THE GENERAL BOARD

United States Forces, European Theater

CONDEMNATION AND REPLACEMENT OF ARTILLERY TUBES IN COMBAT

MISSION: Prepare Report and Recommendations on Condemnatich and Replacement of Artillery Tubes in Combat.

The General Board was established by General Orders 128, Headquarters European Theater of Operations, US Army, dated 17 June 1945, as amended by General Orders 182, dated 7 August 1945 and General Orders 312 dated 20 November 1945, Headquarters United States Forces, European Theater, to prepare a factual analysis of the strategy, tactics, and administration employed by the United States forces in the European Theater.

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CONDEMNATION AND REPLACEMENT OF ARTILLERY TUBES IN COMBAT

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3. Ordnance Technical Bulletin Number 124, Headquarters Communications Zone, ETOUSA, Office of the Chief Ordnance Officer, subject: "Condemnation and Disposition of Artillery Tubes", dated 7 December 1944.

4. Ordnance Memorandum Number 114, (Extract) Headquarters Ninth US Army, dated 14 November 1944.

5. Accuracy of Predicted Fire, (Extract) Royal Canadian Army, IG Draft 108, January 1945.

6. After Action Report, (Extract) Third US Army, file R314.7 TGBSY-R, dated 4 September 1945.

7. Revision No. 1, Ordnance Technical Bulletin Number 59, (Extract) Communications Zone, USFET, Office of the Chief Ordnance Officer, dated 18 July 1945.

8. Artillery For a Type Army.

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UNITED STATES FORCES, EUROPEAN THEATER
APO 408

CONDEMNATION AND REPLACEMENT OF ARTILLERY TUBES IN COMBAT

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CONDEMNATION AND REPLACEMENT OF ARTILLERY TUBES IN COMBAT

CHAPTER 1

METHODS OF CONDEMNATION

SECTION 1

GENERAL

1. Purpose of the study. This study is an analysis of the methods used in the European Theater to condemn artillery tubes during combat in order to effect a practical measure of economy in the replacement thereof, and to recommend a practical method for future use.

2. Methods used. Practice used in the European Theater included these methods:

a. Estimated tube life in terms of an arbitrary number of rounds.
b. Practical firing tests.
c. Relative calibration of muzzle velocities.
d. Visual inspection.

SECTION 2

ANALYSIS OF METHODS USED

3. Arbitrary number of rounds. Estimated tube life in terms of an arbitrary number of rounds has, as its major attraction, its ease of application. However, this ease of application is also a disadvantage in that the gun book does not necessarily indicate an accurate record. Using arms often err in the arithmetical conversion of rounds fired to terms of equivalent service rounds.[1]

a. During firing the bore interface is subjected to:[2]

(1) Heating effect.
(2) High temperature chemical effect.
(3) Abrasive effect.
(4) Stressing effect.

b. The cumulative result of these effects is influenced by a number of variables such as:

(1) Rate of fire.
(2) Nature of projectiles and propellants.
(3) Prolonged firing.
(4) Exclusive use of the higher powder zones.

c. Use of projectiles and propellants of our allies, and the enemy's as well, is sometimes desirable and necessary. Little is known in advance about their influence on wear when used in our cannon.

d. The conditions and variables outlined above apply to all calibers. However, in the case of 37mm Guns, M3, M5 and M6; 40mm Gun M1; 57mm Gun M1; 75mm Guns M3, M5 and M6; 75mm Howitzers M1, M2, M3;

and 105mm Howitzers M2A1, M3 and M4, the low cost of replacement tubes; their ease of manufacture and ready availability; as well as the quantities generally present in a field army; all are factors that combine to make a more involved standard of condemnation undesirable. An arbitrary number of rounds is a practical basis for condemnation in the case of these calibers. With respect to calibers other than those enumerated above, the cost and difficulty of manufacture indicates that a more precise basis of condemnation must be used in the interests of economy in both money and transportation. Since these calibers are present in lesser quantities in a field army, a more detailed examination is practical. It is emphasized that expected tube life figures, in these calibers, are of value only for supply planning purposes when all pieces in a theater are considered, and such figures have no other purpose.

4. Practical firing tests.

a. Actual performance achieved considerable popularity during the European Campaign. It was believed that the ability of the piece to hit within four probable errors in range of the expected center of impact was its truest test.[3, 4, 5] However, it is appreciated that the practical firing test is liable to many errors which are inherent in this method.

b. Errors exist in location and plotting of the piece and fall of shot:

(1) Ground survey methods are affected by the difficulties of accurate observation under combat conditions.[1]

(2) Aerial observation is subject to errors in height.[1]

c. Errors in the piece may result from variations in degree of coppering.[6]

d. Errors of personnel may occur from irregular ramming[6] and variations in temperature of the propellant.[6]

e. Errors in the field of exterior ballistics may include:

(1) Weight and shape of projectile.[6]
(2) Steadiness of projectile.[6]
(3) Wind and air temperature.[1]

f. Residual errors exist in range tables.[6]

g. The practical firing test is not entirely accurate, however, erratic performance of the piece as reported by the using arm is of sufficient importance to warrant further critical examination to determine serviceability. It is probable that reports of erratic performance will be the first indication of unserviceability.

5. Relative Calibration of Muzzle Velocities.

a. Determined relative muzzle velocities eliminate the errors due to location and plotting and those pertaining to exterior ballistics. However, certain errors inherent to the practical firing test are still present.

b. Errors in the piece due to variations in the degree of coppering.[6]

c. Errors of personnel, such as irregular ramming[6] and variations in temperature of the propellant.[6]

d. Errors due to equipment of the Ballistic and Technical Service Detachment. While this equipment is generally quite accurate, erratic results may occasionally happen.

e. Although relative calibration of muzzle velocities is less susceptible to error than other methods previously discussed, it is not advisable to condemn tubes on this basis alone because the loss in muzzle velocity for certain pieces is very slight throughout the life of the cannon. This is true of the 105mm Howitzers, M-2 and M-3, 155mm Howitzer, M-1, and the 8-inch Howitzer, M-1.[7] Therefore, it is obvious that while relative calibration of muzzle velocity affords valuable information on the expected life to be obtained from certain tubes, it is not infallible. It must also be considered that the primary mission of ballistic and technical service detachments is to furnish relative muzzle velocities to artillery commanders in order that pieces may be regrouped by firing batteries to give more accurate results. Since the full time of these detachments is occupied by their primary mission, their diversion to another purpose, i.e. condemnation of tubes, is not economical. Information of relative muzzle velocities obtained by these teams, however, is valuable in applicable cases when used with other data.

6. Visual Inspection. The physical appearance of artillery tubes was frequently used as a basis for condemnation; however, experience has shown that this method, by itself, is not a suitable method except in obvious cases, such as: visible structural failure, damage by accident, or hostile fire, or in the case of the calibers outlined in paragraph 3 d above. Erosion and other conditions are often over-estimated by a visual inspection. Irregularities and uneveness seem large even when felt with the fingers.[2] The 105mm Howitzer frequently stripped one or more lands and many tubes were condemned for this reason. Land stripping actually is not a serious defect in this weapon unless the cumulative length of missing lands exceeds 110 linear inches. Below this figure such a condition does not materially affect the range.[8]

7. Training. It was evident during the European Campaign that artillery maintenance officers were poorly prepared to perform their duties. Few had ever seen old and partially worn tubes and their knowledge was confined to the theory that the tube had an expected service life of so many rounds. They were completely uninformed on the subjects of interior and exterior ballistics and were not prepared to interpret the many defects that occur in the life of cannon, nor could they explain or detect the causes of erratic performance. As a result, no Ordnance expert was readily available to assist the using arms by a superior knowledge and with a prompt explanation of the condition of the bore or many other questions of performance. Because of this, the using arms frequently became alarmed when heat-checks, scoring and abrasion developed in their first set of tubes. After one experience, however, they were generally reassured and were willing to wait until Ordnance was ready to exchange tubes. The development of this attitude was not easy, and Ordnance maintenance officers were subjected to many aggravating demands for early and uneconomical exchange of tubes. Had the supply been adequate, it is doubtful if the demands could have been resisted.

SECTION 3

BALLISTIC AND TECHNICAL SERVICE DETACHMENTS

8. Requirement. Ballistic and technical service detachments can service two-thirds of an artillery battalion in 24 hours.[1] It is assumed that a type army would have 106 organic, attached and assigned artillery, anti-aircraft and tank destroyer battalions, and that ap-

proximately 32 of these are of a nature to require calibration.[9] In addition, it is assumed that approximately 800 tanks, armed with 90mm guns, will require calibration at various stages of their life in order to determine their ability to pierce hard targets. If an ammunition expenditure equivalent to 12 Army Group desired maintenance rate is expended daily, it is evident that sufficient ammunition will be expended to consume approximately 15.5 tubes per day.[10] Tubes should be calibrated three times during their life at 25%, 50% and 75% of expected life,[7, 8] except anti-aircraft guns, which should be calibrated at 500 rounds and each 200 rounds thereafter, or an average of seven calibrations during their expected tube life.[11] It is seen that 48 tubes should be calibrated daily and the efforts of six ballistic and technical service detachments would be required. Battle losses, particularly of tanks and tank destroyers, tend to decrease the demand expressed above and it is felt that detachments should actually be available on the basis of one per corps and one for army. In addition to determining muzzle velocity, detachments should be equipped to take wear measurements and must be supplied with the necessary pullover gages. Since many types of artillery are not calibrated because their loss of muzzle velocity is relatively small and unimportant, it is necessary for Ordnance maintenance companies also to have pullover gages.

Bibliography

Chapter 1

1. Remarks of Lieutenant Colonel W. H. Trammell, Ordnance Department, Chief of Weapons Division, Ordnance Service, Communications Zone, throughout the European Campaign. Appendix No. 1.

2. Evaluation of Erosion of Cannon Bores, published by Office, Chief of Ordnance, APG, 1945.

3. Ordnance Bulletin Number 57, Headquarters First US Army, subject: "Condemnation of Major Caliber Gun Tubes", dated 26 October 1944. Appendix No. 2.

4. Ordnance Technical Bulletin Number 124, Headquarters Communications Zone, ETOUSA, Office of the Chief Ordnance Officer, 7 December 1944. Appendix No. 3.

5. Ordnance Memorandum Number 114, (Extract) Headquarters Finth US Army Army, 14 November 1944. Appendix No. 4.

6. Accuracy of Predicted Fire, (Extract) Royal Canadian Army, IG D Draft 108, January 1945. Appendix No. 5.

7. After Action Report, (Extract) Third US Army, file R314.7 TGBSY-R, dated 4 September 1945. Appendix No. 6

8. Revision No. 1, Ordnance Technical Bulletin Number 59, (Extract) Communications Zone, USFET, Office of the Chief Ordnance Officer, 18 July 1945. Appendix No. 7

9. Artillery For A Type Army. Appendix No. 8.

10. Computation of Daily Calibration Requirements on a Type Army, Appendix No.9

11. Letter, The General Board, United States Forces, European Theater, Office of the Ordnance Officer, Subject: "Anti-aircraft Artillery Tubes", dated 6 October 1945, and 1st Ind. Appendix No. 10.

