ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

Final Report

On

PROJECT: AMRL NO. 37 - STUDY OF ERRORS IN FIELD ARTILLERY PRACTICE

Project No. 37

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ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

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FINAL REPORT
ON
STUDY OF ERRORS IN FIELD ARTILLERY PRACTICE

1. PROJECT: AMRL, No. 37 - Study of Errors in Field Artillery Practice. Final Report.

a. Authority: Ltr. AGF, 413.68 (R) (8 Apr 1944) GNRQT-10/78261 dated 8 April 1944.

b. Purpose: To summarize the findings of this study with respect to sources of error in field artillery practice and to indicate the nature and direction of corrective measures.

2. DISCUSSION:

The primary objective of this project has been to determine the principal causes of human error in the use of the fire-control instruments employed by the field artillery and to develop improved designs of instruments which will reduce the frequency of such errors. In the course of this study, however, it has become increasingly evident that the fire-control instruments are not the only contributors to error and that for a complete study of the problem, equal consideration must also be given to the errors arising from deficiencies in artillery procedures.

3. CONCLUSIONS:

a. Errors in field artillery practice may be divided into two categories with respect to source: (1) instrumental and (2) procedural. These appear to occur in an estimated ratio of 1 to 3.

b. Instrumental errors can be largely eliminated by proper design of instruments based upon independent study of instrument function.

c. Errors arising out of weaknesses in procedure cannot be evaluated independently of the system as a whole nor can the gains from changes in procedure with respect to reduced errors, be accepted without weighing them against possible disadvantages in other respects.

d. The study of errors arising out of artillery procedures should be part of a continuing critical analysis of overall operations in relation to effectiveness of artillery fire. There is need for the establishment of such a complete program of operational research.

4. RECOMMENDATIONS:

a. That all fire-control instruments which are shown to produce

errors in field artillery practice be replaced with improved instruments designed to eliminate the sources of error.

b. That in this replacement program, provisions be made for maximum possible standardization of fire-control instruments for the various artillery pieces.

c. That full consideration be given to the evaluation of avoidable human errors arising in artillery procedures, as measured by their influence upon overall effectiveness of field artillery practices.

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1 Incl.
Appendix

APPENDIX

1. Instrumental Sources of Error:

a. Field observations, tests and laboratory analysis of the fire-control instruments employed in field artillery have demonstrated the importance of these instruments as sources of error*, arising primarily from deficiencies in design and placement of scales with consequent confusion and uncertainty in operation and reading. The characteristics of certain instruments are such as actually to invite errors when reading particular scale values. As these deficiencies have long been recognized, prolonged and repeated training of personnel have been emphasized as a means of overcoming them.

b. Since instruments serve specific purposes within the whole artillery system, they can be studied independently, re-designed or suitably modified as a result of such study and put back into the same system. The only change will be in the manner of manipulating the instrument itself and the overall artillery procedure will not be affected. In this way the major fire-control instruments employed by the field artillery--panoramic telescope, elevation quadrant, gunner's quadrant and aiming circle--have been subjected to critical analysis and field test. Furthermore, tests with modified instruments have shown that the major sources of error existing in them can be largely eliminated.**

c. With respect to the training problem, skill in manipulation of fire-control instruments should be relatively easier to attain than an understanding and development of skill in the more basic operations such as surveying, making the computations required in the conduct of fire, etc. Primary objectives in the design of fire-control instruments, therefore, should be simplicity of operation and a manner of reading so direct and obvious that only a minimum period of training is required to develop proficiency in their use. Fatigue, intelligence ratings of personnel, inadequate illumination of dials, etc., undoubtedly influence the frequency of errors. The demonstrated deficiencies in instrument design are, however, more basic and until these are corrected, the other factors may be considered of secondary importance. Concurrent with improvement in instruments should go considerations of maximum possible standardization of fire-control instruments employed with the various artillery pieces. The variety of instruments now employed to perform the same function leads to confusion and complication of training, supply and maintenance. It is especially disturbing to have to re-train personnel, so far as use of instruments is concerned, when they are shifted from one type of artillery piece to another.

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* Errors referred to here are human errors in the use of the instruments rather than inherent in the instruments themselves.

** Project No. 37, Second Partial Report, 22 March 1945
" " " Third Partial Report, 6 April 1945
" " " Fourth Partial Report, 28 March 1945

Incl.

