Setting a method of determination of "Fire for Effect" firing data and Conversion of the METCM into the METEO-11

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***Abstract*—**This paper is focused on setting a method of determination of Fire for Effect firing data in the perspective of automated artillery fire support control system and deals with a proposed method of conversion of the METCM meteorological message into the METEO-11 format. This method is designed for artillery of these armies that are using the METEO-11 meteorological message during a spare (manual) method of firing data calculation. Artillery units of the Army of the Czech Republic, reflecting the current global security neighborhood, can be used outside the Czech Republic. The paper presents problems in the process of complete preparation, from results arising from creating a fictional auxiliary target; by using an adjustment gun; Abridged preparation and Simplified preparation. The paper presents problems of current Artillery communication and information system and suggests requirements of the future system.

***Keywords*—**fire support, complete preparation, adjustment gun, simplified preparation, Fire for Effect.

I. Introduction

There are several ways to set firing data for Fire for Effect (FFE) of artillery units. They differ in accuracy and terms, which permit us to apply FFE. For FFE it is important to decide the most accurate way of setting the firing data in every situation.

This decision making action was provided by artillery commanders during training activities, where they generally had only instruments and information, which usually resulted in one and the only way of setting firing data for effective fire. While using Artillery Fire Support Control System (ASRPP-DEL) it is necessary to define specific terms for setting firing data for effective fire by different means.

Firing data for FFE can be set by these methods:

- Complete preparation – Accurate Predicted Fire (APF);
- By results from creating fictional auxiliary target;
- By using an adjustment gun;
- Abridged preparation. [3]

This work was supported in part by the University of Defence Grant of specific research SV12-FEM-K107-03-BLA.

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Terms and Conditions which permit the subsequent FFE are available in the publication Pub-74-14-01 Pravidla střelby a řízení palby pozemního dělostřelectva.

This chapter defines conditions by which ASRPP-DEL sets the way of FFE firing data computation.

Two standard types of meteorological messages are used in the North Atlantic Treaty Organisation (NATO) during the firing data calculation – METCM meteorological-computer message and the METBK meteorological-ballistic message [1, 2]. The METCM is used in automated artillery fire control systems and the METB3 during spare (manual) methods of firing data calculation.

The proposed method of conversion of the METCM into the METEO-11 format can be divided into three consecutive phases:

- header (baseline data) of the meteorological message recalculation;
- ground meteorological data conversion;
- meteorological data average values in the individual layers conversion.

II. Accurate Predicted Fire

The Complete preparation (APF) is the way of setting FFE firing with such accuracy that adjustment of fire is not necessary. This is the key to achieving the effect of surprise. Due to this reason APF is the main way of setting firing data for effective fire. For calculation of data using complete preparation these measures have to be included:

1. Topographical-geodetically preparation;
2. Reconnaissance and target detection;
3. Meteorological preparation;
4. Ballistic preparation.

These conditions are mentioned in Scheme 35-The way of setting firing data for complete preparation, Complete preparation.

A. Topographical - geodetically preparation

Fire schedule will determine basis for tactical command of firing, especially choose of the unit which will lead the firing, time of fire, in case of need signals for start or end of fire Publication Pub-74-14-01 Pravidla střelby a řízení palby pozemního dělostřelectva sets terms and conditions of topographical-geodetically preparation for complete preparation as follows:

- Fire position coordinates have to be set geodetically by using GPS, topographically by using a map of geodetically data and using instruments or topographical connector.

- Orientation bearings to aim guns have to be set gyroscopically, astronomically or geodetically and by switching a bearing by simultaneously aiming on luminary object or by directional order and magnetically including calculation of compass rectification set in 5 km distance from fire positions and for leading set KPzP including calculation of correction of device for set place. [3]

These conditions have to be perfectly known and applied by members of reconnaissance teams. These members have to mark an accuracy of gained coordinates and orientation bearings in “Sketch of topographical-geodetically positioning” (Basis for topographical-geodetically preparation for ASRPP-DEL, 2 Content of “Sketch of topographical-geodetically connection”) [1].

On the basis of setting coordinates and orientation bearings, accuracy standards for mentioned ways and technical possibilities of current instruments, it is possible to set maximal norms of accuracy for setting angle coordinates on the value of 40 m and orientation bearings on the value of 3 units of artillery quantity (dc).

However there is one question remaining. Are topographical connectors, which are currently included in equipment of artillery units, able to reach this accuracy and in which conditions? In rules of fire from 1992 use of this topographical connector was restricted by length of marching axis (axis of march) for maximum of 3 km. This distance, by the mistake of 3% of driven distance set by technical parameters of the instrument, represents a total mistake up to 90 m. But in publication Pub-74-14-01 there is no restriction for marching axis distance. From the reason of securing an accuracy of artillery units fire and so its efficiency, it is useful to cut out a regulation about setting angle coordinates and orientation bearings using topographical connector from conditions for complete preparation until any instruments will be able to reach standards for topographical-geodetically positioning.

