AD 677529

CHAMBERLAIN MANUFACTURING Corporation

WATERLOO, IOWA

CHAMBERLAIN MANUFACTURING CORPORATION
Waterloo, Iowa

AD ______________

FINAL SUMMARY REPORT
DESIGN, DEVELOPMENT, AND FABRICATION OF PROJECTILE METAL PARTS FOR CARTRIDGE, HE, 152-MM, XM657

CONTRACT DAAA21-67-C-0744

Submitted 25 January 1968

This Work Was Supported By The U. S. Army Materiel Command, Technical Supervision By Picatinny Arsenal, Dover, New Jersey

ORDNANCE DIVISION

75

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DISTRIBUTION OF THIS REPORT IS NOT LIMITED

Approved By Everett S. Frank
Everett S. Frank
Engineering Supervisor

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Irving Herman
Vice President

COPY NO.: 26

CHAMBERLAIN MANUFACTURING CORPORATION
Waterloo, Iowa

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CHAMBERLAIN MANUFACTURING CORPORATION
Waterloo, Iowa

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ABSTRACT

On 13 March 1967 Chamberlain Manufacturing Corporation began the design, development, and fabrication of projectile metal parts for the Cartridge, HE, 152-mm, XM657E1. All projectiles were fabricated from AISI 4340 steel by hot forge-cold draw forming methods. Major problems in forming the projectile nose were solved by external contour machining and annealing of the drawn cans, then nosing the parts while cold, in one operation. Annealing of the projectile immediately after nosing was found necessary to avoid cracking. Weight control problems were solved by close control of the ogive wall thickness and relaxing the tolerance on the bourrelet relief diameter. Final requirements of the subject contract were completed with the shipment of 292 projectiles on 29 November 1967. According to proving ground reports, all projectiles performed satisfactorily during tests.

CHAMBERLAIN MANUFACTURING CORPORATION
Waterloo, Iowa

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1. INTRODUCTION

1.1 On 13 March 1967 the subject contract was executed to design, develop, and fabricate projectiles for the Cartridge, HE, 152-mm, XM657E1. Although the Company did not receive the final executed document until 31 March 1967, work was started at an earlier date because of the officially stated urgency of the program. Armed Service Procurement Regulations allow incurrence of pre-contract costs in cases of this nature.

1.2 The original contractual scope of work divided the program into the following tasks:

1.2.1 Conduct of design studies utilizing state-of-the-art information, preliminary drawings and data furnished by the Project Officer.

1.2.2 Preparation of Ordnance format component, fabrication and assembly drawings for the designs tested including calculations and/or other data supporting designs for tests.

1.2.3 Development of fabrication and metal forming processes to produce a one-piece projectile of the desired configuration and physical requirements.

1.2.4 Fabrication of 50 projectiles for submission to the Artillery Ammunition Laboratory for testing.

1.3 During the performance of the work outlined above, negotiations were progressing between Picatinny Arsenal and the Company for an additional 1,200 projectiles. This larger quantity was considered in planning and performing various aspects of the work. On 8 May 1967 this facility received Modification 2 to the subject contract which required fabrication of 1,200 additional projectiles. In general, the configuration and physical properties of all projectiles were to be sufficient to withstand firing from the XM81 gun. Safety in handling and firing was to be the prime requirement.

1.4 Some observations in the following report are preliminary and are not substantiated by detailed study. However, they are based on the author's experience with and understanding of the fabrication processes involved.

1.5 The final shipment in fulfillment of the subject contract was made on 29 November 1967.

2. CONCLUSIONS

2.1 The XM657E1 Projectile can be hot-forged and cold-formed successfully using the method described in Section 5 of this report.

2.2 The pre-nosing profile of the partially-drawn can is extremely critical because the shape of the ogive changes rapidly during the nosing process. For instance, during experiments, changing the contour position .200 inch axially varied the nose thread length from .25 inch to 1.0 inch.

2.3 Nosing of this projectile cannot be accomplished by conventional hot-nosing methods. Annealing is necessary immediately after nosing to prevent cracking of the body. No delay can be tolerated in the performance of this annealing operation.

2.4 Finish of the nosing die and lubrication of the part are critical. These conditions especially influence the eventual position of the nose threads and the nose wall thickness.

2.5 Final control of the projectile weight is accomplished by machining of the bourrelet weight relief diameter.

2.6 Approximate yield strength levels of 130,000 psi and 115,000 psi were achieved in the projectile sidewall and transversely in the base, respectively, in recognition of the safety factor required.

2.7 Proving ground test reports indicated that the projectile design which evolved is functional and has the required safety factor.

3. RECOMMENDATIONS

3.1 External contour machining and annealing of the partially drawn can is recommended before nosing.

3.2 It is recommended that contour-machined drawn cans be nosed cold in one operation.

3.3 Annealing of the nosed end of the projectile without delay after nosing is recommended to prevent their cracking.

3.4 Fragmentation tests should be performed on groups of projectiles of this design made from various materials and with various metallurgical structures to determine the optimum material and heat treatment procedure.

3.5 Fabrication of additional quantities of this projectile is recommended.

3.6 The following dimensional revisions are recommended:

3.6.1 To facilitate inspection, change the base thread shoulder radius from .060+.010 inch to .030+.040 inch.

3.6.2 Change nose wall thickness dimension from .330-.030 inch to .340-.070 inch to facilitate better control.

3.6.3 Maximum wall thickness should not vary more than .030 inch in any single plane.

3.6.4 A maximum outside diameter of 5.595 inch presently appears on the drawing for both the painted and unpainted projectile. To allow for the thickness of the coat of paint, the maximum outside diameter of the painted projectile should be changed to 5.597 inch.

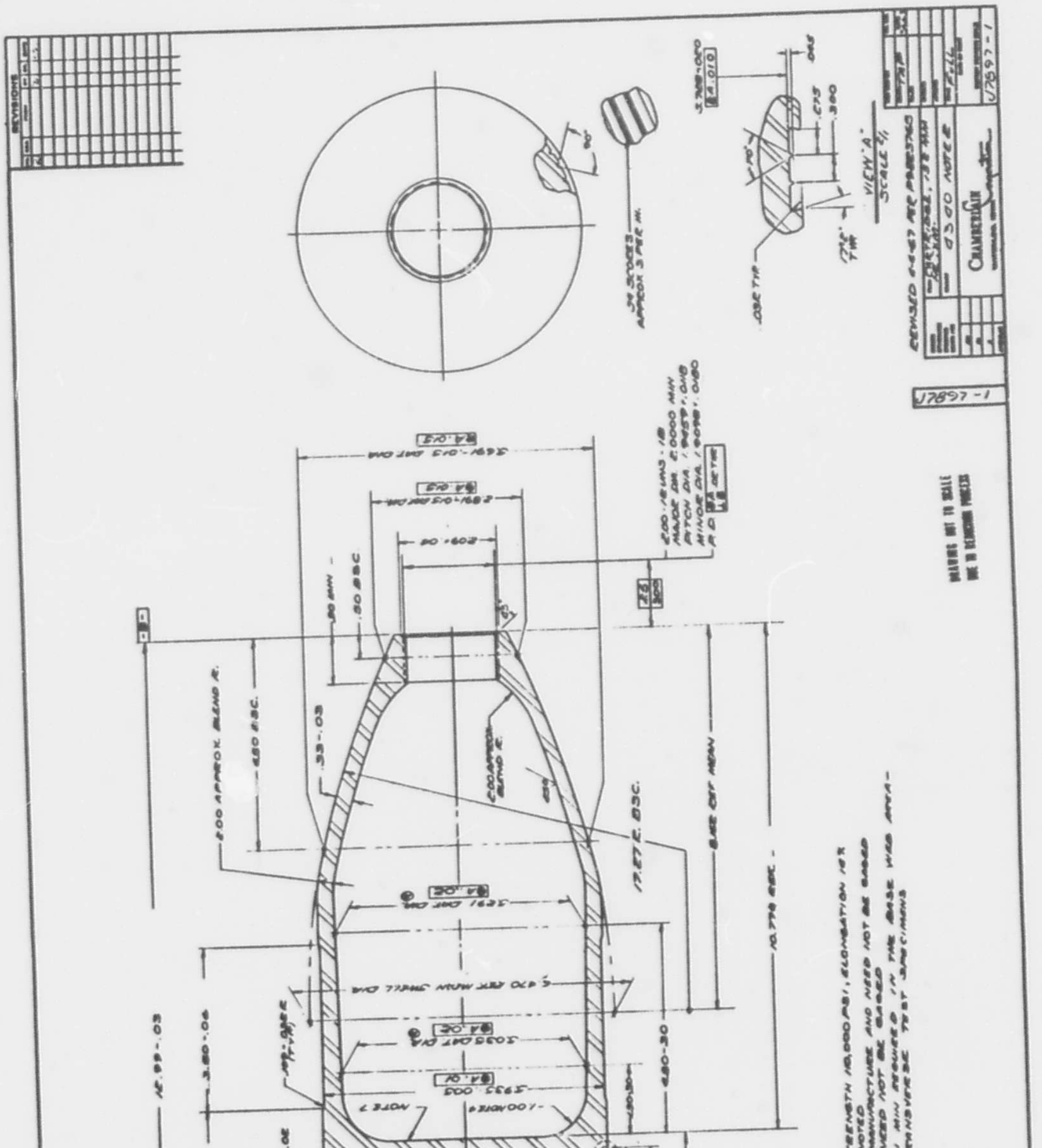
4. DESIGN ACTIVITY

4.1 Projectile Body

4.1.1 Tolerance, tolerance accumulations and dimensional practices based on the probable method of manufacture were discussed with an Arsenal representative at this facility on 30 March 1967. The objective of this discussion was to develop a projectile design which would provide a large safety factor against premature functioning and other malfunctioning. An initial design study of the XM657 projectile, shown by Drawing No. J7897-1 on the following page, resulted from this meeting. Preliminary calculations based on strength requirements indicated that the projectile design would withstand firing stresses successfully. The material selected for the projectile was AISI 4340 steel which was known to be through-hardening, amenable to forge and cold drawing forming techniques and would provide the required strength. The through-hardening characteristic was especially important in the relatively thick base of the projectile.

4.1.2 It was reported that the first 40 projectiles had weight variations of approximately three pounds. As a first approach to investigating this problem, one each heavy and light projectile was checked dimensionally to determine the most feasible area for weight control. Tabulated on Page 7 are the results of this inspection.

4.1.3 Because the bourrelet relief had a .005 inch tolerance, the only weight control areas which remained were the ogive wall and the thickened area just aft of the nose thread. The Technical Supervisor requested that effort be made to effect weight control within .5 pound by thinning the nose wall in the ogive area. He also gave permission to experiment with various inside blend radii to determine the radius most compatible with fabrication and structural integrity. Extensive nosing experiments were performed and are described fully in Paragraphs 5.1.5 through 5.1.5.3.


NOTES,
1 SPEC MIL-A-2550 APPLIES
2 MATERIAL: STEEL. YIELD STRENGTH 110,000 PSI, ELONGATION 10%
3 FINISH ALL OVER EXCEPT AS NOTED
4 DIMENSIONS CONTROL TOOL MANUFACTURE AND NEED NOT BE GAGED
5 UNTOLERANCED DIMENSIONS NEED NOT BE GAGED
6 YIELD STRENGTH OF 80,000 PSI MIN REQUIRED IN THE BASE WEB AREA-TO BE DETERMINED BY TRANSVERSE TEST SPECIMENS
7 SURFACE FINISH AS FORGED
J7897-1
CHAMBERLAIN

DIMENSIONS OF ONE HEAVY AND ONE LIGHT
WEIGHT XM657E1 PROJECTILE

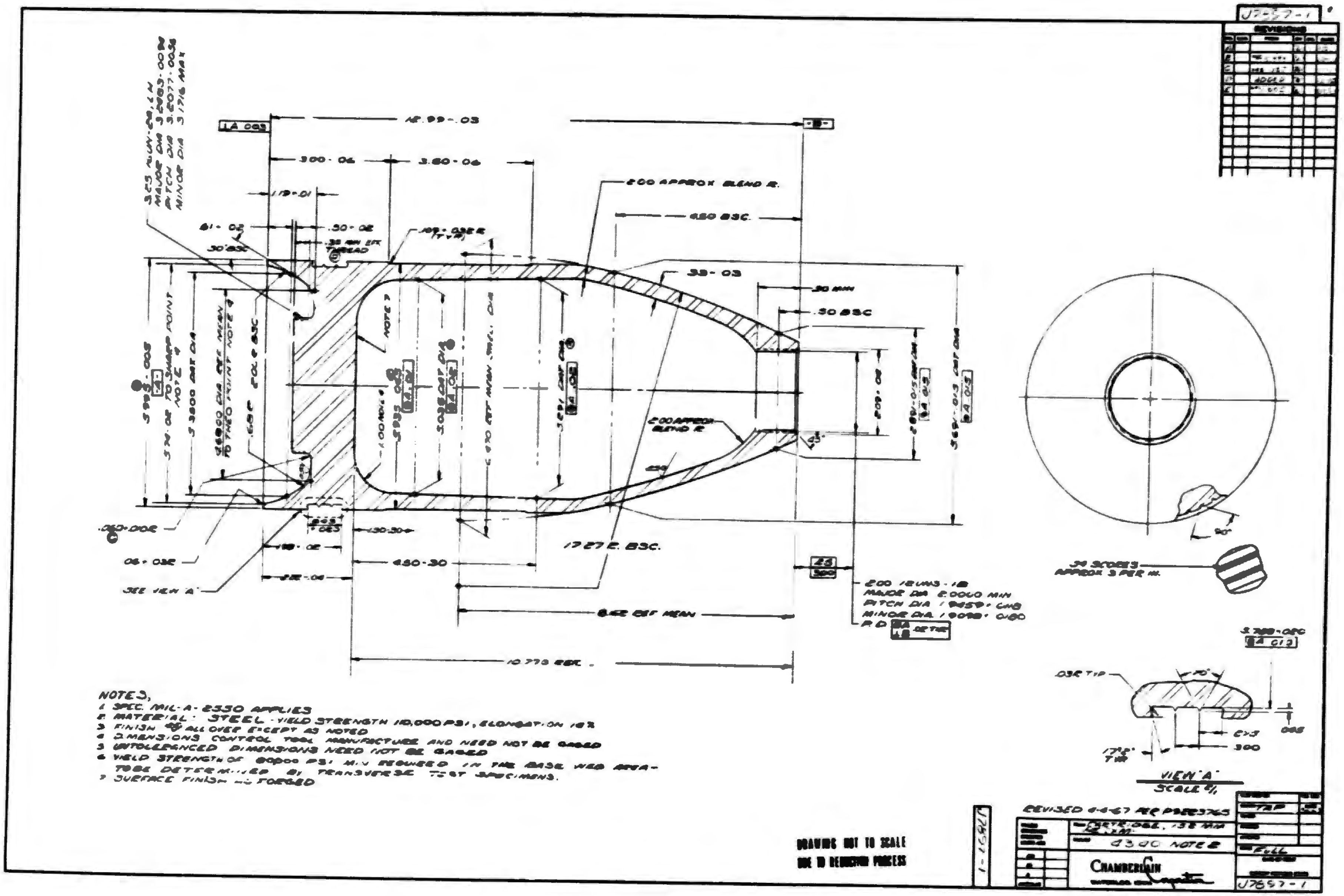
	PROJECTILE 34			PROJECTILE 60		
DISTANCE FROM BASE (Inches)	RIGHT SIDE	LEFT SIDE	AVG.	RIGHT SIDE	LEFT SIDE	AVG.
10.50	.243	.256	.249	.318	.322	.320
10.25	.263	.262	.262	.317	.322	.320
10.00	.267	.265	.266	.320	.322	.321
9.75	.275	.273	.274	.328	.328	.328
9.50	.289	.281	.285	.335	.336	.336
9.25	.293	.290	.292	.337	.339	.338
9.00	.299	.298	.298	.338	.341	.340
8.75	.306	.306	.306	.345	.347	.346
8.50	.310	.311	.310	.347	.351	.349
8.25	.305	.309	.307	.339	.346	.342
8.00	.299	.302	.301	.333	.338	.335
7.75	.310	.308	.309	.338	.343	.340
7.50	.313	.314	.313	.328	.337	.332
7.25	.319	.312	.315	.334	.338	.336
7.00	.335	.322	.328	.353	.354	.354
Overall Length	-.150			--		
Thread Length	.960			.960		
Weight (Pound)	30.02			33.17		

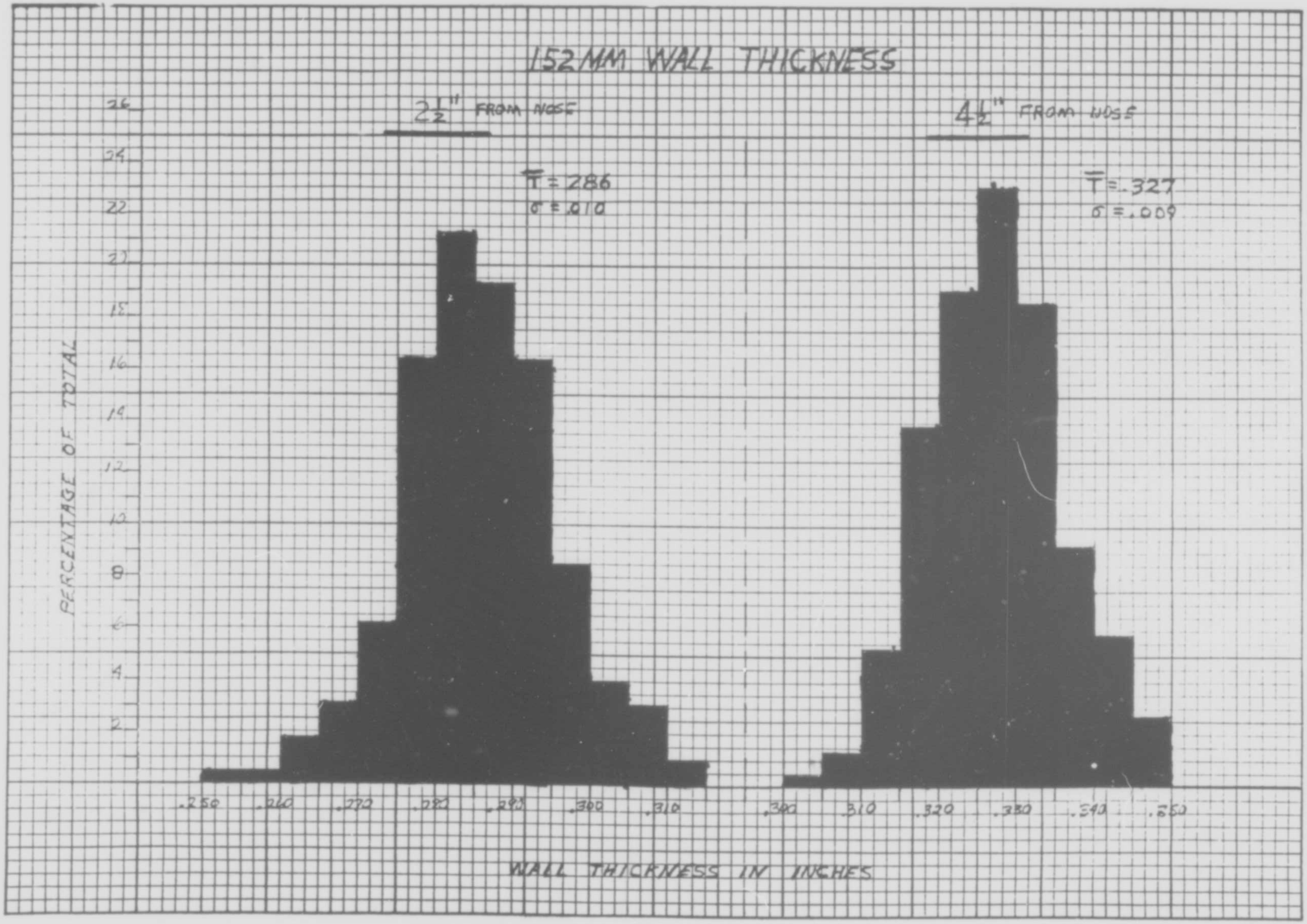
4.1.4 The Technical Supervisor specified a weight range of 30.1 to 30.6 pounds for the finished and banded projectile. To facilitate this control, the bourrelet weight relief diameter was retoleranced to a range of 5.935-.005 inches to 5.935-.065 inches. This revision, and revisions to the base boss thread requested by the Arsenal are incorporated in Drawing No. J7897-1, Revisions B through D, on the following page. Company-conducted weight calculations showed that the projectile weight would vary from 28.61 to 29.75 pounds without the .9 pound finish machined rotating band. In the ogive area from 2.5 to 4.5 inches aft of the nose, calculated weight varied a maximum of .26 pound considering the full wall thickness tolerance of .030 inch. Using the wall thickness measured at two points and a wall variation of ± 2 sigma the total projectile weight variation was .54 pound. A graph and supporting data are on Pages 10 and 11.

4.2 Rotating Band

4.2.1 A Chamberlain Manufacturing Corporation representative witnessed the Aberdeen Proving Ground recovery firing of the first ten XM657 Projectiles produced under the subject contract. On-site firing data indicated that chamber pressure, range and impact points all were within expected values. However, gilding metal from rotating bands wiped back about 3/16 inch from the bottom of the bands. Chamberlain's designers had expected this condition because no relief had been provided for metal displacement. Therefore, as requested by the Technical Supervisor, a cannelure was added to the rotating band as shown in the revised detail of Drawing No. J7897-2 on Page 12.

