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ELECTROCHEMICAL MACHINING OF CARTRIDGE CHAMBER AND RIFLING CONTOURS FOR SMALL ARMS

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and

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SEPTEMBER 1976

US ARMY ARMAMENT COMMAND

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and
ROCK ISLAND ARSENAL

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The feasibility of electrochemically machining rifling and cartridge chamber contours in gun barrels was determined. Electrochemical machining (ECM) tests were conducted using single-electrode, continuous-feed, straight-plunge cutting. Multiple-groove, straight rifling was formed successfully in 7.62mm and 20mm, Cr-Mo-V steel (MIL-S-46047) gun barrel sections.

Cartridge chambers were machined in 20mm sections of AISI 1018 cold rolled

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steel and Cr-Mo-V steel. Although ECM tests were successful with the mild steel (1018), shape and surface-finish tolerances were not concurrently achieved in the low alloy steel (Cr-Mo-V). Test results did indicate that ECM of cartridge chambers in the low alloy steel could be possible with additional experimentation.

Based on program test results and state-of-the-art, when compared to the efficiencies of other forming processes such as rotary forging and broaching, it is recommended that no immediate efforts be made to apply ECM in the production of small arms gun barrels. However, future developments in ECM should be monitored for application of small arms rifling and chambering, especially for gain twist rifled gun barrels. (Maiorano, C. and Kirschbaum R. A.)

FOREWORD

This report was prepared by Charles Maiorano of Anocut Engineering Company, Elk Grove Village, Illinois 60007, in compliance with Contract DAAF01-70-C-1076 and by Raymond A. Kirschbaum of the Research Directorate, GEN Thomas J. Rodman Laboratory, Rock Island Arsenal, Rock Island, Illinois 61201.

The work was authorized as part of the Manufacturing Methods and Technology Program of the U.S. Army Materiel Development and Readiness Command, and was administered by the U.S. Army Industrial Base Engineering Activity.

CONTENTS

TABULAR DATA

1. INTRODUCTION

Small caliber gun barrels are generally rifled by broaching, and chambered by step drilling, contour reaming, and polishing. The operations are slow and expensive, particularly for the machining of prototype barrels of new, difficult-to-machine alloys. Consequently, this program was conducted to determine the adaptability of electrochemical machining to replace or augment these operations. The feasibility of eliminating the multistep conventional machining operations through the use of single-step electrochemical processing has been of particular interest, even for machining conventional materials, for possible reduction of machining time and for elimination of costly tool wear. During feasibility testing, the sharpness of contours and the quality of finishes obtainable by various combinations of electrochemical machining parameters were of particular concern. The parameters tested in various combinations were those of electrolyte strength, pressure, temperature, voltage, amperage, electrode feed rate, and starting gap. Work materials used in the testing were Cr-Mo-V steel (MIL-S-46047) and 1018 cold-rolled steel.

2. PROCEDURE

2.1 General

The testing was conducted in three parts:

a. The rifling in a 20mm gun barrel was electrochemically machined in accordance with section D-D, Rock Island Arsenal Drawing 77980, sheet 1.

b. The rifling in a 7.62mm gun barrel was electrochemically machined in accordance with section B-B, Rock Island Arsenal Drawing 11701204, sheet 1.

c. The cartridge chamber in a 20mm gun barrel was electrochemically machined in accordance with U. S. Army Weapons Command Print 7790801, sheet 2, section E-E.

Straight (rather than spiral), short length (maximum length of 8 inches) rifling grooves were machined. This method was used for more simple and economical testing since some means of accurately rotating the gun barrel section or tool would have been required for spiral grooves. Although such a rotating mechanism could have been constructed, this action would have been unnecessary and costly for feasibility tests. Also, the straight-plunge machining of the grooves minimized any difficulties, e.g., vibrations and dimensional inaccuracies, which, if introduced by a rotating mechanism, could have "masked" other problems encountered.

The workpiece blanks, listed in Table I, were provided by Rock Island Arsenal.

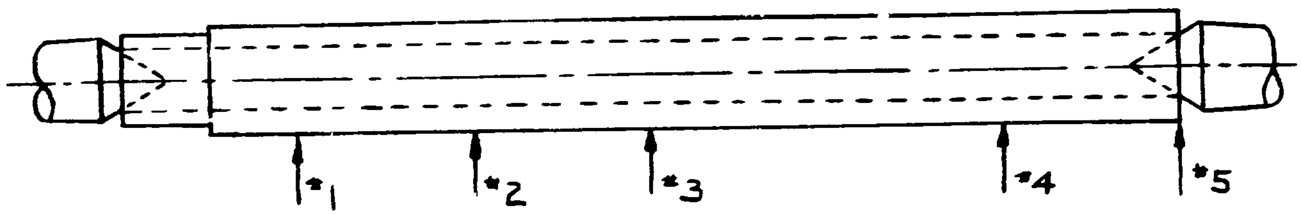
Fixtures, cathodes, cathode guides and electrolyte inlet manifolds were fabricated for rifling and chambering tests. Photographs of this tooling are presented in Appendix A. The fixtures were built to hold the gun barrel sections for test machining in standard (8 - 16 in. maximum stroke) 10,000 amp Anocut underdrive machines. The guides were designed to ensure that the cathode entered the workpiece at the correct location and the proper angle, remained straight and held to a minimum of vibration.

The electrolyte entered the top of the workpiece, proceeded through the combination manifold and guide (moving downward around the outside of the cathode) and emerged from the bottom of the workpiece. This flow direction was selected to produce the best possible surface finish on the sides of the cut. Fresh and uncharged electrolyte flowed down between the previously-cut hole and the sides of the cathode when this flow direction was used. Charged electrolyte from the cutting zone exited through the unfinished predrilled hole in the bottom of the part. The Anocut machine used for this testing was equipped with a large electrolyte pump capable of producing 200 psi of electrolyte pressure at a flow rate of 200 gpm. The electrolyte system of the machine contained a by-pass valve so that varying amounts of electrolyte could be directed around the tooling and returned directly to the electrolyte tank. With this high-pressure pump and electrolyte system, tool electrolyte pressures up to a maximum of 200 psi were easily attainable. The relatively small electrolyte outlet hole beneath the workpiece served to restrict the flow through the cutting area and to produce back pressure when higher inlet pressures were used.

2.2 Methods and Techniques

Electrolytes carry a charge when leaving the cutting zone and this charge can cause some etching as it passes over the workpiece surface. Although metal removed by such etching can seldom be measured, the etching does cause deterioration in the machined surface. Consequently, in all the machining tests, electrolyte flow was directed from the top through the bottom of the predrilled workpieces to produce better surface finishes. Fresh, uncharged electrolyte flowed downward between the already-cut hole and the side of the cathode; when charged from the cutting zone, it emerged from the unfinished, predrilled hole in the bottom of the part. Also, when any holes are electrochemically machined where the length-to-diameter ratio is large (above 15:1), an accurate guide is essential for the cathode. So, the cathode guides used in the rifling tests facilitated hole location, angle, concentricity and surface finish.

TABLE I. WORKPIECE BLANK (20MM) INSPECTION READINGS



PARTS

POSITION	1	2	3	4	5	6	7
#1	.0005	.0040	.0015	.0010	.0008	.0005	.0030
" #2	.0005	.0040	.0015	.0015	.0002	.0025	.0030
" #3	.0010	.0020	.0018	.0005	.0006	.0022	.0022
" #4	.0010	.0018	.0020	.0002	.0006	.0021	.0012
" #5	.0005	.0028	.0005	.0001	.0005	.0010	.0002

Readings (in inches) taken @ 5 places on parts between centers to show lack of concentricity between I.D. & O.D. before ECM.

Anocut Eng. Co.
Part #11701204
Sect. "B-B"
G.H.K.

The direction of electrolyte flow was particularly important for precision during test machining of the cartridge chambers. Generally, clean electrolyte was supplied to the finishing end of the electrode for final generation of the part size and finish.

Electrolyte pressures are measured at the point where the electrolyte enters the tooling or machining area. Measuring pressures at this location is expedient although it is not the area in which the electrolyte is cutting. Positive control of pressure is desired in the machining gap between the workpiece and the cathode or tool. Therefore, the pressure in the electrolyte inlet manifold should not be assumed to be equal to the pressure in the machining gap. Pressures in these two places are seldom the same and are not linearly related.

2.3 Tests

2.3.1 20mm Rifling Tests

The 6 in. long blank used for this testing had a predrilled hole through its entire length. A V-block fixture was used to locate and clamp the part. Preliminary experimentation was conducted at electrolyte inlet pressures of 150 and 175 psi. The bulk of the testing was conducted at 210 psi. Machining conditions in each complete experiment were generally the same, except the cathode feed rates were increased from 0.050 to 0.210 in. per min. The performance of this operation was not satisfactory at the 0.210 in. per min. feed rate so the cathode feed rate was reduced to 0.180 in. per min.; this appeared to be optimum with a 210 psi electrolyte pressure. Machining conditions used during the testing are listed in Table 2.

2.3.2 7.62mm Rifling Tests

A V-block fixture was used to locate and clamp the part. Again, tests were conducted at electrolyte inlet pressures of 150, 175 and 200 psi. The tooling appeared to perform best at 175 psi, and all complete test runs were conducted at this pressure. The cathode feed rate was varied from 0.180 to 0.275 in. per min. The voltage was varied from 12 to 11 volts and the amperage was varied from 12.5 to 10.5 amps. Machining conditions used during the testing are presented in Table 3.

2.3.3 20mm Cartridge Chamber Tests

Experiments were conducted in machining a cartridge chamber cavity in each of five Cr-Mo-V steel gun barrel sections. Unexpected difficulty was encountered with the occurrence of striations (grooves and channels) in the surface of the cavities, and more difficulty arose with size tolerance than was expected. After these five workpieces had been machined, considerably more testing appeared to be necessary to reach conclusive results. Therefore, Anocut prepared additional cold-rolled steel blanks for continuation of the testing, and Rock Island Arsenal prepared additional blanks of Cr-Mo-V steel. A total of sixteen

TABLE 2. 20MM RIFLING TESTS MACHINING CONDITIONS

TEST NO.	MACHINE NO.	VOLT	AMP	FEED IN/MIN	PRES. PSI	FLOW DIR.	TEMP. °F.	STARTING GAP(IN.)	MACHINE TIME (MIN)	ADDITIONAL DATA
1.	Vu-6888	12.5	100	.050	150	CROSS-FLOW	90	.020		FEED INCREASED IN STEPS TO .300 IN/MIN AND PRESSURE INCREASED TO 200 PSI WHILE RUNNING
2.	Vu-6888	13	150	.150	200	CROSS-FLOW	90	.020		
3.	Vu-6888	13	150	.150	200	CROSS-FLOW	92	.020		VOLTAGE INCREASED IN STEPS TO 15 VOLTS AND BACK TO 13 VOLTS WHILE RUNNING
4.	Vu-6888	13	150	.150	150	CROSS-FLOW	92	.020		FEED INCREASED TO .240 IN/MIN WHILE RUNNING
5.	Vu-6888	13	150	.210	200	CROSS-FLOW	95	.020	29	
6.	Vu-6888		150	.180	210	CROSS-FLOW	95	.020	33	TIMES NOTED ARE FOR 6" LONG SECTIONS.

TABLE 3. 7.62MM RIFLING TESTS MACHINING CONDITIONS

TEST NO.	MACHINE NO.	VOLT	AMP	FEED IN/MIN	PRES. PSI	FLOW DIR.	TEMP. °F.	STARTING GAP(IN.)	MACHINE TIME (MIN)	ADDITIONAL DATA
1.	Vu-6888	12	12	.180	175	CROSS-FLOW	95	.020	27	AT 1" DEPTH FEED INCREASED TO .200 IN/MIN; AT 2" DEPTH FEED INCREASED TO .250 IN/MIN
2.	Vu-6888	12	12	.200	175	CROSS-FLOW	92	.020	30	
3.	Vu-6888	12	12	.250	175	CROSS-FLOW	93	.020	24	
4.	Vu-6888	12	12	.250	175	CROSS-FLOW	92	.020	24	
5.	Vu-6888	12	12.5	.250	175	CROSS-FLOW	92	.020	24	
6.	Vu-6888	12	12.5	.250	175	CROSS-FLOW	90	.020	24	
7.	Vu-6888	11	10.5	.275	175	CROSS-FLOW	90	.020	22	

tests were made with the 1018 cold-rolled steel blanks. Tests were completed with the ten additional Cr-Mo-V steel blanks provided by Rock Island Arsenal to bring the total of cartridge chambering tests to thirty-one.

Various cathode feed rates and various electrolyte pressures were tried during the first series of tests on the Cr-Mo-V steel workpieces. Back pressure was used throughout these tests and was established by use of an electrolyte flow restrictor at the electrolyte exit from the tooling. Restrictors of 3/8 and 1/4 in. diameter bores were alternatively tried in the initial testing and the 3/8 in. restrictor was used in most of the succeeding tests. The cathodes used were altered for the difference in electrochemical machinability of the Cr-Mo-V and cold-rolled steel workpieces. Cross sections were examined to determine part tolerances. Machining conditions used during the testing are presented in Tables 4 and 5.

3. RESULTS AND DISCUSSION

3.1 20mm Rifling

Electrochemically machining the rifling in 20mm gun barrels is feasible. The 6 in. long samples produced were within tolerances for geometric sizes and had a very smooth surface finish.

Further effort is required to produce tooling and machinery for handling the full-length barrels and to develop a turning mechanism to provide the rifling spiral. The tooling for full-length barrels should embody the principles developed in this test tooling. Also, machining parameters should coincide with those developed in this test work, e.g.,

Electrolyte: 3.25 lbs. of $NaNO_3$ per U.S. gal. of water

Electrolyte temperature: 95°F

Machining voltage: 13 volts

Machining current: 150 amps.

