APPROVED FOR RELEASE
1/16/2006
HR 70-14

[redacted] SECRET

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CENTRAL INTELLIGENCE AGENCY
WASHINGTON 25, D. C.

2810

24 Oct 1962

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MEMORANDUM FOR: The Director of Central Intelligence

SUBJECT : "Combat Against Enemy Nuclear Artillery, Free Rockets, and Guided Missiles in Offensive and Defensive Operations of an Army" (Chapter III)

1. Enclosed is a verbatim translation of Chapter III of a seven-chapter TOP SECRET Soviet publication entitled "Combat Against Enemy Nuclear Artillery, Free Rockets, and Guided Missiles in Offensive and Defensive Operations of an Army". It was issued by Scientific-Research Artillery Institute No. 1 in Leningrad in October 1960.

[redacted]

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[redacted]

Richard Helms
Deputy Director (Plans)

Enclosure

[redacted]

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The Director for Intelligence, The Joint Staff

The Assistant Chief of Staff for Intelligence, Department of the Army

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COUNTRY : USSR

SUBJECT : "Combat Against Enemy Nuclear Artillery, Free Rockets, and Guided Missiles in Offensive and Defensive Operations of an Army" (Chapter III)

DATE OF INFO : October 1960

APPRAISAL OF CONTENT : Documentary

SOURCE [redacted]

Following is a verbatim translation of Chapter III of a TOP SECRET Soviet publication titled "Combat Against Enemy Nuclear Artillery, Free Rockets, and Guided Missiles in Offensive and Defensive Operations of an Army". This document contains seven chapters and was published on 15 October 1960 by Scientific-Research Artillery Institute No. 1 in Leningrad. Each chapter will be disseminated as it becomes available and is translated.

In some cases, there are imperfections in the original text which leave doubt as to the accuracy of translation. Question marks are inserted in brackets following uncertain words or phrases. As in other IRONBARK reports, transliterated Cyrillic letters are underlined in translation, while Greek and Roman letters are given as in the original.

Chapter III

"Methods of Determining Settings for Fire for Effect Against Enemy Offensive Nuclear Weapons"

The special features of the combat employment of enemy guns (launchers) and, in particular, the short time they spend at firing positions (launch sites), their high degree of mobility, and the considerable distance of the siting areas from the forward subunits of our troops, present a whole series of requirements for the methods of determining fire settings used by missile troops and artillery; we are considering the most important of them here.

The methods of determining settings must be characterized by great accuracy and ensure surprise opening of fire, be simple in planning and execution, and require as small an expenditure of time as possible in order not to hold up the preparation of guns (missiles) for firing when located at a firing position (launch site).

The accuracy of the method exerts a direct effect on the expenditure norm of shells or on the size of the TNT equivalent (yield) of a nuclear charge. Thus, when firing shells with conventional filling, a doubling of the preperation error results in an increase of the expenditure norm approximately fourfold [?].* If it is considered that artillery fire against enemy guns (launchers) entails a considerable shell expenditure, then the need for more accurate methods of determining settings becomes evident.

* It is known that $N = K_? \frac{E^1_x E^1_z}{S_{ts}}$, when $E^1_x = E^1_z = \zeta$,

$$N = \frac{K_?}{S_{ts}} \cdot \zeta ? [?]$$

The effect of the accuracy of the method for determining settings on the size of yield of a nuclear charge is even more considerable. Let us assume that there is an individual target which it is necessary to destroy with about 90 percent certainty with a nuclear charge. We know that to destroy such a target with a fire error of magnitude τ_1, a nuclear charge with a yield q_1 is necessary, having a radius of destruction $R_{p\,1} = 3 \times \tau_1$. Let us suppose that with another method of determining settings, the fire error τ_2 is m times greater than τ_1, i.e., $\tau_2 = m \times \tau_1$. Then with this method of determining settings, the radius of destruction $R_{p\,2}$, which ensures the destruction of the target, will be:

$$R_{p\,2} = 3 \times \tau_2 = 3 \times m \times \tau_1 = mR_{p\,1}$$

We know that for the majority of targets, including enemy offensive nuclear weapons, the following equation is valid:

$$\frac{R_{p\,1}}{R_{p\,1}} \approx \frac{\sqrt[?]{q_1}}{\sqrt[?]{q_2}}$$

when [?] $q_2 \approx$ [?] $q_1 \left(\frac{R_{p\,2}}{R_{p\,1}}\right)^{?}$ [?] or $q_2 \approx$ [?]

$$q_1 \left(\frac{mR_{p\,?}}{R_{p\,?}}\right) \approx \text{[?]}\; m^{?} q_1 \;\text{[?]}$$

Consequently, when firing with nuclear ammunition against individual targets, a doubling of the fire error results in doubling the required radius of destruction, and increasing the required yield of the nuclear charge approximately eightfold.

With an increase in the size (area) of a target, the effect of a fire error on the [one word missing] yield of the nuclear charge required for its destruction is slightly reduced [?].

It should be noted that the fire error is basically [one word missing] the error in the method of determining settings (errors of preparation [?]) and dispersion. The proportion* of errors of preparation in [?] the fire error differs for various types of missiles and artillery and is approximately 30 to 60 percent for tactical missiles, 10 to 40 percent for operational-tactical missiles, and in the order of 90 percent for rifled artillery. For this reason the accuracy of methods of determining settings will only partially influence change in the yield of the nuclear charge. This effect will be predominant for rifled artillery, but for tactical and operational-tactical missiles, in the majority of cases, it will take second place to the effect of dispersion. However, even in this case, there is no doubt about the need to use more accurate methods of determining fire settings. As [?] the proportion of preparation errors in the fire error increases and the effect of dispersion decreases (work is now being done on just these lines), the need to employ more accurate methods of determining settings becomes all the more apparent.

In the overwhelming majority of cases, enemy offensive nuclear weapons must be destroyed immediately after detection. The response time (vremya gotovnosti) of missile or artillery subunits to open fire against an enemy gun (launcher) that has been located consists of the time to occupy a launch site or firing position (if it is not already occupied), the time to prepare the missile or artillery equipment (launchers) and ammunition for firing, and the time for fire planning and to prepare settings for fire for effect. This time differs for various types of missiles (artillery) and various methods of determining settings.

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* The ratio of the square of the preparation error to the square of the fire error is borne in mind, for example: [?]

[equation missing]

For rifled artillery systems, which, as a rule, occupy firing positions in advance, the minimum time is needed, being equal to the time to prepare [one adjective missing] fire (carrying out adjustment of fire); this in the main depends on the method of determining settings.

For tactical and operational-tactical missiles this time depends, in the main, on the time taken to prepare (check) missiles, but the time to determine fire settings also has considerable importance.

The continuous improvement in the methods of preparation for fire from a launch site with the object of reducing the preparation time for opening fire, and the requirement for immediate opening of fire when called for, necessitate, when combating enemy offensive nuclear weapons, the employment of those methods of determining fire settings which are the simplest to plan and which ensure the opening of fire in the shortest time. This should not [?] exceed the time to prepare missiles (guns) on the launch site (firing position) for firing.

Let us make a preliminary evaluation of the various methods of determining settings for fire for effect in order to bring out the possibilities of employing them when planning the combat against enemy offensive nuclear weapons.

For rifled artillery, the main methods of determining settings for fire for effect against enemy batteries are: full preparation (polnaya podgotovka), the use of data of registration (pristrelochnyy) pieces (POR) [?], transfer of fire (perenos ognya), and adjustment directly on the targets (pristrelka neposredstvenno po tselyam) with the aid of aircraft, helicopters, a radar set [?] or a sound-ranging battery (BZR).

Of these methods of determining settings, the most accurate methods are based on direct adjustment on the target with the aid of an aircraft or helicopter. In addition to great accuracy, these methods also have several other especially important features which permit their use when planning the combat against enemy offensive nuclear weapons. It is known that it is very important to detect and destroy (neutralize) an enemy gun (launcher) before it fires. Only such means of reconnaissance (which are also the means of carrying out adjustment of fire) as aircraft and helicopters can locate an enemy gun (launcher) before it fires and can ensure adjustment of fire on it in a short time.

Such means of reconnaissance that ensure adjustment of fire, such as radar sets and a sound-ranging battery, can locate (determine the coordinates of) a gun (launcher) only when it fires. Adjustment on a target will make sense when less time is spent on its planning and execution than is required for the enemy gun (launcher) to evacuate the firing position. A comparison with this time makes it possible to conclude that only a radar set, in certain cases, ensures adjustment on the target in time. If it is taken into account that it permits great accuracy of adjustment on targets detected by other means, then the advisability of the widespread use of radar sets when planning the combat against enemy offensive nuclear weapons becomes apparent. As for adjustment by means of a sound-ranging battery, it should be considered inadvisable [?], in view of the low degree of accuracy and duration of ranging and also in view of the unreliability of sound-ranging at extreme distances.

