JOURNAL OF SCIENCE OF THE MILITARY ACADEMY OF LAND FORCES

Volume 47 Number 2 (176) 2015

DOI: 10.5604/17318157.1216088

SELECTED PROBLEMS IN COMPLETING THE TASKS RELATED TO THE TECHNICAL PREPARATION OF MORTARS

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Received on 15 August 2014; accepted after revision in January 2015

Abstract:

The article presents the problems encountered while completing the tasks related to the technical preparation of mortars. The first part describes the binding rules applied to determine the zero settings of the sight and the zero line of sight, and to check and define adjustments for the line of sight deviation. The paper presents a practical solution making it possible to verify quickly whether the determined zero settings are correct. The next part focuses on significant problems related to the determination of individual adjustments in subunits equipped with mortars. The final part contains a summary, conclusions drawn from the analysis and experience gained in practice during firing, and also the proposal of relevant solutions.

***Key words**:*

mortars, individual adjustments of mortars, technical preparation

INTRODUCTION

One of the most difficult tasks charged to the contemporary artillery is to ensure the accuracy of artillery fire support. In order to achieve the high accuracy of fire for effect it is necessary to complete the tasks related to the preparation for firing and directing fire to the maximum possible extent. The technical preparation for firing, as one of the elements of preparation for firing and directing fire, is often underestimated. The most important element of technical preparation is the preparation of mortars for firing. It is performed before the firing takes place, whereas during the firing the operation of mechanisms is observed to detect and eliminate any defects in accordance with the provisions of the operating instructions for a given equipment type. The preparation of mortars for firing includes:

– general inspection of mortars;

– checking the operation of mechanisms;
– checking the aiming devices;
– determination of individual adjustments of a mortar[1].

The checking of mortar aiming devices consists in:

– checking the zeroing of the sight;
– checking the zero line of sight;
– checking and defining adjustments for the line of sight deviation.

Both 120 mm M-120 and 98 mm M-98 mortars are equipped with the same type of the sight, MPM-44 (MPM-44M). Sights are calibrated in scale divisions, and not in mils, because the sight setting of 7-50 does not correspond to the angle of elevation of the tube of 7-50 (45º). However, a change in the angle of elevation by means of a quadrant by one mil (0-01) corresponds to a change in the sight setting, with the bubble level of the sight centred, by one scale division.

Unlike in guns, in the case of mortars the larger is the angle of elevation of the tube, the smaller is the setting of the sight. When the zero settings are determined, the angle of elevation of the tube measured on the reference flat by means of a quadrant totals 7-50 (45º), which corresponds to the sight setting of 10-00. Therefore, irrespective of the angle of elevation of the tube, the total of the sight setting and the value read from the quadrant should always be 17-50. The sight setting as a function of the angle of elevation of the tube measured with the use of a quadrant is presented in Figure 1.

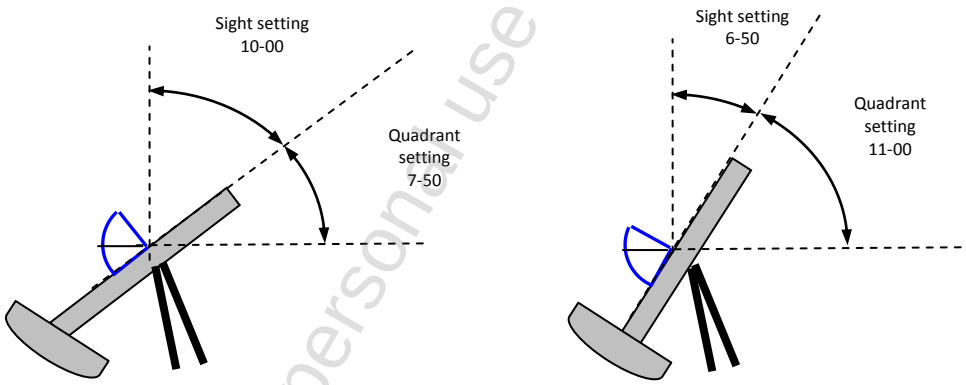

Fig. 1. MPM-44 sight setting as a function of the angle of elevation of the tube measured with the use of a gunner's quadrant
Source: Own work