Cathode feed rate: 0.180 in. per min.

Electrolyte pressure: 210 psi

The inspection results of the test machining are given in Appendix B.

TABLE 4. 20MM CHAMBER TESTS MACHINING CONDITIONS (MATERIAL: MIL-S-46047)

TEST NO	MACHINE NO.	VOLT	AMP	FEED IN/MIN	PRES. PSI	BACK PRES. PSI	FLOW DIR.	TEMP. °F.	STARTING GAP (IN.)	ADDITIONAL DATA
1.	Vu-67	12	200 to 1700	.060 to .300	140	—	CROSS FLOW	90	1.280 FROM END	TAPERED PORTIONS OF CUT HAD BAD STRIATIONS
2.	Vu-67	12	200 to 3300	.300 to .430	140	—	CROSS FLOW	90	1.280 FROM END	STRIATIONS - CUT UNDERSIZE CATHODE DIA REDUCED BEFORE NEXT CUT
3.	Vu-67	12	300 to 3500	.450	125	—	CROSS FLOW	90	1.280 FROM END	STRIATIONS - INSULATION OF CATHODE DAMAGED DURING RELOCK - LEFT FLAT IN PART
4.	Vu-67	12	200 to 2300	.300	210	—	CROSS FLOW	90	1.290 FROM END	DEEP STRIATIONS ON FORWARD PART OF CUT
5.	Vu-67	12	200 to 2200	.300	210	—	CROSS FLOW	90	1.290 FROM END	SAME STRIATIONS AS RUN #4 ONLY ONE ROCK ISLAND SAMPLE PART LEFT - DECIDED TO MAKE MORE SIMULATED PARTS FROM COLD ROLLED STEEL IN ORDER TO CONTINUE TESTING
6.	Vu-6485	12	200 to 2100	.300	210	3/8" Dia. Restriction in exit.	CROSS FLOW	88	1.280 FROM END	BAD STRIATIONS - .834" DIM. IS .881" NEED MORE ROCK ISLAND ARSENAL PARTS
7.	Vu-6485	12	200 to 2200	.300	210	—	CROSS FLOW	90	1.280 FROM END	SOME STRIATIONS - .834" DIM IS .882"
8.	Vu-6485	12	200 to 2350	.400	210	—	CROSS FLOW	90	1.280 FROM END	LESS STRIATIONS - .834" DIM. IS 870"
9.	Vu-6485	12	200 to 2800	.500	210	—	CROSS FLOW	90	1.280 FROM END	.834" DIA. IS .845" CATHODE TO BE 1.0524" DIA. IS 1.048" 1.158" DIA. IS 1.173 REWORKED
10.	Vu-6485	12	200 to 2850	.500	210	—	CROSS FLOW	90	1.280 FROM END	.834" DIA IS .822" 1.0524" DIA IS 1.048" RELEAVE INSULATION TO 1.058" DIA IS 1.172" INCREASE FLOW
11.	Vu-6485	12	200 to 2700	.500	210	—	CROSS FLOW	90	1.290 FROM END	SAME AS # 10 RELEAVE INSULATION AT TI TO INCREASE FLOW AND REDUCE BACK PRESSURE
12.	Vu-6485	12	200 to 2650	.500	210	—	CROSS FLOW	90	1.280 FROM END	SAME AS # 10
13.	Vu-6485	12.5	200 to 1400	.500	210	3/8" Dia. Restriction in exit.	CROSS FLOW	90	1.280 FROM END	STRIATIONS - .834" DIA. IS .821"
14A.	Vu-6485	12	1400 to 2650	.500	210	"	CROSS FLOW	90	1.280 FROM END	CUT ONLY 1.875" DEEP TO SEE WHEN STRIATIONS START. THEY WERE IN STRAIGHT PORTION OF CUT.
14B.	Vu-6485	12	200 to 700	.500	210	"	CROSS FLOW	86	3.155 FROM END	SOME STRIATIONS. .834" DIA. IS .828" CATHODE TIP TO BE REWORKED TO TRY TO IMPROVE FLOW
15A.	Vu-6485	15	700 to 2700	.500	210	"	CROSS FLOW	90	1.280 FROM END	CUT ONLY 1.150" DEEP TO SEE WHEN STRIATIONS START. THERE WERE NONE
15B.	Vu-6485	12		.500	210	"	CROSS FLOW	90	2.430 FROM END	BAD STRIATIONS

TABLE 5. 20MM CHAMBER TESTS MACHINING CONDITIONS (MATERIAL: 1018 COLD ROLLED STEEL)

TEST NO	MACHINE NO.	VOLT	AMP	FEED IN/MIN	PRES. PSI	BACK PRES. PSI	FLOW DIR.	TEMP. °F.	STARTING GAP(IN.)	ADDITIONAL DATA
1.	Vu-67	12	200 to 2800	.300	210		CROSS FLOW	90	1.280" FROM END	SOME SMALL STRIATIONS
2.	Vu-67	12	200 to 2800	.300	210	3/8" DIA RESTRICTION IN EXIT		90	1.280" FROM END	PART SMOOTH WITH INCREASED BACK PRESSURE BUT 0.010" TO 0.012" TOO LARGE PART IS 0.020" OVERSIZE
3.	Vu-67	12	200 to 2800	.300	200	1/4" DIA RESTRICTION IN EXIT		90	1.280" FROM END	
4.	Vu-67	12	200 to 3150	.325	200	3/8" DIA RESTRICTION IN EXIT		92	1.280" FROM END	0.001" TO 0.006" OVERSIZE IN CATHODE RECUT
5.	Vu-67	12	200 to 2800	.300	210	3/8" DIA RESTRICTION IN EXIT		92	1.280" FROM END	LARGE DIA OK - 1.052" BUT 0.834" DIA IS 0.026" UNDERSIZE
6.	Vu-67	12	200 to 2800	.300	210	3/8" DIA RESTRICTION IN EXIT		90	1.280" FROM END	SAME AS RUN # 5 - CATHODE TO BE REWORKED
7.	Vu-67	12	200 to 2800	.300	210	3/8" DIA RESTRICTION IN EXIT		90	1.280" FROM END	.834" DIA IA NOW .857" TO .864" CATHODE TO BE REWORKED
8.	Vu-67	12	200 to 2800	.300	210	3/8" DIA RESTRICTION IN EXIT		90	1.280" FROM END	BEST PART YET, BUT .834" DIA IS .845" TO .848". CATHODE DIA TO BE REDUCED IN THIS AREA
9.	Vu-67	12	200 to 2800	.300	210	3/8" DIA RESTRICTION IN EXIT		90	1.280" FROM END	BURRS ON CATHODE LEFT LINES. .834" DIM IS STILL .838" TO .843" - THIS AREA REDUCED .003"
10.	Vu-67	12	200 to 2800	.300	210	3/8" DIA RESTRICTION IN EXIT		90	1.280" FROM END	.834" DIM IS .847" TO .848"!
11.	Vu-6485	12	200 to 2800	.300	210	3/8" DIA RESTRICTION IN EXIT		90	1.280" FROM END	1.0524" DIM IS 1.051" AND .834" DIM IS .831" TO .833"
12.	Vu-6485	12	200 to 3050	.300	210	3/8" DIA RESTRICTION IN EXIT		98 to 100	1.280" FROM END	.834" DIM. IS .828"
13.	Vu-6485	12	200 to 3200	.300	210	3/8" DIA RESTRICTION IN EXIT		98 to 100	1.280" FROM END	.834" DIM. IS .8275"
14.	Vu-6485	12.5	200 to 2750	.300	210	3/8" DIA RESTRICTION IN EXIT		90 90	1.280" FROM END	.834" DIM. IS .847"
15.	Vu-6485	12	200 to 2700	.300	210	3/8" DIA RESTRICTION IN EXIT		82 to 84	1.280" FROM END	.834" DIM. IS .841"
16.	Vu-6485	12	200 to 2900	.300	210	3/8" DIA RESTRICTION IN EXIT		88	1.280" FROM END	.834" DIM. IS .834" TO .837"

3.2 7.62mm Rifling

In this test machining, considerable difficulty was encountered in maintaining location. The predrilled holes in the gun barrel sections were not exactly concentric with the outside diameters of the sections. Also, the end faces of the sections were not exactly square (perpendicular) with the bore. This meant that the line of motion of the cathode, as the cathode moved through the workpiece, was not always parallel to the axes and surfaces of the predrilled holes in the rigidly clamped workpieces. This condition caused the cathodes to cut off center in some tests. In one test, this caused one cathode to break off in the upper manifold-guide. However, electrochemical machining or rifling in a 7.62mm barrel is feasible. The 6 in. long samples produced in these tests had very smooth surface finishes and the rifling forms were within tolerances.

Tooling and machinery for handling full-length barrels and a turning mechanism for the rifling spiral are required. The tooling for full-length barrels should embody the principles developed in this test tooling. Also, machining parameters should coincide with those developed in this test work, e.g.,

Electrolyte: 3.5 lbs. of $NaNO_3$ per U.S. gal. of water

Electrolyte temperature: 90°F

Machining voltage: 11 volts

Machining current: 10.5 amps.

Cathode feed rate: 0.275 in. per min.

Electrolyte pressure: 175 psi

The inspection results of this testing are given in Appendix C.

3.3 20mm Cartridge Chamber

Results of test machining the 20mm cartridge chamber were less promising than the results of the rifling tests. Problems were encountered in an attempt to concurrently achieve both size and finish tolerances. The striations occurring in the machined cavity surface, particularly in the test blanks of Cr-Mo-V steel (MIL-S-46047) material, were the most difficult problem. Although both size and finish tolerances were achieved in electrochemical machining of the cartridge chamber cavity in a cold-rolled steel test blank, the combination of both size and surface-finish tolerances was not achieved in the MIL-S-46047 blanks. The striations appeared to be related to the alloy. Although the exact causes are not known, striations are affected by electrolyte pressure, electrolyte composition, electrolyte flow in the machining gap (which is related to the surface finish on the electrode), and by the composition and heat treatment of a given alloy.

In summary, although size and surface tolerances were not obtained with MIL-S-46047 material, these tests indicated that cartridge chambers could probably be electrochemically machined with additional experimentation. Testing of various combinations of electrolytes, electrodes, and work material heat-treatments or preshaping would be required.

The inspection results of this testing are given in Appendix D.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

4.1.1 Rifling. Multiple groove, straight rifling of 7.62 and 20mm contours can be electrochemically machined in gun steel (MIL-S-46047); and no significant technical problem is foreseen in development of special equipment to electrochemically machine spiral rifling in such gun bores. Machining rates in the tests conducted indicate that ECM would be faster when compared to conventional broaching of rifling. However, for bores of smaller diameter, contemporary limits of ECM have to be considered. For example, in conventional direct shaping by continuous flow of a salt-base electrolyte and travel of the tool or workpiece, the minimum radius obtained at the intersections of machined surfaces is approximately 0.002 in. and the maximum ratio of length-to-bore diameter of a rifled barrel is approximately 70 to 1. Smaller radii and larger ratios are possible but special equipment, electrolytes and techniques would have to be developed.

4.1.2 Chambering. Although ECM tests were successful with the mild steel (1018), shape and surface-finish tolerances were not concurrently achieved in the low-alloy steel (Cr-Mo-V) by direct-plunge cutting with a center hole flow-through cathode of the 20mm cartridge contour. Test results did indicate that successful machining would be accomplished with further development work. However, as is the case for rifling, the minimum radius obtainable is approximately 0.002 in. and additional development would be required to approach the tolerances required in small-bore cartridge chambers.

4.2 Recommendations

Based on program test results and state-of-the-art, when compared to the efficiencies of other forming processes such as rotary forging and broaching, it is recommended that no immediate efforts be made to apply ECM in the production of small arms gun barrels. However, future developments in ECM should be monitored for application of small arms rifling and chambering, especially for gain twist rifled gun barrels. It is also recommended that ECM be considered as a preparatory process, prior to chamber reaming and/or rifling, to achieve stress-free surfaces for improved machinability and formability in close-tolerance shaping.

