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Case study

Striking a target with indirect fire with no need for registration fire in rocket artillery – fire mission with solution

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ABSTRACT

The paper presents a method of solving a fire mission by rocket artillery subunits involving the determination of settings on the basis of complete data on firing conditions (predicted fire). This is the primary means of determining the settings for effective fire in rocket artillery. The paper describes how to: fill out a sheet of calculated corrections, draw up a chart of cumulative corrections, solve a geometric task using a calculator, use the chart of cumulative corrections to determine range and directional corrections and prepare a firing command. The article provides commentary and identifies the most common errors made at each stage of solving the mission.

KEYWORDS

rocket artillery, fire mission, full details of firing conditions

Introduction

The effective conduct of fire support by artillery requires a high level of knowledge and skill from commanders of all ranks. One can improve their skills by completing fire missions. The aim of this paper is to present subsequent actions to be performed by the person designated to execute firing mission No. 6 during the Individual Firing Skills Training (Polish: TIUS) as part of determining the settings on the basis of complete data on firing conditions (predicted fire). The scope of this article is to solve the fire mission without the use of ammunition within the Individual Firing Skills Training. The paper describes how to fill in a sheet of calculated corrections, how to draw up a chart of cumulative corrections, how to solve a geometric task using a calculator, how to use the chart of cumulative corrections to determine range and directional corrections and how to prepare a firing command.

Individual Firing Skills Training

The provision of effective and efficient fire support by the Artillery and Missile Forces (Polish: WRiA) requires the maintenance and improvement of individual firing skills. It is important to maintain realism during drills and firing. The following are carried out in the units and subunits of the Artillery and Missile Forces:

– tactical and special classes (Polish: zajęcia taktyczno-specjalne, ZT-S),
– tactical and special training (Polish: ćwiczenia taktyczno-specjalne, ĆT-S),
– artillery training [1, p. 11].

Artillery training is the systematic performance of specific activities aimed at achieving optimum efficiency in their execution by artillery commands, units and subunits and individual officers. Artillery training includes:

– individual firing skills training – conducted with individual officers of the unit (subunit) of the Artillery and Missile Forces,
– training in directing fire (Polish: TKO) – with units (subunits) of the Artillery and Missile Forces [1, p. 12].

Fire missions during the Individual Firing Skills Training are assessed in accordance with the conditions for the performance of fire missions specified in the *Exercise and Firing Programme of the Artillery and Missile Forces* (Polish: *Program ćwiczeń i strzelań Wojsk Rakietowych i Artylerii*) [1]. The grade for the completion of a firing mission by indirect fire (semi-direct fire) is given on the basis of the grades for the fulfilment of three conditions:

– the required working time during the execution of the fire mission,
– accuracy of settings for effective fire,
– instructional firing rules.

The grade for completing a fire mission is determined as follows:

– Excellent – if the working time of the firing mission and the accuracy of determination of the settings for effective fire are rated very well, and there is not more than one error in respect of the instructional firing rules.
– Good – if the working time of the firing mission and the accuracy of the settings for effective fire are rated at least well, and there are no more than two errors in respect of the instructional firing rules.
– Satisfactory – if the working time of the firing mission and the accuracy of the determination of the settings for effective fire are rated at least satisfactorily, and there are no more than three errors in respect of the instructional firing rules.

The start of the firing mission is considered to be the moment when the gunner acknowledges the command and declares "Roger that". The time spent preparing the means for determining the settings is not added to working time during the execution of the mission. The gunner's working time is the sum of the individual working times during the execution of the fire mission. First command time covers the time from the gunner's "Roger that" declaration until they give the entire firing command. Individual working times are measured from the explosion or observation until the gunner gives the next firing command. The last working time is counted from the end of effective fire until a command is given to record the settings. During training without firing live ammunition, the accuracy of determining the settings for effective fire is established by comparing the settings for effective fire (on aiming instruments) with the control data of the training supervisor [1, p. 49-50].

When conducting the Individual Firing Skills Training, errors in the application of the instructional firing rules during the execution of the fire mission include:

1) errors in determining the manner of firing at the target:
   a) firing with three batteries in an artillery squadron, each with a different sight setting (Polish: “strzelanie w nakładkę”) instead of firing at the target with different angles of elevation (Polish: “ostrzał celu z ustopniowaniem”) and vice versa,
   b) firing at the target without division into battery sections instead of with division into battery sections and vice versa,
   c) firing at the target with a single aiming setting instead of three and vice versa,
   d) firing at the target with a single deviation setting instead of two and vice versa,
   e) determining the sheaf with an error exceeding 0-02, stroke of the sight with an error greater than 25 m;
2) an error in determining the attrition of projectiles against a target if the determined attrition rate differs by more than 25% from the standard necessary to hit the target (from that specified in the command);
3) errors made during registration fire (and not due to incorrect observations) if the error in determining the correction is greater than 50 m in range and 0-05 in the direction;
4) errors made while engaging in effective fire:
   a) in range – greater than 25 m (50 m when shooting at targets of 100 m depth and above), and 1 Ug and above when demolishing,
   b) in direction – greater than 0-03,
   c) in the correction of the sheaf – greater than 0-02;
5) errors during the establishment of a secondary target:
   a) corrections based on registration fire were determined on the basis of three explosions,
   b) a secondary target was established more than 250 m in range and 0-25 in direction relative to the firing position from the commanded point of creation,
   c) systematic errors other than those referred to in point (3) is to be considered as one error [1, p. 51-52].

