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THE ADJUSTMENT OF LOT SIZES OF AMMUNITION AND  
AMMUNITION COMPONENTS FOR GREATER ECONOMY IN  
SERVICE AND SPEED IN PRODUCTION

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U.S. ARMY ABERDEEN RESEARCH AND DEVELOPMENT CENTER  
BALLISTIC RESEARCH LABORATORIES  
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July 29, 1941.

REPORT  
ON  
THE ADJUSTMENT OF LOT SIZES OF AMMUNITION AND AMMUNITION  
COMPONENTS FOR GREATER ECONOMY IN SERVICE AND SPEED IN  
PRODUCTION

ABSTRACT

Small lots of complete rounds are causing delays in manufacture and congestion at the Proving Ground. They will also cause annoyances in issue to service, and lack of economy in surveillance. Maximum authorized lot-sizes are satisfactory. The high frequency of small lots is attributable to the impracticability of attaining the maximum authorized lot sizes of complete rounds under existing prohibitions against the use of more than one lot of any component in a lot of complete rounds.

There is a readily available remedy for this condition. It has been observed that for many components (see Table I), differences between lots may be no greater than differences between the articles within the lots. Under these conditions, the effective lot for practical purposes may extend over a considerable number of arbitrary component lots. It has been successful practice for over three years to group such lots into grand lots. Grand lots are true lots in every sense. By merely changing the existing restrictions on lots to grand lots (as shown in Table I), almost all difficulties due to lot size will cease.

The grouping of lots into appropriate grand lots requires analysis of design, manufacturing conditions, and inspection results in a manner now performed by the Quality Control Unit of the Inspection Section, Ammunition Division, and described in the Manual for Analysis of Acceptance Tests and Inspections (AATI). It is recommended that this Section supervise the grouping of lots into grand lots and be given authority to select the different lots of components that are to be assembled into a single lot of complete rounds.

It is believed that this procedure will increase the average size of lots of complete rounds from about 6,000 to about 18,000. It is further recommended that sample sizes for complete rounds be slightly increased for the larger lot sizes and that it generally be prescribed that samples of ammunition lots be taken in order of production and that they be so marked. Compounded blending of powder is also recommended for larger caliber seacoast guns and mortars.

## INTRODUCTION

1. On July 16, 1941, a conference was held at the Technical Staff Conference Room, Office Chief of Ordnance, Colonel S. H. Miles, Jr., presiding, to consider the advisability of taking steps to eliminate small lots of complete rounds.

2. Objections to small lot sizes. Small lots of complete rounds are objectionable for the following reasons:

(a) Delay and increased cost in manufacture associated with the accomplishment of lot cards, final inspections, and the clearing of production lines for the next lot.

(b) Congestion at the Proving Ground associated with the tests of minimum sample sizes from small lots of the order of a few hundred to a few thousand complete rounds.

(c) Inconvenience to the using arms caused by the issue of a consignment of ammunition consisting of more than one lot, which is of course disconcerting in the adjustment of fire.

(d) The surveillance of an unnecessarily large number of small lots in storage. (and the concomitant cost of more extensive function testing.)

3. Action taken by the conference. Due to the considerable number of technical issues involved which appeared to require study (especially those relating to the sampling, quality control, and field service), the conference adjourned after a general discussion. Lt. Col. C. S. Reed and Major L. E. Simon were directed to prepare and to submit to the Chief of Ordnance a report on the general subject matter discussed.

## GENERAL CONCLUSIONS

4. Lots and grand lots. The term lot applied to a group of articles means that they are essentially alike. It is through this meaning that division into lots serves a useful purpose. However, the fact that all articles in a lot are essentially alike does not make it inconsistent for two or more lots to be essentially alike. In fact, it is expected that a single manufacturer's lots should be very much alike, if he is a good manufacturer. Extensive tests made under the existing system of surveillance of war reserve ammunition show conclusively that for a considerable period of time the flow of a component from a single manufacturer may be so uniform as to preclude distinguishing between the quality of one part of the product and that of another part. For example, this is quite true with regard to artillery primers. Under these conditions, divisions of the product into lots are nothing more or less than arbitrary divisions with respect to time, the individual articles of the lot being essentially alike and the lots themselves being essentially alike.

