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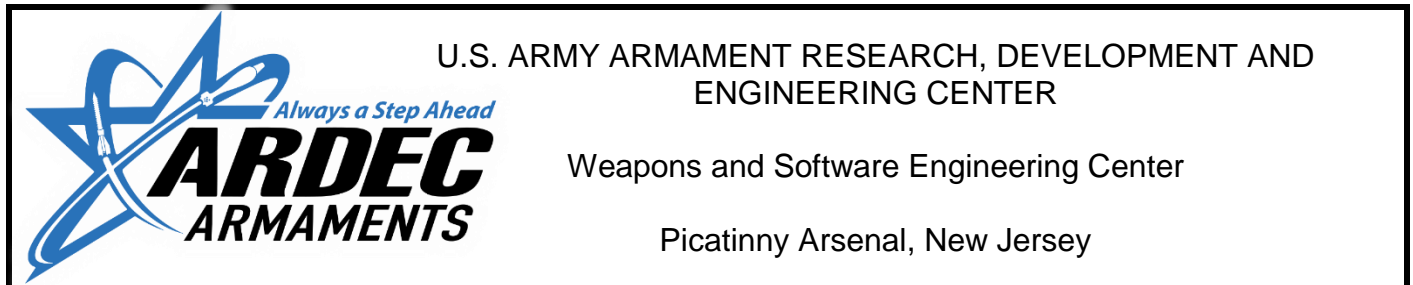
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Technical Report ARWSE-TR-17028

REDESIGN OF COPPER CYLINDER USED FOR M4, M16, AND M249 FIRING PIN INDENT

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October 2018



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14. ABSTRACT <p>A series of design experiments was conducted to update the U.S. Government copper crusher drawing for 5.56-mm weapon firing pin indent testing to current material standards with appropriate requirements that result in a manufacturable, consistent, and reliable crusher for firing pin indent testing. Three characteristics were determined to best define the cylinder, and were applicable to the final drawing revision. A clear definition of the production material was needed, as the state of the material controls the initial mechanical state of the product. The dimensional limits of the part are of second concern because without these constraints, the item cannot function as intended. For this case, the cylinder's length, diameter, and surface-end perpendicularity was constrained in order to allow for proper fit and function during gaging use; the establishment of compression testing at 45,000 psi by Frankford Arsenal, Philadelphia, PA, remains the ideal test for evaluating the cylinders mechanical properties.</p>					
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CONTENTS

	Page
Introduction	1
Background	1
Description	1
Uses	2
History	3
Material and Functional Baseline Methodology	4
Vendor Samples	4
Sample Dimensional	4
Chemical Composition	5
Indent Testing	5
Compression Testing	6
Hardness Testing	6
Grain Size	7
Material and Functional Baseline Results and Analysis	7
Sample Dimensional Analysis	7
Chemical Composition Analysis	8
Indent Analysis	8
Compression Analysis	13
Hardness Analysis	18
Grain Size Analysis	20
Design Development	25
Conclusions	29
Recommendations	29
References	31
Appendix – Sensitivity Drop Fixture Data	33
Distribution List	61

FIGURES

1 Frankford Arsenal copper pressure cylinders (DR8440920)	1
2 Percussion primers sensitivity testing fixture (DR8648625)	10
3 Plot of individual sample indents	12

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FIGURES
(continued)

	Page
4 Percentage overall length remaining versus applied compressive load	16
5 Overall length remaining versus pressure	16
6 Percentage overall length remaining versus pressure, target compression range of 81 to 84% original length (OL)	17
7 Interlaboratory cylinder compression reproducibility study	18
8 Copper cylinder hardness results	20
9 Commercial source Lot 873, 75X	21
10 Frankford Arsenal, Lot 1C-71, 75X	21
11 Rock Island Lot 2C-91, 75X	22
12 C10200 coil after straightening and machining to size, before anneal, 75X	22
13 C10200 coil after 650°C anneal, 75X	23
14 C11000 rod after 650°C anneal, 75X	23
15 C10200 coil, 500°C anneal, 75X	24
16 C11000 rod, 500°C anneal, 75X	24
17 Percentage original length at 45,000 psi pressure shown in the target compression range of 81 to 84% OL	27
18 45,000 psi compression results were nearly identical for FA 4C-71 and PRPF coil 650, ball drop results differed	28

TABLES

1 Tensile requirement	2
2 Dimensional inspection of copper cylinders	7

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TABLES
(continued)

	Page
3 Chemical composition testing	8
4 M4 bolt action indent, plug gage DR84402219, weapon held horizontal, selector on SEMI	9
5 M4 bolt action indent, plug gage DR84402219, weapon held vertical, selector on SEMI	9
6 M4 muzzle down position indent, plug gage DR8440220, weapon held vertical, selector on SEMI	9
7 M249 indent, plug gage DR84402219, weapon held horizontal	9
8 Sensitivity test fixture indent depth	11
9 Compression results at 1,500 lb	13
10 Compression results at 1,700 lb	14
11 Compression results at 1,900 lb	15
12 Independent laboratory mechanical test results	18
13 Hardness results	19
14 Grain size results	25

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INTRODUCTION

Evaluation of material, manufacturing, geometry, and annealing response characteristics of copper cylinders used for small caliber weapons testing is critical toward understanding the impact each characteristic has on the copper cylinder's ability to accurately and consistently measure firing pin indent. For this effort, material testing of cylinders from multiple sources was conducted to evaluate the characteristics of copper cylinders required to properly specify the copper cylinder design used on the M4 carbine, M16 rifle, and M249 squad automatic weapon (SAW) for measurement of firing pin indent energy. Methods for evaluating copper cylinder suitability as a gage for firing pin indent were also established to validate U.S. Government prototype and industry designs against the consistently reliable U.S. Government copper cylinders produced by Frankford Arsenal, Philadelphia, PA, prior to its closing in the 1970s. This information was later applied through a series of design experiments to update the U.S. Government copper crusher drawing for 5.56-mm weapon firing pin indent testing to current material standards with appropriate requirements that, when met, result in a manufacturable, consistent, and reliable crusher for firing pin indent testing.

BACKGROUND

Description

The pressure cylinder, shown in figure 1, and specified by U.S. Army drawing (DR) 8440920, is 0.3990 to 0.4010-in. long and has a diameter of 0.2245 to 0.2265 in. The required material is copper rod specified per MIL-C-12166 (August 14, 1952) in the cold drawn condition. The MIL-C-12166 specified that the electrolytic copper rod be of the best grade, made either by hot rolling or extrusion, and finished by cold drawing to the specified diameter. The material shall contain not less than 99.90% copper, silver being counted as copper. The material tensile requirement is also stated as shown in table 1 with the electrical resistivity of the rod not to exceed 0.15940 ohm at 20°C. In order to ensure proper fit in the fixture holding the cylinder, all edges are specified to be broken 0.03 in., and the cylinder ends shall be perpendicular within 0.0005 in. of the center axis of the cylinder. Later drawing revisions translated the perpendicular requirement to circular runout.

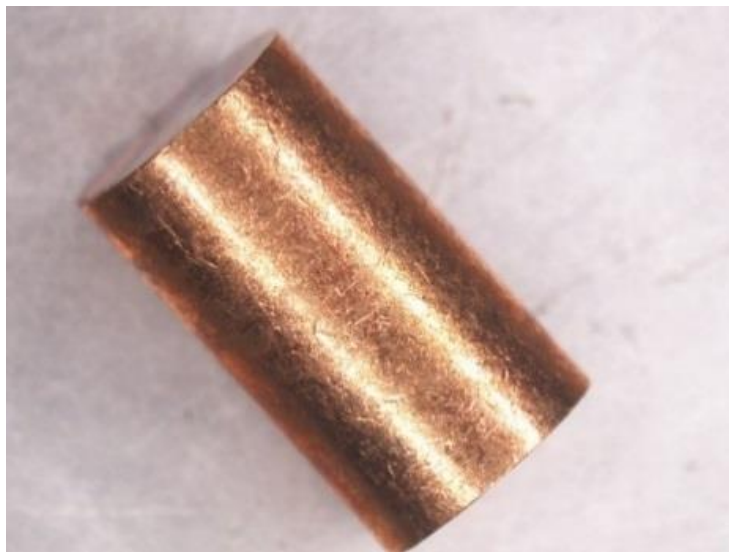


Figure1
Frankford Arsenal copper pressure cylinders (DR8440920)

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Table 1
Tensile requirement

Ordered diameter	Tensile strength, minimum	Elongation in 10 in., minimum
Inch	Psi	Percent
0.252	45,000	1.75
0.2255	50,000	1.25
0.1456	50,000	0.75

Drawing 8440920 also notes use of MIL-C-20109 (ref. 1). This specification outlines the grade, class, and size of the cylinders for which DR8440920 is specified as a size C cylinder. The dimensions listed in MIL-C-20109 correspond to the dimensions listed on the DR8440920. The general requirements also specify that the standard deviation of the length of any single lot of cylinders not exceed 0.00020 in., the standard deviation of the diameters shall not exceed 0.00050 in., and the faces of the individual copper pressure cylinder shall be parallel to each other within 0.0005 in. The copper pressure cylinders shall be annealed uniformly, and after annealing, the physical state of the copper cylinders shall be such that upon application of an initial load of 45,000 psi on the face of the cylinder, the resulting remaining length shall be between 0.81 and 0.84 of the original length. The MIL-C-20109 also specifies that cylinders be produced in 50,000 unit or greater lots, the cylinders be sent to Frankford Arsenal to be compressed in the compression machine for construction of the tarage table, and that the coppers are evaluated for acceptance.

Uses

Prior to the development of piezoelectric pressure sensors, copper pressure cylinders were primarily used to measure pressure for ammunition testing. To measure pressure, a copper crusher cylinder is compressed by a piston fitted to a piston hole into the chamber of the test barrel. Pressure generated by the burning propellant acts on the base of the piston, forcing the piston to move, thereby permanently compressing the copper cylinder. Pressures measured by this system are expressed in "copper units of pressure" (ref. 2).

The M4 series carbines, M16 series rifles, and M249 series machine guns all require the use of coppers to measure the indent force of the firing pin. The MIL-DTL-70599, MIL-DTL-63997, MIL-DTL-32309, and MIL-DTL-70446 all state the use of DR8440920 "cylinder, pressure" for conducting the indent test. The resulting indent is measured from the initial height of the cylinder to the bottom of the indent. This requires that the indicator gage measure the initial height of the copper cylinder prior to indent. The M4, M16, and M249 all require that the bolt action indent not be less than 0.020 in. when using plug gage DR8440219. The M4 and M16 also have a less than 0.008-in. muzzle down position indent requirement using plug gage DR8440220. The M4, M16, and M249 also require that the firing pin indent location not be off-center more than one half the maximum diameter of the indent. For this report, investigation of the copper cylinder was focused on M4, M16, and M249 usage. Lake City Army Ammunition Plant, Independence, MO, also uses the copper cylinders on:

- Remington 700
- Universal receiver
- M14
- M134

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- M240
- M1903
- M1
- M2
- M3
- XM218
- M88 (McMillian)
- M107 (Barrett)

History

The stockpile of Frankford Arsenal copper crushers, the U.S. Army standard used as a gage for firing pin indent testing, is dwindling. Stock piles of these cylinders have existed since Frankford Arsenal's closure at U.S. Government facilities and at contractor facilities producing weapons and ammunition for the U.S. Government. The last copper cylinders conforming to DR8440920 were produced by Rock Island Arsenal, Rock Island County, IL, in the 1990s. Currently, no U.S. Government agency or commercial vendor produces cylinders to DR8440920. The crusher, DR8440920, contains a material specification and military specification for copper pressure cylinders that are now defunct. In recent years, copper cylinder stock piles have dwindled to a level that organizations have resolved to procure commercially produced cylinders in order to meet their production test needs. These commercial cylinders, typically produced to the Sporting Arms and Ammunition Manufacturers Institute (SAAMI), Newtown, CT, specifications, do not conform completely to the requirements of DR8440920, and until now, have not been previously assessed by the U.S. Government.

The copper cylinder specified by DR8440920 has had a long history of uses since its inception. In 1930, the U.S. Army, through Frankford Arsenal, used DR5039436 to produce copper cylinders in order to measure the pressure of ammunition. Eventually, these cylinders were adopted to measure firing pin indent on a multitude of weapons including the current day M4 carbine, M16 rifle, and the M249 SAW. In 1970, DR5039436 was transitioned to DR8440920 at Rock Island Arsenal, where copper cylinders were produced on and off for several years by equipment transferred to Rock Island from Frankford Arsenal. In the 1990s, this equipment was sold or placed into storage, ending the production of copper cylinders.

In 2013, the first crushers manufactured at U.S. Army Armament Research, Development and Engineering Center (ARDEC), Picatinny Arsenal, NJ, were machined from C10200 O61 coiled copper. The material was selected based upon availability, as the engineer overseeing the project at the time was having difficulty finding a supplier for such a small purchase order. The coil material was straightened prior to machining, imparting a small amount of strain hardening to the initial O61 starting condition, and subsequently cut to length. These cylinders, as machined and without any additional annealing, performed satisfactorily, meeting minimum pin indent requirements for use with the M249, thus, incorporating DR13051594 into the U.S. Government technical data system. However, when used with the M4 and M16, the indent depth was found to be too shallow when testing accepted weapons.

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Due to the inability to obtain Frankford Arsenal cylinders for production weapon testing and the M4/M16 inability to properly indent the ARDEC cylinders, a study was initiated to baseline existing copper cylinders and to modernize the current U.S. Government drawing in order to meet both production and weapon testing requirements. Updating the U.S. Government copper cylinder drawing and related specifications is essential to ensure current production standards are used with resulting end items embodying similar performance attributes to the legacy Frankford Arsenal cylinders. To ensure that weapons with light firing pin energy, resulting in misfires in the field, are not accepted, and weapons with adequate firing pin energy are not rejected.

MATERIAL AND FUNCTIONAL BASELINE METHODOLOGY

Vendor Samples

In order to establish a baseline of the copper cylinder's material, as well as functional characteristics, samples were collected from multiple sources that included commercial as well as governmental producers. Due to the limited availability of copper cylinders, in some cases, only a single lot from a production source could be tested. Samples were collected from the following producers:

- Commercial source
 - Lot 873
- Frankford Arsenal
 - Lot FA 1C-71
 - Lot FA 4C-71
- Rock Island Arsenal
 - Lot 2C-91
- Picatinny rapid prototype facility (PRPF)
 - Prototype samples for annealing experiment
 - C10200 O61 coil
 - C110000 H04 rod

Sample Dimensional

Commercial Source

Samples purchased from a commercial source were to be produced to American National Standards Institute (ANSI)/Sporting Arms and Ammunition Manufacturers' Institute (SAAMI) Z299.4. Per the standard, the cylinders are 0.2255 to 0.2270 in. in diameter and 0.3990 to 0.4010 in. in length. The material is copper development association alloy 102.

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Frankford Arsenal

Samples collected from Frankford Arsenal were to conform to U.S. Government DR8440920 as described previously.

Rock Island Arsenal

Samples collected from Rock Island Arsenal were to conform to U.S. Government DR8440920 as described previously.

Picatunny Rapid

The PRPF prototype copper cylinders were produced using C10200 O61 copper coil and C11000 H04 copper rod obtained from commercial industry. The prototype cylinders were machined to conform to DR13051594 (2015 version), which specified a 0.3990 to 0.4010-in. length and a diameter of 0.2245 to 0.2265 in. Ends of the cylinder were to be perpendicular to the central axis within 0.0005 in. Both PRPF cylinder sets required annealing after machining. Due to its oxygen content, C11000 is subject to embrittlement when heated above 370°C in a reducing atmosphere; therefore, the PRPF samples were annealed in a vacuum furnace to guard against embrittlement and prevent scale formation on the exterior of the cylinder. The PRPF sets were initially vacuum annealed at 650°C for 30 min at ARDEC, and later at 550° and 500°C at a heat treatment contractor to examine and optimize indent characteristics. The contractor was employed after difficulty controlling the ARDEC furnace.

In order to capture the “as-produced” state of the copper cylinders and compare those dimensions to the drawing dimensions, several samples from each vendor type were selected and inspected. Cylinders were inspected for their length, diameter, and perpendicularity using circular runout of the ends as these were the most common dimension shared by all the sample types. Results of the dimensional inspection are discussed in the “Sample Dimensional Analysis” section.

Chemical Composition

The composition of the copper (used to produce the copper cylinders) plays a significant role in its ability to be fabricated into a cylinder, and its indent characteristics. As material standards have changed since the establishment of the Frankford Arsenal cylinders, and several of the vendor specifications do not specifically share the type of copper used, copper cylinder samples were sent to an independent laboratory for chemical composition testing and comparison to chemical requirements outlined in American Society for Testing and Materials (ASTM) B187. Copper content, oxygen content, and other trace materials expected to be contained within the copper cylinders were measured and recorded for each vendor type. Results of the chemical composition can be found in the “Chemical Composition Analysis” section.

Indent Testing

The purpose for this study is directly related to the inability to obtain Frankford Arsenal cylinders for indent testing of M4, M16, and M249 weapons both in production and testing environments. Exactly how and why indent testing came to be included in the series of functional tests required by rifles, carbines, and machine guns is not completely clear today as most of the history related to this test is either missing or was not adequately recorded. What is known, is that the indenting of copper cylinders is directly proportional to the energy exerted by the firing pin. This energy exerted by the weapon through the firing pin is in turn transferred to the ammunition. Too little energy results in the failure of the ammunition primer to activate and fire the cartridge. Too much energy results in a puncture of the primer that can lead to other negative effects on the ammunition's

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performance and the weapon's part life.

For this study, two methods of testing were used to assess the indent performance of the copper cylinders. The initial assessment was conducted using functional weapons and the weapon indent procedures outlined in MIL-DTL-70599, MIL-DTL-63997, MIL-DTL-32309, and MIL-DTL-70446. These procedures require that the copper cylinder first be measured for its initial height prior to being held in place with plug gage DR8440920 inside the chamber of the weapon. Once in place, the trigger was to be released in order for the firing pin to strike the cylinder. The resulting depth measured from the initial height of the cylinder was then collected. This testing method was conducted on M4s, M16s, and M249s. In addition to the bolt action indent, the M4 and M16 both require a muzzle down indent to capture the indent generated by the slamming bolt assembly and free floating firing pin.