Striking a target with indirect fire with no need for registration fire in rocket artillery – fire mission No. 6

For rocket artillery, the conditions of fire mission No. 6 are as follows:

1. Target: any type of single or group target.
2. Determination of settings for effective fire: based on complete data on firing conditions (predicted fire), use of firing results.
3. Conditions for completing the fire mission:
   a) firing of fragmentation, fragmentation-explosive, cluster and precision-guided projectiles,
   b) the fire mission is carried out during destruction and incapacitation by a regiment (at least two divisions), a squadron, a battery, a support company, a platoon, or a single weapon,

c) the fire mission involving the preparation of barrage fire consists of determining the settings for the planned or indicated firing lines and opening fire on the permanent barrage firing lines,

d) arbitrary observation angle [1, p. 96].

In rocket artillery, firing at a target by indirect fire without registration fire is based on determining the firing settings by means of measurements and calculations: on the basis of complete data on firing conditions (predicted fire) (Polish: PDoWS). It is a basic way of determining settings that ensures the required accuracy (for rocket artillery $E_D \leq$ 60-70 m; $E_k \geq$ 5,000-10,000 [2, p. 209]) and resulting in surprising fire. The essence of determining settings on the basis of complete data on firing conditions is to measure the actual firing conditions, determine their deviations from the tabulated conditions and calculate corrections for these deviations to an accuracy that provides a specified probability of hitting the target.

Content of the fire mission

Striking a target with indirect fire with no need for registration fire (fire mission No. 6).

Battle formation:

2 bar (WIŚNIA) consisting of **8**×122 mm WR-40 assumed the following battle formation:

SO-21: 33U XS 44500 65090; Z = 100; T_{Kz} = 2 – 00

The commander of the rocket artillery squadron decided to determine the settings for effective fire on the basis of complete data on firing conditions (predicted fire) and ordered the actuary to calculate the corrections and draw up a sheet of calculated corrections (APO) for the 9M22U projectile with MRW-U fuse with MPH for the range: 11 km, 13 km, 15 km and directions: **T_{Kz}, T_{Kz} + 6, T_{Kz} – 6 – 00**.

The squadron is in possession of the following meteorological message: Meteo 1101-29100-0140-50563-0205-523704-0405-533804-0804-544004-1204-544004-1604-554105-2004-564205-2404-574306-3004-594507-4004-604507-5003-604507…

A meteorological post used a **WR-2M rifle-wind meter** with ZP-1 cartridges to determine the azimuth of the ballistic wind and the distance to the point of impact:

T_W = 35 – 00 D_P = 50 m

Command of the Squadron Leader (Chief of Staff):

"DUNAJ. Stop. Fire. Target VC 7114. BATTERY 360×200. Incapacitate.

33U XS 44500 79090; Z=150. All salvos complete. This is WISŁA"

Tasks to be completed as commander of the 2nd battery:

1) prior to the squadron leader's command, on the basis of ballistic and meteorological conditions:

a) draw up a sheet of calculated corrections (APO),

b) draw up a chart of cumulative corrections (Polish: WPS);

2) on the basis of the squadron leader's command:

a) identify topographical data for the target,

b) plot the target on the chart and measure corrections to the range and direction,

c) determine corrections to active trajectory section (Polish: AOT) and settings for effective fire against the VC 7114 target,

d) give the firing command.

Solution

A. Drawing up a sheet of calculated corrections (APO)

1) The following is to be entered in advance into the sheet:
   - latitude of the firing position (if necessary) or coordinates,
   - details concerning type of equipment, type of projectile, charge number, type of casing and type of fuse (in line 1),
   - charge temperature, altitude of directional artillery fire position (in line 2),
   - range to calculate corrections, vertices, input altitudes to the "meteoaverage" message and the sight (in line 7),
   - directions (topographic azimuths) to calculate corrections (in line 9).
2) After the determination of the deviations for ballistic firing conditions from the tabulated ones, the following procedure is followed:
   - enter the charge temperature in line 2, subtract 15° from it and obtain the deviation of the charge temperature from its table value, which is entered in lines 22, 29 and 36; moreover, an additional correction in range should be entered into the sheet,
   - for every range, enter the deviations of the ballistic firing conditions from the tabulated ones in rows 21-23, 28-30 and 35-37 to calculate the corrections, and the correction for rotation of the Earth and the correction for systematic deviation in rows 42-43,
   - calculate the range corrections and enter them in lines 21-23, 28-30 and 35-37,
   - add the corrections for range and enter the total in rows 25, 32 and 39 for each range.
3) Upon receipt of the "meteoaverage" message, proceed as follows:
   - enter into the sheet, in lines 3 to 6, the content of the "meteoaverage" message,
   - determine the difference in height between the meteorological station and the firing position (by subtracting the altitude of the firing position from the altitude of the station); after dividing the difference in altitude of the meteorological station and the firing position by the value of the barometric degree (in the case of the SO altitude up to 500 m – by 10) a correction for bringing the atmospheric pressure to the altitude of the firing position is obtained; enter the results in lines 14, 15 and 16; in these lines also enter the deviation of the atmospheric pressure at the level of the meteorological station and add to it the correction which will bring it to the altitude of the firing position,
   - enter the corresponding message groups in the line for each range on the basis of the input altitude Y_K,
   - determine the direction and speed of the wind, calculate the angle of the wind for each direction and each range and enter these data in lines 10 and 11,
   - determine, on the basis of the angle and speed of the wind, the longitudinal and transverse components of the wind for each range and each direction from a table of ballistic wind distribution and enter them in lines 13 and 14,
   - enter the deviations of the atmospheric pressure and temperature from their tabulated values in rows 14 to 17 for each of the ranges,
   - calculate the corrections for range and direction, with corrections for the longitudinal and transverse components of the wind to be determined and entered for each range and each direction (rows 13 and 14), and corrections for pressure and temperature deviations to be entered only once for each range in rows 14-17.
4) Add the directional corrections from lines 42 and 44 together and enter the sum of these corrections in lines 45, separately for each range and each direction.