Full preparation must be used as often as possible when planning the combat against enemy offensive nuclear weapons, because it ensures the constant readiness of any quantity of artillery to open effective surprise fire for effect. It is true that when firing at long distances, full preparation is inferior in accuracy to other methods of determining settings. However, it should be considered that in the majority of cases it will be possible by means of a radar set, and sometimes an aircraft, to check the accuracy of settings computed on the basis of full preparation and to make adjustments as a result of which the accuracy of settings will be materially improved.

Transfer of fire requires preliminary adjustment on datum marks (reper). For transfer of fire to exceed the accuracy of full preparation, one to two hours before opening fire for effect each battery should adjust on a datum mark, from which the transfer of fire to the target will be effected. Because as a rule the time for opening fire against an enemy gun (launcher) will not be known beforehand, in order to be in a state of constant readiness to open fire, each battery must carry out a check of the adjustment on the datum mark approximately every two hours. Adjustment on a great number of datum marks allows the enemy to detect [?] our artillery grouping. For this reason, and also in view of the absence of substantial advantages in accuracy over full preparation, transfer of fire is not advisable when planning the combat against enemy nuclear weapons.

The method of determining settings based on POR [?] (registration piece) data requires a lot of time for planning and for adjustment on datum marks. Its employment depends to a considerable degree on the situation. It does not differ in accuracy from full preparation, if it is planned on a battalion scale, but is inferior to full preparation when planned on a larger scale. Consequently, this method of determining settings is inferior to full preparation in a number of very important characteristics, and it is not advisable to use it when planning the combat against enemy offensive nuclear weapons.

Full preparation is the main method of determining settings for tactical and operational-tactical missiles with a nuclear charge.

Let us turn to a more detailed consideration of those methods of determining settings, which it is advisable to employ when combating enemy offensive nuclear weapons.

I Characteristics of the Methods of Determining Settings for Firing Tactical and Operational-Tactical Missiles

Full preparation is the main method of determining settings for firing tactical and operational-tactical missiles against enemy offensive nuclear weapons. Full preparation as a method of determining settings for firing missiles has been examined in several studies; therefore, we shall make use of just the conclusions from these studies, mainly those which analyze the method according to accuracy and time. Because only missiles with nuclear charges are used to destroy enemy offensive nuclear weapons, and, at the same time, one missile is expended as a rule against any given target, the main characteristics of accuracy of full preparation are the probable errors of the shot (sredinnaya oshibka vystrela). Taking into account that nuclear bursts can be surface [?] and air, the characteristics of accuracy of full preparation will be the probable errors of the shot in range (Vrd_p or Vd_p), in bearing (Vb_p), and in height (Vrv_p) [?].

Apart from the errors of the shot, when firing at a given range, the ratio $\mathcal{E}$ of the lesser of the probable errors in range or in bearing of the shot to the greater, is also of interest. We shall call the probable error having the greater value, Vp. Then when $Vb_p < Vp = Vd_p$ or

when $Vb_p < Vp = Vrd_p$, $\mathcal{E} = \dfrac{Vb_p}{Vp}$

when $Vd_p < Vp = Vb_p$, $\mathcal{E} = \dfrac{Vd_p}{Vp}$

when $Vrd_p < Vp = Vb_p$, $\mathcal{E} = \dfrac{Vrd_p}{Vp}$.

The probable errors of a shot with full preparation for operational-tactical and tactical missiles taken from studies (13) and (14) are shown in Tables 4 and 5, with the values of $\mathcal{E}$.

Probable Error of Shot with Full Preparation

for Operational-Tactical Missiles

(Missile 8K11) **Table 4**

Designation	Values of probable errors of shot when firing at [range] D (km)						
	60	80	100	120	140	160	180
Vd_p	370	450	550	610	690	770	850
Vb_p	370	370	370	380 [?]	385	395	400
ε	1.0	0.82	0.70	0.62	0.56	0.51	0.47

Table 5

Probable Errors of Shot with Full Preparation for 3R10 Tactical Missiles

	Values of probable errors of shot when firing at D (km)											
	10	12	14	16	18	20	22	24	26	28	30	32
	a) When firing with fuse mechanism VDM-T											
[missing]	178	168	161	157	-	-	-	-	-	-	-	-
	63	76	87	100	-	-	-	-	-	-	-	-
	0·38	0·45	0·54	0·64	-	-	-	-	-	-	-	-
	50[?]	70	82	95	-	-	-	-	-	-	-	-
	b) When firing with fuse mechanism 3917											
	-	-	382	348	318	294	278	268	263	260	261	267
	-	-	81	97	110	124	139	154	178	192	216	262
	-	-	0·21	0·28	0·35	0·42	0·50	0·57	0·66	0·74	0·83	0·98
	-	-	10	10	10	10	10	10	10	10	10	10

As experience from a number of exercises has shown, the time taken to determine fire settings based on full preparation is 10 to 20 minutes for operational-tactical missiles and 10 to 15 minutes for tactical missiles.

By the time the troops master the method of computing settings proposed by Colonel [name missing] and Lt. Colonel [name missing] of the Faculty of Firing of the Military Artillery Academy, i.e., in practice this year, the time to determine fire settings for operational-tactical missiles on the basis of full preparation will be reduced to 6 to 8 minutes. With the entry into service of electronic equipment, this time will be reduced to 3 to 4 minutes. There is reason to think that this time is the limit of possibility for operational-tactical missiles.

With the existing method of computing, the time for determining fire settings on the basis of full preparation is 10 to 15 minutes. It comprises the time spent on measuring the parameters of the ballistic wind within the limits of the powered (aktivnyy) sector of the trajectory, processing the results of these measurements (7 to 10 minutes), and the time spent on direct computation of settings (3 to 5 minutes). If one were to automate the processing of the results of measuring the ballistic wind within the limits of the powered sector of trajectory and also the computing of the settings, or if one were to organize the work of the meteorological post so that it would give data on the ballistic wind immediately before receiving the fire task (and such an opportunity will frequently present itself), then the time taken to determine the settings for firing tactical missiles on the basis of full preparation would be 3 to 5 minutes.

2. Characteristics of the Methods of Determining Fire Settings Employed by Artillery

The main methods of determining settings employed by artillery when planning the combat against enemy offensive nuclear weapons are:

— full preparation;

— full preparation with corrections from data obtained by check shots (kontrolnyy vystrel);

— adjustment directly on target with the aid of an aircraft, helicopter, and a radar set.

The majority of these methods of determining settings have been examined in various scientific-research studies (NIR), manuals, and instructions Therefore, in reviewing them we shall touch on only those features that arise in connection with the issue of new instruments and the further development of certain methods.

1. Full Preparation

Full preparation is the basic method of determining fire settings, permitting any quantity of artillery to deliver surprise effective fire for effect under all circumstances of a combat situation.

The measures for planning and executing full preparation require a relatively small expenditure of forces, weapons, and time.

The accuracy of full preparation is characterized by the total probable errors in range $E_{x_{pp}}$ and in bearing $E_{z_{pp}}$ shown in Table 6, when the target coordinates are determined with a probable circular error (krugovaya oshibka) of $r = 20$ m.

An analysis of the dependence of the accuracy of full preparation on the accuracy of determining the target coordinates allows us to conclude that when firing at a range of 12 km and over, an increase to 50 m of the probable error in determining the target coordinates does not lead

Table 6

Probable Errors of Full Preparation

Artillery Systems	Values of probable errors (m); in range $E_{x_{pp}}$ (in numerator) and bearing $E_{z_{pp}}$ (in denominator) when firing at range D (km)						
	8	10	12	16	20	24	26
130 mm gun	65/29	-/-	89/35	116/45	151/54	178/69	200/80
152 mm gun	66/29	-/-	101/35	127/44	164/69	-/-	-/-
122 mm howitzer	68/29	88/36	104/47	-/-	-/-	-/-	-/-
152 mm howitzer	68/30	83/35	101/44	-/-	-/-	-/-	-/-

to a significant increase in the errors of full preparation. From this viewpoint, target coordinates determined with a probable error of up to 50 m will be considered hereafter as accurate and justifying the use of full preparation. If, on the other hand, target coordinates are determined with an error exceeding 50 m, the use of full preparation should be considered inadvisable in practice.

The amount of time for determining fire settings on the basis of full preparation on a battalion scale, when target coordinates are known, does not exceed 1 to 1.5 minutes.

Thus, from the viewpoint of providing constant readiness of the artillery to open fire, full preparation is unrivalled among the methods of determining settings. Therefore, it is advisable to use it in all cases, and especially for the initial fire concentration against an enemy gun (battery) or launcher. At the same time, because of the relatively low precision of full preparation, it is advisable to continue subsequent fire for effect after incorporating corrections determined from data obtained from check shots (salvos), on which a fix has been obtained with the aid of speedy and high-precision equipment to adjust fire.