4.2.2 Later, in response to a telephone request from the Technical Supervisor, this facility checked density of the rotating band before and after banding. Specimens were cut from a band blank and an applied band was removed from a partially complete projectile body. The applied band had been worked in a six-jaw West Tire setter at a gauge pressure of 1,800 psi. Test specimens were cut at random from the two bands. The specific gravity of each specimen was determined by weighing on a Sartorius-Werke laboratory balance


NOTES,
1 SPEC. MIL-A-2550 APPLIES
2 MATERIAL: STEEL - YIELD STRENGTH 110,000 PSI, ELONGATION 16%
3 FINISH ALL OVER EXCEPT AS NOTED
4 DIMENSIONS CONTROL TOOL MANUFACTURE AND NEED NOT BE GAGED
5 UNTOLERANCED DIMENSIONS NEED NOT BE GAGED
6 YIELD STRENGTH OF 80000 PSI MIN REQUIRED IN THE BASE WEB AREA - TO BE DETERMINED BY TRANSVERSE TEST SPECIMENS.
7 SURFACE FINISH AS FORGED
DRAWING NOT TO SCALE
DUE TO REDUCED PROCESS
VIEW 'A'
SCALE 4/1
SEE VIEW 'A'
200 APPROX BLEND R.
650 BSC.
17.27 R. BSC.
842 REF MEAN
10.770 REF.
12.99 - .03
36 SCORES APPROX 3 PER IN.
REVISED 4-4-67 PER P9223765
CHAMBERLAIN
J7857-1


152MM WALL THICKNESS
2½" FROM NOSE
T̄ = .286
σ = .010
4½" FROM NOSE
T̄ = .327
σ = .009
PERCENTAGE OF TOTAL
2
4
6
8
10
12
14
16
18
20
22
24
26
.250
.260
.270
.280
.290
.300
.310
.300
.310
.320
.330
.340
.350
WALL THICKNESS IN INCHES

FOR GROUPED DATA SET 1

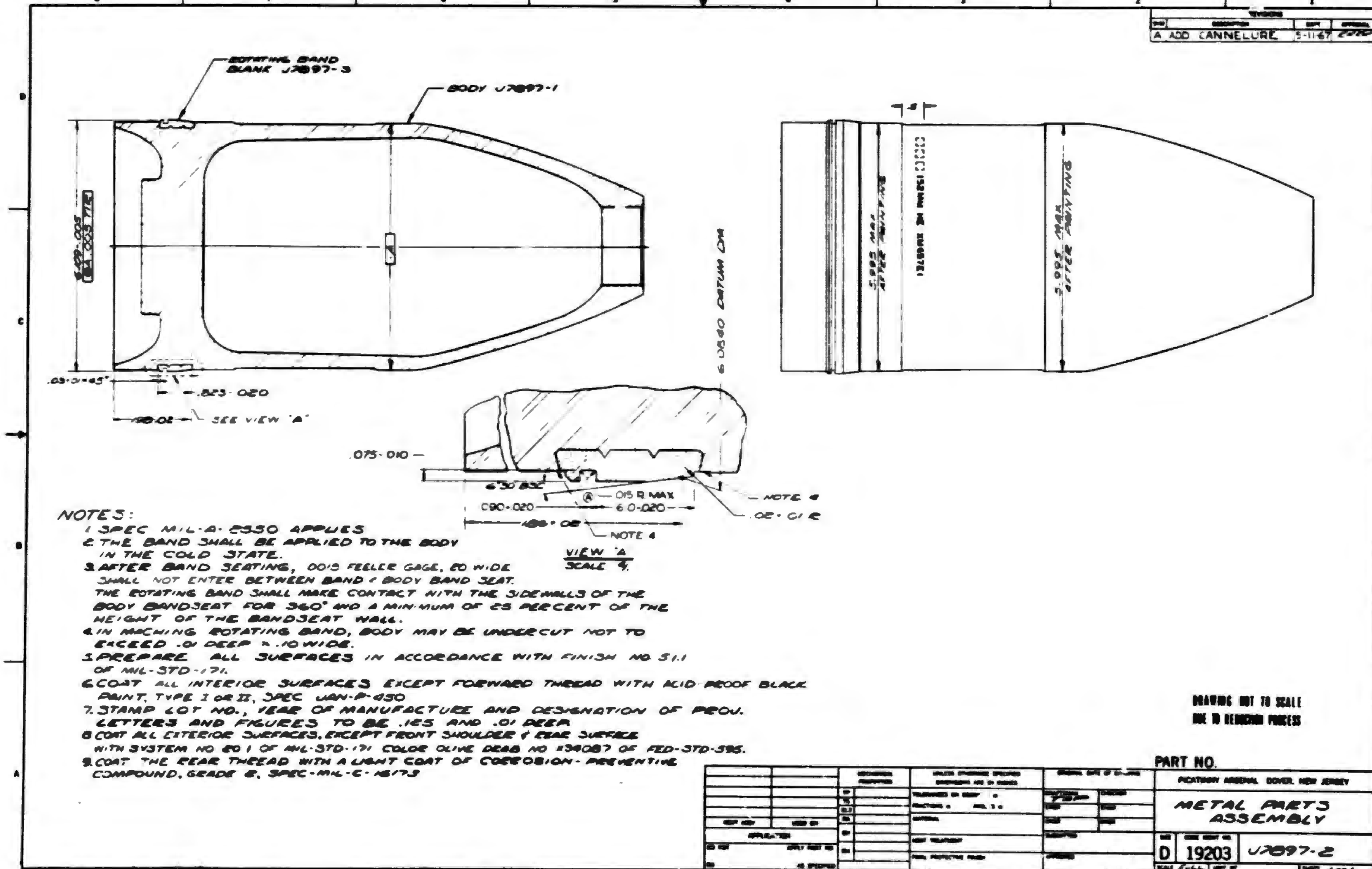
X-VALUE	FREQUENCY
.2525	1
.2575	1
.2625	4
.2675	7
.2725	14
.2775	37
.2825	48
.2875	39
.2925	37
.2975	19
.3025	9
.3075	7
.3125	2

NUMBER OF VALUES = 225
ARITHMETIC MEAN = .285611 $\overline{T}$ = .286
STANDARD DEVIATION = 1.02583 E-2 σ = .010
SAMPLE VARIANCE = 1.05233 E-4

FOR GROUPED DATA SET 1

X-VALUE	FREQUENCY
.3025	2
.3075	3
.3125	12
.3175	31
.3225	43
.3275	52
.3325	42
.3375	21
.3425	13
.3475	6

NUMBER OF VALUES = 225
ARITHMETIC MEAN = .327144 $\overline{T}$ = .327
STANDARD DEVIATION = 8.90717 E-3 σ = .009
SAMPLE VARIANCE = 7.93376 E-5


A ADD CANNELURE 5-11-67
ROTATING BAND BLANK U7897-3
BODY U7897-1
SEE VIEW 'A'
6.0840 DATUM DIA
5.995 MAX AFTER PAINTING
152MM HE XM687E1
.075-.010
.015 R MAX
6.0-.020
NOTE 4
.02-.01 R
VIEW 'A'
SCALE 4
NOTES:
1. SPEC MIL-A-2550 APPLIES
2. THE BAND SHALL BE APPLIED TO THE BODY IN THE COLD STATE.
3. AFTER BAND SEATING, .0015 FEELER GAGE, .20 WIDE SHALL NOT ENTER BETWEEN BAND & BODY BAND SEAT. THE ROTATING BAND SHALL MAKE CONTACT WITH THE SIDEWALLS OF THE BODY BANDSEAT FOR 360° AND A MINIMUM OF 25 PERCENT OF THE HEIGHT OF THE BANDSEAT WALL.
4. IN MACHINING ROTATING BAND, BODY MAY BE UNDERCUT NOT TO EXCEED .01 DEEP X .10 WIDE.
5. PREPARE ALL SURFACES IN ACCORDANCE WITH FINISH NO. 51.1 OF MIL-STD-171.
6. COAT ALL INTERIOR SURFACES EXCEPT FORWARD THREAD WITH ACID PROOF BLACK PAINT, TYPE I OR II, SPEC JAN-P-450
7. STAMP LOT NO., YEAR OF MANUFACTURE AND DESIGNATION OF PROJ. LETTERS AND FIGURES TO BE .125 AND .01 DEEP.
8. COAT ALL EXTERIOR SURFACES, EXCEPT FRONT SHOULDER & REAR SURFACE WITH SYSTEM NO. 20.1 OF MIL-STD-171 COLOR OLIVE DRAB NO. 34087 OF FED-STD-595.
9. COAT THE REAR THREAD WITH A LIGHT COAT OF CORROSION-PREVENTIVE COMPOUND, GRADE 2, SPEC-MIL-C-16173
DRAWING NOT TO SCALE DUE TO REDUCTION PROCESS
PART NO.
PICATINNY ARSENAL DOVER, NEW JERSEY
METAL PARTS ASSEMBLY
D 19203 U7897-2

accurate to .1 milligram. First, the weight in air was determined. Then a length of string was attached to the specimen and the new weight was registered. The specimen was suspended in a beaker of water and the scale reading was taken. Assuming that W = weight in air and w = weight in water, the specific gravity was obtained via the following formula:

$$\text{Specific Gravity} = \frac{W}{W - w}$$

The density (lb./in.^{3}) of each specimen then was obtained by multiplying its specific gravity (gm/cm^3) by the standard metric to English conversion factor of .03613. Below are the values obtained from the density checks.

UNAPPLIED SAMPLES

	Sample 1	Sample 2
Weight in Air (gm)	19.8288	16.4228
Plus String	19.8434	16.4321
Weight in Water (gm)	17.5936	14.5644
	2.2498	1.8677
Specific Gravity =	8.814 gm/cm^3	.793 gm/cm^3
Density =	.3184 lb./in.^{3}	.3177 lb./in.^{3}

APPLIED SAMPLES

	Sample 1	Sample 2
Weight in Air (gm)	29.2438	31.0050
Plus String	29.2556	31.0168
Weight in Water (gm)	25.9286	27.5118
	3.3270	3.5050
Specific Gravity =	8.780 gm/cm³	8.846 gm/cm³
Density =	.3176 lb./in.³	.3196 lb./in.³

In the above calculations, no correction was made for the density of the water at room temperature. Chamberlain Manufacturing Corporation personnel are satisfied that gilding metal rotating bands are approximately the same density applied to the projectile as in the blank stage.

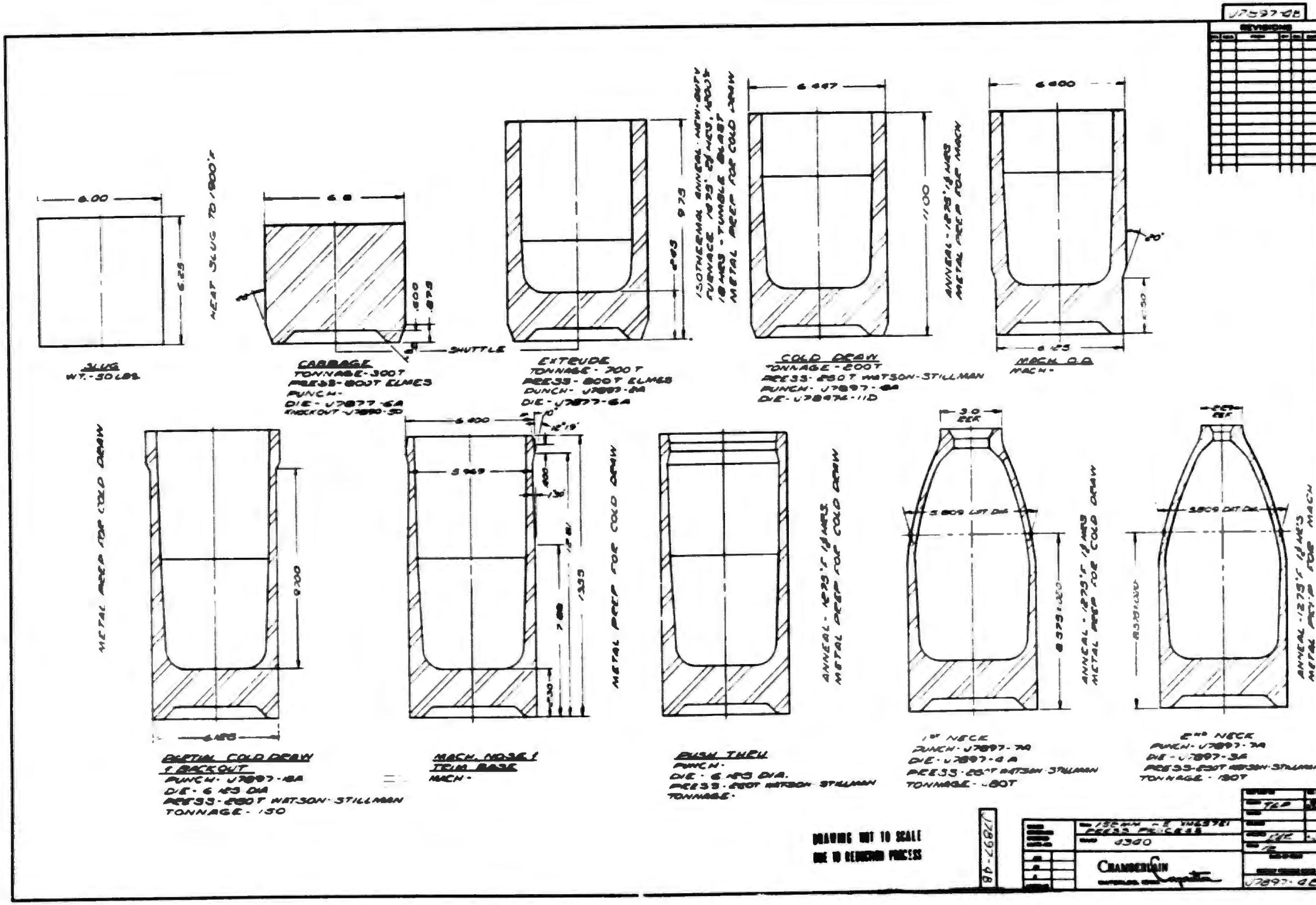
5. FABRICATION AND PRODUCTION

5.1 Press Forming

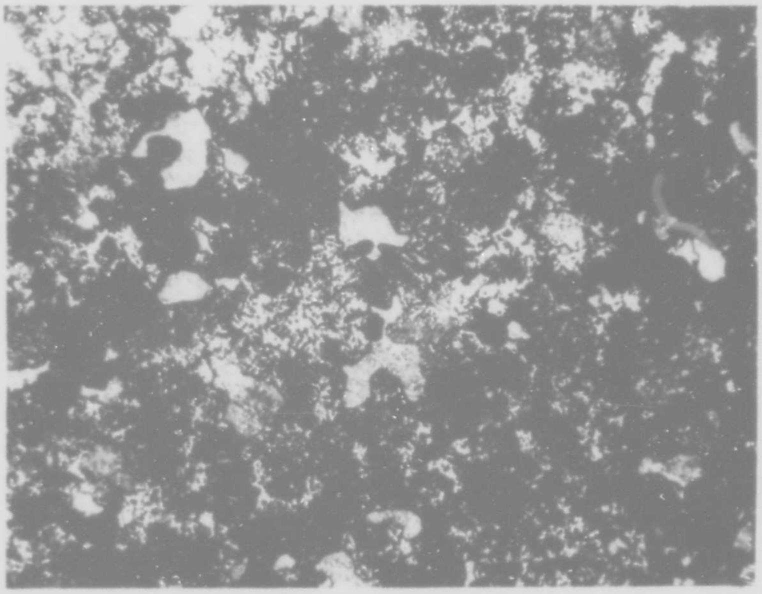
5.1.1 The initial quantity of 50 projectile bodies was forged at the Chamberlain Manufacturing Corporation, Waterloo, Iowa plant using multiple-purpose equipment typical of a research and development facility. Forging was performed on the additional 1,200 projectile bodies at the Chamberlain-operated Scranton Army Ammunition Plant because the equipment at that facility was better suited to production. A representative of the Waterloo facility witnessed the production of these forgings at Scranton.

5.1.2 Drawing No. J7897-4B on the following page shows the press process used for this initial quantity starting with a slug cut from 6.0 inches diameter AISI 4340 round steel bar. Because of the program's urgency and the temporary tooling involved, 100 slugs were started through the process at the Waterloo facility to assure that the required initial quantity of 50 projectiles would be obtained. The cabbage (pre-form) and backward extrusion operations were performed as a continuous operation in the same die by shuttling punches on a horizontal slide attached to the press ram. An excessive amount of scale appeared on forgings received from Scranton for the production quantity of projectiles. However, most of this scale was removed by shot blasting and was not considered a major problem.

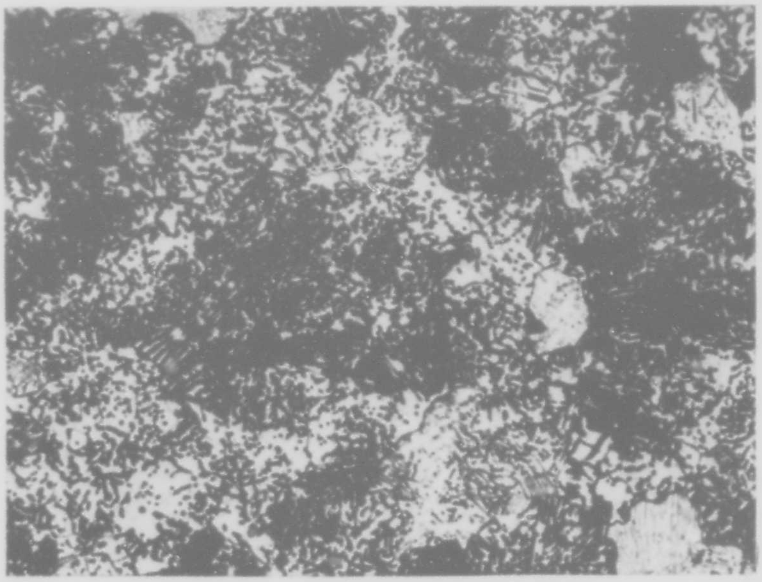
5.1.3 An isothermal anneal was prescribed after extruding to achieve good spheroidization of carbon with a minimum of pearlitic formulation. Photograph No. 8043 on Page 17 shows microstructure of samples from cups forged during the initial production of projectiles. The purpose of this microstructure was to provide a structure suitable for cold drawing and nosing operations. Hardness was in the range of Rockwell "B" 92 following this anneal. All remaining operations thus can be conducted with sub-critical temperature anneals to lower the hardness. Subsequent elongation of the carbon spheroids is not a hindrance to good metal flow in the cold operations.



SLUG
WT.-50 LBS.
HEAT SLUG TO 1800°F
CABBAGE
TONNAGE-300T
PRESS-800T ELMES
PUNCH-
DIE-U7877-6A
KNOCKOUT-U7880-5D
SHUTTLE
EXTRUDE
TONNAGE-700T
PRESS-800T ELMES
PUNCH-U7897-8A
DIE-U7877-6A
ISOTHERMAL ANNEAL-NEW-BUFF
FURNACE 1275° 24 HRS. ADD'L
18 HRS-TUMBLE BLAST
METAL PREP FOR COLD DRAW
COLD DRAW
TONNAGE-200T
PRESS-250T WATSON-STILLMAN
PUNCH-U7897-9A
DIE-U7897-11D
ANNEAL-1275°F 18 HRS
METAL PREP FOR MACH
MACH. O.D.
MACH-
METAL PREP FOR COLD DRAW
PARTIAL COLD DRAW
& BACKOUT
PUNCH-U7897-18A
DIE-6.125 DIA
PRESS-250T WATSON-STILLMAN
TONNAGE-150
MACH. NOSE & TRIM BASE
MACH-
METAL PREP FOR COLD DRAW
PUSH THRU
PUNCH-
DIE-6.125 DIA.
PRESS-250T WATSON-STILLMAN
TONNAGE-
ANNEAL-1275°F 18 HRS
METAL PREP FOR COLD DRAW
1ST NECK
PUNCH-U7897-7A
DIE-U7897-4A
PRESS-250T WATSON-STILLMAN
TONNAGE-80T
ANNEAL-1275°F 18 HRS
METAL PREP FOR COLD DRAW
2ND NECK
PUNCH-U7897-7A
DIE-U7897-3A
PRESS-250T WATSON-STILLMAN
TONNAGE-130T
ANNEAL-1275°F 18 HRS
METAL PREP FOR MACH
DRAWING NOT TO SCALE
DUE TO REDUCTION PROCESS
4340
CHAMBERLAIN
J7897-4B



500X MAGNIFICATION



1000X MAGNIFICATION

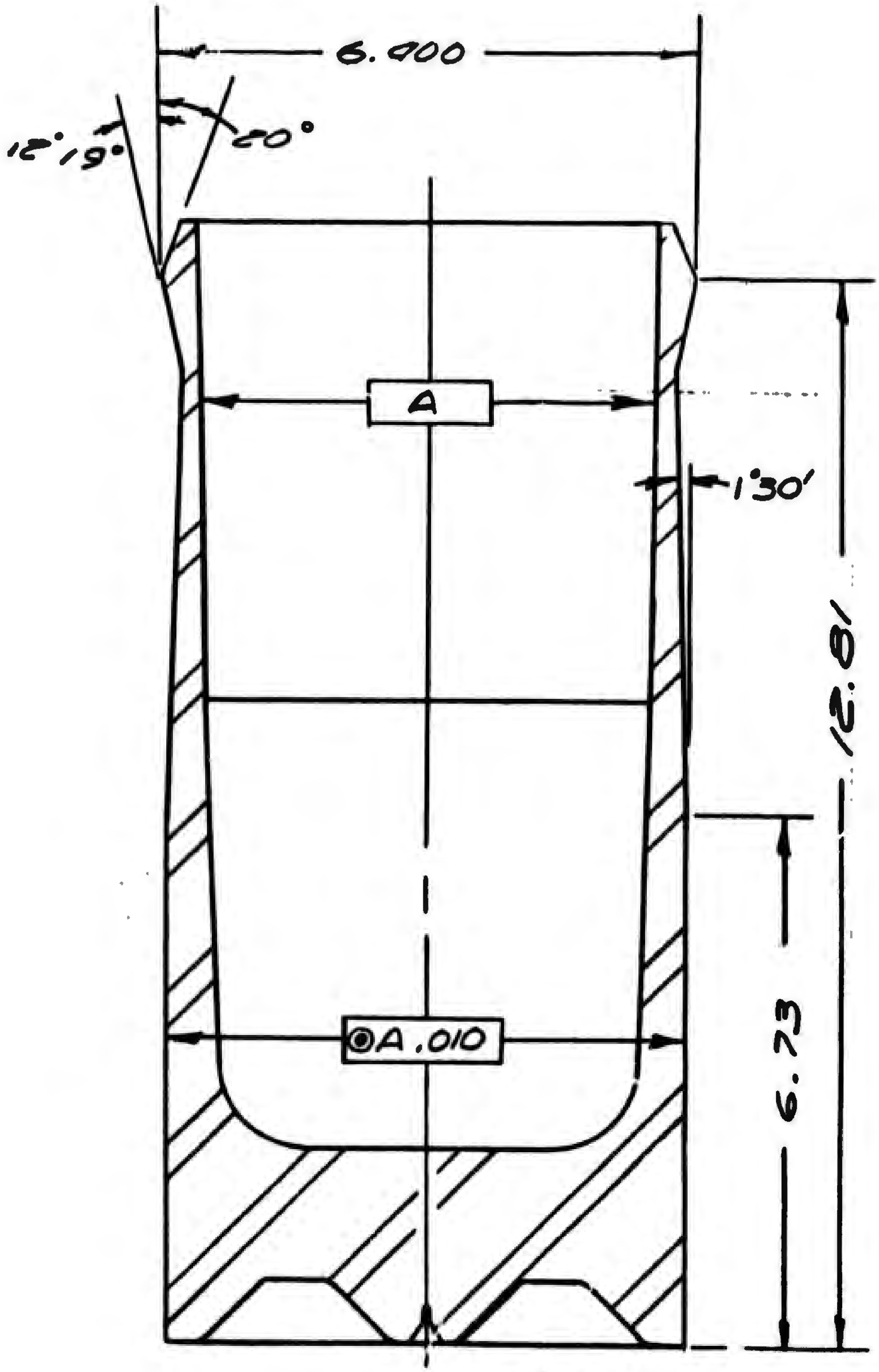
PHOTO NO. 8043
Photomicrographs Of Isothermal Annealed Structure In 4340 Steel Forged Cups.

