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R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1354.

A Proposed System for Testing
Armour-Piercing Shot.

(Copy No. 18.)

BUREAU OF MINES
DIVISION OF METALLIC MINERALS
ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH
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Introduction

This report presupposes no knowledge of actual shot quality. It attacks the specific problem of designing a better test for shot.

The present specification permits poor shot to be accepted and also permits good shot to be rejected. A competent proof officer can judge shot quality from the physical appearance of the shot after striking the plate. However, a specification is needed which will form a reliable basis upon which to judge shot.

The problem of controlling and improving shot quality may be undertaken as a separate project.

REASONS FOR CHANGING PRESENT METHOD:

The present method permits reproofing if shot fail. Reproofs often pass the shot. If all lots are not reproofed, then lots of shot might be rejected which were of the same quality as accepted shot. If any lot is reproofed often enough it can probably be passed.

Accepted shot are not reproofed and yet proofing officers will admit that if they were they might be rejected on the results of a reproof.

The specification is therefore not drawn up so as to separate good shot from bad. Considerable personal judgment on the part of proofing officer is required.

These obvious defects in the present system led officials of the Department of Munitions and Supply (Ottawa) to request a study of the present method.

If a satisfactory measure of shot quality were available, then manufacture of shot could be studied and improved by comparing shot properties and history of shot of different quality.

The testing method recommended considers the shot-plate phenomena as of current production conditions. The Quality Control Chart method is proposed. This system has been applied to Ordnance Testing in the United States and is gradually replacing older inspection methods.

PRESENT INSPECTION PRACTICE:

The present method of testing shot involves the use of calibrated armour plate. Calibrating is done by determining the ballistic limit of the plate with four "standard" shot. This value is called the critical velocity. An arbitrary* addition is made to this critical velocity and

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* Based on type of "standard" shot used.

(Present Inspection Practice, cont'd) -

the proving velocity is obtained. It is required that 80 per cent of the shot under test must pass through the plate when fired at the proving velocity.

Results of tests performed in this manner are recorded, as, for example, 4 wins, 3 failures; 6 wins, 4 failures; and so on.

If we assume that the proving velocity is accurate and 80 per cent of a lot of shot actually would pass through the plate at the proving velocity, then the following would hold true:

1. In selecting each shot for test there would be 8 chances out of 10 that a winning shot would be selected and 2 chances out of 10 that a failing shot would be selected.

2. Some variation of results of tests on samples of 10 would therefore be normally expected.

3. It can be easily demonstrated that samples of 10 shots could be obtained which would contain from 4 to 10 wins.

4. Using small samples, therefore, the true percentage of successful shots in the lot cannot be accurately ascertained.

5. If samples of 10 containing less than 8 per cent wins are judged to be rejects, then a considerable amount of satisfactory material will be unnecessarily rejected.

The failure of small samples to accurately indicate quality has been fully described by Lt.-Col. L. E. Simon, Ordnance Department, United States Army, Assistant Director of Ballistic Research Laboratory, Aberdeen, Maryland, in his book, "An Engineer's Manual of Statistical Methods."

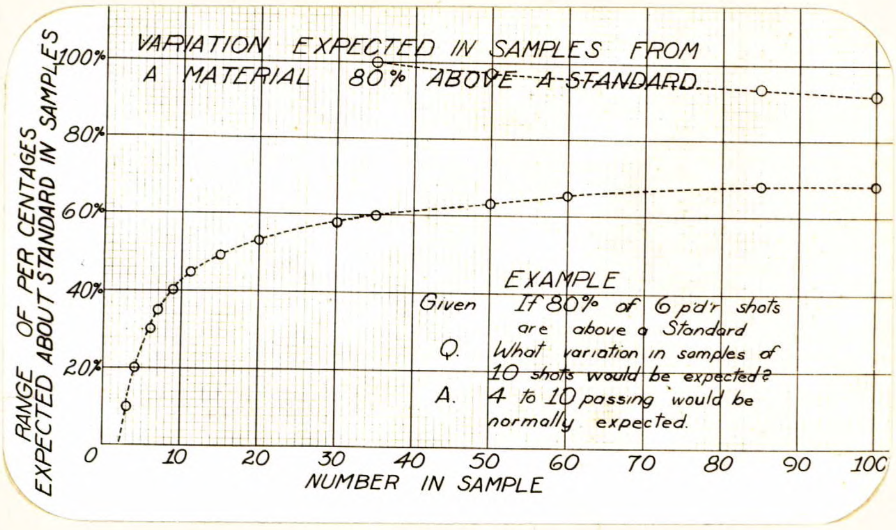
Proof that a lot of shot will give samples varying in the number of wins can be easily obtained from an examination of the present shot proof results. When a lot of shot is rejected because of one win, four failures, reproof may easily give a result such as eight wins and two failures. In fact, if sufficient reproof is taken, almost any rejected

(Present Inspection Practice, cont'd) -

lot will give a sample which will pass the test. Also, reproof from accepted lots of shot will give samples which will fail the test. Therefore, it is partly a matter of chance whether a lot of shot is accepted or rejected.