5. This does not necessarily mean that the maximum lot-size of the component is too small. It is essential that the flow of product be sampled from time to time, in order to ensure continuance of uniformity. It does mean, however, that more than one lot of such a component can be used in a single lot of complete rounds without prejudicing the essential sameness of the lot of complete rounds. This condition obtains to a marked extent for primers, and to a substantial extent for point detonating fuzes, boosters, loaded shell, and cartridge cases. Experience shows that with these components, continuous flows of essentially the same quality can be expected to persist for 10 to 30 lots. These groups of lots are called grand lots<sup>1</sup>.

<sup>1</sup> See Ballistic Research Laboratory Report No. 115.  
O.S.M. No. 2-43.  
AATI No. 2-1 and 2-2.

In recent manufacture this uniformity occurs to a considerable degree in mechanical time fuzes. Essential sameness from lot to lot has never existed in powder-train time fuzes or in lots of propellant powder to a degree which would justify the use of more than one component lot in a complete-round lot.

6. Identification of grand lots. Contrary to popular belief, small samples from large lots cannot yield a reliable indication of the quality of those lots. However, by methods now in use in the Inspection Section one can judge from the small sample and other evidence whether or not a lot offered for acceptance appears to be the same as its predecessors and knowing the general quality level of the predecessors from accumulated data on the predecessors, one can then infer the quality of the current lot with considerable assurance. That is to say, percentage sampling, as done in ammunition, will not separate good lots from bad. However, when used in connection with other evidence, it will serve to separate good grand lots from bad, and good manufacturers from bad. By making scientific use of this hind sight as an intelligent guide to foresight, the Inspection Section can judge whether or not the next lot in a series is essentially the same as its predecessors and consequently whether or not this subsequent lot can be safely incorporated in the same lot of complete rounds. A group of lots which for both engineering and statistical reasons are thus judged to be composed of member lots which are essentially the same is a grand lot. Based on these considerations, it appears that ammunition components can be assembled safely into complete rounds in accordance with Table I.

TABLE I

LIMITATIONS ON COMPONENTS WHICH MAY  
BE USED IN THE SAME LOT OF COMPLETE  
ROUNDS, FIXED AND SEMI-FIXED

| Component             | Restriction on Use |                |                  |
|-----------------------|--------------------|----------------|------------------|
|                       | One Lot            | One Grand Lot  | Any Accepted Lot |
| Adapter & Booster     |                    | X              |                  |
| Booster               |                    | X              |                  |
| Burster               |                    | X              |                  |
| Canister              |                    | X              |                  |
| Cartridge, Case       |                    |                | X                |
| Fuze, B.D.            | X <sup>a</sup>     |                |                  |
| Fuze, Dummy           |                    |                | X                |
| Fuze, P.D.            |                    | X <sup>b</sup> |                  |
| Fuze, Time, Mech.     | X <sup>b</sup>     | X <sup>b</sup> |                  |
| Fuze, Time, Pdr.Tr.   | X                  |                |                  |
| Primer                |                    | X              |                  |
| Propelling Chg.       | X                  |                |                  |
| Shell, A.P.           |                    |                | X                |
| Shell, Chem. (loaded) |                    | X <sup>c</sup> |                  |
| Shell, H.E., (loaded) |                    | X <sup>c</sup> |                  |
| Shell, Practice       |                    |                | X <sup>c</sup>   |
| Shell, T.M., (loaded) |                    |                | X <sup>d</sup>   |
| Shrapnel              |                    | X              |                  |

- (a) B.D. fuzes for 3" and larger, one grand lot.  
 (b) Lots of the same grand lot will be permitted if deemed practicable by Inspection Section, Amm. Div., Ind. Service.  
 (c) Must be same zone.  
 (d) Must be of same manufacturer.