Art-an/2

ARKUSZ OBLICZEŃ POPRAWEK ~~DYWIZJONU~~ (BATERII)

Szerokość geograficzna stanowisk ogniowych 51,1°N

Nr																					
1.	Rodzaj sprzętu **WR-40**	Rodzaj pocisku **9M22U**				Wariant balistyczny **MPH**				Rodzaj łuski….......................................				Rodzaj zapalnika **MRW-U**							
2.	~~$\Delta Vo_{sum\ dz\ kontr}$~~ = ...	~~δVo kontr dz kier ( )ba=~~ ~~δVo kontr dz kier ( )ba=~~ ~~δVo kontr dz kier ( )ba=~~				~~ΔV_{ol}..........ba=~~ ~~ΔV_{ol}..........ba=~~ ~~ΔV_{ol}..........ba=~~				~~ΔV_{op}.........ba=~~ ~~ΔV_{op}.........ba=~~ ~~ΔV_{op}.........ba=~~				~~t^0_{pr}..............ba=~~ t^0_{pr} 2 ba= **10°C** ~~t^0_{pr}..............ba=~~				~~Z_B..................ba=~~ Z_B 2 ba= **100 m** ~~Z_B..................ba=~~			
3.	Meteo **1101**	Yk	Δt⁰	Tw	W	Yk	Δt⁰	Tw	W	Yk	Δt⁰	Tw	W	Yk	Δt⁰	Tw	W	Yk	Δt⁰	Tw	W
4.	Data, godz. min. **29.01. 10.00**	02	**52**	**37**	**04**	12	**54**	**40**	**04**	24	**57**	**43**	**06**	50	**60**	**45**	**07**	10			
5.	Wysokość ASM(Z_M) **140 m**	04	**53**	**38**	**04**	16	**55**	**41**	**05**	30	**59**	**45**	**07**	60	**60**	**45**	**07**	12			
6.	Δh, Δt^0 **-5 mmHg, -13°C (50563)**	08	**54**	**40**	**04**	20	**56**	**42**	**05**	40	**60**	**45**	**07**	80	**60**	**45**	**07**	14			

Nr																
7.	Donośność (km). Wierzchołkowa. Wysokość wejściowa do komunikatu. Celownik.	D_0= 11	Y =1080 / Y_k= 1500		C = 326		D_0= 13	Y =1930 / Y_k= 2700		C = 436		D_0= 15	Y = 3420 / Y_k= 4800		C = 601	
8.	Grupa komunikatu.	X	X	**1604-554105**			X	X	**(2704)-584407**			X	X	**5003-604507**		
9.	Kierunek strzelania (Ts)	X	X	**56**	**2**	**8**	X	X	**56**	**2**	**8**	X	X	**56**	**2**	**8**
10.	Kierunek (Tw) i prędkość wiatru (W)	X	X	**41**		**5**	X	X	**44**		**7**	X	X	**45**		**7**
11.	Kąt wiatru (Kw = Ts – Tw)	X	X	**15**	**21**	**27**	X	X	**12**	**18**	**24**	X	X	**11**	**17**	**23**
12.	POPRAWKI	Popr. tabel.	Odchyłki warunków strzelania od tabela-rycznych	X	X	X	Popr. tabel.	Odchyłki warunków strzelania od tabela-rycznych	X	X	X	Popr. tabel.	Odchyłki warunków strzelania od tabela-rycznych	X	X	X
13.	meteorologiczne – na podłużną składową wiatru	0,1ΔXw	**0**	**0**	X	X	0,1ΔXw	**-2**	**+56,8**	X	X	0,1ΔXw	**-3**	**+118,5**	X	X
			3	X	**-59,1**	X		**+2**	X	**-56,8**	X		**+1**	X	**-39,5**	X
		-19,7	**5**	X	X	**-98,5**	**-28,4**	**+6**	X	X	**-170**	**-39,5**	**+5**	X	X	**-197,5**
14.	na odchyłkę ciśnienia i temperatury powietrza: ~~.... ba~~ ~~$\Delta h_{SO} = \Delta h_M + \frac{Z_M - Z_B}{10}$~~	$0,1\Delta X_h$					$0,1\Delta X_h$					$0,1\Delta X_h$				
15.	2 ba $\Delta h_{SO} = \Delta h_M + \frac{Z_M - Z_B}{10}$		**+9**	**+71,1**				**+9**	**+87,3**				**+9**	**+108**		
16.	~~.... ba~~ ~~$\Delta h_{SO} = \Delta h_M + \frac{Z_M - Z_B}{10}$~~	**+7,9**					**+9,7**					**+12**				
17.	na temperaturę powietrza	0,1ΔXt° **-16,5**	**-5**	**+82,5**			0,1ΔXt° **-21,2**	**-8**	**+169,6**			0,1ΔXt° **-25**	**-10**	**+250**		
18.	Suma poprawek meteorologicznych donośności (ΔDm): ~~........... ba~~	X	X				X	X				X	X			
19.	2 ba	X	X	**+154**	**+95**	**+55**	X	X	**+314**	**+200**	**+87**	X	X	**+477**	**+319**	**+161**
20.	~~........... ba~~	X	X				X	X				X	X			
21.	~~na odchyłkę~~ ~~$\Delta V_{0sum} = \Delta V_{0sum\ dz\ kontr} + \delta Vo^{kontr}_{dz\ kier} + \Delta V_{0l} + \Delta V_{0p}$~~	~~ΔX_{Vo}~~					~~ΔX_{Vo}~~					~~ΔX_{Vo}~~				
22.	~~$\Delta t^o_{pr} = t^o_{pr} - 15^0C$~~	~~$0,1\Delta Xt^o_{pr}$~~					~~$0,1\Delta Xt^o_{pr}$~~					~~$0,1\Delta Xt^o_{pr}$~~				
23.	...e i sumaryczne ~~.... baterii~~ – ~~na malowanie pocisku~~															