APPENDIX A

Photographs

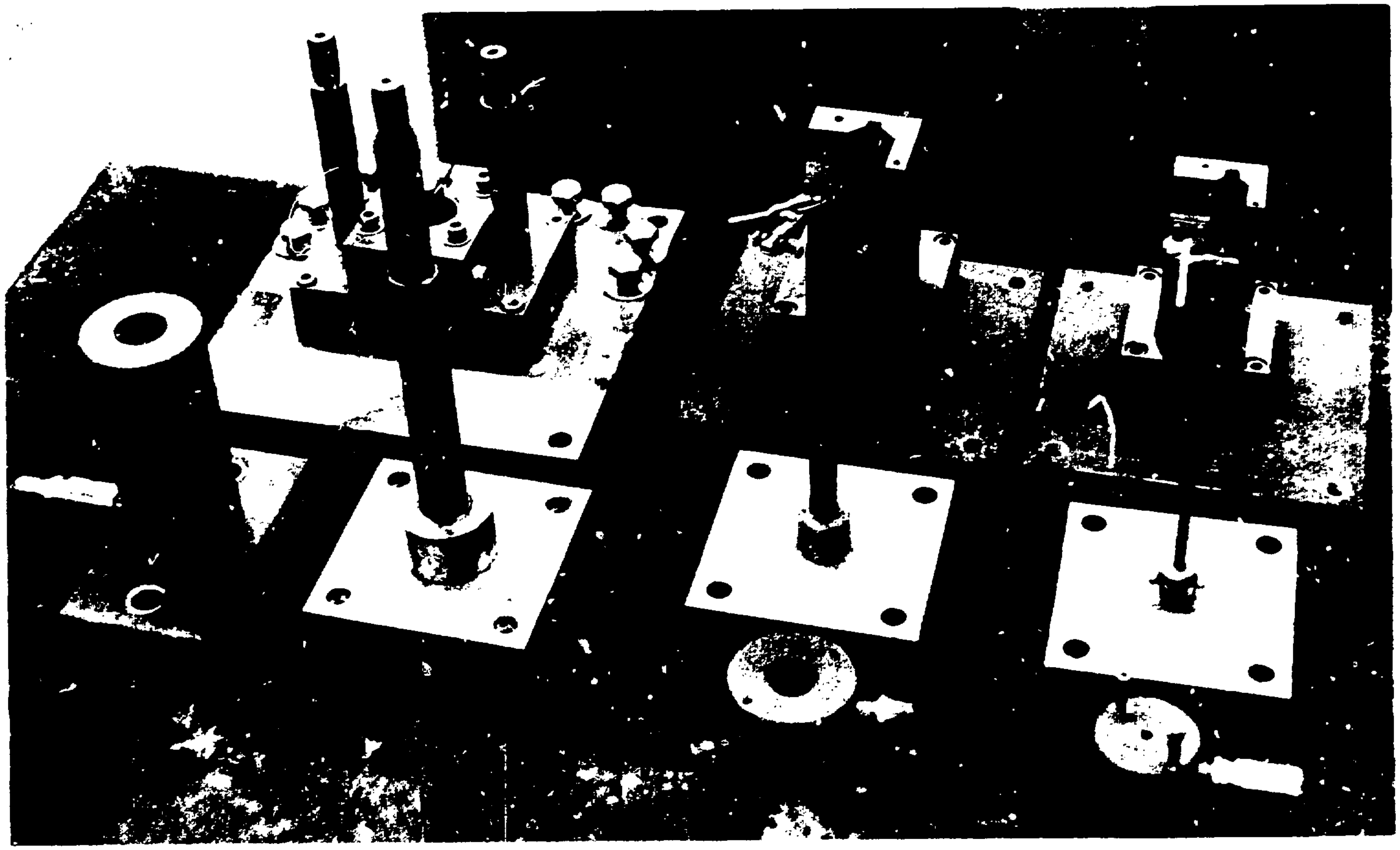


FIGURE 1. ECM TOOLING, RIFLING AND CHAMBER

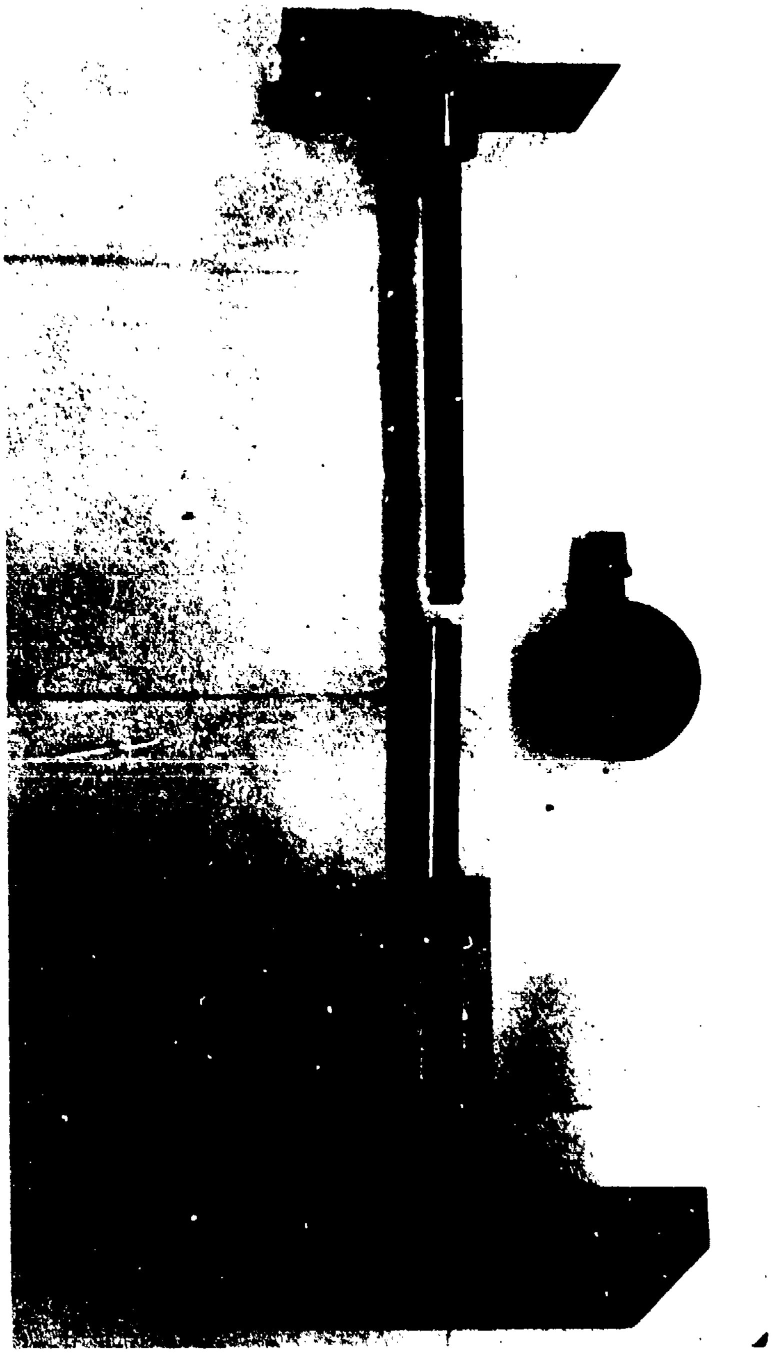


FIGURE 2. 20MM RIFLING TOOLS

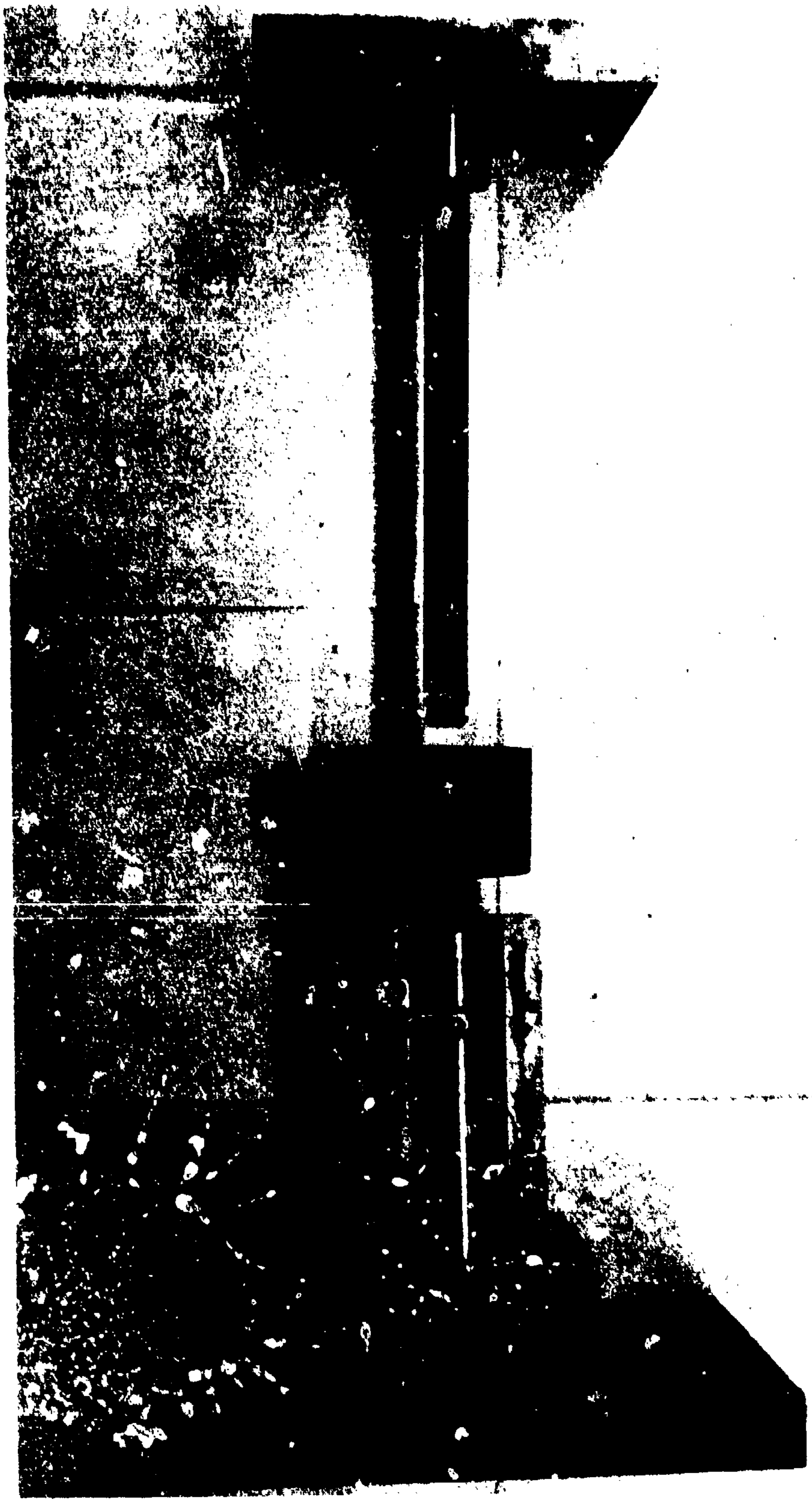


FIGURE 3. 20MM RIFLING TOOL ARRANGEMENT

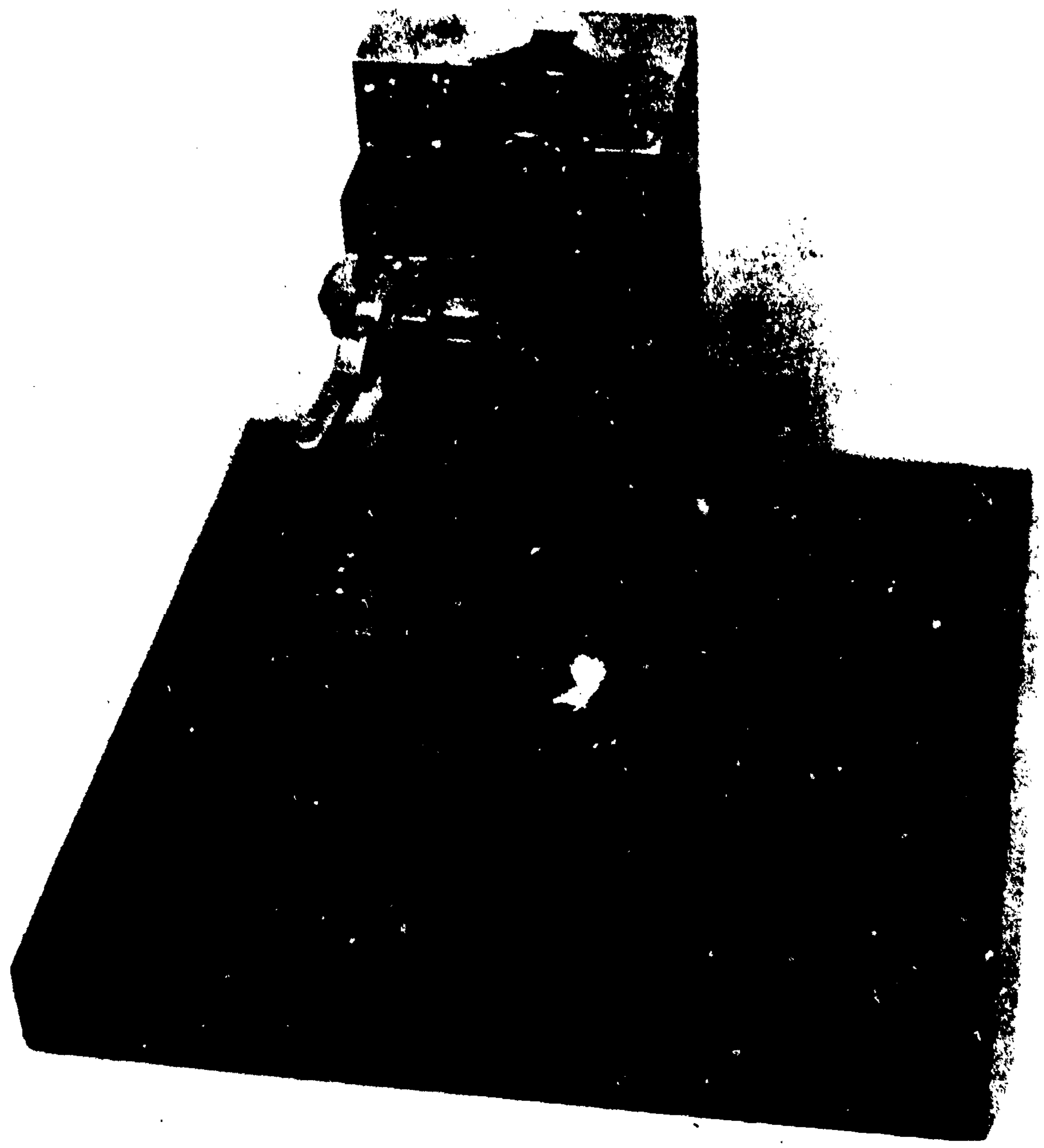


FIGURE 4. WORKPIECE HOLDER FOR 20MM RIFLING

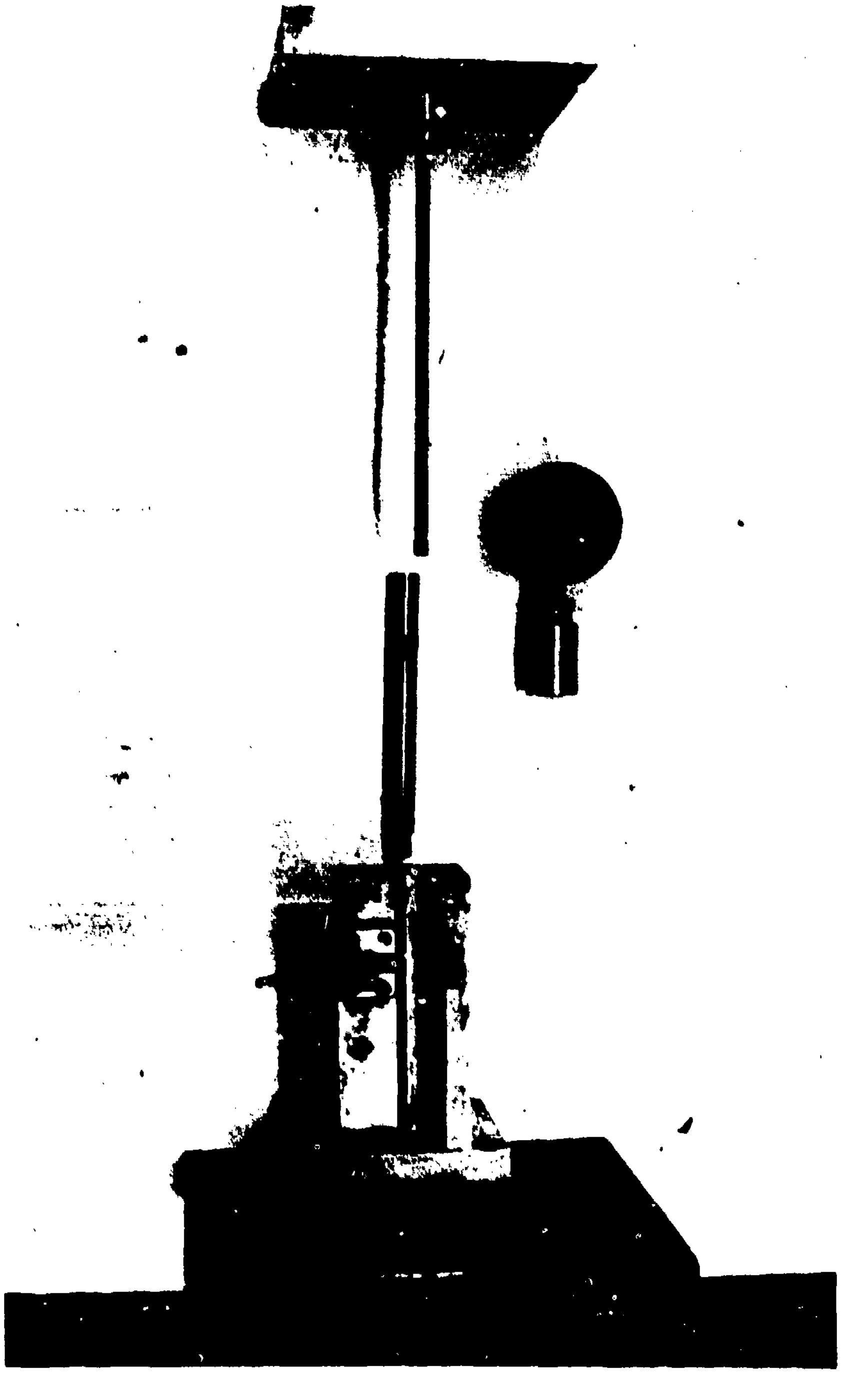