Figure 1.

EXPECTED VARIATION IN SAMPLES DRAWN FROM A MATERIAL 80 PER CENT OF WHICH IS ABOVE STANDARD.



The above considerations are drawn from the data presented in the shot-proof results and classified as wins or failures. Now it is realized that the proofing officer, after observing the tests, may have <u>very sound reasons for accepting or rejecting lots of shot</u>. However, the specification itself is not so drawn that it can be adhered to without a great many unnecessary rejections.

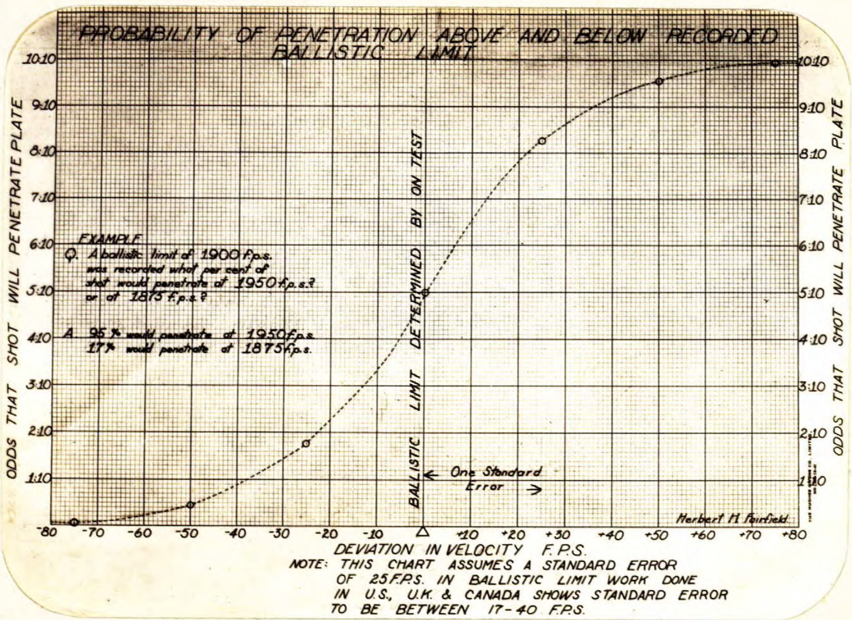
Calibrating Plate:

If four shots are bracketed so that two penetrate and two fail to penetrate, from their velocities the ballistic limit can be calculated. It should be realized that if the ballistic limit test were repeated on the same plate with similar shot the second ballistic limit might be quite different from the first. This is easily demonstrated. Therefore, any ballistic limit must be considered to have a margin of error.

Work in the United Kingdom and the U.S.A. on the variation of ballistic limits has produced enough evidence to show that a ballistic limit value can be safely interpreted, as follows:

Figure 2.

PROBABILITY OF PENETRATION OF ARMOUR PLATE.



(Calibrating Plate, cont'd) -

From the foregoing, it can be seen that a ballistic limit test enables us to predict a range within which other ballistic tests might fall. Proof officers are well aware of this. From their experience they know that some penetrations can be effected below ballistic limit and some failures to penetrate occur above ballistic limit.

The fact that successive ballistic tests differ can easily be demonstrated. Now, if the proving velocity of the shot is determined from one ballistic test it is obvious then that it is a matter of chance whether the proving velocity is 2100, 2200, or any other value within a considerable range. Using such a standard to test shot is obviously an unreliable procedure.

Proof of Unreliability of the Present Acceptance Test:

The statement has been made that some rejected lots of shot will not be any different from accepted lots. Obviously, some rejected lots might be below standard; shattering shots, for example, are certainly defective. This is inferred from a casual study of proof results. Should it be necessary to obtain a practical proof of the above statement, the following procedure is recommended:

> Select a rejected lot of shot which shows no obvious defects such as shattering or mushrooming and run fifteen reproofs using the present system. Select any accepted lot of shot and run fifteen reproofs using the present system.

Examinations of these results would show the fallability of the present system.

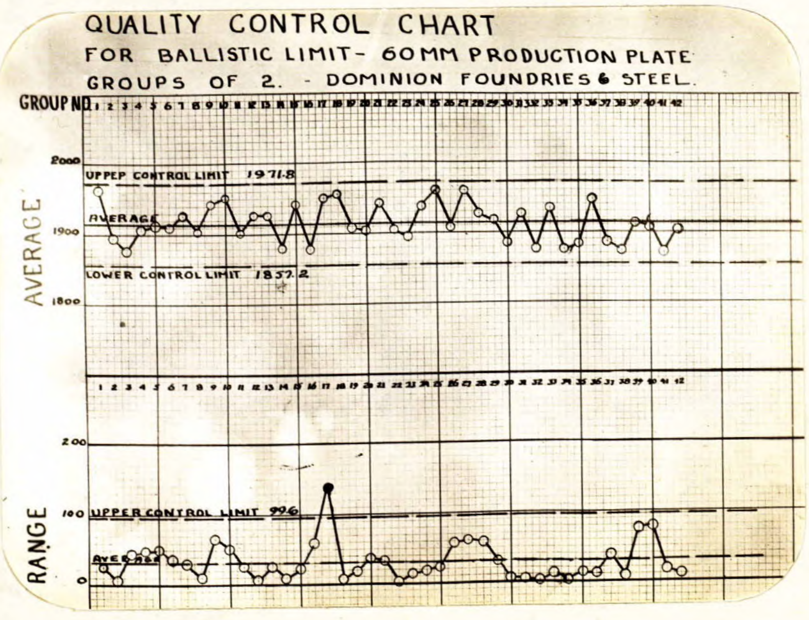
It is assumed that many rejected lots of shot are saved from the scrap-heap by the exercise of good judgment on the part of the proof officer.