2. Full Preparation with Corrections from Data Obtained by Check Shots

The essence of this method of determining settings for fire for effect consists of: allotting a check group of bursts at settings calculated on the basis of full preparation; determining (with the aid of equipment for adjustment of fire) the deviations of the center of the check group of bursts from the target in range and bearing; and using the results obtained to determine the appropriate corrections, taking into account the accuracy of full preparation and the accuracy of the method of determining the deviations.

To determine the deviations of the center of the check group of bursts from the target, use is made either of a radar set or an aircraft.

In view of the above, depending on the method of determining deviation, in future we shall refer to full preparation with corrections from data obtained by check shots respectively as full preparation incorporating corrections determined with the aid of a radar set, and full preparation incorporating corrections determined with the aid of an aircraft.

Before we turn to a specific examination of these methods, let us examine some theoretical premises on the problem of corrections.

Let us assume that fire for effect is opened against a target whose coordinates are determined accurately on the basis of one of the methods of determining settings (for example, full preparation), the accuracy of which is characterized by a probable error E_1. At the same time, the elevation (pritsel) and azimuth (uglomer) settings are arranged so that the center of dispersion of the shells coincides with the center of the target. Under such conditions it is obvious that the expected deviation from the target center of the shell grouping numerically equal to the amount of expected correction K_1 will equal zero.

During the fire for effect, a check group of bursts is allotted.

With the aid of means to adjust the fire, the deviation of the center of the check group of bursts from the target is determined with an accuracy characterized by the probable error E_2. It is obvious that in this case the deviation obtained is numerically equal to the correction K_2, which should be incorporated in order to continue fire for effect.

Thus, we have a case where the settings for fire against a target are determined by two methods. According to one of them fire for effect must be continued on the settings previously calculated, i.e., without incorporating a correction ($\underline{K}_1 = 0$), while according to the other a certain correction $\underline{K}_2$ is needed.

In other words, we have two distributions* (raspredeleniye) corresponding to the two methods of determining the position of the mean (sredniy) point of the bursts in relation to the target: the first distribution with the center at a point $\underline{K}_1 = 0$ distant from the target, which is characterized by a probable error E_1; the second distribution with the center at a certain point at a distance $\underline{K}_2$ from the target, which is characterized by a probable error E_2.

The next task consists of combining the distributions and finding the distance of the center of the new distribution from the target and the probable error of this distribution. The distance of the center of the new distribution from the target will evidently correspond to the amount of correction (we shall call it optimum, and refer to it as $\underline{K}$) and the probable error of the distribution ($E_{\underline{k}}$) which is the accuracy of determining this correction.

For the new case the amount of the optimum correction $\underline{K}$, derived at taking into consideration the accuracy values (ves tochnosti) of the individual measurements (corrections), will equal:

$$\underline{K} = \frac{K_1 q_1 + K_2 q_2 \; [?]}{q_1 + q_2} \qquad (1)$$

* Both these formulations are subject to the normal law.

where q_1 and q_2 are the accuracy values of the measurements (corrections) respectively equalling:

$$q_1 = \frac{1}{E_1^2} \quad \text{and} \quad q_2 = \frac{1}{E_2^2}$$

Substituting these values in formula (1), and taking into account that $K_1 = 0$, we obtain:

$$K = \frac{E_1^2}{E_1^2 + E_2^2} K_2 \qquad (2)$$

Taking $$\frac{E_1^2}{E_1^2 + E_2^2} = \lambda$$

we obtain the final formula for determining the amount of the optimum correction:

$$K = \lambda \times K_2 \qquad (3)$$

Therefore, to determine the optimum correction it is necessary to multiply the amount of correction, determined by results of check shots, by a certain coefficient $\lambda = f\,(E_1\,E_2)$.

With the aid of the graph (Figure 5), based on the data in Table 7, we shall observe the changes of coefficient λ depending on the changes [?] of errors E_1 and E_2.

Table 7

$$\lambda = f(E_1, E_2)$$

0	0·1	0·25	0·5	0·75	1·0	1·5	2·0	3·0	4·0	5·0
0	0·01	0·05	0·2	0·35	0·5	0·69 [?]	0·8	0·9	0·94	0·96

It is apparent from the graph that:

— coefficient λ may vary between 0 and 0·95, and therefore for any ratio between E_1 and E_2 the amount of optimum correction will always be less than the amount of deviation of the check group of bursts (the amount of correction arrived at with the aid of means to adjust the fire);

— in case of E_1 = [?] E_2, i.e., when the accuracy of the method, on the basis of which fire was opened, and the accuracy of determining the deviation of the check group of bursts are equal to each other, the amount of optimum correction is numerically equal to half the amount of deviation;

— in proportion as the accuracy of the method of determining settings for opening fire increases, the optimum correction becomes a [smaller?] proportion of the amount of deviation;

— with decreased accuracy in the method of determining settings for opening fire, the amount of optimum correction increasingly approaches the amount of deviation, determined with the aid of means to adjust the fire.

Graph

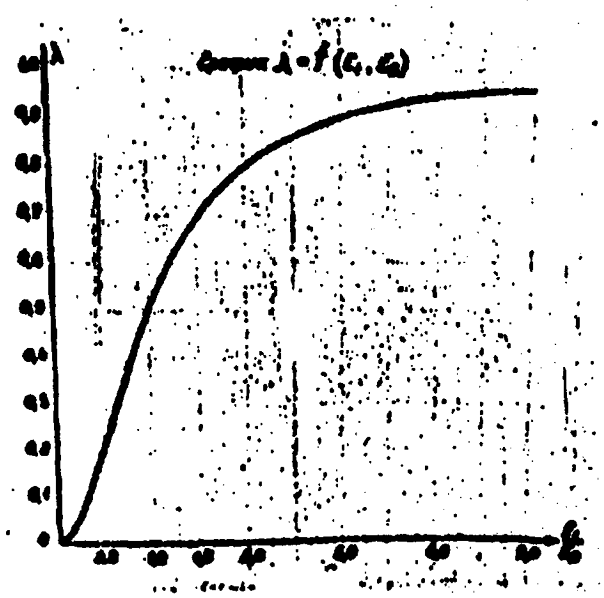

Figure 5

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The precision of determining optimum correction is characterized by a probable error, which can be calculated by the formula:

$$E_k = \frac{E_1 \cdot ? \; E_2}{\sqrt{E_1^2 + E_2^2}} \qquad (4)$$

when the probable errors E_1 and E_2 have no common sources of error, or with the aid of formula: [15]

$$E_k = \sqrt{E_?^2 + \frac{E_1^{1\,2} \cdot ? \; E_2^{1\,2}}{E_1^{1\,2} + E_2^{1\,2}}} \qquad (5)$$

when the probable errors E_1 and E_2 have common sources of error. In the above formula $E_1^1 = \sqrt{E_?^2 \; ? \; E_?^2}$ and $E_2^1 = \sqrt{E_?^{?} \; ? \; E_?^{?}}$ are probable errors in method of determining settings for fire and in the method of determining the deviation of the check group of bursts [on the basis ?] of common (recurring) errors for these methods:

E_o [?] is the probable error which takes into account only the common sources of error for these methods.

Table 8 was worked out in order to simplify the analysis in determining the optimum correction of the dependence of accuracy on the ratio (amount [?] of errors $E_1 E_2$ [and ?] E_o, on the basis of which the graph (Figure 6) was drawn.

The following can be seen from the graph (Figure 6).

Graph

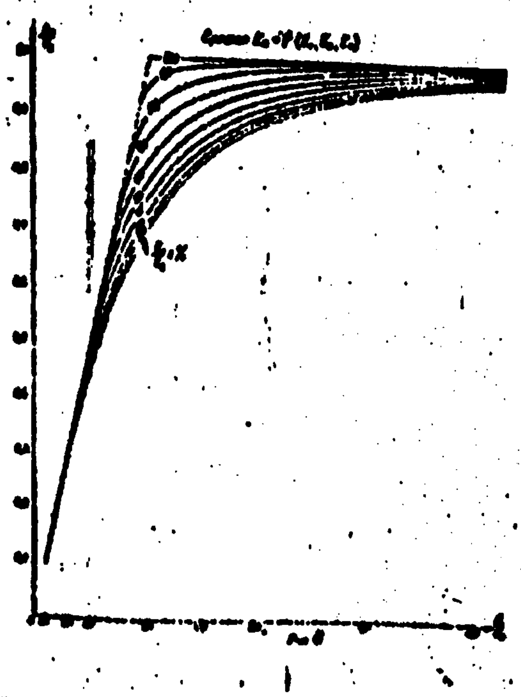

Figure 6

The accuracy of optimum correction is, as a rule - and where there are no common errors, is always - higher than the accuracy of either the method of determining settings for opening fire or the method of determining the deviation of the check group of bursts.

