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**Original article**

# How to assess the accuracy of artillery fire

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INFORMATIONS

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ABSTRACT

*The article presents the new proposal regarding the assessment of accuracy of artillery fire while conducting fire tasks with live ammunition. Simultaneously the assessment of settings determination accuracy through their comparison has been explained.*

KEYWORDS

*fire accuracy assessment, artillery training, settings comparison*



## 1. Introduction

The works on the new shooting program for the Missile and Artillery Forces commenced on the initiative of the Branch of the Missile and Artillery Forces in 2016. In the new program the new method of assessment of the fire for effect accuracy during artillery shootings was proposed. The assessment of the fire for effect accuracy is carried out whenever live ammunition is used during artillery shootings[1]. During execution of fire tasks without live ammunition the accuracy of determined settings is assessed through their comparison.

The article discusses the method of accuracy of settings determination through their comparison and benchmarks the assessment of the fire for affect accuracy during shooting with live ammunition applying the new and current method of the assessment.

In that regard the difference between artillery fire accuracy and assessment of precision of conducting a fire task is to be borne in mind. The information regarding median errors of setting determination depending on the methods of determination the settings for effective fire can be found in the specialized literature[2]. In English language

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[1] The assessment of the effective fire accuracy is realized during the training of individual shooting skills and fire control trainings (special-tactical classes and exercises) conducted with artillery sub-units.

[2] See: *Objasnienia do Instrukcji strzelania i kierowania ogniem artylerii naziemnej,* part. I, Art. 776/88, p. 89, Table 17.

literature dispersion errors are more frequently mentioned according to the type of ammunition and equipment used, which is depicted in Figure 1.

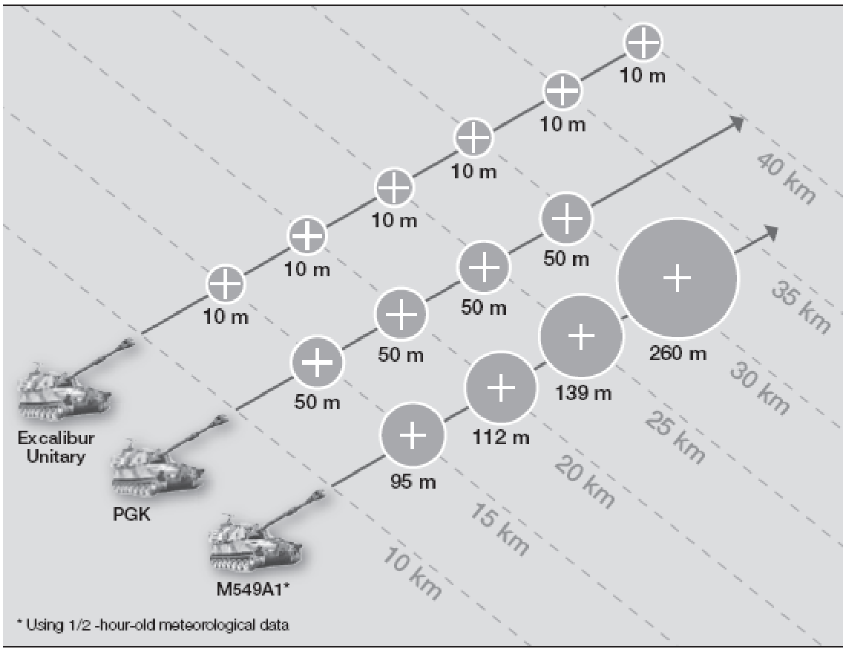


**Fig. 1.** Dispersion errors while shooting with various types of equipment and ammunition.

*Source: Moorhead J., Improving the accuracy conventional cannon rounds, [in:] Field Artillery, January-February 2007, p. 31*

Therefore, a dispersion error and a settings determination terror differ in their notions. Yet both of the factors affect the precision of a fire task execution. The precision of fulfillment of undertakings related to shooting preparation and fire control such as target coordinates indication, coordinates indication and cannons orientation at a fire position and metrological and ballistic preparation primarily impact the accuracy of settings determination. The phenomenon of scattering of projectiles trajectories and points of their impacts while shooting with the same cannon under the best possible conditions is called dispersion[3]. The dispersion seems unavoidable; it is possible to influence its size but only to a limited extent.

During artillery exercises and shootings the value of the mean deviation of projectiles trajectory over effective fire in relation to the center of a target is assessed. Therefore, the impact of both above-mentioned factors on fire accuracy is evaluated. While conducting exercises in which live ammunition is not used for shooting the accuracy of fire cannot be determined hence only the accuracy of settings determination is verified.