Suggested System of Acceptance Tests for Armour-Piercing Shot:

The phenomena of armour attack have been studied quite closely by many investigators. It is apparent that with armour plate from one producer, and shot from one producer, ballistic limits determined tend to form a normal distribution. In the case of 60-mm. armour made by Dominion Foundries and Steel Limited, Hamilton, Ontario, the average of each successive group of two ballistic limits normally falls within 1857-1972 f.p.s. The difference between successive ballistic limits is normally less than 100 f.p.s. There is, then, a normal range for the ballistic limit phenomena. Should any group of ballistic limit exceed the aforementioned limits, then we may be certain that an assignable cause for lack of control is present. Having once determined the normal limits for this phenomena, then each successive test can be classified as either normal or abnormal. When an abnormal test is encountered an immediate investigation into the cause of this difference in variation of quality should be made.

Figure 3.

LIMITS OF NORMAL VARIATION FOR BALLISTIC LIMIT OF 60MM. ARMOUR.



(Suggested System of Acceptance Tests, cont'd) -

Now, it is probable that if samples from current shot production were used to determine ballistic limit of armour plate the ballistic limit so obtained would tend to fall within a certain range. When sufficient tests have been made so that the range can be accurately delineated, then a measure of shot quality will be available.

The proposed method of acceptance tests for armour piercing shot is, therefore, as follows:

> Samples of shot are used to determine the ballistic limit of currently produced armour plate. When sufficient evidence is at hand the expected range within which this ballistic limit is expected to follow can be definitely determined. Having these limits, it will then be possible to classify each lot as normal, above normal, or below normal.

This system is recommended by:

The American Society for Testing Materials,
The American Standards Association,
United States Ordnance,
The Ministry of Aircraft Production of the United Kingdom.

The technique is usually referred to as the Quality Control Chart system.

Interpretation of Unsatisfactory Results:

In using the suggested system, when a result is obtained which falls outside of normal limits several things may have occurred. If the ballistic limit is unusually high it is usually inferred that the shot is defective. The proof officer may judge from physical evidence that this is so and reject that lot of shot. If in the judgment of the proof officer the shot appears to be satisfactory, then an investigation should be made to make sure that the plate is of

(Interpretation of Unsatisfactory Results, cont'd) -

normal quality. Calibrated shot can be used in such a case.

If the ballistic limit obtained is unusually low the proof officer may decide that the plate is satisfactory and the low result is due to a superior-quality shot. Obviously, such a lot of shot should be thoroughly investigated in the hope that some clue may be unearthed which will lead to great improvement of shot. If in the judgment of the proof officer a low ballistic limit is due to poor-quality plate then this case can be refereed by the use of calibrated shot.

This system will pick out 'extra poor' and 'extra good' lots of shot.

Calibrated Shot:

It is now obvious to most of those who have observed ballistic tests that an exact calibration value cannot be obtained. The best that can be expected is a range within which results are likely to fall.

Suppose a lot of 4,000 shot are to be used as a reference standard. First, of course, there should be assurance that the history of each of these shot was identical or as close to being identical as is practically possible. If samples from this lot are used to determine ballistic limit on a series of normal production plates, then the range of ballistic limit which the shot will be capable of can be determined. Obviously, the greater number of samples tested the more accurate will be the estimate of ballistic limit for the shot. No fewer than 100 shot should be used. The final figure obtained will be a certain figure ± the margin of error. Let us assume that the calibrated shot has a ballistic limit of 2200 ± 80 f.p.s. Also let us assume that

(Calibrated Shot, cont'd) -

an unusual ballistic limit of 2300 f.p.s. has been obtained with shot under test against regularly produced plate. The question is raised, Is this shot unusually poor, or is the plate unusually good? Now, if some of the calibrated shot are used, a second ballistic limit can be determined on the same plate. If it is within 80 f.p.s. of the first ballistic limit, then the extreme variation may be assumed to be due to the plate and the shot is acceptable. If the ballistic limit obtained with calibrated shot differs by more than 80 f.p.s., then the quality of the shot under test is at fault.

This report has been made as brief as possible, in an attempt to convey in a simple manner the ideas involved in inspection. Should the Quality Control system be applied, further details will be required.

Two reports on Quality Control* are attached for the information of those who may be interested.

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* Investigations Nos. 1235 and 1298.

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