FIGURE 5. 7.62MM RIFLING TOOLS

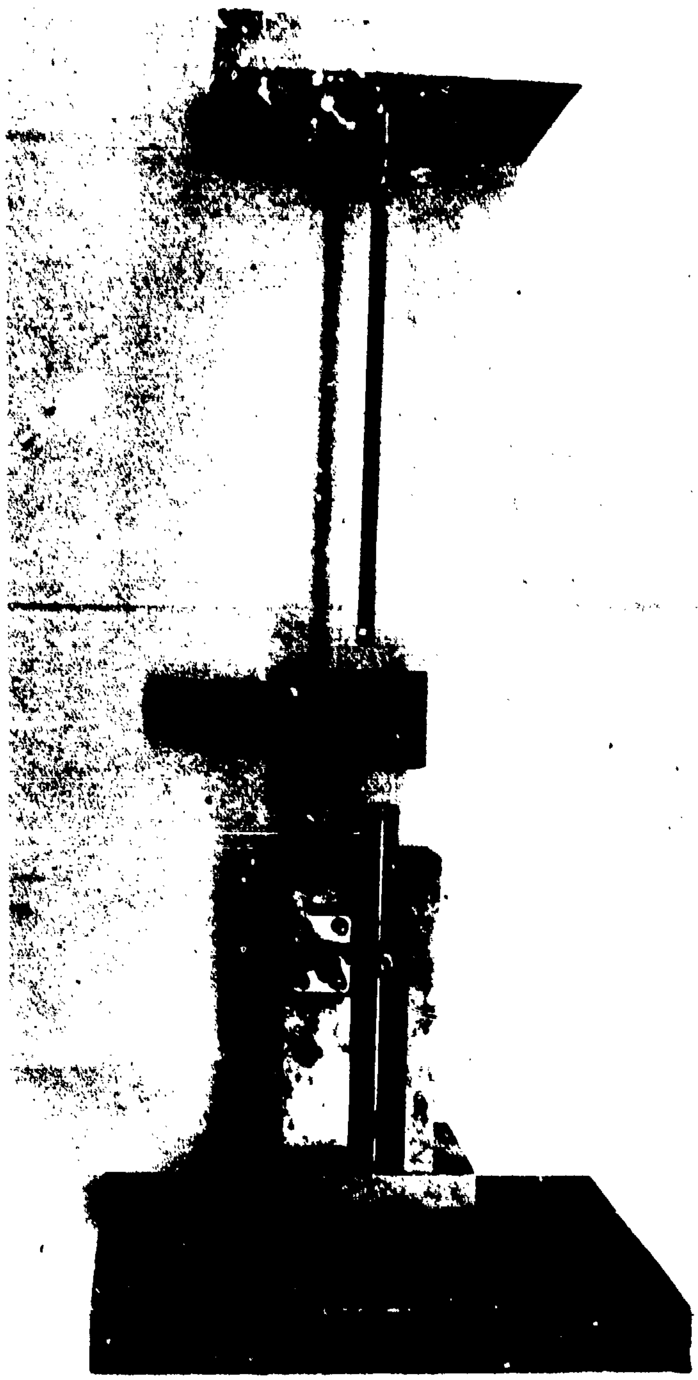


FIGURE 6. 7.62MM RIFLING TOOL ARRANGEMENT

FIGURE 7. 7.62MM RIFLING CATHODE TIP AND GUIDES

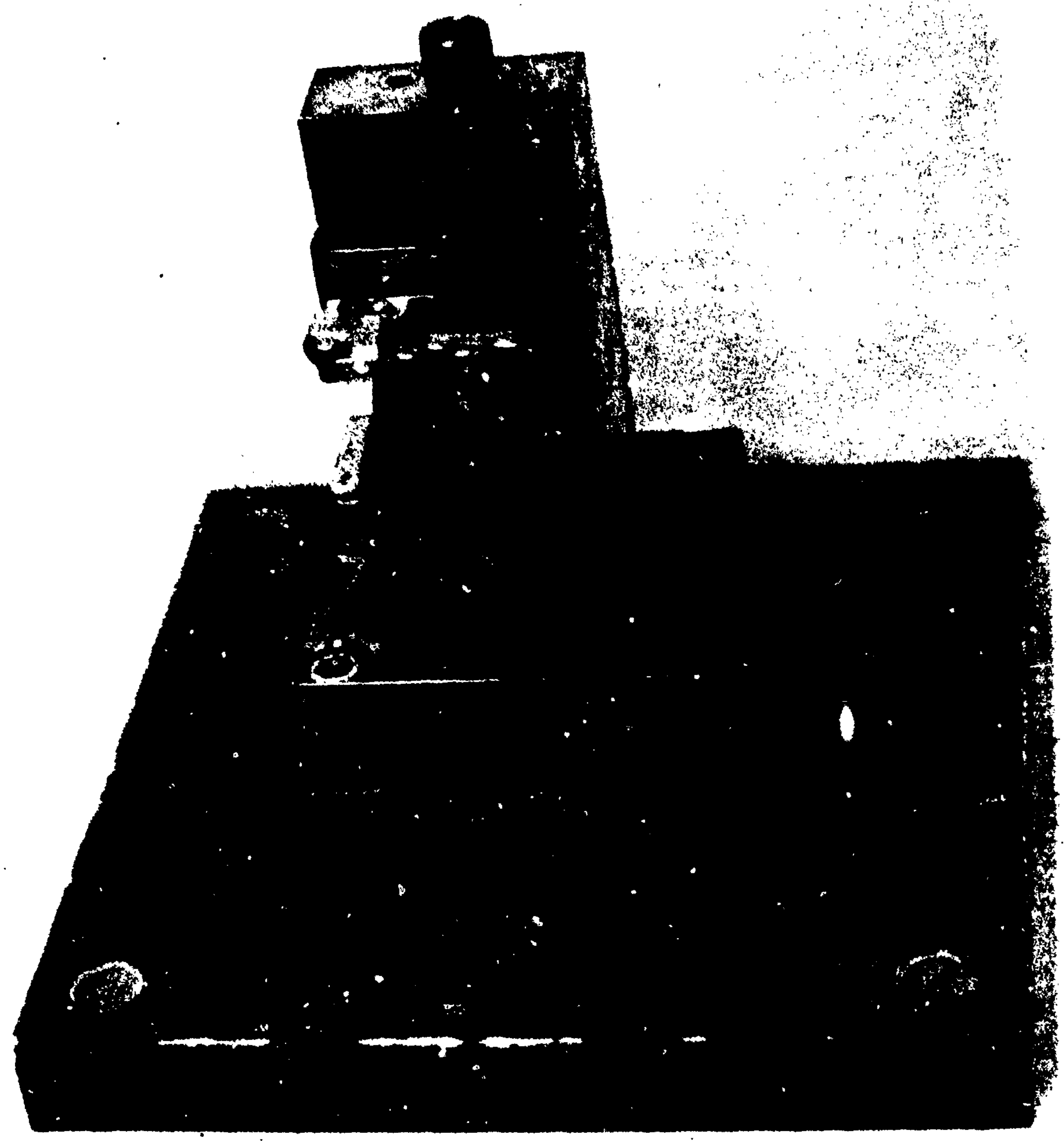


FIGURE 8. WORKPIECE HOLDER FOR 7.62MM RIFLING

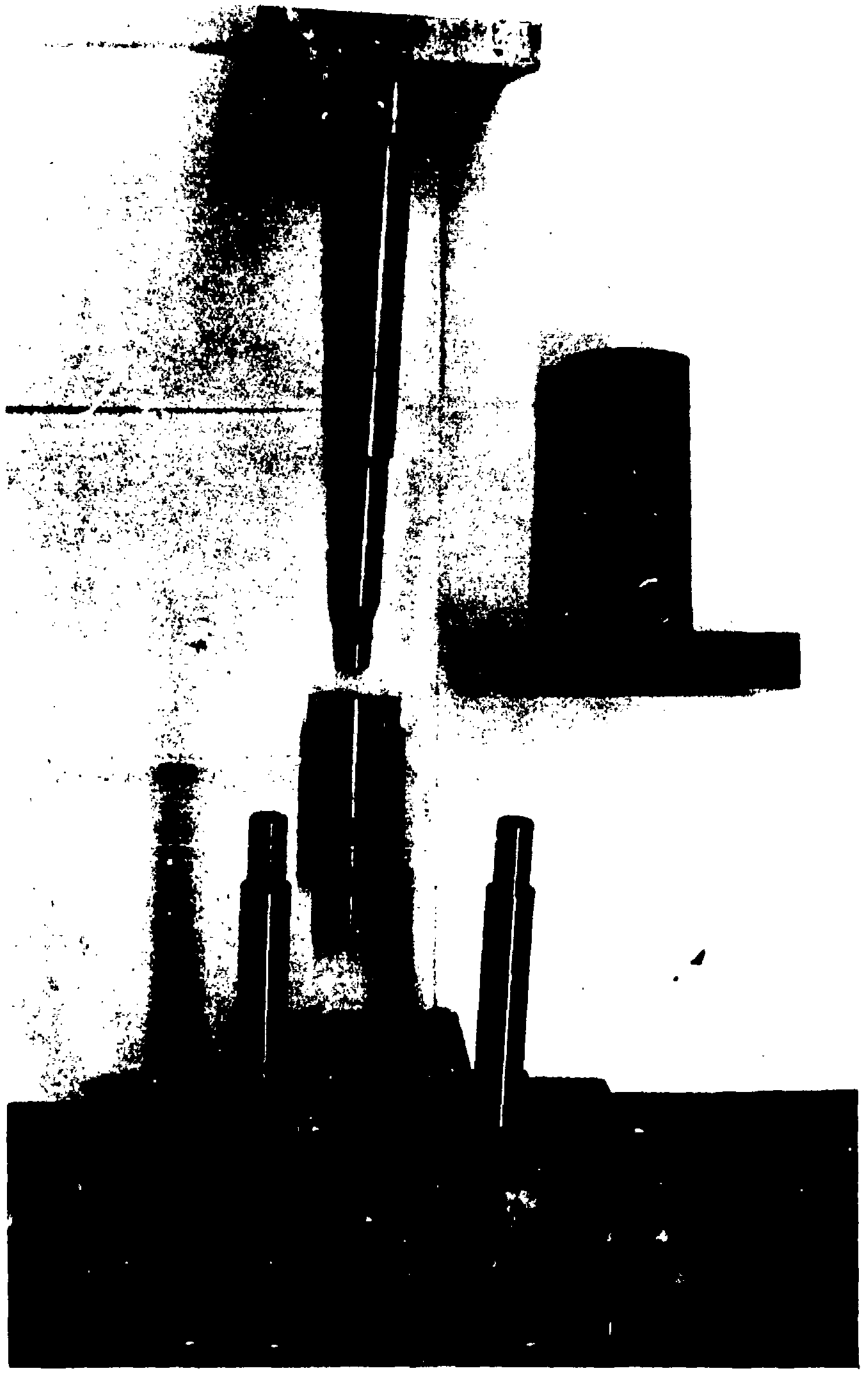


FIGURE 9. 20MM CARTRIDGE CHAMBER TOOLING

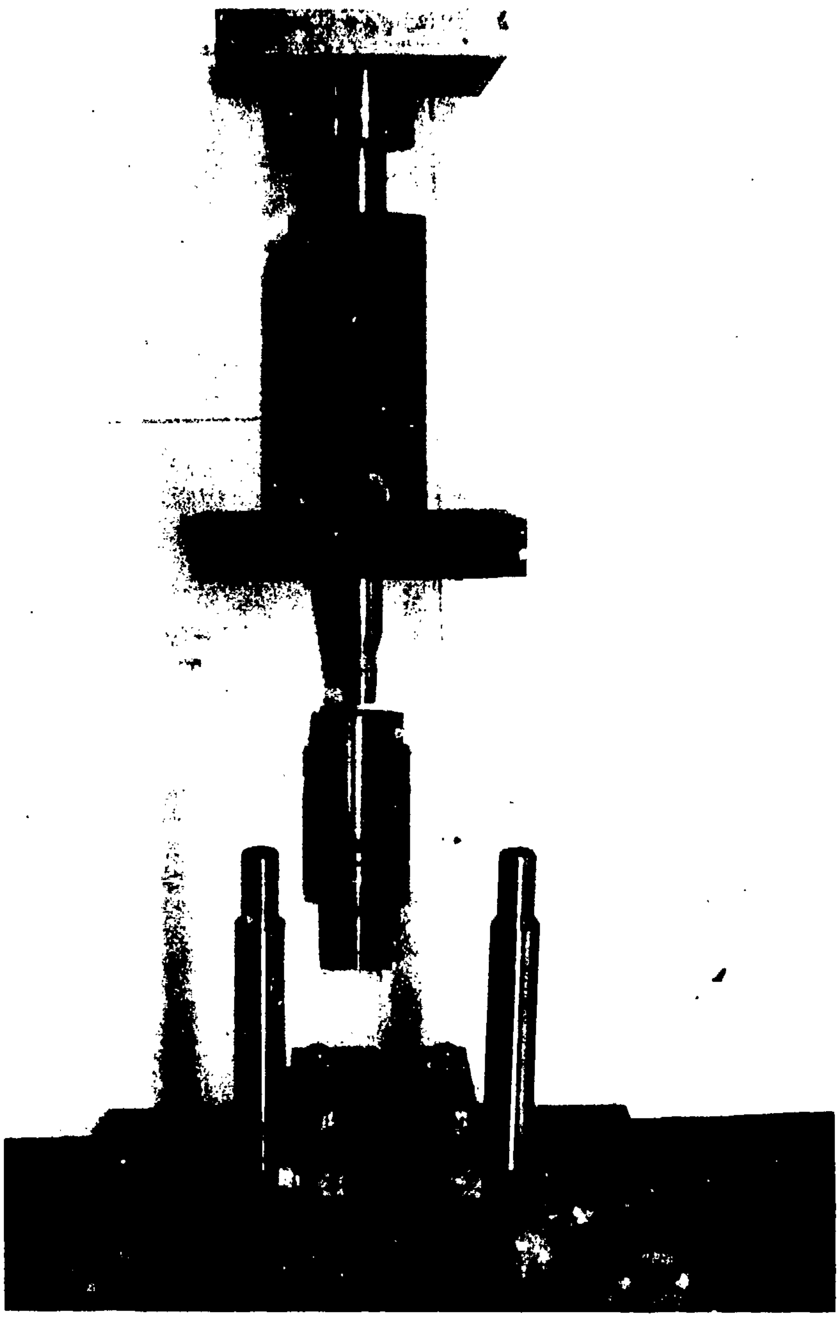