B. Reconnaissance and target acquisition (TA)s

Fire Publication Pub-74-14-01 Pravidla střelby a řízení palby pozemního dělostřelectva sets, that for complete preparation target coordinates must be set with a maximal probable circle mistake of 50m. This is conditioned by carrying out the following requirements:

- Targets must be found in bounds of effective range of artillery (TA) instruments (DPz).

- Reconnaissance emplacement has to be desired geodetically, by GPS or topographically via a map and by using instruments or by using navigation instrument.

- Orientation bearings have to be set gyroscopically, astronomically, geodetically with possibility of switching a bearing, or magnetically including rectification of compass set in the distance of 5 km from emplacement. [3]

The term “effective range” of instrument is not defined anywhere. But it can be characterized as a distance at which it is possible to reliably acquire the target data necessary for artillery fire. Technical range of artillery TA optical instruments is mentioned in the table 1. However, acquisition of targets at the instruments maximal technical range is unreal, since above 10 km it is not possible to precisely identify objects. That means unreliable determination of target (if the target is a person, animal, civilian or a soldier, military or civilian vehicle, etc.). This is given by optical attributes of instruments (mainly magnification) and by possibility of “detection” of object by using optical instruments mentioned in table 1. It is necessary to bear in mind that detection means discovering the object (a person, personal vehicle, helicopter, etc.), not its determination. So it is necessary to count with an effective range of current optical instruments used by artillery units on its effective range up to 10 km. In the case when new artillery TA instrument is established with such attributes, which allow this instrument to identify targets on distance above 10 km, this instrument will have to meet more strict norms on orientation accuracy so that spatial norm for determination target coordinates will not be exceeded.

The mistake for setting coordinates of emplacement for PzPK Sněžka using navigation instrument is 0,2% of the driven distance. This means, 20ms fault of 10kms movement. A probable mistake for setting the target coordinates by using a radar type SCB 2130 L-2 is 10 m in a distance and 2 units of an artillery quantity in a direction. The mistake in distance is constant and this accuracy is invariable with increasing distance. The mistake in direction increases with increasing distance and at the distance of 15 km the mistake is of 30m. In a case where PzPK is moving on a distance of 10 km, the setting of target coordinates accuracy for complete preparation for targets in a distance above 15 km would not be allowable. If the PzPK emplacement position determination is more accurate and it is set on a value of 0,1% of driven distance, the target coordinates determination accuracy will be allowable for the target distance up to 20 km. From the mentioned dependences it is possible to deduce a relation for calculation of maximum target distance from an emplacement for PzPK Sněžka:

$$dp = \tfrac{1}{2}\,[50 - (0{,}002 \times d_{př})]$$

where:

dp observer distance;

½ constant, invert value of probable mistake for setting target coordinates using radar type SCB 2130 L-2 in direction (2 dc);

50 constant, characterizing maximal mistake for setting target coordinates in direction in meters, which results from maximal probable circle mistake for setting target coordinates;

0,002 constant, characterizing a mistake for setting emplacement for PsPK Sněžka coordinates using navigation instrument (0,2 %);

$d_{př}$ movement distance before taking observer emplacement by PzPK Sněžka in meters.

A calculated observer distance (dp) is possible to take for an effective range of radar SCB 2130 L-2.

The probable circle mistake for setting target coordinates, detected by radar ARTHUR in range of its technical possibilities, is 50 m including mistakes of its own positioning, which meets the requirement for APF. Effective range of radar ARTHUR is identical to its technical range. [2]

The accuracy of artillery TA instrument positioning (setting coordinates) is defined with table T-2.1 in publication Pub-74-14-01. From this publication it is clear that the artillery TA emplacement has to be pinpointed with the same accuracy as gun firing positions. This means, up to 40 ms in length and 3 units of artillery quantity in orientation direction.

In the case of compliance with the mentioned requirements, the conditions for determining target coordinates for APF are met. An artillery observer has to count on described values (target coordinates determination accuracy and artillery reconnaissance instrument positioning) and in the case of call for fire (CFF), according to CFF in ASRPP-DEL, he will declare information “accurate” or “inaccurate”, mentioned behind the figure target position.

C. *Meteorological preparation*

Fire Publication The publication Pub-74-14-01 Pravidla střelby a řízení palby pozemního dělostřelectva determines that for complete preparation, meteorological conditions have to be determined from meteorological message METC, METEO--STŘEDNÍ or METEO-STŘEDNÍ PŘIBLIŽNÁ. All these messages have to comply with spatial and time validity.