No.	Group	Subgroup	Item	I-A	I-B	I-1	I-2	I-3	II-A	II-B	II-1	II-2	II-3	III-A	III-B	III-1	III-2	III-3
24.	donośności	~~balistyczne~~																
25.			~~Suma poprawek balistycznych (ΔD_b)~~															
26.			~~Popr. sum. ($\Delta D_{sum} = \Delta D_m + \Delta D_b$)~~															
27.			~~Odległości topograficzne do sporządzenia wykresu $D_T = D_o - \Delta D_{sum}$~~															
28.		balistyczne i sumaryczne 2 baterii / na odchyłkę	~~$\Delta V_{0sum} = \Delta V_{0sum\ dz\ kontr} + \delta Vo^{kontr}_{dz\ kier} + \Delta V_{0l} + \Delta V_{0p}$~~	~~ΔX_{Vo}~~					~~ΔX_{Vo}~~					~~ΔX_{Vo}~~				
29.			$\Delta t^o_{pr} = t^o_{pr} - 15^0C$	$0{,}1\Delta X_{tpr}^{0}$ -14,3	-5	+71,5			$0{,}1\Delta X_{tpr}^{0}$ -12	-5	+60			$0{,}1\Delta X_{tpr}^{0}$ -9,4	-5	+47		
30.			~~na malowanie pocisku~~															
31.			Dodatkowa pop. donośności			0					0					0		
32.			Suma poprawek balistycznych (ΔD_b)			+71,5					+60					+47		
33.			Popr. sum. ($\Delta D_{sum} = \Delta D_m + \Delta D_b$)			+226	+167	+127			+373	+260	+147			+524	+366	+208
34.			Odległości topograficzne do sporządzenia wykresu $D_T = D_o - \Delta D_{sum}$			10774 / 10800	10833 / 10800	10873 / 10900			12626 / 12600	12740 / 12700	12853 / 12900			14476 / 14500	14634 / 14600	14792 / 14800
35.		~~balistyczne i sumaryczne~~ ..... ~~baterii~~ / ~~na odchyłkę~~	~~$\Delta V_{0sum} = \Delta V_{0sum\ dz\ kontr} + \delta Vo^{kontr}_{dz\ kier} + \Delta V_{0l} + \Delta V_{0p}$~~	~~ΔX_{Vo}~~					~~ΔX_{Vo}~~					~~ΔX_{Vo}~~				
36.			~~$\Delta t^o_{pr} = t^o_{pr} - 15^0C$~~	~~$0{,}1\Delta Xt^o_{pr}$~~					~~$0{,}1\Delta Xt^o_{pr}$~~					~~$0{,}1\Delta Xt^o_{pr}$~~				
37.			~~na malowanie pocisku~~															
38.																		
39.			~~Suma poprawek balistycznych (ΔD_b)~~															
40.			~~Popr. sum. ($\Delta D_{sum} = \Delta D_m + \Delta D_b$)~~															
41.			~~Odległości topograficzne do sporządzenia wykresu $D_T = D_o - \Delta D_{sum}$~~															
42.	kierunku		na obrót ziemi															
43.			uchylenie systematyczne			+0-04					+0-04					+0-04		
44.			na poprzeczną składową wiatru	$0{,}1\Delta Z_w$ -1,1	+5 / +4 / +2	-5,5	-4,4	-2,2	$0{,}1\Delta Z_w$ -1,3	+7 / +7 / +4	-9,1	-9,1	-5,2	$0{,}1\Delta Z_w$ -1,6	+6 / +7 / +5	-9,6	-11,2	-8
45.			Suma poprawek kierunku (ΔK)			-0-02	0-00	+0-02			-0-05	-0-05	-0-01			-0-06	-0-07	-0-04

Obliczył .... Sprawdził ....

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Fig. 1. Sheet of calculated corrections for 2 bar
Source: Author's own elaboration on the basis of [3, p. 202-204].

5) Add up the range corrections for the deviations of meteorological and ballistic firing conditions from the tabulated ones to obtain the cumulative corrections (lines 26, 33 and 40).
6) Subtract the corresponding summed range corrections from the range taken for the calculation of the corrections to obtain the topographic distances for drawing up the chart of the calculated corrections (lines 27, 34, 41) [3, p. 202-204].

Figure 1 shows a completed sheet of calculated corrections for 2 rocket artillery batteries. It is important to highlight the inclusion of an additional range correction for the ballistic properties of the projectile (line 31) and a directional correction for systematic deviation (line 43). In the present case: the missile index 9M22U, the fuse MRW-U with index 9E244 and the MPH ballistic properties are tabulated hence the value of the range correction equals 0 [4, p. 29]. However, when firing M-210F missiles, the directional correction for systematic deviation is +0-04 [5, p. 22]. Some of the most common mistakes made when filling out the calculated corrections sheet include:

– using the directional correction for the lateral component of the ballistic wind on the active trajectory section $\left(\Delta Z_{W_{az}}\right)$ instead of the directional correction for the lateral component of the ballistic wind on the passive trajectory section $\left(\Delta Z_{W_{bz}}\right)$,
– using the aiming correction for the longitudinal component of the ballistic wind on the active trajectory section $\left(\Delta C_{W_{ax}}\right)$ instead of the range correction for the longitudinal component of the ballistic wind on the passive trajectory section $\left(\Delta X_{W_{bx}}\right)$,
– using the range correction for the temperature deviation of the load ($\Delta X^{\circ}_{t\,pr}$), if the deviation is negative, replace it by a positive one and vice versa,
– adding, instead of subtracting, the corresponding summation of corrections to the ranges in order to calculate the topographic distance needed to draw up the calculated corrections plot.