CHAPTER 2

A NEW METHOD OF GAGING SERVICEABILITY

SECTION 1

CORRELATION OF WEAR AND MUZZLE VELOCITY DROP

9. Recent Developments. Tests have been conducted by the Ordnance Department in the Zone of the Interior which show a definite relationship exists between wear at or near the commencement of rifling, the muzzle velocity, and the life remaining in the tube.[1, 2, 3, 4] Using data published as a result of these tests, it is a simple matter for properly trained artillery inspectors to employ a gage to measure wear at the critical point in each tube at 25%, 50% and 75% of expected tube life. These measurements, when combined with visual inspection and when considered in connection with relative muzzle velocities in applicable cases, will afford a comparison sufficiently accurate to economically condemn the artillery tube. Since erosion is greatest at the commencement of rifling and decreases toward the muzzle, a measurement of this particular conical section can be made with the advance of the gage in the bore as the measure of serviceability.[2]

10. The most reliable index. A measurement of the bore at a fixed point near the commencement of rifling is the most reliable index of serviceability. The most accurate gage for this purpose is the star gage. In many weapons, wear is not uniformly distributed around the bore interface, but is greatest in the vertical axis. For this reason, the three point star gage is not as accurate as desired. The four point star gage, using the horizontal points as guides only, is a much better gage and is preferable for base shop use. Field use requires a more rugged instrument than the delicate star gage, even though a slight sacrifice in precision must be expected.[2]

11. The "Pullover" Gage. A gage known as the "pullover" gage has been developed. It consists of a steel plate machined on one side with a broad dovetailed recess in which a sliding plate moves. One end of the frame plate is rounded to a slightly smaller radius than that of the minimum bore for which it is intended; the sliding plate is likewise rounded at the opposite end. A screw clamp passing through a slot in the sliding plate can be set in any required position. A thumb piece is attached to the plate to enable it to be easily moved.[5] Two connections are hinged to the rear face of the frame to receive rods which serve as handles. These rods are wood or duralumin, and are made in short lengths with metal screw connections for convenience in taking measurements and for ease in packing and transport. The lower rod "B" is graduated in inches. In taking a measurement, a clamp, "C", must be set at the distance on the graduated rod at which the measurement is taken.[5]

SECTION 2

VELOCITY AND WEAR CHARTS

12. The velocity wear chart. An example is shown in Appendix 13. This chart shows vertical bore diameters taken at the commencement of rifling as the X-ordinate and the loss of muzzle velocity as the Y-ordinate. The use of this chart is applicable to weapons that develop an appreciable loss of muzzle velocity as the tube wears, such as the 3-inch Gun, M-7, 90mm AA, Tank and Anti-Tank Gun; 155mm Guns, M-1 and M-2; 8-inch Gun, M-1, and 240mm Howitzer, M-1. As a result of periodic checks of muzzle velocities and comparison with wear measurements taken

with the pullover gage, it can be determined whether the tube is wearing in a normal manner. In the approximately normal case, frequent visual inspections should be made as the bore diameter approaches the condemning limit. At this time the tube may be condemned whenever the artillery inspector thinks advisable, after due consideration of availability of replacement tubes and time. When the relationship between wear and muzzle velocity is not approximately normal, the artillery inspector must be guided by his experience in determining the condemning limit.

13. Percent-Wear Chart. An example is shown in Appendix 14. The chart shows vertical bore diameters taken at the commencement of rifling as the Y-ordinate and percent of remaining tube life as the X-ordinate. The use of this chart is applicable to weapons that do not develop an appreciable loss of muzzle velocity as the tube wears, such as the 105mm Howitzer of all types; 155mm Howitzers, M-1 and M-2; 4.5 inch Gun; and 8 inch Howitzer, M-1. As the tube approaches the condemning limit, as determined by measurements with the pullover gage, it is subjected to frequent close scrutiny to detect any defects that impair its usefulness. The artillery inspector may condemn the tube at any time he deems advisable after due consideration of availability of replacement tubes and time.

Bibliography

Chapter 2

1. Remarks of Lieutenant Colonel W. H. Trammell, Ordnance Department, Chief of Weapons Division, Ordnance Service, Communications Zone, throughout the European Campaign. Appendix No. 1.

2. Evaluation of Erosion of Cannon Bores, published by Office, Chief of Ordnance, APG, 1945.

3. After Action Report, (Extract) Third US Army, file 3314.7 TGBSY-R, dated 4 September 1945. Appendix No. 6.

4. Revision No. 1, Ordnance Technical Bulletin Number 59, (Extract) Communications Zone, USFET, Office of the Chief Ordnance Officer, 18 July 1945. Appendix No. 7.

5. Photographs of Pull-over Gage. Appendices Nos. 11 and 12.

CHAPTER 3

CONCLUSIONS AND RECOMMENDATIONS

SECTION 1

CONCLUSIONS

14. Methods used during the European Campaign. a. No method used for condemning artillery tubes during the European Campaign was entirely satisfactory.

b. The quantities of 37mm Guns, 40mm Guns, 57mm Guns, 75mm Howitzers and Guns, and 105mm Howitzers of all models, present in a field army, together with their relative low cost, ease of manufacture, and ready availability of replacements, rendered condemnation on the basis of expected tube life, or visual inspection by a qualified artillery inspector, reasonably economical and practical.

15. Artillery Tubes and Parts. A shortage of replacement artillery tubes and parts existed throughout the campaign. Especially acute was the lack of replacement tubes and allied parts for the 105mm Howitzer M2 and M3.

16. Relationship between tube wear and serviceability. The relationship between tube wear and serviceability of the tube is sound, and, when combined with visual inspection by a qualified artillery inspector, forms sufficient basis for condemnation in the case of 90mm Guns, 4.5 inch Guns, 155mm Howitzers and Guns, 8 inch Howitzers and Guns, and 240mm Howitzers.

17. The Pull-Over Gage. The pull-over gage is sufficiently accurate and rugged to constitute a practical instrument for field use and should be provided to ballistic and technical research detachments and Ordnance maintenance companies responsible for the maintenance of artillery.

18. Artillery Inspectors.

a. Artillery Maintenance Officers were not well qualified to perform their duties and had only a superficial knowledge of the performance and defects in tubes resulting from prolonged artillery fire.

b. The document "Evaluation of Erosion of Cannon Bores" published by the Office, Chief of Ordnance, is sound, but arrived in the European Theater too late to influence the methods used in condemning artillery tubes. Also, the equipment necessary to implement the doctrine outlined therein was not available.

19. Ballistic and Technical Service Detachments. The function of ballistic and technical service detachments is to furnish artillery commanders with relative muzzle velocities of individual artillery pieces in order that these may be regrouped by firing batteries to give more accurate results. As a corollary of this study, recommendations on the personnel and equipment of ballistic and technical service detachments are attached hereto, marked Appendix 15.

20. Measurements. The condition of artillery tubes of 90mm Guns, 4.5 inch Guns, 155mm Howitzers and Guns, 8 inch Howitzers and Guns and 240mm Howitzers should be carefully observed to determine if the wear is approximately normal. Measurements should be taken at 25%, 50%, and 75% of expected tube life, and compared with relative muzzle velocities in applicable cases.

21. A Proposed Solution. A solution such as might be adopted by a field army is attached hereto, marked Appendix 16.

SECTION 2

RECOMMENDATIONS

22. Basis for Condemnation of Artillery Tubes.

a. Recommend that the basis for condemnation of tubes of 37mm Guns, 40mm Guns, 57mm Guns, 75mm Howitzers and Guns, and 105mm Howitzers of all models be the expected tube life, when gun books are available. When gun books are not available, then condemnation should be on the basis of visual inspection by a qualified artillery inspector.

b. Recommend that the basis for condemnation of tubes of 90mm Guns, 4.5 inch Guns, 155mm Howitzers and Guns, 8 inch Howitzers and Guns, and 240mm Howitzers be established as the relationship between bore measurements taken as described herein, relative muzzle velocities in applicable cases, and expected tube life; all combined with visual inspection.

23. Pull-over Gages. Recommend that pull-over gages be made available to ballistic and technical research detachments and Ordnance maintenance companies charged with maintaining artillery, anti-aircraft and armor.

24. Artillery Inspectors. Recommend that the Ordnance Department revise and increase the course of instruction given artillery maintenance officers to provide personnel adequately trained to perform their duties in combat.

25. Ballistic and Technical Service Detachments. Recommend that ballistic and technical service detachments be made available to field armies on the basis of one per corps and one additional per army. Further more, recommend that the tables of organization of ballistic and technical service detachments be revised by appropriate agencies of the War Department.

26. Artillery Tubes and Parts. Recommend that the procurement of replacement artillery tubes and allied parts be based upon and phased with ammunition procurement and shipped to the theater on the same basis. Only in this way can an adequate supply of replacement tubes and parts be assured in the theater.

APPENDIX NUMBER 1

Remarks of: Lieutenant Colonel W. H. Trammell, Ordnance Department
Chief of Weapons Division, Ordnance Service, Communications Zone, throughout the European Campaign.

CONDEMNATION OF ARTILLERY TUBES

1. From experience gained in the European Campaign it is evident that no practical method of condemning artillery cannon upon expiration of effective life was available. Several methods were employed:

a. Consumption of an arbitrary number of rounds (total and/or equivalent full charges). This method offers as its chief advantage its ease of application. From information readily available from the gun book, an immediate decision could be made as to the necessity of replacement. On the other hand it must suffer from several disadvantages. These are:

(1) The many variables which affect the effective life of cannon including service of the piece, maintenance, and rate of fire, to mention but a few, result in some cannon being effectively employed for at least twice the number of rounds as some other cannon which were subject to higher rates of fire and poor maintenance. It is quite evident from this that an average figure must be arbitrarily designated which would necessitate the condemnation of some weapons with considerable remaining life and at the same time continue in service some weapons which for economic and tactical reasons should be replaced.

(2) The establishment of arbitrary life figure must necessarily be done under controlled conditions where actual firing results can be obtained so that the point of realization of effective accuracy life can be discerned. This calls for extensive firing of weapons under proving ground conditions which, for reasons of economics and time, must necessarily represent very few cannon. It obviously also cannot take into consideration all of the factors which, under field conditions, affect the life of cannon.

For these reasons, chiefly, and due to several other contributing factors, it is obvious that such a method of condemnation, regardless of ease of application, results in very uneconomical usage of cannon tubes and ammunition. It is known, of course, that this method has been employed for some time by the United States Navy but here the tactical limitations of supply during operations justifies the uneconomic replacement of tubes at a comparatively early stage of life.

b. Observation of Actual Firing. This is probably the best method of all in that it uses as its determining factor the actual performance of the weapons (that is the delivery of missiles at the target) which, after all, is the primary purpose of the weapon. There are many difficulties which made such tests impractical, however, under combat conditions. The most serious of

these limitations are:

(1) Lack of efficient observation. Very seldom in combat operations is it possible to have flank observation of such character as to insure the actual impact of each of the test rounds. This is further aggravated by inclement weather and the fact that a considerable portion of corps and army artillery rely upon air observation which at best can be but an approximation. Since the actual condemnation will probably be made on the basis of multiples of probable errors of the firing table, this, in many cases, means that observation must be accurate to within 25 to 50 yards in many cases which is not to be expected from types of observation mentioned above.

(2) Meterological Data. Very often under combat conditions metro data must be obtained at fairly remote locations and must sometimes be used some hours after the data was recorded. Whereas this would not necessarily affect dispersion of a number of rounds fired in a short time, it might clearly affect range which in cases of some weapons may be the determining factor.

c. Use of Calibration Teams (Ballistics and Technical Service Detachments, T/O & E 9-500). The use of calibration teams to condemn weapons is of considerable value in that the muzzle velocities of the weapons can be easily and accurately determined, which after all should reflect the performance of the cannon. The dispersion in muzzle velocities of a group of rounds could readily be interpreted into multiples of firing table probable errors for condemnation purposes. These teams can at the same time furnish the battery commander with comparative muzzle velocities of weapons within a battery or a battalion which can be put to good tactical use. Under optimum conditions, when one lot of ammunition can be reserved for future use of the calibration teams, standard calibration could be obtained which would be of even greater value if along with it the team could furnish average muzzle velocities on other lots of ammunition to be subsequently employed. The use of calibration teams for this purpose has, however, the following disadvantages:

(1) Under some conditions of terrain and cover imposed by combat conditions it is difficult to employ calibration teams in the line without disclosing gun positions. This is further aggravated by the fact that firing from the battery must be determined by tactical conditions which often results in the teams inactivity for a long period. On the other hand tactical conditions often militate against withdrawal of artillery units for calibration purposes.

(2) Quite obviously where calibration team is called upon to cover a considerable number of weapons (for example those of an entire army) it is quite possible that the calibration team will be some distance away from the questionable weapon when replacement seems to be indicated. If the team is dispatched on such a program it is evident that

neither could they be at the site of every questionable weapon at the desired time nor could they fulfill their equally important mission of furnishing muzzle velocity data to the army artillery units since they would be expending too great a percentage of time traveling from one position to another.