The second method of assessing copper cylinders was developed in order to eliminate variabilities generated by the moving parts of the weapons (see appendix for additional details). Cleanliness, lubrication, and part tolerances have an effect on the energy transferred through the weapon. To eliminate this, a method was obtained from Lake City Army Ammunition Depot, that adapted the percussion primers sensitivity testing fixture (DR8648625) used for ammunition primer testing to be able to replicate firing pin indent. It was established that the sensitivity fixture would be able to hold copper cylinders in place using the DR8440920 plug gage, and strike the copper cylinders using a 0.030-in. radius firing pin. The firing pin was struck by a free falling steel ball from a height of 18 in. The ball measured 1 3/16 in. in diameter and weighted 3.94 oz. The force of the falling ball from the specified height was found to be proportional to the indent observed on the M4/M16, and minimized any mechanical interaction that could cause variability in test results. The results of both indent testing methods can be found in the "Indent Analysis" section.

Compression Testing

The MIL-C-20109 used in U.S. Government DR8440920 specifies compression testing of the copper cylinder at Frankford Arsenal. As this facility and equipment are no longer available as specified, compression testing of the cylinder was conducted at ARDEC. Each sample taken from the individual source was measured for its initial length using a micrometer. After being compressed, the resulting height of the cylinder was measured in order to calculate the percent of the original length remaining. The MIL-C-20109 states that after annealing, the physical state of the copper cylinders shall be such that upon application of an initial load of 45,000 psi to the face of the cylinder, the resulting remaining length shall be between 0.81 and 0.84 of the original length. The document also provides a table for determining the applied load (lb) to the corresponding chamber pressure (lb/sq.in.²) for which 45,000 psi is associated with a load of 1,500 lb for cannon (minor) and small arms. The results of compression testing can be found in the "Compression Analysis" section.

Hardness Testing

The hardness of copper cylinders is a function of chemical composition, strain hardening (also known as cold work or work hardening), and annealing. Strain hardening typically occurs in the production process as the manufacturer shapes the metal into its final state. The metal's strength changes based on the crystalline structure. As stresses force the crystals to slip against each other, they become more supportive of each other making the material harder. Subsequently, heating to an appropriate temperature results in softening through recovery, recrystallization, and grain growth. In order to establish the hardness of each cylinder source, sample cylinders were cross sectioned on a water-cooled abrasive saw, mounted in epoxy, polished to submicron finish, and tested with a Struers Durascan 70 hardness tester. Hardness testing was conducted with a Vickers indenter, 300 g of applied load, and a 40X lens. The results of hardness testing can be found in the "Hardness Analysis" section.

Grain Size

Like hardness, grain size influences the metals strength and ductility, and is affected by composition, cold work, and annealing. Generally, as the grain size decreases, the strength of that metal increases and ductility decreases. In order to measure grain size, cylinders were swabbed vigorously in 20-sec increments with a potassium dichromate-based etchant until adequate contrast was achieved for grain examination. Grain sizes were examined and photographed under a light optical microscope. Photographs were scaled to 75X and visually compared against an ASTM plate III wall chart. The results of grain size testing can be found in the "Grain Size Analysis" section.

MATERIAL AND FUNCTIONAL BASELINE RESULTS AND ANALYSIS

Sample Dimensional Analysis

In order to capture the dimensions of the copper cylinders in their "as-produced" state, several samples were measured by ARDEC engineers using calipers. Several other samples were sent to the dimensional inspection laboratory located at the PRPF. Results of the dimensional inspection are shown in table 2.

Table 2
Dimensional inspection of copper cylinders

Source	Length (inches)			Diameter (inches)			Circular runout		
	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
DR8440920 requirements		0.4010	0.3990		0.2265	0.2245		0.0005	
Commercial source Lot 873	0.4006	0.4015	0.3995	0.2273	0.2275	0.2270	0.0010	0.0017	0.0004
Frankford Lot 1C-71 DR8440920	0.4001	0.4010	0.4000	0.2250	0.2250	0.2250	0.0004	0.0006	0.0002
Rock Island Lot 2C-91 DR8440920	0.4008	0.4010	0.4005	0.2252	0.2255	0.2245	n/a	n/a	n/a
PRPF - rod (before anneal) DR13051594	0.4000	0.4013	0.3986	0.2264	0.2267	0.2261	0.0003	0.0022	0.0001
PRPF - coil (before anneal) DR13051594	0.3993	0.4010	0.3975	0.2263	0.2264	0.2262	0.0003	0.0010	0.0000

At the time this test was initiated, DR8440920 was the U.S. Army standard for copper cylinders used for testing, thus all characteristic inspections were directly compared to this standard. In table 2, dimensions not conforming to the requirements of DR8440920 are highlighted in red. In comparing the length of the cylinders, the average for each source was within the acceptable range. Commercial source and PRPF rod samples exceeded the maximum length of 0.4010 in. on at least one sample measured from each source.

In comparing the diameter of the cylinders, the commercial source cylinders exceeded the

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maximum diameter of 0.2265 in., as specified by U.S. Government DR8440920 and ANSI/SAAMI Z299.4, on all of the samples measured. At least one of the PRPF rod samples exceeded the maximum diameter of 0.2265 in. The circular runout was measured to indicate the perpendicularity of the ends of the cylinders. Samples from all sources exceeded the maximum on at least one sample. The average circular runout for Frankford, PRPF rod, and PRPF coil was acceptable. With the exception of a single sample that exceeded circular runout by 0.0001 in., the Frankford cylinders were the only source to meet the drawing specification in their “as produced” state for all dimensional characteristics.

Chemical Composition Analysis

Copper cylinder samples were sent to an independent laboratory for chemical composition testing and comparison to chemical requirements outlined in ASTM B187. A number of copper alloys listed within ASTM B187 satisfy the chemistry and resistivity requirements of specification MIL-C-12166 listed on DR8440920, including both C10200 and C11000. The C11000, also known as electrolytic tough pitch copper, is the most common copper alloy, typically containing 0.02 to 0.04% oxygen. The ASTM B187 provides no specific maximum oxygen content for C11000, only that content may vary depending on the process.

As shown in table 3, commercial source and PRPF cylinders all met the chemical requirements of C10200 copper, which specifies a copper plus silver concentration of 99.95% or greater and a maximum oxygen concentration of 0.0010%. Note that the PRPF rod material was purchased certified to C11000, yet it met the requirements of C10200. Frankford Arsenal and Rock Island Arsenal cylinders did not conform to C10200 due to their oxygen content. Frankford and Rock Island cylinders’ higher oxygen content places them in the category of a C11000 copper. Table 3 provides a summary of the chemical compositions determined for each copper cylinder source.

Table 3
Chemical composition testing

Element	Commercial source Lot 873	Frankford Lot 1C-71	Rock Island Lot 2C-91	PRPF rod	PRPF coil
Cu1 plus Ag	>99.99	>99.99	99.96	>99.99	>99.99
Cu	>99.99	>99.99	99.96	>99.99	>99.99
Ag	<0.01	<0.01	<0.01	<0.01	<0.01
O ₂	0.0006	0.0047	0.04	<0.0005	<0.0005
Cr	<0.01	<0.01	<0.01	<0.01	<0.01
Fe	<0.01	<0.01	<0.01	<0.01	<0.01
Ni	<0.01	<0.01	<0.01	<0.01	<0.01
Si	<0.01	<0.01	<0.01	<0.01	<0.01

Note: Copper (cu), silver (ag), oxygen (O₂), chromium (cr), iron (fe), nickel (ni), and silicon (si).

Indent Analysis

Two methods of testing were used to assess the indent performance of the copper cylinders. The deformation of the copper cylinder is directly related to the energy imparted to the cylinder by way of the firing pin. It was initially assumed that the material composition as well as the hardness and grain size (a result of annealing and/or work hardening) were the most substantial factors in the coppers ability to absorb energy and deform. Because the resulting indent needed to be directly related to the function of the weapon, the initial method of indent testing was conducted using the procedures outlined by MIL-DTL-70599, MIL-DTL-63997, MIL-DTL-32309, and MIL-DTL-70446. This testing method was conducted on M4s, M16s, and M249s. Tables 4 through 7 display the resulting

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firing pin indent measurements collected from each of the weapons. Because the bolt action indent for the M4/M16 does not specify weapon orientation like the muzzle down indent test, the test was repeated with the weapon in the vertical and horizontal orientation.

Table 4
M4 bolt action indent, plug gage DR84402219, weapon held horizontal, selector on SEMI

Source	Sample size	Minimum indent (inches)	Maximum indent (inches)	Average indent (inches)	Standard deviation
Frankford 1C-71	10	0.0200	0.0205	0.0203	0.0003
Frankford 4C-71	10	0.0200	0.0205	0.0203	0.0003
PRPF C10200 coil (annealed at 650°C)	10	0.0205	0.0220	0.0213	0.0004
PRPF C11000 rod (annealed at 650°C)	10	0.0215	0.0225	0.0220	0.0003
Commercial source Lot 873	10	0.0200	0.0210	0.0206	0.0004
Rock Island 2C-91	10	0.0190	0.0200	0.0196	0.0003

Table 5
M4 bolt action indent, plug gage DR84402219, weapon held vertical, selector on SEMI

Source	Sample size	Minimum indent (inches)	Maximum indent (inches)	Average indent (inches)	Standard deviation
Frankford 1C-71	10	0.0200	0.0205	0.0204	0.0002
Frankford 4C-71	10	0.0200	0.0205	0.0204	0.0002
PRPF C10200 coil (annealed at 650°C)	10	0.0205	0.0220	0.0214	0.0005
PRPF C11000 rod (annealed at 650°C)	10	0.0220	0.0235	0.0227	0.0005
Commercial source Lot 873	10	0.0205	0.0215	0.0208	0.0003
Rock Island 2C-91	10	0.0195	0.0200	0.0196	0.0002

Table 6
M4 muzzle down position indent, plug gage DR8440220, weapon held vertical, selector on SEMI

Source	Sample size	Minimum indent (inches)	Maximum indent (inches)	Average indent (inches)	Standard deviation
Frankford 1C-71	10	0.0055	0.0070	0.0062	0.0004
Commercial source Lot 873	10	0.0060	0.0080	0.0071	0.0007

Note: Due to sample quantity limitations, this was only conducted on Frankford and commercial source lots.

Table 7
M249 indent, plug gage DR84402219, weapon held horizontal

Source	Sample size	Minimum indent (inches)	Maximum indent (inches)	Average indent (inches)	Standard deviation
Frankford 1C-71	20	0.0390	0.0425	0.0410	0.0008
PRPF C10200 coil (unannealed)	20	0.0370	0.0410	0.0395	0.0008
Commercial source Lot 873	20	0.0320	0.0430	0.0407	0.0016

The indent test with the M249 in table 7 used two weapons yielding two distinct populations
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of results. The values for the average indent and the standard deviation were calculated for each weapon using each type of copper cylinder, and the values were averaged across weapons, to reflect the consistency of the results for the various cylinder samples. Since the M249 was less sensitive to the slight variations of material, initial temper, and annealing process than the M4 and M16, the remainder of the evaluations focused on the M4 and M16.

Because of the variabilities within each weapon, a second method of indenting copper cylinders was devised in order to provide a consistent striking force. This method was able to measure the variability of the copper cylinders without the influence of the weapon's moving parts. This method, obtained from Lake City Army Ammunition Depot, adapted the percussion primers sensitivity testing fixture (DR8648625) to hold copper cylinders in place using the DR8440920 plug gage and strike the copper cylinder using a 0.030-in. radius firing pin (fig. 2). The firing pin was struck by a free falling steel ball from a height of 18 in. The ball measured 1 3/16 in. in diameter, weighed 3.94 oz, and produced an indent in the Frankford cylinders averaging 0.023 in., which is consistent with the indent produced by M4 carbine and M16 rifles using the same cylinders. Table 8 displays the resulting indent measurements collected using the test fixture located at ARDEC. Figure 3 is a plot of the resulting indents using the fixture.



Figure 2
Percussion primers sensitivity testing fixture (DR8648625)

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Table 8
Sensitivity test fixture indent depth

Source	Sample size	Minimum indent (inches)	Maximum indent (inches)	Average indent (inches)	Variance	Standard deviation
Frankford 1C-71	100	0.0225	0.0240	0.0230	1.334e-7	0.00037
Frankford 4C-71	50	0.0225	0.0235	0.0232	8.21e-8	0.00029
PRPF C10200 coil (unannealed)	35	0.0195	0.0225	0.0208	4.6e-7	0.00068
PRPF C10200 coil (annealed at 650 C)	100	0.0235	0.0260	0.0248	2.163e-7	0.00047
PRPF C10200 coil (annealed at 550 C)	7	0.0220	0.0240	0.0231	4.796e-7	0.00069
PRPF C10200 coil (annealed at 500 C)	10	0.0230	0.0240	0.0235	1.429e-7	0.00039
PRPF C11000 rod (unannealed)	35	0.0125	0.0145	0.0135	1.706e-7	0.00041
PRPF C11000 rod (annealed at 650 C)	100	0.0245	0.0275	0.0260	2.749e-7	0.00052
PRPF C11000 rod (annealed at 550 C)	7	0.0235	0.0245	0.0240	1.429e-7	0.00038
PRPF C11000 rod (annealed at 500 C)	10	0.0235	0.0245	0.0241	1.020e-7	0.00030
Commercial source Lot 873	89	0.0220	0.0245	0.0232	2.326e-7	0.00048
Rock Island 2C-91	50	0.0210	0.0220	0.0216	1e-7	0.00032

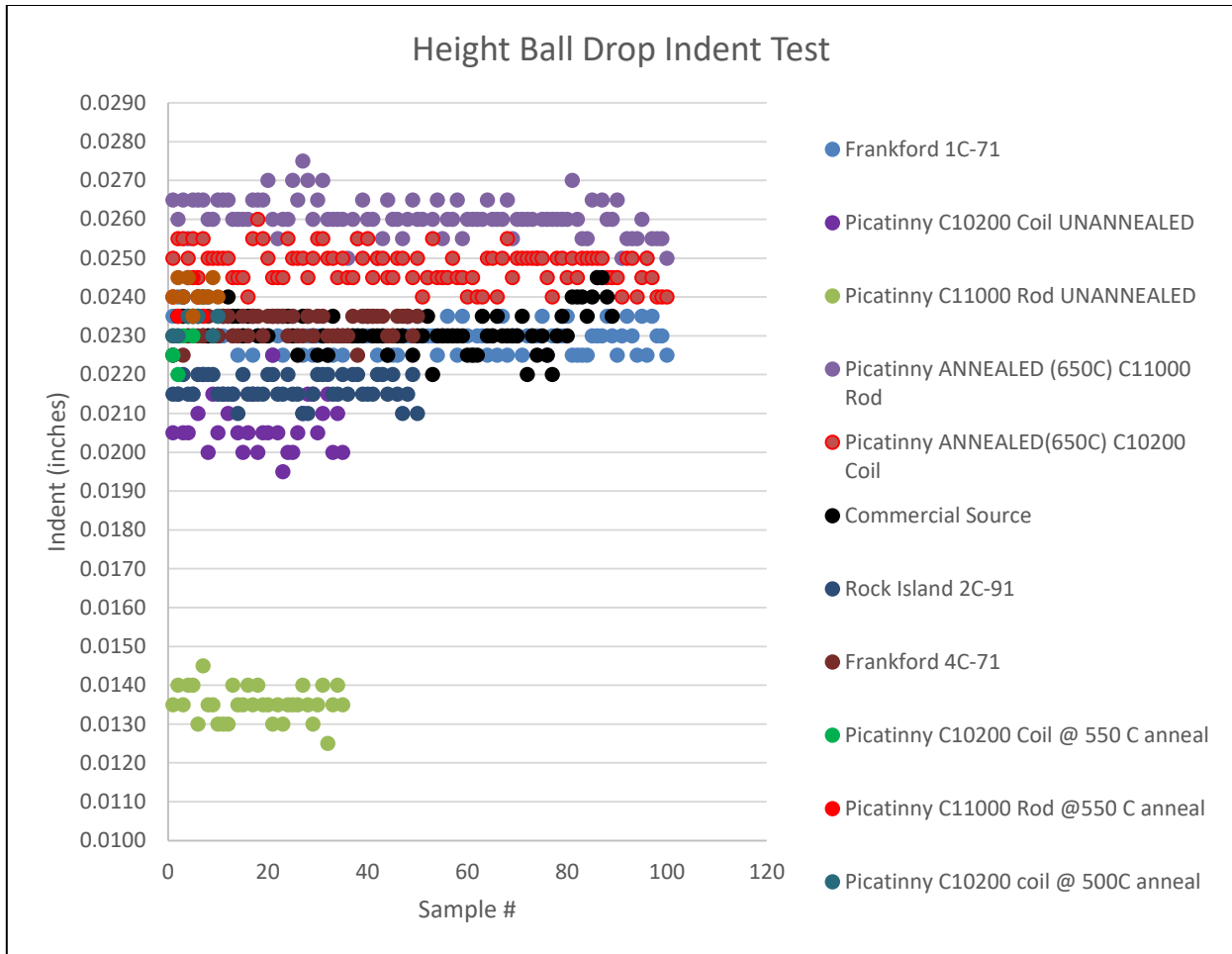


Figure 3
Plot of individual sample indents

The objective of the sensitivity fixture indent test was to eliminate the variability caused by weapon components, and to study the indent characteristics between vendor lots and the sample to sample variability within a single lot. Because the Frankford Arsenal cylinder has been the U.S. Army's standard for several years, the resulting average indent of each vendor lot was directly compared to the average indent of the Frankford cylinders. Even between Frankford lot 1C-71 and 4C-71, there are some obvious differences in the depth of the indent. Commercial source cylinders averaged similar indent depths when compared to Frankford cylinders. The variance and standard deviation of the commercial source lot was greater than that seen with the two Frankford lots. In changing the anneal temperature applied to the PRPF C10200 samples, the resulting average indent was gradually brought closer to that seen on the Frankford cylinders. The requirements outlined in DR8440920 do not provide guidance as to the consistency of the indent depth, but do provide limits for diameter, length, material composition, compression, and end parallelism. These characteristics, if controlled and held constant, should limit the variability seen between copper cylinder productions. Material starting temper and annealing temperature appear to be the most significant factors affecting indent. This can be directly seen with the PRPF C11000 and C10200 samples comparing indent depths from their as-manufactured tempers of H04 (C11000) and O61 (C10200) to indent depths after vacuum annealing samples at 650° and 500°C.