In order to make it easier to draw up a chart of cumulative corrections, it is advisable to create a table, which aggregates the most important information from the sheet (Table 1). Preparation of a summary in the form of a table (Table 1) is not necessary but it definitely makes the work easier later on when preparing the chart of cumulative corrections. The table reduces the possibility of making a mistake of reading the wrong value directly from the sheet of calculated corrections (APO).

Table 1. Table of results of corrections calculated for WR-40 9M22U projectile MRW-U fuse MPH

D_0	11			13			15		
T_S	56-00	2-00	8-00	56-00	2-00	8-00	56-00	2-00	8-00
D_T	10800	10800	10900	12600	12700	12900	14500	14600	14800
ΔD	+226	+167	+127	+374	+260	+147	+524	+366	+208
ΔK	-0-02	0-00	+0-02	-0-05	-0-05	-0-01	-0-06	-0-07	-0-04

Source: Authors' own elaboration.

B. Drawing up the chart of cumulative corrections (WPS)

1. To create the chart (WPS) on the graph paper, a coordinate system is drawn up with its positive semi-axes. The horizontal semi-axis corresponds to the topographic distances (D_T), while the vertical semi-axis corresponds to the range corrections (ΔD_S).

2. The scale of the vertical semi-axis (ΔD_S) is chosen based on the values of cumulative corrections so that the value of the actual scale interval is: 10 m. The scale of the horizontal semi-axis (D_T) is selected based on the topographic distances so that the value of the actual scale interval is: 50 m or 100 m.
3. The chart of cumulative corrections is prepared by assigning the corresponding cumulative corrections (range and direction) to topographic distances (rounded to the nearest 100 m). The points on the graph paper are connected with a line. The scale of the direction corrections is created by interpolating on the sections between the points.

Chart of cumulative corrections
2 bar 122 mm WR-40 LANGUSTA. 10:00 29.01.2021
9M22U MRW-U fuse MPH

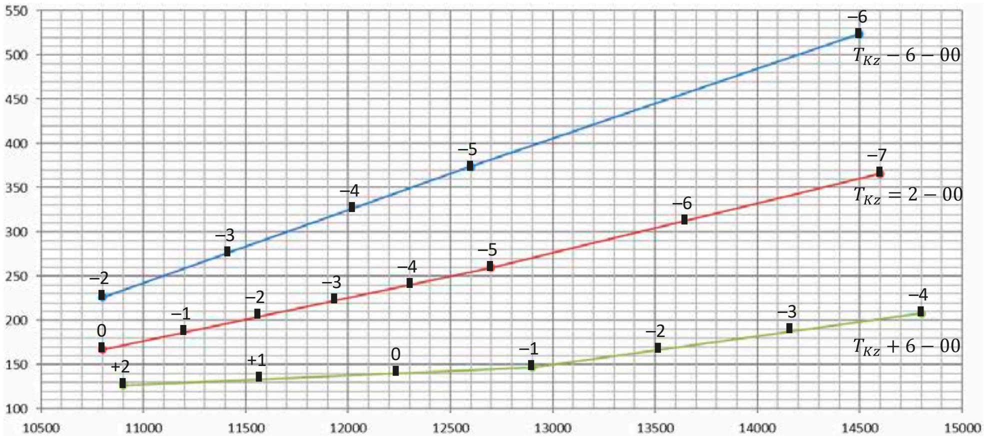

Fig. 2. Chart of cumulative corrections for 2 bar
Source: Author's own elaboration.

The most common mistakes during the preparation of the chart:

– incomplete description of the chart (no time and date of the meteorological report, no ballistic wind variant),
– incorrect scaling of semi-axis, e.g. the actual scale interval of 33 m,
– failure to determine corrections of direction along the entire length of the chart.

C. Failure to determine the topographic data of the target

To determine the topographic data for the target a geometric problem needs to be solved. The solution of the geometric problem is a linear and angular relationship in the horizontal and vertical planes of the directional launcher of the battery (platoon) or each launcher and the target. The input data necessary to determine the relationship are the rectangular plane coordinates and the altitude of the directional launcher of the battery (platoon) or each launcher and the centre of the target (shooting targets of individual guns) [6, p. 22]. The geometric problem can be solved:

1) in analytical way, with the use of:
   – calculator with trigonometric functions,
   – calculator and a table to determine the coordinates (*sec(t)* and *tg(t)*),
   – logarithm tables,

– "SKART" and "UKART" artillery calculator,
– calculator, a computer with a programme that calculates topographical and other data;

2) in descriptive way, with the use of:
– fire control instrument (Polish: PKO),
– PA-1 artillery converter and map,
– compass and a composite scale.