From the foregoing it is evident that no system used in this theater was completely satisfactory. Each has its disadvantages and impracticabilities. None is free from compromise.

In the belief that the best approach to the problem must admit some compromise, in order to achieve simplicity and universality of application, tests have been conducted at Aberdeen Proving Ground which show conclusively that there is a definite relationship between wear at or near the origin of rifling and effective life of the cannon. Effective life can be defined as the maximum number of rounds which can be delivered to the target area by the cannon without encountering excessive compromise with the tactical employment of the weapon (i.e. failure of the weapon to economically fulfill its mission). In some weapons this point is represented by excessive loss of muzzle velocities resulting in lack of penetration (tank and anti-tank weapons). In others excessive dispersion, with attendant exorbitant consumption of ammunition to accomplish a given mission, determines this point. Using the data obtained from the Aberdeen tests it is quite simple to employ a suitable gauge in each questionable weapon which will show the wear at the critical point (this point will vary depending upon individual characteristics of the weapon) which when the wear corresponding to end of effective life has been determined from experience, can be used to immediately condemn cannon or estimate remaining life. This gauge if made available to battery personnel could also be used to approximate loss in muzzle velocities between instrumental calibration for the information of fire directing personnel.

It is recommended in order to effectively employ this gauge, certain arbitrary points in the life of the various weapons must be established. As pointed out above this point may be determined by loss of muzzle velocity or excessive dispersion depending upon the particular weapon. It is suggested that these figures (points) be given consideration by the using arms and if agreeable with all concerned, that they be established as critical points of life for which correlated wear measurements can be determined. Having this information, it will be very simple to employ the "Good/No-Good" gauge in condemning cannon.

Recommendations:

It is recommended that:

(1) A board of officers with representatives from the Armored Force, Field Artillery, Anti-Aircraft Artillery (CAC) and the Ordnance Department be appointed to determine:

(a) In case of tank and anti-tank weapons, the minimum acceptable armor penetrating performance at ranges of 300, 500, 1000, and 2000 yards from which can be derived the maximum allowable loss of muzzle velocity prior to condemnation.

(b) In the case of Field Artillery weapons, the maximum dispersion (in terms of firing table probable error), or the maximum loss of range (loss of muzzle velocity), for each weapon, from which can be determined the point on the life curve where condemnation should occur.

(c) In the case of anti-aircraft artillery, the maximum loss in muzzle velocity commensurate with accomplishment of mission. (It is believed that this point will be incurred prior to serious dispersion).

(d) The wear at or near the origin of rifling in each of the weapons covered above corresponding to the point in life indicated as being determinative in (a), (b), and (c) above.

(2) A suitable gauge (pullover type or similar) be developed and procured for issue to Ordnance maintenance companies to be used in condemnation under provisions of the standards established in (1) above and for information to the using arm to estimate muzzle velocity changes between periodic instrumental calibrations.

(3) Velocity calibration teams (Ballistics & Technical Service Detachments, T/O & E 9-500) be equipped, trained and assigned on the basis of one per army (or separate corps) so organized and equipped as to be able to calibrate all major caliber field and anti-aircraft artillery at periods not to exceed 1/4 of the life of respective weapons. (Note: The presently organized teams are capable of calibrating artillery at the average rate of approximately 2/3 battalion per day, taking into consideration movement, tactical limitations and inclement weather).

(4) Training of all ordnance maintenance personnel, calibration team personnel and possibly battery mechanics to include complete coverage of all factors leading to condemnation of cannon such as bore wear, physical damage and the like and that concise statements of condemning factors be included in 1000 series technical manuals. Emphasis should be placed on land stripping, or other bore irregularities (some of which are repairable in the field) and in general to all points which can be removed from the realm of "judgement" and recorded as scientific data.

HEADQUARTERS
ORDNANCE SERVICE
FIRST UNITED STATES ARMY

26 October 1944

ORDNANCE BULLETIN)
:
NUMBER 57)

CONDEMNATION OF MAJOR CALIBER GUN TUBES

1. Major caliber gun tubes of First Army will be condemned on the basis of fair wear and tear in accordance with the following standards:

a. Results of a practical firing calibration test as outlined in Inclosure No. 1.

b. Results of velocity calibration performed by the 6821st Calibration Team.

c. Approval of the Maintenance Officer, First Army Ordnance Section.

2. Tubes will not be condemned by visual inspection alone unless unquestionably damaged by enemy action or other means. Weapons of higher caliber will develop considerable erosion from the forcing cone forward starting at 9 o'clock and continuing clockwise around the tube. This will reach a point where daylight can be seen around the projectile after it is rammed. This condition will be considered critical only when a loss of muzzle velocity occurs sufficient to cause dispersion (more than four probable errors) or when the piece can no longer be used tactically because of shortened range.

3. No tubes will be condemned on the basis of number of rounds fired. Artillery units will be informed that estimated tube life expressed in number of rounds is quoted for supply planning purposes only and will not govern or influence replacement.

4. Before major caliber artillery tubes will be allocated for replacement, performance tests as outlined in Inclosure No. 1 will be completed. One copy will be forwarded to the Maintenance Officer, Headquarters, First US Army Ordnance Office for approval. One copy will be attached to the tube when replacement is made giving the details of the test and brief summary of the number of rounds fired by the tube and its performance. The summary will also include:

a. Overlay of rounds fired in relation to target.

b. Range.

c. Number of rounds fired in test.

d. Dispersion in relation to probable error listed in the firing table.

By command of Lieutenant General HODGES:

1 Incl:
Firing test of questionable artillery tubes.

/s/ J. B. Medaris,
/t/ J. B. MEDARIS,
Colonel, Ord Dept,
Ordnance Officer.

Appendix No. 2.

OFFICIAL:

/s/ F. A. Hansen,
/t/ F. A. HANSEN,
Colonel, Ord Dept,
Executive Officer.

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FIRING TEST OF QUESTIONABLE ARTILLERY TUBES

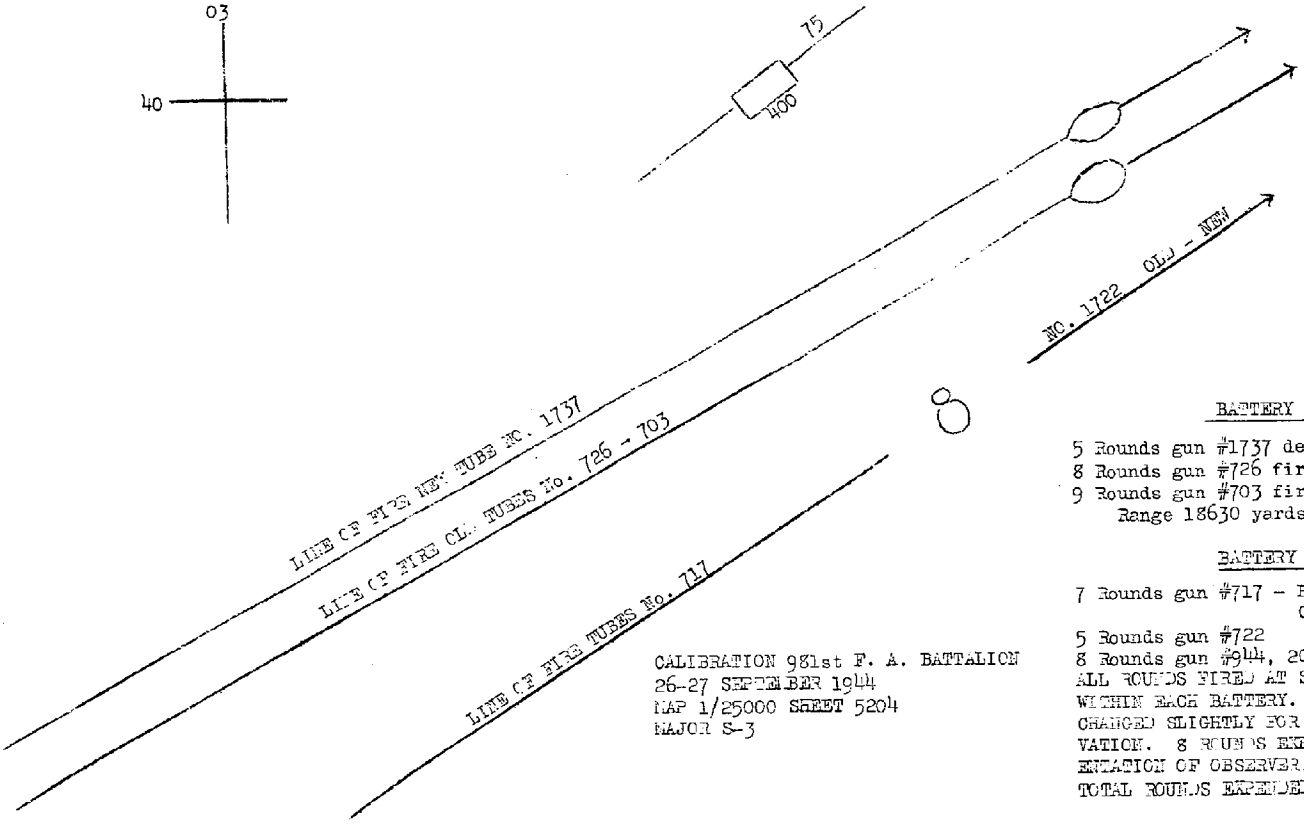
1. The procedure of the test is as follows: Select a gun which has not fired an excessive number of rounds and is functioning properly. Fire this weapon in comparison with the tube to be tested. Both guns should be fired at the same target using the same firing data. It is important that the same lot number of fuze, powder and the same weight projectile be used. Each piece should be fired individually, observed and carefully plotted to scale on a map. The deciding factor of serviceability lies in the dispersion of the rounds in relation to the target. It is quite probable that the tube in question will fire short of the target, but if the rounds fired are well grouped within the limits of four probable errors, the tube can continue to be fired until it is impossible to reach the targets required in its tactical employment. Frequent throwing of rotating bands precedes erratic rounds and when the point is reached where 50% of the rounds fired have stripped bands, a serviceability test should be conducted.

2. As shown by the attached overlay, tubes No. 726, 703 and 717 of the *** Field Artillery Battalion, which incidentally have the highest number of rounds fired in First Army Artillery, are still functioning satisfactorily. The groups are well within the probable error listed in the Firing Tables. The only difference in the new and old tube is the loss of approximately 700 yards of range. This does not affect the normal employment of the weapon as it is extremely unusual when maximum range is needed. Tube No. 717 does not fall short by comparative firing. Given below is a tabulation of the number of rounds fired on the tubes at the time of the test.

Tube No.	Rounds Fired	
	Super	Normal
726	1270	871
703	1203	824
717	969	783

3. The appearance of these tubes indicate considerable wear from the forcing cone forward for 8 to 12 inches, between 9 and 3 o'clock. After the projectile is rammed, it is possible to see daylight through the tube. During the test no rotating bands were thrown, but it was reported by the battery that one was stripped occasionally during firing.

4. The above is quoted as an example of an actaul experiment and can be considered normal.



CALIBRATION 981st F. A. BATTALION
26-27 SEPTEMBER 1944
MAP 1/25000 SHEET 5204
MAJOR S-3

BATTERY "B"

5 Rounds gun #1737 deflection changed
8 Rounds gun #726 fired at gey
9 Rounds gun #703 fired at gey
Range 18630 yards - charge super

BATTERY "C"

7 Rounds gun #717 - Range 20560 yards
Charge Super

5 Rounds gun #722
8 Rounds gun #944, 2061 not plotted
ALL ROUNDS FIRED AT SAME QUADRANT WITHIN EACH BATTERY. DEFLECTION CHANGED SLIGHTLY FOR BETTER OBSERVATION. 8 ROUNDS EXPENDED FOR ORIENTATION OF OBSERVER.
TOTAL ROUNDS EXPENDED - 50

HEADQUARTERS
COMMUNICATIONS ZONE, ETOUSA
OFFICE OF THE CHIEF ORDNANCE OFFICER
APO 887

ORDNANCE TECHNICAL)
)
BULLETIN NUMBER 124)

7 December 1944

CONDEMNATION AND DISPOSITION OF ARTILLERY TUBES

Rescission . . . . . Section I

Condemnation of Gun Tubes . . . . . Section II

SECTION I - RESCISSION

1. Ordnance Office Memorandum No 12, this headquarters, dated 8 July 1944, is hereby rescinded.

SECTION II - CONDEMNATION OF GUN TUBES

1. In order to provide a uniform method of condemning gun tubes, and to insure that the full accuracy life of each tube has expired before replacement, the following procedure will govern the condemnation of all artillery tubes in this theater:

a. Visual inspection:

(1) Experience has proved that erosion of the forcing cone, and wear of the rifling are not, in themselves, sufficient grounds for condemnation. Erosion in weapons of higher caliber will usually start at 9 o'clock, and, continuing forward, develop clockwise around the tube until daylight can be seen around the projectile after it is rammed. This condition will not be considered critical unless dispersion of the rounds in relation to the target is greater than that specified by the firing table.