CHAMBERLAIN MANUFACTURING CORPORATION

5.1.4 Following the isothermal anneal, the cups were cold drawn and trimmed to length. Photograph Nos. 8121 and 8123, Appendix A, illustrate the cold draw and trimming operations, respectively. After the outside diameter of the drawn can was machined, a partial cold drawing operation was performed. Photograph No. 8167, Appendix A, shows the partially drawn can. In preparation for nosing, the base was trimmed and the area to be nosed was machined externally. The operations described thus far were performed with no significant problems. Photograph Nos. 8066 through 8068, Appendix A, show typical base machining operations. Photograph No. 8101, Appendix A, shows the external machining of the area to be nosed.

5.1.5 Considerable difficulty was encountered with the nosing operation. Some projectiles did not machine clean around the entire circumference of the nosed area. Photograph Nos. 8064 and 8065, Appendix A, show this problem as it existed during machining. Observation of the nosing operation indicated that metal tended to "pull away" from the die as pieces were nosed inward. This problem was alleviated by nosing them in one operation instead of two. The study of projectile nosing was continued as described in the following paragraphs to improve still further the quality of nosing and to study the feasibility of effecting projectile weight control in the nosed area (See Paragraph 4.1.3).

5.1.5.1 During production of drawn cans it was noted that the pushout stage of the partial draw operation produced "ears" which were forced inward during the nosing operation. After an unsuccessful attempt to eliminate this stage of the operation and nose the completely drawn cans at 1,320°F, experiments were performed with an added contour machining operation before nosing. These experiments resulted in developing the contour shown by the sketch on the following page. Using this contour design, however, necessitated substituting a 6.060-inch diameter partial cold draw die for the 6.125-inch diameter die used previously. During these experiments it was noted that the die finish is very critical and that the piece must be well lubricated for successful performance of nosing. Dimensional inspection was performed before and after



OPER. #80
CONTOUR NOSE
MACH. STAMETS

nosing on 17 drawn cans which were contour machined as described. The pre-nosing measurements demonstrated that in any free metal flow situation such as a partial draw, the unconfined metal will follow the path of least resistance and the metal flow cannot be controlled closely. However, measurements taken after nosing and machining indicated that contour machining before nosing resulted in improved control of ogive wall thickness and projectile weight.

5.1.5.2 Continued development of the contour machining concept resulted in the adoption of the partially drawn can configuration shown by the sketch on the following page. Additional modifications which improved the quality of nosing are listed below.

Revert to the use of the original 6.125-inch diameter partial cold draw die.

Anneal the area of the internally machined drawn can to be nosed at 1,300°F for 30 minutes in a salt bath furnace and allow to cool in ambient air.

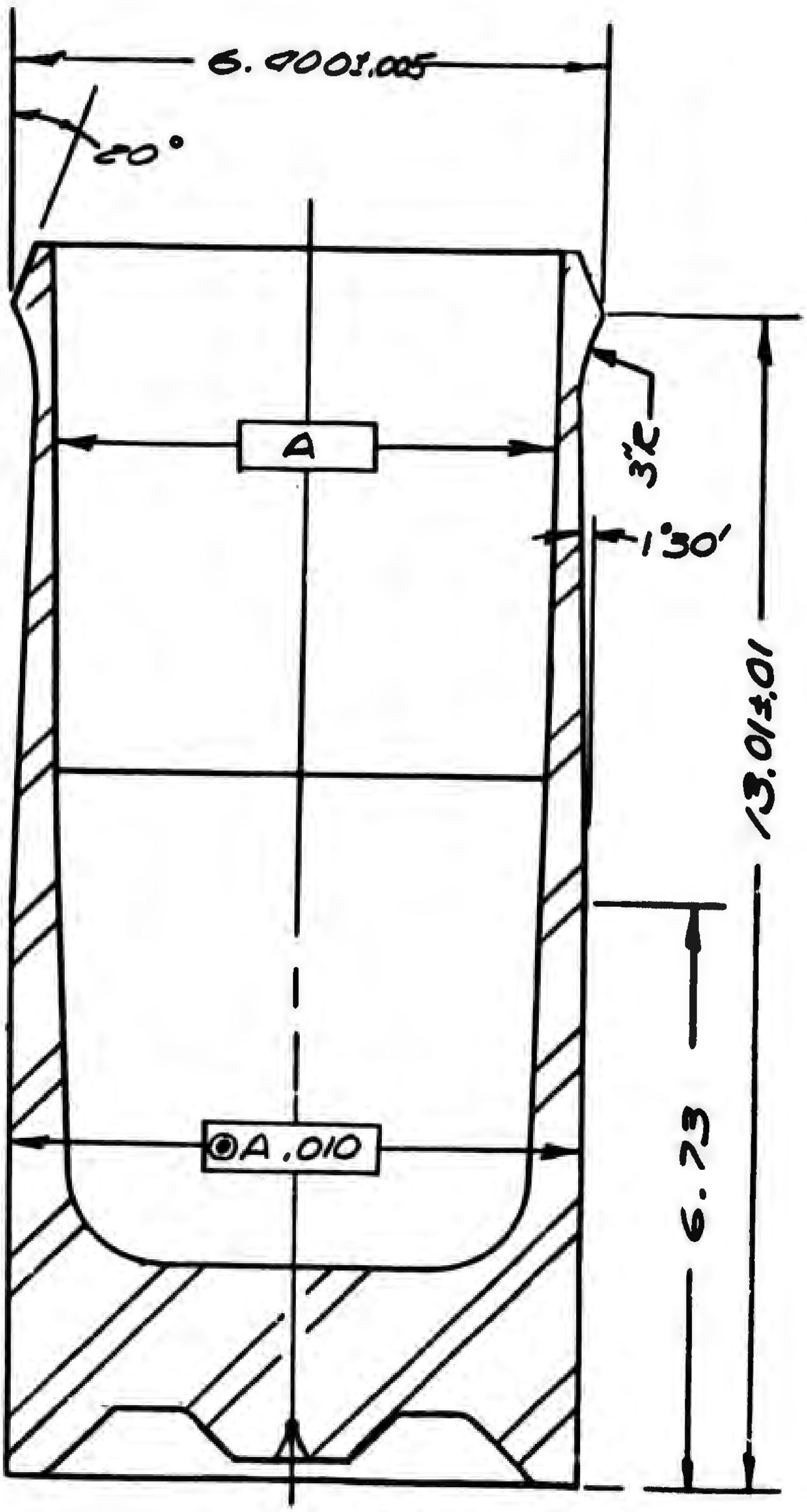
Perform nosing in one operation as mentioned previously.

Stress relieve approximately three inches of the nosed end of the projectile at 800°F for one hour immediately after nosing and allow to cool in ambient air. This operation is imperative to prevent cracking of parts and no delay can be tolerated in its performance.

5.1.5.3 Nosing was performed successfully by the method described above and this method was used throughout the remainder of contract performance.

5.2 Heat Treatment

5.2.1 Heat treatment experiments were conducted to determine the best temperatures and times required to meet the minimum mechanical properties. The first experiment consisted of heating drawn shell bodies to 1,475°F and holding at heat for 1.5 hours, followed by an oil quench in 110°F oil and a 1,225°F temper for 1.5 hours at heat. This first attempt resulted in the following mechanical properties:



OPER. #80
CONTOUR NOSE
MACH. STAMETS

SAMPLE LOCATION	ULT. STRENGTH (psi)	YIELD STRENGTH (psi)	% ELONGATION (1 In. Gage)
Base	129,700	95,100	19.3
Sidewall	138,700	111,800	22.3
Sidewall	137,700	100,400	21.8
Base	131,500	87,700	19.3

5.2.2 A decision was reached to lower the tempering temperature to 1,100°F to increase minimum yield strength. Except for four projectiles described in Paragraph 5.2.2.1, all projectiles were heat treated by this method. Below are tensile test results of samples from projectiles so heat treated.

SAMPLE LOCATION	ULT. STRENGTH (psi)	YIELD STRENGTH (psi)	% ELONGATION (1 In. Gage)
Sidewall	154,100	131,600	16.7
Sidewall	154,300	127,500	20.3
Base	139,800	114,800	13.2
Base	141,600	115,100	13.7

Rockwell hardness readings taken on the above lot revealed the following levels for two positions 180° opposite in the weight relief undercut area.

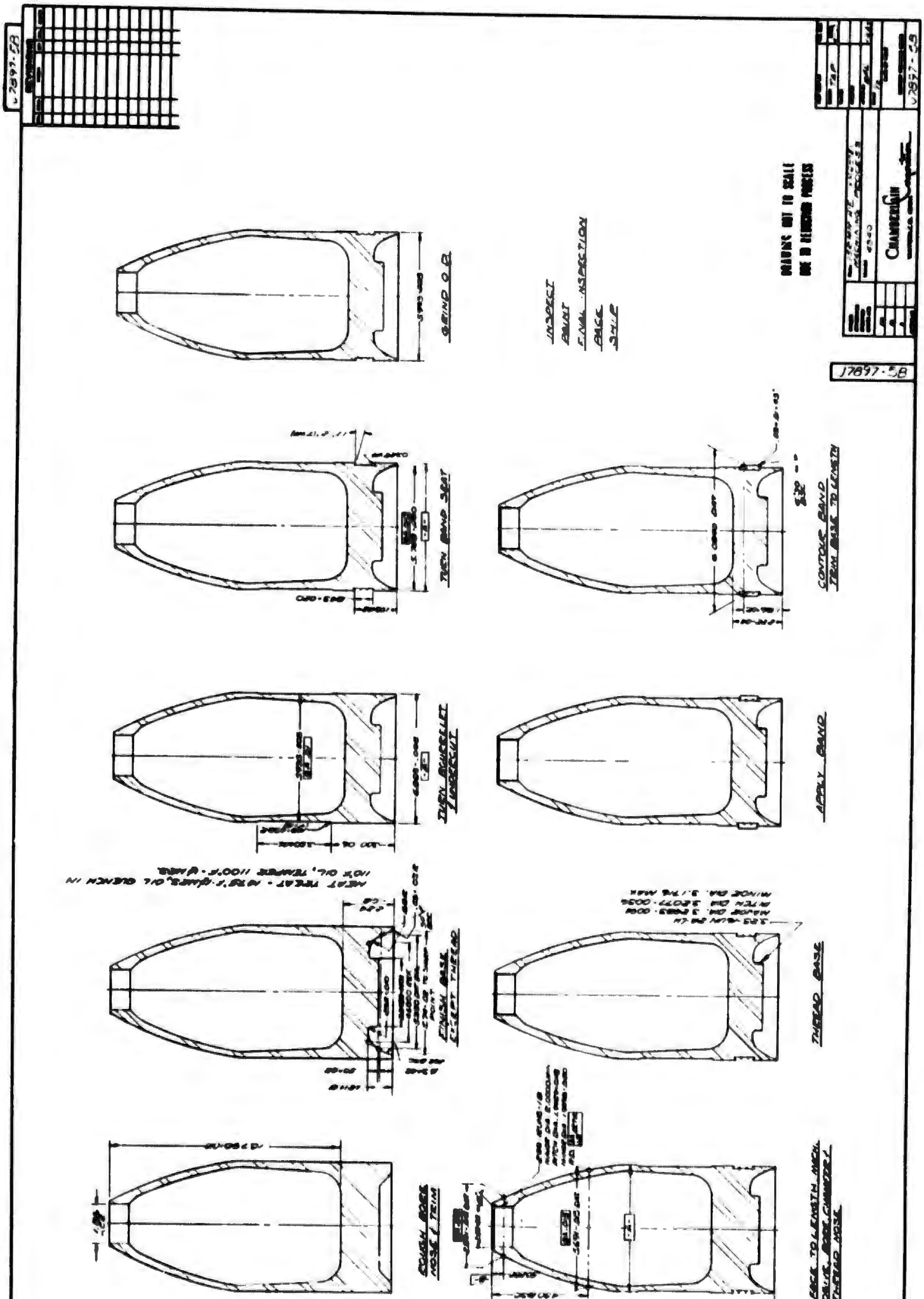
SAMPLE	RANGE (R"C")	SAMPLE	RANGE (R"C")
1	34-35	6	33-34
2	34-36	7	35-36
3	34-34	8	34-35
4	34-35	9	34-34
5	34-35	10	35-36

5.2.2.1 In accordance with a telephoned request by the Technical Supervisor, four projectiles were heat treated for special fragmentation tests. This process consisted of heating the bodies to 1,475°F, oil quenching, and tempering back to 700°F to provide a sidewall hardness of Rockwell "C" 48. However, the resulting projectiles had a hardness of Rockwell "C" 44 to 45 with about .020 inch outside decarburization. Measurements showed that this heat treatment distorted the bourrelet dimensions slightly but only the aft bourrelet dimension was slightly out of tolerance.

5.3 Machining

5.3.1 Drawing No. J7897-5B on the following page shows the prototype machining sequence which evolved from setups using multiple purpose equipment and existing tooling. This process was used for the production of the first 50 projectiles. The following discussion explains the drawing schematic more fully.

OPERATION	DESCRIPTION
1	Chuck on as-drawn bourrelet. Rough bore the minor nose diameter and rough cut to length on nose end.


ROUGH BORE NOSE / TRIM
FINISH BASE, CHAMF. THREAD
THEN BOURRELET / UNDERCUT
THEN BAND SEAT
GRIND O.B.
INSPECT
PAINT
FINAL INSPECTION
PACK
SHIP
THREAD BASE
APPLY BAND
CONTOUR BAND / TRIM BASE TO LENGTH
DRAWING NOT TO SCALE DUE TO REDUCED PROCESS
J7897-5B

OPERATION	DESCRIPTION
2	Reverse part, chuck on bourrelet. Machine base cavity leaving .020 inch surplus thickness. Turn major thread diameter.
3	Heat treat, 1,475°F for 1.5 hours, quench in 110°F agitated oil, temper at 1,100°F for 1.5 hours.
4	Grip on base spud and use live center cup on the ogive. Turn bourrelet to 5.998+.005 inch. Cut weight relief undercut to size.
5	Chuck on bourrelet. Turn band seat to finish size.
6	Centerless grinder. Grind O.D. to finish size.
7	Chuck on bourrelet. Contour nose. Face to length on nose, bore, chamfer and thread.
8	Chuck on bourrelet. Thread base.
9	West tire setter. Apply rotating band.
10	Chuck on bourrelet. Contour turn band, face base to final overall length for .003 inch perpendicularity with bourrelet.

5.3.2 Appendix B of this report consists of a set of process sketches which illustrate the basic operations employed on the added 1,200 projectiles. Starting with the extruded slug, the operations are arranged in the order of their performance and each was completed without significant problems. Photograph Nos. 8116 through 8120 and Photograph No. 8122, Appendix A, illustrate the performance of several projectile machining operations as described by their respective titles. To expedite the completion of the 1,200 projectiles, three additional lathes were received by this facility from the Ravenna, Ohio Ordnance Depot. These lathes were used for cutoff, nose boring and contouring operations (See Photograph Nos. 8206 and 8207, Appendix A).

5.3.3 Because vendors were unable to furnish XM657 rotating bands in time to meet proposed delivery schedules, 155-mm, M107 bored blanks were used. These blanks were cut to length, sized, and turned on the outside diameter to adapt them to the XM657 Projectile.

5.3.4 As requested by the Technical Supervisor, experiments were performed for attaching the base cover plate by epoxy adhesive and by spot-welding. Investigation showed that spot-welding of covers was unsatisfactory because of a stress relief required afterward and added handling difficulties. Therefore, covers were secured with Tra-Bond 2129 epoxy adhesive, produced by Tra-Con, Inc., Medford, Massachusetts. Of the 50 projectiles equipped with base cover plates, five were attached by spot-welding and 45 were secured with epoxy adhesive as described. Later in the program, however, an integral base cover and tracer attachment was designed by the Arsenal, thus eliminating the need for the separate base cover.

6. DRAWINGS

6.1 The following drawings were completed during the performance of the subject contract and are listed below for record only. Except for those cited in the preceding paragraphs to support the discussion, none are included with this report.

DRAWING NO.	DESCRIPTION
J7897-1	152-mm Body Drawing
J7897-2	Metal Parts Assembly
J7897-3	Rotating Band
J7897-1A	Necking Guide Insert
J7897-2A	Extrusion Punch
J7897-3A	Necking Die No. 1
J7897-4A	Necking Die No. 2
J7897-5A	Knockout Rod, Two Inch
J7897-6A	Mandrel Jaw
J7897-7A	Pusher Punch
J7897-8A	Hot Press Hold-Down Plate
J7897-9A	Knockout Rod, Three Inch
J7897-10A	Collet Pads, Cri-Dan "D"
J7897-11A	152-mm Ogive Cam, Stamets Lathe
J7897-12A	Straight Cam - Stamets Lathe
J7897-13A	Extrusion Tip
J7897-14A	Extrusion Punch
J7897-15A	Preform Punch
J7897-16A	Preform Tip
J7897-17A	Ejector Tip
J7897-18A	Cold Draw Punch
J7897-19A	Form Tool, Band Seat
J7897-20A	Tire Setter Jaws
J7897-21A	Long Center, Stamets Lathe
J7897-22A	Short Center, Stamets Lathe
J7897-23A	Tool Holder, Stamets Lathe
J7897-24A	Tool Insert, Band Seat
J7897-25A	Threading Insert, Base
J7897-26A	Threading Insert And Holder

CHAMBERLAIN MANUFACTURING CORPORATION
Waterloo, Iowa

FINAL SUMMARY REPORT
CONTRACT DAAA21-67-C-0744

DRAWING NO.	DESCRIPTION
J7897-27A	Thread Tool Holder
J7897-28A	Center Drill Mandrel
J7897-29A	Roughing Cam, Stamets Lathe
J7897-30A	Contour Cam, Stamets Lathe
J7897-31A	Contour Cam, Stamets Lathe
J7897-32A	Nicking Rack
J7897-33A	Center
J7897-34A	Template, Monomatic, Band Seat And Body Relief
J7897-35A	Adapter, Sleeve, Reid Nose Boring
J7897-36A	Mandrel Adapter, Seneca Falls Center Drill
J7897-37A	Mandrel Body, Seneca Falls Center Drill
J7897-38A	Rear Cam, Expanding Mandrel
J7897-39A	Front Pads, Expanding Mandrel
J7897-40A	Rear Pads, Expanding Mandrel
J7897-41A	Body, Expanding Mandrel, Stamets Lathe
J7897A-42A	Center, Stamets Lathe
J7897A-43A	Form Tool, Band
J7897A-44A	Collet Pads, Hepburn Lathe
J7897A-45A	Tool Block, Hepburn Lathe
J7897A-46A	Stop, Hepburn Lathe
J7897A-47A	Radius Tool Holder, Hepburn Lathe
J7897-1B	152-mm Forging Process
J7897-2B	Temporary Press Process, Waterloo
J7897-3B	Press Process, Scranton
J7897-4B	Press Process, Waterloo
J7897-5B	Machining Process
J7897-1D	Base Forging Gage Assembly
J7897-2D	Datum Ring, Base Cavity, Machining Gage
J7897A-3D	Final Acceptance Datum Ring, Base Cavity
J7897A-4D	3.5-Inch Go Thread Ring
J7897A-5D	3.5-Inch Go Thread Set Plug
J7897A-6D	3.5-Inch Lo Thread Ring
J7897A-7D	3.5-Inch Lo Thread Set Plug
J7897A-8D	Wall Thickness Gage
J7897A-1E	Packing Box For 152-mm, XM657E1

7. INSPECTION

7.1 Copies of all dimensional inspection reports were submitted with the shipments of projectiles.

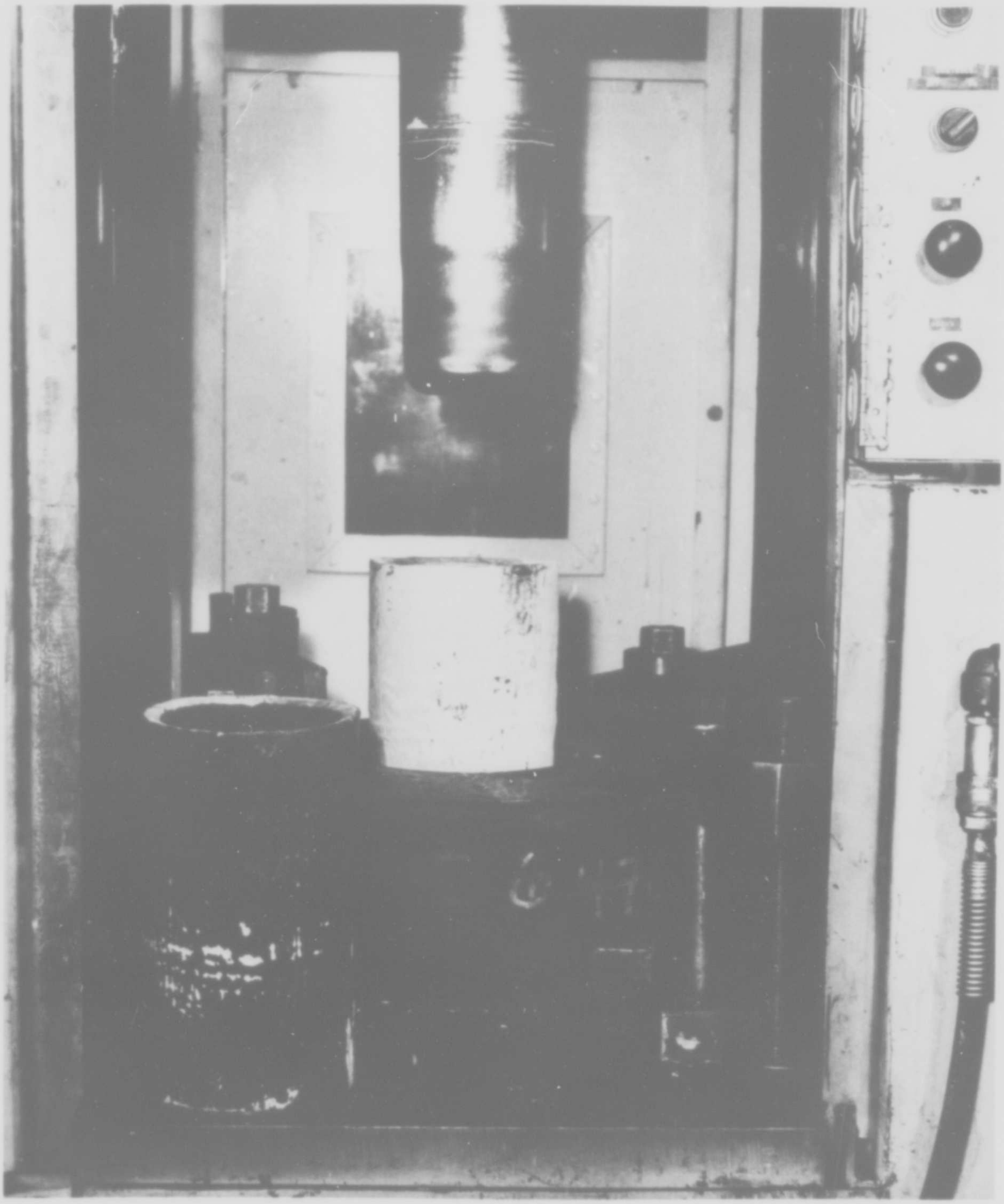
8. SHIPMENTS

8.1 In fulfillment of the subject contract the following shipments were made to Picatinny Arsenal, Dover, New Jersey, as indicated:

LOT NO. (YCC)	QTY.	DESCRIPTION	SHIP DATE
92-1	10	XM657E1 Projectiles	1 Apr 67
92-2	30	XM657E1 Projectiles	3 May 67
92-3	10	XM657E1 Projectiles	18 May 67
42-4	100	XM657E1 Projectiles (50 w/Base Cover Plates)	5 Jul 67
42-5	94	XM657E1 Projectiles	17 Jul 67
92-6	62	XM657E1 Projectiles	15 Sep 67
92-6	4	XM657E1 Projectiles (w/o Band-Spec. Heat Treat)	13 Oct 67
92-7	216	XM657E1 Projectiles	19 Oct 67
92-7	216	XM657E1 Projectiles	27 Oct 67
92-7	216	XM657E1 Projectiles	3 Nov 67
92-7	292	XM657E1 Projectiles	29 Nov 67

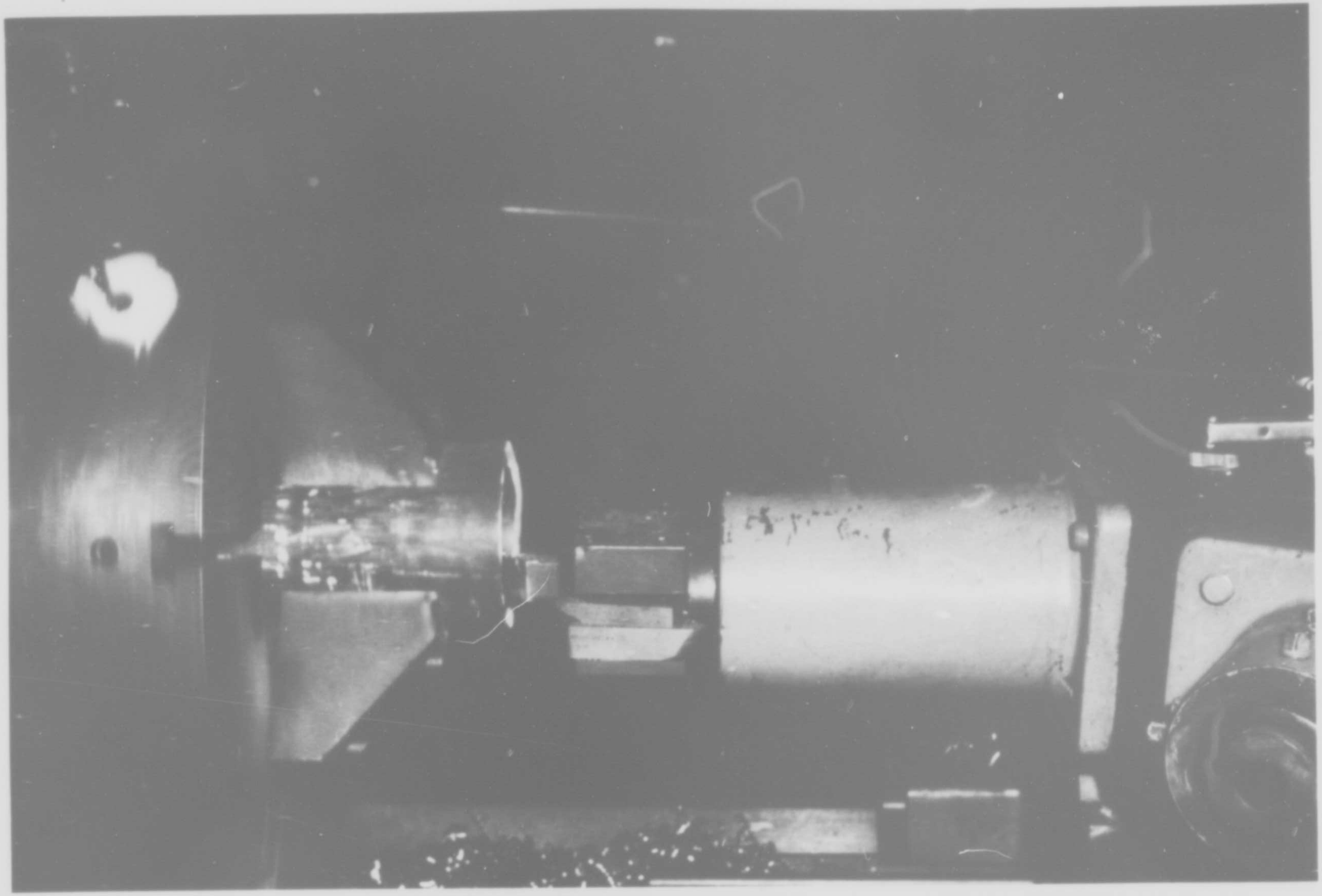
APPENDIX A

PHOTOGRAPHS



PHOTOGRAPH NO. 8121
First Cold Draw 152-mm, XM657E1.

CHAMBERLAIN MANUFACTURING CORPORATION



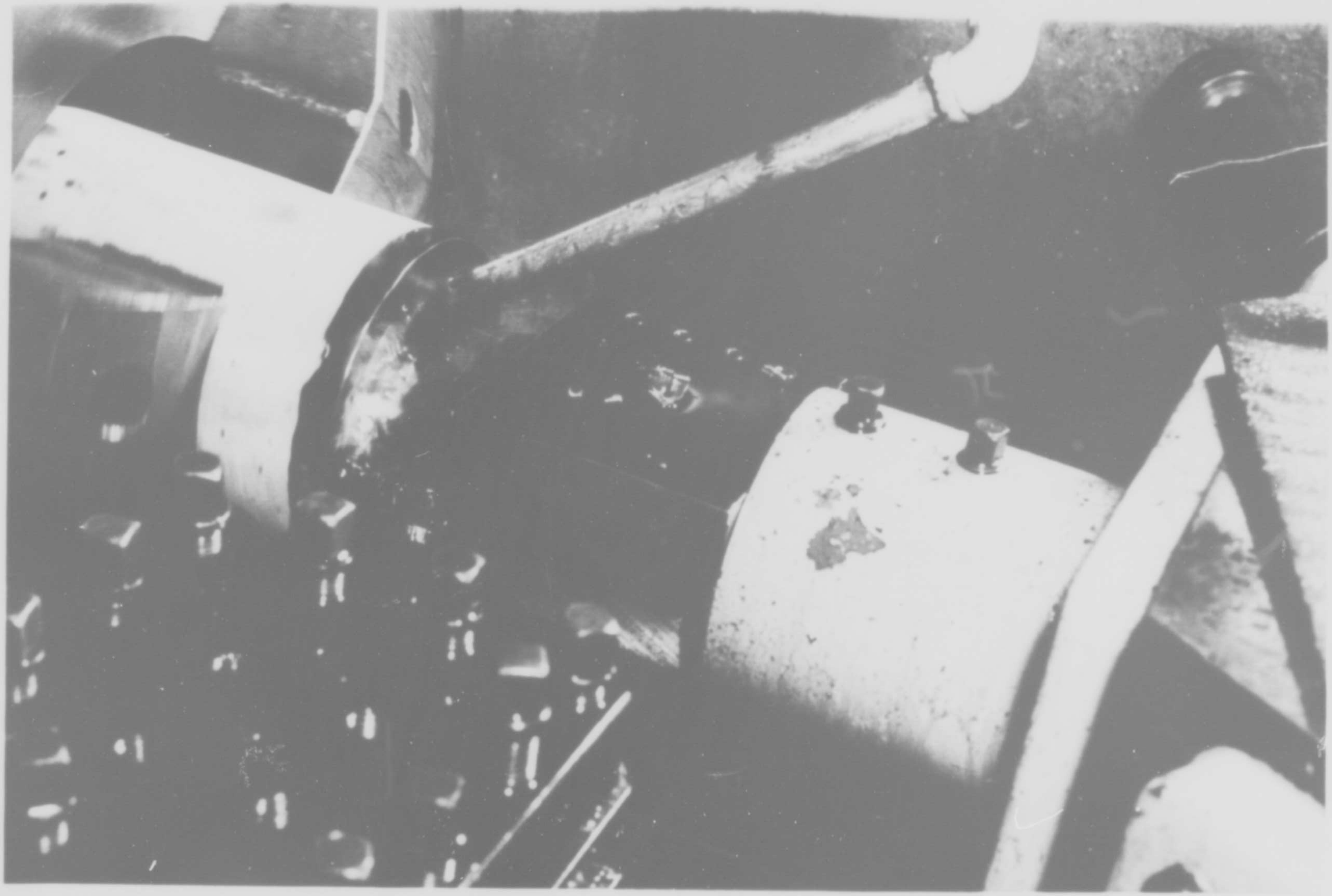
PHOTOGRAPH NO. 8123
Trim After First Cold Draw 152-mm, XM657E1.

CHAMBERLAIN MANUFACTURING CORPORATION

PHOTO NO. 8167

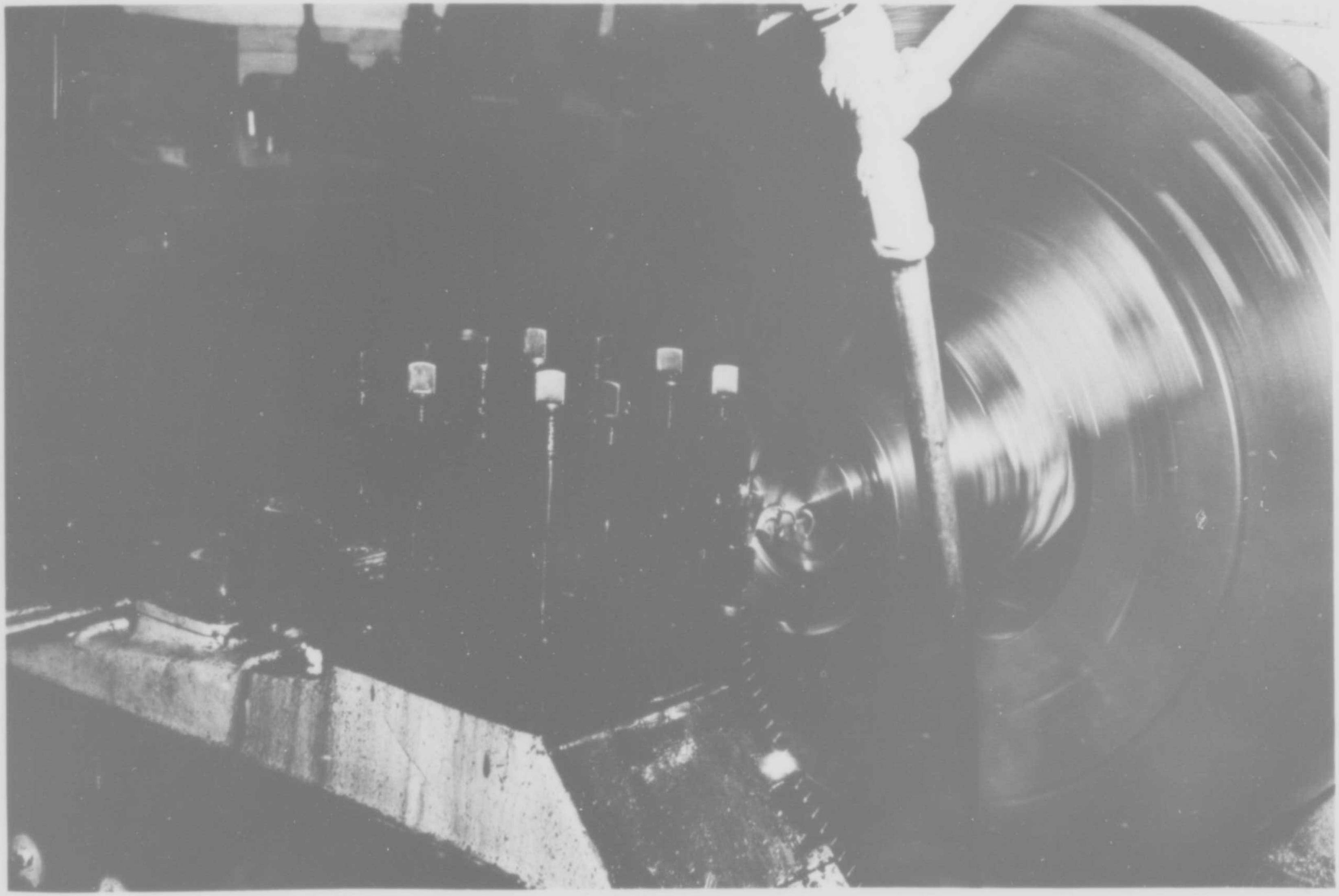
Partially Drawn Can For 152-mm, XM657E1 Projectile. (U)

CHAMBERLAIN MANUFACTURING CORPORATION



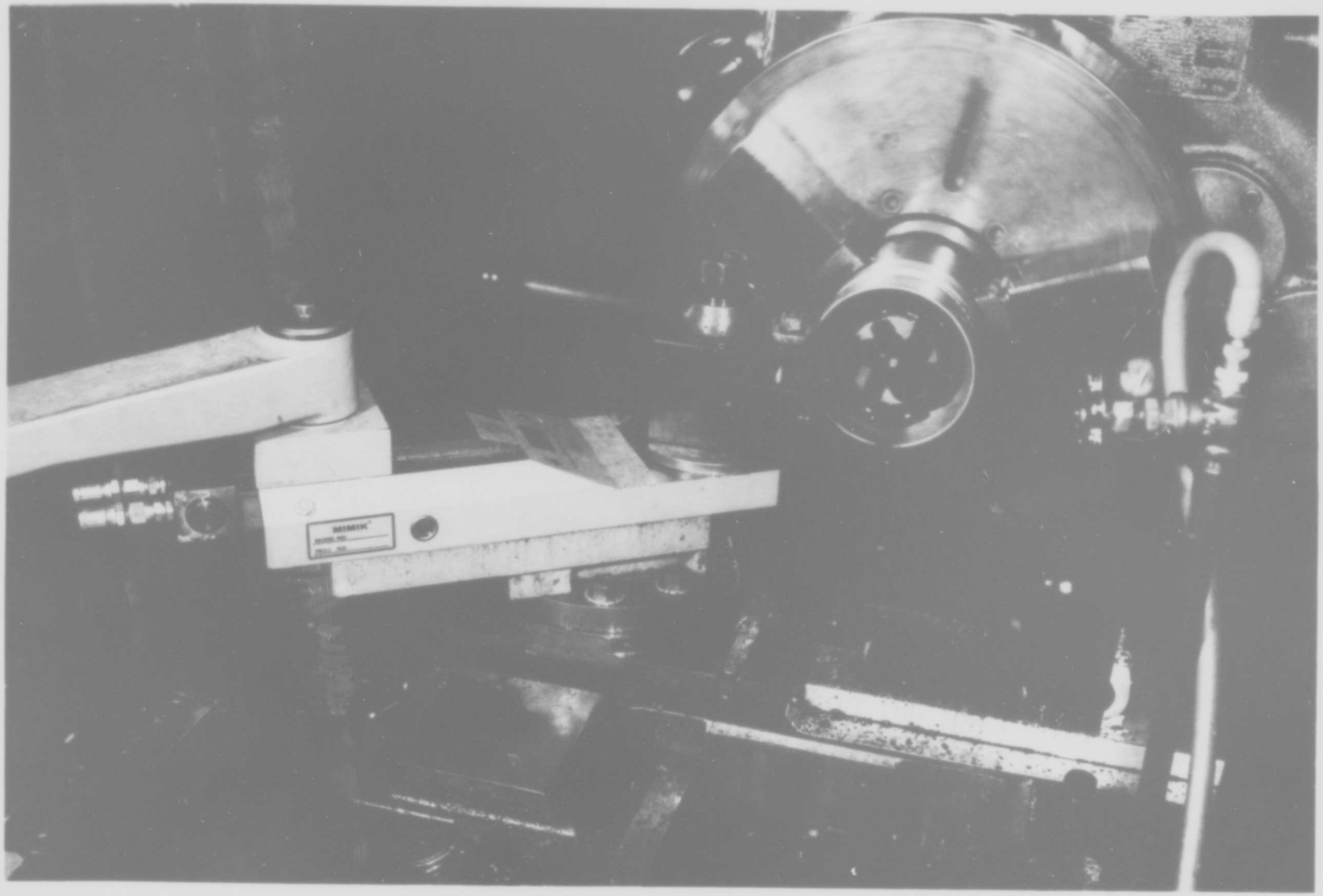
PHOTOGRAPH NO. 8066
Trepan Machining Of Base Cavity On Projectile For Cartridge, HE, 152-mm, XM657.

CHAMBERLAIN MANUFACTURING CORPORATION



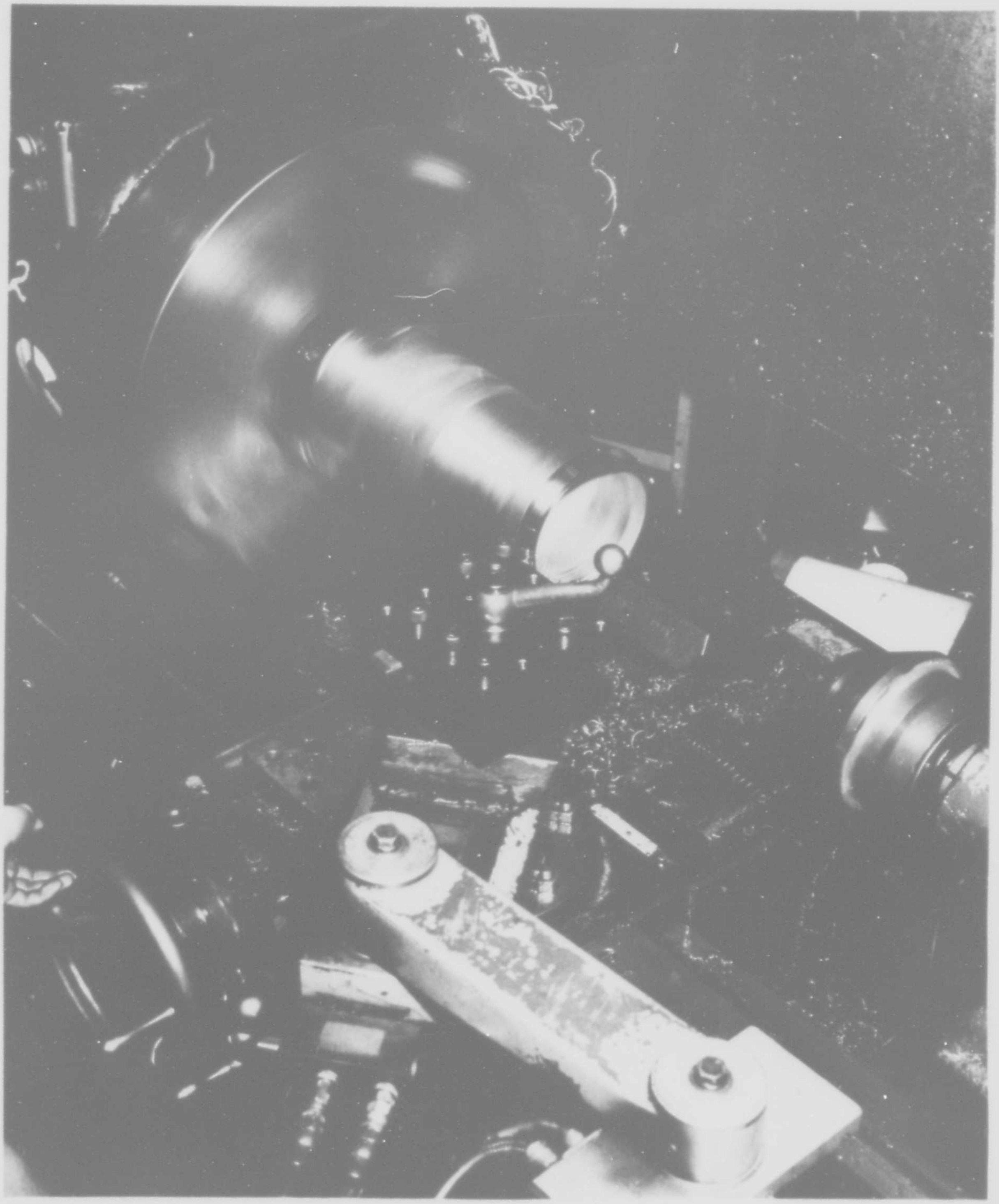
PHOTOGRAPH NO. 8067
Finish Machining Of Base Cavity On Projectile For Cartridge, HE, 152-mm, XM657.