Compression Analysis

Compression testing of the cylinder was conducted at ARDEC. Each sample taken from the individual sources was measured for its initial length using a micrometer. After being compressed, the resulting height of the cylinder was measured in order to calculate the percent of the original length remaining. The MIL-C-20109 states that after annealing, the physical state of the copper cylinders shall be such that upon application of an initial load of 45,000 psi on the face of the cylinder, the resulting remaining length shall be between 0.81 and 0.84 of the original length. Because the face diameter of the copper cylinders varies both within the lot and between the sources, samples were compressed at three different load points. The multiple load points account for the variation in pounds per square inch seen by the cylinders due to the varying diameter of each cylinder, and also provides a trend line for comparing cylinders compression characteristics. Tables 9 through 11 and figures 4 through 6 provide a summary of the resulting remaining length for each tested sample.

Table 9
Compression results at 1,500 lb

Source	Average diameter (inches)	Average pressure (psi)	Average percent overall length remaining
Commercial source Lot 873	0.2275	36,917	87.5
Frankford Lot 1C-71 DR8440920	0.2250	37,726	86.7
Frankford Lot 4C-71 DR8440920	0.2250	37,726	86.6
Rock Island Lot 2C-91 DR8440920	0.2255	37,559	88.4
PRPF rod (after 650°C anneal) DR13051594	0.2264	37,261	85.7
PRPF coil (after 650°C anneal) DR13051594	0.2265	37,228	86.8
PRPF rod (after 500°C anneal) DR13051594	0.2265	37,228	86.8
PRPF coil (after 500°C anneal) DR13051594	0.2265	37,228	86.9

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Table 10
Compression results at 1,700 lb

Source	Diameter (inches)	Pressure (psi)	Percent overall length remaining
Commercial source Lot 873	0.2275	41,821	84.7
Frankford Lot 1C-71 DR8440920	0.2250	42,756	83.7
Frankford Lot 4C-71 DR8440920	0.2250	42,756	83.6
Rock Island Lot 2C-91 DR8440920	0.2255	42,566	85.5
PRPF rod (after 650°C anneal) DR13051594	Not conducted		
PRPF coil (after 650°C anneal) DR13051594	Not conducted		
PRPF rod (after 500°C anneal) DR13051594	0.2265	42,191	83.9
PRPF coil (after 500°C anneal) DR13051594	0.2268	42,191	84.0

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Table 11
Compression results at 1,900 lb

Source	Diameter (inches)	Pressure (psi)	Percent overall length remaining
Commercial source Lot 873	0.2275	46,783	81.8
Frankford Lot 1C-71 DR8440920	0.2250	47,786	80.6
Frankford Lot 4C-71 DR8440920	0.2250	47,786	80.5
Rock Island Lot 2C-91 DR8440920	0.2255	47,574	82.5
PRPF rod (after 650°C anneal) DR13051594	0.2265	47,155	79.6
PRPF coil (after 650°C anneal) DR13051594	0.2265	47,155	81.0
PRPF rod (after 500°C anneal) DR13051594	0.2265	47,155	80.8
PRPF coil (after 500°C anneal) DR13051594	0.2265	47,155	81.0

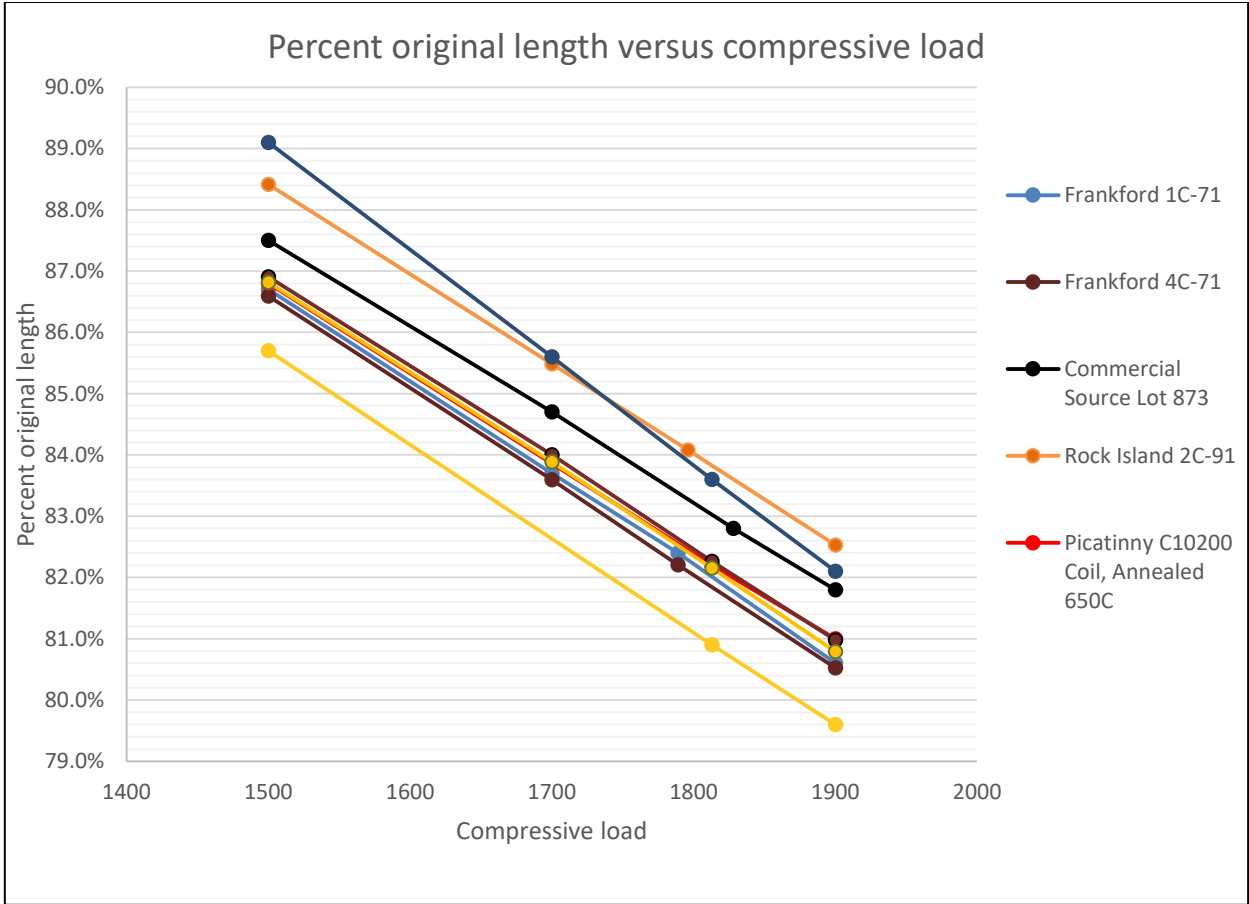


Figure 4
Percentage overall length remaining versus applied compressive load

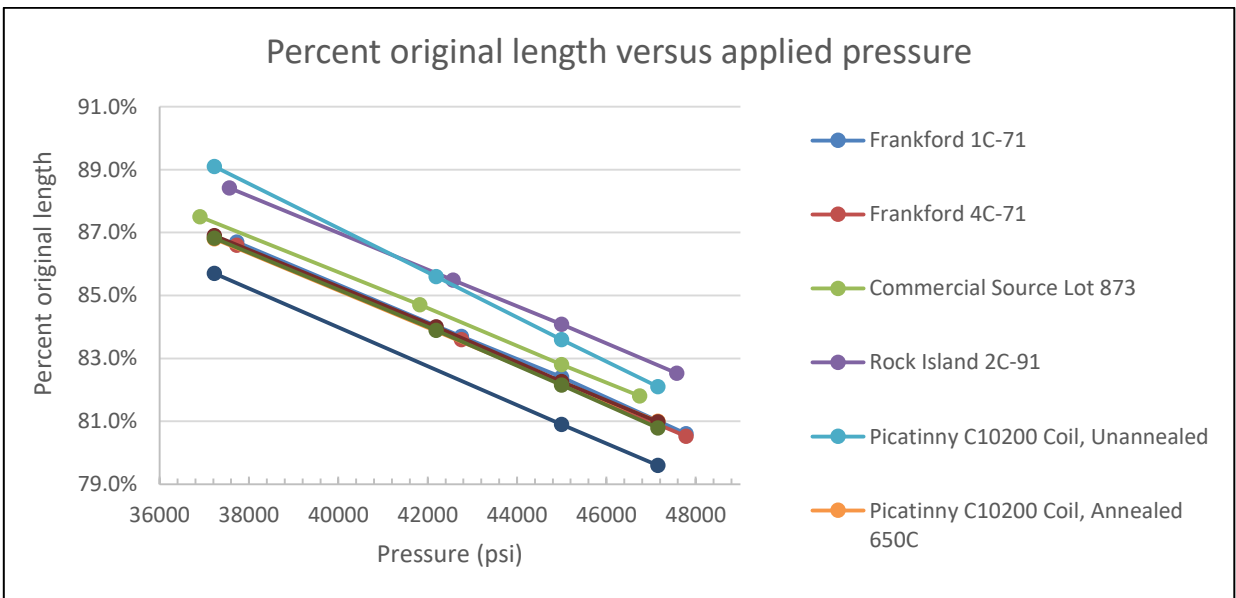


Figure 5
Overall length remaining versus pressure

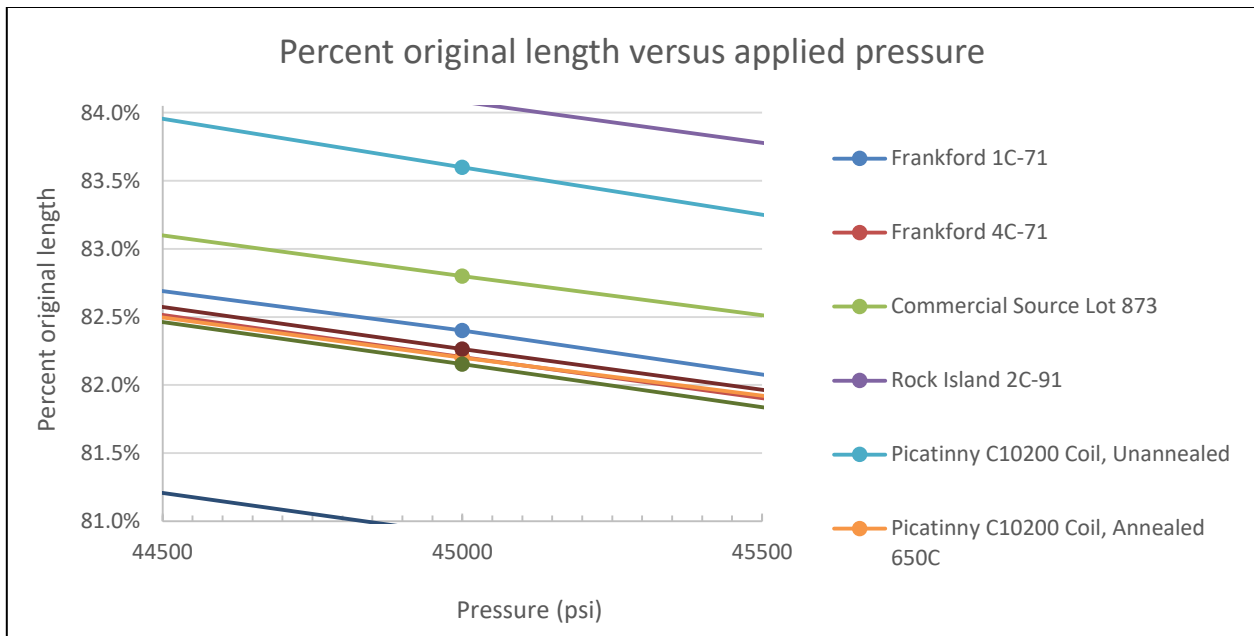


Figure 6

Percentage overall length remaining versus pressure, target compression range of 81 to 84% original length (OL)

The outdated copper cylinder specification MIL-C-20109 does not specify a methodology for compression testing, it only states that “the coppers shall then be compressed in the Frankford Arsenal compression machine.” The ARDEC compression testing method throughout this study has been performed on an MTS servo-hydraulic test frame fixtured with compression platens. Each crusher was preloaded to 25 lb to ensure both platens were in contact with the crusher and were flat. The compressive load was then applied to the crusher over 30 sec (0.0044 to 0.0055 in./in *min strain rate) until the specified compressive load was achieved. The crusher was held at the compressive load for 5 sec to ensure no springback occurred and full compression was achieved. Following compaction, each crusher was again measured with a micrometer.

Near the completion of this study, an inquiry was made by a contractor asking for a specification governing compression testing for cylinder acceptance. The procedure outlined in section 8 of ASTM E9, standard test methods of compression testing of metallic materials at room temperature, was identified as a likely candidate. The ARDEC test methodology closely followed this method with the one exception that bearing surfaces and the test specimens had not been cleaned or lubricated in accordance with ASTM E9 sections 8.2 and 8.3.

Commercial source samples, due to their abundance, were sent to an independent laboratory for compression testing in accordance with the procedures outlined in section 8 of ASTM E9 to see how well results from an outside laboratory compared to ARDEC results. Ten commercial source cylinders were compressed at each of the three compressive loads of 1,500, 1,700, and 1,900 lb. The percent of original length for 45,000 psi was extrapolated from the data. Results are shown in table 12. Additionally, 10 commercial source samples were tested with an applied pressure of 45,000 psi at ARDEC, in accordance with ASTM E9, cleaning with methanol and lubricating the bearing surfaces with molybdenum disulfide. As shown by the results in figure 7 from ARDEC and the independent laboratory testing, lubrication of the bearing surfaces, as directed in ASTM E9, resulted in greater compression. This is attributed to the fact that without lubrication, friction on the bearing surfaces impedes the ability of the material to move and compress. The ARDEC and independent laboratory results differed by 1.6% for a pressure of 45,000 psi when no lubrication was

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used during ARDEC testing. The difference in compression results between the two laboratories was reduced by half to 0.8% when ASTM E9 methodology and lubrication was used.

Table 12
Independent laboratory mechanical test results

Source	Compressive load (lb)	Percent overall length remaining
Commercial source Lot 873	1,500	86.4
Commercial source Lot 873	1,700	83.4
Commercial source Lot 873	Extrapolated:1,826 lb/ 45,000 psi	81.2
Commercial source Lot 873	1,900	80.0

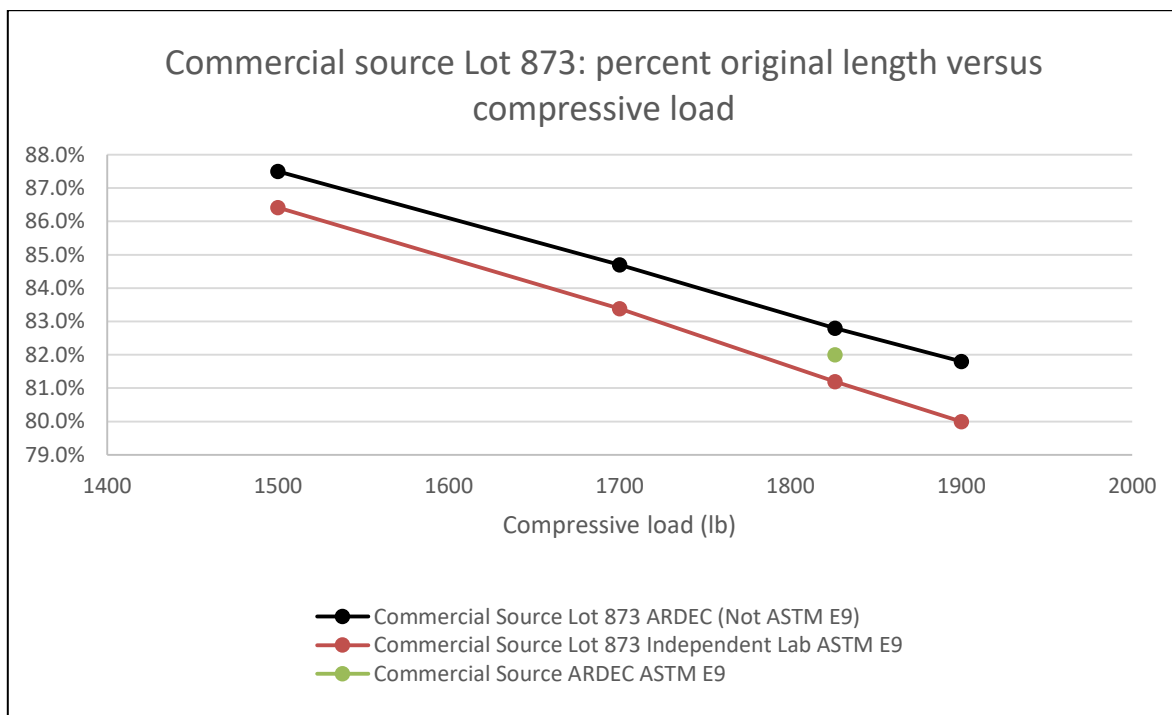


Figure 7
Interlaboratory cylinder compression reproducibility study

Hardness Analysis

The hardness of each cylinder source was collected using a Struers Durascan 70 after cylinders were cross sectioned on a water-cooled abrasive saw, mounted in epoxy, and polished to submicron finish. Hardness testing was conducted with a Vickers indenter, 300 g of applied load, and a 40X lens. Table 13 provides a summary of the hardness results for each source of copper cylinder.