FIGURE 10. 20MM CARTRIDGE CHAMBER TOOL ARRANGEMENT

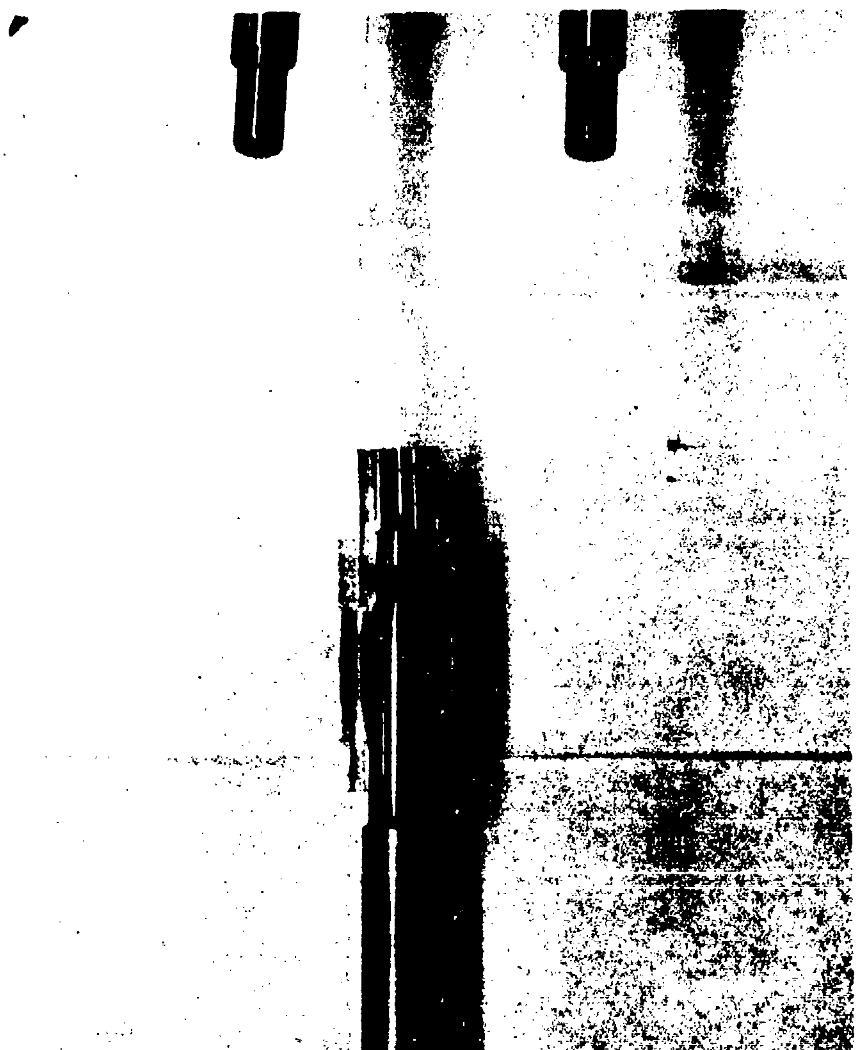


FIGURE 11. 20MM CARTRIDGE CHAMBER CATHODE - WORKPIECE

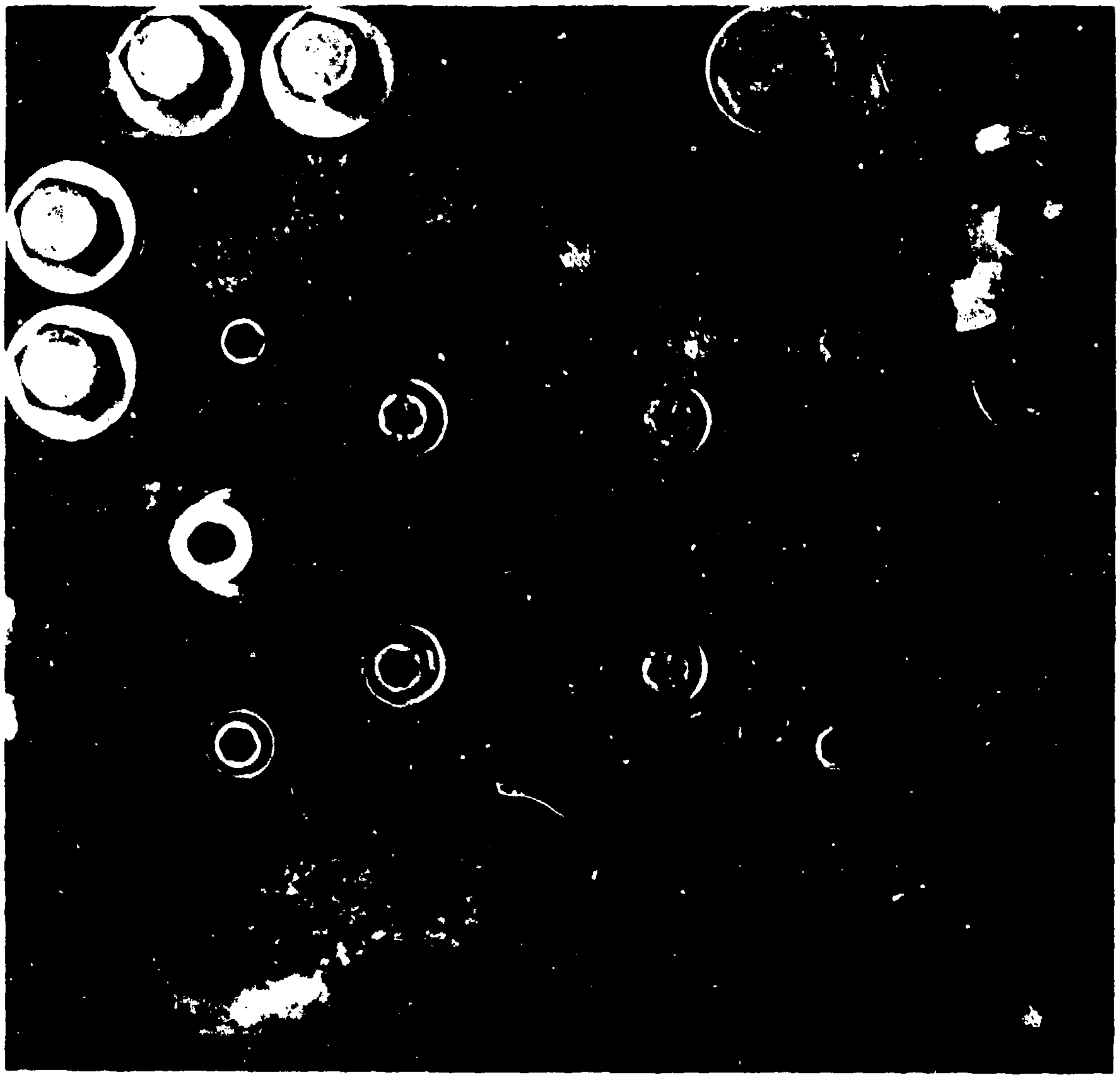
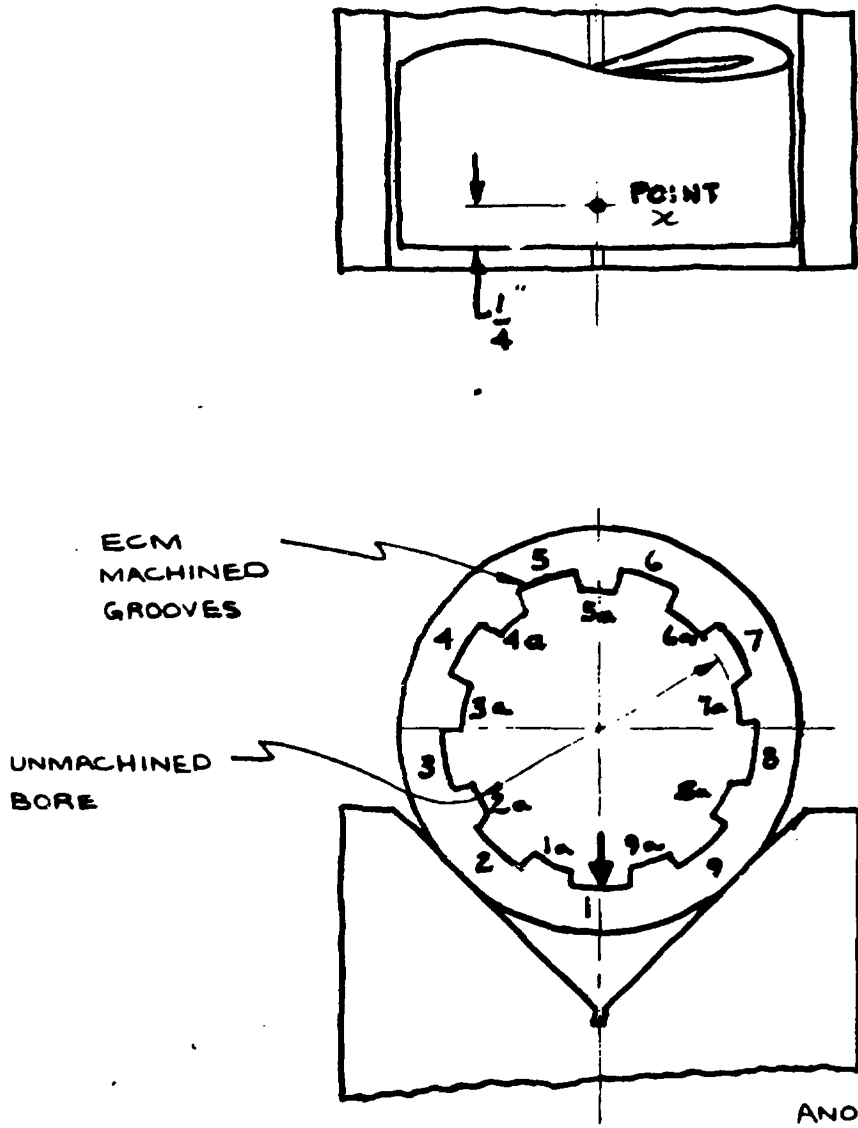


FIGURE 12. 20MM CARTRIDGE CHAMBER WORKPIECE HOLDER

APPENDIX B

Inspection Results of 20mm Rifling Tests



READINGS TAKEN @ POINT X 1/4" IN FROM TOP END OF PART.