This dependence can be used when the battery officer has to verify the correctness of the zeroing. The angle of elevation of the tube can be calculated by applying the following formula:

[1] *Instrukcja* strzelania i kierowania ogniem pododdziałów artylerii naziemnej, cz. I: Dywizjon, bateria, pluton, działo; *Sztab Generalny, Szefostwo Wojsk Rakietowych i Artylerii, Warszawa 1993, item 56, p. 30.*

$$\varphi_K = (17-50) - C_O^C \quad (1)$$

where:

φ_K - the angle of elevation of the tube [mil] (quadrant setting);

C_O^C - the sight calculated for a target.

Example 1.

The mortar commander reported the sight setting of the mortar, after levelling, on a target, which totalled 6-80. Calculate the required angle of elevation of the tube, determined by means of a quadrant on the reference flat of the mortar.

Solution:

From the value of 17-50 the value of the sight of the aimed mortar should be deducted and, thus, the appropriate setting of the quadrant will be obtained.

$$\varphi_K = (17-50) - (6-80) = 10-70$$

The appropriate angle of elevation of the tube, indicated by means of a quadrant, should total 10-70. If the verification of the zeroing is carried out correctly, this value will not exceed +/- 0-01. Otherwise, the zeroing should be verified once again.

In subunits equipped with M-98 and M-120 model 38 and model 43 mortars the zero settings and the zero line of sight are determined for sight 10-00. The instruction "*Opis i użytkowanie 120 mm moździerzy wz.38 i wz.4.*" (the description and operation of 120 mm mortars, models 38 and 4)[2] contains the detailed information about the distance between the bipod to be mounted and the pivot of the mortar breechblock. This information is very important for defining the direction adjustments for the line of sight deviation and when fire missions are carried out. The determination of direction adjustments for the line of sight deviation is carried out for the consecutive settings of the angle of elevation, every 100 mil (according to the sight) from zero to the highest value and the other way round[3]. Concurrently, attention should be paid to the fact that along with extending the elevation mechanism, there is an increase in the value of a direction adjustment for the line of sight deviation, which has to be taken into account when the mortar settings on a target are determined. The opinions expressed by commanders of mortar platoons and the authors' many years of artillery practice in operating various types of mortars show that its value may amount even to 0-10 in direction.

When individual adjustments of mortars are determined, after the zero settings and the zero line of sight have been verified for the value of 10-00, there is a possibility of elevating the tube without repositioning the bipod only up to the value of about 7-50 (Fig. 2). It means that the determination of individual adjustments of a mortar has to be carried out in two stages. In the first stage adjustments within the range of sight

[2] *Opis i użytkowanie moździerzy wz.38 i wz.43.MON, Warszawa p. 89.*

[3] *Instrukcja artylerii Działoczyny artylerii naziemnej, DWLąd., SWRiA, Warszawa 2007, p. 152-153.*

angles from 10-00 to 7-50 are determined and in the second stage, after repositioning the bipod, within the range of angles from 7-50 to the lowest value of the sight.