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Table 13
Hardness results

Source	Hardness (Vickers, HV0.3)			Standard deviation
	Average	Maximum	Minimum	
Commercial source Lot 873	51	58	47	2.4
Frankford Lot 1C-71 DR8440920	50	61	45	2.8
Rock Island Lot 2C-91 DR8440920	62	78	57	4.6
PRPF rod (before anneal) DR13051594	111	118	105	4.1
PRPF coil (before anneal) DR13051594	56	68	49	4.4
PRPF rod (after 650°C anneal) DR13051594	48	61	44	2.8
PRPF coil (after 650°C anneal) DR13051594	51	58	45	2.8
PRPF rod (after 500°C anneal) DR13051594	76	100	58	12.3
PRPF coil (after 500°C anneal) DR13051594	67	81	57	6.6

Hardness data was found to contain too much spread and variability at such a low hardness level to provide useful and reliable information for determining whether or not cylinders had been annealed to the ideal range for firing pin indent (fig. 8). Note that PRPF coil cylinders annealed to 500°C and tested at the conclusion of the cylinder study reported higher hardness than their unannealed counterparts, suggesting error with these last two datasets.

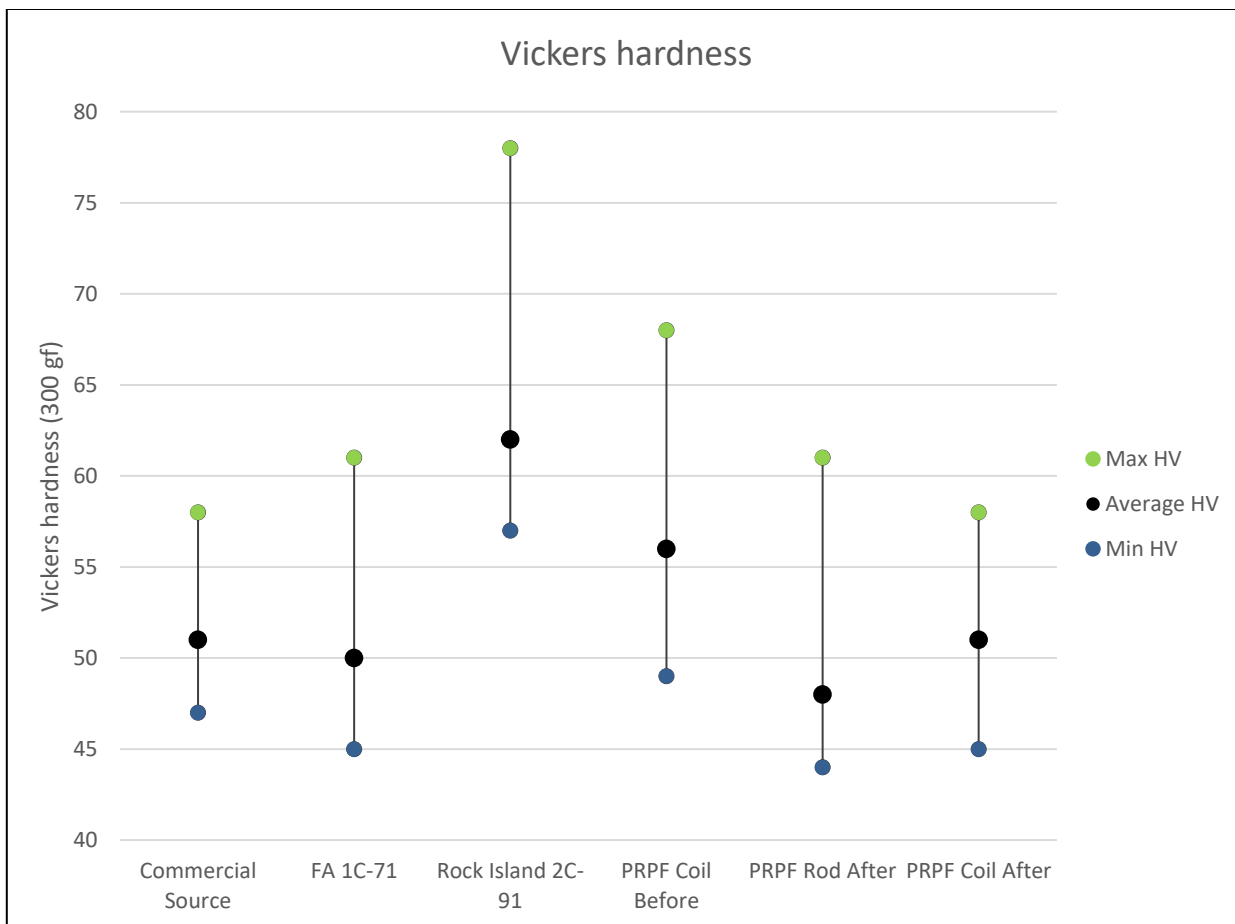


Figure 8
Copper cylinder hardness results

Hardness test result variability is perhaps why previous drawing revisions and associated specifications did not include hardness requirements. A target range for compression (0.81 to 0.84 original length), contained within MIL-C-20109, was the only test for acceptability provided by DR8440920.

Grain Size Analysis

Grain size and yield strength are related by the Hall-Petch equation, which demonstrates that as average grain size increases, yield strength and, therefore, hardness decreases. Conversely, as grain size decreases, with exception to sizes smaller than 10 nm, yield strength and hardness increases. Given the impact that grain size has on strength, the purpose of grain size evaluation was to determine if a range of grain sizes could be associated with suitable cylinders for firing pin indent testing.

In order to examine and compare grain size, the samples used for hardness evaluation were swabbed vigorously in 20-sec increments with a potassium dichromate-based etchant until adequate contrast was achieved for grain examination. Grain sizes were examined and photographed under a light optical microscope. Photographs were scaled to 75X and visually compared against an ASTM plate III wall chart. Micrographs for commercial source, Frankford, Rock Island, ARDEC coil before and after annealing, and ARDEC rod after annealing samples are shown scaled to 75X magnification in figures 9 through 16. Grain sizes are listed in table 14. Overall, grain sizes were found to be very

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uniform for each source, with exception to the coil material, which displays a mix of both large and fine grain sizes, while the grain sizes of the rod material were observed to be more uniform. The uniformity of the rod material is due to starting with material cold worked to the H04 (hard) condition. Increased cold work favors finer and more uniform grain sizes upon annealing. Cold work stresses the crystal structure; therefore, less energy in the form of a lower annealing temperature is required to initiate recovery, recrystallization, and grain growth. The non-uniform grain sizes observed in the coil material are a function of the starting condition and how the material was formed into a cylinder. The coil was already annealed to the O61 condition; straightening the coil prior to machining likely imparted an uneven amount of cold work across the cross section of the material. Upon annealing, the grains that were more stressed began growing sooner than those that were less stressed resulting in uneven grain growth.

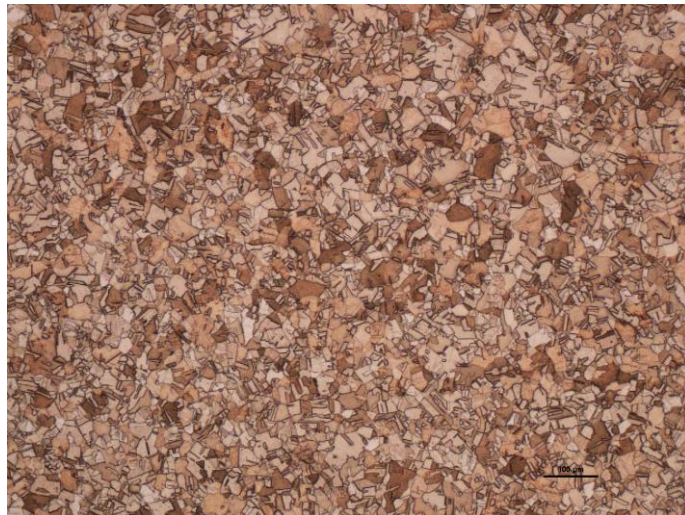


Figure 9
Commercial source Lot 873, 75X

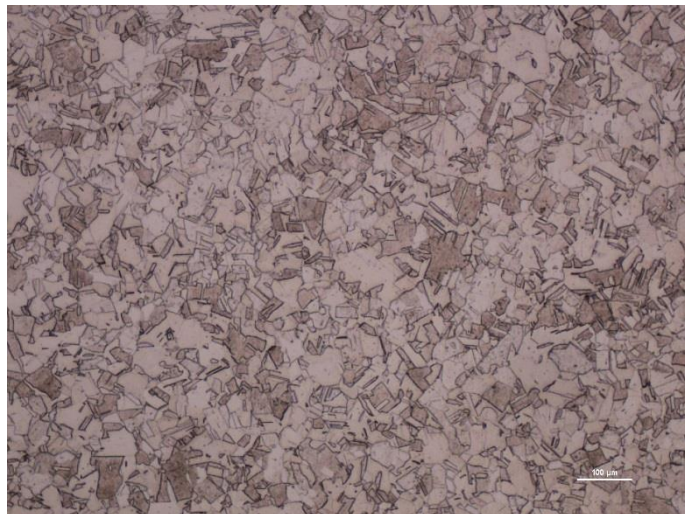


Figure 10
Frankford Arsenal, Lot 1C-71, 75X

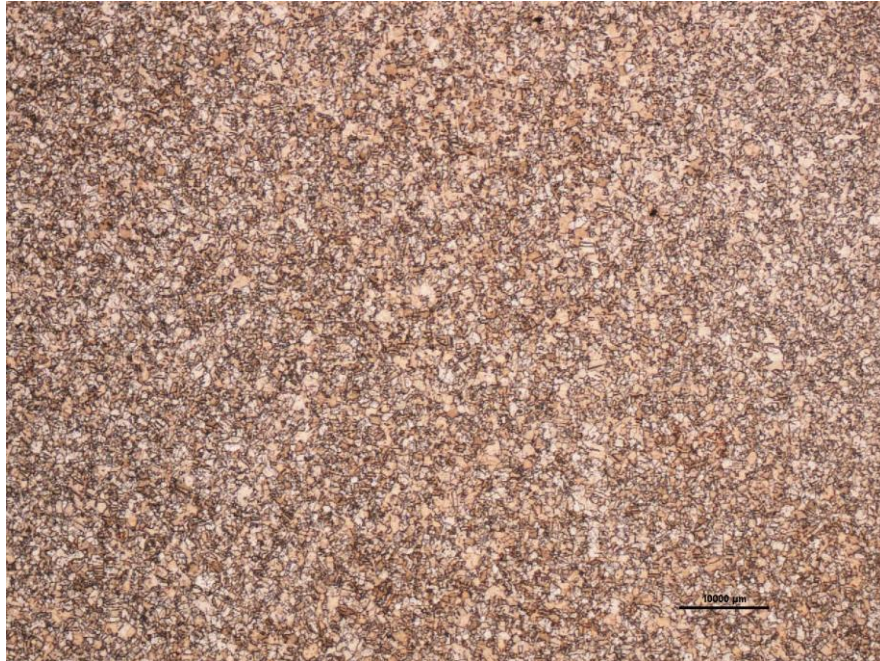


Figure 11
Rock Island Lot 2C-91, 75X

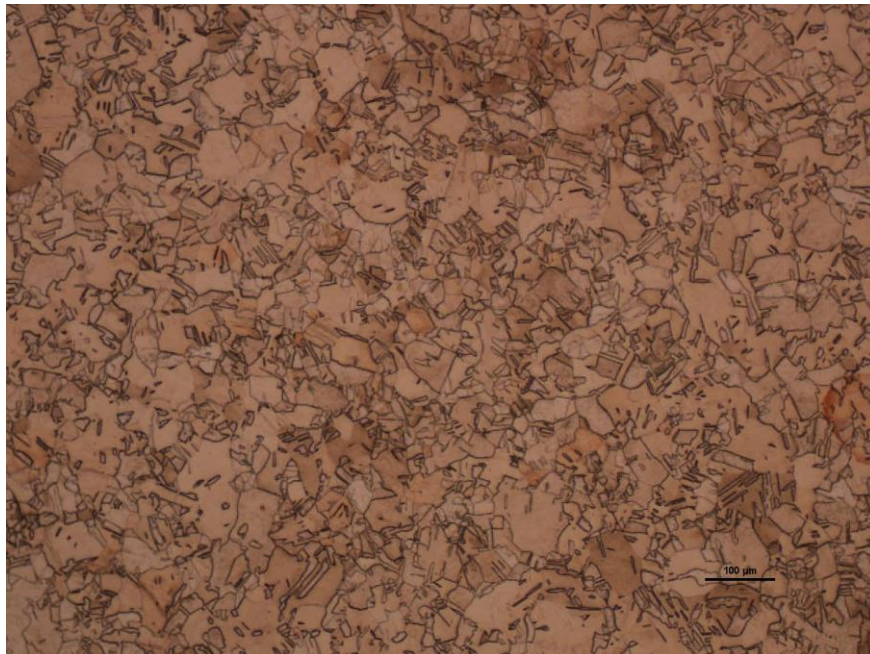


Figure 12
C10200 coil after straightening and machining to size, before anneal, 75X

