

Interpolation Issue in PVNPG-14M Application for Technical Control of Artillery Fire

Martin Blaha, Ladislav Potužák, Daniel Holesz

Abstract—This paper focused on application support for technical control of artillery units – PVNPG-14M, especially on interpolation issue. 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 principles, evolution and calculation in the process of complete preparation. The paper presents expertise using of application of current artillery communication and information system and suggests the perspective future system. The paper also presents problems in process of complete preparing of fire especially problems in permanently information (firing table) and calculated values. The paper presents problems of current artillery communication and information system and suggests requirements of the future system.

Keywords—Fire for effect, application, fire control, interpolation method, software development.

I. INTRODUCTION

CURRENTLY there are changes in the character of the environment of the modern battlefield. This is associated with a significant shift of requirements for timeliness and accuracy of carrying out artillery support. Current factors determine the increased requirements on artillery fire control system. It is essential that the processes performed within fire control are conducted more efficiently than ever before. Current conditions of the artillery of the Czech army is characterized by reducing the number of personnel, equipment, technology but on the other hand army leads to the introduction of new (modern) equipment. There are implemented measures, whose purpose is to increase the effectiveness of components of the artillery fire control system. One of the main ways of increasing the effectiveness is automation.

To streamline the process of preparing fire elements (fire input) for the artillery fire, which is part of the management of artillery fire system is developed the modern alternative fire control software (PVNPG-14M). The fire control system is designed to calculate the fire elements using all possible situations. It will also serve as a possible starting platform for the development of the national platform for perspective automated fire control system. [1], [2], [8]

PVNPG-14M software utilizes digitized tables of firing for 152 mm ShKH model 77. The method how the artillery firing tables were assembled does not completely define the fire elements for artillery firing. In some cases, it is necessary to perform interpolation between the values which are entered in

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the firing tables. To do this, it was necessary to adjust the automated calculation via PVNPG-14M and implement the interpolation method into software. This article describes how software PVNPG-14M uses interpolation method.

Interpolation is further used in the preparation of fire control in determining targets in an alternative manner and within the meteorological preparation of artillery.

PVNPG-14M software uses an interpolation method for determining values of corresponding distances for the individual bullets and cartridges, then interpolates when it is necessary to determine additional correction deliberate angle for each bullets from the table of additional correction deliberate angle.

II. INTERPOLATION OF VALUES FOR EACH DISTANCE

Values are interpolated on based of distance. The values in firing tables are tabulated for the distance increments of 200 m. In order to set the value of the distances that are not tabulated, it is necessary to use an interpolation method.

Tables of firing are one-dimensional tables, where one corresponds to a distance value tuple other values. It uses linear interpolation.

First, the distances are calculated from the input distance then the corresponding data are obtained from the table to.

$$d_{DB1} = d - (d \bmod 200) \Rightarrow DATA(d_{DB1})$$

$$d_{DB2} = d_{DB1} + 200 \Rightarrow DATA(d_{DB2})$$

Subsequently, to determine all values of the interpolation, distance d is used in:

$$DATA(d) = DATA(d_{DB1}) + \frac{DATA(d_{DB2}) - DATA(d_{DB1})}{200} * (d \bmod 200)$$

If the input distance d satisfies the condition:

$$d \bmod 200 = 0 \text{ AND } d \neq 0$$

Then is the result of interpolation only:

$$DATA(d)$$

III. INTERPOLATION ISSUE OF ADDITIONAL CORRECTION DELIBERATE ANGLE

The value of the additional correction deliberate angle is determined from a table of additional correction deliberate angle. Additional correction deliberate angle is obtained on the

basis of two data, level angle and deliberate angle. Deliberate angle values are tabulated from 300 mils with step part by 20. The level angle is tabulated with step part by 10 mils. On the table can be seen as a Cartesian coordinate system, the level angle is represented by the y-axis and deliberate angle is represented by x-axis and the value of correction is the z axis. The table of additional correction deliberate angle consists of a discrete function of two variables.

Due to the high complexity of calculating interpolation function with several variables, the interpolation method with larger error (but with much lower computational complexity) was chosen. With regard to the correction values, this method achieves sufficient accuracy. The method consists of neglecting the 3rd dimension and subsequent linear interpolation. The method is applicable to non-decreasing function, which complies with firing table [1], [9].