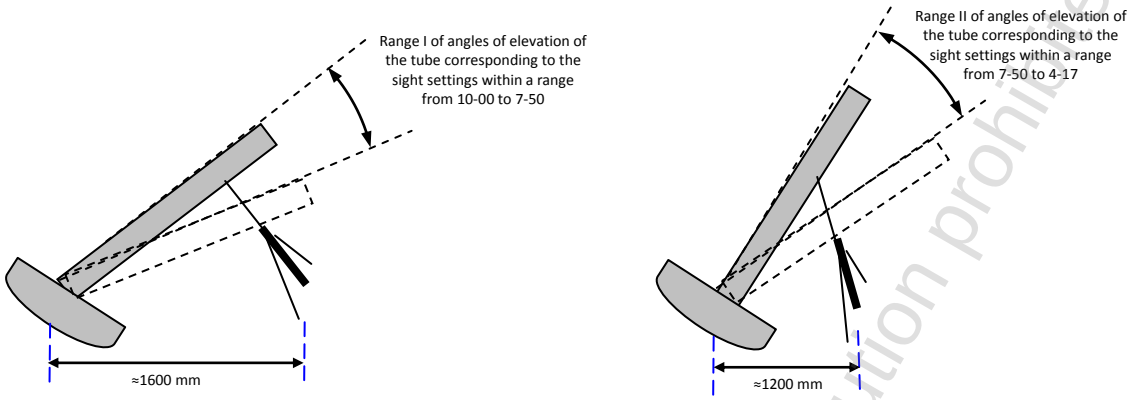

Fig. 2. Ranges of angles of elevation of the tube appropriate for respective distances between the bipod and the pivot for the M-120 model 43 mortar

Source: Own work

Unfortunately, after repositioning the bipod of the mortar the direction adjustment for the line of sight deviation will be zeroed again. It raises some doubts about the correctness of taking account of its value during the determination of settings. The above activity could be reduced to absurdity and, for a certain range of sight settings, instead of regulating the angle of elevation of the tube by means of the elevating mechanism (for which adjustments for the line of sight deviation are determined), only the appropriate angle between the tube and the bipod could be used. In reality, the determination of a direction adjustment for the line of sight deviation is possible and reliable only when the position of the bipod is not changed or when such change is made by a strictly defined value, as it is the length of the extended elevation mechanism that affects the value of such adjustment and maintains its interdependence with the sight angle. With a discretionary position of the bipod this interdependence is changed, because, with the same settings retained, the elevation mechanism can be less extended, if the bipod legs are moved closer to the baseplate.

Mortars of the M-120 model 43 type have two grooves on the tube to mount the clamping ring of the bipod (Fig. 3). This design solution ensured that the mortar tube could have a better stabilisation at high angles of elevation without the necessity of changing the position of the bipod.

On 9 April 2015, at CSAiU (the Artillery and Arms Training Centre) in Toruń, in order to verify the described instability and resultant errors in direction, and in particular a direction adjustment for the angle of elevation of the tube, the measurements were conducted, focusing on individual adjustments of the mortar concerning changes in the direction of the mortar (errors in direction), caused by a change in the angle of elevation of the tube. By decreasing the angle of elevation of the tube from the sight value equal to 10-00 to the maximum extension of the elevation mechanism the line of

sight deviation was obtained totalling 0-39 mil. There were no objections regarding the technical condition of the mortar and it was commissioned for operation directly after its major repair.

Fig. 3. Mortar, 120 mm M-120 model 43, with two visible grooves on the tube intended for mounting the clamping ring of the bipod at two different positions
Source: Own collection

A deviation of 0-39 in direction can be dangerous as it occurs when the elevation mechanism is significantly extended, which corresponds to high angles of elevation of the tube and fire at close distance. It is equivalent to the value of error in direction for a charge of 4-48 m (firing at a distance of 1235 m - $U_K[m] = 39 \cdot 1.235 = 48.16m$).

a) **b)**

Fig. 4. a) M-98 mortar at the firing position with a high angle between the bipod and the tube with the extended worm gear of the elevation mechanism b) M-98 mortar at the firing position with the unstable positioning of the bipod spurs in relation to the ground surface.
Source: Own collection

During combat operations, a change to the position of the bipod when a fire mission is carried out makes it necessary to direct the mortar again at the registered point and to take account of a difference in the direction adjustment for the line of sight deviation,

appropriate for the position of the bipod within the second range of angles of elevation. Based on the information obtained from commanders of firing platoons during qualification courses it is known that such artillery practice is not used, as it prolongs the time needed to complete the mission.