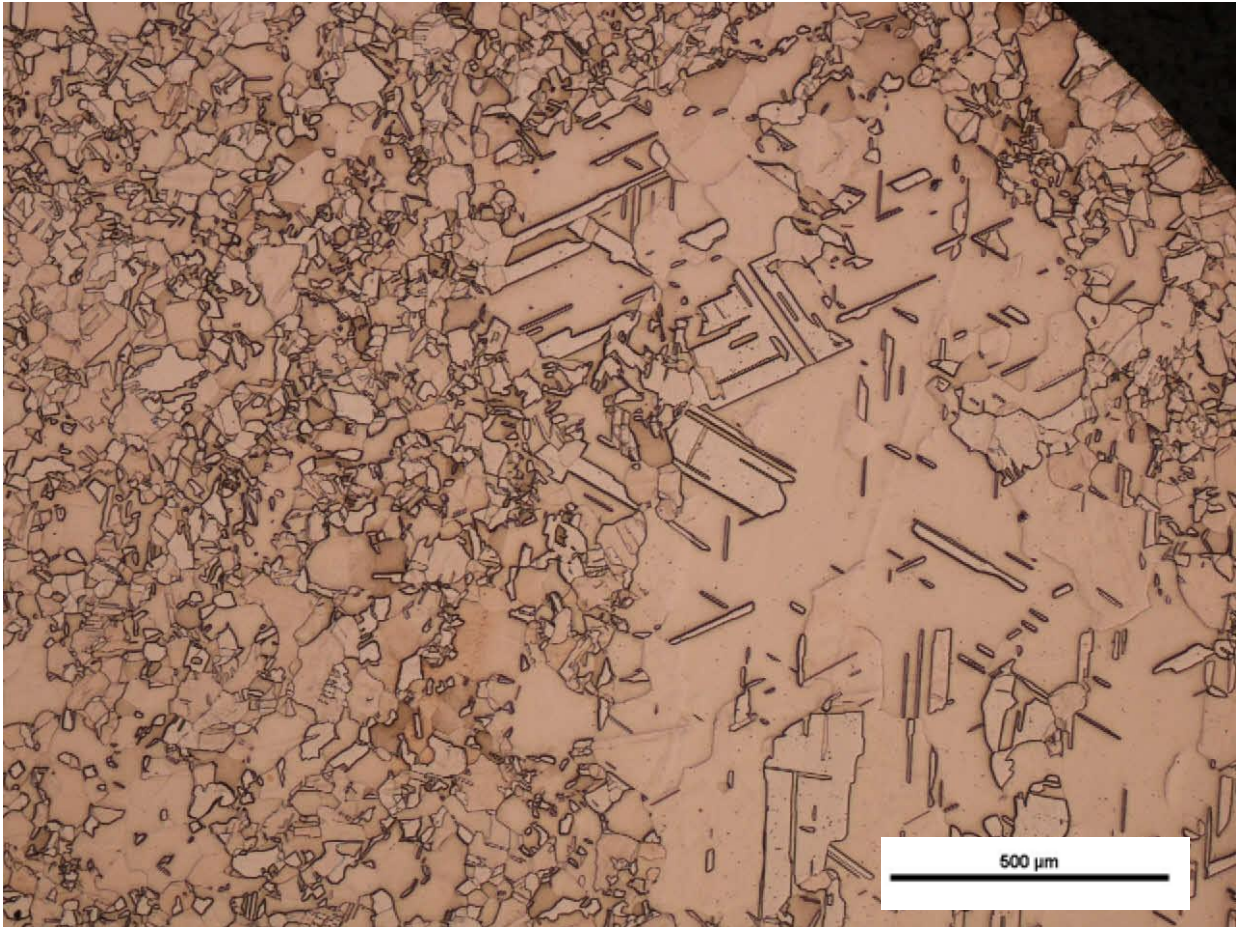


Figure 13
C10200 coil after 650°C anneal, 75X

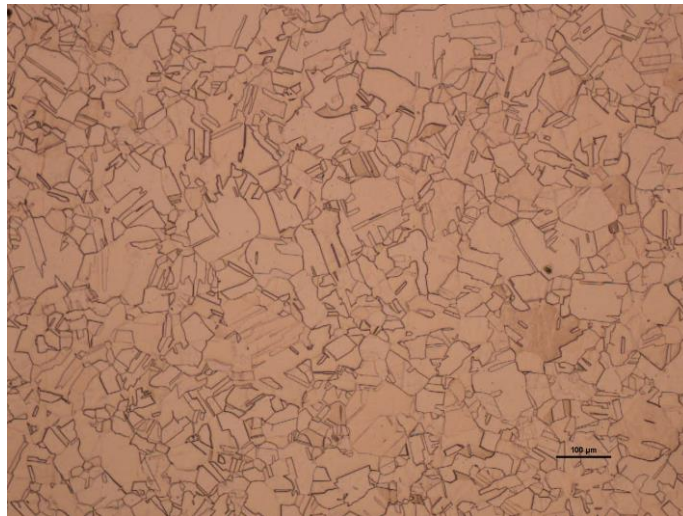


Figure 14
C11000 rod after 650°C anneal, 75X

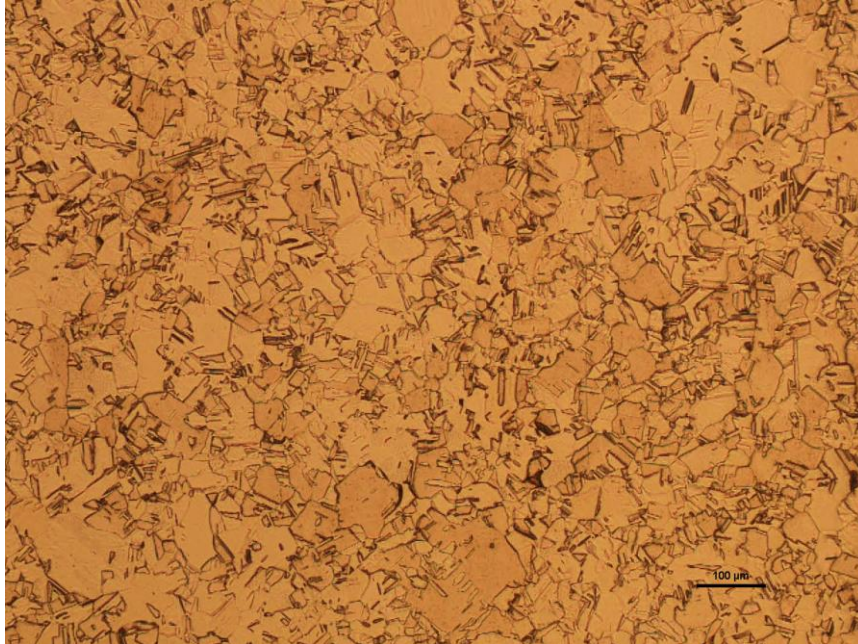


Figure 15
C10200 coil, 500°C anneal, 75X

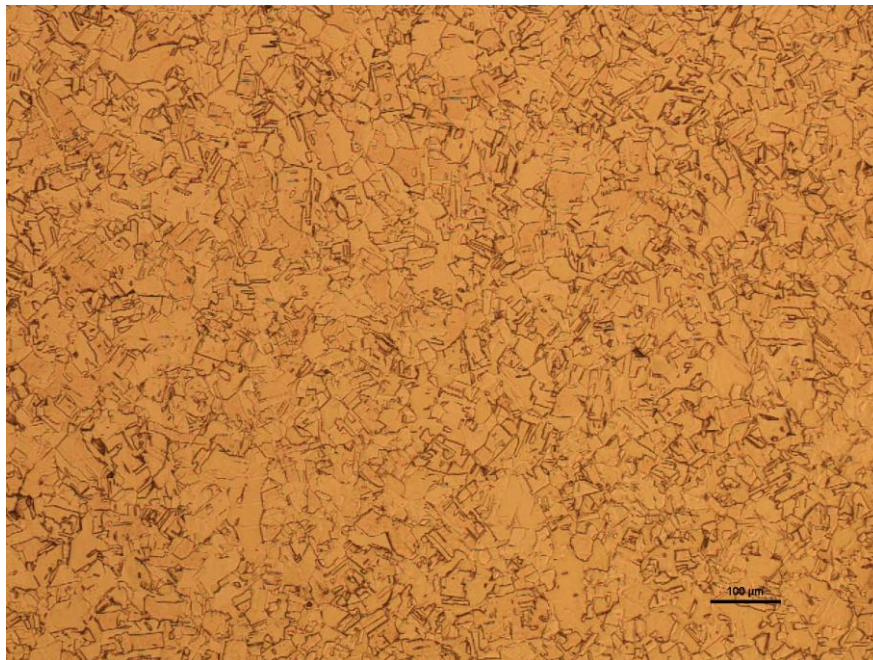


Figure 16
C11000 rod, 500°C anneal, 75X

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Table 14
Grain size results

Source	Average micron size
Commercial source Lot 873	20
Frankford Lot 1C-71 DR8440920	25 to 35
Rock Island Lot 2C-91 DR8440920	10
PRPF rod (before anneal) DR13051594	Cold worked to H04 – N/A
PRPF coil (before anneal) DR13051594	25 to 35
PRPF rod (after 650°C anneal) DR13051594	35 to 45
PRPF coil (after 650°C anneal) DR13051594	Mixed 35 and >200
PRPF rod (after 500°C anneal) DR13051594	25
PRPF coil (after 500°C anneal) DR13051594	35

Refined grains and grain uniformity after annealing to the appropriate strength level is likely the reason MIL-C-12166 required the starting material to meet a tensile requirement of 50,000 psi for a 0.2255-in. diameter rod, despite the fact that after annealing, the final product would be well below a 50,000 psi tensile strength. The H04 rod up through 3/8-in. diameter would be expected to have a tensile strength of 45,000 to 60,000 psi, meeting the MIL-C-12166 requirement.

DESIGN DEVELOPMENT

Using the data collected and discussed previously, engineers sought to answer the question of what ultimately makes a suitable cylinder. Per the original Frankford Arsenal standards, a suitable copper cylinder was designed around:

- Proper composition.
- Cold worked to a specific tensile strength prior to anneal to achieve uniform grain structure and uniform properties.
- Proper dimensions.
- Compressibility to a specific range after anneal.

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All of these characteristics are still applicable to the current design of the copper cylinder. The problem with the old specification is that the specified material standards are no longer in practice. The lack of guidance regarding compression testing procedures and the lack of engineering studies show why compressibility adequately defines the cylinder's performance.

Proper material composition and work hardening were the first concerns of this engineering study. Per DR8440920, the required material is specified for MIL-C-12166 (August 14, 1952) in the cold drawn condition. The MIL-C-12166 specifies that the electrolytic copper rod be of the best grade made either by hot rolling or extrusion and finished by cold drawing to the specified diameter. The material shall contain not less than 99.90% copper, silver being counted as copper. As of 2016, most copper rod production is tested per ASTM B187, which outlines the copper content, oxygen content, and other trace elements expected to be contained within the copper. Analysis of the sample copper cylinders, including the Frankford Arsenal cylinders, reflected a composition of C10200 or C11000 per ASTM B187. Those same samples, with the exception of the coil material, likely met tensile strength prior to anneal based upon what is known about the rod material (H04) and from grain structures observed in the samples. In redesigning the DR13051594, ASTM B187 was used to replace the MIL-C-12166 specification. Due to its oxygen content, C11000 is subject to embrittlement when heated above 370°C in a reducing atmosphere; therefore, the C10200 material was selected for drawing Note 2.

Dimensioning of the copper cylinder is the second largest concern, as the cylinder must be the correct size to fit into the testing device and must have limited variance in order to provide consistent results. Obvious differences were seen between the U.S. Government cylinder (Frankford Arsenal) and the commercial equivalent. Initial observations noted differences in the diameter and the perpendicularity/circular runout of the cylinder ends. This situation was further exacerbated when the commercial cylinder samples were inspected and found not to conform to their associated standard. While the enlarged diameter did not impact the performance of the cylinder, it did impact the cylinder's ability to fit into U.S. Government gage fixtures and made removal of the cylinder from the fixture difficult. A tolerance stack study was conducted to determine what the maximum allowable diameter could be in order to fit the gage fixture without issue. This data was presented to the commercial vendor for discussion. It was discovered that while the manufacturer did inspect the length of the cylinder, no other dimensions were being inspected, including the diameter. The diameter was not inspected because the copper rod stock is ordered from the foundry at the specified diameter. No receiving inspections were being conducted. Based on this discussion, the tolerance stack study, and the diameters shown in the U.S. Government cylinder drawing and commercial standard, the diameter was determined to be 0.2265 plus 0.0005/-0.0020 in. cylinder length, and remained unchanged at 0.4010 to 0.0020 in.

While the ASTM B187 specification defines the composition of the copper material, and outlines the temper designation of the initial rod material, this study determined that a specific anneal had to be applied to the final copper cylinders in order to achieve their optimal mechanical state. Within this study, several annealing methods and temperatures were investigated. Variations in the initial material temper and work hardening caused by the manufacture of the cylinders influenced the grain structure of the final cylinder. A range of 500° to 650°C, with soak times of 30 min to 4 hr in a vacuum furnace, was determined to be the optimal range for annealing the cylinders to their ideal mechanical state. In order to confirm the ideal mechanical state, testing methods had to be established for lot sampling. The original Frankford Arsenal specification outlined 45,000 psi with a resulting height of 0.81 to 0.84 of the original height. Discussion of incorporating the ball drop indent testing was also discussed as a possible test method. After studying the results of both testing methods, compression testing was selected based on the past use of the method, the commercial industry use of a similar method to test copper cylinder production, and the availability of ASTM E9 for standardizing the testing procedures. Variations of compression data were seen between each of the sample types, but the majority of the samples fit within 0.81 to 0.84 of the original height. Ball

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drop indent testing had a much larger data variance, and without the establishment of a procedure, could have a much larger variance from vendor to vendor. As can be seen in figure 17, Frankford Arsenal cylinders, as well as commercial source and prototype PRPF cylinders, fit within the compression range at 45,000 psi. Also note the difference in ball drop performance between cylinder types shown in figure 18. While the ball drop indent testing could perform as accurately as the compression testing with the established net of a common procedure and equipment, determination of the upper and lower bounds for acceptance would be exhaustive. It is also unknown what the risks of establishing a new method could incur. Failure to establish a proper procedure and upper and lower limit bounds could potentially pass borderline weapons or fail acceptable weapons. Because of its established history in defining copper cylinders, compression testing is the best method for copper cylinder lot acceptance, in conjunction with the material and dimensional constraints.

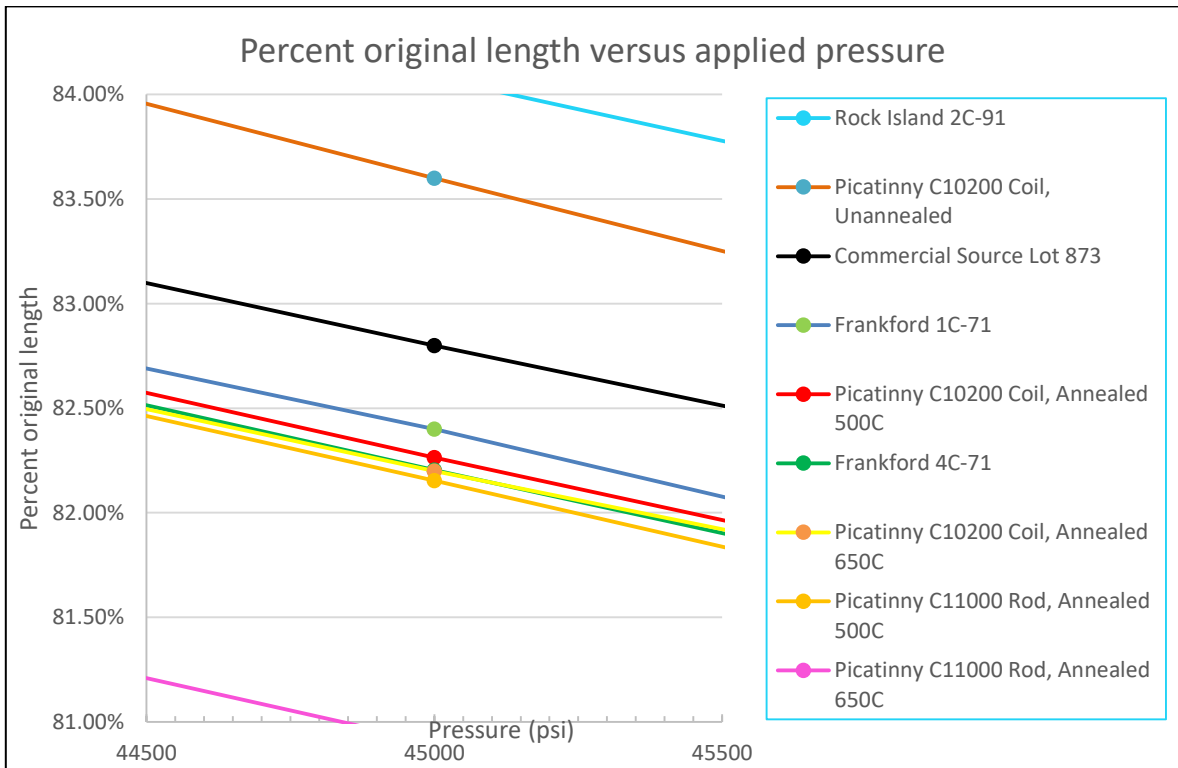


Figure 17
Percentage original length at 45,000 psi pressure shown in the target compression range of 81 to 84% OL

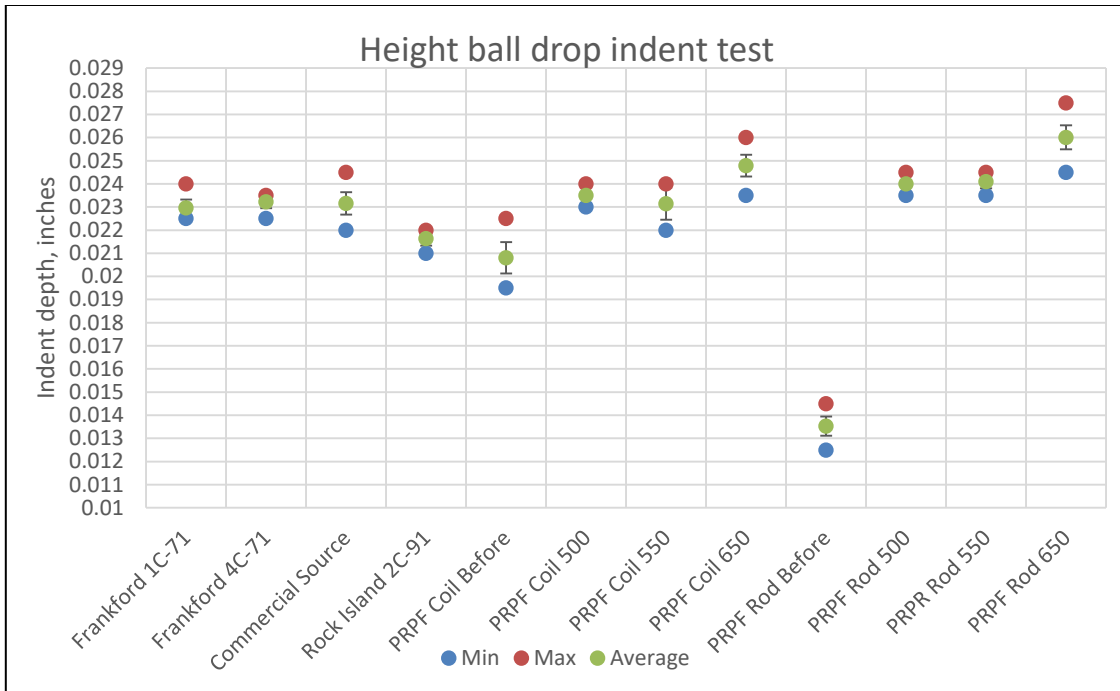


Figure 18

45,000 psi compression results were nearly identical for FA 4C-71 and PRPF coil 650, ball drop results differed

Hardness and grain size testing were also discussed as possible testing characteristics. Hardness was not selected as a controlling property because results fail to correlate well with compression results. For example, commercial source, Frankford, and annealed 650 coil and rod samples were all very comparable with an average hardness near 50 HV0.3. The annealed rod 650 failed to meet the compression range set by MIL-C-20109, while commercial source, Frankford, and annealed coil samples all compressed to the target range of 81 to 84% original length.

As for grain size, annealed coil samples appear to meet the requirements of a suitable crusher based upon ball drop and compression results. The coil grain structure consisting of non-uniform grains that are a mix of fine and very coarse sizes is worrisome. A uniform structure would be expected to provide more consistent results. In order to achieve a uniform structure, the starting material needs to be cold worked to an adequate tensile strength prior to annealing, as was the case with the PRPF rod samples. Grain sizes of approximately 20 to 35 μ appear to be associated with suitable cylinders. Rod samples annealed at 650°C grain sizes were larger than 35 and compressed too much. Rock Island cylinders were smaller than 20 μ (~10 μ) and did not indent or compress as much as Frankford cylinders. Grain size will influence how the cylinder performs during compression and indent testing and, therefore, would not need to be specified as an additional requirement.

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CONCLUSIONS

Evaluating the material, manufacturing, geometry, and annealing response characteristics of copper cylinders used for small caliber weapon testing is critical in understanding the impact each characteristic has on the copper cylinder's ability to accurately and consistently measure firing pin indent. For this effort, material testing of cylinders from multiple sources was conducted to evaluate the characteristics of copper cylinders required to properly specify the copper cylinder design used on the M4 carbine, M16 rifle, and M249 squad automatic weapon for measurement of firing pin indent energy. Samples of copper cylinders collected from legacy Frankford Arsenal, Philadelphia, PA, productions were compared and studied against Rock Island Arsenal, Rock Island County, IL, commercial, and the U.S. Army Armament Research, Development and Engineering Center, Picatinny Arsenal, NJ, production samples. The study of these cylinders focused on the materials chemical composition, hardness, grain size, compressibility, dimensions, and indent resistance. Each of these tests defined a specific mechanical property of the cylinder and were influential in the redesign of drawing 13051594.

Three characteristics were determined to best define the cylinder, and were applicable to the final drawing revision. In any production setting, clear definition of the production material is the first concern. The state of the material controls the initial mechanical state of the product, its machinability, and its ability to be processed to the final state. The dimensional limits of the part are of second concern because without these constraints, the item cannot function as intended. For this case, the cylinders length, diameter, and surface end perpendicularity were constrained in order to allow for proper fit and function during gaging use. Ideally, engineers would prefer to see every sample and every characteristic of a product examined during production. This is not feasible because of cost and product destruction, thus limited testing and sample sizes must be selected that can ideally evaluate the product. In the case of copper cylinders, the establishment of compression testing at 45,000 psi by Frankford Arsenal remains the best test for evaluating the cylinders mechanical properties.