7. Effect of restrictions on lot-size. At the present time, the size of a lot of complete rounds may be limited by the exhaustion of any one of 5 components:

Fuze  
Booster  
Loaded Shell  
Propellant Powder  
Primer

Under the conditions recommended, the bulk of complete rounds will seldom suffer lot-size restriction from any component except propellant powder; a lesser portion will seldom suffer restriction except from powder-train time fuze and propellant powder; and a still smaller portion will be restricted by the lot of base detonating fuze and propellant powder.

8. Since propellant powder is made in lots of 50,000 to 100,000 lbs., the lot of propellant powder will not impose a severe restriction on the smaller calibers, a single lot being sufficient for at least 100,000 rounds of 37 mm.'s, 36,000 rounds of 75 mm.'s, and 20,000 rounds of 3" AA's.

9. Reducing the limiting effect of lots of propellant.

It is not readily practicable to establish charges with a sufficient degree of accuracy to permit rounds from more than one lot of propellant powder to be mixed in a lot of complete rounds without introducing excessive dispersion. It can be shown that such an attempted procedure would require the firing of rounds for establishment-of-charge on a number of different days and to a total of 50 or 100 rounds. On the other hand, powder lots can be made as large as one wishes by cross-blending of lots. For example: given three lots, A, B, and C, each consisting of 100 lbs. of powder, blend  $\frac{1}{3}A + \frac{1}{3}B + \frac{1}{3}C$  to make  $\frac{1}{3}$  of a new lot D which is 3 times larger, and repeat 3 times.

Blending is cheap (about \$100.00 per blend), but there are handling and storage difficulties associated with such a procedure. This procedure was suggested at the conference for use with powder for large propellant charges. For those calibers where the cost of acceptance testing and firing for establishment of charge is very high, cross-blending of lots to produce larger lots might effect a material saving of time and money. For small powder charges, it certainly would not pay.

#### ANALYSIS OF THE SITUATION

10. Basic meaning of lot. A definition of lot is given in "Single and Double Sampling Inspection Tables" by H.F. Dodge and H.G. Romig, The Bell System Technical Journal, XX, (1941), 1-2.

By a lot will be meant the collection of individual pieces from a common source, possessing a common set of quality characteristics, and offered as a group for inspection and acceptance at one time.

This is the sense in which lot is generally used in Ordnance. By grand lot, as used in the Ordnance Surveillance System and in the AATI, is meant a group of lots which for engineering reasons are believed to be essentially the same and which on sampling inspection and statistical analysis do not appear to be different. This is an effective lot with respect to use of components. Essential sameness generally is inferred by similarity of conditions such as the same manufacturer, manufactured under essentially the same conditions, under the same drawings and specifications, with essentially the same raw materials, and in the absence of any untoward events which would indicate a difference. Naturally the basic



function of designation by lots consists of a convenient method of handling aggregations of articles which are believed to be essentially alike, i.e., the lot is assumed to be homogeneous. This is convenient in manufacture, handling, storage, and issue.

11. Lot-size of components. If the above definitions are accepted, it is quite obvious that the grand lot, if properly selected, is a true lot; and the ordinary lots (while also true lots) are mere arbitrary batches of this larger lot the size of which is regulated by the condition of uniformity of quality. It is believed that this is as it should be. It stands to reason that for any article manufactured there must be an economically-right lot size which would almost certainly be different for every different article. However, it would be practically impossible to determine a priori the economically-right lot size, since the size would vary from manufacturer to manufacturer and even from time to time with the same manufacturer. The procedure briefly described in the preceding paragraphs for the establishment of grand lots attempts to determine the economically-right lot size a posteriori. This method is believed to be the only practical way to determine the economically-right lot size. Therefore, it is evident that the effective-lot size, or grand lot size, not only changes from component to component but even changes from time to time in accordance with the expertness of the manufacturer and the proven uniformity of his product.