The most considerable superiority in accuracy of optimum correction, as compared with the methods enumerated above, occurs when the accuracy of the methods are either equal or differ from each other up to 1.5 to 2 times.

When there are common sources of error, the lower the amount of error [arising from?] common sources, the higher will be the accuracy of optimum correction [?].

When common errors comprise the main proportion of the errors, then the probable error of optimum correction is close to the probable error of the most accurate method.

When common errors are equal to the probable error in either of the methods, the probable error of optimum correction is equal to the common error, i.e., where E_2 or $E_1 = E_o$, then $E_k = E_o$.

Summing up the question of the accuracy of optimum correction, the following conclusion can be drawn: because of the realistically possible ratios between the errors in the method of determining settings for opening fire against a target and the errors in the method of determining the deviation from the target of the center of the check group of bursts vary between 0·7 and 3, one may expect a considerable gain in the accuracy of determining settings for fire for effect against a target as a result of introducing optimum correction, especially in cases when common sources of error are either nonexistent or small. If common sources of error comprise a major part of the error in the method of determining settings for opening fire or of the error in the method of determining deviations, then the introduction of optimum correction

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Table 8

$E_x = f(E_1, E_2, E_0)$

??	0	10	20	30	40	50	60	70	80	90	100
?.0	0.970	0.971	0.972	0.975	0.979	0.98?	0.987	0.9??	0.996	0.999	1.0
?.0	0.949	0.9?0	0.9?2	0.957	0.963	0.970	0.978	0.986	0.998[?]	0.998	1.0
?.0	0.894	0.896	0.902	0.910	0.922	0.935	0.9?1	0.967	0.9?2	0.995	1.0
?.3	0.8?3	0.835	0.842	0.8?5	0.871	0.8??	0.916	0.941	0.967	0.989	1.0
?.0	0.707	0.711	0.721	0.758	0.762	0.791	0.825	0.86?	0.906	0.9?1	1.0
?.9	0.689	0.678		0.701		0.7?5		0.82?		0.9	-
?.?	0.6??		0.640		0.682		0.745		0.8	-	-
?.7	0.574	0.577		0.607		0.6?7		0.7	-	-	-
?.6	0.513		0.529		0.567		0.6	-	-	-	-
?.5	0.447	0.451	0.461	0.476	0.491	0.5	-	-	-	-	-
?.4	0.37?		0.383[?]		0.4	-	-	-	-	-	-
?.3	0.2?7	0.290[?]		0.3	-	-	-	-	-	-	-
?.2[?]	0.1?7		0.2	-	-	-	-	-	-	-	-
?.1	0.099	0.1	-	-	-	-	-	-	-	-	-

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does not give any considerable advantage in accuracy.

The question of optimum correction has been explained in general terms. When considering in specific cases the question of the amount and accuracy of optimum correction, it is essential to:

— compute probable errors in range E_{x_1} and bearing E_{z_1} for the method of determining settings on the basis of which fire is opened, as well as probable errors in determining the deviations from the target of the center of the check group of bursts E_{x_2} in range and E_{z_2} in bearing relative to the method of determining deviations;

— determine the probable values of the common errors in range E_{x_0} and bearing E_{z_0};

— according to formula (2) or the graph (Figure5) work out the coefficients λ_x and λ_z, which determine the amount of optimum correction in range K_x and bearing K_z;

— according to formula (4) or (5) or the graph (Figure 6) find the characteristics of the accuracy of determining optimum correction in range E_{x_k} and bearing E_{z_k};

— work out the appropriate practical recommendations.

The accuracy of determining corrections is not a complete analysis (kharakteristika) of the accuracy of the method under review to determine settings for fire for effect. To obtain a complete analysis of the accuracy of the method, it is necessary to take into account, over and above the errors in determining corrections, the errors in range and bearing due to calibration error (raznoboy) of the battery guns, which are not fully eliminated in the process of determining the deviations of the check group of bursts from the target and lead to the lowering of effectiveness of fire, and also take into account the result of not making allowance (neuchet) for the changeability of meteorological conditions during the course of fire for effect.

Thus, the total of probable errors in range E_x and bearing E_z, in the method under review, of determining settings for fire for effect will equal:

$$E_x = \sqrt{E^{?}_{??} + E^{?}_{x_{\underline{p}}} + E^{?}_{x_{\underline{st}}}} \qquad (6)$$

$$E_z = \sqrt{E^{?}_{??} + E^{?}_{z_{\underline{p}}} + E^{?}_{z_{\underline{st}}}}$$

E_{x_p} and E_{z_p} are probable errors due to variation in performance of battery guns in range and bearing; $Ex_{\underline{st}}$ and $Ez_{\underline{st}}$ are probable errors in range and bearing due to not taking into account the changeability of meteorological conditions over a period of time.

Probable errors due to calibration error of the battery guns, where these are not eliminated during the process of adjustment of fire, may be calculated as follows:

$$Ex_{\underline{p}} = \sqrt{E^2 x_{\underline{sos}} + Ex_{\underline{pr}}} \text{ and } Ez_{\underline{p}} = Ez_{\underline{pr}} \qquad (7)$$

where $Ex_{\underline{sos}}$ is the probable adjustment (sostrel) error of battery guns in range which is taken to equal 0.75; $\underline{Vd}$;

$Ex_{\underline{pr}}$ and $Ez_{\underline{pr}}$ are probable errors in range and bearing due to errors in the sighting mechanism (pritselnoye prisposobleniye) (taken to be $Ex_{\underline{pr}} = 1 \Delta x$, $Ez_{\underline{pr}} = 0.055\% \; \underline{D}$).

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Probable errors in range and bearing due to not taking into account the changeability (out-of-dateness) of basic meteorological factors (ballistic wind and temperature) during the period Δt (in hours), representing one-half of the mean duration of fire for effect, can be found from the expressions:

$$
\left.
\begin{aligned}
E x_{\underline{st}} &= \sqrt{(0.3\sqrt{\Delta t} 0.1 \Delta x_?)^? \quad (0.5\sqrt{\Delta t} \times 0.1 \Delta x_?)^? \quad [?]} \\
E z_{\underline{st}} &= 0.3\sqrt{\Delta t} \quad 0.1 \Delta z_? \qquad [?]
\end{aligned}
\right\} \quad (8)
$$

Where $\Delta x_?$, $\Delta z_?$, $\Delta x_?$ are tabular (tablichnyy) deviations in range x and bearing z, caused by the ballistic wind and temperature.

Taking the mean duration of fire for effect to be equal to one hour, we shall get a value for Δt equal to 0.5.

Let us now pass to a practical examination of the methods proposed to determine settings for fire for effect.

Full Preparation with the Introduction of Corrections Determined with the Aid of a Radar Set

When using this method, fire for effect against a target is opened on the basis of full preparation. In the process of firing, a check group of bursts is arranged. With the help of a radar set, the deviations of the center of the check group of bursts from the target in range and bearing are determined. On the basis of the deviations obtained, the appropriate corrections are determined and introduced, taking into account the accuracy of full preparation and the accuracy of the method of determining the deviations, and fire for effect is continued.

To determine the deviations of the center of the check group of bursts, use is made of an ARSOM-type radar set when howitzers are firing, and of an "Utes" ("Saturn") radar set when the firing is being done by guns.

It is known that adjustment of fire on the target with the help of a radar set can be done both by the basic gun of a battery as well as by battery salvos. In study [16] it has been proved that the accuracy of adjustment of fire by firing salvos is approximately the same as that when adjustment of fire is done by means of one gun of a battery and, in practice, does not depend much on the [one word missing] of salvos. Taking this into account, as well as the necessity of carrying out adjustment of fire in the shortest possible time under conditions when one radar set is assisting the fire of several batteries, it is better to determine the optimum correction from one battery salvo.

Determination with the help of a radar set of the deviations of the center of the check group of bursts (salvo) from the target, the coordinates of which have been found from an aerial photograph, is accompanied by:

— errors in determining the mean point (center) of the check group of bursts;

— errors in determining the deviations of the center of the check group of bursts from the target;

— errors in determining the target coordinates,

— errors in determining the coordinates of the radar set's position;

— errors in the orientation (oriyentirovaniye) of the radar set;

— errors in determining the height of the target over that of the radar set's position;

— errors in using graphs (graficheskaya rabota).