The first step is to calculate the interpolated distance and tabulated points from the beginning of the coordinate system. It uses the Pythagorean theorem, as the axes of the coordinate system form with interpolated points and tabular points a right triangle. Tabular points will be calculated using modulo 10 for level angle and modulo 20 for a deliberate angle.

$$dl = \sqrt{x^2 + y^2}$$

$$dV_1 = \sqrt{v_{1x}^2 + v_{1y}^2}$$

$$v_{1x} = x - (x \text{ mod } 20)$$

$$v_{1y} = y - (y \text{ mod } 10)$$

$$dV_1 = \sqrt{v_{2x}^2 + v_{2y}^2}, \quad v_{2x} = v_{1x} + 20$$

$$v_{2y} = v_{1y} + 10$$

Subsequently, the lowest table value (V1) and the next higher (V2) to the interpolated point of coordinate are obtained (Figs. 1-3).

The next step is to calculate the length difference of table points. Then calculate the difference in length of interpolated coordinate with tabulated point V1 and the difference of table values at points V1 and V2 (Fig. 4).

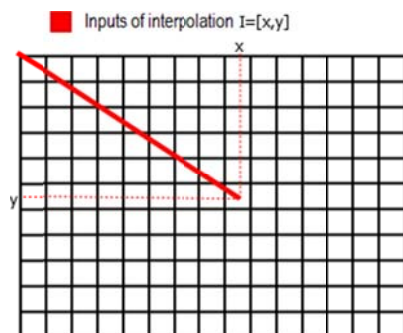


Fig. 1 Inputs of interpolation

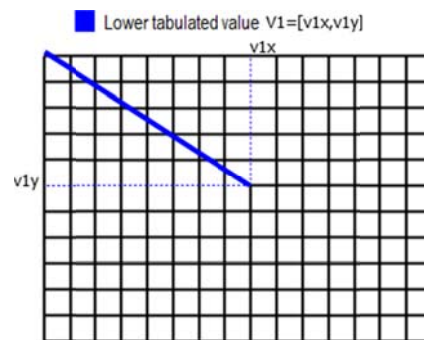


Fig. 2 Lower tabulated value

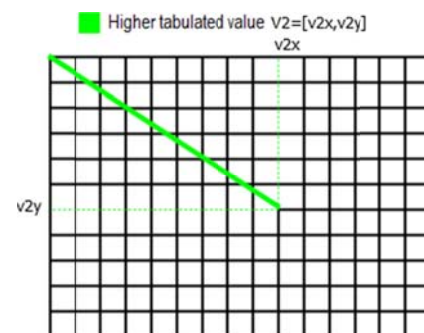


Fig. 3 Higher tabulated value

$$\Delta d_V = dV_2 - dV_1$$

$$\Delta d_I = dl - dV_1$$

$$\Delta V = V_2 - V_1$$

Following the calculation of the interpolative coefficient, which divides the value ΔV equally on the length Δd_V .

$$k = \frac{\Delta V}{\Delta d_V}$$

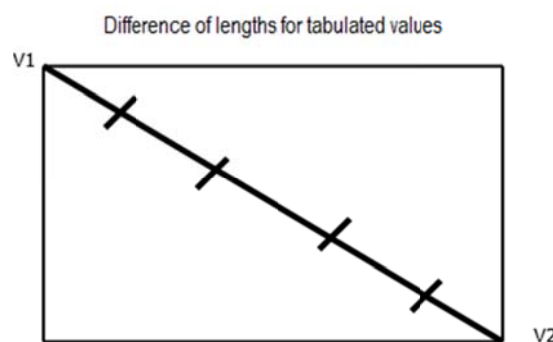


Fig. 4 Difference of lengths for tabulated values

Interpolated value of the input coordinate is obtained by multiplying the interpolation coefficient and value of length Δd_I and then adding to the value of correction at point V1.

$$I = V_1 + (\Delta d_I * k)$$

IV. CALCULATING THE OVERALL CORRECTION OF DISTANCE

Overall correction of distance is calculated as the sum of the effect of corrections for ballistic and meteorological conditions.

A. Correction Distance for Ballistic Conditions

Correction distance for ballistic conditions (ΔD_B) is obtained by the sum correction distance for the overall change in initial velocity, change temperature cartridges, Czechoslovak cartridge type and unpainted missiles. [4], [7]

1. Correction Distance for the Overall Change in Initial Velocity

Correction distance for the overall change in initial velocity (ΔD_{V_0}) is calculated as the multiplication of total change in the initial projectile speed (ΔV_0) and table correction distance of change the initial projectile speed by 1% (ΔX_{V_0}), which is obtained from the firing tables.

The total change of the initial projectile speed (ΔV_0) is the sum of the initial changes caused by the wear rate mainly (ΔV_{0d}) and changes in initial velocity due to changes caused by the dust charge (ΔV_{0n}).

Change of the initial velocity is mainly caused by wear. The wear can be determined on the number of fired shots or can be calculated as the change of the initial fee rate determined by measuring the depth of the chamber apparatus (PMNK) (ΔV_{0d}^{PMNK}). Change of the initial velocity caused by wear of the barrel can be determined by comparison fire with ballistic fire station ($\delta \Delta V_{0u}$). [3], [6]

The value corresponding to the number of barrel wear shot wounds must be part of the documentation of weapon.