## 2. Assessment of settings determination accuracy through comparison

The essence of assessment of settings determination accuracy comes down to the comparison of settings specified in advance (in the course of the training preparation)

[3] R. Piotrowski, *Rozrzut pociskow przy strzelaniu uderzeniowym*, WSO im. gen. J. Bema, p. 3.

by a training supervisor with the settings determined by a trainee conducting the fire task4. Employing the devices used by a training supervisor in the course of the training preparation for setting determination by a trainee fulfilling the fire task is of utmost importance. This method ought to be used for trainings of individual shooting skills conducted without live ammunition e.g. in a lecture room. According to the author, it is a mistake to utilize this method of the fire accuracy assessment during fire control trainings and execution of fire tasks in which Automated Fire Control System TOPAZ is involved. In such the case the data to which a training supervisor could compare the settings determined by the system does not exist. He/she can merely examine whether any errors appeared while the coordinates of the order of battle and meteorological and ballistic data were typing to the system memory.

The current shooting program provides that: "…During trainings when the shooting is exercised without live ammunition (involving simulators), if a fire task is executed without registration fire, the accuracy of settings determination for effective fire is specified through comparison of settings for effective fire (on sights) with control data of a training (shooting) supervisor'[5]. The cited point raises a number of concerns. First of all, as a general rule, a training supervisor's data will be distinct from settings on the sights, since individual corrections are applied by cannons (mortars, launchers) commanders. Furthermore, nor is it clear whether a superior evaluates the correctness of settings for effective fire determined by a commander conducting the task or whether the compatibility of settings implemented into the cannons in accordance with the received command is only assessed. The new shooting program proposes to assess only the time of the execution of a fire task when conducting fire control trainings without live ammunition.

Table 1 presents the standards for assessment of fire accuracy through settings comparison.

**Table 1.** The standards for assessment of fire accuracy through settings comparison

| **No.** | **Method of settings determination of effective fire** | **Mark** | | | | | |
|---|---|---|---|---|---|---|---|
| | | in range [in % $D_T^c$] | | | in azimuth [in mrad] | | |
| | | very good | good | satisfactory | very good | good | satisfactory |
| 1. | Arbitrary method for settings determination of effective fire | 1 | 1,5 | 2 | 4 | 6 | 8 |
| 2. | Determination of registered corrections during creation of auxiliary targets | 0,5 | 1 | 1,5 | 3 | 4 | 5 |

*Source: Developed based on Shooting Program., point 6006*

[4] See: *Program strzelan wojsk rakietowych i artylerii wojsk ladowych,* DWLad Wewn. 87/2006.

[5] Program strzelan wojsk rakietowych i artylerii wojsk ladowych, DWLad Wewn. 87/2006., point 2081.

The sample method of the assessment of the settings determination accuracy through comparison of the settings during the training of individual shooting skills is specified below. Table 2 presents the completion of the fire task prepared by a training supervisor.

**Table 2.** The task developed by a training supervisor

| No | Command | C<br>Sights | K<br>Direction | Observations |
|---|---|---|---|---|
| 1. | Battery shooting. Target VC7500 – infantry. Reduced charge. Scale in milliradians. Direction gun 1 shell - fire. FO 1 indent 1 burst in the target vicinity. | 236 | KZ<br>Primary direction<br>+2-53 | "2-01, 2434, ?" |
| 2. | Fire. | -5<br>231 | -0-02 | "1-85, 2500" |
| 3. | Sheaf 0-05<br>Battery 2 quick shells each – Fire. | -9<br>222<br>225<br>219 | +0-04<br>KZ<br>Primary direction<br>+2-55 | "salvo Right 15; +, Width 1-40" |
| 4. | Narrow the sheaf at direction gun by 0-03<br>3 shells each - Fire | -6<br>216<br>219<br>213 | -0-03 | „salvo Left 15, Short overweighed - , Width 0-80" |
| 5. | Extend sheaf from the direction gun by 0-01<br>4 shells each - Fire | +4<br>212<br>215<br>209 | +0-03 | „salvo Right 15; +/-,Width 0-80" |
| 6. | Extend sheaf from the direction gun by 0-01<br>4 shells each - Fire | | -0-05 | „Target destroyed" |
| 7. | Cease fire. Record the target VC 7500 - Infantry | | | |
| 8. | Battery in the target VC 7500 | 212<br>215<br>209 | KZ<br>Primary direction<br>+2-50 | 236 shells used |

*Source: own elaboration*

Table 3 depicts the execution of the fire task by a trainee.