(2) Pastilles, scratches, bruises, pits, etc., have little or no effect on the accuracy of the weapon, and such defects will not be considered as conclusive evidence of an unserviceable tube.

(3) Tubes will not be condemned on number of rounds fired. Artillery units will be informed that estimated tube life, expressed in number of rounds, is quoted for supply planning purposes only and will not govern or influence replacement.

(4) Condemnation by visual inspection will be made only when tubes are so obviously damaged by enemy action or other means that all question of doubt is removed.

b. Serviceability Test:

(1) Tubes will be tested for serviceability when loss of range resulting from loss of muzzle velocity prevents tactical employment of the weapon, or when dispersion exceeds probable error specified by the firing table. Stripping of an abnormal percentage of rotating bands usually precedes excessive dispersion.

(2) Fire the tube to be tested at a known target. Use the same powder charge, same lot number of fuze and projectiles of identical weight throughout the test. At least one warming round and five test rounds should be fired. The results of the test fire will be observed and carefully plotted to scale on a map. If possible the doubtful tube should be fired in comparison with a tube of unquestioned accuracy.

(3) The deciding factor of serviceability lies in dispersion of the rounds in relation to the target. The tube in question may fire short of the target, but if the rounds fired are within the limits of four probable errors, the tube will be continued in service.

(4) Results of the test will be recorded along with recommendation and submitted to the Army Maintenance Officer. Approval of the Army Maintenance Officer will be required on all resulting requests for replacement tubes. This report will include:

(a) Overlay of rounds fired in relation to target.
(b) Range.
(c) Number of rounds fired in test.
(d) Dispersion in relation to probable errors listed in firing tables.

(5) When possible a Velocity Calibration Test will be made in conjunction with the serviceability test on all major caliber tubes (4.5" and larger) plus the 90mm AA Gun tubes, and the report of this test submitted with the serviceability test reports.

* * * * * *

Following is Extract of Section II, Memorandum Number 114, Headquarters Ninth United States Army, dated 14 November 1944:

* * * * * * *

II. CONDEMNATION OF FIELD ARTILLERY HOWITZER AND GUN TUBES.

1. Before major caliber artillery tubes will be considered for replacement, performance tests will be conducted by the using unit in the following manner:

a. A minimum of six rounds will be fired from the piece to be tested using the same deflection setting and the same quadrant elevation. Lot numbers of each component of complete rounds will be the same for each round fired. Bilateral observation will be necessary so that the point of impact of each round can be plotted accurately to scale.

b. This overlay of rounds fired in relation to target, together with the range and number and type of rounds fired in the test for each weapon, will be forwarded to the Army Ordnance Maintenance Officer.

2. When a tube is determined to be unserviceable as a result of this test, a replacement will be authorized the using unit by the Army Ordnance Officer.

* * * * * * *

Extracts of Accuracy of Predicted Fire, Royal Canadian Army, IG Draft 108, January 1945.

* * * * * * * * * * * * *

SECTION 6 - ERRORS IN FIXATION OF THE TARGET

18. Even in European conditions the location of targets will generally involve the use of maps. For example if the eastings and northings of an enemy battery are obtained by flash spotting, the height will normally have to be read from the map. Only when targets are in view from ground OPs can they be completely fixed by survey methods.

Eastings and northings.

19. Very often the location of targets will depend entirely on maps, possibly aided by vertical air photographs. Until revised by aerial survey, the maps of France were known to be liable to errors as great as 100 meters even in the position of important landmarks such as crossroads and churches. Reliable 1/25,000 maps or vertical air photographs (controlled basic cover) allow the deduction of eastings and northings to an accuracy of about 25 meters, but height cannot be obtained from the basic cover.

Heights.

20. Heights can be obtained from gridded oblique photographs, but the method has not received wide publicity and the only normal method of obtaining heights is by means of map contours. Even the revised maps of France have been officially stated to be liable to errors as great as 40 meters in height, and much larger errors may be assumed likely in maps of the Far East.

Flash spotting and sound ranging.

21. When targets are fixed by these methods, an accuracy is assigned to the fixation by the survey regiment. These accuracy figures have been found to be reliable, but the height of the target is still subject to error as described in para 18.

Registration by observed fire.

22. The location of a target can be obtained from the gun data used during a shoot in which fire has been adjusted on to the target, e.g., by air O.P., arty, R., or sound ranging. This method is subject to almost all the errors set out in Table I, and co-ordinates deduced by this method will have p, e.s of the order of magnitude indicated in serial 22.

Summary.

23. With 1/25,000 maps such as may be expected on the continent, or with controlled basic cover, the eastings and northings of a target which can be identified on the map or photograph should be obtainable with p.e.s. of 25 meters, giving a p.e. in range of 35 meters. A similar p.e. would apply to a flash spotting "Z" location. A figure of 20 meters has been taken as an estimate of the p.e. in height. The corresponding errors in range can be obtained by taking 4 times the figures given in Table III, colms. (3) and (4).

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SECTION 8 - DROOP AND JUMP

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Gun to gun variation of jump

29. The range scales of sighting systems incorporate an allowance equal to the range table value of jump. A similar allowance is made when deducing angles of departure from quadrant elevations during calibration.

30. If a gun has a constant value of jump which happens to be always less than the range table value, a false (too low) MV will be deduced as the result of calibration. When a target is subsequently engaged, at the range used during calibration, the additional elevation applied in consequence of this false MV will exactly cancel the deficiency in jump. At other ranges, the compensation will not be exact, as is shown in Table IV, colns. (4) and (14).

31. In analysis of Shoeburyness firing trials shows a gun to gun variation in jump with a p.e. of 2 mins. The p.e. of the resulting range errors should therefore be one-fifth of the values in Table IV colns. (4) and (14).

TABLE IV

The effect of a constant error in jump equal to - 10 mins.

	25-pr. charge 3	5.5-in charge 4
Calibration range	8,000 yds	11,000 yds
Range error due to - 10 mins.	-48 yds	-59 yds
Corresponding MV error	9.7 f.s.	7.5 f.s.

RANGE	RANGE ERROR					
	-10 mins. elevation	-9.7 f.s. on sights	TOTAL	-10 mins. elevation	-7.3 f.s. on sights	TOTAL
(1)	(2)	(3)	(4)	(12)	(13)	(14)
yds.	yds.	yds.	yds.	yds.	yds.	yds.
6,000	-59	40	-19	-91	44	-47
8,000	-48	48	0	-77	51	-26
10,000	-33	57	24	-67	57	-10
12,000				-56	62	6
14,000				-42	68	26

Day to day variation of jump

32. An analysis of Shoeburyness firing trials shows a day to day variation of jump with a p.e. of 1 min. The p.e. of the resulting range error is, therefore, one-tenth of the values given in Table IV, colns. (2) and (12).

SECTION 9.- ERRORS IN GRADUATION OF SIGHTS

33. Records have been taken at S. of A. of the tangent elevations (T.E.) recorded on the T.E. scale of various sights when the range reader is set to ranges in steps of 500 yards, with the MV corrector scale readers always set to range table MV. These T.Es. have been compared with the T.Es. to be expected from the range table, due allowance being made for jump and where necessary for correction to range indicator. The results for eight 25-pr. guns and eight 5.5-in guns are summarized in Table IV. There was no significant variation of the error between charges.

TABLE V

Errors in graduation of sights

	Greatest error recorded	Average absolute value of errors	p.e.
	mins.	mins.	mins.
25-pr	14	5.7	4.9
5.5-in.	22	3.3	2.8

SECTION 10.- ERRORS IN ADJUSTMENT OF SIGHTS

34. Sights are tested at an elevation of 20 degrees, and with care there is no reason why sights should not be within 1 minute of the correct adjustment at this elevation at the time of adjustment.

35. Tolerances of 5, 10 and 15 mins., respectively, are allowed at elevations of 10, 30 and 40 degrees and, moreover, the tests at these elevations are required to be carried out only occasionally. The result of a series of tests on eight 25-pr. guns at S. of A. showed the following errors at 10 and 30 degrees, when exact adjustment had been secured at 20 degrees.

TABLE VI

Errors due to the sighting gear

Elevation	Average absolute value of errors	p.e.
degs.	mins.	mins.
10	3.6	3.1
30	2.9	2.5

36. Experience has shown that there is a very real danger of the complicated linkage of the Probert-sight being thrown out of adjustment as the result of vibration due to travelling or prolonged firing. The "quick sight test" has been introduced as a means of disclosing gross error. The test is simple and can be carried out during brief pauses in firing. A tolerance of 10 mins. is allowed at the elevation of 20 degrees. If this tolerance is exceeded, the complete test and adjustment must be carried out.

Summary

37. A p.e. of 3 mins. has been taken in Table I as the error due to adjustment of sights. This value assumes that the complete sight test has been carried out and that there is no error at 20 degrees.

SECTION 11.- LAYER'S SYSTEMATIC ERROR

38. An analysis of records kept at S. of A. shows that the mean of a group of lays by one layer will differ in elevation from the mean of a group by another layer.

The means of 5-lay groups by individual layers were distributed about the true elevation with a p.e. of 2 mins.

SECTION 12.- PROPELLANT VARIATION

Lot to Lot variation

39. In calibration firings at S. of A., each gun fires the same assortment of propellant lots on each day, and an analysis of the results discloses systematic variations between propellant lots. Much more conclusive evidence on this subject is probably available from records of propellant proof, but the data in S. of A. records (Acl. A to K) indicates the following values for the p.e.'s of lot to lot variations in MV.

TABLE VII

Lot to lot variation of MV

Gun	25-pr.					5.5-in.
Charge	2	3	Super	2	3	4
p.e. (f.s.)	2.0	2.9	4.7	1.5	4.2	2.6

Nature to nature variation

40. Very large variations of MV have been reported with new guns, between certain different natures of propellant, in spite of the care taken to insure that all natures give the same MV in new guns. For example, OB Proc 28,250 records differences of over 30 f.s. between FNH and cordite WM for 7.2-in. howitzers. An even more disturbing difference is recorded in OB Proc 29,526, namely a difference of about 20 f.s. between Canadian and British proved lots of cordite FM. These lots have therefore to be treated as different natures of propellant.

41. The importance of sorting propellants by natures (and if possible also by lots) is stressed during training, and reports from active theaters show that efforts are made to comply with this requirement. Even when ammunition has been sorted, it will often happen that the only nature of propellant available in the gun position is of a different nature from that used during the calibration of the guns. The errors which may be introduced in these circumstances may well double the total p.e. recorded in Table I.

* * * * * * * * * * * * *

SECTION 15.- CHARGE TEMPERATURE

53. If the local temperature is changing rapidly, the measurement of charge temperature presents considerable difficulty, and it is uncertain whether the present method gives a reliable value. Even when all precautions are taken to shield ammunition from direct sunlight and to insure a free passage of air, it is unlikely that the assigned charge temperature can be relied upon to 10°F. A.p.e. of 5°F has been assumed in Table I and default of better information.