On the basis of the authors' analysis of carried out firings, conducted with respect to their accuracy and the time needed to complete fire missions using M-120 model 43 and M-98 mortars, it was observed that the fact of not taking account of a difference in the direction adjustment for the line of sight deviation after the bipod was repositioned had a significant influence on the accuracy of carrying out fire missions in direction. The severity of this error becomes particularly noticeable during registration by firing with a rangefinder, when after the first accurate burst the condition for firing for effect is fulfilled, however, the computed adjustments can be entered only after the bipod is repositioned. The activity of repositioning the bipod itself prolongs the time of completing the fire mission. When a difference in the direction adjustment for the line of sight deviation is taken into account, because of a change in the bipod position, it additionally extends the time needed to complete the fire mission.

The last element of preparing mortars for firing is the determination of individual adjustments of a mortar. In *"Instrukcja artylerii Działoczyny artylerii naziemnej"* (the Artillery Instruction: Field Artillery Manual Gunnery) it is not specified unambiguously which signs should be adopted for respective individual adjustments while firing from mortars. It could be misleading to identify firing from cannons at higher angles with firing from mortars, because when firing from cannons at higher angles the firing range decreases along with an increase in the sight setting, whereas in the case of mortars, it works the opposite way. Such incorrect interpretation may result in introducing individual adjustments to the settings with a double error. Summarising the above discussion it should be emphasised that a change of the sign of individual adjustments while firing from cannons using higher angles does not apply to firing from mortars.

During combat operations making use of formulas to calculate individual adjustments is impractical. To facilitate calculations at the firing position squad commanders may use the firing tables for respective types of arms, which include also auxiliary tables. The auxiliary tables contain the sight adjustments for respective deviations, specified for the given values of the sight and charge. These calculations are much simpler and can be done mentally, without using calculators. Unfortunately, the firing tables for the M-98 mortar do not include any auxiliary tables. Therefore, the commanders of M-98 mortars have to do these calculations algebraically, making use of the formulas contained in *"Instrukcja Artylerii Działoczyny Artylerii Naziemnej"*.

Mortar commanders enter individual adjustments to the sight settings and deviations. Adjustments to the sight settings are entered because there is no levelling mechanism in the mortars. The following individual adjustments are made to the sight setting in mortars:

- for the positioning of a mortar in relation to the ranging (base) mortar;
- for a difference in altitude between the mortar and the ranging mortar;

– for a projectile weight deviation.

The table of individual adjustments of the mortar is prepared by the mortar commander. The number of tables of individual adjustments of a mortar depends on the number of charges for a given type of a mortar and projectile. Taking into account the structure of the firing tables for mortars it can be noted that the optimum solution for making calculations for a table with individual adjustments is to prepare such table for the sight ranges from 3-50 to 10-00 with increments every 50 scale divisions (0-50). Tables 1, 2 and 3 present auxiliary tables for the 98 mm mortar, facilitating the preparation of tables with individual adjustments.

Table 1. Table for calculating the sight adjustments for a projectile weight deviation

Charge	1	2	3	4	Charge
Sight in scale divisions	Sight adjustments in scale divisions for a projectile weight deviation by one sign				Sight in scale divisions
3-50	0.5	0.4	0.3	0.1	3-50
4-00	0.7	0.6	0.4	0.2	4-00
4-50	0.9	0.8	0.5	0.3	4-50
5-00	1.0	1.0	0.7	0.3	5-00
5-50	1.2	1.3	0.9	0.4	5-50
6-00	1.8	1.5	1.1	0.5	6-00
6-50	2.0	2.0	1.3	0.6	6-50
7-00	2.8	2.4	1.6	0.7	7-00
7-50	3.5	2.7	1.8	0.8	7-50
8-00	3.7	4.0	2.4	1.0	8-00
8-50	5.3	5.2	3.2	1.4	8-50
9-00	8.0	8.6	5.2	1.7	9-00
9-50	17.0	27.0	9.0	3.5	9-50
10-00	-	-	14.0	7.0	10-00

In order to calculate an adjustment the sight adjustments, taken from the table depending on the charge and the sight, should be multiplied algebraically by a projectile weight deviation (number of signs on the projectile).