**Table 3.** The execution of the fire task by a trainee.

| No | Command | C<br>Sights | K<br>Direction | Observations |
|---|---|---|---|---|
| 1. | Battery shooting. Target VC7500 – infantry. Reduced charge. Scale in milliradians. Direction gun 1 shell - fire. FO 1 indent 1 burst in the target vicinity. | 245 | KZ<br>Primary direction<br>+2-53 | „2-01, 2434, ?" |

| No | Command | C<br>Sights | K<br>Direction | Observations |
|---|---|---|---|---|
| 2. | Fire. | -6<br>239 | -0-02 | „1-85, 2500” |
| 3. | Sheaf 0-08<br>Battery 2 quick shells each – Fire. | -8<br>231<br>237<br>225 | +0-04<br>KZ<br>Primary direction<br>+2-55 | „salvo Right 15; +, Width 1-40” |
| 4. | Narrow the sheaf at direction gun by 0-05<br>3 shells each - Fire | -1<br>230<br>236<br>224 | -0-03 | „salvo Left 15, Short overweighed -, Width 0-80” |
| 5. | Extend sheaf from the direction gun by 0-01<br>4 shells each - Fire | +4<br>234<br>240<br>228 | +0-03 | „salvo Right 15; +/-,Width 0-80” |
| 6. | Extend sheaf from the direction gun by 0-01<br>4 shells each - Fire | | -0-05 | „Target destroyed” |
| 7. | Cease fire. Record the target VC 7500 - Infantry | | | |
| 8. | Battery in the target VC 7500 | 234<br>240<br>228 | KZ<br>Primary direction<br>+2-50 | 236 shells used |

*Source: own elaboration*

The assessment of determined settings accuracy for effective fire is presented in Table 4.

**Table 4.** The assessment of fire accuracy through settings comparison

| **Settings for effective fire specified by the training supervisor** | | **Settings for effective fire determined by the trainee** | |
|---|---|---|---|
| Sights<br>222 | Primary direction<br>+2-55 | Sights<br>231 | Primary direction<br>+2-55 |
| Accuracy errors | | | |
| in range [mrad] | | in azimuth [mrad] | |
| 231-222 = 9 mrad | | +2-55 – 2-55 = 0-00 | |
| Calculation of the error in range in square meters | | | |
| $D_T^C = 7963$ ; $\Delta X_{tys.} = 18$<br>$\delta D = 9 \cdot 18 = 162m$ | | | |
| Calculation of the error in range in $\% D_T^C$ | | | |
| 2,03% | | | |
| Mark for the error in range: 2 | | Mark for the error in azimuth: 5 | |
| **Total Mark for the execution of the fire task: 2** | | | |

*Source: own elaboration*

A training supervisor is obliged to conduct the following undertakings while assessing the accuracy of determined settings through settings comparison:

- compare the settings for effective fire with own settings;
- calculate the distinction in range and azimuth in milliradians;
- recalculate the distinction in range specified in milliradians into range error in meters;
- calculate the value of range error in meters in $\% D_T^C$;
- compare the value of the error with the marking standards according to Table 1;
- assess the accuracy of the determined settings.

The permissible error in $\% D_T^C$ for any method for settings determination amounts to 2%. The trainee made the error in range amounting to 162 m, which in $\% D_T^C$ is 2.03%. Therefore, the mark for accuracy in range is 2. The trainee avoided the error in azimuth and achieved mark 5. Pursuant to the shooting program the mark for the accuracy of the settings determination for effective fire is established based on the lower mark for the accuracy in range or azimuth of the first salvo of effective fire. Hence, in the presented example the mark for the accuracy of determined settings is unsatisfactory.

## 3. Assessment of effective fire accuracy based on shooting

The essence of the effective fire accuracy based on shooting comes down to comparison of topographical data to the center of an assessed salvo (single gun, platoon, battery) with the topographical data to a target. It should be noted that while assessing the accuracy of settings for effective fire determined by an artillery sub-unit or unit that determined coordinates by their own means, the target coordinates set by the accuracy control group are to be regarded as the correct ones[6]. Moreover, while assessing the accuracy of settings determination of an artillery sub-unit or unit, which did not determine the coordinates by their own (permanent) means, the target coordinates provided by a superior are considered appropriate[7].

The essence of the assessment of the effective fire accuracy based on the center salvo of a battery is displayed in Figure 2.

[6] Ibidem, point 2064.

[7] Ibidem, point 2065.