METCM is valid for distances up to 50 km and for a 4h time period. Nevertheless in the message is stated time validity, which has to be considered in the case where the time period is shorter than standard validity of 4 hours.

Table 1. The range of reconnaissance instruments

S.n.	Instrument	Parameter	Value	Note
1	Infrared camera SOPHIE	Range (target detection): - person - tank - helicopter	 3 km 9 km 11,5 km	IPzS LOS, KPzP
2	Laser range-finder HALLEM II	Range	50 – 15 000 m	IPzS LOS, KPzP
3	Night vision KLÁRA	Range	2,5 km	KPzP
4	Laser range-finder VECTOR IV	Range	4 km	KPzP
5	Day overview camera	Range (detection) target:	to 5 km	IPzS LOS
6	Day aiming camera	Range (detection) target:	to 10 km	IPzS LOS
7	Infrared camera TD 92 B2	Range (detection) target:	to 9 km	PzPK SNĚŽKA
8	Laser range-finder MOLEM	Range	20 km	PzPK SNĚŽKA
9	Radio locator SCB 2130 L-2	Range (detection) target: - person - tank	9 km 33 km	PzPK SNĚŽKA
10	Laser range-finder LPR-1	Range	20 km	Substitute reconnaissance instrument (by PzPK SNĚŽKA)
11	Radio locator ARTHUR	Range: mortars, guns, rocket launchers, tactical rockets launchers	 20 km 30 km 40 km	

METEO-STŘEDNÍ is valid for distances up to 10 km and for a 3 hour time period, or the distance up to 35 km and for 2 hours’ time period. METEO-STŘEDNÍ PŘIBLIŽNÁ is valid only for division units, whose meteorological squad created this message and it is valid for 1 hour time period. All these norms are valid for stabilized weather conditions. ASRPP-DEL has to have available actual local time and overview of the real deployment of units, placing a great emphasis on fire positions. From meteorological messages the system gathers information about meteorological station position, about the time of processing the message and about its validity. On a basis of these mentioned entry data ASRPP-DEL automatically provides an overview about actuality of meteorological message from the time and space point of view. In a case where the time of the end of validity of the message is coming up (e.g. 30 minutes before the end of validity), it automatically sends a signal to starting probing.

D. *Ballistic preparation*

The publication Pub-74-14-01 Pravidla střelby a řízení palby pozemního dělostřelectva determines that ballistic fire conditions have to be set, especially total change of beginning projectile speed. This means that for meeting conditions for complete preparation it is necessary to determine distance correction for:

- total change of muzzle projectile speed;
- change of propellant temperature;
- cartridge case of Czechoslovakian type (alternatively of the other, newly established type);
- unpainted projectile. [3]

Into weapon set individual corrections there is included distance correction for projectile weight change.

III. Fictional auxiliary target creation – Registration fire

According to the results of fictional auxiliary target creation (FPC) it is possible to determine data for FFE with such accuracy, after which it is not necessary to adjust fire. At the same time the following restrictions have to be met:

- observer distance of created FPC cannot exceed artillery reconnaissance instruments technical possibilities (table 1);
- adjusted distance and direction corrections can be used only for projectiles with the same table corrections for fire conditions changes;
- time period of validity for values, determined by fictional auxiliary target creation is up to 3 hours;
- switch of fire by simple method can be used in the case of high-pitched trajectory fire, if the difference between the fictional auxiliary target bearing and eliminated target bearing (switching angle) equals 300 dc or if it is smaller than 300 dc, and if the difference between fictional auxiliary target topographical distance and eliminated target topographical distance equals 1 km or if it is smaller than 1 km;
- switch of fire by coefficient of fire method can be used in the case of flat and rounded trajectory, if the switching angle equals 300 dc or if it is smaller than 300 dc, and if the difference between fictional auxiliary target topographical distance and eliminated target topographical distance equals 2 km or if it is smaller than 2 km.

IV. The application of an adjustment gun

Use either SI (MKS) or CGS as primary units. (SI units are A publication Pub-74-14-01 Pravidla střelby a řízení palby pozemního dělostřelectva establishment results in a statement that fire data for an effective fire can be determined by using an adjustment gun, if the fictional auxiliary target is created by one of guns of the whole battery and if a discrepancy between platoons (batteries) master guns and a battery master gun, which created a fictional auxiliary target, is known. [3] Use of ASRPP-DEL suppose directing fire from distracted fire positions and therefore from the one fire position area. And so these tasks are not performed by fire batteries but by a specific number of guns, which can be considered as one compact unit. In this case it could be possible to determine firing data for FFE by switch of fire from a fictional auxiliary target.

The determination of firing data by using an adjustment gun could be considered as a good idea, if the subordinate task force will have an assigned fire unit, which would take a different fire position than other battalion fire units.