RECOMMENDATIONS

The following actions are suggested for future study and development related to copper cylinder indent testing of small caliber weapon systems:

- Develop a reusable electronic method of evaluating weapon firing pin indent.
- Present study findings to commercial industry and continue discussion that will bring U.S. Government and commercial copper cylinder standards in line to a standard product that is acceptable to each group.
- Determine the criticality and maximum constraints for cylinder end parallelism, circularity, or other dimensional controls.

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REFERENCES

1. MIL-C-20109, "Copper Pressure Cylinders and Copper Pressure Spheres; Cannon (Major and Medium), Cannon (Minor), Small Arms, Pistol and Revolver," September 21, 1951.
2. ANSI/SAAMI Z299.3 - 2015.

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APPENDIX
SENSITIVITY DROP FIXTURE DATA

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MIN **0.0225**
MAX **0.0240**
Average **0.0230**
St. Dev **0.00037**
 1.334E-
variance 07

#	Vendor	indent depth
1	Frankford 1C-71	0.0235
2	Frankford 1C-71	0.0240
3	Frankford 1C-71	0.0240
4	Frankford 1C-71	0.0230
5	Frankford 1C-71	0.0230
6	Frankford 1C-71	0.0235
7	Frankford 1C-71	0.0230
8	Frankford 1C-71	0.0230
9	Frankford 1C-71	0.0230
10	Frankford 1C-71	0.0235
11	Frankford 1C-71	0.0230
12	Frankford 1C-71	0.0235
13	Frankford 1C-71	0.0230
14	Frankford 1C-71	0.0225
15	Frankford 1C-71	0.0230
16	Frankford 1C-71	0.0230
17	Frankford 1C-71	0.0225
18	Frankford 1C-71	0.0230
19	Frankford 1C-71	0.0230
20	Frankford 1C-71	0.0230
21	Frankford 1C-71	0.0225
22	Frankford 1C-71	0.0230
23	Frankford 1C-71	0.0225
24	Frankford 1C-71	0.0230
25	Frankford 1C-71	0.0235
26	Frankford 1C-71	0.0230
27	Frankford 1C-71	0.0225
28	Frankford 1C-71	0.0230
29	Frankford 1C-71	0.0225
30	Frankford 1C-71	0.0230
31	Frankford 1C-71	0.0230
32	Frankford 1C-71	0.0225
33	Frankford 1C-71	0.0225
34	Frankford 1C-71	0.0230

35	Frankford 1C-71	0.0225
36	Frankford 1C-71	0.0230
37	Frankford 1C-71	0.0230
38	Frankford 1C-71	0.0230
39	Frankford 1C-71	0.0235
40	Frankford 1C-71	0.0230
41	Frankford 1C-71	0.0235
42	Frankford 1C-71	0.0225
43	Frankford 1C-71	0.0230
44	Frankford 1C-71	0.0225
45	Frankford 1C-71	0.0225
46	Frankford 1C-71	0.0225
47	Frankford 1C-71	0.0230
48	Frankford 1C-71	0.0230
49	Frankford 1C-71	0.0230
50	Frankford 1C-71	0.0235
51	Frankford 1C-71	0.0230
52	Frankford 1C-71	0.0230
53	Frankford 1C-71	0.0230
54	Frankford 1C-71	0.0225
55	Frankford 1C-71	0.0230
56	Frankford 1C-71	0.0235
57	Frankford 1C-71	0.0230
58	Frankford 1C-71	0.0225
59	Frankford 1C-71	0.0235
60	Frankford 1C-71	0.0230
61	Frankford 1C-71	0.0225
62	Frankford 1C-71	0.0230
63	Frankford 1C-71	0.0230
64	Frankford 1C-71	0.0225
65	Frankford 1C-71	0.0230
66	Frankford 1C-71	0.0225
67	Frankford 1C-71	0.0235
68	Frankford 1C-71	0.0225
69	Frankford 1C-71	0.0230
70	Frankford 1C-71	0.0230
71	Frankford 1C-71	0.0225
72	Frankford 1C-71	0.0230
73	Frankford 1C-71	0.0230
74	Frankford 1C-71	0.0230
75	Frankford 1C-71	0.0235
76	Frankford 1C-71	0.0225
77	Frankford 1C-71	0.0230

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78	Frankford 1C-71	0.0230
79	Frankford 1C-71	0.0230
80	Frankford 1C-71	0.0235
81	Frankford 1C-71	0.0225
82	Frankford 1C-71	0.0225
83	Frankford 1C-71	0.0225
84	Frankford 1C-71	0.0225
85	Frankford 1C-71	0.0230
86	Frankford 1C-71	0.0230
87	Frankford 1C-71	0.0230
88	Frankford 1C-71	0.0235
89	Frankford 1C-71	0.0230
90	Frankford 1C-71	0.0225
91	Frankford 1C-71	0.0230
92	Frankford 1C-71	0.0235
93	Frankford 1C-71	0.0230
94	Frankford 1C-71	0.0225

95	Frankford 1C-71	0.0235
96	Frankford 1C-71	0.0225
97	Frankford 1C-71	0.0235
98	Frankford 1C-71	0.0230
99	Frankford 1C-71	0.0230
100	Frankford 1C-71	0.0225

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MIN 0.0195
MAX 0.0225
Average 0.0208
St. Dev 0.00068
variance 4.6E-07

MIN 0.0125
MAX 0.0145
Average 0.0135
St. Dev 0.00041
variance 1.70612E-07

#	Vendor	indent depth
101	Picatinny C10200 Coil UNANNEALED	0.0205
102	Picatinny C10200 Coil UNANNEALED	0.0215
103	Picatinny C10200 Coil UNANNEALED	0.0205
104	Picatinny C10200 Coil UNANNEALED	0.0205
105	Picatinny C10200 Coil UNANNEALED	0.0215
106	Picatinny C10200 Coil UNANNEALED	0.0210
107	Picatinny C10200 Coil UNANNEALED	0.0220
108	Picatinny C10200 Coil UNANNEALED	0.0200
109	Picatinny C10200 Coil UNANNEALED	0.0215
110	Picatinny C10200 Coil UNANNEALED	0.0205
111	Picatinny C10200 Coil UNANNEALED	0.0215
112	Picatinny C10200 Coil UNANNEALED	0.0210
113	Picatinny C10200 Coil UNANNEALED	0.0215
114	Picatinny C10200 Coil UNANNEALED	0.0205
115	Picatinny C10200 Coil UNANNEALED	0.0200
116	Picatinny C10200 Coil UNANNEALED	0.0205
117	Picatinny C10200 Coil UNANNEALED	0.0215
118	Picatinny C10200 Coil UNANNEALED	0.0200
119	Picatinny C10200 Coil UNANNEALED	0.0205
120	Picatinny C10200 Coil UNANNEALED	0.0205
121	Picatinny C10200 Coil UNANNEALED	0.0225
122	Picatinny C10200 Coil UNANNEALED	0.0205
123	Picatinny C10200 Coil UNANNEALED	0.0195
124	Picatinny C10200 Coil UNANNEALED	0.0200
125	Picatinny C10200 Coil UNANNEALED	0.0200
126	Picatinny C10200 Coil UNANNEALED	0.0205
127	Picatinny C10200 Coil UNANNEALED	0.0210
128	Picatinny C10200 Coil UNANNEALED	0.0215
129	Picatinny C10200 Coil UNANNEALED	0.0215
130	Picatinny C10200 Coil UNANNEALED	0.0205
131	Picatinny C10200 Coil UNANNEALED	0.0210
132	Picatinny C10200 Coil UNANNEALED	0.0215
133	Picatinny C10200 Coil UNANNEALED	0.0200
134	Picatinny C10200 Coil UNANNEALED	0.0210
135	Picatinny C10200 Coil UNANNEALED	0.0200

#	Vendor	indent depth
136	Picatinny C11000 Rod UNANNEALED	0.0135
137	Picatinny C11000 Rod UNANNEALED	0.0140
138	Picatinny C11000 Rod UNANNEALED	0.0135
139	Picatinny C11000 Rod UNANNEALED	0.0140
140	Picatinny C11000 Rod UNANNEALED	0.0140
141	Picatinny C11000 Rod UNANNEALED	0.0130
142	Picatinny C11000 Rod UNANNEALED	0.0145
143	Picatinny C11000 Rod UNANNEALED	0.0135
144	Picatinny C11000 Rod UNANNEALED	0.0135
145	Picatinny C11000 Rod UNANNEALED	0.0130
146	Picatinny C11000 Rod UNANNEALED	0.0130
147	Picatinny C11000 Rod UNANNEALED	0.0130
148	Picatinny C11000 Rod UNANNEALED	0.0140
149	Picatinny C11000 Rod UNANNEALED	0.0135
150	Picatinny C11000 Rod UNANNEALED	0.0135
151	Picatinny C11000 Rod UNANNEALED	0.0140
152	Picatinny C11000 Rod UNANNEALED	0.0135
153	Picatinny C11000 Rod UNANNEALED	0.0140
154	Picatinny C11000 Rod UNANNEALED	0.0135
155	Picatinny C11000 Rod UNANNEALED	0.0135
156	Picatinny C11000 Rod UNANNEALED	0.0130
157	Picatinny C11000 Rod UNANNEALED	0.0135
158	Picatinny C11000 Rod UNANNEALED	0.0130
159	Picatinny C11000 Rod UNANNEALED	0.0135
160	Picatinny C11000 Rod UNANNEALED	0.0135
161	Picatinny C11000 Rod UNANNEALED	0.0135
162	Picatinny C11000 Rod UNANNEALED	0.0140
163	Picatinny C11000 Rod UNANNEALED	0.0135
164	Picatinny C11000 Rod UNANNEALED	0.0130
165	Picatinny C11000 Rod UNANNEALED	0.0135
166	Picatinny C11000 Rod UNANNEALED	0.0140
167	Picatinny C11000 Rod UNANNEALED	0.0125
168	Picatinny C11000 Rod UNANNEALED	0.0135
169	Picatinny C11000 Rod UNANNEALED	0.0140
170	Picatinny C11000 Rod UNANNEALED	0.0135

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#	Vendor	indent depth			
			MIN	0.0245	206
			MAX	0.0275	207
			Average	0.0260	208
			St. Dev	0.00052	209
			variance	2.749E-07	210
					211
					212
					213
					214
					215
					216
					217
					218
					219
					220
					221
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					231
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					235
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					237
					238
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					240
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					242
					243
					244
					245
					246
					247
					248

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249	Picatinny ANNEALED C11000 Rod	0.0260
250	Picatinny ANNEALED C11000 Rod	0.0260
251	Picatinny ANNEALED C11000 Rod	0.0270
252	Picatinny ANNEALED C11000 Rod	0.0260
253	Picatinny ANNEALED C11000 Rod	0.0255
254	Picatinny ANNEALED C11000 Rod	0.0255
255	Picatinny ANNEALED C11000 Rod	0.0265
256	Picatinny ANNEALED C11000 Rod	0.0245
257	Picatinny ANNEALED C11000 Rod	0.0265
258	Picatinny ANNEALED C11000 Rod	0.0260
259	Picatinny ANNEALED C11000 Rod	0.0260
260	Picatinny ANNEALED C11000 Rod	0.0265
261	Picatinny ANNEALED C11000 Rod	0.0250
262	Picatinny ANNEALED C11000 Rod	0.0255
263	Picatinny ANNEALED C11000 Rod	0.0255
264	Picatinny ANNEALED C11000 Rod	0.0255
265	Picatinny ANNEALED C11000 Rod	0.0260
266	Picatinny ANNEALED C11000 Rod	0.0250
267	Picatinny ANNEALED C11000 Rod	0.0255
268	Picatinny ANNEALED C11000 Rod	0.0255
269	Picatinny ANNEALED C11000 Rod	0.0255
270	Picatinny ANNEALED C11000 Rod	0.0250

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349	Picatinny ANNEALED C10200 Coil	0.0250
350	Picatinny ANNEALED C10200 Coil	0.0245
351	Picatinny ANNEALED C10200 Coil	0.0250
352	Picatinny ANNEALED C10200 Coil	0.0245
353	Picatinny ANNEALED C10200 Coil	0.0250
354	Picatinny ANNEALED C10200 Coil	0.0250
355	Picatinny ANNEALED C10200 Coil	0.0250
356	Picatinny ANNEALED C10200 Coil	0.0250
357	Picatinny ANNEALED C10200 Coil	0.0250
358	Picatinny ANNEALED C10200 Coil	0.0245
359	Picatinny ANNEALED C10200 Coil	0.0245
360	Picatinny ANNEALED C10200 Coil	0.0245
361	Picatinny ANNEALED C10200 Coil	0.0240
362	Picatinny ANNEALED C10200 Coil	0.0250
363	Picatinny ANNEALED C10200 Coil	0.0250
364	Picatinny ANNEALED C10200 Coil	0.0240
365	Picatinny ANNEALED C10200 Coil	0.0245
366	Picatinny ANNEALED C10200 Coil	0.0250
367	Picatinny ANNEALED C10200 Coil	0.0245
368	Picatinny ANNEALED C10200 Coil	0.0240
369	Picatinny ANNEALED C10200 Coil	0.0240
370	Picatinny ANNEALED C10200 Coil	0.0240

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MIN **0.0220**
MAX **0.0245**
Average **0.0232**
St. Dev **0.00048**
variance 2.3261E-07

	Vendor	#
471	Commercial source	0.0225
472	Commercial source	0.0235
473	Commercial source	0.0235
474	Commercial source	0.0235
475	Commercial source	0.0235
476	Commercial source	0.0235
477	Commercial source	0.023
478	Commercial source	0.023
479	Commercial source	0.023
480	Commercial source	0.023
481	Commercial source	0.0235
482	Commercial source	0.024
483	Commercial source	0.0235
484	Commercial source	0.0235
485	Commercial source	0.023
486	Commercial source	0.0235
487	Commercial source	0.0235
488	Commercial source	0.023
489	Commercial source	0.023
490	Commercial source	0.023
491	Commercial source	0.0235
492	Commercial source	0.0235
493	Commercial source	0.0235
494	Commercial source	0.0235
495	Commercial source	0.023
496	Commercial source	0.0225
497	Commercial source	0.0235
498	Commercial source	0.0235
499	Commercial source	0.023
500	Commercial source	0.0225
501	Commercial source	0.023
502	Commercial source	0.0225
503	Commercial source	0.0235
504	Commercial source	0.023
505	Commercial source	0.023
506	Commercial source	0.023
507	Commercial source	0.023

508	Commercial source	0.023
509	Commercial source	0.023
510	Commercial source	0.0235
511	Commercial source	0.023
512	Commercial source	0.023
513	Commercial source	0.023
514	Commercial source	0.0225
515	Commercial source	0.023
516	Commercial source	0.023
517	Commercial source	0.023
518	Commercial source	0.0235
519	Commercial source	0.0225
520	Commercial source	0.023
521	Commercial source	0.023
522	Commercial source	0.0235
523	Commercial source	0.022
524	Commercial source	0.023
525	Commercial source	0.023
526	Commercial source	0.023
527	Commercial source	0.023
528	Commercial source	0.023
529	Commercial source	0.023
530	Commercial source	0.0225
531	Commercial source	0.0225
532	Commercial source	0.0225
533	Commercial source	0.0235
534	Commercial source	0.023
535	Commercial source	0.023
536	Commercial source	0.0235
537	Commercial source	0.023
538	Commercial source	0.023
539	Commercial source	0.023
540	Commercial source	0.023
541	Commercial source	0.0235
542	Commercial source	0.022
543	Commercial source	0.023
544	Commercial source	0.0225
545	Commercial source	0.023
546	Commercial source	0.0225
547	Commercial source	0.022
548	Commercial source	0.023
549	Commercial source	0.0235
550	Commercial source	0.023

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551	Commercial source	0.024
552	Commercial source	0.024
553	Commercial source	0.024
554	Commercial source	0.0235
555	Commercial source	0.024
556	Commercial source	0.0245
557	Commercial source	0.0245
558	Commercial source	0.024
559	Commercial source	0.0235

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	MIN	0.0210
	MAX	0.0220
	Average	0.0216
	St. Dev	0.00032
	variance	1.004E-07
#	Vendor	indent depth
371	Rock Island 2C-91	0.0215
372	Rock Island 2C-91	0.0215
373	Rock Island 2C-91	0.022
374	Rock Island 2C-91	0.0215
375	Rock Island 2C-91	0.0215
376	Rock Island 2C-91	0.022
377	Rock Island 2C-91	0.022
378	Rock Island 2C-91	0.022
379	Rock Island 2C-91	0.022
380	Rock Island 2C-91	0.0215
381	Rock Island 2C-91	0.0215
382	Rock Island 2C-91	0.0215
383	Rock Island 2C-91	0.0215
384	Rock Island 2C-91	0.021
385	Rock Island 2C-91	0.022
386	Rock Island 2C-91	0.0215
387	Rock Island 2C-91	0.0215
388	Rock Island 2C-91	0.0215
389	Rock Island 2C-91	0.0215
390	Rock Island 2C-91	0.022
391	Rock Island 2C-91	0.022
392	Rock Island 2C-91	0.0215
393	Rock Island 2C-91	0.0215
394	Rock Island 2C-91	0.022
395	Rock Island 2C-91	0.0215
396	Rock Island 2C-91	0.0215
397	Rock Island 2C-91	0.021
398	Rock Island 2C-91	0.021
399	Rock Island 2C-91	0.0215
400	Rock Island 2C-91	0.022
401	Rock Island 2C-91	0.022
402	Rock Island 2C-91	0.022
403	Rock Island 2C-91	0.0215
404	Rock Island 2C-91	0.0215
405	Rock Island 2C-91	0.022
406	Rock Island 2C-91	0.0215