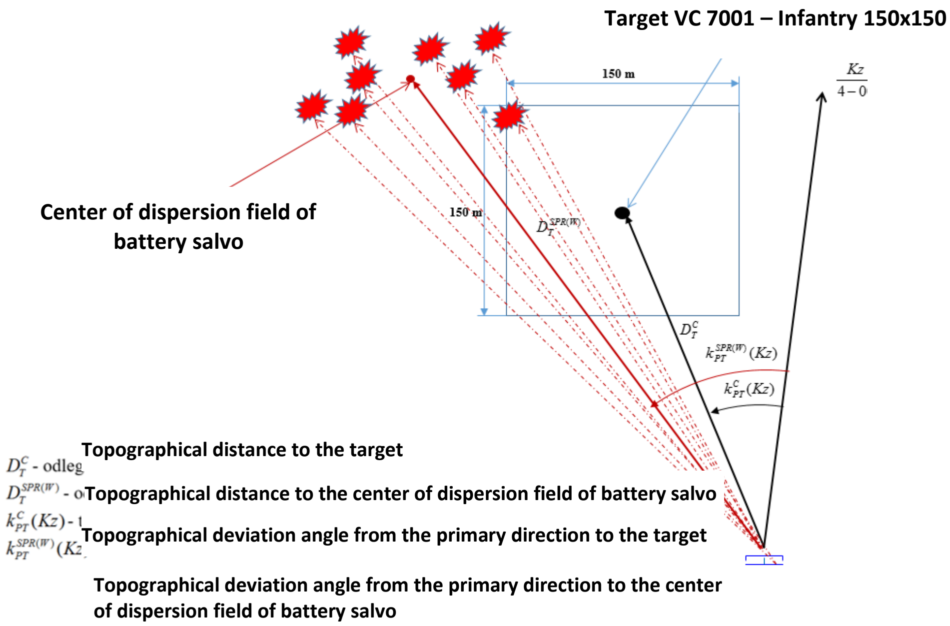


**Fig.2.** Assessment of the effective fire accuracy based on the center of a battery salvo

*Source: own elaboration*

The inspection of the determined settings accuracy is frequently conducted during the execution of fire tasks on the basis of 2-3 shots from the direction gun. The substance of the assessment of effective fire based on the center of 2-3 shots from direction gun is depicted in Figure 3.

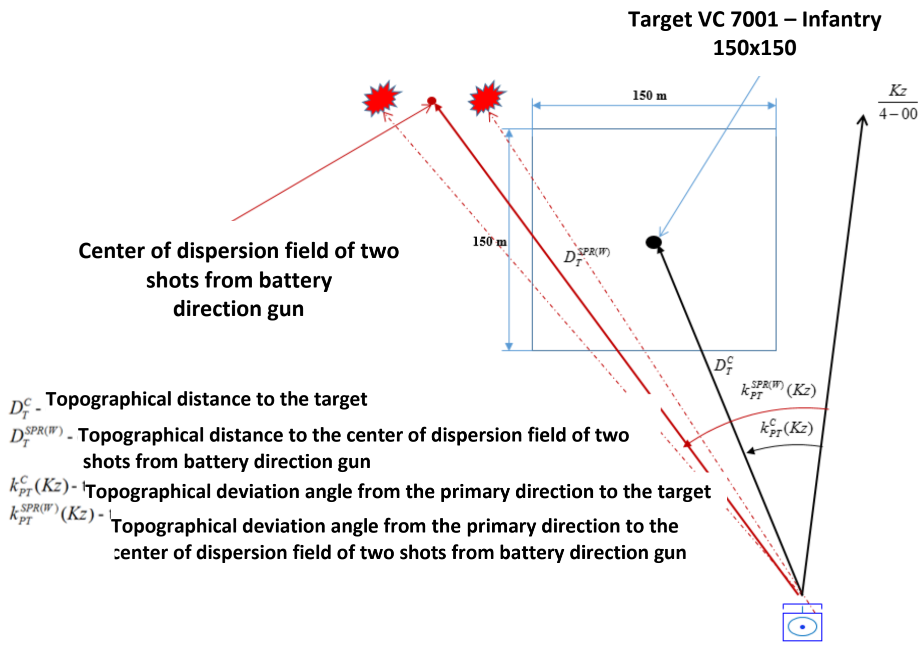


**Fig. 3.** Assessment of the effective fire accuracy based on the center of two shots from a battery direction gun

*Source: own elaboration*

Table 5 presents the standards of the fire accuracy assessment based on shooting with live ammunition.