* * * * * * * * * * * * *

SECTION 16.- WEIGHT AND SHAPE OF PROJECTILE

* * * * * * * * * * * * *

Medium and heavy guns

57. Shell are weight marked in terms of "units" which are roughly 1% of the normal shell weight, and detachments are trained to sort shell by weight markings. The maximum errors which can occur as the result of an error of 1 unit (1 lb.) for the 5.5-in gun 100-lb. shell are as follows:

Charge 2	30 yds.
Charge 3	24 yds.
Charge 4	26 yds.

58. Although variations in weight are unlikely to be a major source of error, care in sorting shell by weight marking and in reporting and allowing for variations of weight are important if accuracy is to be maintained. Care in handling shell is also important in order to avoid obliteration of the weight markings.

* * * * * * * * * * * *

SECTION 17.- STEADINESS OF THE PROJECTILE

* * * * * * * * * * * * *

Summary.

65. If a gun produces unsteady projectiles, as the result of oval wear or muzzle brakes or any other similar cause, the ranging may be short of that expected from the instrumental MV by amounts corresponding to a loss of 20 f.s. in MV. Calibration by fall of shot should correct this error, but a gun may develop ovality between two calibrations. A figure of 4 f.s. has been allowed in Table I for the 25-pr. as the p.e. due to this source. The error for the 5.5-in gun has been taken to be zero.

* * * * * * * * * * * * *

SECTION 19.- RESIDUAL ERRORS IN RANGE TABLES

Errors in range and elevation scales

75. Although range tables for a new equipment are prepared with the greatest care, they are necessarily based on limited data and are in consequence liable to small errors. The magnitude of such errors may be inferred from the history of the 5.5-in. gun range tables which were amended in 1942 by amounts which corresponded to maximum errors as follows:

Charge 2	124 yds.
Charge 3	110 yds.
Charge 4	275 yds.

These range tables were subsequently amended by War Office letter 270/Ctges/29/7/RA2 d 22 Jan 44 which notified a further change of approximately 100 yds. at charge 2.

* * * * * * * * * * * * *

Reference: After Action Report, Third US Army, file R 314.7

TGBSY-R, dated 4 September 1945.

* * * * * * *

ANNEX NO. 12, Section III. MAINTENANCE

8. Provisional Wear Characteristics of Guns: The following data is quoted from Headquarters European Theater of Operations, Ordnance Section:

"1. The table shown below was compiled by Colonel Leslie E. Simon based on extensive Proving Ground records and certain records which he has reviewed in the field. It should be understood that it is not the final word from the Chief of Ordnance, but it will serve as an index for use until more exact data becomes available:

PROVISIONAL WEAR CHARACTERISTICS OF GUNS

Weapon	Velocity Drop Units Given	Remarks	Advance of Forcing Cone	Init. M.V.
40mm Gun M1	17.5 f.s./1000 rds	Direct Fire Weapon	0.4" @ 5000 rds	2870
**57mm Gun M1	8.5 f.s./1000 rds	Direct Fire Weapon	13" @ 1000 rds	2975
75mm Gun M1 1897	7.3 f.s./1000 rds		0.22" @ 7000 rds	1950
**76mm Gun M1	7.5 f.s./100 rds		No information	2600
**3" Gun M3	9.0 f.s./100 rds		0.1" @ 800 rds	2800
*90mm Gun M1	9.2 f.s./100 rds		7.0" @ 2000 rds	2700
105mm How M2A1	2.0 f.s./1000 rds	Misc. charges fired	0.07" @ 5000 rds	1550
*120mm M1 (4.7" Gun)	20 f.s./100 rds		27" @ 1000 rds	3125
*155mm Gun M1A1	7.5 f.s./100 rds	Misc. charges fired	No information	2800
155mm How M1	3.3 f.s./1000 rds	Misc. charges fired	No information	1850
8" How M1	No appreciable drop in 2000 rounds	Misc. charges fired	0.15" @ 1600 rds	1950
*8" Gun M1	33 f.s./100 rds		36" @ 450 rds.	2850
*240mm How M1	3.3 f.s./100 rds	Misc. charges fired	No information	2300

*Guns which should be calibrated periodically.
**Direct fire weapons which should be calibrated if, and only, if used as field artillery.

****

"2. This table indicates average rates of wear. A specific weapon may wear somewhat faster or slower, or may have started out with a velocity slightly higher or lower than the tabulated velocity. Nevertheless, the table is a good guide. The simple practice of merely counting rounds rather than some artificial "equivalent rounds" is recommended.

"3. If a gun is calibrated approximately twice during its life, the table should apply well during the interim, just as one sets one's watch occasionally, while tolerating a slight degree of inaccuracy during the interim.

"4. It should be observed, however, that no amount of calibration is as important as keeping ammunition lots straight as careful, orderly practices, and as the avoidance of mixing zone weights of shell without appropriate correction. The shooting of one, and only one, ammunition lot is of utmost importance in the 105mm How and smaller calibers. In calibers larger than 105mm, the use of the same powder lot is important, but projectile lots may be mixed without inducing unwarranted dispersion."

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COMMUNICATIONS ZONE
US FORCES, EUROPEAN THEATER
OFFICE OF THE CHIEF ORDNANCE OFFICER

APO 887
18 July 1945

REVISION NO 1)
ORDNANCE TECHNICAL)
BULLETIN NO 59)

* * * * * * * * * * * * *

E X T R A C T

18. CANNON:

a. All cannon tubes will be judged for serviceability by visually inspecting the bore and by taking a gauge measurement of the bore diameter. The criteria for condemnation or determination of remaining life will be as tabulated in chart "Service Life of Artillery Cannon" published hereinunder. (Reference is also invited to the manual "Evaluation of Erosion in Cannon Bores", O.C.O., A.S.F.). Areas where lands have been stripped, or where deformations of the rifling occur, should be corrected by honing or filing to approximate proper contours and to smooth roughened edges which may result in progressive tube damage. It is pointed out, that apparently serious bore defects such as gouges, missing or stripped lands, and the like, have little effect on accuracy, especially in low velocity weapons. No tube which contains bulges, or other physical deformation affecting strength of the tube will be considered serviceable for overseas shipment. All breech group parts will be repaired to function properly; however, weapons with cracked breech rings or breech blocks will be considered unserviceable unless replacement of the defective part (s) can be made.

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Appendix No. 7.

Weapon	Estimated Life E.F.C.	Estimated Life Tot. Rds.	Vertical Bore Diamater at Condemnation	All Measurements at (b)	Vertical Bore Diameter 25% Life Remaining	Vertical Bore Diameter 50% Life Remaining	Vertical Bore Diameter 75% Life Remaining	Est. Loss of MV (Max Chg) 50% Life Remaining	Max. Vertical Bore Diamater for Overseas Shipment (c) & (d)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9) (f/s)	(10)
GUNS (c)									
37mm, M3, M5, M6	700	2000	1.528	9.55 BT	1.510	1.494	1.477	117 (HE)	1.494
37mm, M1A2	——	2000	——	——	——	——	——	——	——
40mm, M1	——	10000	1.625	13.73 BT	1.609	1.593	1.581	40 (HE)	1.593
57mm, M1	1000	2000	2.310	19.02 BT	2.306	2.299	2.283	143 (APC)	2.299
75mm, M3	——	7500	2.970	14.50 BT	2.967	2.963	2.958	10	2.963
75mm, M5, M6	——	——	——	NOT ESTABLISHED		——	——	——	——
76mm, M1	——	——	SEE 3" M7		——	——	——	——	——
3", M5, M7	3000	——	3.090	25.17 BT	3.078	3.064	3.042	94 (APC)	3.064
90mm, M1,M2,M3	——	2000	3.672 (e)	24.85 BT	3.655	3.633	3.604	100 (HE)	3.633
4.5", M1	3000	4000	4.610	37.90 BR	4.602	4.592	4.566	65	4.592
120mm, M1	——	1000	4.940	41.00 BT	4.910	4.875	4.830	183	——
155mm, M1918	4000	——	6.270	53.75 BR	6.243	6.203	6.156	62	6.203
155mm, M1, M2	1800	3000	6.305 (f)	54.90 BR	6.268	6.230	6.182	65	6.230
8", M1	700	1250	8.360	82.35 BR	8.321	8.272	8.190	112	8.272
HOWITZERS (d)									
75mm, M1, M2, M3	20000	——	3.020	11.32 BT	3.017	3.008	2.992	25	3.014
105mm, M2A1, M3, M4	8000	——	——	(See Note (a) on reverse side)			——	——	——
155mm, M1	15000	——	6.220	36.10 BR	6.207	6.190	6.167	70	6.200
8", M1	3000	——	8.115	38.70 BT	8.110	8.085	8.064	——	8.095
240mm, M1	2000	——	9.636	73.85 BR	9.606	9.578	9.540	42	9.597

NOTES:

(a) Col. 5 (BT - ..." from breech of tube
(BR - ..." from rear face of breech ring
Col. 9 Letters In ( ) indicate type of ammunition giving loss of MV indicated.

APPENDIX NO. 7

(b) All measurements in inches. Point of measurement to be accurate to 1/64 ". Bore measurement to be made with pullover or star gauge at points indicated.

(c) Guns: Maximum allowable wear for overseas deployment indicates 50% remaining life.

(d) Howitzers: Maximum allowable wear for overseas deployment indicates 33-1/3% remaining life.

(e) Determined by tactical employment (MV loss (HE) at condemnation 150 f/s). Ballistic life of weapon only 1/2 at this point.

(f) (1) Should the bore at 12 o'clock and usually immediately forward of the commencement of rifling, exhibit scoring <u>or</u> the lands be worn smooth at the 6 o'clock position, this measurement should read 6.225 inches.

(2) Should <u>both</u> the scoring at 12 o'clock and smooth lands at 6 o'clock exist, the reading should be at 6.210 inches.

(g) (1) <u>If gun books are available</u>, limit for condemnation - 8000 full service rounds.

(2) <u>If gun books are not available</u>, the condition of stripping of the lands will be utilized to determine serviceability. Making physical measurement of the length of stripping of each land and adding these lengths, the following limits will govern:

> Limit for condemnation - 110 linear inches of stripped lands. All "humped or raised" or rough lands should be filed to appropriate proper contour to ensure the unobstructed passage of the projectile.

ARTILLERY FOR A TYPE ARMY

6 Infantry Divisions	24	organic battalions
	6	105mm How Bns attached
	6	155mm How Bns attached
	6	90mm TD Bns attached
SUBTOTAL	42	Battalions
3 Armored Divisions	9	organic battalions
	3	105mm How Bns (Armd) attached
	3	155mm How Bns (SP) attached
	3	90mm TD Bns attached
SUBTOTAL	18	Battalions
3 Corps Artillery	12	Battalions, 155mm How
	9	Battalions, 155mm Guns
	9	Battalions, 8" How
SUBTOTAL	30	Battalions
1 Army Artillery	3	Battalions, 240mm How
	3	Battalions, 155mm Gun
	1	Battalion, 8" Gun
SUBTOTAL	7	Battalions
Army Anti-Aircraft Artillery	9	Battalions
GRAND TOTAL	106	Battalions

COMPUTATION OF DAILY CALIBRATION REQUIREMENTS ON A TYPE ARMY

Type	No. on Hand	Desired Daily Expenditure rate rds/gun	Daily Ammunition Expenditure	Equivalent No. of Tubes	Daily Calibration requirements (Factor of 3**)
90mm Tk & AT	1124	12	13488	*13	39
90mm AA	108	6	672	.3	2.1***
Gun 155mm	144	25	3600	2	6
Gun 8"	6	10	60	.1	.3
How 240mm	18	15	270	.14	.42
				15.54	47.8

*Tube life assessed at 1000 rds due to type of Ammunition.

**Each tube should be calibrated at three points, in its life. 25%, 50%, 75%.

***Antiaircraft tubes should be calibrated after 500 rds and each 200 rds thereafter or a total of approximately seven calibrations.

Appendix No. 9.

THE GENERAL BOARD
UNITED STATES FORCES, EUROPEAN THEATER
Office of the Ordnance Officer
APO 408

6 October 1945

472.81 TGBOR

SUBJECT: Anti-Aircraft Artillery Tubes.