PLUS READINGS INDICATE ID. TO OD. WALL THICKNESS IS HEAVIER.

READINGS SHOW UNIFORMITY OF GROOVE DEPTH IN RELATIONSHIP TO OD. MOUNTED IN V-BLOCK AND AS BORED ID.

SET INDICATOR @ ZERO ON GROOVE 1 AND RESET @ ZERO ON LAND 1a FOR CHECK

PART # 5

GROOVE	READING	LAND	READING
1	0	1a	0
2	+.0010	2a	-.0005
3	+.0005	3a	-.0007
4	+.0020	4a	-.0006
5	.0000	5a	-.0005
6	-.0010	6a	-.0004
7	-.0025	7a	+.0003
8	-.0015	8a	+.0003
9	-.0005	9a	+.0002

ANOCUT ENG. CO
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PART #7790801
SECT "D-D"
JOB #6997

FIGURE 1. CONCENTRICITY OF LANDS AND GROOVES, PART 5

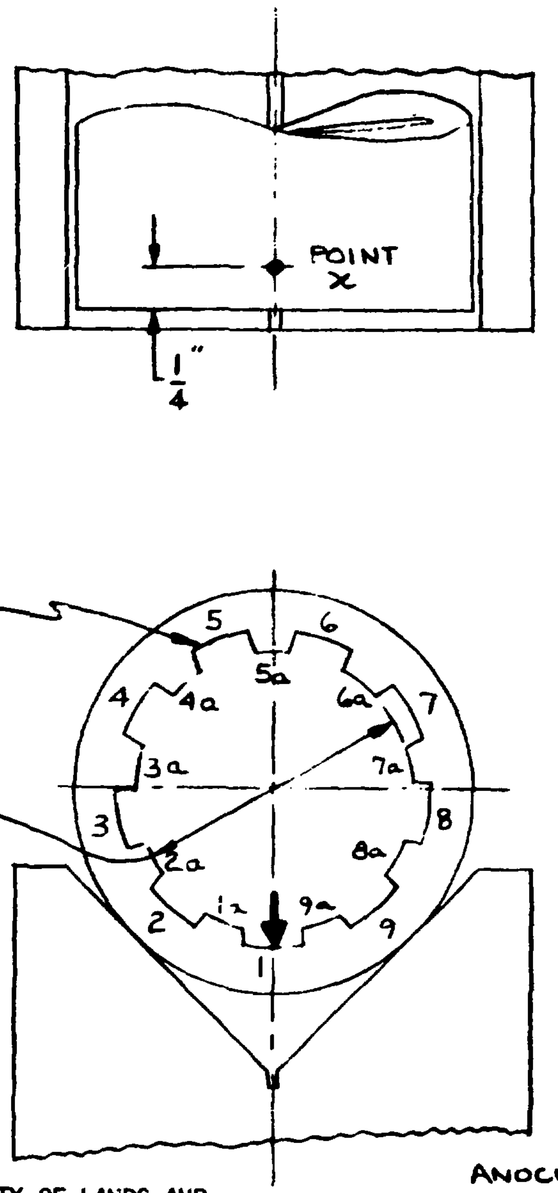

FIGURE 2. CONCENTRICITY OF LANDS AND GROOVES, PART 6

READINGS TAKEN @ POINT X 1/4" IN FROM TOP END OF PART.

PLUS READINGS INDICATE ID. TO OD WALL THICKNESS IS HEAVIER.

READINGS SHOW UNIFORMITY OF GROOVE DEPTH IN RELATIONSHIP TO OD. MOUNTED IN V-BLOCK AND AS BORED ID.

SET INDICATOR @ ZERO ON GROOVE 1 AND RESET @ ZERO ON LAND 1a FOR CHECK.

PART # 6

GROOVE	READING	LAND	READING
1	0	1a	0
2	-.0015	2a	+.001
3	.0000	3a	+.0005
4	+.0030	4a	"
5	+.0075	5a	"
6	+.0120	6a	"
7	+.0130	7a	"
8	+.0105	8a	"
9	+.0045	9a	"

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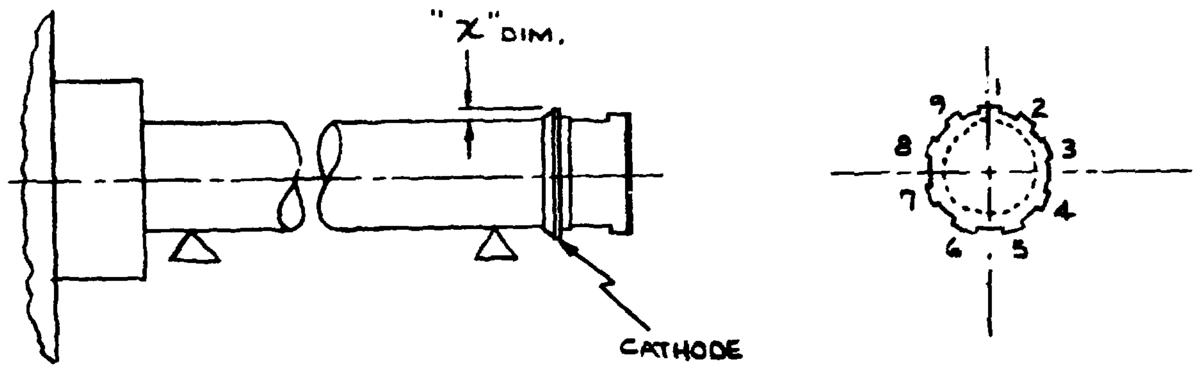
4-29-71 GHK.

PART #7790801
SECT "D-D"
JOB #6997

$.797^{+.000}_{-.001} = \begin{matrix} .797 \\ .796 \end{matrix}$ $\begin{matrix} .797 \\ \underline{.684} \\ .113 \end{matrix}$ $\begin{matrix} .796 \\ \underline{.686} \\ .110 \end{matrix}$

$.686^{+.000}_{-.002} = \begin{matrix} .686 \\ .684 \end{matrix}$

$X = .0565'' / .055''$



	1	2	3	4	5	6	7	8	9
A	.7460	.7465	.7460	.7460	.7455	.7460	.7460	.7460	.7455
B	.6895	.6900	.6895	.6895	.6890	.6890	.6890	.6895	.6895
X	.0565	.0365	.0565	.0565	.0565	.0570	.0570	.0565	.0560

A = READING OVER CATHODE TIP.
B = " " CATHODE BODY
X = RELATIONSHIP BETWEEN A & B @ 9 CATHODE TIP LOCATIONS

ANOCUT ENG. CO.
CATHODE INSPECTION
PART # 7790801 SECT "D-D"
JOB # 6997
ECM TOOLING LAYOUT #34700620
3-1-71 G.H.K.