**Table 5.** Standards of the fire accuracy assessment based on shooting with live ammunition

| No. | Method of settings determination for effective fire | Mark | | | | | |
|---|---|---|---|---|---|---|---|
| | | in range [in % $D_T^c$] | | | in azimuth [in mrad] | | |
| | | very good | good | satisfactory | very good | good | satisfactory |
| A. For tube artillery | | | | | | | |
| 1. | Based on complete shooting conditions data | 2 | 3 | 4 | 8 | 12 | 20 |
| 2. | Targets registration fire | 1,5 | 2 | 2,5 | 7 | 10 | 15 |
| B. For rocket artillery | | | | | | | |
| 1. | Based on complete shooting conditions data | 2<br>3 | 4<br>5 | 6<br>7 | 15<br>20 | 25<br>30 | 35<br>50 |
| 2. | Targets registration fire | 1,5<br>2,5 | 2,5<br>4 | 4<br>6 | 10<br>15 | 15<br>25 | 20<br>40 |
| C. For mortars | | | | | | | |
| 1. | Based on complete shooting conditions data or shifting fire from auxiliary target | 3 | 4 | 5 | 15 | 25 | 35 |
| 2. | Targets registration fire | 2,5 | 3 | 3,5 | 8 | 12 | 20 |
| 3. | Determination of registered corrections based on the results of auxiliary target creation | | | | | | |

*Source: own elaboration based on the shooting program for Missile and Artillery Forces DWLad Wewn. 87/2006, point 6001*

The presented standards are not ultimate, for depending on the conditions of fire tasks execution they can be additionally expanded.

The assessment of two fire tasks executed by a tube artillery sub-unit is described in the subsequent part of the article. The first task is conducted to the target located at the shooting distance of 5000 m, the second task 15000 m. In both tasks it was assumed that the settings for the effective fire are determined based on the complete shooting conditions data. The inspection of the determined settings was conducted on the basis of 2 shots from the battery direction gun. Table 6 presents the assessment of the effective fire accuracy to the target located at the distance of 5000 m and Table 7 - located at the distance of 1500 m.

**Table 6.** Assessment of fire accuracy based on shooting – a target at the distance of 5000 m

| Topographical data to target | | Topographical data to center of salvo | |
|---|---|---|---|
| $D_T^C$ | $k_{PT}^C(Kz)$ | $D_T^{SPR(W)}$ | $k_{PT}^{SPR(W)}(Kz)$ |
| 5000 | -1-00 | 5200 | -1-20 |
| Accuracy errors | | | |
| Calculation of error in range in [m] | | Calculation of error in azimuth [mrad] | |
| $\delta D = 5200 - 5000 = 200m$ | | $\delta K = 0 - 20$ | |

| Accuracy errors | |
|---|---|
| Calculation of error in range in $\%D_T^C$ | Calculation of error in azimuth [m] |
| 4% | $\delta K[m] = 0-20 \cdot 5{,}2 \cdot 1{,}05 = 109m$ |
| Mark for error in range: 3 | Mark for error in azimuth: 3 |
| Total mark for the accuracy of tfire task execution: 3 | |

*Source: own elaboration*

**Table 7**. Assessment of fire accuracy based on shooting - a target at the distance of 1500 m

| **Topographical data to target** | | **Topographical data to center of salvo** | |
|---|---|---|---|
| $D_T^C$ | $k_{PT}^C(Kz)$ | $D_T^{SPR(W)}$ | $k_{PT}^{SPR(W)}(Kz)$ |
| 15000 | -1-00 | 15600 | -1-20 |
| Accuracy errors | | | |
| Calculation of error in range in [m] | | Calculation of error in azimuth [mrad] | |
| $\delta D = 15600 - 15000 = 600m$ | | $\delta K = 0-20$ | |
| Calculation of error in range in $\%D_T^C$ | | Calculation of error in azimuth [m] | |
| 4% | | $\delta K[m] = 0-20 \cdot 15{,}6 \cdot 1{,}05 = 327{,}6m$ | |
| Mark for error in range: 3 | | Mark for error in azimuth: 3 | |
| Total mark for the accuracy of tfire task execution: 3 | | | |

*Source: own elaboration*

The following activities ought to be undertaken while assessing the accuracy of effective fire based on shooting:

- to calculate topographical data to a target and to the center of the dispersion field of a salvo of shooting fire assets (fire asset);
- to calculate the difference of topographical data in range in meters and in azimuth in milliradians to a target and to the center of the dispersion field of a salvo of shooting fire assets (fire asset);
- to calculate the value of an error in range in meters in $\% D_T^C$ ;
- to compare errors values with marking standards according to Table 5;
- to assess the accuracy of determined setting.