Changing the initial fee speed determined by measuring the depth of the chamber apparatus PMNK (ΔV_{0d}^{PMNK}) corresponds to the extension of the chamber in millimeters (Δl) adjusted constants belonging identified extension. Insertion depth of the chamber (Δl) identify with instruments for measuring the depth of fee by service of weapon and professional supervision of technical authorities. Data for conversion extending chamber [mm] to decrease the initial speed [%] must be included in the documentation and complete weapon are also included in the tables shootings.

Advanced correction changes the initial wear speed caused by the barrel ($\delta \Delta V_{0u}$) is determined to test artillery firing range if the initial speed change due to wear of the barrel bore (ΔV_{0d}) reaches the full percentage. The value must be written into the documentation of weapon [2], [5], [10].

Change of the initial speed due to changes caused by the powder charge (ΔV_{0n}) determines the operator based on the documentation that is supplied with every piece of ammunition.

2. Correction Distance for Change Temperature Cartridges

Correction distance for change temperature cartridges is calculated by multiplying the temperature change over the table and filling one-tenth the distance table correction charge

for changing the temperature of 10 °C (ΔX_{T_n}). Change of temperature versus table temperature is the difference of temperature measured and the table contents.

Temperature is measured by service of weapon using the manner set. The value of the distance correction for temperature change load by 10 °C (ΔX_{T_n}) is obtained from firing table. It leads to the firing of ammunition caliber 152 mm Czechoslovak cartridge-type must correction distance for change the filling temperature of 10 °C (ΔX_{T_n}) adjusted according to firing table. [12], [15], [4]

The design of prospective weapon sets should allow for automatic measurement of temperature dust cartridges or powder charge should be kept in an ensemble in a constant temperature equal to the table temperature.

3. Correction for Distance of Czechoslovak Cartridge Type

In case of fire ammunition caliber 152 mm cartridge Czechoslovak type is necessary to include a distance correction for this type of cartridge (ΔD_{NK}) by adding the correction equal to the distance correction table to change the initial speed of 1 % v_0 and the coefficient from fire table.

4. Correction for Distance of Unpainted Missiles

In case of firing with unpainted missiles, one must include the repair of a distance corresponding to the distance correction to change the air pressure of 10 Torr (ΔX_H) to the topographic distance.

B. Correction Distance for Meteorological Conditions

Correction distance for meteorological conditions (ΔD_M) is obtained by the sum of the distance correction to change the ground-level air pressure in the firing position, ballistic change of air temperature and the longitudinal component of ballistic wind.

The conclusions of [1] shows that the artillery of The Czech Army at present can utilize meteorological reports METEOSTŘEDNÍ, METEOSTŘEDNÍ – PŘIBLIŽNÁ and METCM. Report METB, which is designed for manual processing is not adequate without identify differences in the design and definition of coefficients used for the needs of artillery use. Report METCM is intended for computer processing, which in the case of using the software SG/2 Sharable Software Suite (S⁴) module ensures NATO Armaments Meteorological Kernel (NAMK). The software automatically detects the required values and their conversion to make repairs at a distance and direction. Conversion algorithm is already established, tested and approved and there is no need to deal with it again. To calculate the distance, correction is needed to describe the complete procedure for determining a distance correction for the influence of meteorological conditions in terms of reports METEOSTŘEDNÍ and METEOSTŘEDNÍ-PŘIBLIŽNÁ.

1. Correction for Changing the Distance of Ground-Level Air Pressure in the Firing Position

Correction for changing the distance of ground-level air pressure ($\Delta D_{\Delta H}$) is calculated as multiply of changes in ground level air pressure for the altitude of firing position (ΔH_B) and

one tenth of the distance table correction to change the air pressure of 10 Torr (ΔX_H).

Change in ground-level air pressure is presented in meteorological report for the height of artillery meteorological stations. If the height of the firing position is different, it is necessary to change the ground-level air pressure, indicated in a meteorological report, recalculate into the height of the firing position. Super elevation of meteorological station is calculated from the altitude of meteorological unit station [11], [13].

The barometric level of calculated changes for “ground-level air pressure” (related to altitude of firing position) is used. Barometric level is defined as the change of altitude in meters corresponding to the change in air pressure of 1 Torr.

The value depends on the degree of barometric pressure and thus also on the altitude of firing position and meteorological stations and the air temperature. In case firing in flat terrain, it is more suitable to neglect the real influence of flat terrain and use the barometric level equal to 10. This means that the change in height of 10 m will change the air pressure of 1 Torr.