TO : Chief of Section, AAA Section, General Board, United States Forces, European Theater, APO 408, United States Army.

1. The Ordnance Section, General Board, is making a study to determine a suitable method of condemning and replacing artillery gun tubes in combat. Answers to the following questions would be of assistance in the project and would be used as supporting evidence for the final recommendations.

a. What is the maximum loss in muzzle velocity which a 90mm gun can develop before it becomes tactically useless?

b. Does the gun become erratic before the muzzle velocity loss exceeds the limits of the director?

c. At what point or points in the life of the gun is muzzle velocity measurement necessary? Muzzle velocity measurements would normally be made by Ballistic and Technical Service Detachment teams using sky screens and chronograph.

d. What is the allowable limit of muzzle velocity variation between guns of the same battery?

2. Aberdeen Proving Ground has developed a suitable gauge for measuring wear of gun tubes at commencement of rifling, the point of maximum wear. A definite relationship has been established between wear at this point and loss of muzzle velocity. For the 90mm gun, the tubes wear to a point where a loss of 165 f.s. is reached, then it becomes erratic. At this point it is condemned on a basis of three things, tube wear measurement, visual inspection for loss of lands, erosion, etc., and loss of muzzle velocity. Figures on loss of muzzle velocity, although valuable, would not necessarily be required for tube condemnation, but can be used as a check against wear measurement. Would this method of tube condemnation be more suitable than methods followed in the recent campaign?

/s/ N. M. LYNDE,
/t/ N. M. LYNDE,
Col., Ord. Dept.,
Ordnance Officer.

472.81 TGBAA 1st Ind.
THE GENERAL BOARD, UNITED STATES FORCES, EUROPEAN THEATER, APO 408, U. S. Army, 11 October 1945.

TO: Chief of Section, Ordnance Section, The General Board, USFET, APO 408, U. S. Army.

1. Reference basic communication, submit herewith opinion on questions a, b, c, and d, your paragraph 1, above, i.e.

a. The minimum muzzle velocity which a 90mm gun can develop before it becomes tactically useless is 2,400 feet seconds providing a director is being used since this is the minimum velocity capable of being set into the present equipment. Practically, the minimum velocity is at least 100 feet second greater than this, as explained below.

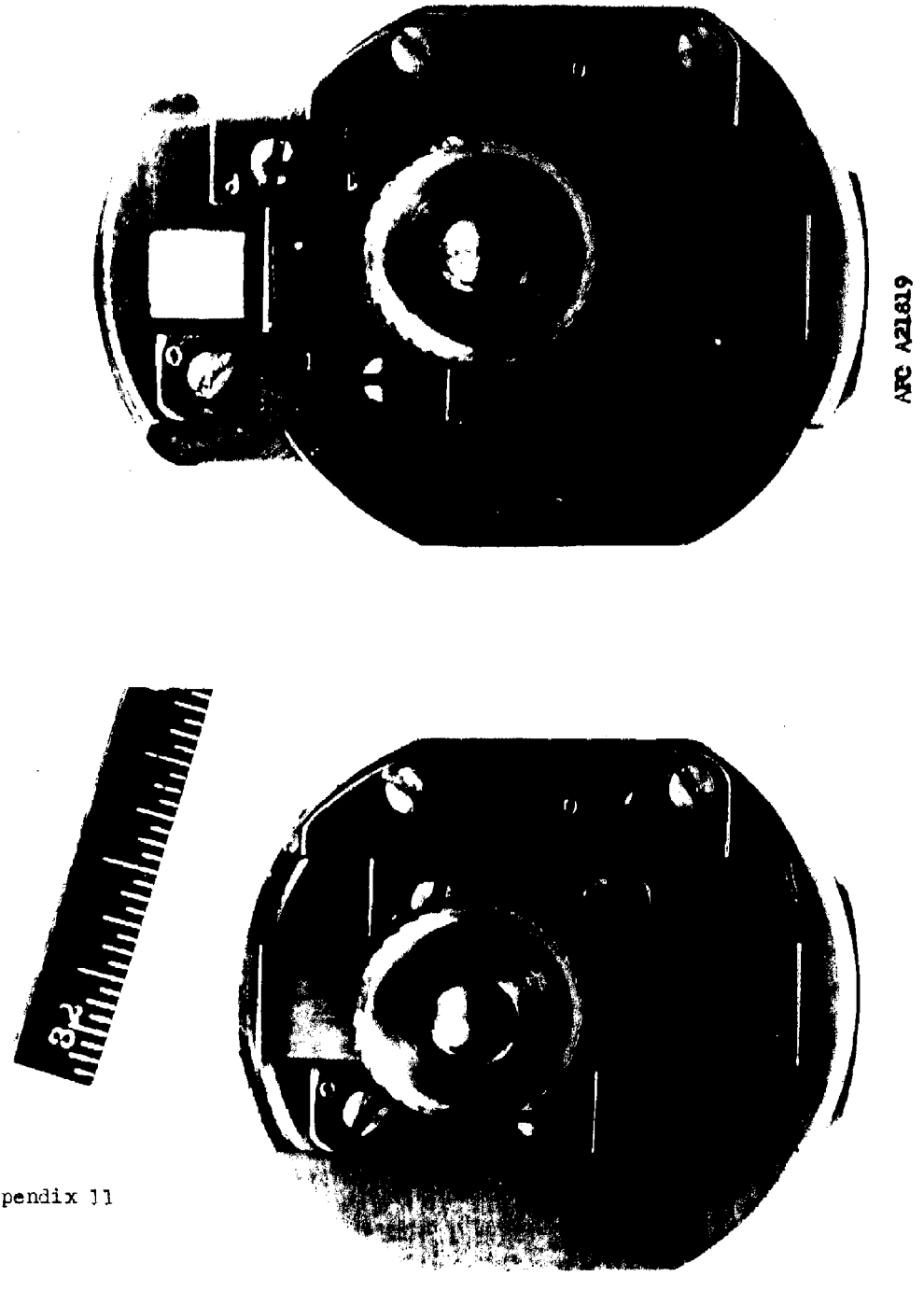
b. Based on the experience of 552,000 rounds of 90mm ammunition from not more than fifteen battalions of the Antwerp X Command, it was my experience that guns would become erratic before its muzzle velocity exceeded the correctible limit of the director. This point usually appeared between 2,525 and 2,575 feet seconds.

c. Based upon the experience indicated in the preceding paragraph it is believed that measurement of muzzle velocity is necessary as follows: After the first 500 rounds; after the first 800 rounds; thereafter, after every 200 rounds. This would normally involve some seven measurements in the life of a tube since with proper maintenance, tubes average between 1,700 and 1,800 rounds.

d. In the Antwerp X defenses, where extreme accuracy of fire was an absolute necessity, the following orders applied; the average point for targets with a height of 1,000 yards and a range of 6,000 yards gave a probable error of 40 yards slant range. This figure was used as the allowable difference and 20 feet seconds which corresponds to one probable error was arbitrarily used. This figure was found feasible and gave excellent results without unnecessarily burdening the Ordnance in switching tubes. Needless to say, many tubes were used more than once.

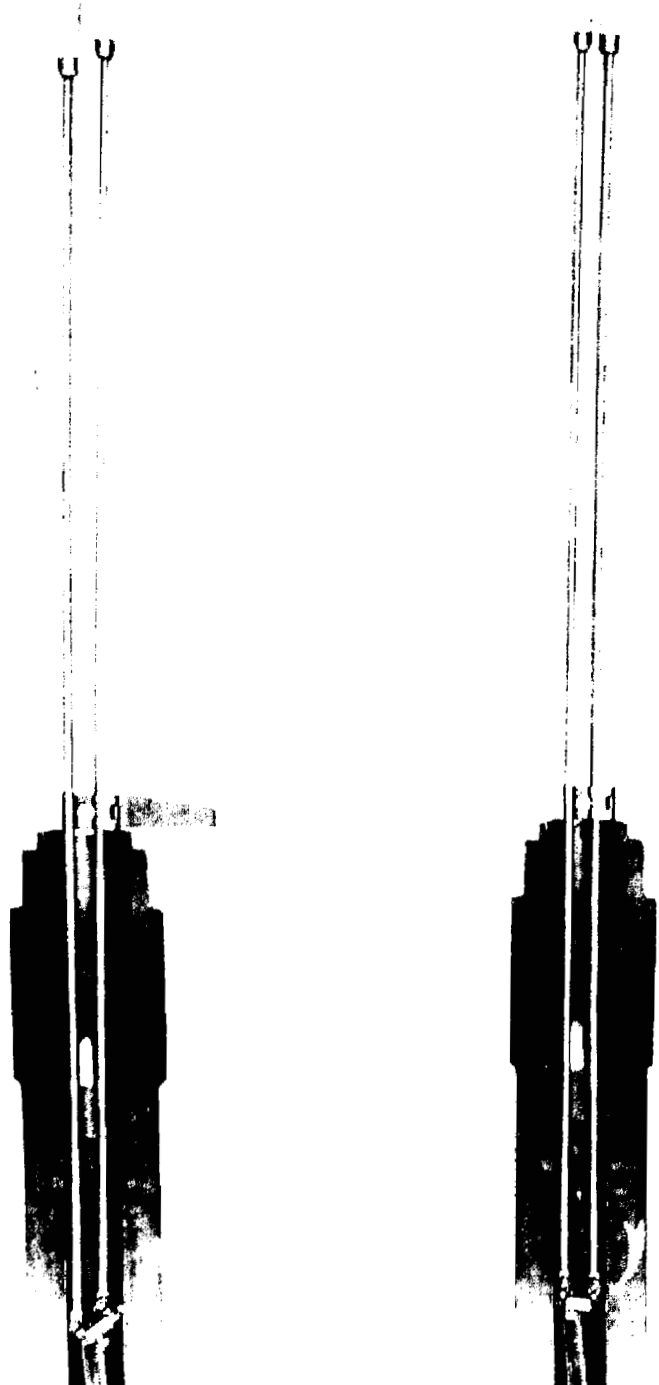
2. Reference paragraph 2, basic communication, loss in muzzle velocity was never the criterion in the change of tubes but by experience it was found that after a loss of approximately 150 feet seconds, guns became erratic and/or obvious wear, pits and other defects were noticed. The method outlined is considered suitable.

/s/ CLARE H. ARMSTRONG,
/t/ CLARE H. ARMSTRONG,
Brigadier General, U. S. A.
Antiaircraft Officer.



Appendix 11

Figure 25. Pullover gage head before (right view) & after (left view) reading.