Errors in determining the mean point (center) of the check group of bursts depend on the variation in performance of the guns of a battery, the number of shells in a salvo (η_s), and dispersion. The probable errors in determining the center of the check group of bursts in range $E_{x_{tsg}}$ and bearing $E_{z_{tsg}}$ are obtained from the expressions:

$$E_{x_{tsg}} = \sqrt{\frac{E^2_{x_g} + Vd^2}{\eta_s}} \quad \text{and}$$

$$E_{z_{tsg}} = \sqrt{\frac{E^2_{z_g} + Vb^2}{\eta_s}} \qquad (9)$$

The accuracy in determining the deviations of the center of the check group of bursts from the target, in the absence of errors in determining the target's position and the position of the radar set, as well as of errors in calculating other factors bearing on the accuracy of determining deviations, is characterized by a probable error in range E_{x_g}, and in bearing E_{z_g}. When the deviations are determined from one check salvo, the probable errors, regardless of the range of fire, are taken as:

(a) for an ARSOM radar set: $E_{x_g} = 35m$, $E_{z_g} = 4$ mils [del. ugl.]

(b) for an "Utes" radar set: $E_{x_g} = 60m$, $E_{z_g} = 1.5$ mils

The accuracy of determining the coordinates of a target from an air photograph is characterized by a probable circular error $\tau_{ts} = 20m$.

As the mean characteristic of the accuracy in determining the coordinates of the radar's position, we shall take the probable circular error radius τ_M = 15 m.

The probable error in orientation of the radar set can be taken as equal to $Ez_{\underline{or}}$ = 1mil.

The error in determining the height of the target over that of the radar set's position leads to an error in range which is characterized by a probable error equal to $Ex_{\Delta h} = 3.6 \operatorname{ctg} \theta_{\underline{s}}$.

The probable error in using graphs is taken to be equal to $\tau_{\underline{gr}}$ = 10 m.

Errors in determining the coordinates of the target, the coordinates of the radar set's position, the target's height over that of the radar set's position, and the errors in using graphs will cause a further error in determining the deviation of the center of the check group of bursts from the target in range. In addition, the errors in determining the target's coordinates, the coordinates of the radar set's position, and in using graphs, as well as errors in the orientation of the radar set will cause a further error in determining the deviation of the center of the check group of bursts from the target in bearing.

The total probable errors in determining the deviation of the center of the check group of bursts from the target in range $E_{x_{\underline{rs}}}$ and in bearing $E_{z_{\underline{rs}}}$ are calculated from the formulas:

$$(10)\quad \begin{cases} Ex_{\underline{rs}} = \sqrt{\dfrac{Ex_{\underline{g}}^2 + \underline{Vd}^2}{n_{\underline{s}}} + Ex^2_{\underline{g}} + \tau^2_{\underline{ts}} + \tau^2_M + Ex^2_{\Delta h}\,[?] + \tau^2_{\underline{gr}}} \\ Ez_{\underline{rs}} = \sqrt{\dfrac{Ez_{\underline{g}}^2 + \underline{Vb}^2}{n_{\underline{s}}}\,[?] + Ez^2_{\underline{g}} + \tau^2_{\underline{ts}} + \tau^2_M + Ez^2\,?? + \tau^2_{\underline{gr}}} \end{cases}$$

[redacted]

The values of the total probable errors, calculated from formula (10) when a six-gun battery is firing at various ranges, are given in Table 9.

An analysis of the sources of these errors, which accompany full preparation, and the determination of deviations of the center of the check group of bursts from the target with the aid of a radar set, show that under conditions when the firing positions of batteries and the position of the radar set are tied in independently, the main [?] errors of full preparation and in determining the deviations are errors in determining the coordinates of the target and errors in range, arising from error in determining the height of the target. The probable errors in range and in bearing, caused by general sources of error, are determined from the formulas:

$$E_{x_{\varrho}} = \sqrt{\zeta^2_{\underline{ts}} + (3\ ctg\theta_{\underline{s}})^2} \quad \text{and} \quad E_{z_{\varrho}} = \zeta_{\underline{ts}}$$

When there are errors arising from general sources, the probable errors in determining the optimum corrections in range $E_{x_{\underline{krs}}}$ and in bearing $E_{z_{\underline{krs}}}$ must be calculated from formulas similar to formula (5).

Having the probable errors of full preparation and the probable errors in determining the deviations of the center of the check group of bursts from the target with the aid of a radar set, as in the graph (Figure 5), we shall determine the values of coefficients $\lambda_{x_{\underline{rs}}}$ and $\lambda_{z_{\underline{rs}}}$ which are used to determine the optimum corrections for range and bearing respectively. The values of these coefficients for various conditions are given in Table 10.

From Table 10 it is evident that the magnitude of the optimum correction represents on an average:

[redacted]

Table 9

Probable Errors in Determining, with the Aid of a Radar Set, the Deviation of a Check Group of Bursts from the Target, the Coordinates of Which Have Been Determined from An Air Photograph

Radar Set	Art. system	Values of the probable errors (m) in range Ex_{rs} (in numerator) and in bearing Ez_{rs} (in denominator) when firing at range $\underline{D}$ ($\overline{km}$)						
		8	10	12	16	20	24	26
"Wtes" ("Saturn")	130 mm gun	67/31	-	68/35	69/40	71/45	72/51	75/55
	152 mm gun	66/31	-	73/35	76/40	80/46	-	-
ARSOM [?]	122 mm how.	46/43	48/49	52/56	-	-	-	-
	152 mm how.	46/43	48/49	49/56	-	-	-	-

— about three-fourths of the magnitude of the deviation in range of the center of the check group of bursts from the target for all guns;

— about one-half of the magnitude of the deviation in bearing of the center of the check group of bursts from the target for guns, and about one-third for howitzers.

So, we have examined the determination of optimum corrections under conditions when the coordinates of the target are determined by means of one of the most widely used methods - from an air photograph ($\tau_{ts} = 20$ m) - and have found the probable errors which characterize the accuracy of determining these optimum corrections; these errors, as is evident from a comparison of Tables 9 and 11, are considerably (up to 1.5 times) less than the probable errors of the method of determining deviations.

Another possible way of using the method under review (of determining settings) is the case when the coordinates of the target are determined with the aid of a radar set and the determination of the deviations of the center of the check group of bursts from the target is done with the aid of the same radar set. Under the same firing conditions, let us calculate the magnitude and accuracy of the optimum corrections for this case too.

Determination, with the aid of a radar set, of the deviations from the target of the center of the check group of bursts, the coordinates of which have been determined by the same radar set, is accompanied by the same errors as in the first case, with the exception of errors in determining the radar set's position and errors in orientation, which in the present case do not affect the accuracy of determining the deviations, as well as errors in determining the target coordinates, which are accepted as being equal to $\tau_{ts} = 20$ m for an ARSOM radar set and $\tau_{ts} = 45$ m for an "Utes" radar set.

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Table 10

Values of Coefficients $\lambda_{x_{rs}}$' and $\lambda_{z_{rs}}$' When Firing Against a Target the Coordinates of Which Have Beeen Determined from an Air Photograph

Art. system	$\lambda_{x_{rs}}$' when firing at range D (km)							$\lambda_{z_{rs}}$' when firing at range D (km)						
	8	10	12	16	20	24	26	8	10	12	16	20	24	26
130 mm gun	0.48		0.63	0.74	0.82	0.86	0.82	0.47		0.50	0.56	0.59	0.64	0.68
15[illegible] gun	0.50	-	0.66	0.74	0.80	-	-	0.4[illegible]		0.52	0.55	0.7	-	-
122 mm how.	0.68	0.77	0.80	-	-	-	-	0.32	0.34	0.42	-	-	-	-
152 mm how.	0.69	0.75	0.80	-	-	-	-	0.33	0.33	0.38	-	-	-	-

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From formulas like (5), we have calculated the probable errors in determining the optimum correction for range $E_{x_{krs}}$ and bearing $E_{z_{krs}}$, the values of which are given in Table 11.

Table 11

Probable Errors in Determining Optimum Corrections $E_{x_{krs}}$ and $E_{z_{krs}}$ When Firing Against a Target the Coordinates of Which Have Been Determined from an Air Photograph

Art. system	Values of probable errors (m) in range $E_{x_{krs}}$, (in numerator) and in bearing $E_{z_{krs}}$, (in denominator) when firing at range D (km)						
	8	10	12	16	20	24	26
1	2	3	4	5	6	7	8
130 mm gun	49/25		56/20	60 [?]/36	?/?	68 [?]/44	71 [?]/47
122 mm gun [sic]	49/26		61/29	66/33	73/40	-	
122 mm how	40/27	44/32	48/39	-	-	-	-
152 mm how.	41/28	43/32	46/37	-	-	-	-

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The total probable errors in determining the deviation from the target of the check group of bursts, the coordinates of the target having been determined by the same radar set, are calculated from the formulas:

$$E_{x_{rs'}} = \sqrt{\frac{E_{xr}^2 + V_d^2}{n_s} + E_{xg}^2 + \tau_{ts}^2 + E_{x_{\Delta h}}^2 + \tau_{gr}^2} \qquad (11)$$

$$E_{z_{rs'}} = \sqrt{\frac{E_{zr}^2 + V_b^2}{n_s} + E_{zg}^2 + \tau_{ts}^2 + \tau_{gr}^2}$$

As in the case when the coordinates of the target are determined from an air photograph, we have calculated the coefficients $\lambda_{x_{rs'}}$ and $\lambda_{z_{rs'}}$, which determine the magnitude of the optimum correction for range and bearing respectively, as well as the probable errors in determining the optimum correction for range $E_{x_{krs'}}$ and for bearing $E_{z_{krs'}}$, the values of which are given in Tables 13 and 14.