Table 2. Table for calculating the sight adjustments for a difference in altitude of the mortar in relation to the ranging mortar

Charge	1	2	3	4	Charge
Sight in scale divisions	Sight adjustments in scale divisions per each 10 m of a difference in altitude				Sight in scale divisions
3-50	0.5	0.4	0.3	0.1	3-50

Charge	1	2	3	4	Charge
Sight in scale divisions	Sight adjustments in scale divisions per each 10 m of a difference in altitude				Sight in scale divisions
4-00	0.6	0.5	0.4	0.2	4-00
4-50	0.7	0.8	0.5	0.3	4-50
5-00	1.0	1.0	0.7	0.3	5-00
5-50	1.2	1.3	0.9	0.4	5-50
6-00	1.8	1.5	1.1	0.5	6-00
6-50	2.0	2.0	1.3	0.6	6-50
7-00	2.8	2.4	1.6	0.7	7-00
7-50	3.5	2.8	1.8	0.8	7-50
8-00	3.7	4.0	2.4	1.0	8-00
8-50	5.3	5.2	3.2	1.5	8-50
9-00	8.0	8.6	5.2	1.8	9-00
9-50	9.0	13.5	8.6	3.5	9-50
10-00	9.0	14.0	14.0	7.0	10-00

Table 3. Signs of sight adjustments for a difference in altitude

Position of the mortar in relation to the ranging mortar	Sign of sight adjustment
Higher	-
Lower	+

In order to calculate adjustments the sight adjustments, taken from the table depending on the charge and the sight, should be multiplied by the number of tens contained in the difference in altitude value, expressed in metres

Table 4. Table for calculating the sight adjustments for the positioning of a mortar in relation to the ranging mortar

Charge	1	2	3	4	Charge
Sight in scale divisions	Sight adjustments in scale divisions per each 10 m of the positioning				Sight in scale divisions
3-50	2.5	1.2	0.8	0.6	3-50
4-00	2.5	1.3	0.9	0.7	4-00
4-50	2.6	1.4	0.9	0.7	4-50
5-00	2.7	1.5	1.0	0.8	5-00
5-50	3.0	1.6	1.1	0.8	5-50

Charge	1	2	3	4	Charge
Sight in scale divisions	Sight adjustments in scale divisions per each 10 m of the positioning				Sight in scale divisions
6-00	3.3	1.7	1.2	0.9	6-00
6-50	3.6	2.0	1.3	1.0	6-50
7-00	4.0	2.3	1.4	1.1	7-00
7-50	5.0	2.5	1.6	1.3	7-50
8-00	6.0	3.3	2.0	1.6	8-00
8-50	7.5	4.0	2.5	2.0	8-50
9-00	10.0	6.6	4.0	2.5	9-00
9-50	10.0	10.0	10.0	10.0	9-50
10-00	10.0	10.0	10.0	10.0	10-00

Table 5. Signs of sight adjustments for positioning

Positioning	Sign of sight adjustment
Backward	+
Forward	-

In order to calculate adjustments the sight adjustments, taken from the table depending on the charge and the sight, should be multiplied by the number of tens contained in the positioning value, expressed in meters.

On the basis of the presented auxiliary tables the exemplary tables of individual adjustments for the first mortar were prepared for the following conditions:

- firing will be carried out using the first and the fourth charge and OB-98 projectiles with weight deviations of "+++";
- the positioning of the first mortar in relation to the ranging mortar read by means of a plotting board totals +30 m (the mortar is shifted backwards by 30 m);
- the position of the first mortar is 10 m lower in relation to the ranging mortar.

The tables were compiled for the first charge and the fourth charge and presented in Table 6 (for the fourth charge) and Table 7 (for the first charge).

The analysis of the data included in the table of individual adjustments of a mortar shows that the calculated adjustments for charge 4 for the firing ranges close to the maximum adopt the values oscillating around 13 scale divisions (6815 m – 11.7 scale divisions, 7020 m – 14.4 scale divisions). In the case of charge 1, for the firing ranges close to the maximum they adopt the values of approximately 50 scale divisions (2062 m – 43.7 scale divisions, 2091 m – 62 scale divisions).