CHAMBERLAIN MANUFACTURING CORPORATION



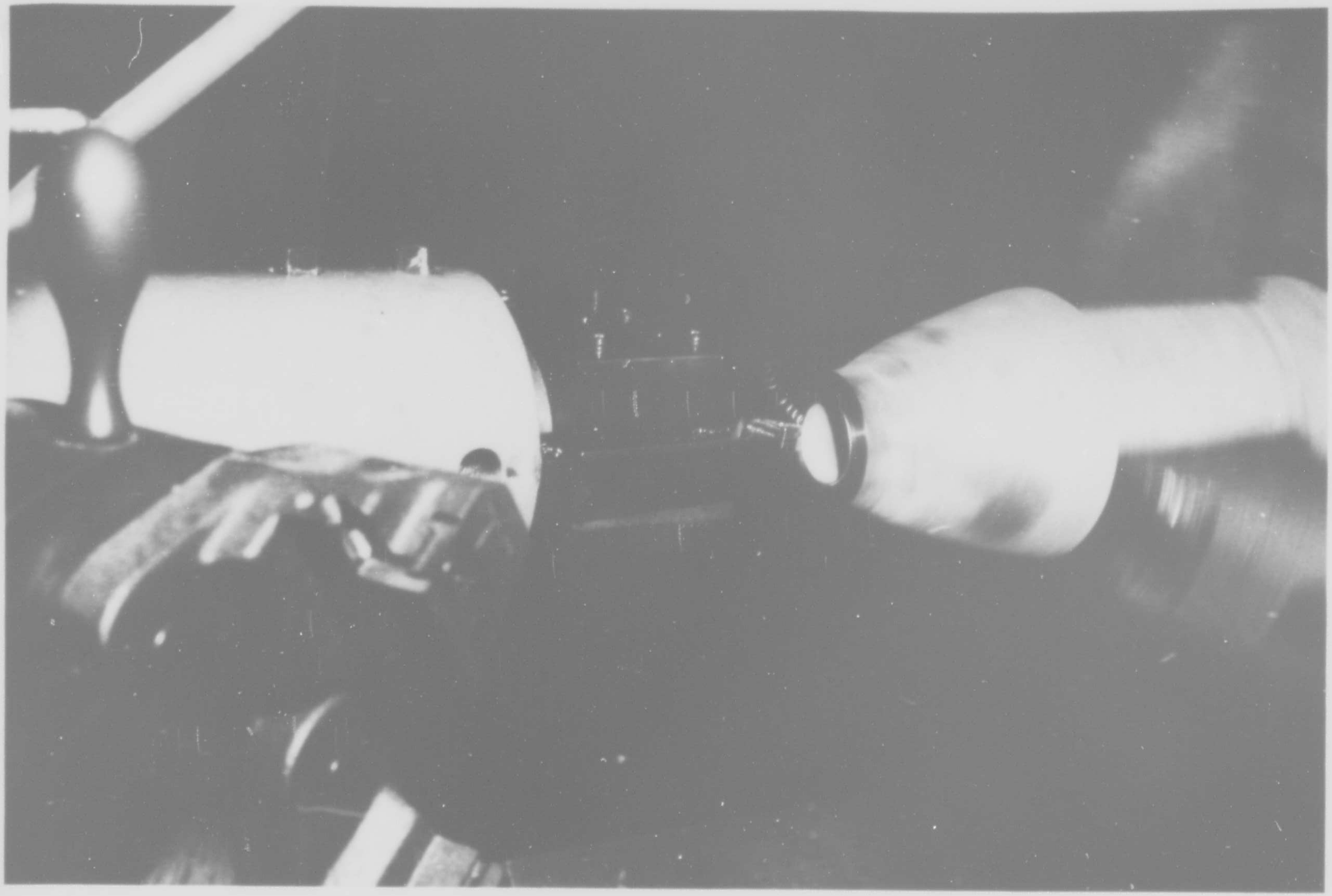
PHOTOGRAPH NO. 8068
Threading Base Of Projectile For Cartridge, HE, 152-mm, XM657.

CHAMBERLAIN MANUFACTURING CORPORATION



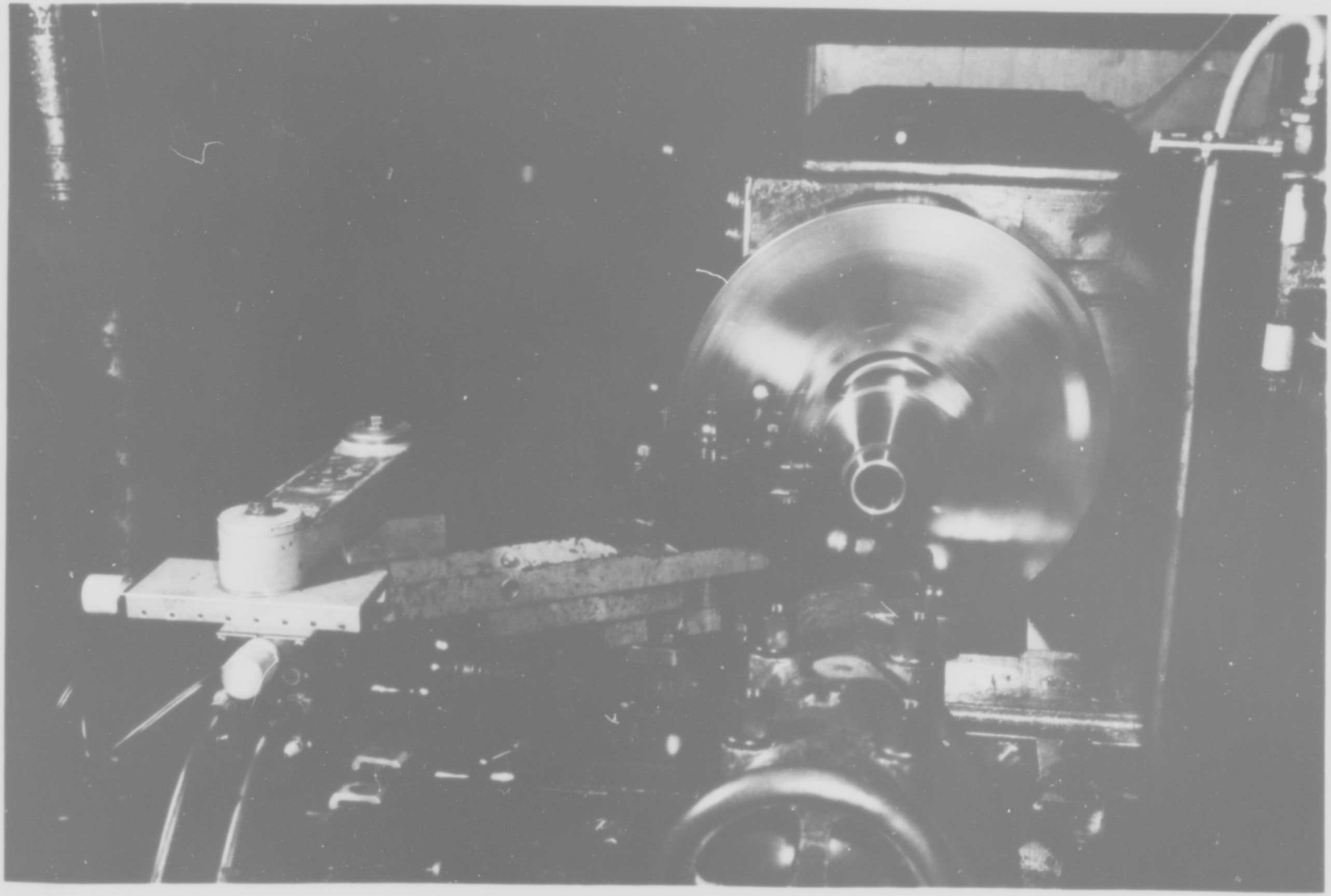
PHOTOGRAPH NO. 8101
Contour Machining Of Projectile, 152-mm, HE, XM657E1 Before Necking Operation.

CHAMBERLAIN MANUFACTURING CORPORATION



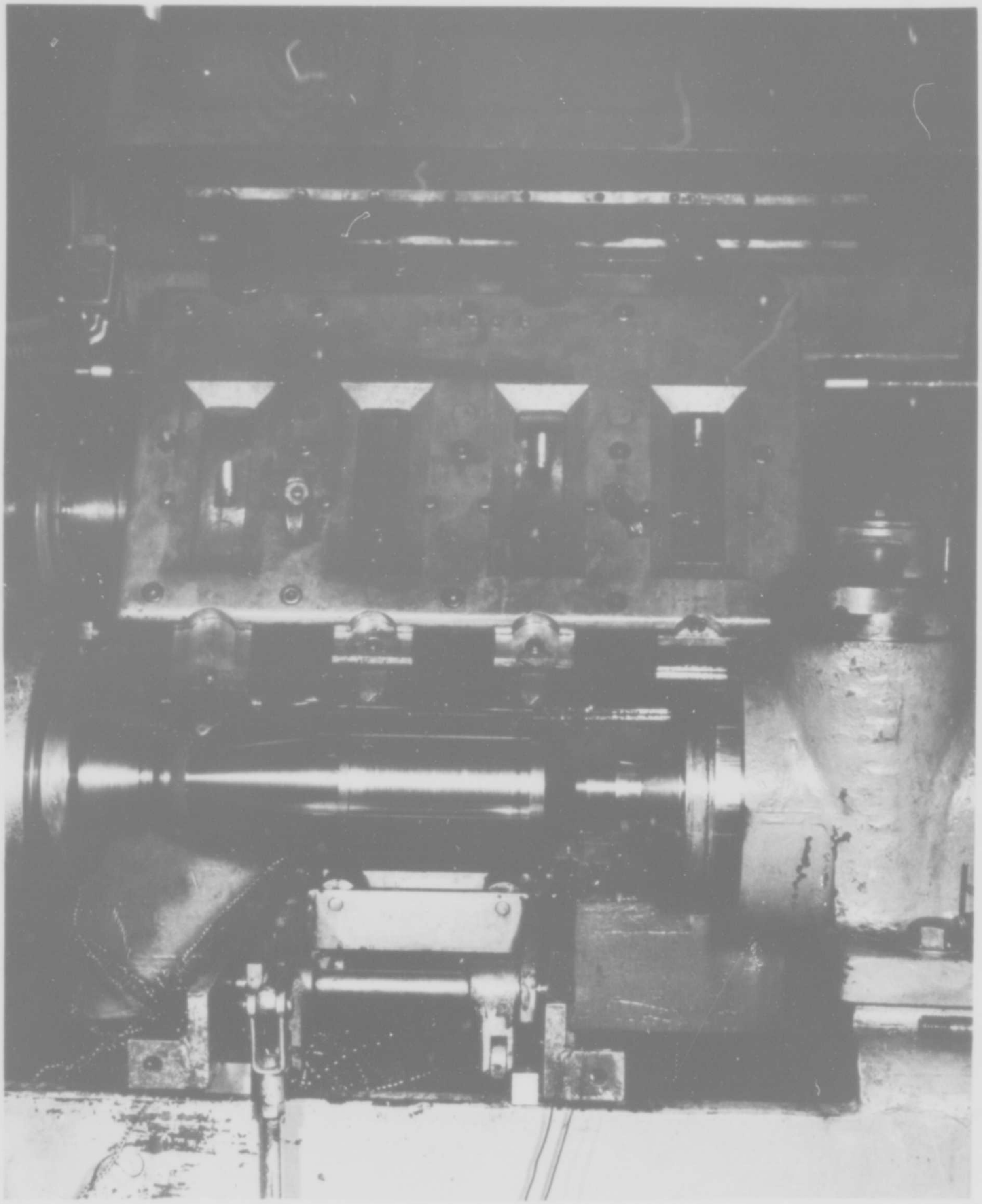
PHOTOGRAPH NO. 8064
Facing And Rough Boring Operation On Projectile For Cartridge, HE, 152-mm, XM657.

CHAMBERLAIN MANUFACTURING CORPORATION



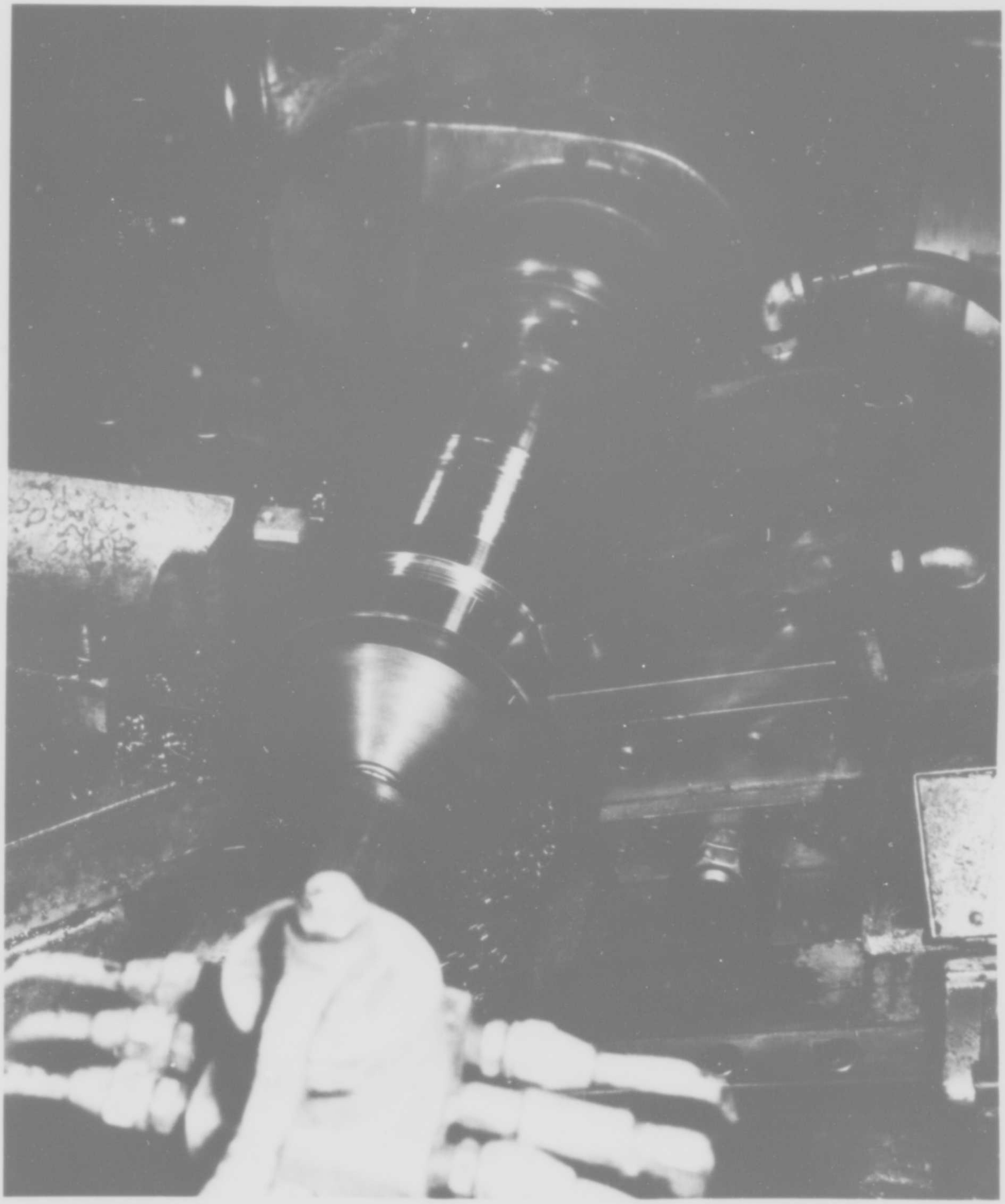
PHOTOGRAPH NO. 8065
Machining Of Nose Contour On Projectile For Cartridge, HE, 152-mm, XM657.

CHAMBERLAIN MANUFACTURING CORPORATION



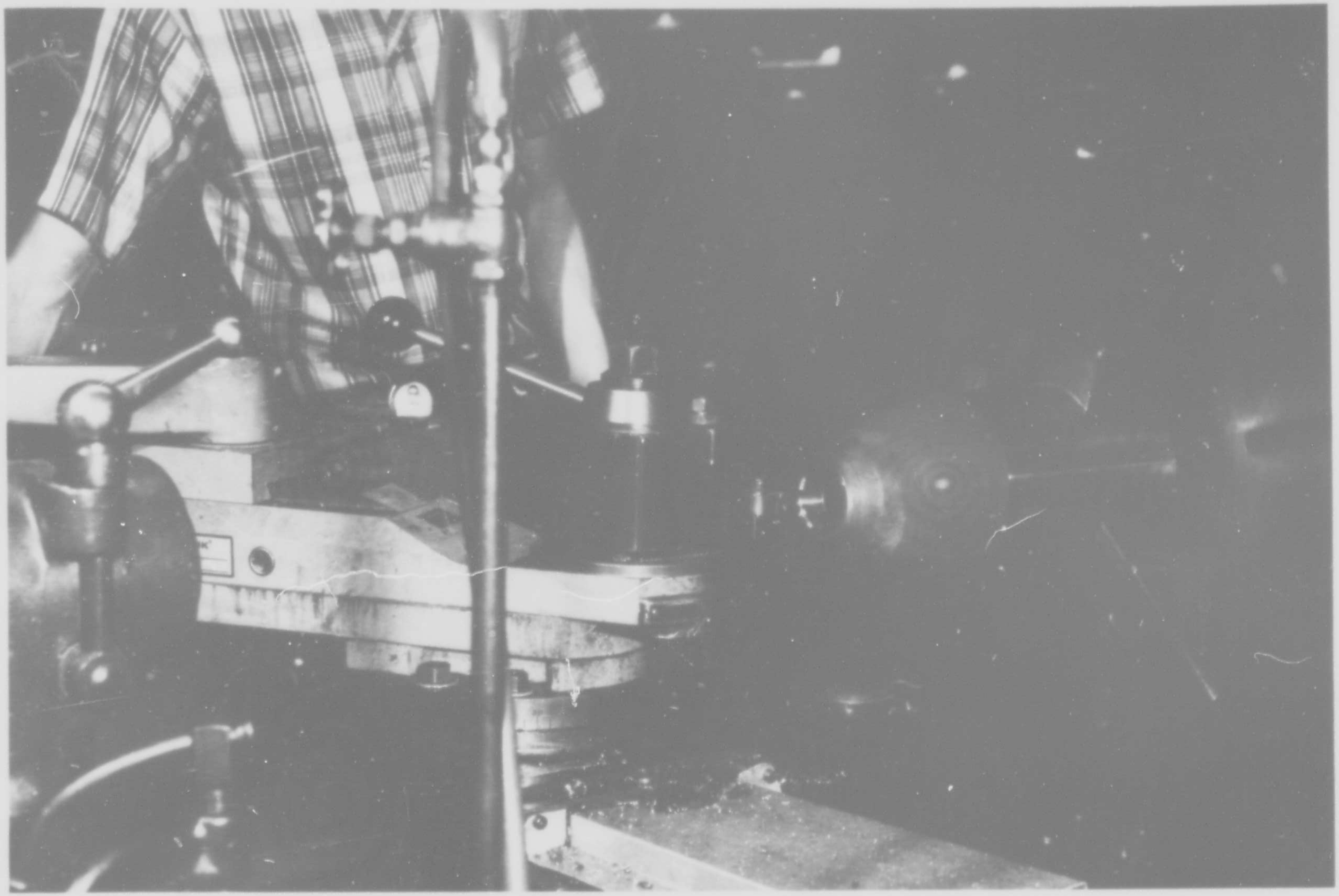
PHOTOGRAPH NO. 8116
Finish Turn Ogive Rough Turn Bourrelet 152-mm, XM657E1.

CHAMBERLAIN MANUFACTURING CORPORATION



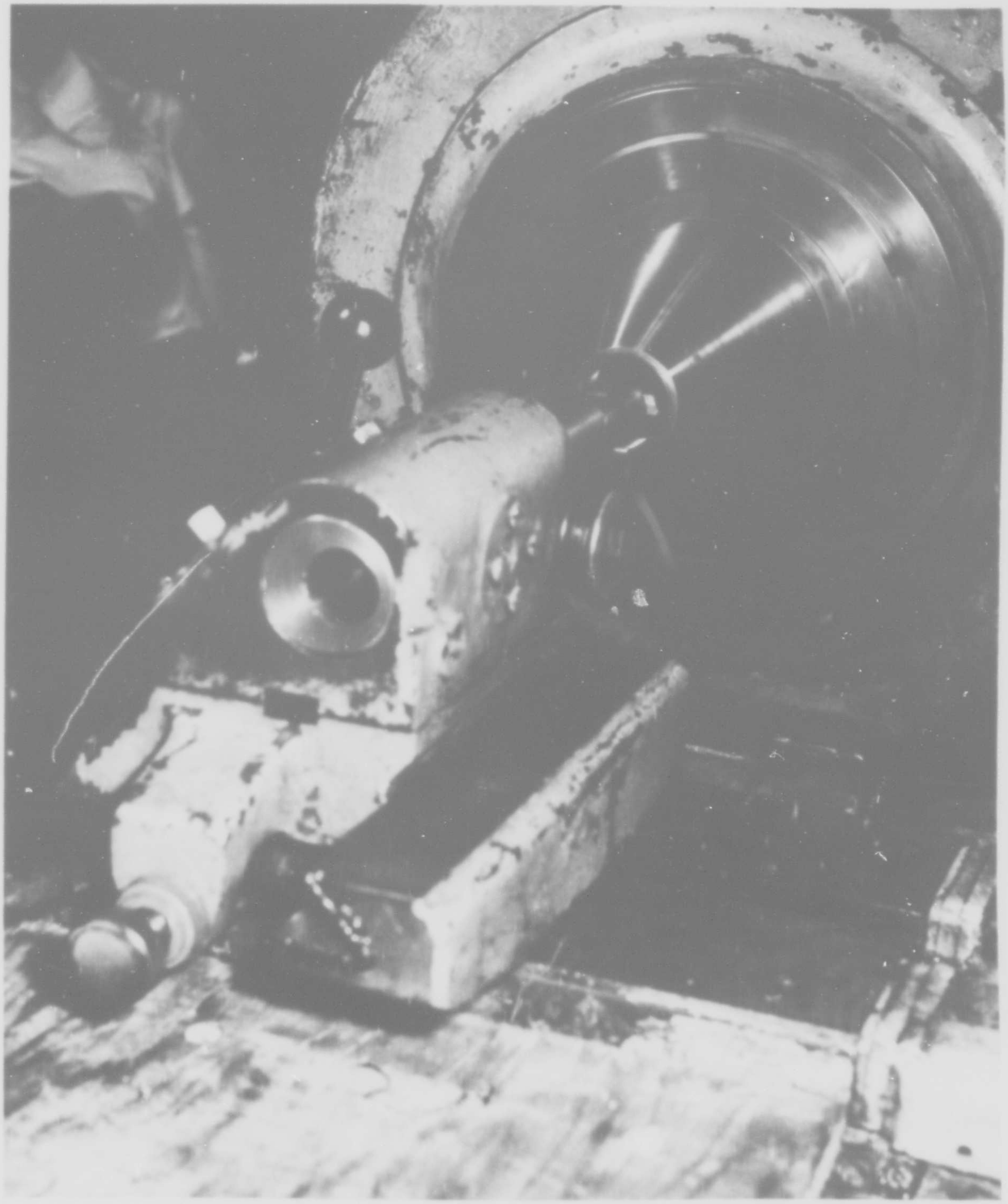
PHOTOGRAPH NO. 8117
Turn Band Groove And Bourrelet Weight Relief 152-mm, XM657E1.