407	Rock Island 2C-91	0.022
408	Rock Island 2C-91	0.022
409	Rock Island 2C-91	0.0215
410	Rock Island 2C-91	0.0215
411	Rock Island 2C-91	0.0215
412	Rock Island 2C-91	0.022
413	Rock Island 2C-91	0.022
414	Rock Island 2C-91	0.0215
415	Rock Island 2C-91	0.022
416	Rock Island 2C-91	0.0215
417	Rock Island 2C-91	0.021
418	Rock Island 2C-91	0.0215
419	Rock Island 2C-91	0.022
420	Rock Island 2C-91	0.021

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MIN **0.0225**
MAX **0.0235**
Average **0.0232**
St. Dev **0.00029**
variance **8.21E-08**

#	Vendor	indent depth
421	Frankford 4C-71	0.0230
422	Frankford 4C-71	0.0230
423	Frankford 4C-71	0.0225
424	Frankford 4C-71	0.0230
425	Frankford 4C-71	0.0235
426	Frankford 4C-71	0.0230
427	Frankford 4C-71	0.0230
428	Frankford 4C-71	0.0235
429	Frankford 4C-71	0.0230
430	Frankford 4C-71	0.0230
431	Frankford 4C-71	0.0235
432	Frankford 4C-71	0.0235
433	Frankford 4C-71	0.0230
434	Frankford 4C-71	0.0230
435	Frankford 4C-71	0.0235
436	Frankford 4C-71	0.0230
437	Frankford 4C-71	0.0235
438	Frankford 4C-71	0.0235
439	Frankford 4C-71	0.0230
440	Frankford 4C-71	0.0235
441	Frankford 4C-71	0.0235
442	Frankford 4C-71	0.0235
443	Frankford 4C-71	0.0235
444	Frankford 4C-71	0.0230
445	Frankford 4C-71	0.0235
446	Frankford 4C-71	0.0230
447	Frankford 4C-71	0.0230
448	Frankford 4C-71	0.0235
449	Frankford 4C-71	0.0230
450	Frankford 4C-71	0.0235
451	Frankford 4C-71	0.0235
452	Frankford 4C-71	0.0230
453	Frankford 4C-71	0.0230
454	Frankford 4C-71	0.0230
455	Frankford 4C-71	0.0230
456	Frankford 4C-71	0.0230

457	Frankford 4C-71	0.0235
458	Frankford 4C-71	0.0225
459	Frankford 4C-71	0.0235
460	Frankford 4C-71	0.0235
461	Frankford 4C-71	0.0235
462	Frankford 4C-71	0.0235
463	Frankford 4C-71	0.0235
464	Frankford 4C-71	0.0230
465	Frankford 4C-71	0.0230
466	Frankford 4C-71	0.0235
467	Frankford 4C-71	0.0235
468	Frankford 4C-71	0.0235
469	Frankford 4C-71	0.0230
470	Frankford 4C-71	0.0235

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Cylinder Dimensional Inspection

LOT #	ID #	OD 0.2245" to 0.2265"	Length 0.3990" to 0.4010"
-------	------	--------------------------------	------------------------------------

Rock Island	1	0.2255	0.4005
Rock Island	2	0.2250	0.4010
Rock Island	3	0.2250	0.4005
Rock Island	4	0.2250	0.4010
Rock Island	5	0.2255	0.4010
Rock Island	6	0.2245	0.4005
Rock Island	7	0.2255	0.4005
Rock Island	8	0.2255	0.4010
Rock Island	9	0.2250	0.4010
Rock Island	10	0.2250	0.4005
Rock Island	11		

average	0.2252	0.4008
min	0.2245	0.4005
max	0.2255	0.4010

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LOT #	ID #	OD 0.2245" to 0.2265"	Length 0.3990" to 0.4010"	Circular Runnout Surface A 0.0005"	Circular Runnout Surface B 0.0005"
FA 1C-71	1	0.2250	0.4005	0.0003	0.0002
FA 1C-71	2	0.2250	0.4010	0.0003	0.0004
FA 1C-71	3	0.2250	0.4000	0.0005	0.0003
FA 1C-71	4	0.2250	0.4000	0.0003	0.0004
FA 1C-71	5	0.2250	0.4005	0.0005	0.0006
FA 1C-71	6	0.2250	0.4005	0.0004	0.0005
FA 1C-71	7	0.2250	0.4000		
FA 1C-71	8	0.2250	0.4000		
FA 1C-71	9	0.2250	0.4000		
FA 1C-71	10	0.2250	0.4000		
FA 1C-71	11	0.2250	0.4000		
FA 1C-71	12	0.2250	0.4005		
FA 1C-71	13	0.2250	0.4000		
FA 1C-71	14	0.2250	0.4000		
FA 1C-71	15	0.2250	0.4000		
FA 1C-71	16	0.2250	0.4000		
FA 1C-71	17	0.2250	0.4000		
FA 1C-71	18	0.2250	0.4005		
FA 1C-71	19	0.2250	0.4005		
FA 1C-71	20	0.2250	0.4005		
FA 1C-71	21	0.2250	0.4000		
FA 1C-71	22	0.2250	0.4000		
FA 1C-71	23	0.2250	0.4000		
FA 1C-71	24	0.2250	0.4000		
FA 1C-71	25	0.2250	0.4000		
FA 1C-71	26	0.2250	0.4000		
FA 1C-71	27	0.2250	0.4000		
FA 1C-71	28	0.2250	0.4000		
FA 1C-71	29	0.2250	0.4000		
FA 1C-71	30	0.2250	0.4000		
FA 1C-71	31	0.2250	0.4000		
FA 1C-71	32	0.2250	0.4000		
FA 1C-71	33	0.2250	0.4000		
FA 1C-71	34	0.2250	0.4000		
FA 1C-71	35	0.2250	0.4000		
FA 1C-71	36	0.2250	0.4005		
FA 1C-71	37				
FA 1C-71	38				

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FA 1C-71	39				
FA 1C-71	40				
FA 1C-71	41				
FA 1C-71	42				
FA 1C-71	43				
FA 1C-71	44				

average	0.2250	0.4001	0.0004
min	0.2250	0.4000	0.0002
max	0.2250	0.4010	0.0006

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LOT #	ID #	OD 0.2245" to 0.2265"	Length 0.3990" to 0.4010"	Circular Runnout Surface A 0.0005"	Circular Runnout Surface B 0.0005"
Commercial Source Lot 873	1	0.2270	0.4010	0.0011	0.0007
Commercial Source Lot 873	2	0.2270	0.4010	0.0017	0.0012
Commercial Source Lot 873	3	0.2270	0.4005	0.0005	0.0005
Commercial Source Lot 873	4	0.2270	0.4000	0.0013	0.0010
Commercial Source Lot 873	5	0.2270	0.4015	0.0004	0.0013
Commercial Source Lot 873	6	0.2270	0.4010	0.0006	0.0011
Commercial Source Lot 873	7	0.2275	0.4005		
Commercial Source Lot 873	8	0.2275	0.4005		
Commercial Source Lot 873	9	0.2270	0.4010		
Commercial Source Lot 873	10	0.2275	0.4010		
Commercial Source Lot 873	11	0.2275	0.4005		
Commercial Source Lot 873	12	0.2275	0.4010		
Commercial Source Lot 873	13	0.2275	0.4010		
Commercial Source Lot 873	14	0.2275	0.4010		
Commercial Source Lot 873	15	0.2275	0.4010		
Commercial Source Lot 873	16	0.2275	0.3995		
Commercial Source Lot 873	17	0.2275	0.4005		
Commercial Source Lot 873	18	0.2275	0.4000		
Commercial Source Lot 873	19	0.2275	0.4010		
Commercial Source Lot 873	20	0.2275	0.4010		
Commercial Source Lot 873	21	0.2275	0.4010		
Commercial Source Lot 873	22	0.2270	0.4005		
Commercial Source Lot 873	23	0.2270	0.4010		
Commercial Source Lot 873	24	0.2270	0.4005		
Commercial Source Lot 873	25	0.2270	0.4010		
Commercial Source Lot 873	26	0.2275	0.4005		
Commercial Source Lot 873	27	0.2275	0.4010		
Commercial Source Lot 873	28	0.2270	0.4005		
Commercial Source Lot 873	29	0.2275	0.4005		
Commercial Source Lot 873	30	0.2275	0.3995		
Commercial Source Lot 873	31	0.2275	0.4005		
Commercial Source Lot 873	32	0.2275	0.4005		
Commercial Source Lot 873	33	0.2270	0.4005		
Commercial Source Lot 873	34	0.2270	0.4005		
Commercial Source Lot 873	35	0.2270	0.4005		
Commercial Source Lot 873	36	0.2275	0.3995		
Commercial Source Lot 873	37				
Commercial Source Lot 873	38				

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Commercial Source Lot 873	39				
Commercial Source Lot 873	40				
Commercial Source Lot 873	41				
Commercial Source Lot 873	42				
Commercial Source Lot 873	43				
Commercial Source Lot 873	44				

average	0.2273	0.4006	0.0010
min	0.2270	0.3995	0.0004
max	0.2275	0.4015	0.0017

ANSI/SAAMI Z299.4-1992



***Voluntary Industry Performance Standards
for Pressure and Velocity
of Centerfire Rifle Sporting Ammunition
for the Use of Commercial Manufacturers***



Headquarters

11 West 42nd Street, 13th Floor

New York, NY 10036

Tel: 212 642-4900 Fax: 212 398-0023

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SECTION III - EQUIPMENT
CENTERFIRE RIFLE
SAAMI VOLUNTARY PERFORMANCE STANDARDS

USAGE OF CRUSHER CYLINDER
PRESSURE TESTS

Copper crusher cylinders of the nominal sizes listed below shall be used for pressure tests of centerfire rifle cartridges.

Crusher cylinders shall not be precompressed before using.

Sample tarage tables are shown on pages 204, 205 and 206, but only the tarage table furnished with the particular lot of crushers should be used.

SIZE DESIGNATION	NOMINAL SIZE	PISTON		AVERAGE PRESSURE LIMITS (CUP) IN UNITS OF 100
		DIAMETER	AREA	
A	.146" x .400"	.206"	1/30 sq. inch	Below 240
B	.225" x .500"	.206"	1/30 sq. inch	240 to 550
C	.225" x .400"	.206"	1/30 sq. inch	Over 550

It is recommended that pressures be recorded in Copper Units of Pressure.*

*The designation Copper Units of Pressure (CUP) was adopted by the Technical Committee at their meeting of January 8, 1969, to replace the previous designation of pounds per square inch. Advances in the art of pressure-sensing devices have shown that pressures recorded by deformation of copper crusher cylinders are not necessarily a true measure of pounds per square inch for the transient phenomena encountered in sporting arms ammunition.

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SECTION III - EQUIPMENT
 CENTERFIRE RIFLE
 SAAMI VOLUNTARY PERFORMANCE STANDARDS

SAMPLE TARAGE TABLE
 .225 x .400 COPPER
 SIZE C

SAMPLE TARAGE TABLE
 COPPER CRUSHER CYLINDERS
 0.225 INCH DIAMETER, 0.400 INCH LONG
 FOR USE WITH 0.206 INCH DIAMETER PISTON
 AREA = 1/30 SQUARE INCH *CUP in Units of 100

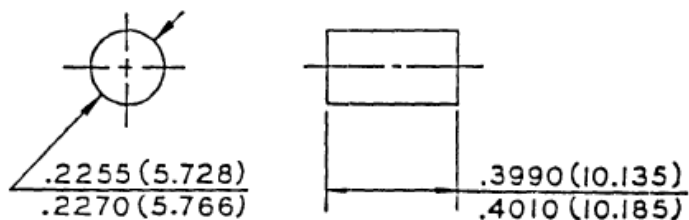
Final Length	Pressure CUP*	Final Length	Pressure CUP*	Final Length	Pressure CUP*	Final Length	Pressure CUP*
.399	30	.359	383	.319	590	.279	783
.398	60	.358	390	.318	595	.278	787
.397	78	.357	395	.317	600	.277	792
.396	96	.356	400	.316	605	.276	797
.395	106	.355	405	.315	610	.275	802
.394	117	.354	411	.314	614	.274	807
.393	127	.353	416	.313	619	.273	812
.392	138	.352	421	.312	623	.272	816
.391	150	.351	427	.311	628	.271	821
.390	158	.350	433	.310	633	.270	826
.389	167	.349	438	.309	637	.269	831
.388	175	.348	444	.308	642	.268	836
.387	184	.347	450	.307	647	.267	840
.386	193	.346	455	.306	651	.266	845
.385	202	.345	460	.305	656	.265	850
.384	211	.344	466	.304	661	.264	855
.383	219	.343	471	.303	666	.263	860
.382	226	.342	477	.302	670	.262	864
.381	234	.341	483	.301	675	.261	869
.380	241	.340	488	.300	680	.260	874
.379	248	.339	493	.299	685	.259	879
.378	255	.338	497	.298	690	.258	884
.377	263	.337	502	.297	695	.257	888
.376	270	.336	507	.296	700	.256	893
.375	277	.335	511	.295	705	.255	898
.374	284	.334	516	.294	710	.254	903
.373	290	.333	521	.293	715	.253	908
.372	297	.332	526	.292	720	.252	913
.371	304	.331	531	.291	725	.251	917
.370	311	.330	535	.290	729	.250	922
.369	318	.329	540	.289	734		
.368	325	.328	545	.288	739		
.367	332	.327	550	.287	744		
.366	339	.326	555	.286	749		
.365	345	.325	560	.285	754		
.364	351	.324	565	.284	759		
.363	358	.323	570	.283	764		
.362	364	.322	575	.282	768		
.361	370	.321	580	.281	773		
.360	376	.320	585	.280	778		

NOTE - TARAGE TABLES ARE ESTABLISHED FOR EACH LOT OF CYLINDERS. ONLY THE TABLE FURNISHED BY THE MANUFACTURER WITH EACH SHIPMENT OF CYLINDERS SHOULD BE USED

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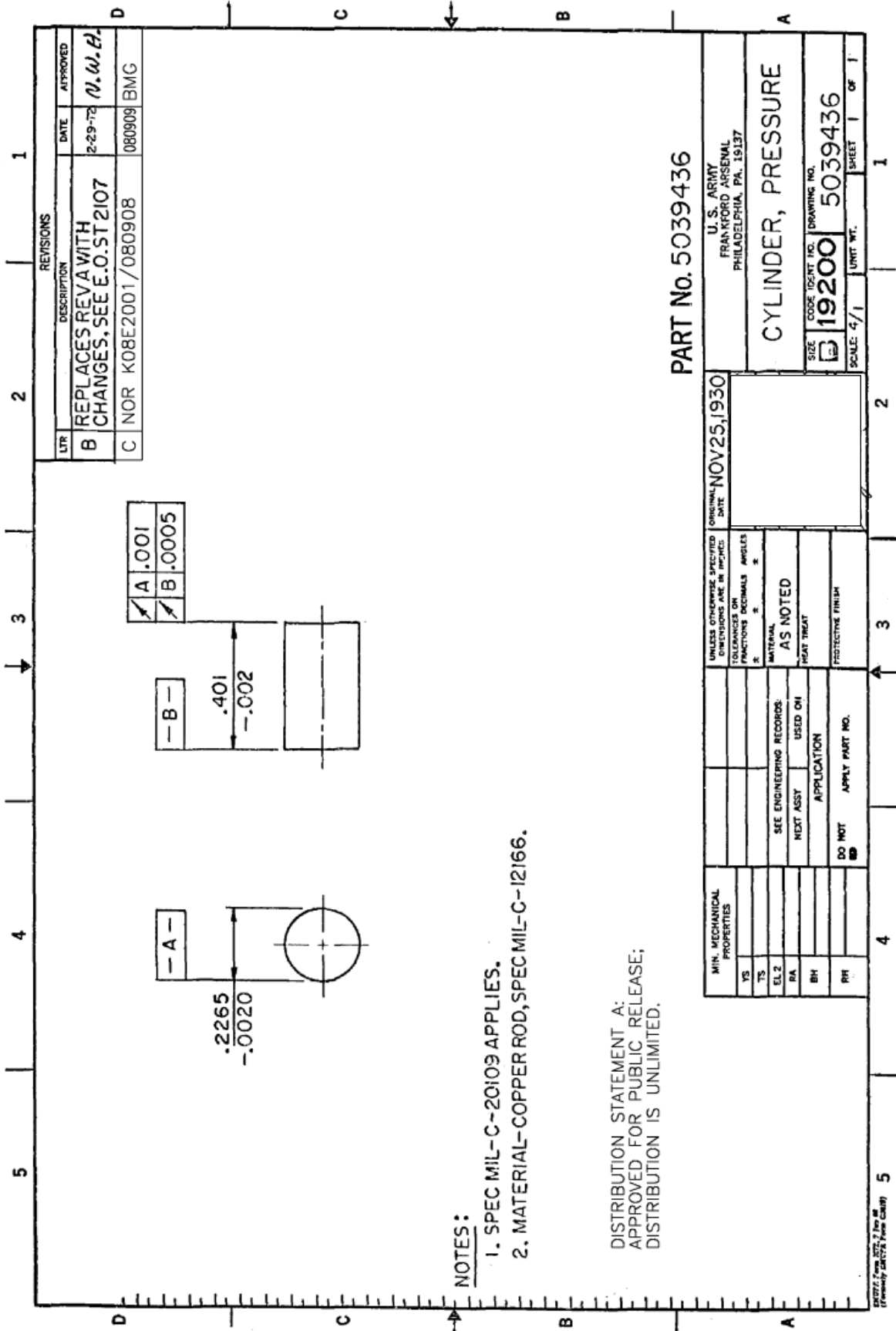
SECTION III - EQUIPMENT
CENTERFIRE RIFLE
SAAMI VOLUNTARY PERFORMANCE STANDARDS