This situation may happen in a case when it is necessary to support a task force which is performing tasks on its own direction, this means in an area where the fire cannot be directed from the main fire position area because of too long a range of fire. Then it is excluded that units from the main fire position area and assigned fire units could conduct fire into the area, where they could use results of a fictional auxiliary target creation by the second fire unit.

The distance between fire positions is also very important. However, the publication Pub-74-14-01 does not set results of fictional auxiliary targets' validity by using an adjustment gun in terms of mutual distance between units, which created a fictional auxiliary target and which will use all the results for the determination of fire data for an effective fire. For a case where it could be possible to use an adjustment gun to determine fire data by a unit located in another area, the determined process is represented in a scheme - The way of setting fire data for an effective fire, an adjustment gun. [1]

ASRPP-DEL by this way, mentioned above, finds a value of a discrepancy between all of the guns and a master gun, which had created a fictional auxiliary target. Then this value is multiplied by a table distance correction for the 1% change of a beginning projectile speed for the specific projectile, filling, topographical distance and the final value is added to adjusted corrections for a fictional auxiliary target. By this action we can get calculated distance for a target to engage. Calculated direction (calculated side divergence) is obtained by a sum of topographical direction (topographical side divergence), adjusted direction correction and the difference between derivations on an eliminated target and derivations on a fictional auxiliary target.

V. Abridged preparation

In the publication Pub-74-14-01 it is mentioned that fire data preparation is considered as an abridged preparation, if any of all conditions are not met, or if there is data gained from a fictional auxiliary target creation used for a setting fire data and if these data are from 3 to 8 hours old. [3] In these cases, fire data for effective fire have to be set by adjustment fire. A decision-making process for considering achieving conditions is represented in a scheme - The way of setting fire data for an effective fire, using a complete preparation and according to results of a fictional auxiliary target creation. [2]

The fire data for effective fire set by abridged preparation can be used for effective fire without any adjust fire, if that fire is led by a battalion on a multiple target with a purpose of "Scotch", where conditions for complete preparation are not met within a maximum of two points and at the same time these borders are not overstepped:

- fire positions coordinates are set topographically from the map of scale 1:50 000 and by using instruments;
- orientation bearings are set magnetically including the calculation of a compass correction, set in a 10 km distance from fire positions;
- target coordinates are set by some of the ways mentioned in table T-2.1 of publication Pub-74-14-01 with the level of accuracy 1,2 or 3;
- fire meteorological conditions are set from the meteorological message METEO-STŘEDNÍ PŘIBLIŽNÁ, which is not older than 1 hour and which is used up to 1600 m height;
- there is included only the change of initial shell speed, caused by wearing out of the barrel, where corrections for

changes of all shell ballistic characteristics are calculated, which are mentioned in tables for fire.

For ASRPP-DEL it is necessary for this case to exactly set the number of firing guns. From the table T-1.4 from publication Pub-74-14-01 it is clear that the battalion can have 2-3 batteries and the battery can have 6-8 guns. This means that the battalion can have 12-24 guns. For ASRPP-DEL, a principle can be formulated, that if the system sets 12 or more guns for fire on the multiple target with the purpose of "Scotch!" and if all conditions from the chapter 5 Abridged preparation will be met, it will not be necessary to do an adjust fire for the setting of fire data for effective fire.

Conditions and variants for setting fire data for an effective fire by abridged preparation are mentioned in the scheme - The way of setting fire data for effective fire, The Abridged preparation.

VI. Meteorological Data Average Values in the Individual Layers Conversion

The word "data" is plural, not singular. The subscript for the Meteorological data in the individual zones of the METCM are listed in the relevant lines of the meteorological message and they are expressed by the following symbols:

ZZdddFFFTTTTPPPP,

where: ZZ is the line number indicating the zone code (table I);
ddd is the wind direction;
FFF is the wind speed in units of knots;
TTTT is the virtual air temperature in tenths of Kelvin degrees;
PPPP is the air pressure in units of millibars [9].

Virtual air temperature, wind direction and wind speed are expressed as average values of the appropriate zone in the METCM. Therefore it was established an assumption – these meteorological data average values correspond to the meteorological data in the medium height of particular zones (table II). Hence the courses of the virtual air temperature, wind direction and wind speed are linear in the interval from the bottom to the upper boundary of the appropriate zone.

The air pressure in the individual heights above AMS is not consider during the firing data calculation (its effect is included in the virtual air temperature) [10]. Therefore the air pressure in the individual heights above AMS is not converted.

Meteorological data in the individual layers of the METEO-11 are expressed by the following symbols:

hhTTSSRR,

where: hh is the layer code;
TT is the average change of virtual air temperature due to tabular value;
SS is the average wind direction in hundreds of mils (in the METEO-11 is usually used the division of the circle into the 6000 mils);
RR is the average wind speed in meters per second [9].