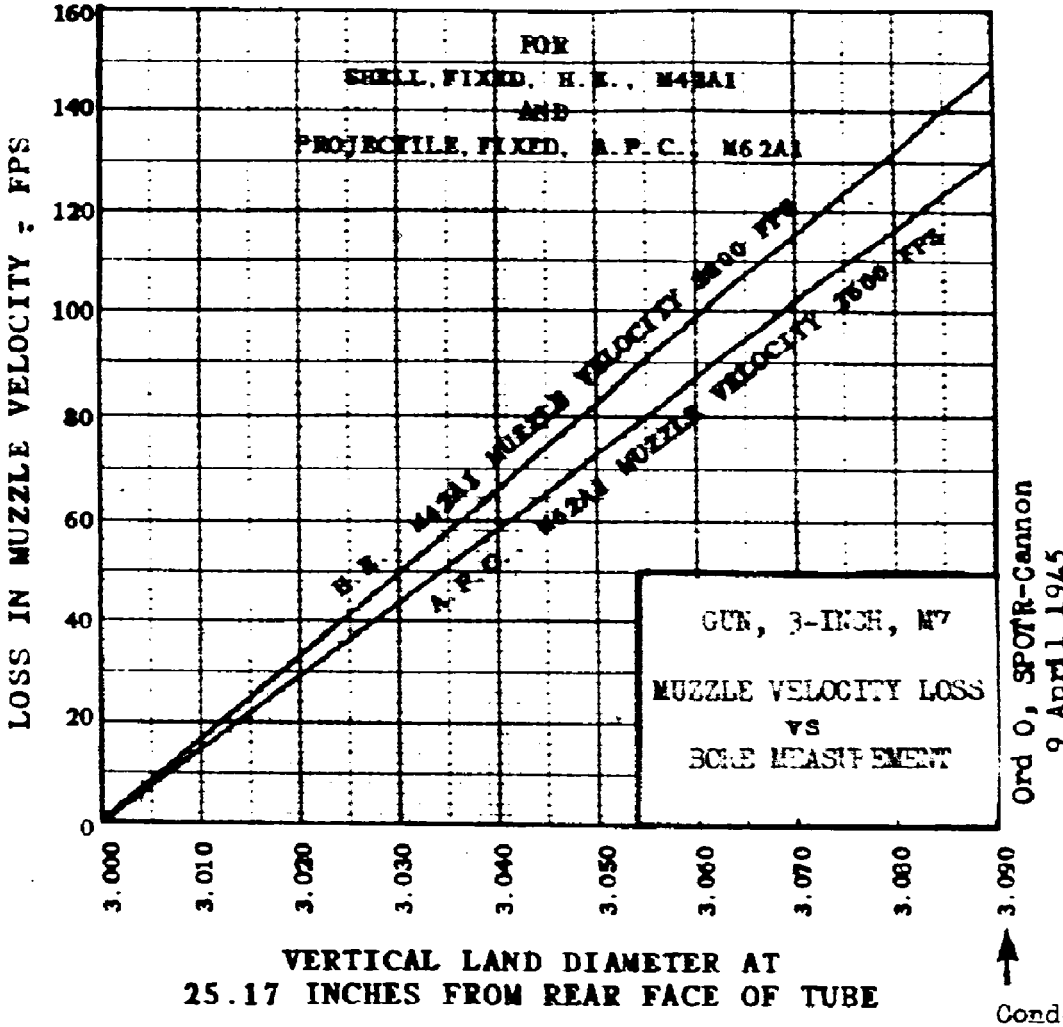


Appendix 12.

Figure 24. Pullover gage inserted in sectionalized tube.

Appendix 13

Velocity-Wear Chart



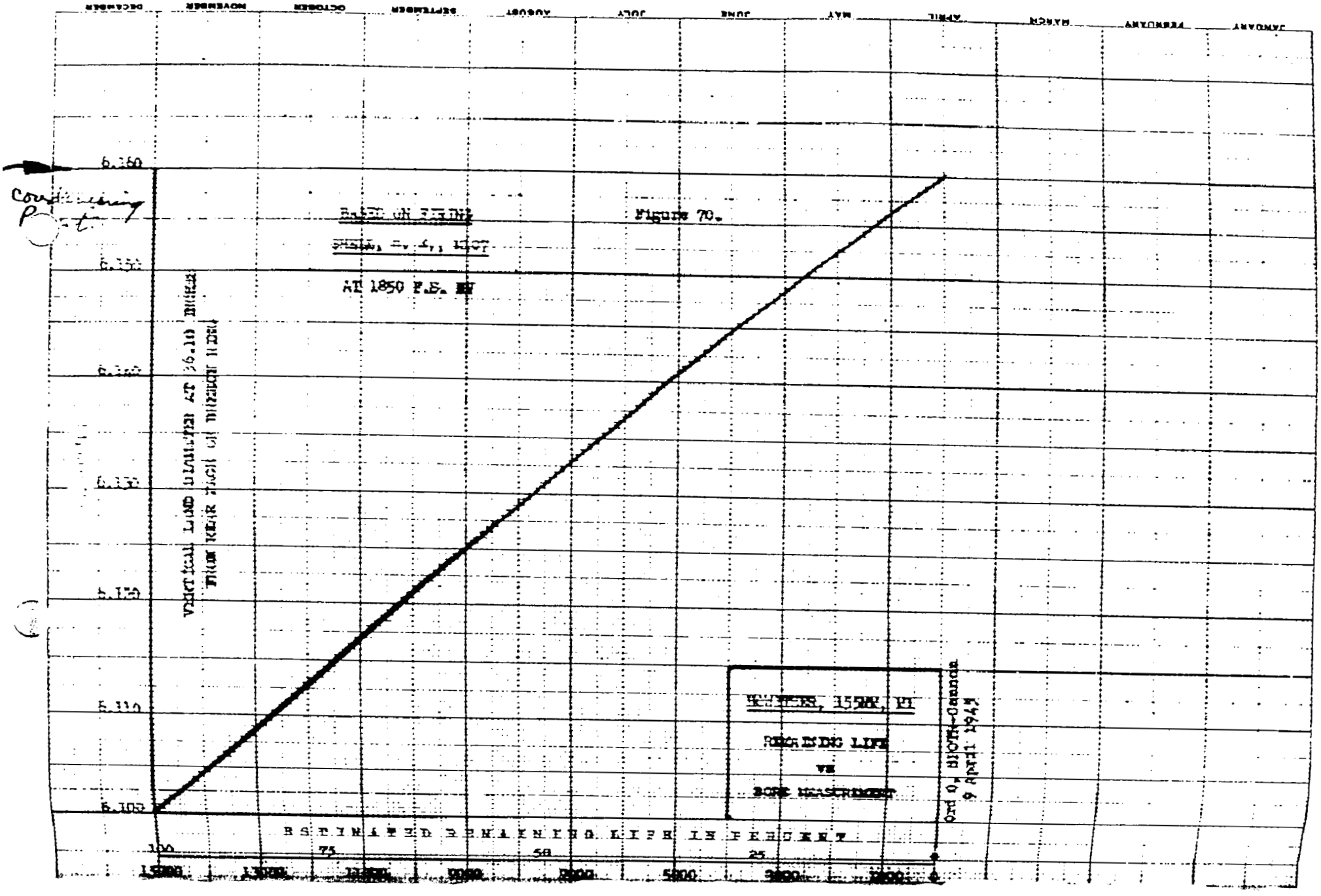
Ord O, SPOTR-Cannon
9 April 1945

Figure 50.

Condemning limit based on 5% drop in M.V. Tube still accurate but value as A-T

Appendix 14

Percent-Wear Chart



APPENDIX NUMBER 15

BALLISTIC AND TECHNICAL SERVICE DETACHMENTS

1. It is believed, from results of interview with Commanding Officers of the 282nd and 283rd Ballistic and Technical Service Detachments, that study of the T/O & E for these units should be made. Since Detachments were not the subject of this study only general needs are covered.

2. a. Both commanding officers feel that there should be two officers per team, but that due to their technical knowledge, responsibility, and the necessity of convincing artillery commanders of considerable rank, that the findings and decisions of the detachments are sound, higher grade is needed. Both Lt. Towner and Lt. Browne recommend a Major and Captain, the former to be the detachment commander, the latter the calibration squad commander. Both officers said that lack of rank in dealing with artillery commanders was a constant handicap, not because of lack of cooperation, but because artillery commanders did not consider a junior officer's opinions very seriously.

b. Both Lt. Towner and Lt. Browne feel that the calibration squad chief should be a Master Sergeant.

c. Both officers feel that additional transportation is necessary and although they are not in accord as to their exact requirements they do agree that two additional 1/4 ton trucks, 4x4, one additional 1-1/2 ton truck, 6x6, one M5 generator, and additional trailers are desirable.

d. Additional equipment desired is as follows:

Pull-over gages
Improved Chronographs
Improved Amplifiers
Improved Skyscreens
Pressure gages, crusher type
Photographic Equipment (For obtaining pictures of unusual gun bores for reports to the Office Chief of Ordnance)

3. These requirements are general in nature and are not to be construed as basis for recommended changes independent of a detailed study of the report made by all detachments to the Research and Development Service, Aberdeen Proving Ground, during operation.

Interview with Lt. R. F. Towner, Commanding Officer, 283rd Ballistic and Technical Service Detachment.

1. What should be the primary mission of calibration teams?

A. (a) To provide operational data for FA. Team should be attached to Corps Fire Direction Center.
(b) To condemn artillery gun tubes.

2. What other uses are recommended for calibration teams?

A. Secondary mission of calibrating own and enemy ammunition.

3. Does the Artillery make use of calibration results to:
a. Re-group guns?
b. Apply range correction factors?
c. Make demands on Ordnance for tube replacements <u>before</u> the are completely worn out?

A. a. Yes, in general they do.
b. Yes, they do both.
c. Yes, at the beginning they did, teams data confused Artillery further.

4. Do you feel that calibration teams tend to increase or decrease the artillery's confidence in their weapons?

A. Don't believe any difference. Artillery has seen what weapon will do on the ground and no amount of data offsets this.

5. What method or combination of methods do you feel is most satisfactory and practical for determining tube replacement in combat:
a. Visual inspection?
b. Visual inspection plus "pullover gage" readings?
c. Visual inspection plus MV loss?
d. Number of rounds fired?
e. Loss of range?
f. Observed fire?

A. Combination of all of them, giving greatest weight to visual inspection and pullover gage readings. Team could make report to Ordnance companies with copy to Army.

6. How should calibration teams be assigned? One per Army, Corps?

A. One per Corps with calibration officer in Army to coordinate teams.

7. How do you think calibration teams should be organized, equipped and employed?

A. <u>T/O CALIBRATION TEAM</u>

1 - Major	1 - M/Sgt
1 - Captain	1 - T/Sgt
	2 - T/3
	2 - T/4
	2 - T/5

Major - Team Commander, coordinates condemnation and supply of gun tube at Corps level.

MUST HAVE: Responsibility of condemnation of gun tube, special job knowledge, technical skill.

Captain - Calibration squad commander, performs calibration procedure and coordinates with Corps FDC in so doing.

M/Sgt - Calibration squad leader, technical knowledge of calibration procedure and condemnation of tube.

T/Sgt - Expert maintenance man (equipment), with supply and administration of unit.

2 - T/3 - Assistant equipment maintenance men, condemnation equipment operators.

2 - T/4 - Calibration equipment operators, computation of data.

2 - T/5 - Jeep drivers (1 for officer), also fill in when help is needed with calibration squad.

EQUIPMENT

3 - Chronographs (biggest maintenance headache)
4 - Skyscreens
4 - Amplifiers
1 - Complete Set Pullover gages.
1 - Shop truck (specially constructed inside)
1 - 1-ton trailer (equipment and supplies)
2 - 1/4 ton trucks (1 per officer)
2 - 1/4 ton trailers
1 - Special truck (about 1½ ton) specially built body to permit efficient calibration use (standing headspace) (single phase 110V generator in truck if possible or in 1 ton trailer)

8. Can dispersion in muzzle velocities of a group of rounds be readily interpreted into multiples of firing table probable errors for condemnation purposes?

A. No.

9. Did your team ever have any occasion to calibrate enemy material?

A. Yes, in February 1945 at Clevreux, Luxembourg, D Battery, 176th Field Artillery Battalion (4.5") firing German 88mm guns.

10. What caliber weapons do you think should be calibrated?

A. 8" gun and Howitzer
155mm gun and Howitzer
4.5" gun and Howitzer
90mm gun
240mm Howitzer

11. What volume of work can present team perform?

A. 2 Battalions per day under ideal conditions. 1½ Battalions per day is normal.

12. Are practical firing tests valuable?

A. Generally no. In some special case, however, they are valuable.

13. How often should tubes be calibrated?

A. Every 25% of tube life and regrouped if necessary.

Recommend maintenance technicians organic in team rather than replacement teams.

Lt. Towner recommends:

1. A thorough and comprehensive research on field calibration equipment. Original equipment was unsatisfactory, made it work by reworking and modifying, but it is still unsatisfactory.

2. Conduct research for equipping teams with factual data for calibration and condemnation of gun tubes, to be published in TM or TB with suitable changes when necessary.

Take team here in ETO and run firing tests for assembling data for Aberdeen, using guns and ammunition here.

Interview with Lt. E. V. Browne, Commanding Officer, 282nd Calibration Team, under Ninth and Seventh U. S. Armies.

1. Are you familiar with Ord TB 59, ETOUSA?

A. Yes, Hillerslaben tests proved to verify Aberdeen's figures. 155mm gun, 155mm How. 4.5" figures were off slightly. In general, I believe that all guns will fire more rounds than Aberdeen says. Ord TB 52 was used at Hillerslaben and serviceability determined by use of star gauge (3 point), visual inspection, and calibration. All three were used to determine serviceability and not any one method.