Table 6. Table of individual adjustments for the 1st mortarcharge 4 (variant)

ange (m)	Sight (scale division)	$\Delta X_{mil.}$	Tabular sight adjustments for:			Sight adjustments, after the firing position has been established, calculated for:			Total sight adjustments (7)+(8)+(9)	Direction adjustment for the line of sight deviation	
			Positioning in relation to the ranging mortar by 10 m	Projectile weight deviation by one sign	Difference in the altitude of the mortar in relation to the ranging mortar by 10 m	Adjustment for the mortar positioning in relation to the ranging mortar +10m x 3	Projectile weight deviation Δq +++	Difference in the altitude of the mortar in relation to the ranging mortar -10m		Range of distances between the bi-pod and the pivot	
										I 1600 mm	II 1200 mm
1	2	3	4	5	6	7	8	9	10	11	12
1530	3-50	15	0.6	0.1	0.1	+1.8	+0.3	+0.1	+2.2		-0-09
2272	4-00	14	0.7	0.2	0.2	+2.1	+0.6	+0.2	+2.9		-0-07
2986	4-50	14	0.7	0.3	0.3	+2.1	+0.9	+0.3	+3.3	-	-0-06
3652	5-00	13	0.8	0.3	0.3	+2.4	+0.9	+0.3	+3.6	-	-0-05
4264	5-50	12	0.8	0.4	0.4	+2.4	+1.2	+0.4	+4.0	-	-0-04
4845	6-00	11	0.9	0.5	0.5	+2.7	+1.5	+0.5	+4.7	-	-0-03
5360	6-50	10	1.0	0.6	0.6	+3.0	+1.8	+0.6	+5.4	-	-0-02
5818	7-00	9	1.1	0.7	0.7	+3.3	+2.1	+0.7	+6.1	-	-0-01
6214	7-50	7	1.3	0.8	0.8	+3.9	+2.4	+0.8	+7.1	-0-03	0-00
6542	8-00	6	1.6	1.0	1.0	+4.8	+3.0	+1.0	+8.8	-0-02	-
6815	8-50	5	2.0	1.4	1.5	+6.0	+4.2	+1.5	+11.7	-0-01	-
7020	9-00	4	2.5	1.7	1.8	+7.5	+5.1	+1.8	+14.4	-0-01	-
7227	10-00	1	10.0	3.5	3.5	+30	+10.5	+3.5	+44	0-00	-

Source: Own work

Table 7. Table of individual adjustments for the 1st mortar charge 1 (variant)

Range (m)	Sight (scale divisions)	$\Delta X_{mil.}$	Tabular sight adjustments for:			Sight adjustments, after the firing position has been established, calculated for:			Total sight adjustments (7)+(8)+(9)	Direction adjustment for the line of sight deviation	
			Positioning in relation to the ranging mortar by 10 m	Projectile weight deviation by one sign	Difference in the altitude of the mortar in relation to the ranging mortar by 10 m	Adjustment for the mortar positioning in relation to the ranging mortar +10m x 3	Projectile weight deviation Δq +++	Difference in the altitude of the mortar in relation to the ranging mortar -10m		Range of distances between the bipod and the pivot	
										I 1600 mm	II 1200 mm
1	2	3	4	5	6	7	8	9	10	11	12
448	3-50	4	2.5	0.5	0.5	+7.5	+1.5	+0.5	+9.5		-0-09
672	4-00	4	2.5	0.7	0.6	+7.5	+2.1	+0.6	+10.2		-0-07
880	4-50	4	2.6	0.9	0.7	+7.8	+2.7	+0.7	+11.2	-	-0-06
1080	5-00	4	2.7	1.0	1.0	+8.1	+3.0	+1.0	+12.1	-	-0-05
1264	5-50	4	3.0	1.2	1.2	+9.0	+3.6	+1.2	+13.8	-	-0-04
1439	6-00	3	3.3	1.8	1.8	+9.9	+5.4	+1.8	+17.1	-	-0-03
1600	6-50	3	3.6	2.0	2.0	+10.8	+6.0	+2.0	+18.8	-	-0-02
1745	7-00	3	4.0	2.8	2.8	+12	+8.4	+2.8	+23.2	-	-0-01
1866	7-50	2	5.0	3.5	3.5	+15	+10.5	+3.5	+29	-0-03	0-00
1962	8-00	2	6.0	3.7	3.7	+18	+11.1	+3.7	+32.8	-0-02	-
2062	8-50	2	7.5	5.3	5.3	+22.5	+15.9	+5.3	+43.7	-0-01	-
2091	9-00	1	10.0	8.0	8.0	+30	+24	+8.0	+62	-0-01	-
2166	10-00	1	10.0	17.0	9.0	+30	+51	+9.0	+90	0-00	-