2. Sources of Error in Artillery Procedures:

a. The role of fire-control instruments in the causation of errors in field artillery practice is so obvious and so easily demonstrated that other errors, arising out of deficiencies in procedure, may be overlooked. Limited observation indicates, however, that errors from these latter sources are of greater importance. Thus, in one tabulation of errors at the battery the frequency was found to be approximately 0.6 per problem fired. Other data have indicated an average of 0.7 per problem at the fire direction center and 3.0 per problem in the communication system. Errors also occur at the OP, in survey, etc. It may be estimated, therefore, that for every error caused by fire-control instruments, three or more are made as a result of deficiencies in procedure. More extensive data are needed to give exact estimates of relative importance, but it is clear that improvements in the form of changes in procedure or the introduction of mechanical devices to aid in operations are required. Errors from these sources are not easily studied independently of the total system, nor can proposed changes in procedure, designed to improve operation with respect to errors, be wholly evaluated in terms of the improvement thus gained. The effect of such changes upon other aspects of operation must also be studied and the relative gains and losses weighed in making a final recommendation.

b. Errors arising from procedures involve such questions as effect of sequence of operations upon the likelihood of errors and similarly, the effect of wording of commands, manner of making correction, technics of target finding, observation and adjustment, etc. Present procedures have been adopted for many reasons, some of which are not obvious, except from a background of extensive artillery experiences. Others, however, may have been dictated by conditions which are not necessarily fixed. For example, the practice of adjusting direction of fire by commanding successive shifts in deflection, rather than as complete new deflection settings each time, complicates the gunner's job in contrast to that of the No. 1 man who receives each new elevation command as a complete instrument setting. Unquestionably, this greater complication accounts for many of the more frequent errors that occur in adjusting deflection as compared with elevation settings in the course of firing. This suggests the desirability of altering design of the panoramic sight to permit complete deflection commands*. To do this, however, involves certain changes in procedure at FDC and requires individual commands to each gun in cases of non-parallel fire. Hence, to evaluate fully the benefits deriving from such a change in procedure requires study of performance of the system as a whole and not simply the relative performance at the battery.

c. As another example, consider the operations in the battalion FDC. This fairly recent development has become established because of its demonstrated advantages for simultaneous control of the fire of a number of batteries. The battalion center now makes use of five computers: HCO, VCO and three battery computers. The speeding up of battalion fire makes it necessary to employ rapid methods of computation and correction which add to the likelihood of errors. Owing to the concentration of computations, these errors become more important because they may be reflected in the incorrect firing of many pieces.

* This would be possible with a gunner's aid of adequate capacity.

Efforts to simplify FDC operation have resulted in the development of several instruments which combine a number of steps and thus reduce the required exchange of information and the number of men involved in completing computations. One of these is a range-deflection fan which is provided with correction devices for range K, drift and wind. With it, the HCO is able to determine the final corrected data for each battery directly, instead of simply reading off map data and transmitting it to the battery computer who must then apply the necessary corrections. Another more elaborate device performs the normal tasks of the VCO as well. From the standpoint of likelihood of errors at FDC, it is probable that the reduction in number of steps and in the exchange of information between individuals made possible by such instruments would be beneficial up to a certain point. Other factors, however, such as the greater complications of the range-deflection fan and the increased responsibility of its operator, must also be considered in judging the value of such devices. The relation between overall FDC operations and functioning of the entire system must be considered in connection with any proposed changes within the fire-direction center.

d. The same considerations are involved with respect to communications. In the course of transmission of data and commands, by voice, telephone or other means, through so many individuals from the observer to the gunner, many errors occur. Efforts are made to guard against errors in communication through insistence on standard operating procedures in order of sending data and commands, use of standardized phrases, pronunciation, etc. That these fail to provide sufficient safeguard is evident from observation and reports. Suggestions are frequently made that automatic data transmitters and other elaborations of the communication system be employed in order to reduce the number of individuals involved and otherwise to make more certain of the correctness of transmission of data and commands. Such changes would undoubtedly reduce errors but at certain cost, in terms of other practical considerations. Demonstrated reduction in errors would not necessarily justify the adoption of a new procedure. On the other hand, neither should practical difficulties necessarily justify disapproval. Again, the problem is one of studying the operation of the system as a whole, and weighing advantages against disadvantages with respect to their effects upon effectiveness of artillery.

e. A high percentage of the errors arising out of artillery procedures are, according to our observations, detected and corrected before firing. Superficially, it would appear that errors are reduced in importance in proportion to their discovery and correction. In practice this is not the case, for two reasons: first, it is well known that the correction of errors with consequent departure from the normal order of procedures causes confusion further down the line and increases the likelihood of error, at the battery for example. Secondly, and of great practical importance, the occurrence of errors and subsequent correction slows down the rate and reduces the density of fire, which, against certain types of targets, has the same effect as eliminating a certain number of guns. The effectiveness of a battalion may be reduced by one-third or even two-thirds, not because of errors in the actual firing but simply because the fire of one or two batteries arrives on the target area too late.