FIGURE 3. CATHODE INSPECTION

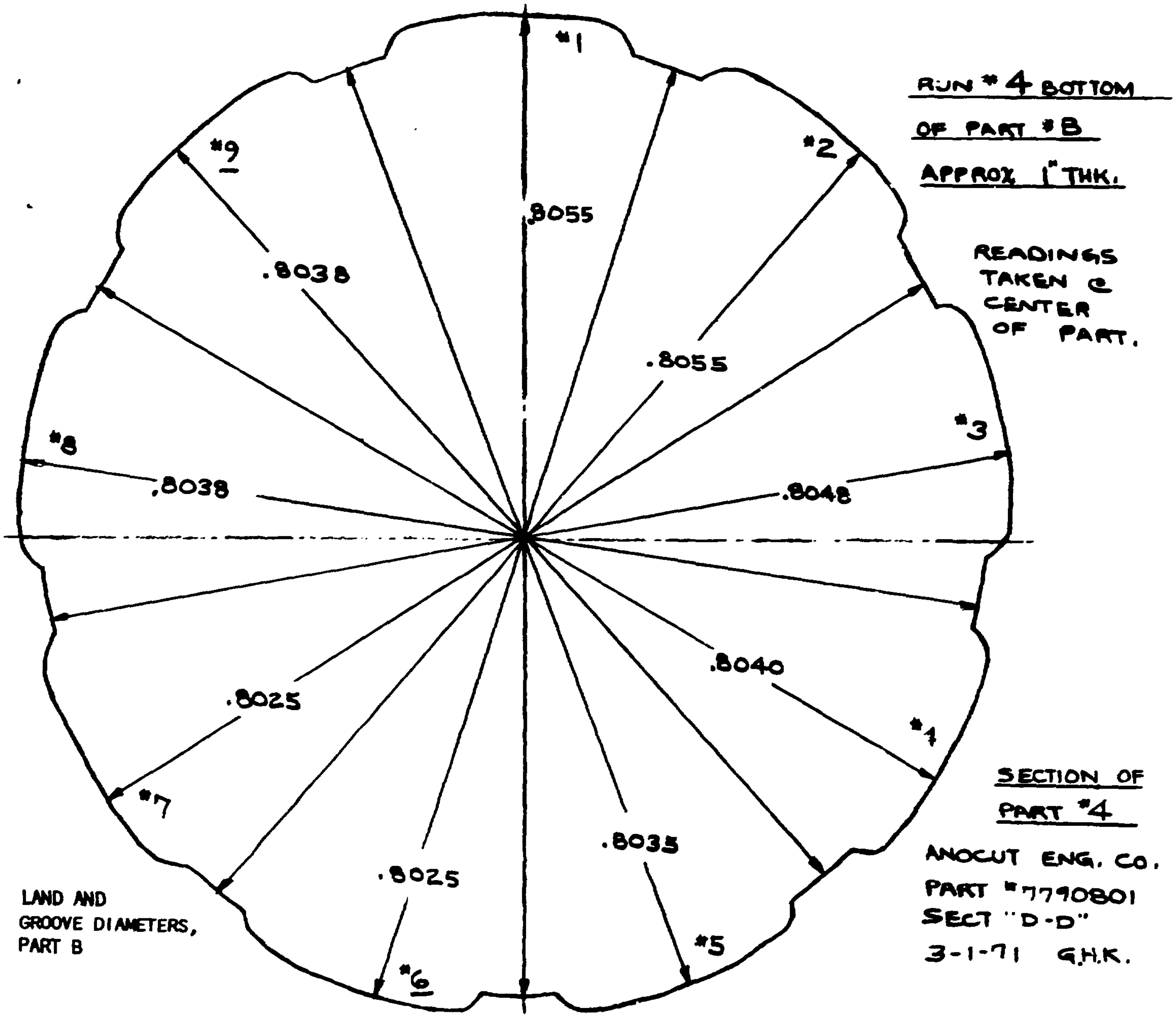


FIGURE 4. LAND AND GROOVE DIAMETERS, PART B

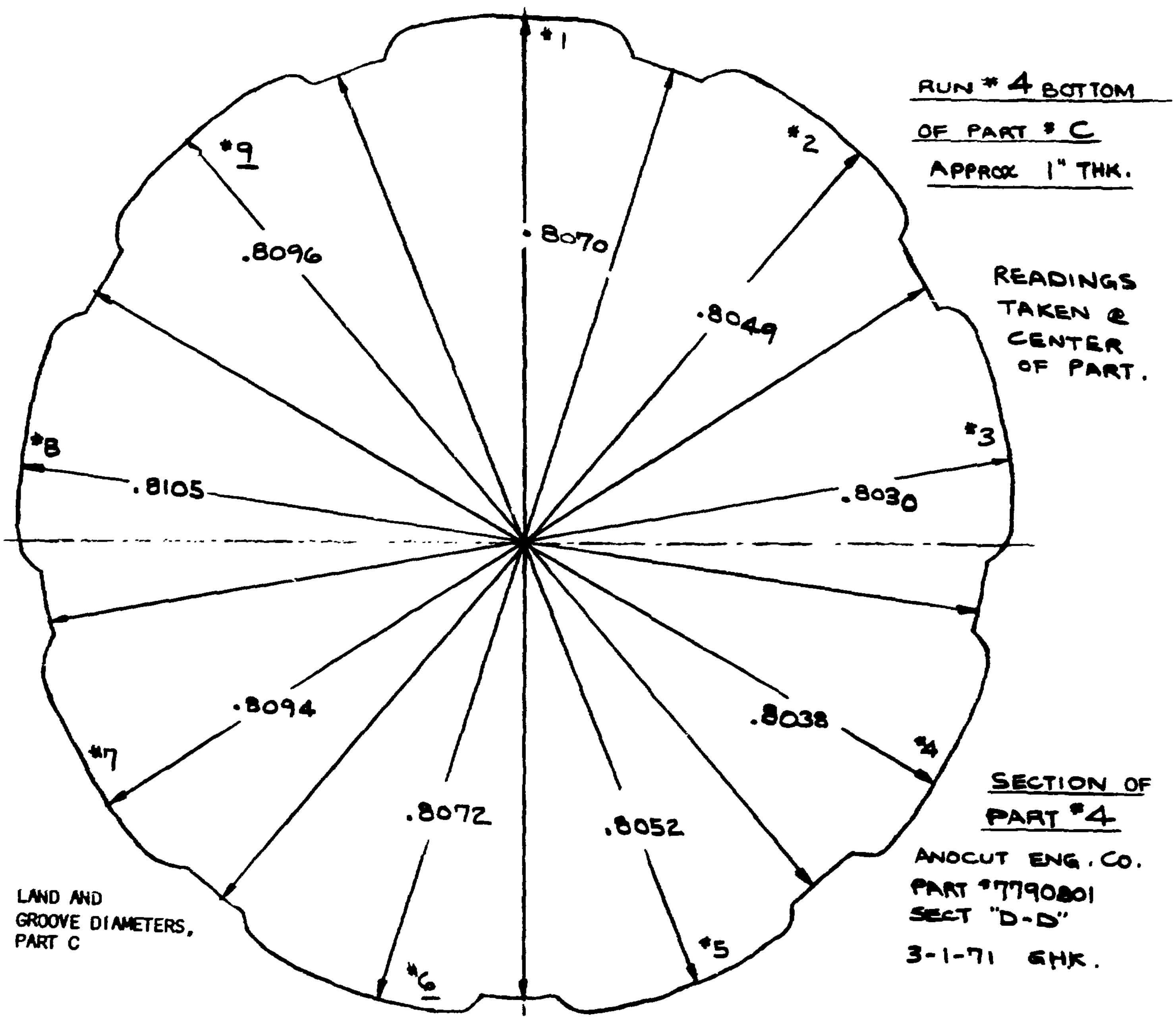


FIGURE 5. LAND AND GROOVE DIAMETERS, PART C

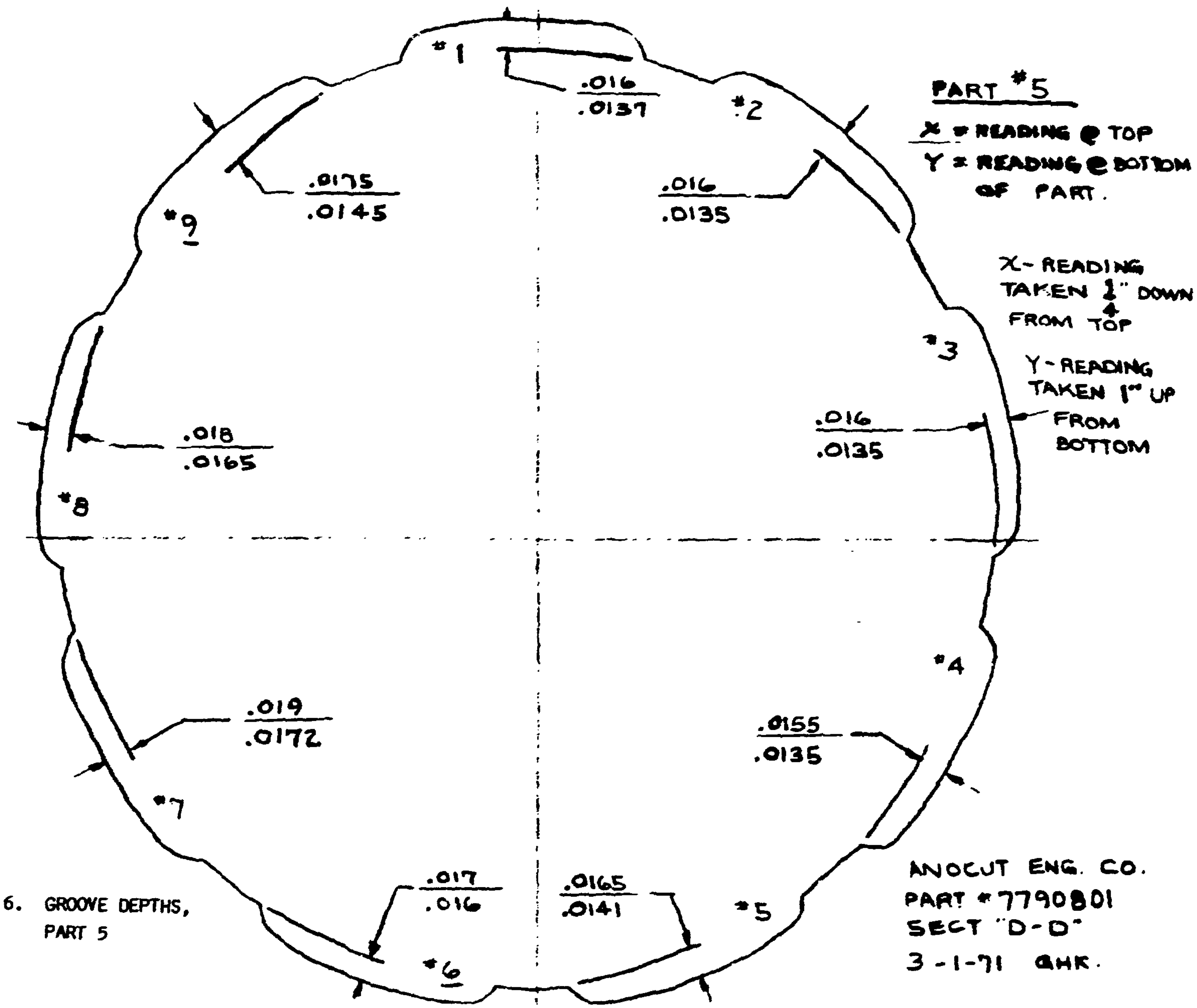


FIGURE 6. GROOVE DEPTHS, PART 5

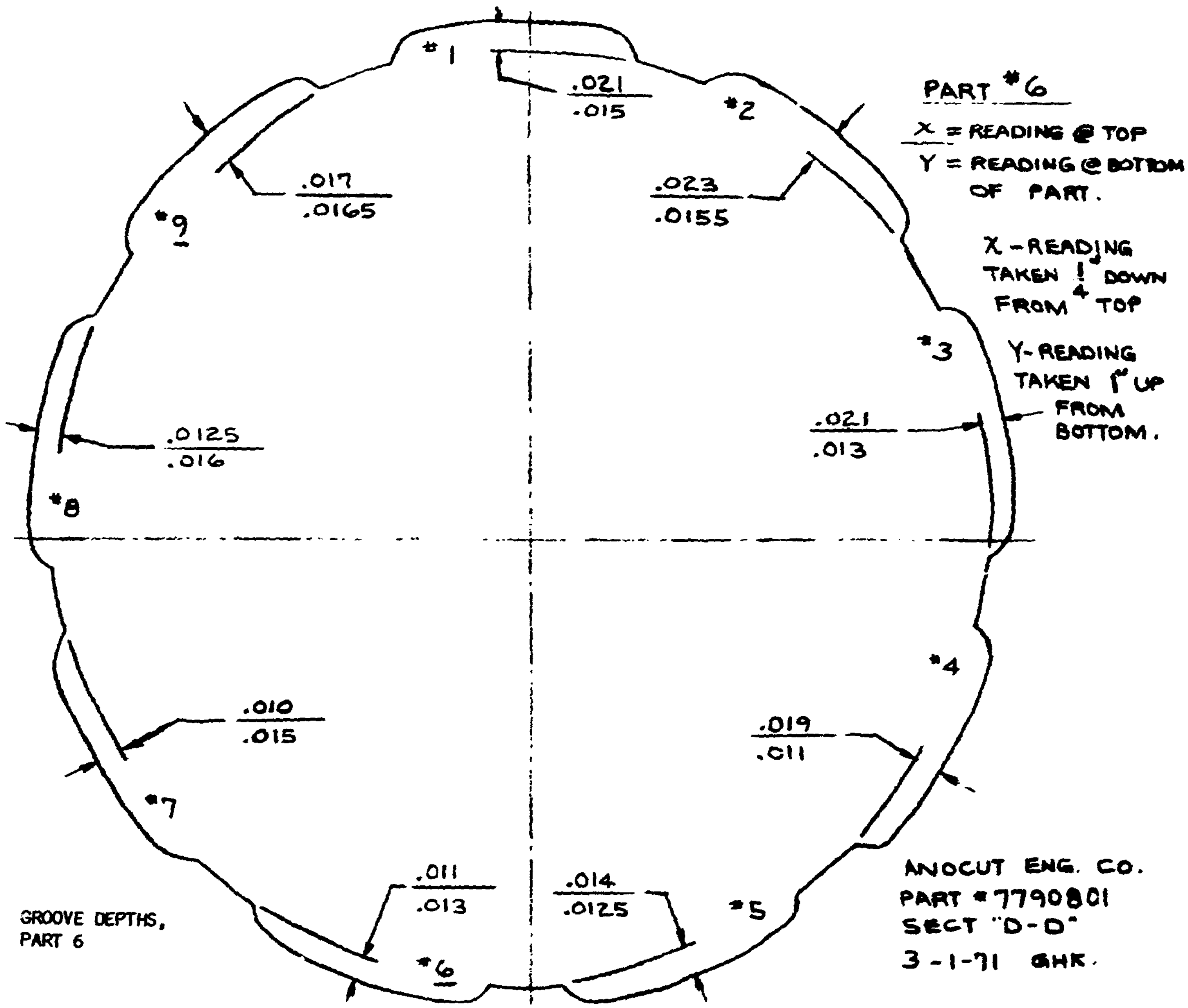
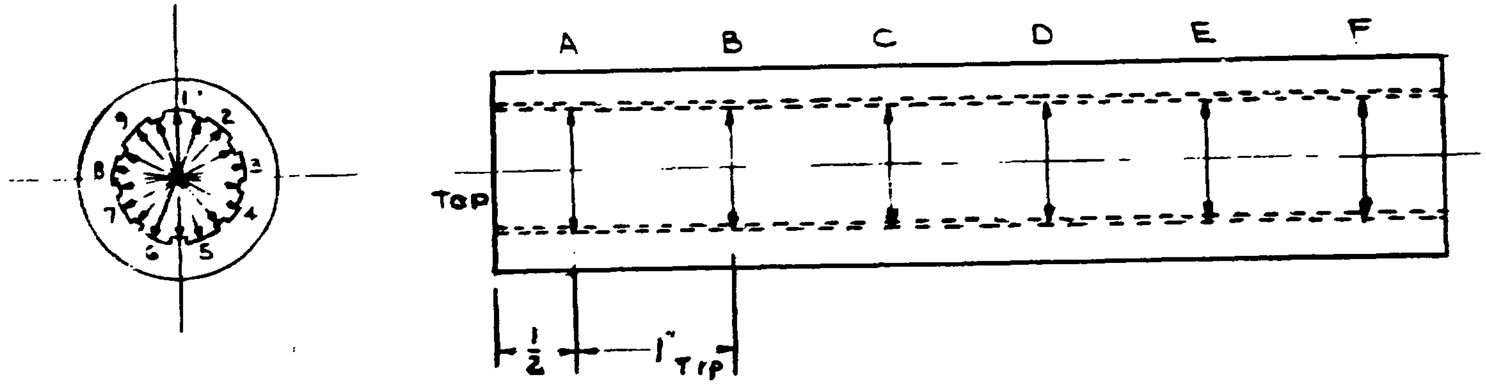


FIGURE 7. GROOVE DEPTHS, PART 6



	POSITIONS A	B	C	D	E	F
GROOVE # 1	.8015	.8006	.8007	.8004	.8003	.8007
" # 2	.7998	.7997	.7998	.7998	.8000	.7995
" # 3	.7997	.7998	.8003	.8005	.8007	.8010
" # 4	.7995	.7998	.8005	.8010	.8005	.8010
" # 5	.8010	.8002	.8009	.8013	.8014	.8010
" # 6	.8030	.8018	.8021	.8024	.8020	.8017
" # 7	.8050	.8020	.8019	.8018	.8012	.8009
" # 8	.8029	.8022	.8015	.8010	.8008	.8006
" # 9	.8010	.8007	.8005	.8001	.7996	.7997

ALL READINGS TAKEN FROM GROOVE TO LAND 180° OPPOSITE TO SHOW UNIFORMITY OF ECM GROOVES.

PART # 5

ANOCUT ENG. CO.
PART # 779C801 SECT. "D-D"
JOB # 6997
ECM TOOLING LAYOUT
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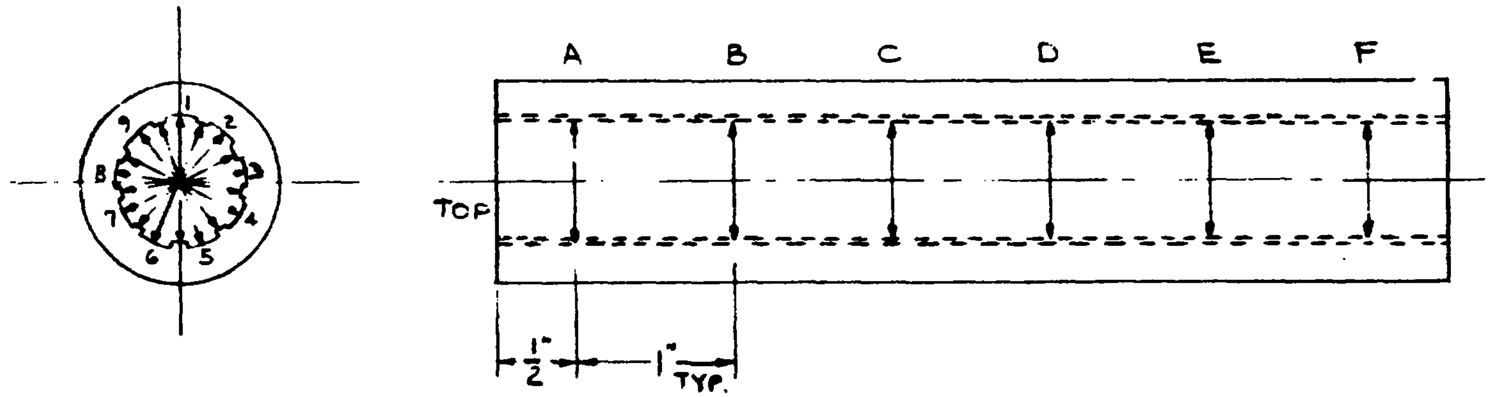
FIGURE 8. LAND AND GROOVE DIAMETERS THROUGH PART 5



	POSITIONS A	B	C	D	E	F
GROOVE # 1	.8094	.8097	.8099	.8053	.8038	.8035
" # 2	.8107	.3113	.8108	.8069	.8051	.8048
" # 3	.8095	.8100	.8100	.8050	.8035	.8028
" # 4	.8052	.8054	.8038	.8020	.8017	.8015
" # 5	.8003	.8004	.7982	.7984	.7996	.7991
" # 6	.7968	.7964	.7964	.7965	.7974	.7985
" # 7	.7962	.7965	.7961	.7962	.7968	.7974
" # 8	.7983	.7987	.7978	.7980	.7985	.7994
" # 9	.8040	.8038	.8022	.8020	.8016	.8015

ALL READINGS TAKEN FROM GROOVE TO LAND 180° OPPOSITE TO SHOW UNIFORMITY OF ECM GROOVES.