The average change of virtual air temperature due to tabular value corresponds to the entire high interval from the AMS altitude up to the medium height of appropriate layer above AMS (table II).

The average wind direction and the average wind speed correspond to the entire high interval from the AMS altitude up to the upper boundary of appropriate layer above AMS (table III).

Table II. Heights Intervals of Individual METCM Zones

Zone code	Zone height above AMS [m]	Medium height of zone [m]	Zone code	Zone height above AMS [m]	Medium height of zone [m]
01	0 - 200	100	14	14 000 - 16 000	15 000
02	200 - 500	350	15	16 000 - 18 000	17 000
03	500 - 1 000	750	16	18 000 - 20 000	19 000
04	1 000 - 1 500	1 250	17	20 000 - 22 000	21 000
05	1 500 - 2 000	1 750	18	22 000 - 24 000	23 000
06	2 000 - 3 000	2 500	19	24 000 - 26 000	25 000
07	3 000 - 4 000	3 500	20	26 000 - 28 000	27 000
08	4 000 - 5 000	4 500	21	28 000 - 30 000	29 000
09	5 000 - 6 000	5 500	22	30 000 - 32 000	31 000
10	6 000 - 8 000	7 000	23	32 000 - 34 000	33 000
11	8 000 - 10 000	9 000	24	34 000 - 36 000	35 000
12	10 000 - 12 000	11 000	25	36 000 - 38 000	37 000
13	12 000 - 14 000	13 000	26	38 000 - 40 000	39 000

Table III. Heights Intervals of Individual METEO-11 Layers

Zone code	Zone height above AMS [m]	Medium height of zone [m]	Zone code	Zone height above AMS [m]	Medium height of zone [m]
02	0 - 200	100	40	3 000 - 4 000	3 500
04	200 - 400	300	50	4 000 - 5 000	4 500
08	400 - 800	600	60	5 000 - 6 000	5 500
12	800 - 1 200	1 000	80	6 000 - 8 000	7 000
16	1 200 - 1 600	1 400	10	8 000 - 10 000	9 000
20	1 600 - 2 000	1 800	12	10 000 - 12 000	11 000
24	2 000 - 2 400	2 200	14	12 000 - 14 000	13 000
30	2 400 - 3 000	2 700	18	14 000 - 18 000	16 000

For each METEO-11 layer is need to calculate:

- the average change of virtual air temperature due to tabular value in Celsius degrees (TT);
- the average wind direction in hundreds of mils (SS);
- the wind speed in meters per second (RR).

A. *The Average Changes of Virtual Air Temperature due to Tabular Value (TT) Calculation*

The average virtual air temperatures in the individual METCM zones ($TTTT_{ZZ}$) correspond to the virtual air temperature values in the medium heights of appropriate zones. The average virtual air temperatures in the individual METCM zones in tenths of Kelvin degrees ($TTTT_{ZZ}$) have to be converted to Celsius degrees as follow:

$$T_{(°C)\,ZZ} = \frac{TTTT_{ZZ}}{10} - 273{,}15\,, \tag{1}$$

where: $T_{(°C)\,ZZ}$ is the virtual air temperature in the medium height of appropriate zone (ZZ) in Celsius degrees.

It is necessary to carry out a simulation (budgeting) of temperature (and also wind) sounding in the particular heights above AMS from the values established according to the (1) relation for calculation of the average changes of virtual air temperature (and also the average wind directions and the average wind speeds) in the individual METEO-11 layers – as if they were actually measured by radiosonde. The radiosonde sends the measured meteorological data at specified intervals after approximately 25-50 meters (depending on the speed of meteorological balloon ascent and on the used meteorological sets). The simulation (budgeting) of temperature and wind soundings can be carried out on the basis of linear interpolations of particular meteorological data in the appropriate heights above AMS from the meteorological data mentioned in the METCM. For these simulations it is sufficient to calculate the meteorological data at intervals of 50 m (in heights above AMS) [5 - 7].

For each height (v) above AMS (after 50 meters) it necessary to calculate the appropriate changes of virtual air temperature due to tabular value (ΔT_v) according to (8) to (13):

- for v=50 m:

at first it is needed to determine the virtual air temperature at the height of 50 m above AMS in Celsius degrees:

$$T_{50} = \frac{T(°C)_{00} + T(°C)_{01}}{2}, \tag{2}$$

where: $T(°C)_{00}$ is the virtual air temperature in the height of 50 m above AMS and it corresponds to T_0T_0' value,