When conducting Individual Firing Skills Training (Polish: TIUS), it is most reasonable to solve geometric problems with the use of PKO For the purposes of this paper, an analytical method was applied and a trigonometric functions calculator was used as well as the formulas in the *Manual of Geodetic Leveling* [7, p. 86-90]. To calculate the topographic distance to the target and the topographic angle of transmission to the target from the principal direction knowing the rectangular plane coordinates of SO and the target, the inverse geodesic problem needs to be solved (Polish: ZGO). If polar data from an observation point is known, the direct geodetic problem needs to be solved first and the rectangular plane coordinates of the target must be determined. The coordinates of the target are known, so the ZGO should be calculated according to the following procedure:

1) Calculating of the fourth-quadrant tangent t_{SO-C} with the use of the formula:

$$tg \times t_{SO-C} = \frac{E_C - E_{SO}}{N_C - N_{SO}} = \frac{\Delta E_{SO-C}}{\Delta N_{SO-C}} \tag{1}$$

where:

E_C (E_{SO}) – Eastern coordinate of target (fire position),
N_C (N_{SO}) – Northern coordinate of target (fire position).

$$tg \times t_{SO-C} = \frac{44500 - 44500}{79090 - 65090} = \frac{0}{14000}$$

2) Determining the value of the fourth-quadrant t_{SO-C} after transforming the formula (1):

$$t_{SO-C} = \text{arc tg} \frac{\Delta E_{SO-C}}{\Delta N_{SO-C}} \tag{2}$$

It should be noted that the obtained arctan is in degrees and to convert the number into thousandths it should be divided by 0.06.

$$t_{SO-C} = \text{arc tg} \frac{0}{14000} = 0° = \frac{0°}{0.06} = 0 - 00$$

3) Conversion of fourth-quadrant t_{SO-C} to topographic azimuth T_{SO-C} taking into account the symbols of coordinate increments:

$$\Delta E_{SO-C} > 0,\ \Delta N_{SO-C} > 0 \rightarrow T_{SO-C} = t_{SO-C}$$

$$\Delta E_{SO-C} > 0,\ \Delta N_{SO-C} < 0 \rightarrow T_{SO-C} = 30 - 00 - t_{SO-C}$$

$$\Delta E_{SO-C} < 0,\ \Delta N_{SO-C} < 0 \rightarrow T_{SO-C} = 30 - 00 + t_{SO-C}$$

$$\Delta E_{SO-C} < 0,\ \Delta N_{SO-C} > 0 \rightarrow T_{SO-C} = 60 - 00 - t_{SO-C}$$

In special cases where:

a) $\Delta E_{SO-C} = 0$ the target is moved away from SO only to the north ($\Delta N_{SO-C} > 0 \rightarrow T_{SO-C} = 0 - 00$) or south ($\Delta N_{SO-C} < 0 \rightarrow T_{SO-C} = 30 - 00$),

b) $\Delta N_{SO-C} = 0$ the target is moved away from SO only to east ($\Delta E_{SO-C} > 0 \rightarrow T_{SO-C} = 15 - 00$) or west ($\Delta E < 0 \rightarrow T_{SO-C} = 45 - 00$).

$$\Delta E_{SO-C} = 0\ i\ \Delta N_{SO-C} = 14000\ (\Delta N_{SO-C} > 0) \rightarrow T_{SO-C} = 0 - 00$$

4) The calculation of the topographic distance to the target is done with the use of one of the formulas:

$$D_T^C = \frac{\Delta E_{SO-C}}{\sin t_{SO-C}} \quad (3)$$

$$D_T^C = \frac{\Delta N_{SO-C}}{\cos t_{SO-C}} \quad (4)$$

$$D_T^C = \sqrt{\Delta E_{SO-C}{}^2 + \Delta N_{SO-C}{}^2} \quad (5)$$

Formula (3) is used when t_{SO-C} is close to $90°$ $(15-00)$, and formula (4) is used when t_{SO-C} is close to $0°$ $(0-00)$. Also, it needs to be remembered to convert thousandths into degrees while using formulas (3) and (4). There are no such restrictions with regards to formula (5).

$$D_T^C = \sqrt{0^2 + 14000^2} = 14000 \text{ m}$$

To convert topographic azimuth T_{SO-C} into topographic transfer angle to the target from the principal direction $kp_t^c(Kz)$, the formula [3, p. 57] should be used:

$$kp_t^c(Kz) = T_{SO-C} - T_{Kz} \quad (6)$$

$$kp_t^c(Kz) = 0-00-2-00 = -2-00$$

While solving the geometric problem, it is also necessary to find the relationship between SO and the target in the vertical plane. The difference between the height of the target and the firing position is calculated with the use of the formula [8, p. 89]:

$$\Delta Z = Z_C - Z_{SO} \quad (7)$$

where:

$Z_C(Z_{SO})$ – the altitude of the target (fire station/battalion)

$$\Delta Z = 150 - 100 = +50\ m$$

In the case of flat shooting and plunging fire (elevation angle less than 45°) the target position angle should also be calculated with the use of a formula created based on the opening angle formula [8, p. 89]:

$$p = \frac{\Delta Z}{0.001 \times D_T^C} \times 0.95 \quad (8)$$

$$p = \frac{+50}{14} \times 0.95 = +3.39 \approx +0-03$$

The geometric solution resulted in the following values:

$D_T^C = 14000$ $\Delta Z = +50$ $kp_t^c(Kz) = -2-00$

$p = +3$

D. Plotting of the target on the chart and determination of the corrections to the range and direction

In order to determine the range (ΔD_O^C) and directional (ΔK_O^C) corrections with the use of the cumulative correction chart it is necessary, after the determination of the topographic data, to:

1) plot a line perpendicular to the chart line from the point corresponding to the topographic distance from the target,
2) mark the target on the perpendicular where it intersects with the chart for the corresponding direction or determine the corresponding place by interpolation between the directions,

3) plot the intersection of the perpendicular with the line of the chart on the axis of the corrections of range and read the correction calculated for the target,
4) read the calculated directional correction to the target from the line of the chart (if the chart is plotted for 2-3 directions, read the directional correction by interpolation).