3. Reduction of Procedural Errors.

a. The foregoing discussion of errors arising from the non-instrumental

sources is limited to a few examples but serves to emphasize the difference in approach that is required in studying them and in the development of corrective measures as compared with errors caused by fire-control instruments. As pointed out earlier, it is a simple matter to remove a particular instrument from the system for independent analsysis and improvement but for the study of errors related to artillery procedures more extensive operational research is needed. The former requires no extensive knowledge of artillery practices; and can be carried out as a separate undertaking. The latter, on the other hand, can be successfully undertaken only from a background of considerable practical experience in the field artillery. Indeed, the study of errors in artillery procedures should be a continuing undertaking of those responsible for field artillery procedures and made a part of the evaluation of every new development so that the relative likelihood of errors is regularly measured along with all the other factors, which, together determine the effectiveness of artillery.

b. It is sometimes stated as a fundamental policy in the field artillery that mechanization of operations must be kept at a minimum and personnel trained in "long-hand" procedures so that they will not be too dependent upon instruments. This policy, it is said, insures the continued operation of the artillery under combat conditions since the loss or damage of instruments is not of major concern. The policy is sound, no doubt, but only so long as it does not handicap operations from the standpoint of speed of fire and likelihood of errors. An instrument designed to replace a "long-hand" procedure should not be condemned simply because it is an instrument. Its possible advantages with respect to speed, reduced errors, simplification of training, lesser skill required in performing the task and the ability of the device to maintain its advantages under combat conditions are some of the factors which must receive equal consideration with the disadvantages of adding another piece of equipment and the likelihood of its being lost or damaged. The artillery archives are replete with descriptions of instruments developed through the years to perform a great variety of operations. Some have become standard equipment but many others have been abandoned and even forgotten. One detects a cyclical interest in instruments in reviewing the history of artillery. It is not surprising that new developments in instruments and mechanical aids seem to be greatest during a war period, owing to the greater military activity. It may be, however, that this expresses a real need for mechanization of procedures which is lost sight of in a period of peace when the problems of selection of personnel and training are not as acute and the deficiencies of procedure are not so clearly noted.

c. It is not within the scope or province of this report to discuss the effectiveness of artillery except to the extent that results are influenced by human errors. An artillery piece is inherently capable of placing fire upon a given target within certain limits of accuracy determined by the gun and ammunition, the exactness of information with respect to meterological conditions and other factors which are subject to measurement. The degree to which performance falls short of this is a measure of the loss of effectiveness.

d. The emphasis in modern artillery usage upon point-target firing, speed of fire against mobile targets, and close support of infantry lines has greatly increased the demand for maximum accuracy and the elimination of human errors. The tremendous amount of ammunition employed in the present war, with attendant difficulties of production, distribution and supply, not to mention cost, further emphasizes the importance of securing and maintaining maximum

effectiveness. The question may also be raised as to the future role of the present artillery weapons in the light of rocket development, potentialities of guided missles, aircraft bombing, etc. Owing to the inherent capacities of the field gun from the standpoint of accuracy, it may be that it will be largely reserved in future warfare for operations against pin-point targets and will require procedures of indirect fire comparable in accuracy and rapidity with those obtainable in direct fire. For such operations the phrase "mission accomplished" takes on a very definite meaning and more certain means would be required for appraising results than are employed in the case of area fire. Thus, there is need for an integrated program of operational analysis, continuing and even accelerated in the post-war period.

e. This program should have for its purpose, continuing critical analysis of artillery procedures and operations in relation to the effectiveness of artillery against all of the various types of targets. It should include a systematic study of after-battle reports from the present war and quantitative analysis of new instruments and other devices in relation to effectiveness. The problem of selection and training of personnel requires simplification and the difficulties during war in this connection must not be forgotten in the period of peace with its greatly reduced tempo. Throughout the investigation, importance of potential errors must be considered along with all other factors. Such a program of operational analysis is particularly applicable to artillery practice since, more than with any other weapon or combat means, artillery practice lends itself to systematic quantitative analysis.