CHAMBERLAIN MANUFACTURING CORPORATION



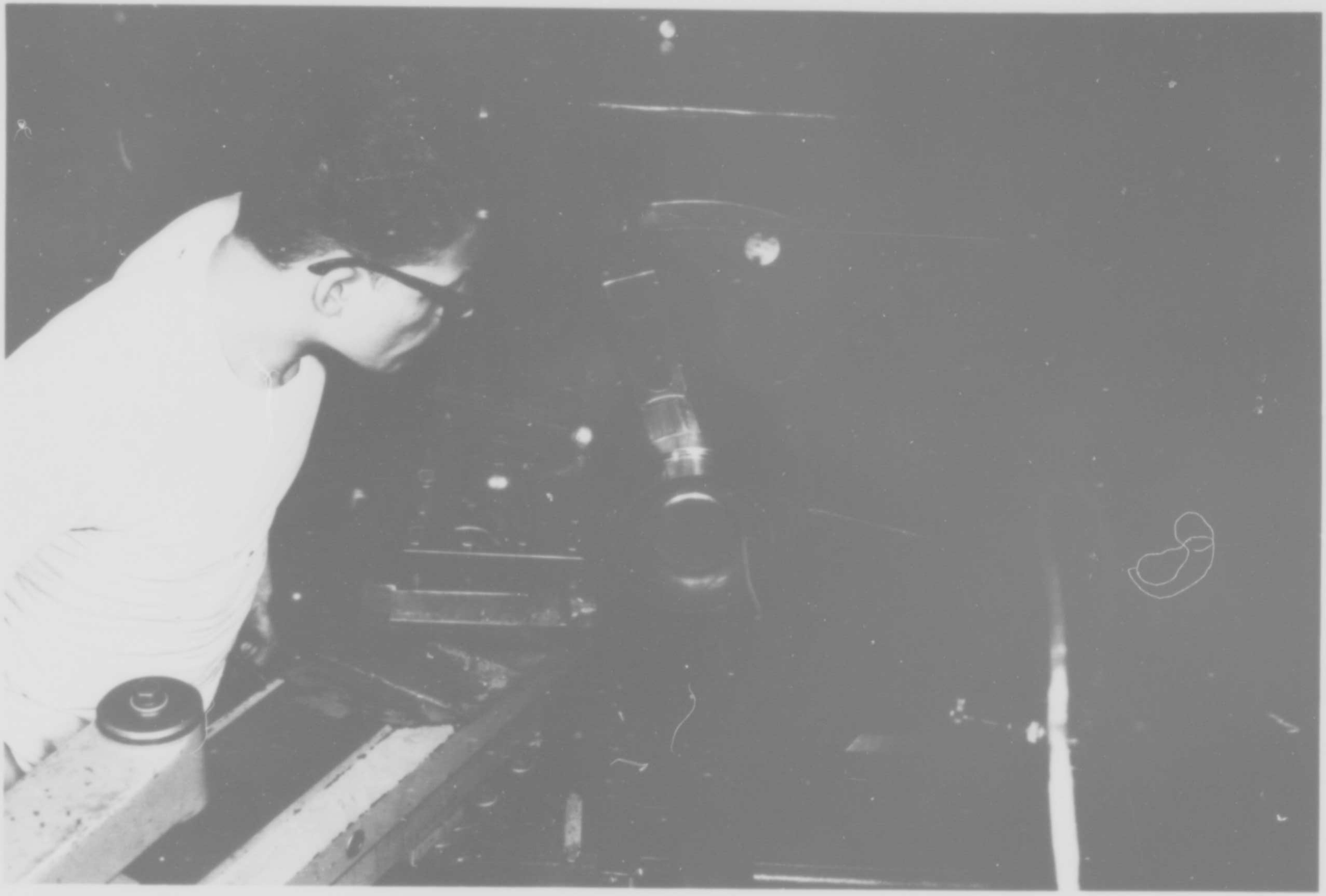
PHOTOGRAPH NO. 8118
Bore Nose I.D. Chamfer And Cut To O.A.L. 152-mm, XM657E1.

CHAMBERLAIN MANUFACTURING CORPORATION



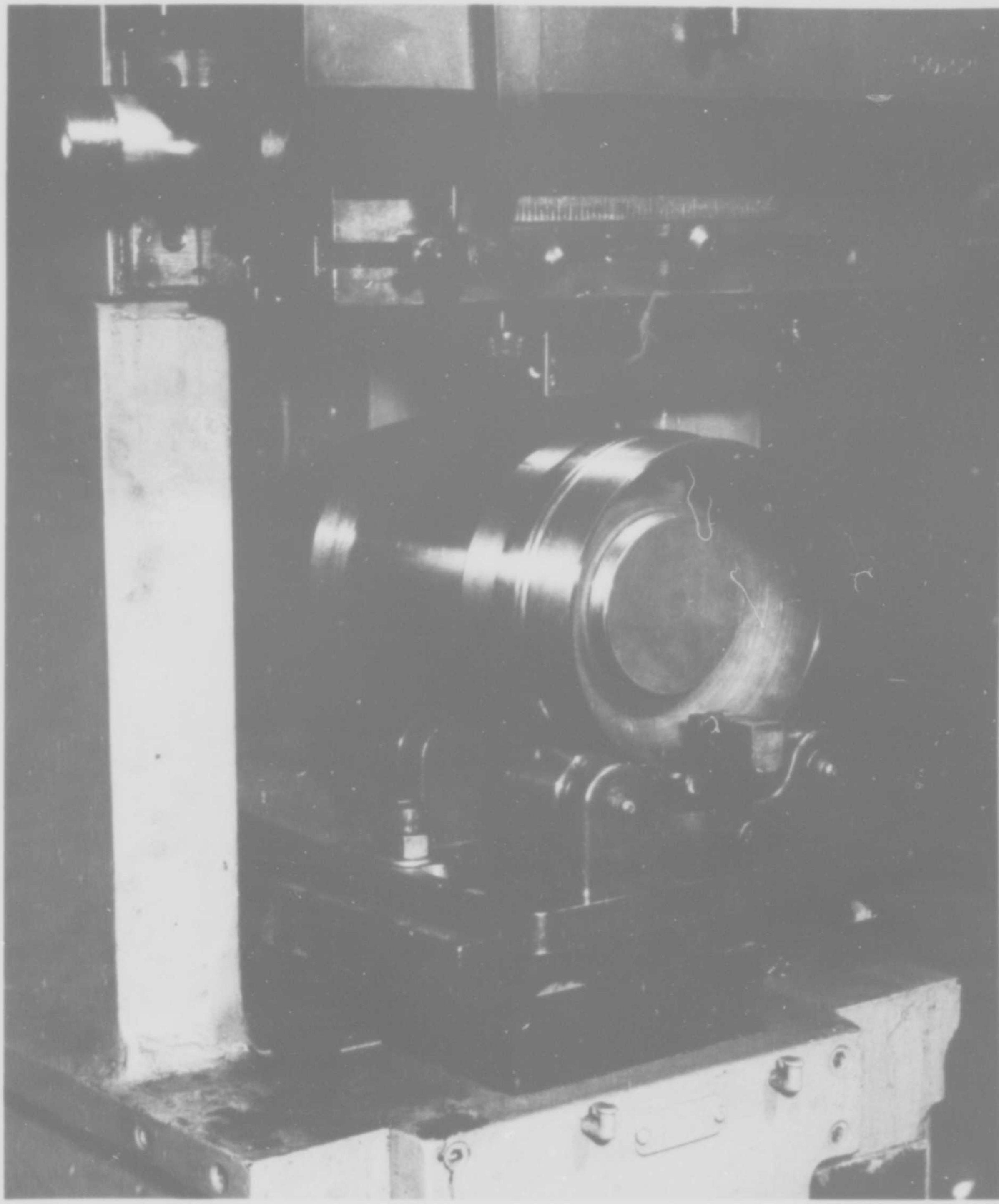
PHOTOGRAPH NO. 8119
Thread Nose 152-mm, XM657E1.

CHAMBERLAIN MANUFACTURING CORPORATION



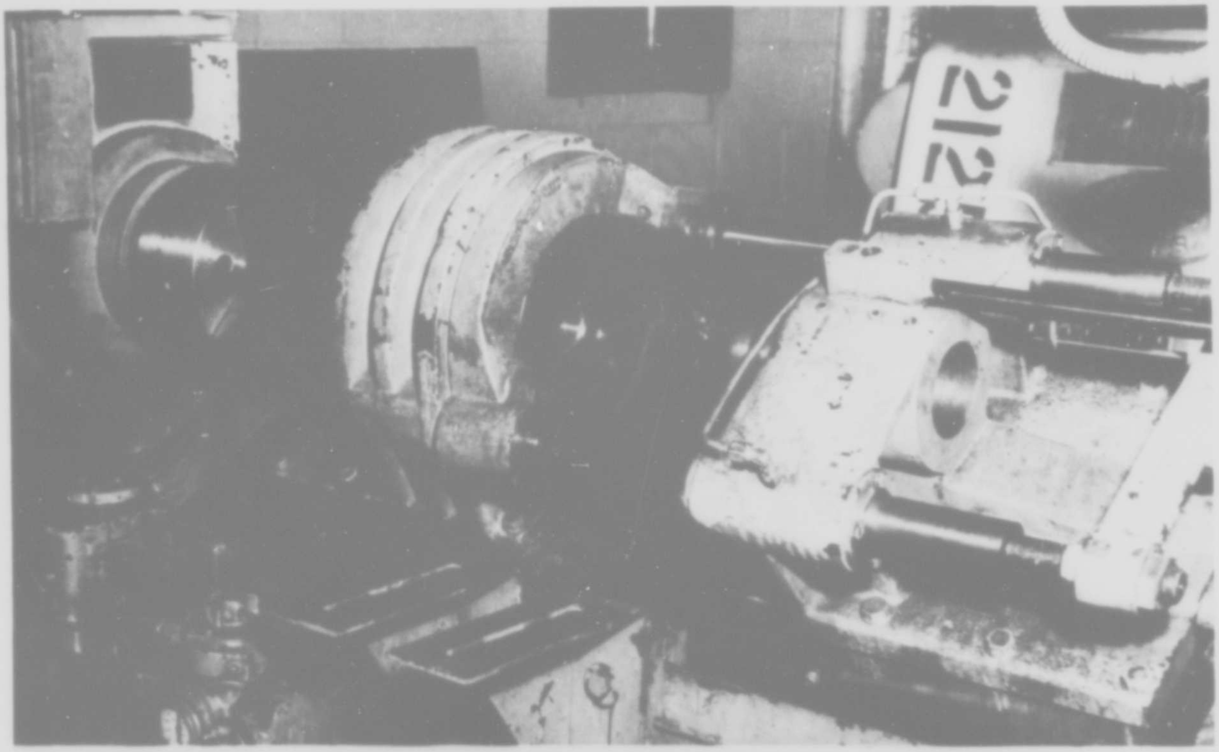
PHOTOGRAPH NO. 8120
17° Band Groove Undercut 152-mm, XM657E1.

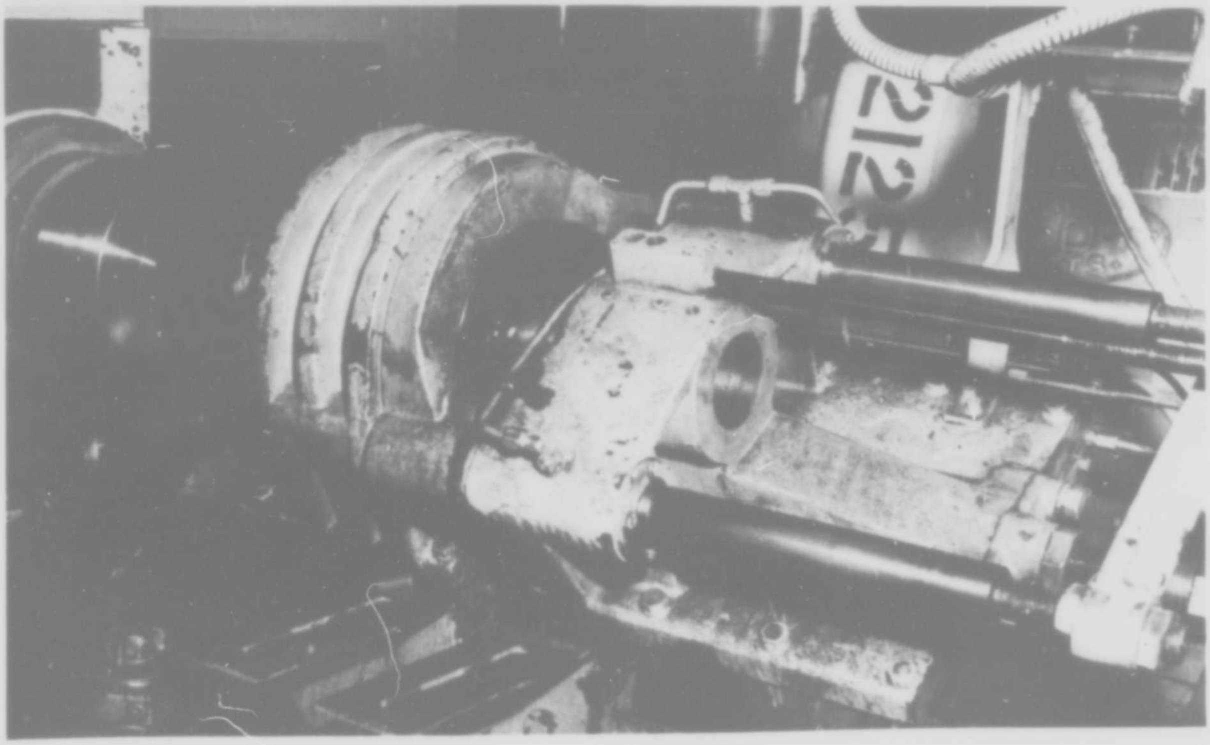
CHAMBERLAIN MANUFACTURING CORPORATION



PHOTOGRAPH NO. 8122
Stamp Nomenclature 152-mm, XM657E1.

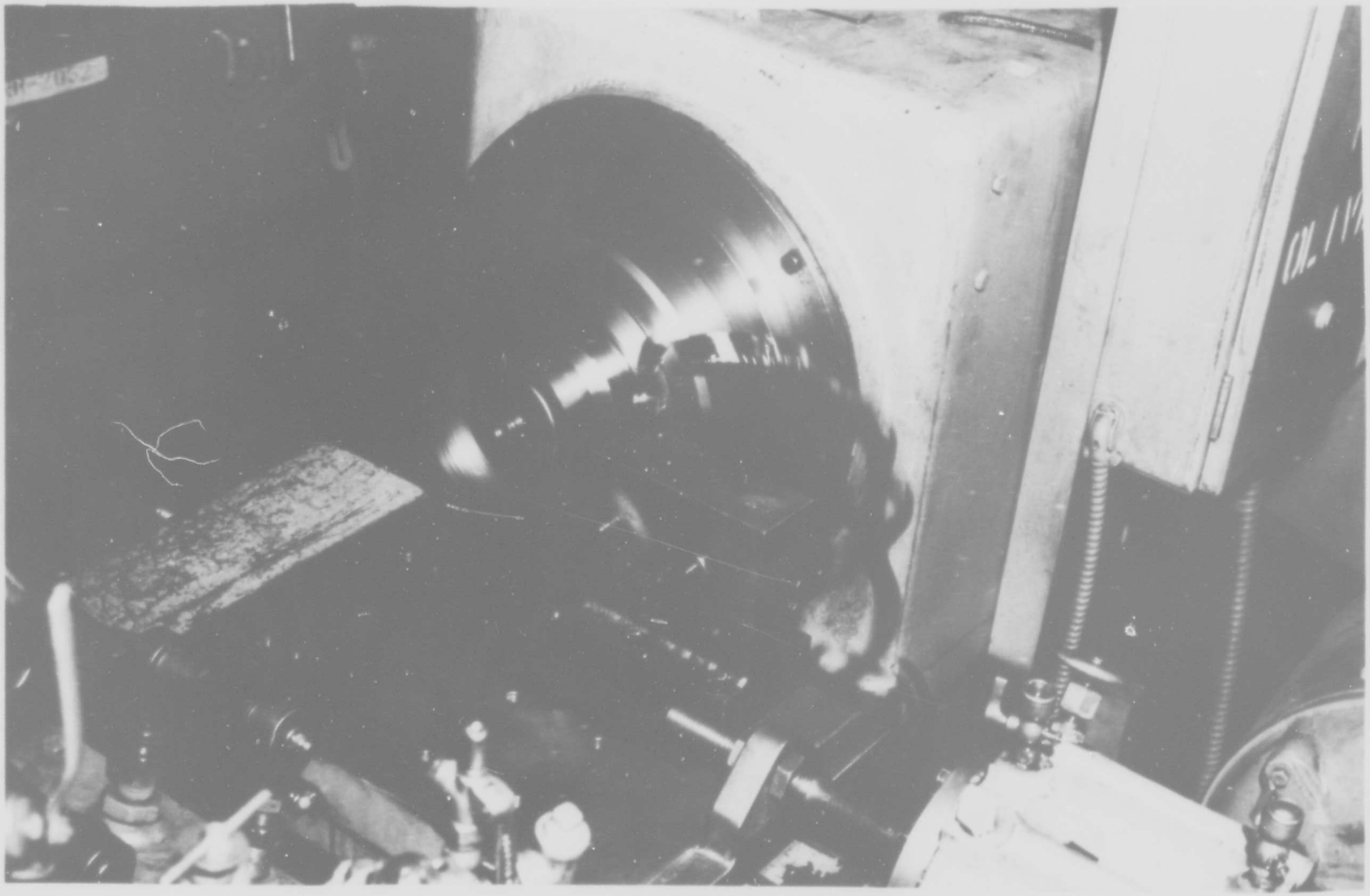
CHAMBERLAIN MANUFACTURING CORPORATION





PHOTOGRAPH NO. 8206
Rough Bore Nose And Establish Overall Length, 152-mm, XM657E1 Projectile. Reid Lathe.

CHAMBERLAIN MANUFACTURING CORPORATION

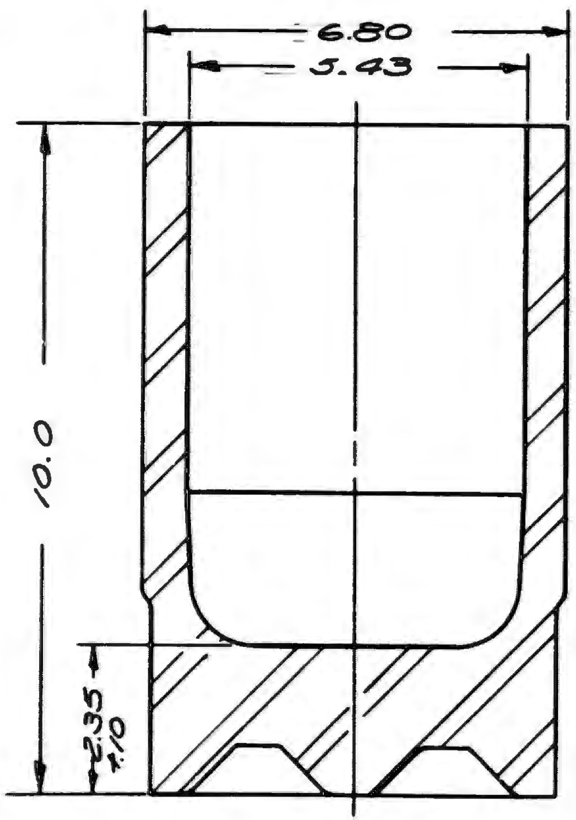


PHOTOGRAPH NO. 8207
Rough Turn Band Seat, 152-mm, XM657E1 Projectile. Hepburn Lathe.