Source: Own work

Table 8 presents the values of probable projectile deflections from the target in the case the mortar commander does not take account of individual adjustments.

The analysis of the data presented in Table 8 indicates that individual adjustments of mortars should be taken into account each time when firing and a failure to do so should be regarded as a serious error. For the assumed firing conditions, irrespective of the firing range, the adjustments correspond to the average deflection of a projectile from the target by about 50 m.

Table 8. Values of probable projectile deflections from the target in the case the mortar commander does not take account of individual adjustments

Range (m)		ΔX_{mil}	Total sight adjustments	Failure to take account of an adjustment could cause a projectile deflection in respect of range [m]
Charge 4	1530	15	+2.2	33
	2272	14	+2.9	40.6
	2986	14	+3.3	46.2
	3652	13	+3.6	46.8
	4264	12	+4.0	48
	4845	11	+4.7	51.7
	5360	10	+5.4	54
	5818	9	+6.1	54.9
	6214	7	+7.1	49.7
	6542	6	+8.8	52.8
	6815	5	+11.7	58.5
	7020	4	+14.4	57.6
	7227	1	+44	44
Average value				49.06 m
Range (m)		ΔX_{mil}	Total sight adjustments	Failure to take account of an adjustment could cause a projectile deflection in respect of range [m]
Charge 1	448	4	+9.5	38
	672	4	+10.2	40.8
	880	4	+11.2	44.8
	1080	4	+12.1	48.4
	1264	4	+13.8	55.2
	1439	3	+17.1	51.3
	1600	3	+18.8	56.4
	1745	3	+23.2	66.6
	1866	2	+29	58
	1962	2	+32.8	65.6
	2062	2	+43.7	87.4
	2091	1	+62	62
	2166	1	+90	90
Average value				58.8 m

Source: Own work

CONCLUSIONS

The analyses presented in the paper and the conclusions drawn on their basis, will be conducive, after their implementation, to the increased accuracy in fulfilling the tasks related to the technical preparation of mortars. The following recommendations can be formulated:

1. supplement the firing tables for the 98 mm M-98 mortars with the auxiliary tables used for the determination of individual adjustments;
2. modify the design of the bipod for the M-98 mortar to limit the possibilities of its mounting to two predefined ranges concerning its distance from the pivot (e.g. by means of a chain attached close to the pivot on the baseplate and to the bipod spurs);
3. add an erratum to "*Instrukcja artylerii Działoczyny artylerii naziemnej*" regarding the signs used in the calculations of individual adjustments for mortars;
4. include in "*Instrukcji strzelania i kierowania ogniem*" (the Instruction for firing and directing fire) a recommendation which obliges to continue the registration in the case where for the introduction of adjustments it is necessary to reposition the bipod.

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BIOGRAPHICAL NOTES

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HOW TO CITE THIS PAPER:

Krzyżanowski S., Piontek J., (2016). Selected Problems In Completing The Tasks Related To The Technical Preparation Of Mortars. *Zeszyty Naukowe Wyższa Szkoła Oficerska Wojsk Lądowych im. gen. Tadeusza Kościuszki Journal of Science of the gen. Tadeusz Kosciuszko Military Academy of Land Forces*, 48 (2), pp. 194-207, http://dx.doi.org/10.5604/17318157.1216088