2. What primarily should be the mission of calibration teams?

A. Re-grouping of artillery and condemning of gun tubes. Recommend giving information to supporting or Army Ordnance on status of tubes life.

Artillery tended to use calibration teams as a club to obtain new tubes. In most cases this backfired on them as team findings proved most tubes still serviceable.

3. What other uses do you recommend for calibration teams?

A. Determination of our own ammunition qualities when there is a question.

Determination of qualities of enemy ammunition.

Determine velocities of enemy guns to enable us to use them

Condemnation of tubes.

Regular calibration for regrouping.

4. Does artillery make use of calibration results?

A. Yes, Depended on operations officer - some used it and some did not. Recommend a study be made to determine relation between firing table figures and actual MV.

Most of the time team results tended to deny artillery tube replacement.

5. Does use of calibration team tend to increase or decrease artillerys confidence in their weapon?

A. Tends to increase confidence.

6. What factors should be considered in condemning gun tubes?

A. All factors should be considered before condemning tubes. Each tube should be considered individually by experienced personnel.

7. How many Ballistic and Technical Service Detachments do you consider necessary and what should be their assignment?

A. Recommend one (1) team per Corps with operational control exercised by Army, to work in conjunction with Ordnance Company that supports Corps Artillery. Extra load of Army and AA Artillery could be handled by these teams. One (1) per Army is insufficient.

Inclosure 2 to Appendix No. 15.

8. What changes do you recommend in Ballistic and Technical Service Detachments?

A. Present organization satisfactory but if tube condemnation is added to primary mission, recommend an additional 6 men per team.

Recommend in addition to present equipment the following be added:

Pullover gauges
Pressure gauges for obtaining chamber pressures.
Photographic equipment for obtaining pictures of gun bores, etc., for study and reports to Aberdeen.

1 - 1½ ton 6x6 truck
2 - 1 ton trailers
1 - M-5 generator
1 - 1/4 ton 4x4 truck
1 - 1/4 ton trailer
1 - 1/4 ton truck with radio for contacting Army Hq.

9. What recommendations do you have?

A. Recommend ammunition be issued by lot numbers with the exception of 155mm How. Lot numbers which vary widely in number often vary considerably in performance. Lot numbers which do not vary widely in number tend not to vary as much in performance.

British have table of MV loss based on gauge readings. I feel that pullover gauge could be used to obtain estimate of MV loss. Recommend calibration at each 1/4 of tubes life.

Artillery School teaches how calibration team data is used. Many units did not know how to use data once it was given to them.

A thorough and comprehensive research on field calibration equipment. Original equipment was unsatisfactory although it was made to work by modifying and re-working it, still is not satisfactory.

Equipment teams with factual data for calibration and condemnation of gun tubes, giving definite figures and condemning limits where possible should be published in TM or TB with suitable changes when necessary.

10. How do you think calibration teams should be organized, equipped and employed?

A. <u>Personnel per Section</u>:

Electronic Chronograph operator (Sect Leader)	1 - M/Sgt
Computer	1 - T/Sgt
Clerk (Phone truck - Gun Position)	1 - T/3 (Calibration)
Gun liaison man (Phone Truck - GP)	1 - T/4
Gun Liaison assistant	1 - T/5
Gauge operators and pressure cylinders	2 - T/5
Pressure chart conversion to lbs per sq inch	1 - T/5

(Two sections per Detachment) Total, 2 x 8 = 16 men.

Commanding Officer - Major, Rank necessary where condemnation responsibility is involved. Also technically better trained, must talk to artillery and convince them by knowledge and rank. For superior knowledge than other Ordnance Officer in theater. Team officers never attempted to argue or convince artillery because of lack of rank. Responsibility of tube condemnation when supply is short is very great.

Officers
(Contact
(Operations
(Tube Condemnation
(Interpretation of results

Detachment Executive - Captain.

11. Did your team ever have any occasion to calibrate enemy materiel?

A. Yes, in October 1944, SE of Duess. 155mm How enemy propelling charges were calibrated using American projectiles and M1918 How. Charts of MV were made up so that Corps Artillery could use enemy propelling charges in American Artillery.

12. What caliber weapons do you think should be calibrated?

A. AT Guns 3", 76mm and up.
90mm AA Guns and up.
4.5", 155mm guns and larger.
155mm, 8" and 240mm Howitzers.

13. What volume of work can the present calibration team perform?

A. Depends on caliber and circumstances, normally a team can calibrate a battalion of heavy artillery every two days. I have done as many as 28 - 155mm howitzers in one day but this was done on a pre-selected range where instruments were set up and guns rolled into a firing position, calibrated, and then replaced by another piece.

14. Are practical firing tests valuable;

A. To satisfy some artillery battalions, yes. A calibration team checks interior ballistics, practical firing tests show up exterior ballistics. However, for the most part, a test of this kind is difficult in combat, particularly on long range weapons. Air observation is absolutely unsatisfactory and weather, enemy counter battery fire, etc., make ground observation too often unreliable. I personally am sold enough on calibration to the point that I think it alone is sufficient, but calibration has not been sold sufficiently to the artillery to make them believe in it.

HEADQUARTERS
ORDNANCE SERVICE
___ UNITED STATES ARMY

Ordnance Bulletin)
Number)

26 October 1945

CONDEMNATION OF ARTILLERY GUN TUBES

1. a. Tubes of 37mm Guns M3, M5 and M6; 40mm Guns M1; 57mm Gun M1, 75mm Guns M3, M5 and M6; 75mm Howitzers M1, M2 and M3; and 105mm Howitzers M2A1, M3 and M4 will be based on expected tube life figures as given in columns (2) and (3) of the table on page 3, where gun books are available. Where gun books are not available, condemnation will be on the basis of visual inspection by a qualified artillery inspector.

b. Artillery tubes of 90mm Guns M1; 4.5 inch Guns M1; 155mm Howitzers M1; 155mm Guns M1 and M2; 8 inch Howitzers M1 and M2; 8 inch Guns M1; and 240mm Howitzers M1 will be condemned on the basis of measurements taken at the commencement of rifling, consideration of relative muzzle velocities in applicable cases; all combined with a visual inspection made by artillery inspectors of supporting Ordnance maintenance companies.

2. Artillery inspectors will take bore measurements monthly of pieces listed in Par. 1b above and will include these in the monthly report of artillery inspections submitted to this Headquarters. It is desired to obtain measurements at approximately 25%, 50% and 75% of expected tube life.

3. Ballistic and technical service detachments will obtain relative muzzle velocities of 90mm Tank and Anti-tank Guns; 155mm Guns; 8 inch Guns and 240mm Howitzers at approximately 25%, 50% and 75% of expected tube life. AA artillery will be calibrated at 500, 800, 1000, 1200, 1400, 1600 rounds and every 200 rounds thereafter until condemned. Forward detachments will coordinate their efforts with artillery inspectors and Corps Artillery S-4 to obtain information as to when to calibrate. Rear detachments will work as directed by the army artillery maintenance officer. Detachments will take bore measurements and enter these on their report of calibration.

4. No tube other than those outlined in Par. 1 a above will be condemned exclusively on the basis of number of rounds fired. Artillery units will be informed that estimated tube life of calibers outlined in Par. 1 b above is expressed in number of rounds for supply planning purposes only, is an average figure for a large number of tubes and will not govern or influence replacement.

5. Tubes other than those outlined in Par. 1 a above will not be condemend by visual inspection alone unless unquestionably damaged by enemy action, structural failure, serious defects or other causes.

6. Tubes outlined in Par. 1 b above will be condemend on basis of visual inspection and gage readings considered together. See page 3 of this bulletin for condemning limit gage readings. A report will be forwarded to the army artillery maintenance officer for each tube replaced showing:

a. Caliber of tube and model of weapon.
b. Organization (battalion)

c. Battery
d. Serial number of tube
e. Reason for replacement
f. Pullover gage reading (vertical) ____
g. Number of rounds (EFC on tube) _____
h. Date of last calibration _____
i. MV of last calibration _____

7. Reports of erratic performance received from the using arms will be promptly verified by bore measurements taken by a qualified artillery inspector who will determine whether the tube is worn beyond serviceability, or whether the erratic performance is attributable to other correctable causes. In cases of doubt a Practical Firing Test will be requested.

SERVICE LIFE OF ARTILLERY CANNON

Weapon	Estimated Life E.F.C.	Estimated Life Tot Rds	Vertical Bore Dis. at Condemnation	All Measurements at (b)	Vertical Bore Dis. 25% Life Remaining	Vertical Bore Dis. 50% Life Remaining	Vertical Bore Dis. 75% Life Remaining	Est. Loss of MV (Max Chg) 50% Life Remaining (F/S)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
GUNS								
37mm, M3, M5, M6	700	2000			(See Note (e) on Page 4)			
37mm, M1A2	---	2000	---	---	---	---	---	---
40mm, M1	---	10000			(See Note (e) on Page 4)			
57mm, M1	1000	2000			(See Note (e) on Page 4)			
75mm, M3	---	7500			(See Note (e) on Page 4)			
75mm, M5, M6	---	----			(See Note (e) on Page 4)			
76mm, M1	---	----			See 3" M7			
3", M5, M7	3000	----	3.090	25.17 BT	3.078	3.064	3.042	94 (APC)
90mm, M1, M2, M3	---	2000	3.672 (c)	24.85 BT	3.655	3.633	3.604	100 (HE)
4.5", M1	3000	4000	4.610	37.90 BR	4.602	4.592	4.566	65
120mm, M1	---	1000	4.940	41.00 BT	4.910	4.875	4.830	183
155mm, M1918	4000	----	6.270	53.75 BR	6.243	6.203	6.156	62
155mm, M1, M2	1800	3000	6.305 (d)	54.90 BR	6.268	6.230	6.182	65
8", M1	700	1250	8.360	82.35 BR	8.321	8.272	8.190	112
HOWITZERS								
75mm, M1, M2, M3	20000	----	3.020	11.32 BT	3.017	3.008	2.992	25
105mm M2A1, M3, M4	8000	----	-----		(See Note (f) on Page 4)			
155mm, M1	15000	----	6.220	36.10 BR	6.207	6.190	6.167	70
8" M1	3000	----	8.115	38.70 BT	8.110	8.085	8.064	-------
240mm, M1	2000	----	9.636	73.85 BR	9.606	9.578	9.540	42

NOTES:
(a) Col. 5 (BT - ..." from breech end of tube

(a) (Br - ..." from rear face of breech ring
Col. 9 Letters in () indicate type of ammunition giving loss of MV indicated.

(b) All measurements in inches. Points of measurement to be accurate to - 1/64". Bore measurement to be made with pullover or star gage at points indicated.

(c) Determined by tactical employment (MV loss (HE) at condemnation 150 f/s). Ballistic life of weapon only 1/2 consumed at this point.

(d) 1. Should the bore at 12 o'clock and immediately forward of the commencement of rifling, show scoring, or the lands be worn smooth at the 6 o'clock position, this measurement should read 6.225 inches.

2. Should both the scoring at 12 o'clock, and smooth lands at 6 o'clock exist, the reading should be 6.210 inches.

(e) Serviceability of 37mm Guns, M3, M9, M6; 40mm Gun, M1; 57mm Gun, M1; 75mm Guns, M3, M5, M6; 75mm Howitzers, M1, M2, M3, and 105mm Howitzers, M2A1, M3, M4, will be based on estimated life as given in columns (2) and (3) where gun books are available otherwise on visual inspection by qualified artillery inspectors.

(f) Serviceability of 105mm M2A1 Howitzers:

1. If gun books are available:

Limit for condemnation - 8000 full service rounds, or stripping of the lands as outlined below.

2. If gun books are not available, the condition of stripping of the lands will be utilized to determine serviceability. Make physical measurement of the length of stripping of each land and add these lengths. If result is greater than 110 inches, the tube will be condemned.

All "humped or raised" or rough lands should be filed to approximate proper contour to ensure the unobstructed passage of the projectile.