CHAMBERLAIN MANUFACTURING CORPORATION

APPENDIX B

PROCESS DRAWINGS

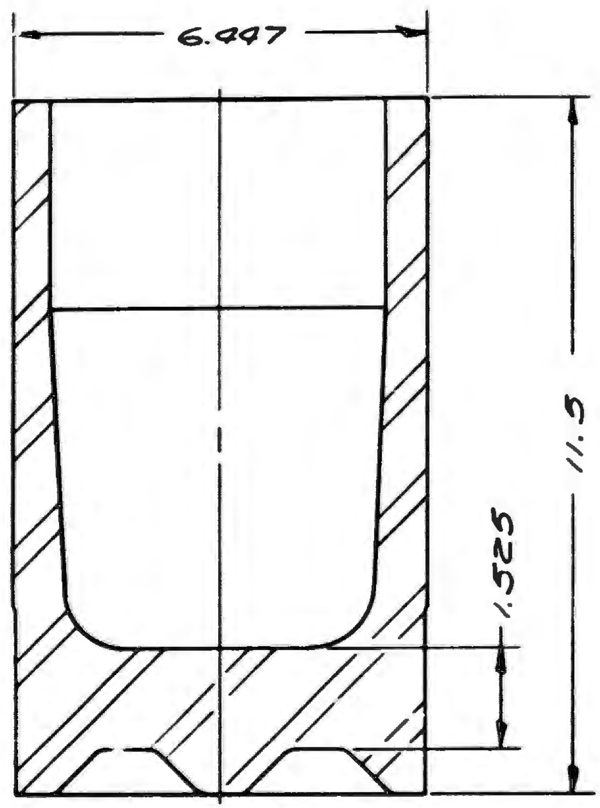


OPER #5
EXTRUSION
TONNAGE : 800T
RECEIVED FROM SCRANTON

OPER #10
ISOTHERMAL ANNEAL
HEVI-DUTY FURNACE - 1975°; 2½ HRS.
1200° 12 HRS. OR E&S FURNACE
1ST ZONE - 1975 F°
2ND ZONE - 1200 F°
3RD ZONE - 1200 F°
4TH ZONE - 1200 F°
10 PCS PER TRAY - 30 MIN PUSH

OPER #15
SHOT BLAST
PANGBORN ROTOBLAST

OPER #18
TUMBLE BLAST
PANGBORN TUMBLEBLAST



OPER #20

METAL PREP FOR COLD DRAW

STAGE 1: CLEAN FOR ONE MINUTE
(PARCO CLEANER NO. 357, 5 GAL/
170 GAL. H_2O)

STAGE 2: HOT RINSE 180-200°F (H_2O)

STAGE 3: PHOSPHATIZE, 4 MIN., 170-180° MAX.
COATING 400 MG. PER. FT²
(52 LBS. BONDERITE 181X PER 100 GAL.
WATER, 5 OZ. ACCELERATOR 130
PER 100 GAL. WATER)

STAGE 4: HOT RINSE 180°-200°F H_2O

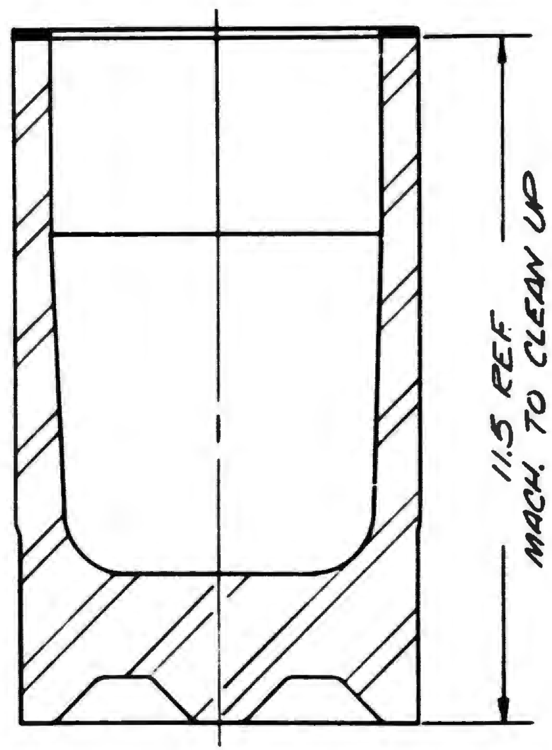
STAGE 5: RINSE, QUICK DIP, 160°F
(PARCOLENE NO. 21, 2.5 OZ. PER
GAL. H_2O)

STAGE 6: DRY FILM SOAP COAT, 4 MIN., 170°-175°F
(BONDERLUBE NO. 234, 75 LBS.
PER 170 GAL WATER)

OPER #25

FIRST COLD DRAW

PRESS : WATSON-STILLMAN 250T
PUNCH : J7897-18A
DIE : J7847A-11D



OPER #30

METAL PREP FOR MACHING

STAGE 1: CLEAN, 4 MIN., 180°-200°F
(PARCO CLEANER NO. 357, 5 GAL/170 GAL H_2O)

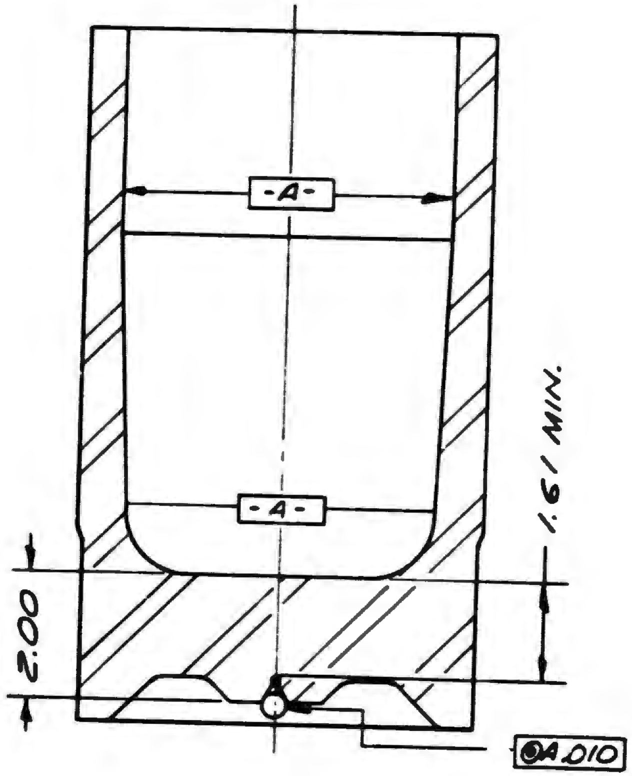
STAGE 2: HOT RINSE DIP, 180°-200°F (H_2O)

STAGE 3: ACID BATH 3 MIN. MINIMUM, UNTIL
SCALE IS REMOVED

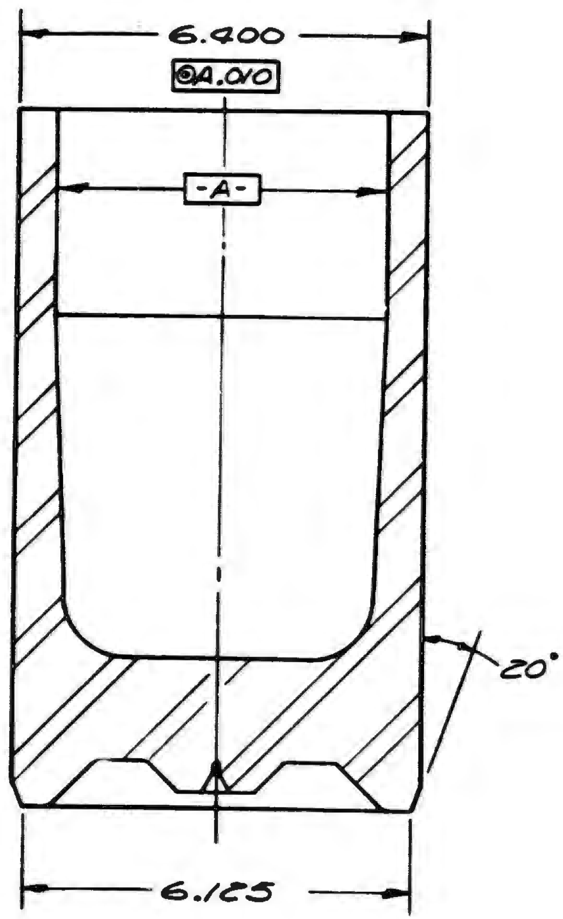
STAGE 4: NEUTRALIZER, 2 MIN.
PARKER ACCELERATOR NO. 130 5% SOL.

OPER #35

MACHINE OPEN END



OPER #40
CENTERDRILL BASE
MACH: SENECA FALLS
CENTERDRILL



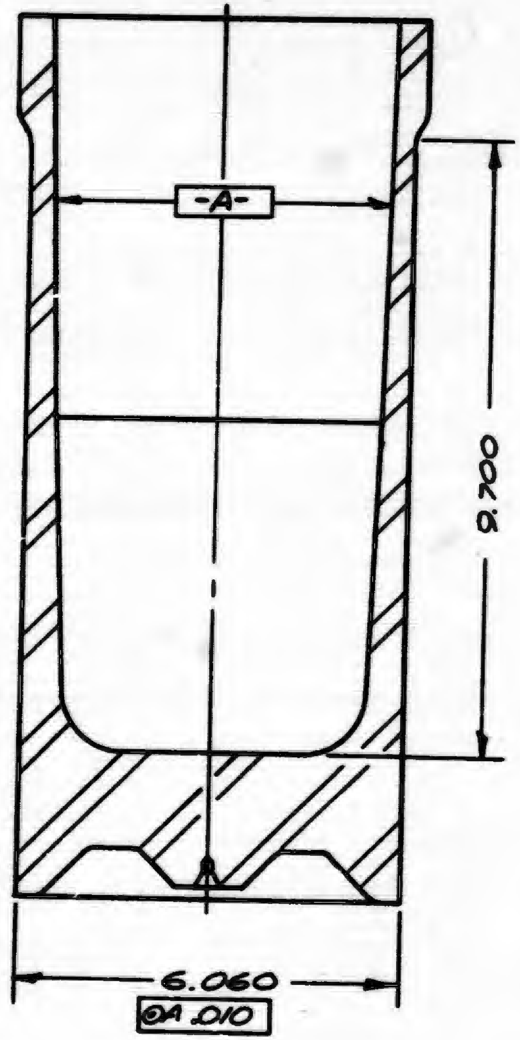
OPER #45
MACHINE O.D.
MACH: STAMETS

OPER #50
ANNEAL
R&S FURNACE - 1300°F
5 MIN. PUSH - 10 PCS. PER TRAY

OPER. #52
ROTO-BLAST & TUMBLE BLAST

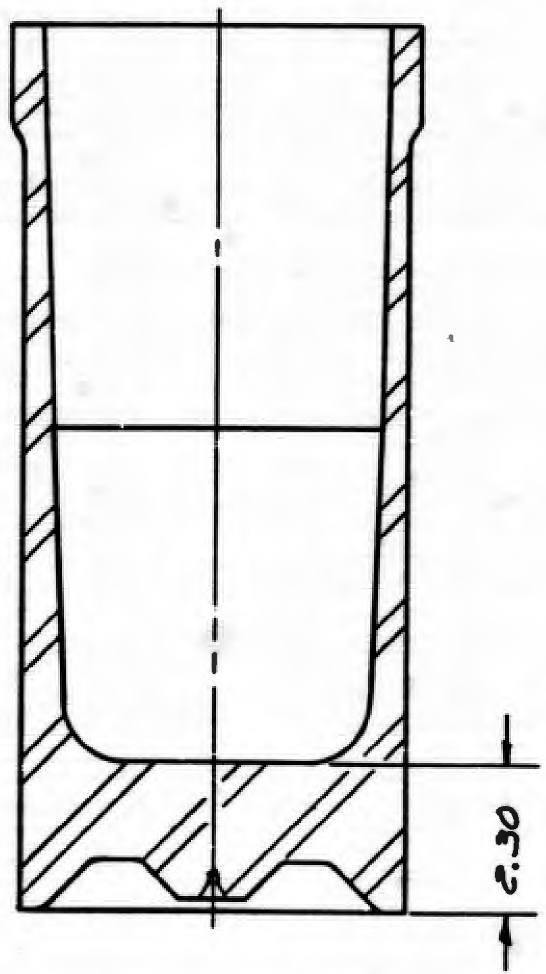
OPER #55
METAL PREP FOR COLD DRAW

STAGE 1: CLEAN FOR ONE MIN. (PARCO CLEANER NO. 357, 5 GAL./170 GAL H_2O)
STAGE 2: HOT RINSE 180°-200°F (OVER FLOWING H_2O)
STAGE 3: PHOSPHATIZE: 4 MIN., 170°-180°F, MAX. COATING 400 MGS. PER SQ.FT. (52 LBS. BONDERITE 181X PER 100 GAL. WATER, 5 OZ. ACCELERATOR 130 PER 100 GAL. WATER)
STAGE 4: HOT RINSE 180°-200°F (H_2O)
STAGE 5: RINSE, QUICK DIP, 160°F (PARCOLENE NO. 21, 2.5 OZ. PER GAL. H_2O)
STAGE 6: DRY FILM SOAP COAT, 4 MIN., 170°-175°F. (BONDERLUBE NO. 234, 75 LBS. PER 170 GAL. WATER)



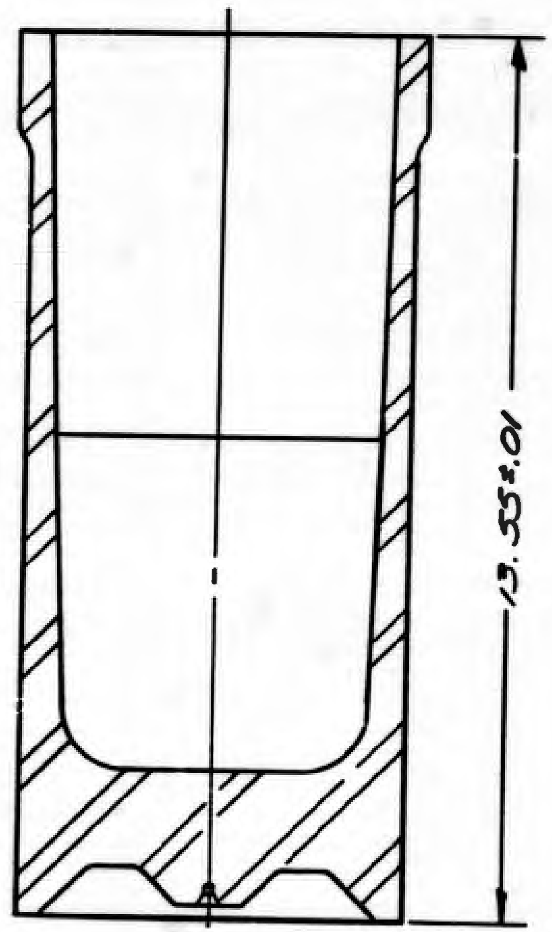
OPER #60
PARTIAL COLD DRAW & BACKOUT
PRESS - 800T ELMES
PUNCH - J7897-18A
DIE - 6.125 DIA.

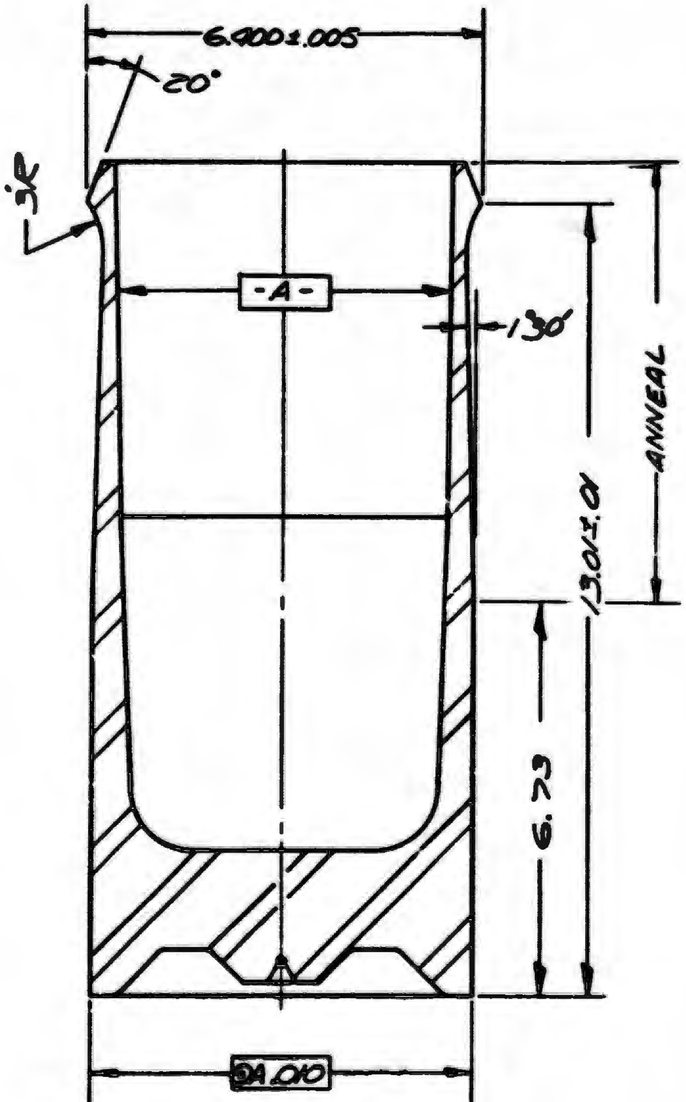
OPER #65
METAL PREP FOR MACHING
STAGE 1: CLEAN, 4 MIN., 180°-200°F
(PARCO CLEANER NO. 357, 3 GAL/170 GAL. H_2O)
STAGE 2: HOT RINSE DIP, 180°-200°F (H_2O)
STAGE 3: ACID BATH, 3 MIN. MINIMUM, UNTIL SCALE
IS REMOVED, 150°-180°F
HCL CONCENTRATION 20°-23° BE
STAGE 4: NEUTRALIZER, 2 MIN
PARKER ACCELERATOR NO. 130
5% SOLUTION



OPER #70
MACH. BASE THICKNESS

OPER #75
MACH. OVERALL LENGTH





OPER #80
CONTOUR NOSE
MACH: STAMETS

OPER #85
ANNEAL NOSE
SALT POT 1300° 30 MIN.

OPER #87
SANDBLAST
ROTOBLAST INSIDE

OPER #90
METAL PREP FOR COLD DRAW

STAGE 1 : CLEAN FOR ONE MIN. (PARCO CLEANER NO. 357, 5 GAL./170 GAL. WATER)

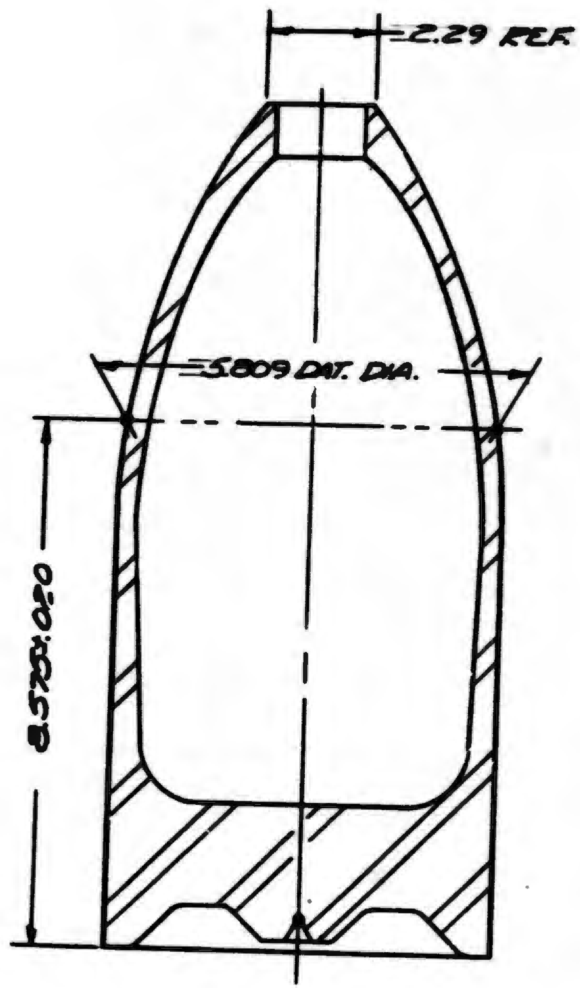
STAGE 2 : HOT RINSE 180°-200°F (H_2O)

STAGE 3 : PHOSPHATIZE, 4 MIN., 170°-180°F MAX. COATING 400 MG. PER SQ.FT. (52 LBS. BONDERITE 181X PER 100 GAL. H_2O, 5 OZ. ACCELERATOR 130 PER 100 GAL. H_2O.)

STAGE 4 : HOT RINSE 180°-200°F (H_2O)

STAGE 5 : RINSE, QUICK DIP 160°F (PARCOLENE NO. 21, 2.5 OZ. PER GAL. H_2O)

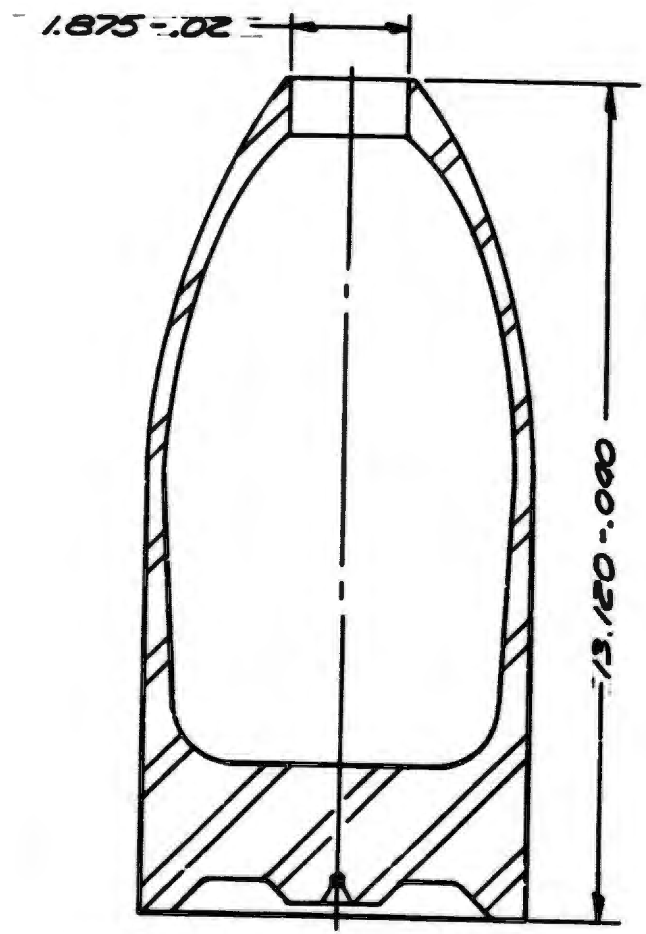
STAGE 6 : DRY SOAP FILM COAT, 4 MIN., 170°-175°F BONDERLUBE NO. 234, 75 LBS. PER 170 GAL. WATER

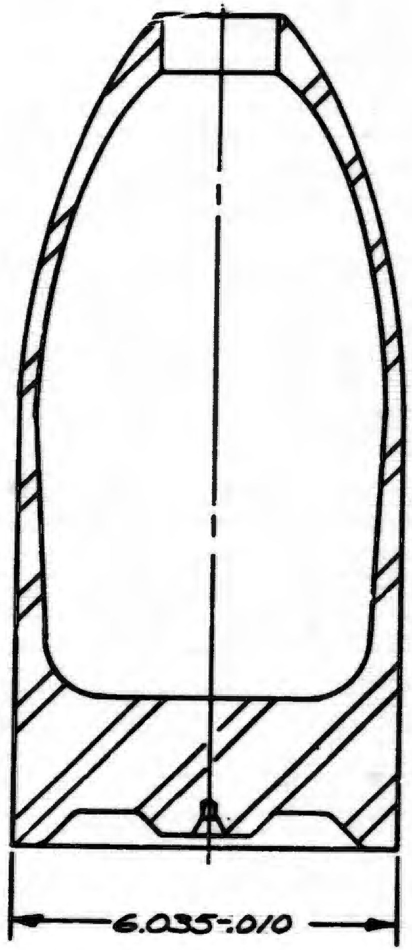


OPER #95
NOSE

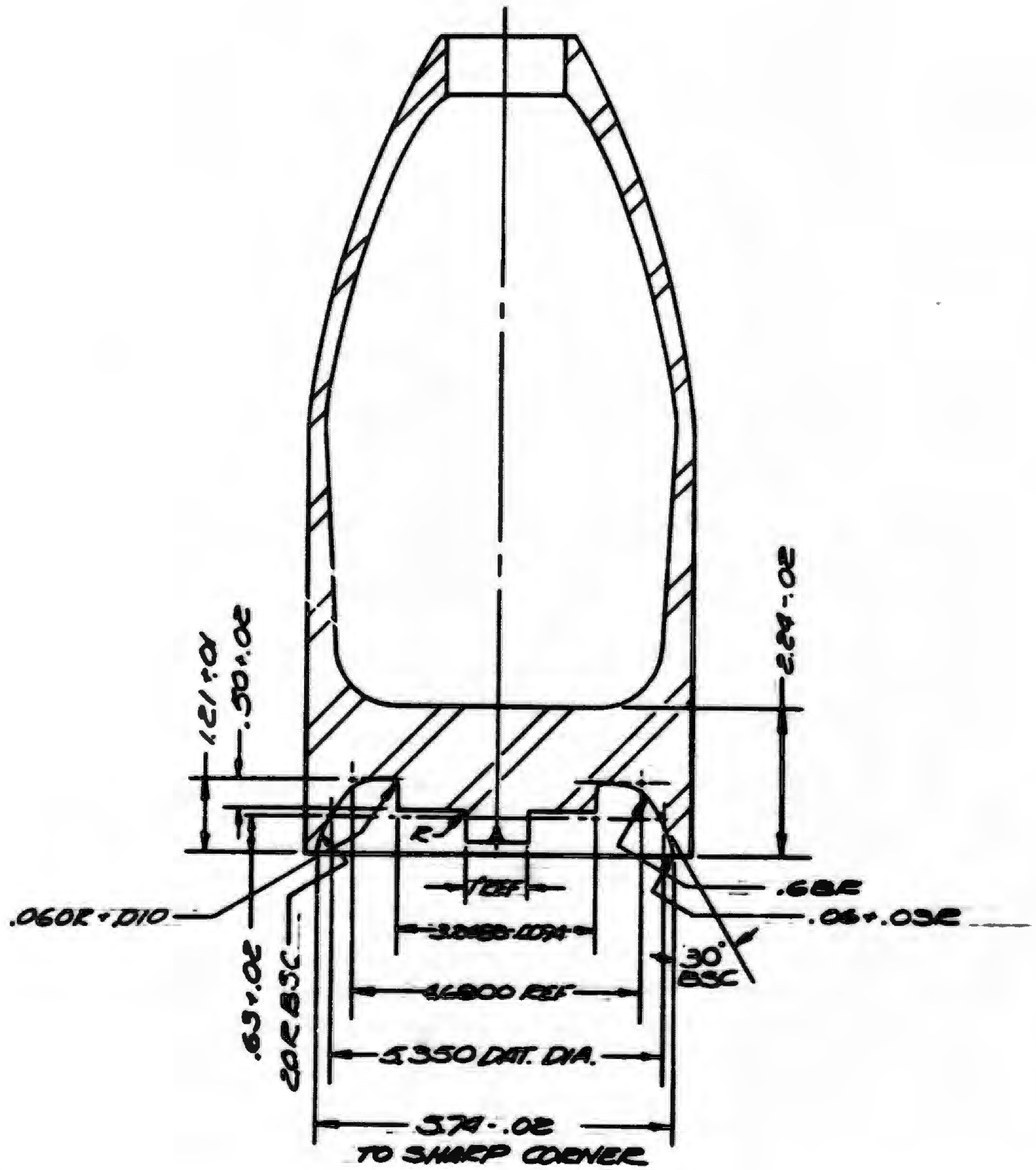
OPER #100
STRESS RELIEVE
IMMEDIATELY AFTER NOSING
800°F FOR 1 HOUR