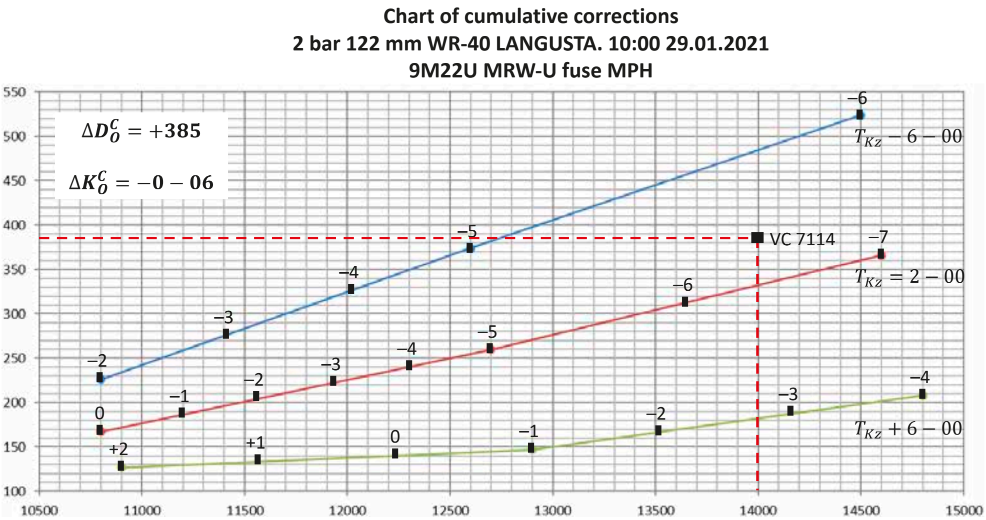

Fig. 3. Target plotted on the chart of cumulative corrections for 2 bar
Source: Author's own elaboration.

As a result of the determination of the range and directional corrections, the process of solving the ballistic mission begins. Add the range correction to the topographic distance to the target and the directional correction to the topographic angle of transmission to the target from the principal direction. After adding up the respective values, the indirect target range and the indirect angle of transmission to the target (D_P^C) from the principal direction are obtained ($kp_p^c(Kz)$). Subsequently, based on the D_P^C derived from the firing tables [9, p. 42], the intermediate sight for the target is determined (C_P^C). In the final step, the value of the correction of the sight on the angle of the target (ΔC) must be read on the basis of C_P^C and p from the firing tables [9, p. 51]. After summing p and ΔC one obtains the correction of the elevation angle on the difference in height of the target and the firing position ($\Delta\varphi$). The final step in solving the ballistic mission is to determine the intermediate elevation angle to the (φ_P^C) target by summing C_P^C with $\Delta\varphi$. A structured form of the above and subsequent calculations is the setting determination scheme [5, p. 31; 10, p. 45].

$D_T^C = 14000$	$\Delta Z = +50$	$kp_t^c(Kz) = -2-00$
$\Delta D_O^C = +385$	$p = +3$	$\Delta K_O^C = -0-06$
$D_P^C = 14385$	$\Delta C = +1$	$kp_p^c(Kz) = -2-06$
$C_P^C = 541 - \frac{15}{11} = 540$	$\Delta\varphi = +4$	
$\varphi_P^C = 540 + 4 = 544$		

E. Determination of corrections to the active trajectory section and settings for effective fire against the VC 7114 target

During the preparation of rocket artillery firing, wind data on the active trajectory section of the rocket projectile are to be additionally determined and taken into account. These data are determined by the battery meteorological stations on the basis of wind measurements by appropriate technical means (rifle-wind meter, field wind meter). On the basis of the wind parameters measured by the meteorological station, the ballistic wind data (speed and azimuth of the direction from which the wind is blowing) in the active trajectory interval are calculated and then used to determine the calculated firing settings. Due to the significant influence of wind on the flight of missiles in the active trajectory interval and the large variations of wind parameters in the ground layer of the atmosphere associated with the passage of time and increasing distance, measurements are made directly at the fire position prior to firing. The time of validity of wind data in the active trajectory interval generally does not exceed 15 minutes after the measurements have been completed [11, p. 58-59]. When the ballistic wind data on the AOT was determined using a rifle-wind meter taking into account the complex effect of ballistic wind, sight adjustments (ΔC_A) and direction (ΔK_A) are calculated according to formula (9) and (10) [5, p. 30]:

$$\Delta C_A = (0.1 \times \Delta C_{W_{ax}} \times W_{ax}) \times (0.1 \times \Delta C_{W_{az}} \times W_{az}) \tag{9}$$

$$\Delta K_A = (0.1 \times \Delta Z_{W_{ax}} \times W_{ax}) \times (0.1 \times \Delta Z_{W_{az}} \times W_{az}) \tag{10}$$

If the data of ballistic wind at AOT is determined using a field wind meter, the adjustments are calculated according to formula (11) and (12) [5, p. 30]:

$$\Delta C_A = 0.1 \times \Delta C_{W_{ax}} \times W_{ax} \tag{11}$$

$$\Delta K_A = 0.1 \times \Delta Z_{W_{az}} \times W_{az} \tag{12}$$

where:

W_{ax} – longitudinal component of ballistic wind at AOT,
W_{az} – transverse component of ballistic wind at AOT,
$\Delta C_{W_{ax}}$ – adjustment of the sight for longitudinal component of ballistic wind at AOT,
$\Delta C_{W_{az}}$ – adjustment of the sight for transverse component of ballistic wind at AOT,
$\Delta Z_{W_{ax}}$ – correction of direction for the longitudinal component of the ballistic wind at AOT,
$\Delta Z_{W_{az}}$ – correction of direction for the transverse component of the ballistic wind has AOT.