The permissible error in range in $\% D_T^C$ for any method of settings determination counts of 4%. In the both described tasks the error in range is 4%. The fire accuracy in range in both cases was marked satisfactory. The error in azimuth in both cases counts of 0-20, which constitutes the threshold to obtain the satisfactory mark. Hence in the presented examples the marks for the accuracy of effective fire are satisfactory.

The recalculation of the error in range in Table 6 and 7 from miliradians to meters constitutes the additional calculating element. The reason for that is to realize the position of the average field of dispersion of two shots from the battery direction gun in relation to the center of the target. The assessment of the accuracy of effective fire to two targets is graphically depicted in Figures 4 and 5.

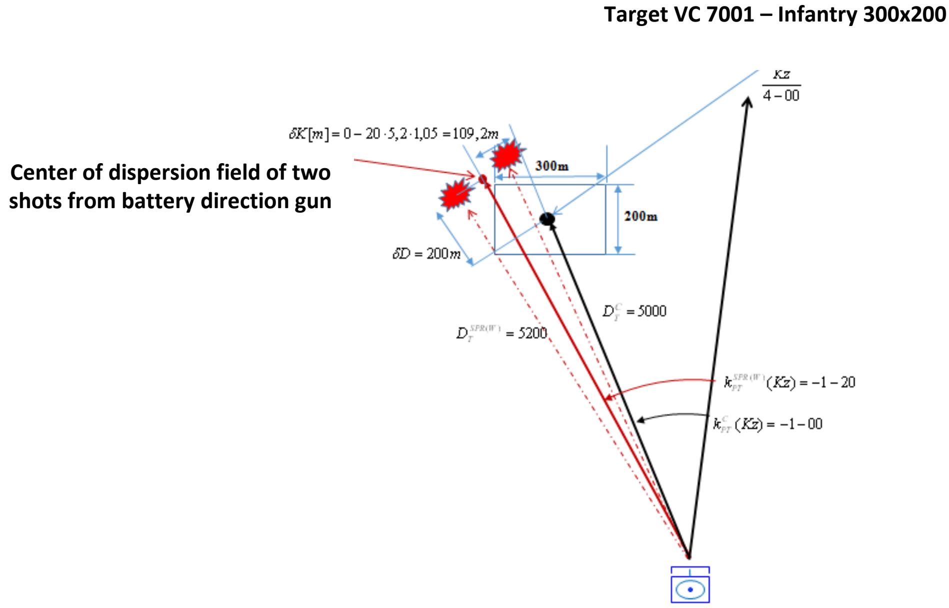


**Fig. 4.** Assessment of the effective fire accuracy based on the center of two shots from the battery direction gun - a target at the distance of 5000 m

*Source: own elaboration*

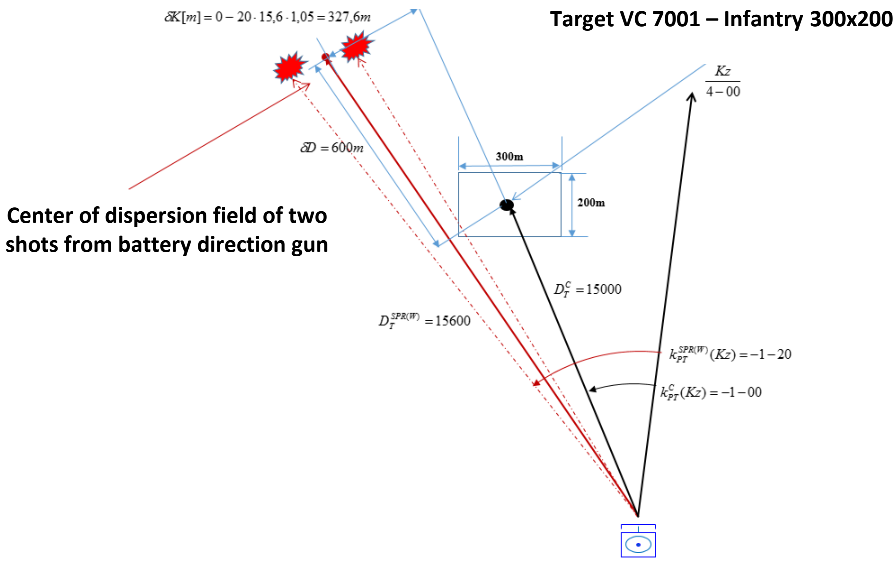


**Fig. 5.** Assessment of the effective fire accuracy based on the center of two shots from the battery direction gun - a target at the distance of 15000 m

*Source: own elaboration*

During the execution of a fire task at the distance of 1500 m, even when an entire battery performs the task with three different sights settings, the target would not be struck. It is presented in the graphical form in Figure 6.