PART # 6

ANOCUT ENG. CO.
PART # 7790801 SECT "D-D"
JOB # 6997
ECM TOOLING LAYOUT
34700620
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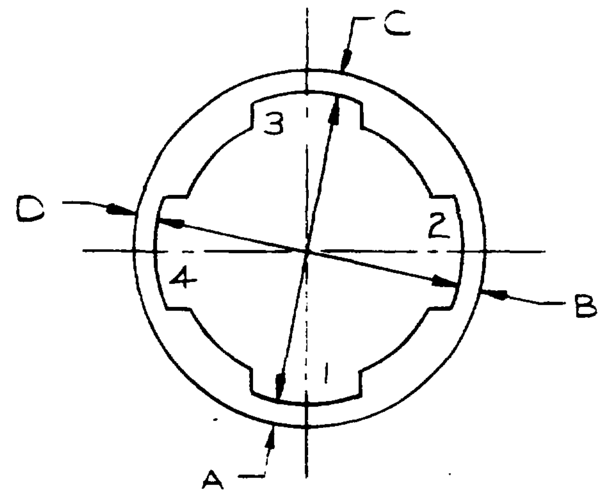
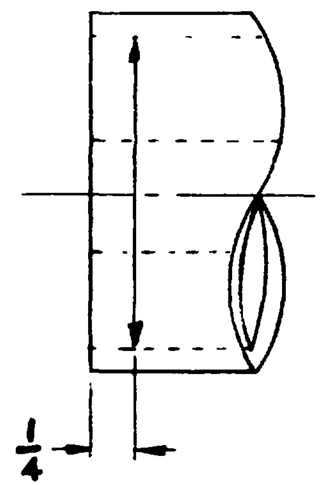
FIGURE 9. LAND AND GROOVE DIAMETERS THROUGH PART 6

APPENDIX C

Inspection Results of 7.62mm Rifling Tests





DIAL BORE GAUGE READINGS TAKEN FROM GROOVE 1 TO 3 AND 2 TO 4 RESPECTIVELY @ $\frac{1}{4}$" IN FROM MARKED END OF SECTION.

WALL THICKNESS READINGS A THRU D TAKEN @ MARKED END OF SECTION.

PART #7

SECTIONS OF PART

	1	2	3	4	5	6
DIA. 1 – 3	.3115	.3120	.3140	.3120	.3140	.3140
DIA. 2 - 4	.3130	.3140	.3100	.3140	.3120	.3100
A	.157	.157	.156	.157	.153	.156
B	.55	.157	.156	.152	.156	.155
C	.152	.152	.152	.152	.153	.152
D	.153	.155	.153	.155	.153	.157

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PART #11701204
SECTION "B-B"

FIGURE 1. GROOVE DIAMETERS, PART 7

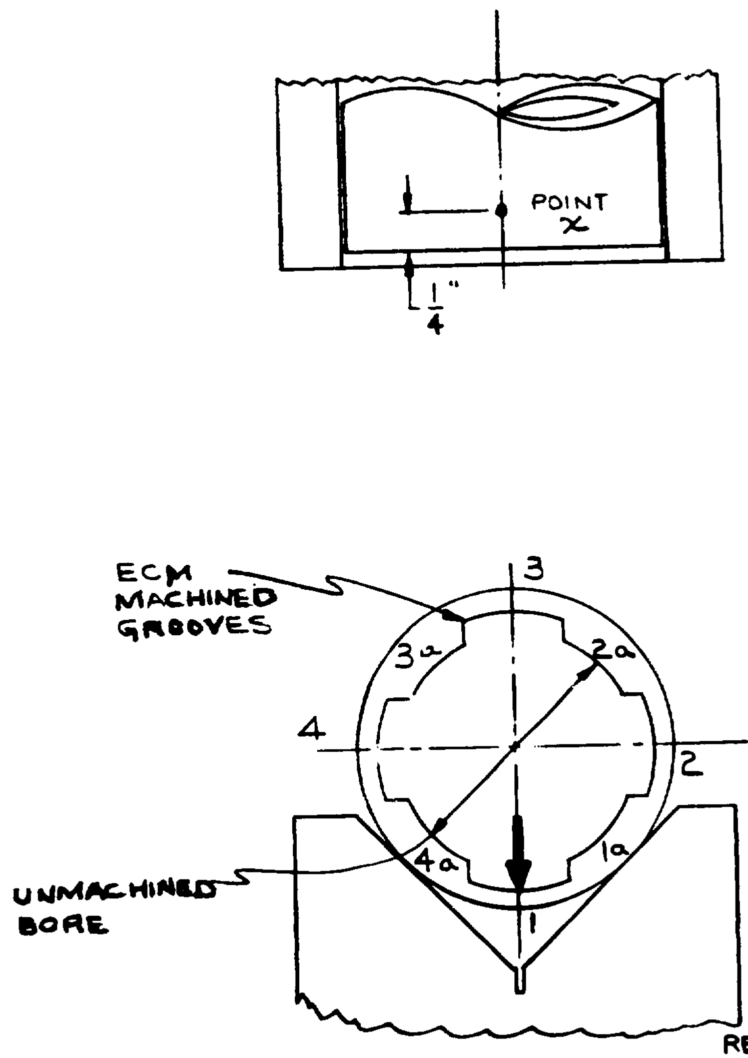

FIGURE 2. LAND DIAMETERS, PART 7

READINGS TAKEN @ POINT X $\frac{1}{4}$" IN FROM MARKED END OF PART.

PLUS READINGS INDICATE ID. TO OD. WALL THICKNESS IS HEAVIER.

READINGS SHOW UNIFORMITY OF GROOVE DEPTH IN RELATIONSHIP TO OD. MOUNTED IN V-BLOCK AND AS BORED ID.

SET INDICATOR @ ZERO ON GROOVE 1 ROTATE PART CLOCKWISE. RECORD READINGS @ LANDS AND GROOVES

PART # 7

SECTIONS OF PART

1	0 \ 1	0 \ 2	0 \ 3	0 \ 4	0 \ 5	0 \ 6
1a	+.0045	+.0025	+.0040	+.0020	+.0050	+.0070
2	-.0020	-.0060	+.0020	-.0060	+.0025	+.0040
2a	+.0030	+.0025	+.0040	+.0015	+.0050	+.0065
3	-.0060	-.0050	-.0030	-.0060	-.0020	-.0020
3a	+.0010	+.0040	+.0040	+.0025	+.0045	+.0060
4	-.0070	-.0020	-.0030	-.0030	-.0030	-.0020
4a	+.0020	+.0040	+.0055	+.0030	+.0060	+.0070
REPEAT 1	0	0	0	0	0	0

ANOCUT ENG. CO
6-1-71 G.H.K.

PART # 11701204
SECTION "B-B"

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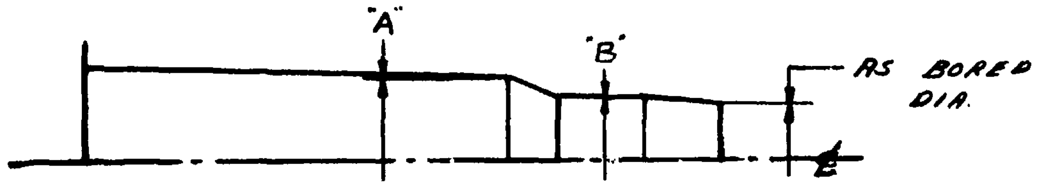
APPENDIX D

Inspection Results of 20mm Chambering Tests

20 MM BREECH

C.R.S. TEST PIECES



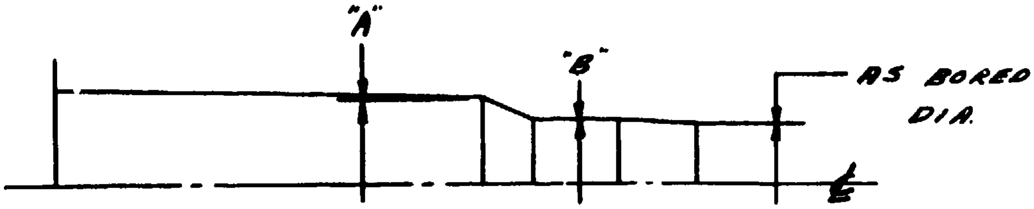
C.R.S. TEST PIECE NUMBER	"A" DIMENSION 1.0524/1.0544 DIA.		"B" DIMENSION .834/.837 DIA.		FEED RATE IN./MIN.	BACK PRESSURE HOLE DIA.
	CATHODE	PART	CATHODE	PART		
1	1.032	1.059	.804	.845	.300	.375
2	1.032	1.062	.804	.847	.300	.375
3	1.032	1.070	.804	.850	.300	.250
4	1.032	1.058	.804	.835	.325	.375
5	1.022	1.052	.780	.808	.300	.375
6	1.022	1.052	.780	.808	.300	.375
7	1.022	1.052	.808	.860	.300	.375
8	1.022	1.053	.796	.847	.300	.375
9	1.022	1.053	.790	.840	.300	.375
10	1.022	1.053	.787	.848	.300	.375
11	1.022	1.051	.787	.833	.300	.375
12	1.022	1.052	.787	.829	.300	.375
13	1.022	1.052	.787	.827	.300	.375
14	1.022	1.052	.787	.847	.300	.375
15	1.022	1.052	.787	.841	.300	.375
16	1.022	1.053	.787	.837	.300	.375

FIGURE 1. 20MM BREECH, COLD ROLLED STEEL

GRS
3-10-72

20 MM BREECH

ROCK ISLAND ARSENAL MATERIAL



R.I.A. TEST PIECE NUMBER	"A" DIMENSION 1.0524/1.0544 DIA.		"B" DIMENSION .834/.837 DIA.		FEED RATE IN./MIN.	BACK PRESSURE HOLE DIA.
	CATHODE	PART	CATHODE	PART		
7	1.022	1.055	.787	.882	.300	—
8	1.022	1.055	.787	.870	.400	—
9	1.022	1.048	.787	.845	.500	—
10	1.022	1.048	.782	.822	.500	—
11	1.022	1.048	.782	.817	.500	—
12	1.022	1.048	.782	.816	.500	—
13	1.022	1.048	.782	.821	.500	.375
(1) 14	1.022	—	.782	.817	.500	—
14-A	1.022	1.042	.785	.828	.500	.375
(2) 15	1.022	—	.782	.829	.500	—
15-A	1.022	1.048	.797	.837	.500	—
16	1.022	1.048	.785	.825	.500	.375
(3) 20	1.022	1.047	.790	.839	.450	—

(1) PARTIAL DEPTH CUT (1.875 DEPTH)

(2) PARTIAL DEPTH CUT (1.150 DEPTH)

(3) BEST OVERALL RUN

FIGURE 2. 20MM BREECH, Cr-Mo-V STEEL (MIL-S-46047)

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Technical Report #

AD ____________ Accession No. ____________

CDR, Rock Island Arsenal
GEN Thomas J. Rodman Laboratory
Rock Island, Illinois 61201

Anocut Engineering Co.
2375 Estes Avenue
Elk Grove Village, IL 60007

UNCLASSIFIED

1. Machining
2. Electrochemical
3. Gun Barrels
4. Rifling
5. Cartridge Chambers

ELECTROCHEMICAL MACHINING OF CARTRIDGE CHAMBER AND RIFLING CONTOURS FOR SMALL ARMS, by C. Maiorano, Anocut Engineering Co. and R. Kirschbaum, Rock Island Arsenal.

Report R-CR-76-037, Sep 76, 47 p. incl. illus and tables (Contract DAAF01-70-C-1076, AMS Code 4932.06.6770) Unclassified Report.

The feasibility of electrochemically machining, rifling and cartridge chamber contours in gun barrels was determined. Electrochemical machining (ECM) tests were conducted using single-electrode, continuous-feed, straight-plunge cutting. Multiple-groove, straight rifling was formed successfully in 7.62mm and 20mm, Cr-Mo-V steel (MIL-S-46047) gun barrel sections.

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Cartridge chambers were machined in 20mm sections of AISI 1018 cold rolled steel and Cr-Mo-V steel. Although ECM tests were successful with the mild steel (1018), shape and surface-finish tolerances were not concurrently achieved in the low alloy steel (Cr-Mo-V). Test results did indicate that ECM of cartridge chambers in the low alloy steel would be possible with additional experimentation.

Based on program test results and state-of-the-art, when compared to the efficiencies of other forming processes such as rotary forging and broaching, it is recommended that no immediate efforts be made to apply ECM in the production of small arms gun barrels. However, future developments in ECM should be monitored for application of small arms rifling and chambering, especially for gain twist rifled gun barrels.

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