The above adjustments of the sight and direction in the case of the active trajectory section (Polish: AOT) are calculated using shooting tables for the range corresponding to the intermediate angle of elevation (φ_P^C). In the article, a case with the use of a rifle-wind meter is analysed. To calculate the adjustments it is necessary to:

1) calculate the wind angle (K_w) using the formula:

$$K_w = T_S - T_w \tag{13}$$

where:

T_S – topographic shooting azimuth,
T_w – topographic wind azimuth,

2) based on D_P^C determine the altitude of the active section of the track using shooting tables (Y_a),
3) based on Y_a, type of bullet and the distance from the rifle-wind meter to the average point of projectile drops of bullets (D_p), determine the speed of the ballistic wind (W_a),
4) based on K_w and W_a determine the longitudinal (W_{ax}) and transverse (W_{az}) component of the wind,
5) with the use of formulas (9) and (10), calculate the sight and direction adjustment for AOT.

The procedure to solve the case from the article is as follows:

1) $K_w = 0 - 00 - 35 - 00 + (60 - 00) = 25 - 00$
2) $D_P^C = 14385 \rightarrow TS\ s. 42 \rightarrow Y_a = 309$
3) $Y_a = 309\ i\ D_P = 50 \rightarrow TS\ s. 95 \rightarrow W_a \approx 4\ \mathrm{m/s}$
4) $TS\ s. 72 - 73 \rightarrow W_{ax} = +3; W_{az} = +2$
5) $\Delta C_A = (0.1 \times -29.8 \times +3) + (0.1 \times -9.2 \times +2) = -11$
6) $\Delta K_A = (0.1 \times -5 \times +3) + (0.1 \times +58 \times +2) = +0\ -10$

While completing the process of determining the settings, the scheme to determine the settings should be supplemented with:

– the calculated angle of elevation (φ_O^C), which is the sum of φ_P^C and ΔC_A.
– the calculated angle of transmission to the target from the principal direction ($kp_o^c(Kz)$), which is the sum of $kp_p^c(Kz)$ and ΔK_A.

Determination of settings:

$\varphi_o^c = 544 - 11 = 533$ $\qquad$ $kp_o^c(Kz) = -2 - 06 + 0\ -10 = -1\ -96$

F. Firing command

The commander's firing command, in addition to the angle of elevation and the angle of transmission, includes the method of firing at the target (fire distribution parameters):

– number of sight settings,
– sight movement,
– value of sheaf distance,
– number of yaw settings,
– number of used bullets.

Considering the performance of a fire mission by rocket artillery, the following should be taken into account:

– battery while performing fire mission independently fires at one sight and deviation setting,
– the beam is determined as convergent when shooting at targets with a width of up to 400 m [3, p. 155-156].

Taking the above into account, the parameters of the fire distribution to perform the fire mission will be as follows:

– number of sight settings: one,
– sight movement: none,

– value of sheaf distance: converged sheaf,
– number of deviation settings: one,
– number of used bullets: volley.

The firing command for the fire mission is as follows: "*Battery. Stop. Target VC 7114. BATTERY. MPH. Scale to thousandths. Sight 533. Principal direction -1-96. Converged sheaf. Fire!*"

Conclusions

Solving fire missions independently helps in developing skills and allows you to put your artillery knowledge into practice. The training format additionally allows for the testing and evaluation of knowledge and skills. The paper discusses an example of a fire mission performed by rocket artillery involving the determination of settings on the basis of full data on the firing conditions (predicted fire). It is a way of guaranteeing adequate accuracy of fire and surprise. In addition, it does not reveal the order of battle in the same way as, for example, registration fire. To sum up the considerations, it is necessary to indicate the most frequent errors that occur during the execution of fire mission No. 6 with rocket artillery:

– incorrect use of firing tables (wrong ballistic variant, reading values from the wrong column or for the wrong range),
– failure to convert or wrong conversion of thousandths to degrees and vice versa,
– incorrect execution of the diagram (gaps in the description, incorrect scaling).

The paper is a starting point for a discussion on solving fire missions. The study helps in preparation for the Individual Firing Skills Training and enables self-improvement.

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Conflict of interests

The author declared no conflict of interests.

Author contributions

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

Ethical statement

The research complies with all national and international ethical requirements.

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Biographical note

Adrian Golonka – holder of teaching and teaching and scientific positions at the Military University of Land Forces since 2012. He is currently an assistant professor at the Artillery and Missile Forces Unit. The areas of his research investigations include innovations in energetics and the use of artillery on the modern battlefield.

Rażenie celu ogniem pośrednim bez wstrzeliwania w artylerii rakietowej – zadanie z rozwiązaniem

STRESZCZENIE W artykule przedstawiono sposób rozwiązania zadania ogniowego przez pododdziały artylerii rakietowej polegającego na określeniu nastaw na podstawie pełnych danych o warunkach strzelania. Jest to podstawowy sposób określania nastaw do ognia skutecznego w artylerii rakietowej. Artykuł zawiera opis sposobu: wypełnienia arkusza poprawek obliczonych, sporządzenia wykresu poprawek sumarycznych, rozwiązania zadania geometrycznego z wykorzystaniem kalkulatora, wykorzystania wykresu poprawek sumarycznych do określenia poprawek donośności i kierunku oraz opracowania komendy ogniowej. W artykule zawarto komentarz oraz wskazano najczęściej popełniane błędy na każdym etapie rozwiązania zadania.

SŁOWA KLUCZOWE artyleria rakietowa, zadanie ogniowe, pełne dane o warunkach strzelania

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