12. Utility of component-lots. No change is recommended in the currently authorized lot-sizes of components or in the sample sizes taken from such lots. In order to judge grand lots, it is essential that samples be taken from the flow of product by orderly sub-groups with respect to time. The existing specifications furnish a satisfactory vehicle for this purpose;

and the recognition of the principle of grand lots provides a ready means of making larger lots of complete rounds with a minimum of change in existing procedure.

13. Stumbling blocks to large lots. The poorer manufacturer prefers small lots for two reasons. First, existing specifications often prescribe a sample size which is proportional to lot size. Small lots mean small samples, and the smaller the sample the more frequently will the poorer manufacturer have his inferior product accepted without detection, since probability of detection does not follow the law assumed in writing such specifications. Second, rejection of a lot represents substantial loss; hence the manufacturer prefers to limit the number of eggs he puts in one basket. Therefore, there is an economic urge for the manufacturer to restrict the size of lots.

14. Lack of uniformity means poor ammunition and small lots of complete rounds. One of the most undesirable characteristics in ammunition, and a characteristic which is highly indicative of careless manufacture, is lack of uniformity in the product. Lack of uniformity means that successive lots will differ one from another. The grand lot system, of course, will detect changes of quality from lot to lot. However, such changes, if they occur, limit the size of the grand lot. Consequently, poor manufacturers will manufacture only small grand lots; very poor manufacturers, perhaps none at all. This situation results in small lot sizes of complete rounds. Furthermore, the very presence of such inconsistent quality from lot to lot strongly indicates that the quality within the lot is also variable and consequently poor.

15. Attainment of large lots without loss of quality. Manufacturers of non-homogeneous lots of components should not have their product accepted at all as it is likely to be a

menace to safety and to the reputation of the Ordnance Department. Here it may well be remarked that experience has shown that about half of the ammunition in the War Reserve which it has been necessary to condemn, became unserviceable due to deterioration: the other half was never any good. It was produced by incompetent manufacturers. Under the grand-lot system, such sources can be ruled out now, or the sources reformed. Certainly no favors should be shown such manufacturers today. Conditions which are specified by contract cannot be abrogated; but at least the poor manufacturers can be made to hew to the line insofar as practicable under existing contracts and specifications. On the other hand, good manufacturers who make a uniform and controlled product as shown by their producing large grand lots should have certain specification requirements waived for them from time to time when violation of the requirement can have no important effect and their flow of product remains homogeneous. Thus the grand lot system can prove to be an important stimulus to better quality.

16. Lot-size of complete rounds. It is manifest from the foregoing discussion that it may be possible to obtain very large lots of complete rounds in the sense that the lot represents an aggregation of articles which are essentially alike. However, part of the utility of a lot inheres in its convenience as a unit for storage, issue, shipment, and handling. Certainly some mistakes will be made. An aggregation will sometimes be designated as a lot when the aggregation is not homogeneous. Sometimes, due to unforeseen circumstances, it undoubtedly will be necessary to suspend or cull certain lots of complete rounds. If lot-sizes of complete rounds are huge the difficulties associated with the suspension of a lot increase proportionately. Therefore, it appears to be the part of wisdom to limit the size of lots of complete rounds. The existing maximum of 20,000

appears to be a reasonable limit for fixed and semi-fixed ammunition with perhaps the exception of the 37 mm. caliber. Consideration could be given to the increase of the limit to 50,000 for this caliber. Furthermore, it is contemplated that the recommendations made herein, if adopted, will yield about a 3-fold increase in average lot-size. This is a very material increase. In the interests of taking only reasonable rather than radical steps it is recommended that the maximum lot size of complete rounds, at least for the present, be allowed to remain as at present specified.

#### SAMPLING

17. Sample size taken from lots of components. As implied par. 12, the sample size from lots of components should remain as now specified. Of course, this results in a variable sample size from the grand lot which is the effective lot in the sense that it defines the aggregation which for practical use is assumed to be homogeneous. One change however is strongly recommended with respect to the selection of samples from lots of components. It is recommended that the samples be selected by the inspector as nearly as practicable in the order of production. The reason for this step is very important.