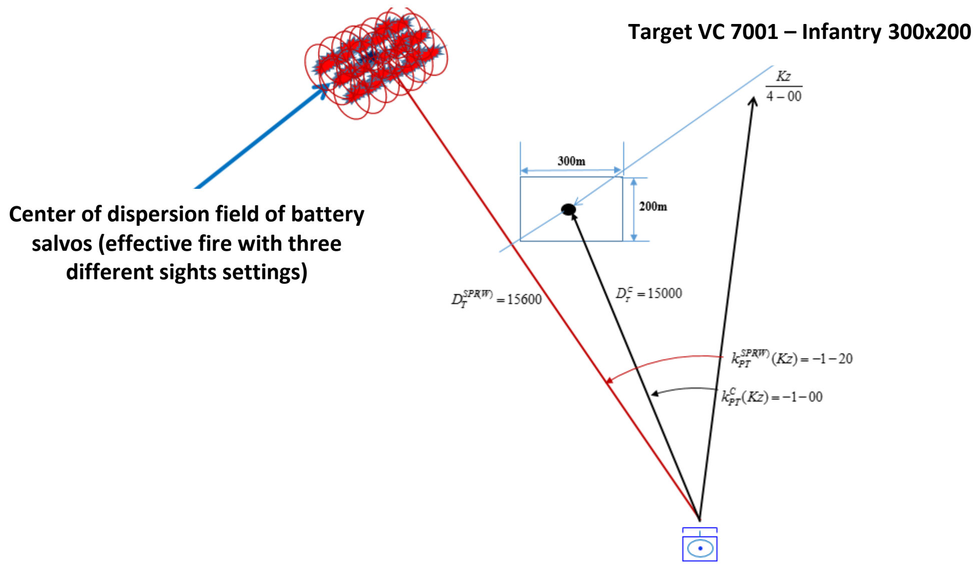


**Fig. 6.** Location of the center of battery dispersion field in relation to the center of target - a task executed at the distance of 1500 m

*Source: own elaboration*

Both depicted examples of the assessment of fire accuracy aimed at drawing the attention to the fact that the accuracy assessment based on the error in % $D_T^C$ while executing a fire task at longer shooting distances seems to be not entirely justified. In the second example the mark for the accuracy of the fire task execution was satisfactory despite the fact that the bursts deviated considerably from the target (600 m in range and 327.6 m in azimuth). During shooting at the distances between 4000 ÷ 6000 m (fire tasks at these ranges are most frequently executed at training grounds conditions) the assessment of fire accuracy based on deviations in range in % $D_T^C$ is of no further relevance. It is confirmed by the graphical representation of the fire task at the distance of 5000 m (Figure 3), where the bursts fall very close to the target.

Currently the works on adaptation of military training field centers for artillery shootings at the ranges exciding 1000 m are in progress. The execution of fire tasks at long distances will significantly depend on the provisions of new the Missile and Artillery Forces' safety manual. The proposals contained will allow for the execution of artillery fire tasks at long distances from the shooting positions located outside of the military training field areas. Thus, according to the author, the application of the new approach to the assessment of effective fire accuracy is legitimate.

## 4. New method of the effective fire accuracy assessment

Two presented examples of the assessment of the effective fire accuracy proved that in situations when a fire task is conducted at the long shooting ranges the mark obtained for fulfillment of the task does not entirely reflect the actual execution of the fire task. The assessment of the fire task execution should not aim at examining the time needed for a sub-unit to accomplish the task but also at proving whether the target would be effectively struck as the result of the accomplishment of the fire task in a real operation. Table 8 presents the proposals of deviation standards in range and azimuth for the fire accuracy assessment, notwithstanding the method of setting determination and the type of artillery assets used to complete the task.

**Table 8.** Proposals of deviation standards in range and azimuth for the fire accuracy assessment[8]

| **Type of target** | **Mark:** | | | | | |
|---|---|---|---|---|---|---|
| | in range | | | in azimuth | | |
| | very good | good | satisfac tory | very good | good | satisfac tory |
| a) to group targets | $0{,}5G_C$ | $0{,}75G_c$ | $1G_C$ | $0{,}5Sz_C$ | $0{,}75Sz_C$ | $1Sz_C$ |
| b) to individual targets | 25 m | 50 m | 75 m | 25 m | 50 m | 75 m |

*Source: own elaboration*

Comments:

– $Sz_C$ - target width, $G_C$ – target depth.