.225 x .400 CRUSHER CYLINDER
SIZE C

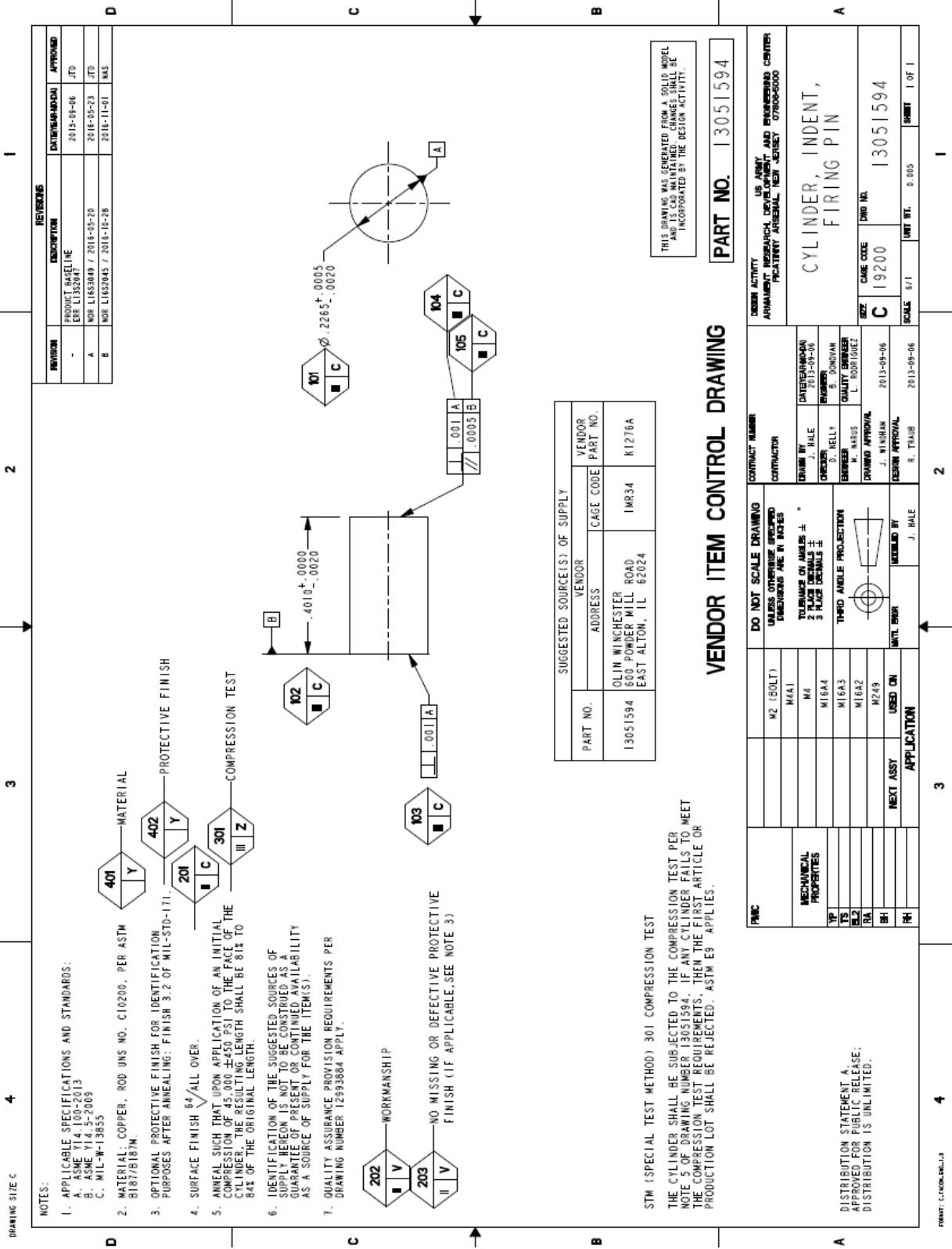


NOTES

1. MATERIAL-COPPER DEVELOPMENT ASSOCIATION ALLOY 102
2. (XX.XX) = MILLIMETERS



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REVISION	DESCRIPTION	DATE	BY	APPROVED
A	ISSUE	2013-09-06	JTD	
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C	MOD L1633049 / 2013-10-28	2013-11-01	MAS	

REVISION	DESCRIPTION	DATE	BY	APPROVED
A	ISSUE	2013-09-06	JTD	
B	MOD L1633049 / 2013-09-26	2013-09-23	JTD	
C	MOD L1633049 / 2013-10-28	2013-11-01	MAS	

REVISION	DESCRIPTION	DATE	BY	APPROVED
A	ISSUE	2013-09-06	JTD	
B	MOD L1633049 / 2013-09-26	2013-09-23	JTD	
C	MOD L1633049 / 2013-10-28	2013-11-01	MAS	

NOTES:

- APPLICABLE SPECIFICATIONS AND STANDARDS:
 A. ASME Y14.100-2013
 B. ASME Y14.5-2009
 C. MIL-W-13855
- MATERIAL: COPPER, ROD UNS NO. C10200, PER ASTM B187/B187M.
- OPTIONAL PROTECTIVE FINISH FOR IDENTIFICATION PURPOSES AFTER ANNEALING: FINISH 3.2 OF MIL-STD-171.
- SURFACE FINISH $\sqrt{64}$ ALL OVER.
- ANNEAL SUCH THAT UPON APPLICATION OF AN INITIAL COMPRESSION OF 45,000 ± 450 GSI TO THE FACE OF THE CYLINDER, THE RESULTING LENGTH SHALL BE 81% TO 84% OF THE ORIGINAL LENGTH.
- IDENTIFICATION OF THE SUGGESTED SOURCES OF SUPPLY HEREON IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM(S).
- QUALITY ASSURANCE PROVISION REQUIREMENTS PER DRAWING NUMBER 12593884 APPLY.

DO NOT SCALE DRAWING UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CONTRACT NUMBER
M2 (BOLT) M441	
M4	
M16A4	
M16A3	
M16A2	
M249	
USED ON	
NEXT ASST	
APPLICATION	

MECHANICAL PROPERTIES	CONTRACT NUMBER
YP	
UTS	
ELZ	
RA	
BH	
PH	

DESIGN BY	DATE	DESIGN APPROVAL	DATE
J. HALE	2013-09-06	J. HALE	2013-09-06
D. NELL	2013-09-06	J. HALE	2013-09-06
L. ROBINSON	2013-09-06	R. TRAHB	2013-09-06

DESIGN BY	DATE	DESIGN APPROVAL	DATE
J. HALE	2013-09-06	J. HALE	2013-09-06
D. NELL	2013-09-06	J. HALE	2013-09-06
L. ROBINSON	2013-09-06	R. TRAHB	2013-09-06

CONTRACT NUMBER	CONTRACT NUMBER
13051594	13051594
OLIN WINCHESTER 600 POWDER MILL ROAD EAST ALTON, IL 62024	OLIN WINCHESTER 600 POWDER MILL ROAD EAST ALTON, IL 62024
13051594	13051594
M16A4	M16A4
M16A3	M16A3
M16A2	M16A2
M249	M249
USED ON	
NEXT ASST	
APPLICATION	

VENDOR ITEM CONTROL DRAWING

THE CYLINDER SHALL BE SUBJECTED TO THE COMPRESSION TEST PER NOTE 5 OF DRAWING NUMBER 13051594. IF ANY CYLINDER FAILS TO MEET THE COMPRESSION TEST REQUIREMENTS, THEN THE FIRST ARTICLE OR PRODUCTION LOT SHALL BE REJECTED. ASTM E9 APPLIES.

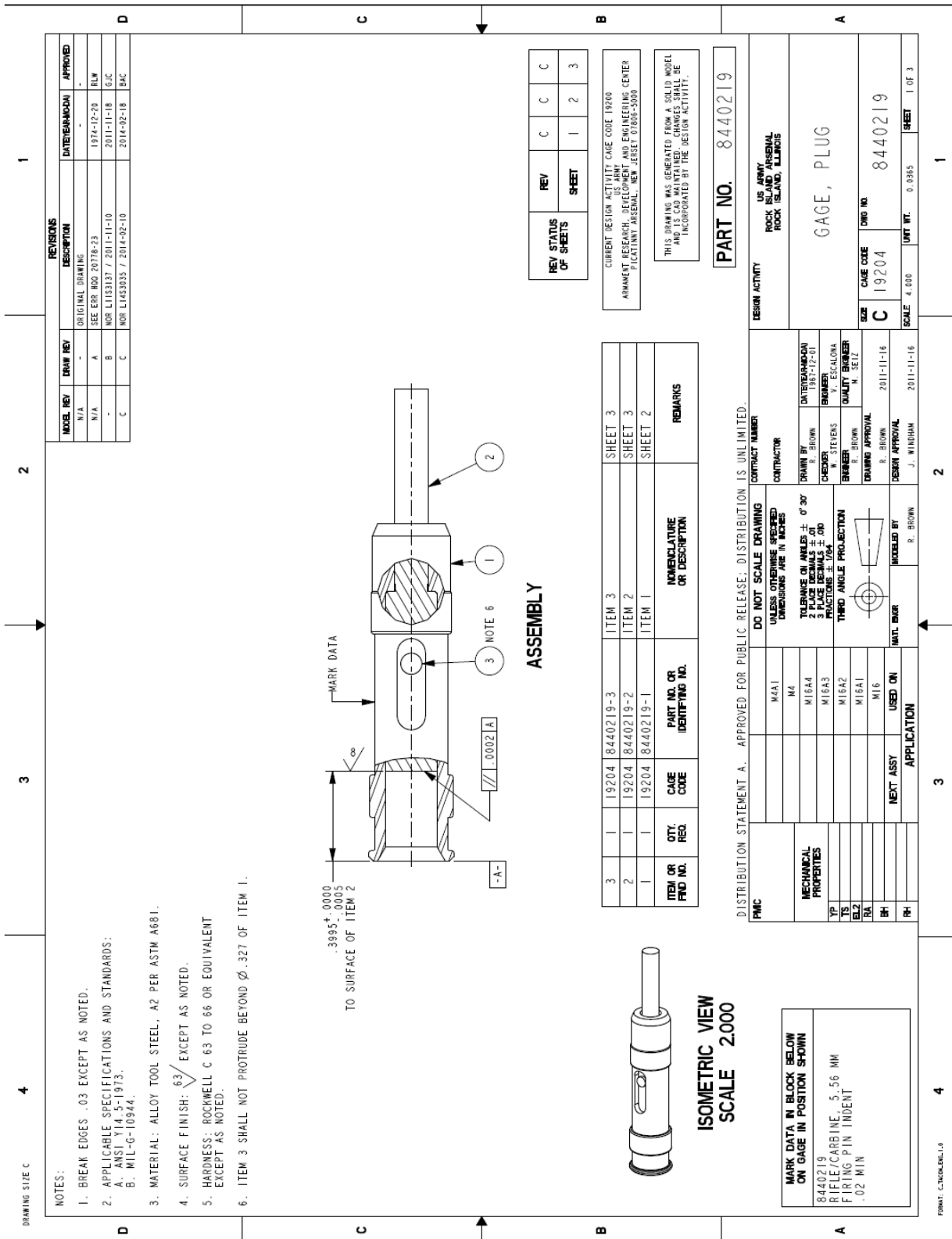
THIS DRAWING WAS GENERATED FROM A SOLID MODEL AND IS CAD MAINTAINED. CHANGES SHALL BE INCORPORATED BY THE DESIGN ACTIVITY.

PART NO. 13051594

REVISION	DESCRIPTION	DATE	BY	APPROVED
A	ISSUE	2013-09-06	JTD	
B	MOD L1633049 / 2013-09-26	2013-09-23	JTD	
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B	MOD L1633049 / 2013-09-26	2013-09-23	JTD	
C	MOD L1633049 / 2013-10-28	2013-11-01	MAS	



DATE	REV	DESCRIPTION	DATE	REV	DESCRIPTION
		ORIGINAL DRAWING			
	A	SEE ERR MOD 20176-23	1974-12-20		BLW
	B	NOI L115137 / 2011-11-10	2011-11-18		GJC
	C	NOI L1453035 / 2014-02-10	2014-02-18		BAC

NOTES:

- BREAK EDGES .03 EXCEPT AS NOTED.
- APPLICABLE SPECIFICATIONS AND STANDARDS:
 - ANSI Y14.5-1973.
 - MIL-G-10944.
- MATERIAL: ALLOY TOOL STEEL, A2 PER ASTM A681.
- SURFACE FINISH: $\sqrt{63}$ EXCEPT AS NOTED.
- HARDNESS: ROCKWELL C 63 TO 66 OR EQUIVALENT EXCEPT AS NOTED.
- ITEM 3 SHALL NOT PROTRUDE BEYOND ϕ .327 OF ITEM 1.

ITEM OR FND NO.	QTY	REQ	CAGE CODE	PART NO. OR IDENTIFYING NO.	INVENTORY OR DESCRIPTION	REMARKS
3	1	1	19204	8440219-3	ITEM 3	SHEET 3
2	1	1	19204	8440219-2	ITEM 2	SHEET 3
1	1	1	19204	8440219-1	ITEM 1	SHEET 2

ASSEMBLY

REVISIONS

REV	STATUS	SHEET	REV	STATUS	SHEET
C	C	C	C	C	C
I	I	I	I	I	I
2	2	2	2	2	2
3	3	3	3	3	3

ISOMETRIC VIEW
SCALE 2.000

MARK DATA IN BLOCK BELOW ON GAGE IN POSITION SHOWN

8440219
RIFLE/CARBINE
FIRING PIN INDENT
.02 MIN

5.56 MM

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MECHANICAL PROPERTIES	DO NOT SCALE DRAWING UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CONTRACT NUMBER
MA1		
M4		
M16A4		
M16A3		
M16A2		
M16A1		
M16		

DESIGN ACTIVITY
US ARMY
ROCK ISLAND ARSENAL
ROCK ISLAND, ILLINOIS

GAGE, PLUG

SCALE 4.000

UNIT WT. 0.9985

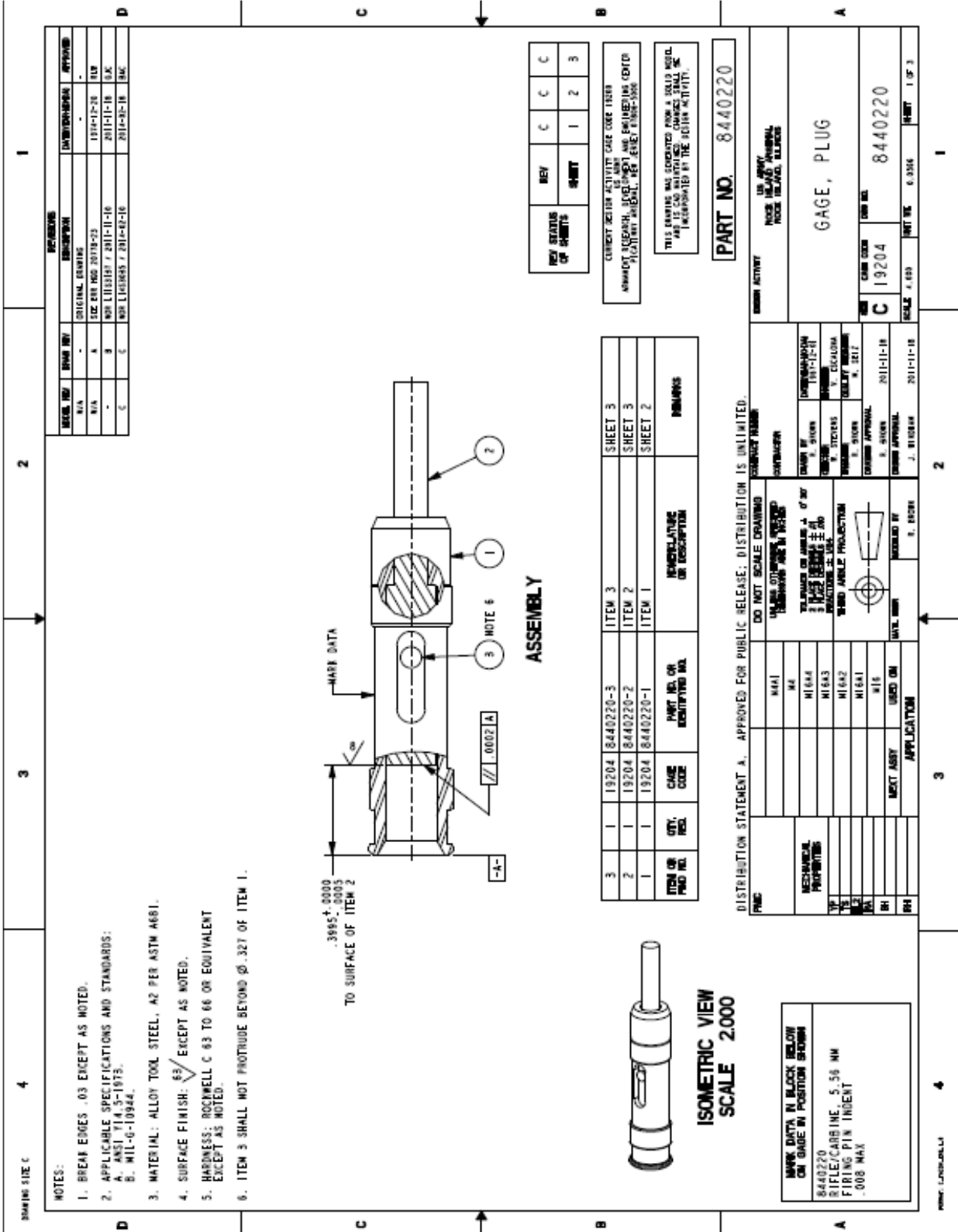
SHEET 1 OF 3

MARK DATA IN BLOCK BELOW ON GAGE IN POSITION SHOWN

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FIRING PIN INDENT
.02 MIN

5.56 MM

FORM: C7000-01-10



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 Thomas C. Grego, Michelle Schütz, Brian Donovan
 Authc./Project Engineer _____ Report number/Date received (to be completed by LCSD)
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Joseph Chiarolanza 7/26/17
 Division Chief (Date)

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