If the firing position is below then meteorological station, the air pressure in ground firing position will be higher and vice versa. The values of barometric levels are given in Table I.

2. Correction for Changing the Distance of Ballistic Air Temperature

Correction for changing the distance of ballistic air temperature ($\Delta D_{\Delta T}$) is calculated as the multiply of changes of ballistic air temperature ($\Delta \tau$) for the respective layers of weather reports and one-tenth the distance correction table for a change of air temperature of 10 °C (ΔX_T). The appropriate layer is selected according to the principles set out in [1].

3. Correction for the Longitudinal Component of Ballistic Wind

Correction of distance for the longitudinal component of ballistic wind (ΔD_w) is calculated as multiply of the longitudinal component of the ballistic wind for the layer of meteorological report (w_x) and one-tenth the distance correction table for longitudinal wind speed of 10 m.s⁻¹ (ΔX_{W_x}).

The longitudinal component of ballistic wind (w_x) is calculated as multiply of wind speed (w) and the cosine angle of the wind (A_w). Wind angle is calculated as the difference in the bearing direction of the firing target (α_s) and bearing wind (α_w) (the angle measured from northern branch of kilometer bands of military coordinate system to the direction of wind in the positive sense). If the bearing direction of the firing target is less than the bearing wind, it is necessary to add to bearing direction of the firing target 60-00. Wind speed (w) and bearing wind (α_w) is obtained from the appropriate layer of meteorological report. Bearing the direction of firing of the firing target (α_s) provides PVNPG-14M when calculating the calculated direction. [4], [14]

In case of firing at long distances (above 30 km), it is necessary to include corrections of distance for the Earth's curvature and rotation.

TABLE I
 TABLE BAROMETRIC DEGREES

ΔH_{DMS} [Torr]	+30	+20	+10	0	-10	-20	-30	-40	-50	-60
+50	11,9	11,5	11,1	10,7	10,3	9,9	9,5	9,1	8,7	8,3
+25	12,3	11,8	11,4	11,0	10,6	10,2	9,8	9,4	9,0	8,6
0	12,7	12,0	11,7	11,3	10,9	10,5	10,1	9,7	9,3	8,9
-25	13,1	12,6	12,1	11,7	11,3	10,9	10,4	10,0	9,6	9,2
-50	13,6	13,1	12,6	12,1	11,7	11,3	10,8	10,4	10,0	9,5
-75	14,1	13,6	13,1	12,6	12,1	11,7	11,2	10,8	10,4	9,9
-100	14,6	14,1	13,6	13,1	12,6	12,1	11,7	11,2	10,8	10,3
-125	15,2	14,7	14,1	13,6	13,1	12,6	12,2	11,6	11,2	10,7
-150	15,8	15,3	14,7	14,2	13,6	13,1	12,7	12,1	11,7	11,2
-175	16,5	15,9	15,3	14,8	14,2	13,7	13,2	12,7	12,2	11,7
-200	17,3	16,6	16,0	15,4	14,9	14,3	13,8	13,3	12,7	12,2
-225	18,1	17,4	16,8	16,2	15,6	15,0	14,5	13,9	13,3	12,8
-250	19,0	18,3	17,6	17,0	16,4	15,8	15,2	14,6	14,0	13,4

V. CONCLUSION

The global environment changes, threats and new tasks require new approach of the Czech Republic defence strategy. Future security environment will be characteristic by dynamic changes of situation. Threats of terrorism causes changes of strategy. It turns from using massive armed forces to effectively using modern, sophisticated forces with quick Command, Control and Decision processes supported by information technologies.

Automation of processes of preparation of fire control is key issue to meeting the increasing demands of the tasks of artillery fire support. They are especially associated with accurate and timely fulfillment of firing tasks in the modern battlefield.

Modern substitute and control software PVNPG-14M is developed to streamline the specific process during the preparation of fire control. It will also serve as a possible starting platform for the development the national perspective artillery automated fire control system.

PVNPG-14M software working with digitized artillery firing tables for 152 mm ShKH model. 77 is used. Because of the way of assembling firing tables, it is necessary used interpolation method for calculation artillery fire elements. This article describes a process of using a method of interpolation that is used within the PVNPG-14M software. [1], [15]

The perspective system must assure Command, Control and Artillery Reconnaissance Connection, Coordination and Fire Control of effectors (Weapon Sets) on the brigade level with Mechanized Forces Control System. The Czech Artillery units need to have intuitive system for mathematical computations what assures prediction capabilities for adequate fire support provision - PVNPG-14M should be the best choice in current conditions. It is necessary to connect Future Artillery Fire Support Control System to the NATO network philosophy system within the Network Enabled Capabilities.

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