As can be seen, the values of the coefficients λ, given in Table 13, vary little in practice from the coefficients given in Table 10. Consequently, the optimum corrections will be the same as in the case when the coordinates of the target are determined from an air photograph.

From Table 14, it is evident that the probable errors in the optimum corrections remain the same as in the case where the coordinates of the target are determined from an air photograph when howitzers are firing, but exceed them considerably when guns are firing. The explanation of this lies in the comparatively big error in determining the coordinates of a target with the aid of an "Utes" ("Saturn") radar set.

In Table 15 are given the total probable errors in range $E_{x_{pp-rs}}$ and in bearing $E_{z_{pp-rs}}$ which characterize the accuracy of the method under consideration of determining settings for fire for effect; they have been calculated by using a formula like (6).

The values of these probable errors are given in Table 12.

Table 12

Probable Errors in Determining, with the Aid of a Radar Set, the Deviation of a Check Group of Bursts from the Target, the Coordinates of Which Have Been Determined by the Same Radar Set

Type of Radar Set	Art. system	Values of probable errors (m) in range $E_{x_{rs}}$, (in numerator) and in bearing $E_{z_{rs}}$, (in denominator) when firing at range $\underline{D}$ (km)						
		8	10	12	16	20	24	26
"Utes" ("Saturn")	130 mm gun	77/40		78/50	78/52	80/53	82/59	84/61
	152 mm gun	76/48		83/50	84/52	88/56	-	-
ARSOM	122 mm how	44/39	46/46	49/53	-	-	-	-
	152 mm how.	44/39	45/45	47/53	-	-	-	-

CSDB-3/651,392

Table 13

Values of Coefficients $\lambda_{x_{rs}}$, and $\lambda_{z_{rs}}$, When Firing Against a Target the Coordinates of Which Have Been Determined by a Radar Set

Art. system	$\lambda_{x_{rs}}$, when firing for range D (km)							$\lambda_{z_{rs}}$, when firing for range D (km)						
	8	10	12	16	20	24	26	8	10	12	16	20	24	26
130 mm gun	0.5[illegible]		0.61	0.71	0.79	0.83	0.86	0.52		0.54	0.57	0.60	0.65	0.69
152 mm gun	0.51		0.63	0.71	0.78	-	-	0.52		0.54	0.57	0.68	-	-
122 mm how	[illegible]	0.78	0.81	-	-	-	-	0.3[illegible]	0.38	0.44	-	-	-	-
152 mm how	0.71	0.77	0.82	-	-	-	-	0.37	0.37	0.41	-	-	-	-

Table 14

Probable Errors in Determining Optimum Corrections $E_{x\,krs}$, and $E_{z\,krs}$, When Firing Against a Target, the Coordinates of Which Have Been Determined by a Radar Set

Art. system	Values of probable errors (m) in range $E_{x\,krs}$, (in numerator) and in bearing $E_{z\,krs}$, (in denominator) when firing at range D (km)						
	8	10	12	16	20	24	26
130 mm gun	63/47		68/48	72/50	75/52	78/56	80/58
152 mm gun	63/47		72/48	77/50	82/54	-	-
122 mm how	39/27	42/31	46/39	-	-	-	-
152 mm how	39/27	41/31	44/37	-	-	-	-

Table 15

Probable Errors of Full Preparation with the Introduction of Corrections Determined with the Aid of a Radar

Method of determining the coordinates	Art. system	Values of probable errors (m) in range Ex_{pp-rs} (in numerator) and in bearing Ez_{pp-rs} (in denominator) when firing at range D (km)						
		8	10	12	16	20	24	26
air photograph (τ_s= 20m)	130 mm gun	56/26		65/30	71/36	81/41	88/49	95/54
	152 mm gun	54/26		80/30	90/35	105/46	-	-
	122 mm how	48/28	60/33	71/41	-	-	-	-
	152 mm how	49/28	54/33	61/39	-	-	-	-
with the aid of a radar set τ_{ts} = 20m for ARSOM and τ_{ts} = 45m for "Utes"	130 mm gun	59/47		76/49	81/52	89/55	96/60	108/63 [?]
	152 mm gun	57/47		89/49	96/52	112/58 [?]	-	-
	122 mm how	47/27	59/33	69/40	-	-	-	-
	152 mm how	47/28	53/32	59/38	-	-	-	-

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To sum up, we shall formulate the following practical recommendations for the planning and employment of full preparation with the introduction of corrections, determined with the aid of a radar set, when firing against the enemy's offensive nuclear weapons.

To support its fire, each battalion must have a radar set (organic or attached) of the appropriate type. The radar set's position is selected in such a way that it should be possible to use the radar set to support the fire of not less than two batteries of the battalion.

With a view to reducing the time spent on fire planning after receiving the fire task, the battalion commanding officer must draw up plans in advance for coordination and communications between the radar set and the firing positions of batteries, as well as with battalion headquarters.

Fire for effect is opened against the target on the basis of full preparation. During the fire concentration (ognevoy nalet), each of the batteries engaged in firing fires one check salvo, in turn.*

As a rule the data necessary for fixing (zasechka) the salvo of each battery (distance of the radar set from the firing position, height of the target above the firing position, map bearing angle (topograficheskiy direktsionnyy ugol) and range to the target) are determined at battalion headquarters at the same time as it determines the settings for fire for effect against the target, and they are passed to the commanding officer of the radar set.

The commanding officer of the radar set reports to battalion headquarters when the radar is ready to fix the salvo of the first (next in turn) battery. Having received the report that the radar set is ready, the battalion chief of staff gives the order to the firing position to prepare the salvo. When the senior officer of the battery reports that he is ready, the battalion chief of staff gives the order "Fire," which is received at the firing position and at the radar set. The report

* If the first salvo was not fixed, a repeat salvo is fired.

that the battery has fired is passed from the firing position simultaneously to the radar set and to battalion headquarters.

After fixing the check group of bursts, the commanding officer of the radar set reports to battalion headquarters the deviations from the target of the center of the check group of bursts and prepares the radar for checking the next battery to fire.

The battalion chief of staff determines the corrections on the basis of the reported deviations.

The range correction is accepted as equal to three-fourths of the magnitude of the range deviation with the opposite sense (obratnyy znak), and the bearing correction as one-half the magnitude of the bearing deviation for guns and one-third for howitzers with the sense opposite to the deviation sense. After determining the corrections, the chief of staff gives the necessary order to the battery firing position and starts to carry out the check of the next battery to fire.

When firing is planned efficiently, not more than 5 minutes per battery are required to conduct the check, and under conditions when several batteries are brought in to fire against the target, this makes it possible in practice to combine the check with fire for effect.

Full Preparation with the Introduction of Corrections Determined with the Aid of an Aircraft

The technical equipment of spotter aircraft which is being developed ensures rapid and accurate determination of the target coordinates and of the deviations of the bursts from the target both directly in the aircraft and on a screen by the transmission of a television image. The accuracy of determining the target coordinates and of the deviations of the bursts from the target, with the help of an aircraft in the given conditions, is characterized by a probable circular error of the order of Z = 30 to 40 m, which allows the use of full preparation and also makes it possible when correcting fire on a target to introduce a correction from only one group of bursts. This fully justifies the employment of such a method of determining settings as full preparation with the introduction of corrections determined with the aid of an aircraft.

By this method, fire for effect is opened against the target on the basis of full preparation. During the firing for effect (as a rule at the beginning) each of the batteries engaged in firing fires a check salvo. With the aid of an aircraft, the deviations of the center of each check group of bursts from the target in range and bearing are determined; from the deviations, the appropriate corrections are determined, taking into account the accuracy of full preparation. After introducing the corrections, fire for effect is continued.

It is most advisable to use this method when firing for effect against a target, the coordinates of which have been determined with the aid of an aircraft, when the same aircraft is employed to determine the deviations of the center of the check group (groups) of bursts. If the coordinates of the target are determined by some other method, or if some other aircraft is used to carry out the check, then time will be needed to call up the aircraft, for the latter to find the target, etc., as a result of which the probability of destroying the target becomes much less and the fire for effect against the target will require a very large expenditure of shells.