The accuracy standards concern:

– individual targets - the center of the target;

– group targets - the location where a particular sub-unit is obliged to shot within a given type of shelling.

It can be assumed that having such the deviation standards for the fire accuracy assessment established, a trainee obtaining the satisfactory mark will strike the target. Figure 7 presents graphically the situation where the center of a battery salvo deviates in relation to the center of the target in range by the value equal to the target depth and in azimuth to the value equal to the target width.

While striking individual targets it was assumed that the average central deviation in depth for tube artillery amounts to 25 m. Given the assumption that the deviation is limited to the value of 4 Ug, the target will be struck with the deviation of the center of a battery salvo by 100 m in range and azimuth. It was also postulated that rocket artillery would conduct fire tasks only against group targets.

[8] The recommendation presented by Maj. M. Sliwinski (the specialist - Inspectorate of the Missile and Artillery Forces at the General Command of Branches of Armed Forces) the author of the article in the project of new shooting program for Artillery and Missile Forces.

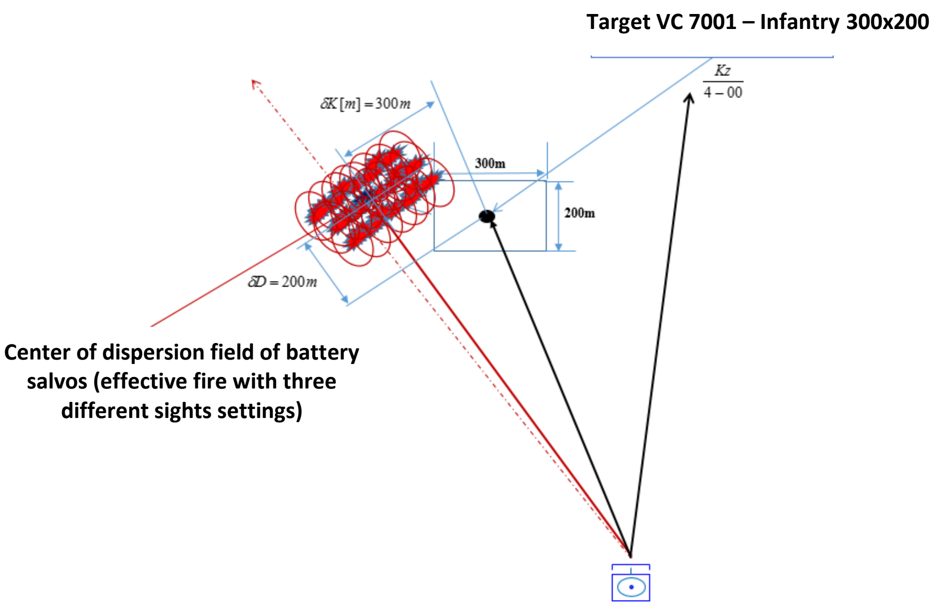


**Fig. 7.** Location of the center of a battery dispersion field in relation to the target center - deviation in range equal to the target depth and in azimuth to equal to the target width

*Source: own elaboration*

## Conclusions

The addressed issues of the artillery fire accuracy are to be considered as the contribution to the discussion in this field. The presented proposals of deviation standards in range and azimuth for the fire accuracy assessment, notwithstanding the method of settings determination and the type of the artillery equipment used for the task execution, ought to be also applied in the process of the assessment of the settings determination accuracy through their comparison during the trainings of individual shooting skills. The depicted recommendations must not be regarded as the ultimate ones but they may possibly inspire further and wider discussion on the subject. The instruction for shooting and fire control begins: "the firepower constitutes the basis for the combat operation of artillery. The fire effectiveness is obtained by its timeliness, accuracy and by appropriate selection of weapons systems and the methods of its execution as well as surprise fire"[9]. We, the artillerists should be always guided by those words cited while fulfilling all fire tasks.

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[9] Instrukcja strzelania i kierowania ogniem pododdzialow artylerii naziemnej, part. I: Dywizjon, bateria, pluton, dzialo; Sztab Generalny, Szefostwo Wojsk Rakietowych i Artylerii, Warsaw 1993, point 1.

**Conflict of interests**

The author declared no conflict of interests.

**Author contributions**

Author contributed to the interpretation of results and writing of the paper. Author read and approved the final manuscript.

**Ethical statement**

The research complies with all national and international ethical requirements.

**ORCID**

The author declared that he has no ORCID ID's

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