1.001"	0.957"
	B	1.497"	1.468"
	C	.074"	.062"
	D	.071"	.058"
	E	.072"	.059"
	F		

Remarks: Scraping inside at one leg, entire length

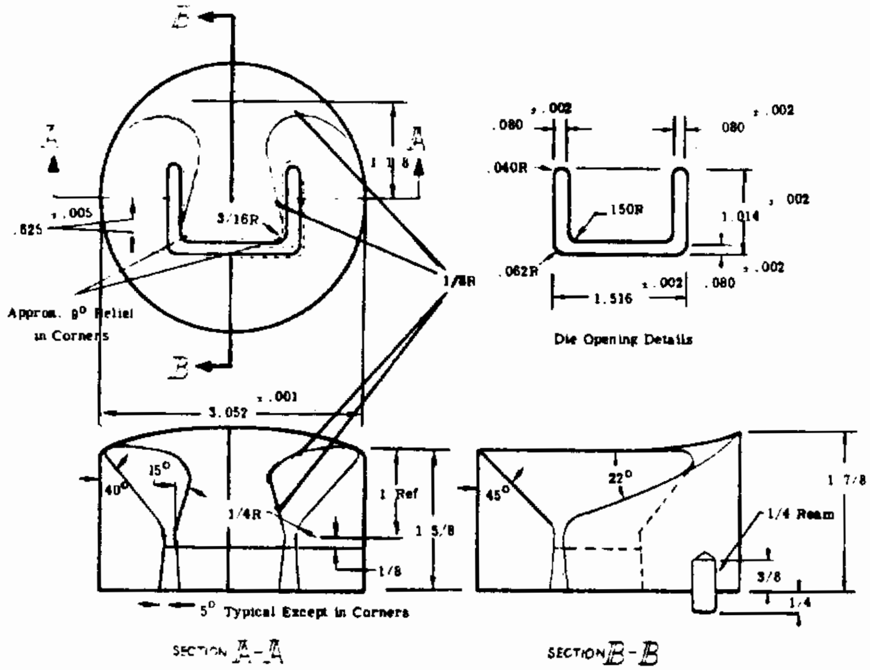
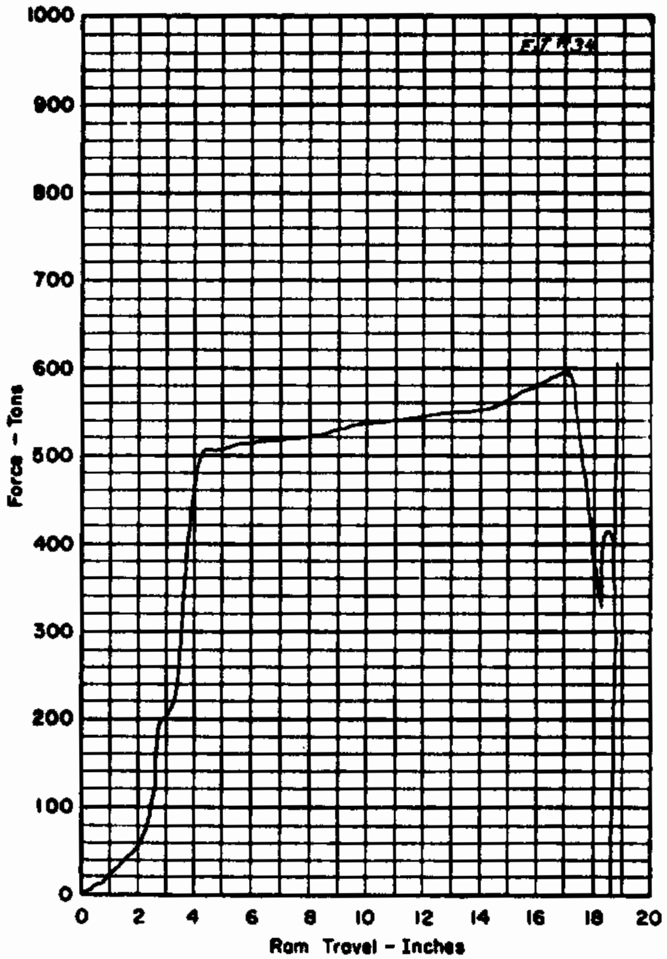


FIGURE 93 DIE DESIGN NO. MC-497-J

Extrusion 34



DATA SHEET FOR PROCESSING U-SHAPE BERYLLIUM

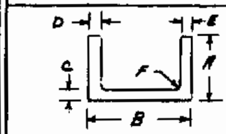
Type of Extrusion Pilot Production Job No. 2571 Extrusion No. 34

NMI Extrusion No. 34682 Be Chem Lot No. 8916 Extrusion Date 10/17/61

Primary purpose of this extrusion: Produce 20' extrusions

Liner	ID (in.) 3.050	Length (in.) 26
	Temp. (°F)	825
	Lubrication	Heavy mica coated
	Condition	----------------
Billet	Material	Be canned in steel (.095") and copper (.065")
	Can Thickness	----------------
	Length (in.)	Be 14" Billet 15-1/2"
	Temp. (°F)	1875
	Lubrication	Aqua dag
	Electroplate	None
	Heating	Under graphite
	Heating Time (min)	a. Scheduled 180 b. Actual 220
	Transfer Time (sec)	30
Die	Material	HDS/Rc 44
	Fabrication	Casting
	Type	.080" orifice
	Design No.	MC-497-J
	Identification No.	A-29 (2nd. use)
	Temp. (°F)	Room
	Lubrication	Aqua dag
	Condition	Used once No. 29 stall
	Rework	None
	No. of Extrusions/Die	One
	Extrusion Ratio	30 to 1

Extrusion Section Dimensions



		Before Pickle	After Pickle
Front	A	1.001"	0.948"
	B	1.497"	1.468"
	C	.076"	.064"
	D	.074"	.061"
	E	.067"	.060"
	F		
Center	A	1.001"	0.954"
	B	1.499"	1.470"
	C	.074"	.063"
	D	.073"	.060"
	E	.069"	.058"
	F		
Rear	A	1.000"	0.957"
	B	1.502"	1.468"
	C	.072"	.061"
	D	.072"	.058"
	E	.072"	.058"
	F		

Remarks: Scraping inside on one leg at middle of extrusion for 8 feet

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