Determination of the deviations of the center of the check group of bursts from the target with the aid of an aircraft is accompanied by:

— errors in determining the mean point of the check group of bursts, errors which depend on variation in performance of battery guns, on the number of shells in the salvo (η_s), and dispersion, which are characterized by the probable errors calculated by the formulas (9);

— errors in determining the deviations of the center of the check group of bursts from the target, which, for most of the existing methods, are characterized by a probable circular error $\tau_g = 30$ m.

Errors in determining the coordinates of the target, and other errors which occur when deviations are determined with the help of a radar set, in this case have no bearing on the accuracy of determining the deviations, because the deviations are measured in relation to an observed target.

The total probable errors in determining with the aid of an aircraft the deviation of the center of the check group of bursts from the target - in range E_{x_g} - and in bearing E_{z_g} - are obtained by the formulas:

$$\left.\begin{aligned} E_{x_g} &= \sqrt{\frac{E^2_{x_g} + V_d^2}{\eta_g} + \tau_g^2} \\ E_{z_g} &= \sqrt{\frac{E^2_{z_g} + V_b^2}{\eta_g} + \tau_g^2} \end{aligned}\right\} \quad (12)$$

The magnitudes of E_{x_g} and E_{z_g} calculated in accordance with formulas (12) are given in Table 16.

Having the probable errors of full preparation, calculated for the case when $\tau_{tg} = 35$m, and the probable errors in determining the deviations of the center of the check group of bursts from the target with the aid of an aircraft, we shall obtain from the graph (Figure 5) the values of coefficients λ_{x_g} and λ_{z_g}, which are used to determine the corrections for range and bearing respectively. The values of these coefficients are given in Table 17.

From Table 17 it is clear that depending on the range of fire, the values of the coefficients λ_{x_g} vary

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CSDB-3/651,392

Table 16

Probable Errors in Determining with the Aid of an Aircraft the Deviations from the Target of the Check Group of Bursts

Art. system	Values of probable errors (m) in range E_{x_s} (in numerator) and in bearing E_{z_s} (in denominator) when firing at range D (km)					
	8	12	16	20	24	26
130 mm gun	$\frac{33}{30}$	$\frac{35}{30}$	$\frac{36}{30}$	$\frac{40}{31}$	$\frac{43}{31}$	$\frac{46}{31}$
152 mm gun	$\frac{32}{30}$	$\frac{44}{30}$	$\frac{48}{30}$	$\frac{55}{31}$	-	-

Table 17

Values of Coefficients Λ_{x_s} and Λ_{z_s}

Art. system	Λ_{x_s} when firing at range (km)						Λ_{z_s} when firing at range (km)					
	8	12	16	20	24	26	8	12	16	20	24	26
130 mm gun [?]	0.82	0.88 [?]	0.92	0.94	0.95	0.95	0.64	0.69	0.75	0.80	0.85	0.??
152 mm gun [?]	0.84	0.85	0.88	0.90	-	-	0.65	0.69	0.75	0.85	-	-

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between 0.80 and 0.95, i.e., differ little from one.

Consequently, in practice the magnitude of the optimum correction in range will differ little from the deviation from the target in range of the center of the control group of bursts, which has been determined with the aid of an aircraft. The values of the coefficients λ_{zs}, and consequently the magnitude of the optimum correction in bearing, will be on an average three-fourths of the magnitude of the deviation in bearing.

An analysis of the errors of full preparation and the errors in determining the deviations of the center of the check group of bursts from the target with the aid of an aircraft shows that among these errors there are no common errors; consequently, it is necessary to calculate the probable errors in determining the optimum corrections for range Ex_{ks} and for bearing Ez_{ks} by using formulas similar to formula (4).

The magnitude of Ex_{ks} and Ez_{ks} are given in Table 18.

Table 18

Probable Errors in Determining the Optimum Corrections Ex_{ks} and Ez_{ks}

Art. system	Values of probable errors (m) in range Ex_{ks} (in numerator) and in bearing Ez_{ks} (in denominator) when firing at range D (km)					
	8	12	16	20	24	26
130 mm gun	30/24	33/25	34/26	38/27	42/28	45/29
152 mm gun	29/24	41/25	46/26	52/29	-	-

From a comparison of the data in Tables 16 and 18 it can be concluded that the accuracy of optimum correction is only slightly superior to the accuracy of determining the deviation from the target of the check group of bursts with the aid of an aircraft. The explanation of this lies in the substantial difference between errors of full preparation and errors in determining deviations. A further decrease in the accuracy of full preparation will likewise not lead to any substantial decrease in the accuracy of optimum corrections.

The total probable errors of the method under review of determining settings for fire for effect - in range $E_{x_{pp-s}}$ and in bearing $E_{z_{pp-s}}$ - calculated by using formula (6), are given in Table 19.

Table 19

Probable Errors of Full Preparation with the Introduction of Corrections Determined with the Aid of an Aircraft

Art. system	Values of average errors (m) in range $E_{x_{pp-s}}$ (in numerator) and in direction $E_{z_{pp-s}}$ (in denominator) when firing at range D (km)					
	8	12	16	20	24	26
130 mm gun	41/25	47/27	51/30	62/32	70/37	79/39
152 mm gun	36/25	66/27	76/29	92/36	-	-

From comparison of the data in Tables 15 and 19 it is clear that this method of determining settings for fire for effect is considerably superior in accuracy to full preparation with the introduction of corrections determined with the help of a radar set.

To sum up, we shall make the following practical recommendations for using the method under consideration to determine settings for fire for effect.

Fire for effect is opened against the target on the basis of full preparation.

During the fire concentration, each of the batteries employed in firing fires one check salvo in turn.* With the aid of an aircraft, the deviations of each check group of bursts from the target in range and bearing are determined, the necessary corrections are introduced, and fire for effect is continued under the most advantageous method of shelling the target.

The correction for range is accepted as equal to the deviation from the target in range of the center of the check group of bursts, taken with the opposite sense; the correction for bearing is accepted as equal to three-fourths of the magnitude of the deviation in bearing, taken with the sense opposite to the deviation sense.

The planning of fire and cooperation with an aircraft when using this method to determine settings for fire for effect does not differ in any way from adjustment on a target with an aircraft; this is described in detail in the manual and is, therefore, not examined here.

When coordination between a battalion and an aircraft in the area of the concentration is planned in advance and is carried out efficiently, up to 5 minutes will be needed to determine the corrections for one battery. A further 5 [?] to 10 minutes will be required to determine the corrections for the remaining batteries of the battalion provided that the check salvos of batteries follow one another at a rate which ensures the determination of the deviations during the time of a single flight [?].

* If necessary, a repeat salvo is fired.

3. Direct Adjustment on a Target

Direct adjustment on an enemy gun (launcher) or battery can be carried out with the help of an aircraft, helicopter, and a radar set.

The determination of settings for fire for effect against a target on the basis of data obtained in adjustment is one of the most accurate methods. In the case of this method, little importance is attached to knowledge of the exact coordinates of the firing position and to strict calculation of the meteorological and ballistic conditions for firing because inaccuracies in the fire preparations are eliminated by adjustment; moreover, when adjusting on a target observed from an aircraft (helicopter), knowledge of the exact coordinates of the target is of little importance. As a rule, adjustment on a target with the aid of an aircraft or a radar set is limited to one salvo per battery, which does not lead to any substantial loss in accuracy, but allows the time spent in adjusting to be reduced to the minimum.

Adjustment calls for efficient planning of coordination between the batteries and the means for fire correction. These distinguishing characteristics of the method under consideration to determine settings for fire for effect in the main predetermine the conditions for using it.

Thus, as a rule, it is advisable to determine settings for fire for effect on the basis of data obtained in adjusting when firing against targets that have been reconnoitered with the aid of means which have been brought in to ensure correction of fire in circumstances when for some reason or other firing conditions cannot be accurately calculated.

The accuracy of determining settings for fire for effect on the basis of data obtained in adjustment depends on the accuracy of the adjusting, the duration of fire for effect, and the accuracy in calculating the variation in performance of the guns.

The probable errors in range and bearing, which characterize the accuracy of the method of determining settings for fire for effect on the basis of data obtained in adjusting against the target are calculated by using a formula similar to formula (6).

The accuracy of adjustment depends mainly on the method of adjustment and is characterized by the probable adjustment errors E_{x_p} in range and E_{z_p} in bearing. In adjusting with the aid of a radar set, when it is limited to arranging one check salvo per battery, the probable errors in adjusting for the battery are calculated from formulas (11) and are given in Table 12.