$T(°C)_{01}$ is the virtual air temperature in the medium height of the 01 zone (100 m) determined according to (7)

and then it can be calculated the change of virtual air temperature in the height of 50 m above AMS due to tabular value in Celsius degree (ΔT_{50}):

$$\Delta T_{50} = T_{50} - (15{,}9 - 0{,}006328 \cdot v), \tag{3}$$

- for v=100 m:

$$T_{100} = T(°C)_{01}, \tag{4}$$

$$\Delta T_{100} = T_{100} - (15{,}9 - 0{,}006328 \cdot v), \tag{5}$$

- for v=150 m:

$$T_{150} = \left[T(°C)_{02} - T_{100}\right] \cdot \frac{50}{v_{02} - (v - 50)} + T_{100}, \tag{6}$$

where v_{02} is the medium height of the METCM 02 zone ($v_{02} = 350$ m) – table II,

$$\Delta T_{150} = T_{150} - (15{,}9 - 0{,}006328 \cdot v), \tag{7}$$

Analogously it is needed to carry out the calculation of all changes of virtual air temperature in the heights after 50 m above AMS due to tabular value in Celsius degree – up to required height above AMS.

Then it will be calculated auxiliary average changes of virtual air temperature due to tabular value in the particular METEO-11 layers (TT_{hh}') according to (7) to (9):

$$TT_{02}' = \frac{\sum_{n=1}^{2} \Delta T_{50 \cdot n}}{2}, \tag{8}$$

where 50·n is the height (v) above AMS in meters,

$$TT_{04}' = \frac{\sum_{n=1}^{6} \Delta T_{50 \cdot n}}{6}, \tag{9}$$

$$TT_{08}' = \frac{\sum_{n=1}^{12} \Delta T_{50 \cdot n}}{12}, \tag{10}$$

etc.

The average changes of virtual air temperature due to tabular value in the particular METEO-11 layers (TT_{hh}) will be determined according to the follow relation:

$$TT_{hh} = \begin{cases} (-1) \cdot TT_{hh}' + 50, \; pro \; TT_{hh}' < -0{,}5 \\ TT_{hh}', \; pro \; TT_{hh}' \geq -0{,}5 \end{cases}, \tag{11}$$

where hh is the code of the METEO-11 layer.

B. The Average Wind Direction (SS) Calculation

The average wind directions in the individual METCM zones (ddd_{ZZ}) correspond to the wind directions in the medium heights of appropriate zones. The average wind directions in the medium heights of appropriate zones (ddd_{ZZ}) is needed to convert to mil (usually used in the METEO-11 – 6000 mils for one circle) as follow:

$$\alpha_{w(dc)\,ZZ}' = ddd_{ZZ} \cdot 10 \cdot \frac{15}{16}, \tag{12}$$

where $\alpha_{w(dc)ZZ}'$ is the wind direction in the medium height of appropriate zone (ZZ) in mils;

ddd_{ZZ} is the average wind direction in the appropriate zone (ZZ) in tens of mils.

Then it will be compared the course of the wind direction. If the wind direction crosses the kilometre north direction (from left or right) the particular wind direction values must be adjusted. If the wind direction crosses the kilometre north direction from the left during a movement from one layer to the next (higher), the 60-00 value must be added to the $\alpha_{w(dc)ZZ}'$ value. If the wind direction crosses the kilometre north direction from the right during a movement from one layer to the next (higher), the $\alpha_{w(dc)ZZ}'$ value must be deduced from the 60-00 value. By this way will be got all adjusted wind direction values in the individual METCM zones $\alpha_{w(dc)ZZ}$ in units of mils. If the wind direction does not cross the kilometre north direction with increasing height above AMS, then the wind direction will be:

$$\alpha_{w(dc)_{ZZ}} = \alpha'_{w(dc)_{ZZ}} . \tag{13}$$

For each height (v) above AMS it is necessary to calculate the wind directions (α_v) in hundreds of mils from the $\alpha_{w(dc)_{ZZ}}$ values according to (14) to (16):

$$\alpha_{50} = \frac{\alpha_{w(dc)_{00}} + \alpha_{w(dc)_{01}}}{2} \cdot 0{,}01 , \tag{14}$$

$$\alpha_{100} = \alpha_{w(dc)_{01}} \cdot 0{,}01 , \tag{15}$$

$$\alpha_{150} = \left\{ \left[\alpha_{w(dc)_{02}} - \alpha_{100} \right] \cdot \frac{50}{v_{02} - (v-50)} + \alpha_{100} \right\} \cdot 0{,}01 , \tag{16}$$

etc.

Then auxiliary average wind directions (in hundreds of mils) in the particular METEO-11 layers (SS'_{hh}) will be calculated according to (17) to (18):

$$SS'_{02} = \frac{\sum_{n=1}^{4} \alpha_{50 \cdot n}}{4} , \tag{17}$$

$$SS'_{04} = \frac{\sum_{n=1}^{8} \alpha_{50 \cdot n}}{8} , \tag{18}$$

etc.