18. Order makes an important contribution to the information yielded by the sample. When a lot of components does not appear to be essentially the same as its predecessors, the inspection division decides that a grand lot has been terminated. However, there is always some degree of incertitude as to whether termination took place with that lot which showed the obvious

lack of control or with its predecessor, or perhaps the lot before that. This incertitude is small but nevertheless exists. Now, if the samples from the lot are taken in the order of manufacture, e.g., a sample of 20 taken in order of manufacture and divided into 4 sub-groups of 5, it is often possible to tell in what part of the lot the change occurred. For example, if the second sub-group of 5 indicated a change in quality, it would appear that the lack of control occurred at about the early part or middle of the lot; and, of course, no suspicion would be attached to the preceding lot. In fact, it is order which is most important in detecting a change in the flow of product from part to part. Under present circumstances, order exists only for the flow from lot to lot. By the simple expedient of having the inspector take his samples in approximate order of production and number the samples accordingly, order can be preserved within the lot. This will further increase the information which can be obtained from the sample, as the sample becomes more nearly representative of the product in the sense that it is a stratified sample. The Proving Ground gives assurance that such a measure will impose no hardship on the Proving Ground, because the first thing which the Proving Ground does upon the receipt of samples is to assign numbers for convenient handling during the proof process. This assignment of numbers by the inspector would be a convenience.

19. Sample size of lots of complete rounds. Since the average lot size will be increased approximately 3-fold under the recommended procedure, it might appear that the sample size should also be increased approximately 3-fold in order to obtain the same amount of information. Extensive theoretical evidence and practical experience is available on this subject, and such evidence shows conclusively that no such proportionate increase in sample size is necessary. Although an accurate discussion of the relation between sample size and lot size involves a number of technical difficulties, it may be said

that for purposes of approximation, sample size proportional to the square root of lot size is a reasonable rule. With this rule, doubling the sample size while tripling the lot size would somewhat more than keep the same accuracy of information (especially if the rule of taking samples in approximate order of production is followed). Therefore, it is recommended that existing specifications be altered with regard to the number of samples to be taken from each lot of complete rounds.

20. In order to accomplish the change in sample size expeditiously the following tentative procedure is recommended. Take the existing sample size, and let us call it a. Then prescribe that for lots of less than 5,000 a sample of a shall be taken; for lots between 5,000 and 10,000 a sample of 1.5a shall be taken; and for lots of 10,000 to 20,000 a sample of 2a shall be taken, the maximum lot size being 20,000. In this connection, some adjustment of specification requirements will be eventually necessary, as a change in sample often changes the requirement. For example, the requirement that the maximum dispersion of the sample rounds shall not exceed 2% of the muzzle velocity is much more rigorous for a 10-round sample than for a 7-round sample. Final adjustment of sample size and alteration of requirements are recommended as problems for special study. However, it is important that a new manufacturer or a manufacturer who has lost control should demonstrate clearly his ability to make a satisfactory product. Therefore, it is recommended that the first lot of a series be limited to approximately 2,500 complete rounds and that a sample of 50 be taken. By the first lot of a series is meant the first lot in a contract or the first lot following a loss of control when a new grand lot is being started. In all sampling, the samples should be taken in approximate order of production, numbered accordingly, and identified by number throughout testing and inspection.

21. Summary. Lots of components are large enough, because a number of ordinary lots can be grouped to a new, larger, and yet homogeneous grand lot. Certain precautions must be observed in this grouping. These precautions will incidentally serve to identify incompetent manufacturers and improve quality. Having attained large effective lots of components, the problem of small lots of complete rounds is almost entirely solved, since the existing limit of 20,000 maximum can be frequently reached. For convenience in handling the maximum of 20,000 complete rounds should not be increased at present.

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