The probable errors in adjusting by batteries on a target with the aid of an aircraft for the case when adjustment is limited to arranging one check salvo per battery are calculated according to formulas (12) and are given in Table 16. The accuracy of adjustment on a target by batteries with the aid of a helicopter, by observation of the [one word missing] of bursts is characterized by probable errors of the order of 1.1 [?] in range and 0.03 [?] in bearing.

The planning of and procedure for carrying out adjustment by the different methods are to be found in the appropriate manual and so these questions are not examined in this paper.

The probable errors in determining settings for fire for effect by batteries on the basis of data obtained by adjustment on the target, calculated with the same values for errors caused by the changes with time in meteorological conditions [?] and errors in calculating the variation in performance of the battery guns as for the preceding methods of determining settings, are given in Table 20.

The time required to carry out adjustment on a target with the aid of an aircraft or a radar set will not differ in practice from the time which is spent on full preparation with the introduction of corrections with the aid of an aircraft or a radar set respectively.

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Table 20

Probable Errors in Determining Settings for Fire for Effect on the Basis of Data Obtained in Adjustment against a Target with the Aid of a Helicopter, an Aircraft, and a Radar Set

[Method?] of Adjustment	Art. system	Values of probable errors (m) in range E_x (in numerator) and in bearing E_z (in denominator) when firing at range D (km)						
		8	10	12	16	20	24	26
Helicopter	122 mm how	40/25	59/31	75/38	-	-	-	-
	152 mm how	42/25	52/31	63/38	-	-	-	-
	130 mm gun	36/25	-	48/37	56/50	73/62	-	-
	152 mm gun	30/26	-	85/37	102/50	125/63	-	-
Aircraft	130 mm gun	43/[?] 31	-	48/32	52/35	62/35	71/39	79/41
	152 mm gun	39/31	-	68/32	78/33	93/38	-	-
Radar Set	122 mm how.	51/39	61/47	72/54	-	-	-	-
	152 mm how.	51/39	56/47	62/54	-	-	-	-
	130 mm gun	82/48	-	84/50	87/[?] 54	92/58	99/63	105/66
	152 mm gun	79/48	-	96/50	104/54	16/59	-	-

The time needed for adjustment on a target with the aid of a helicopter is of the order of 20 minutes for a battery and 30 minutes for a battalion.

4. Comparative Evaluation of the Accuracy of the Various Methods of Determining Settings for Fire for Effect

Under conditions when it is possible to use several methods of determining settings for fire for effect, the problem arises of selecting the most accurate method which will allow the fire task to be carried out with the minimum [?] expenditure of ammunition. With this in view, let us make a comparative evaluation of the accuracy of the various methods of determining settings for fire for effect.

The accuracy of the different methods of determining settings for fire for effect is characterized by probable errors in range E_x and in bearing E_z. The drawing up of a comparative evaluation of the accuracy of methods when use is made of two methods [?] has proved a failure [?] and consequently, as a rule, use is made of the given probable errors [?]. The [one word missing] E_x E_z are included in the formula for determining the expenditure norm of shells and in this way become a comparative evaluation which characterizes the accuracy of the method [?].

The graphs (Figures 7 and 8) show the variations [?] of E_x E_z depending on the range when firing with 130 [?] mm guns and 122 [?] mm howitzers. The results [?] obtained for these systems will be [two words missing] for 152 [?] mm guns and 152 [?] mm howitzers [?].

[Heading probably reads:
Comparative Accuracy of Methods of
Determining Settings for a 130 (?) mm gun]

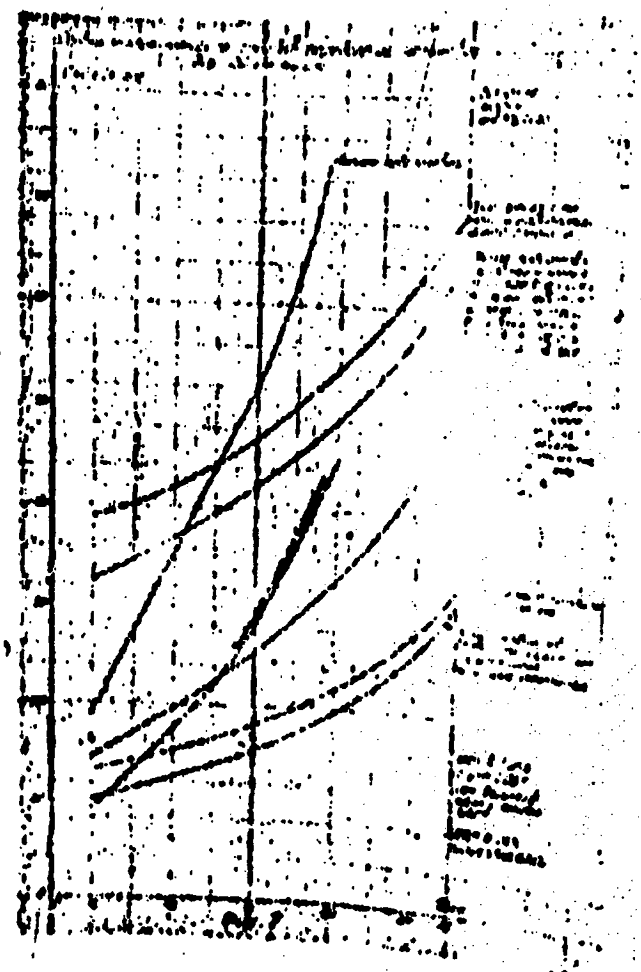

Figure 7.
[Note: Other legend illegible, but see Page]

Comparative Accuracy of Methods of

Determining Settings for a 122 mm Howitzer

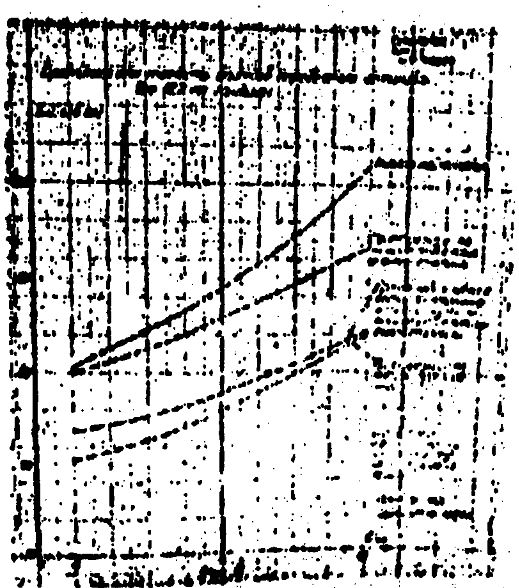

Figure 8.
[Note: Other legend illigible, but see Page]

From the graphs, the following is evident.

1. When firing guns, the most accurate method of determining settings for fire for effect is full preparation with the introduction of corrections determined with the aid of an aircraft. Then, in order of decreasing accuracy, come adjustment with the aid of an aircraft, full preparation with the introduction of corrections determined with the aid of a radar set, and adjustment with the aid of a radar set. In accuracy, adjustment with the aid of a helicopter at ranges up to 20 km occupies an intermediate position.

2. When firing howitzers, the best method as far as accuracy is concerned of determining settings for fire for effect is adjustment with the aid of a helicopter. Then come full preparation with the introduction of corrections determined with the aid of a radar set and adjustment with the aid of a radar set.

Chapter Conclusions

1. The main method of determining settings for firing with operational-tactical and tactical missiles against the enemy's offensive nuclear weapons is full preparation.

The characteristics of the accuracy of full preparation for operational-tactical and tactical missiles are given in Tables 4 and 5.

The time needed to determine settings for firing on the basis of full preparation can be reduced in the near future to 6 to 8 minutes for operational-tactical missiles and 2 to 5 minutes for tactical missiles.

2. The main methods of determining settings for artillery fire against the enemy's offensive nuclear weapons are: full preparation with the introduction of corrections with the aid of a radar set or aircraft, and direct adjustment on the target with the aid of a radar set, aircraft, and helicopter. The characteristics of the accuracy of these methods of determining settings are given in Tables 15, 19 and 20.

Artillery is capable of opening effective fire against a target in 2 to 3 minutes after receiving the fire task. When firing is efficiently planned, the time needed to determine corrections on the basis of check shots is of the order of 5 minutes.

When coordination between a battery (battalion) and the means assisting in the correction of fire is planned in advance and efficiently carried out, the time needed to determine settings for fire for effect on the basis of correction of fire data (from the moment that the fire task is received to the opening of fire for effect) will be: 5 minutes for correction of fire with the aid of a radar set, of the order of 10 minutes for correction of fire with the aid of an aircraft, and of the order of 20 minutes for correction of fire with the aid of a helicopter, provided that the aircraft or helicopter have reconnoitered the target and are in the air.