OPER #105
ROUGH BORE NOSE & TRIM
MACH: REID BROS. LATHE





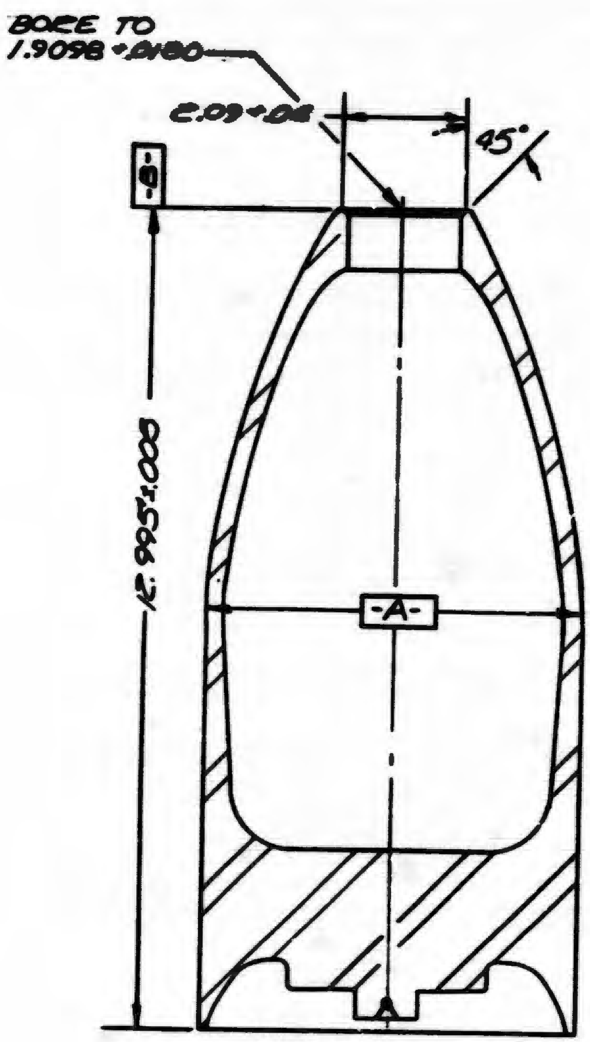
OPER #107
ROUGH MACH. BODY
MACH: STAMETS



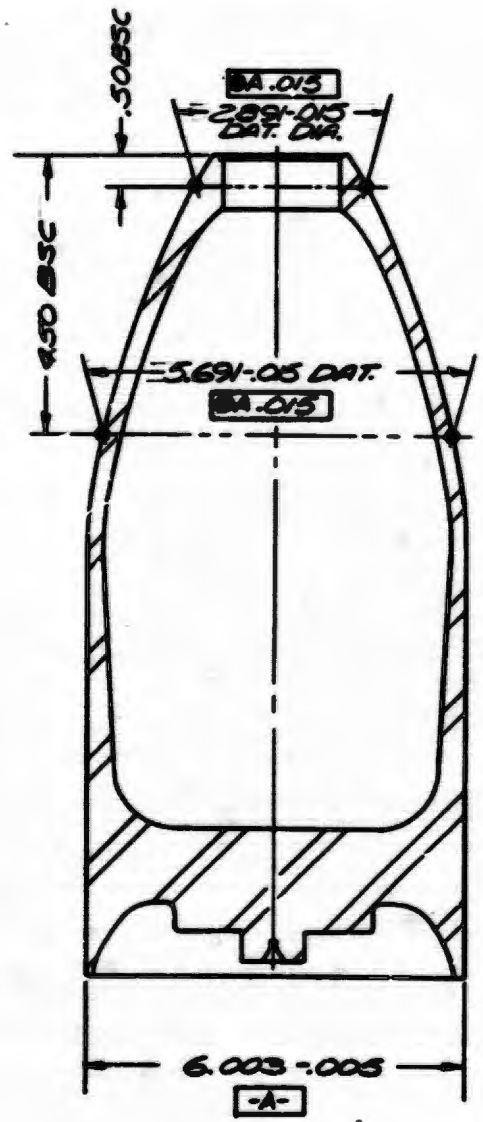
OPER. #110
FINISH BASE EXCEPT
THREAD

OPER. #115
HEAT TREAT
1475°F - 1½ HRS, OIL QUENCH
IN 110° OIL, TEMPER 1100°F - 1½ HRS

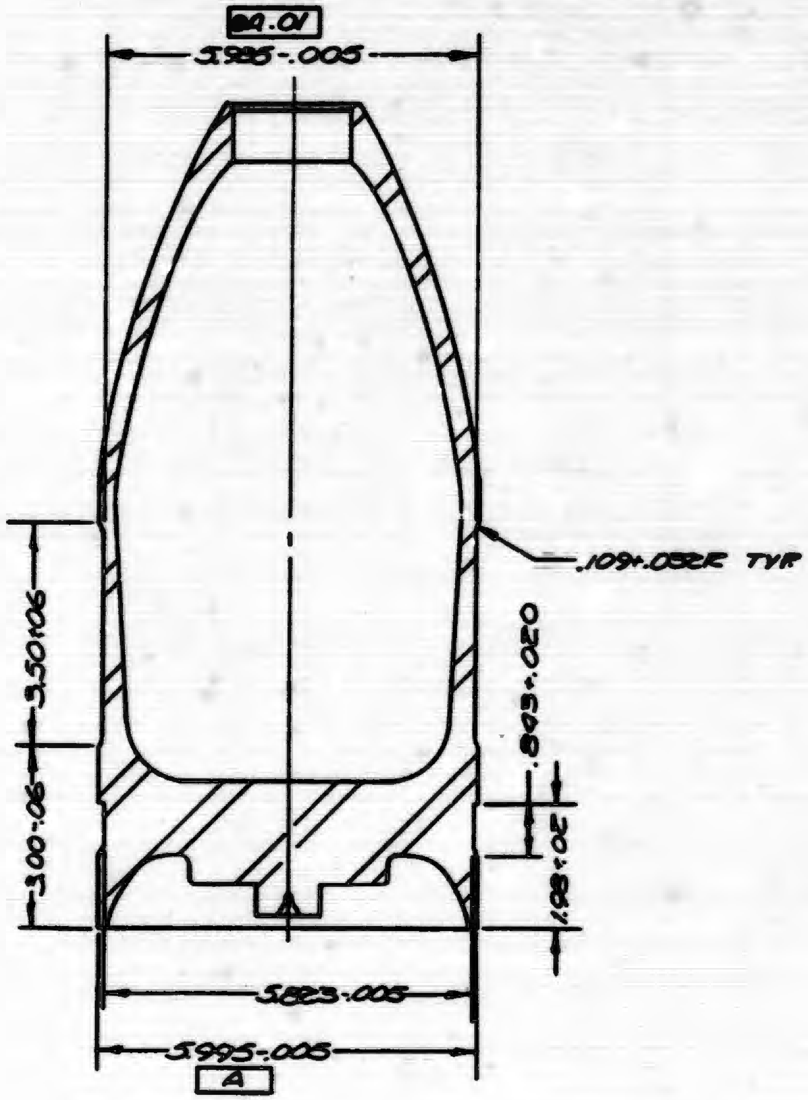
OPER. #118
SHOT BLAST INSIDE
AFTER HEAT TREAT
OIL INSIDE



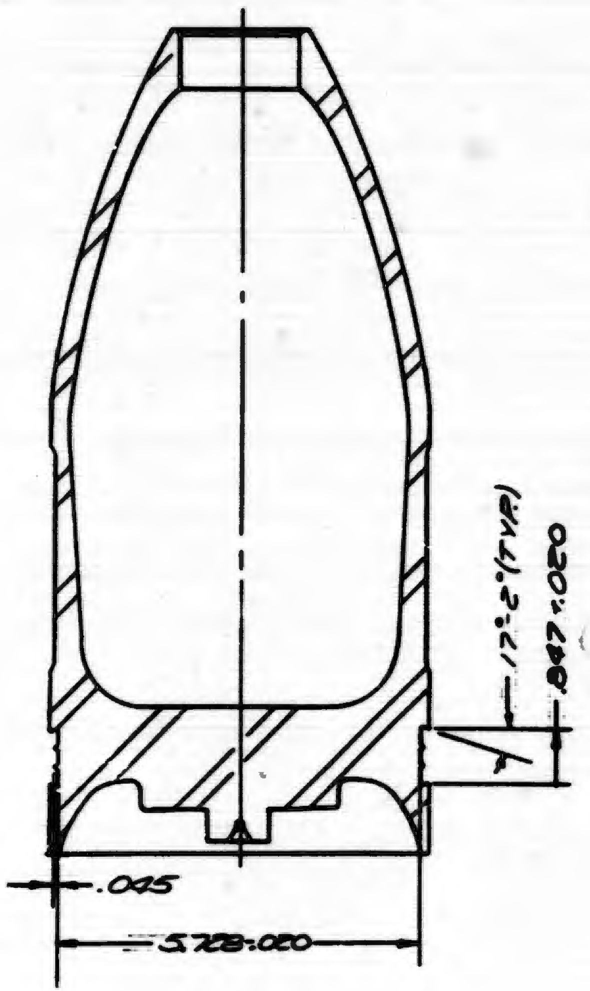
OPER. #119
BORE NOSE & TRIM OAL.
MACH: REID BROS. LATHE



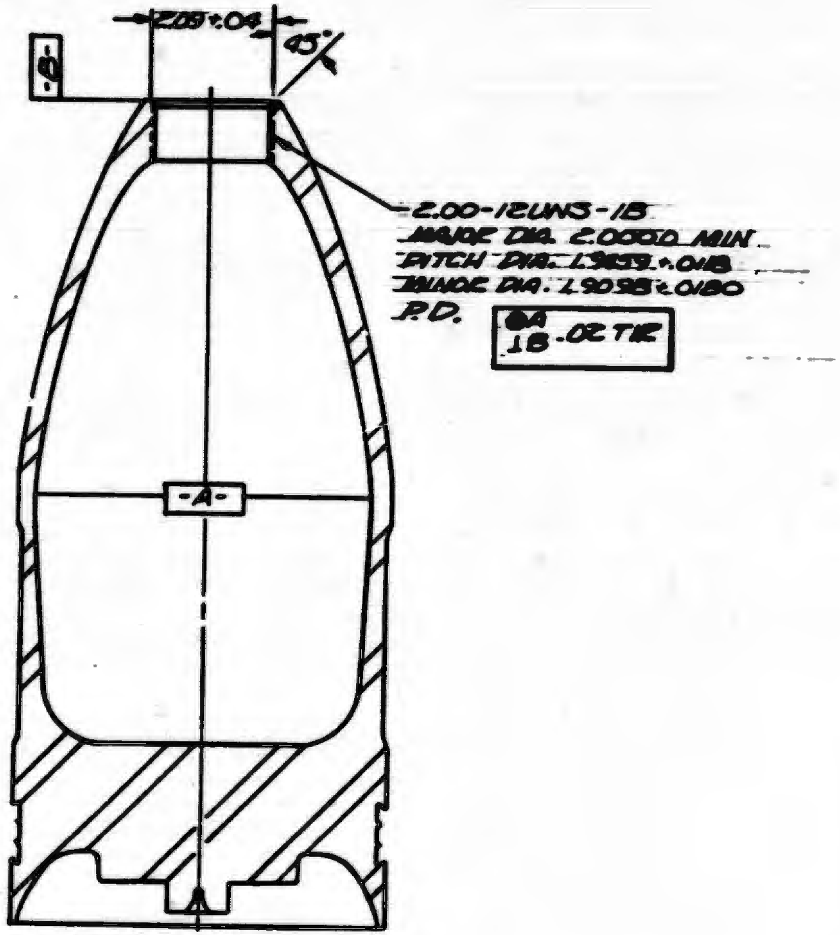
OPER. #120
TURN BOURRELET & OGIVE
MACH: STAMETS



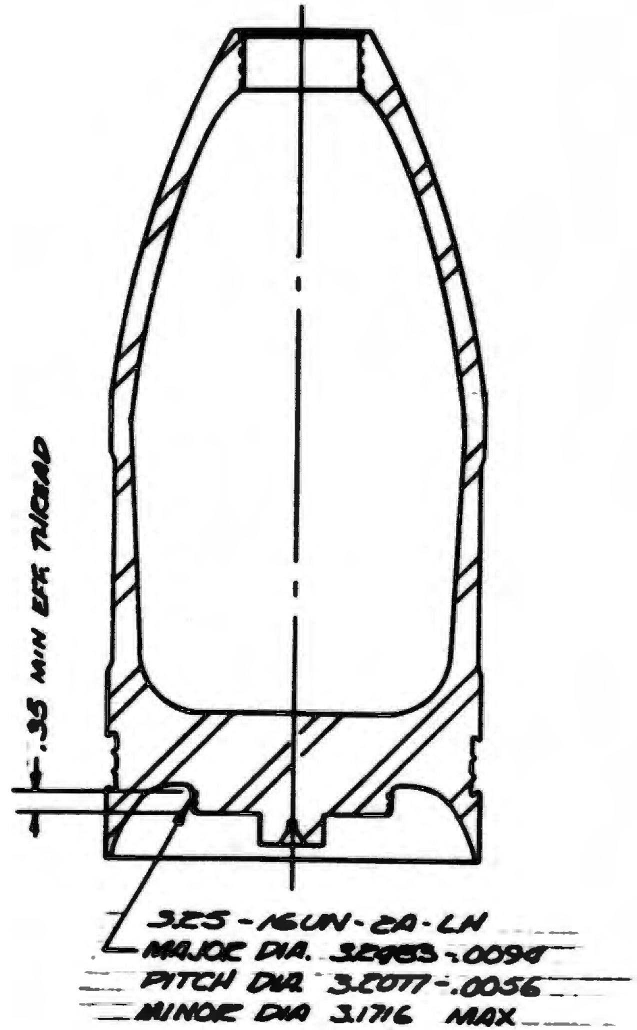
OPER. #121
TURN BAND SEAT &
UNDERCUT



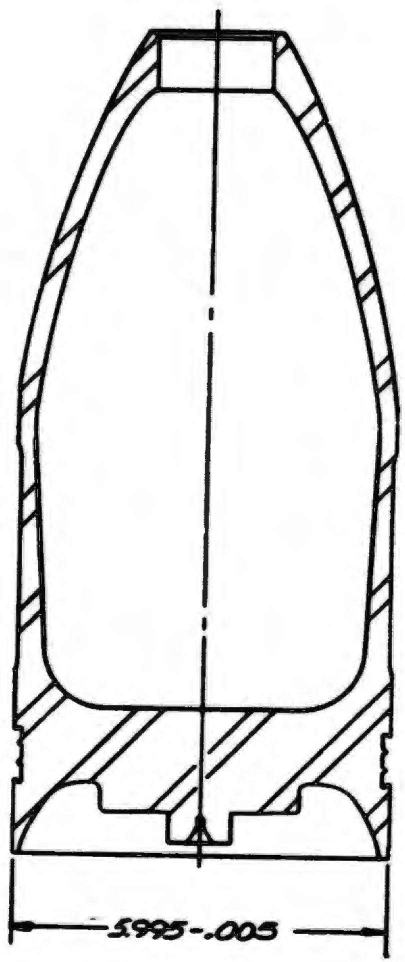
OPER. #125
TURN 17° ANGLE
IN BAND SEAT



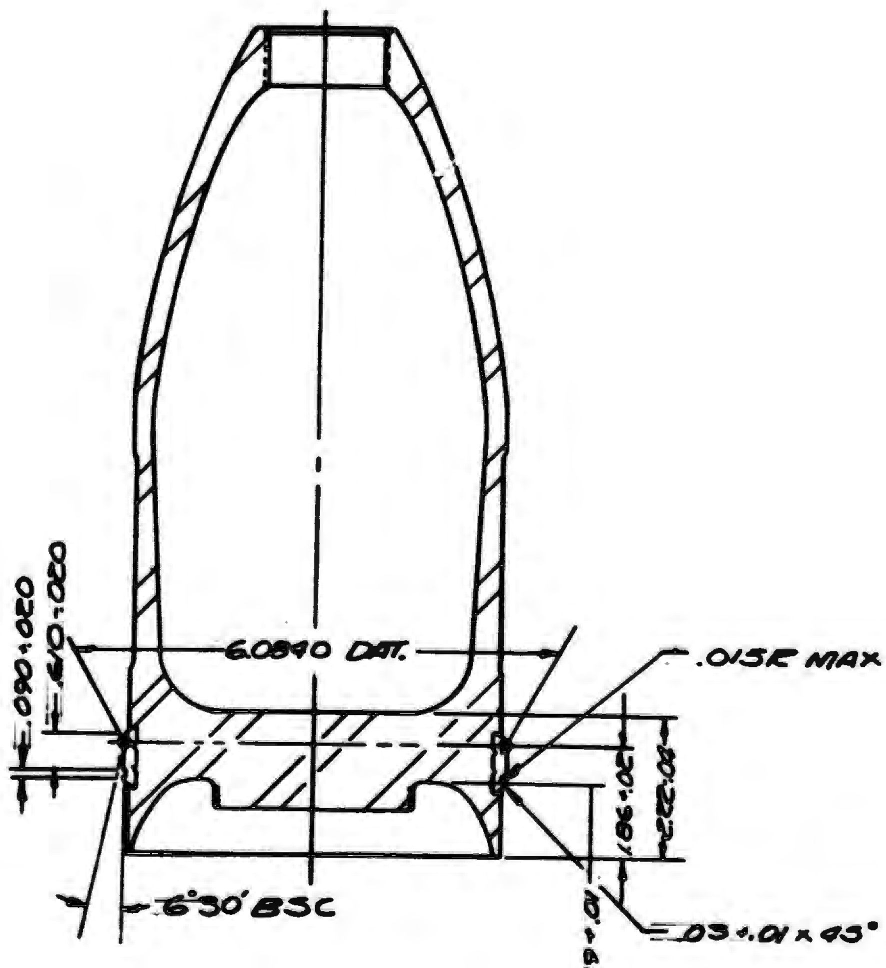
OPER. #130
THREAD NOSE
MACH. CEI-DON 'D'



OPER. #135
THREAD BASE
MACH.- CRI-DAN'D'



OPER. #138
GRIND O.D.
MACH: CINCINNATI CENTERLESS GRINDER



OPER.# 190
TRIM OFF CENTER

OPER. # 195
APPLY BAND
MACH.: WATSON-STILLMAN
TIRE SETTER

OPER.# 150
CONTOUR BAND
TRIM BASE TO LENGTH

OPER. # 155
INSPECTION

OPER. # 160
PAINT

OPER. # 170
PACK

OPER. # 175
SHIP

UNCLASSIFIED
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DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Ordnance Engineering Division, Chamberlain Manufacturing Corporation, Waterloo, Iowa	2a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED; 2b. GROUP: None
3. REPORT TITLE: DESIGN, DEVELOPMENT AND FABRICATION OF PROJECTILE, 152-MM, HE, XM657E1	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates): Final Summary Report, 1 March 1967 Through 31 December 1967	
5. AUTHOR(S) (Last name, first name, initial): Conlee, George D.; Herman, Irving	
6. REPORT DATE: Submitted 25 January 1968	7a. TOTAL NO. OF PAGES: 68; 7b. NO. OF REFS: None
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b. PROJECT NO.: 67 1X579191D334	
c. AMCMS 5584.14.25102.08	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report): None
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10. AVAILABILITY/LIMITATION NOTICES: Unlimited Distribution	
11. SUPPLEMENTARY NOTES: None	12. SPONSORING MILITARY ACTIVITY: U. S. Army Materiel Command, Picatinny Arsenal, Dover, New Jersey

13. ABSTRACT

On 13 March 1967 Chamberlain Manufacturing Corporation began the design, development, and fabrication of projectile metal parts for the Cartridge, HE, 152-mm, XM657E1. All projectiles were fabricated from AISI 4340 steel by hot forge-cold draw forming methods. Major problems in forming the projectile nose were solved by external contour machining and annealing of the drawn cans, then nosing the parts while cold in one operation. Annealing of the projectile immediately after nosing was found necessary to avoid cracking. Weight control problems were solved by close control of the ogive wall thickness and relaxing the tolerance on the bourrelet relief diameter.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
1. Projectile 2. Tank Gun Projectile 3. Cartridge UNITERMS Design Development Manufacture Forging Cold Drawing Nosing Weight Control						

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