The average wind directions in the particular METEO-11 layers (SS_{hh}) will be determined according to the follow relation:

$$SS_{hh} = \begin{cases} (-1) \cdot SS'_{hh} + 50, \; pro \; SS'_{hh} < -0{,}5 \\ SS'_{hh}, \; pro \; SS'_{hh} \geq -0{,}5 \end{cases} . \tag{19}$$

C. The Average Wind Speeds (RR) Calculation

The average wind speeds in the individual METCM zones (FFF_{ZZ}) correspond to the wind speed values in the medium heights of appropriate zones. The wind speeds in the medium heights of appropriate zones in meters per second (FFF_{ZZ}) is needed to convert to meters per second as follow:

$$w_{(m \cdot s^{-1})_{ZZ}} = 0{,}51 \cdot FFF_{ZZ} , \tag{20}$$

where $w_{(m \cdot s^{-1})_{ZZ}}$ is the wind speed in the medium height of appropriate zone (ZZ) in meters per second.

For each height (v) above AMS it is necessary to calculate the wind speeds (w_v) in meters per second from the $w_{(m \cdot s^{-1})_{ZZ}}$ values according to (21) to (23):

$$w_{50} = \frac{w_{(m \cdot s^{-1})_{00}} + w_{(m \cdot s^{-1})_{01}}}{2} , \tag{21}$$

$$w_{100} = w_{(m \cdot s^{-1})_{01}} , \tag{22}$$

$$w_{150} = \left[w_{(m \cdot s^{-1})_{02}} - w_{100} \right] \cdot \frac{50}{v_{02} - (v-50)} + w_{100} , \tag{23}$$

etc.

Then the average wind speeds in the particular METEO-11 layers (RR_{hh}) (in meters per second) will be calculated according to (24) to (25):

$$RR_{02} = \frac{\sum_{n=1}^{4} w_{50 \cdot n}}{4} , \tag{24}$$

$$RR_{04} = \frac{\sum_{n=1}^{8} w_{50 \cdot n}}{8} , \tag{25}$$

etc.

VII. Conclusion

It is necessary to separate the rating of meeting the conditions for topographical-geodetically preparation. While mistakes of setting fire positions Cartesian coordinates are influencing the fire accuracy constantly with rising distance, mistakes of setting orientation bearings are reducing the fire accuracy proportionately with rising firing distance. That is why the requirement on accuracy of setting orientation bearings in relation to setting Cartesian coordinates is relatively stricter.

Conditions for a survey of a target position cannot be rated separately, because these conditions influence each other. The accuracy of setting a position of an artillery reconnaissance instrument shows itself in the accuracy of setting target coordinates.

The accuracy of artillery reconnaissance instruments and the accuracy of setting artillery TA instrument position is mutually determined. [1]

This means that the accurate detection of an artillery reconnaissance instrument position and the accurate detection of orientation bearings provides a possibility of a higher tolerance on artillery TA instruments' accuracy.

Contrarily, a more accurate observation instrument provides less accurate positioning and orientation. By expression of meeting requirements of accuracy for setting fire data by complete preparation in the part of reconnaissance and target detection the information from the artillery observer about accuracy of setting the target position is "accurate". Otherwise (the setting of a target position is "not accurate") the adjustment of fire is necessary.

Processing the data of meteorological preparation can be fully automated by the ASRPP-DEL system. The system will have all necessary data and on its basis it is able to set the validity of the meteorological message for complete preparation and if it is necessary it can also point out a need for starting new probing.

Using adjustment gun spatial standards of created fictional auxiliary target (FPC) validity, depending on distance of units both creating FPC and using FPC results, must be set.

These units will also use these results for setting fire data. Fire data for FFE on an abridged preparation basis can be set by adjustment fire or without it.

The conversion of the METCM into the METEO-11 format is needed to be carried out by using the computer because the manual conversion is time-consuming and can leads to errors. It is advantageous to use the defined mathematical apparatus for the conversion in the own software application or to use it in some program – for example in the MS Excel.

Philosophy of the conversion of the METCM into the METEO-11 format can be also used to develop mathematical apparatuses for other conversions of meteorological messages (as METB3 into METEO-11 format or METCM into METB3 format) in the future.

For ASRPP-DEL it is necessary to exactly set all conditions for each variant of setting fire data for effective fire.

REFERENCES

[1] BLAHA, M., SOBARŇA, M. Principles of the Army of the Czech Republic Reconnaissance and Fire Units Combat using. In *The 15th International Conference „The Knowledge-Based Organization"*. Sibiu (Romania): Nicolae Balcescu Land Forces Academy, 2009, pp. 17-25.

[2] BLAHA, M., BRABCOVÁ, K. Decision-Making by Effective C2I system. In *The 7th International Conference on Information Warfare and Security*. Seattle (USA): Academic Publishing Limited, 2012, pp. 44-51. ISBN 978-1-908272-29-4

[3] Joint Forces Command, Training. *Shooting Rules and ground artillery fire control (gun, platoon, battery compartment)*. Pub-74-14-1. Prague: 2007. 256 p.

[4] *Military Strategy of The Czech Republic*. Praha: MO CR, 2008.

[5] *Long-Time Scheme of Ministry of Defence*. Praha: MO CR, 2008.

[6] *NATO Capabilities/Statements - 2018*. Brusel, 2007.

[7] *Doctrine of the Army of the Czech Republic*. Praha: MO CR, 2005.

[8] BLAHA, M., SOBARŇA, M. Some develop aspects of perspective Fire Support Control System in Czech Army conditions. In *The 6th WSEAS International Conference on Dynamical Systems and Control.* Sousse (Tunisia): University of Sfax, 2010, pp. 179 - 183.

[9] POTUŽÁK, L. *Control and Realization of Fire Support - The Cooperation of Artillery and Units of Artillery Reconnaissance during Fire Support of Forces.* Partial task - Specific research of FEM. Brno: University of Defence, 2006.

[10] *AD-6.1 Doctrine of Communication and Information systems*. Praha: MO CR, 2003.

[11] *AAP-6 NATO Glossary of Terms and Definitions* (english and french). 2009.

[12] BLAHA, M., BRABCOVÁ, K. Communication environment in the perspective Automated Artillery Fire Support Control System. In *The 10th WSEAS International Conference on APPLIED INFORMATICS AND COMMUNICATIONS (AIC '10).* Taipei, 2010. pp. 236-240. ISBN 978-960-474-216-5.

[13] BLAHA, Martin. Communication as a basic for future Artillery Fire Support Control System. In: *The European Conference of COMMUNICATIONS (ECCOM'10)*. Tenerife: WSEAS Press, 2010, p. 140-142. ISBN 978-960-474-250-9.

[14] BLAHA, Martin; POTUŽÁK, Ladislav. Decisions in the perspective Automated Artillery Fire Support. In: *Recent Researches in Applied Informatics & Remote Sensing*. Penang: Wseas Press, 2011, p. 87-91. ISBN 978-1-61804-039-8.

[15] NATO Standardization Agency. AArtyP-1 (A) – Artillery Procedures. Brussels, Belgium, 2004.102 p.

[16] NATO Standardization Agency. AArtyP-5 (A) – NATO Indirect Fire Systems Tactical Doctrine. Brussels, Belgium, 2013. 121 p.

[17] Mukhedkar, R. J. & Naik, S. D. Effects of different meteorological standards on projectile path. *Def. Sci. J.* 2013, **63** (1), 101-107.

[18] Chusilp, P.; Charubhun, W. & Ridluan, A. Developing firing table software for artillery projectile using iterative search and 6-DOF trajectory model. *In* the Second TSME International Conference on Mechanical Engineering, Krabi, 19-21 October 2011.

[19] Chulsilp, P.; Charubhun, W. & Nuktumhang, N. Investigating and iterative method to compute firing angles for artillery projectiles. *In* the 2012 IEEE/ASME International Conference on Advanced Intelligent Mechatronics, Kaohsiung, Taiwan, 11-14, July 2012, pp 940-945.

[20] Vondrák, J. A Complex utilization of artillery reconnaissance assets in a reconnaissance data acquisition for artillery requirements. University of Defence, Brno, Czech Republic, 2008. PhD Thesis.

[21] Blaha, M. A complex utilization of artillery reconnaissance assets in a reconnaissance data acquisition for artillery requirements. Universityof Defence, Brno, Czech Republic, 2012. PhD Thesis.

[22] Preparation Department of ACR. Meteorological preparation of the Czech Artillery. ACR, Prague, Czech Republic, 1998. 112 p.

[23] Jirsák, Č. & Kodym, P. External ballistics and theory of artillery fire. Prague, Czech Republic, 1984. 399 p.

[24] Bartolucci, L.; Chang, M.; Anuta, P. & Graves, M. Atmospheric effects on Landsat TM thermal IR data. IEEE Trans. Geosci. Remote Sensing, 1988, **26** (2), 171-176.

[25] Taeho, L.; Sangjin, L.; Seogbong, K. & Jongmoon, B. A distributed parallel simulation environment for interoperability and reusability of models in military applications. *Def. Sci. J.* 2012, **62** (6), 412-419.

[26] Jameson, T. Computer met message accuracy studies relating to the met measuring set – profiler; ARL-Project report; U.S. Army Research Laboratory: White Sands Missile Range, NM, 2003.