Tests of igniter’s charge position influence on ballistic parameters of artillery rounds

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Abstract. This paper presents a shooting test’s results of igniter’s charge position influence on ballistic parameters of artillery rounds. By igniter charge is meant black powder charge used to transmit ignition from igniter to propellant charge. For shooting tests 100 mm artillery rounds for BS-3 cannon, with NDT-3 18/1 and 15/7 propellants in different configurations of igniter’s charge position were prepared: igniter charge on the bottom of the metal case (A), igniter charge in the perforated metal tube, centrally located along the propellant charge (B), igniter charge in the end of lengthening metal tube, centrally located along the propellant charge, near to the bottom of the projectile (C). Moreover there were few configurations between igniter’s charge position and propellant charges: igniter charge in position A with NDT-3 18/1 propellant charge (1A), igniter charge in position B with NDT-3 18/1 charge (1B), igniter charge in position C with NDT-3 18/1 (1C), igniter charge in position A with 15/7 charge (2A) and igniter charge in position B with 15/7 charge (2B). During each shot the muzzle velocity of the projectile and the pressure of the propellant gases were measured. Obtained results were compared with each other and the conclusions were formed.

1. Introduction
Typical artillery round ignition system includes igniter and igniter’s charge. The role of igniter is to initiate the ignition and igniter’s charge role is to strengthen the igniter’s flame and thus inflammation of the propelling charge. The widely used type of igniter is the impact igniter installed into the bottom of the metal case with igniter’s charge placed above. This type of configuration of impact igniter with igniter’s charge is used in 100 mm artillery rounds, without modular propellant charge, for BS-3 cannon, on which test were carried. In artillery rounds with modular propellant charge the igniter’s charge is a part of the ignition cartridge. For this type of ammunition, especially with long cartridge chamber, to obtain the simultaneous ignition in the whole volume of the cartridge chamber, a two-part ignition cartridge is used. The proper selection of igniter’s charge parameters is a very important issue in internal ballistics. The fact is mass and type of propellant of igniter’s charge has a huge influence on combustion process of propellant charge and finally on ballistic parameters of the artillery rounds, but the influence of igniter’s charge position on ballistic parameters of artillery round is the neglected issue. In this article the study of the igniter’s charge position influence on ballistic parameters of artillery rounds has been tested.
2. Models of ignition systems
For tests, based on 100 mm artillery rounds for BS-3 cannon, three types of ignition systems (bottom, centric and frontal) have been prepared. Bottom and centric ignition system were tested in two different propellant charge configuration. First configuration was with 15/7 nitrocellulose 7 – channel propellant and the second one was with NDT-3 18/1 nitroglycerin 1 – channel propellant. Frontal ignition system was tested in one configuration, with NDT-3 18/1 nitroglycerin 1 – channel propellant. Igniter’s charge was made of black powder and placed in various parts of the metal case.

2.1. Bottom ignition system (original)
The base part of the bottom ignition system, presented in the figure 1, is impact igniter KW-13 (8) and igniter’s charge (g, h) placed above the igniter. During the shot released firing pin hits the igniter (e). Igniter ignites the igniter’s charge (black powder) and then flame and propellant gases from igniter’s charge starts the combustion process of propellant charge (c).

2.2. Centric ignition system
The base part of the centric ignition system, presented in the figure 2, is impact igniter KW-13 (e) and igniter’s charge placed inside the perforated metal tube (g), centrally located along the propellant charge (c) and closed one side by the plug (h). The inner surface of metal perforated tube is coated with flammable viscose foil to protect the gunpowder from pouring out. During the shot released firing pin hits the igniter. Igniter ignites the igniter’s charge (black powder) inside the metal perforated tube. Flame and propellant gases from igniter’s charge burn the viscose foil and flow out through the perforation starting the combustion process of propellant charge.

Figure 1. Bottom ignition system (original): (a) piezoelectric pressure sensor, (b) barrel, (c) propellant charge, (d) cellulosic cap, (e) impact igniter (under the canvas bag), (f) metal case, (g) black powder, (h) canvas bag.

Figure 2. Centric ignition system: (a) piezoelectric pressure sensor, (b) barrel, (c) propellant charge, (d) cellulosic cap, (e) impact igniter (under the canvas bag), (f) metal case, (g) black powder, (h) canvas bag.
2.3. Frontal ignition system

The base part of the frontal ignition system, presented in the figure 3, is impact igniter KW-13 (e) and igniter’s charge placed inside the metal tube (g), centrally located along the propellant charge (c) and closed on the front by the cellulosic plug (h). During the shot released firing pin hits the igniter. Igniter ignites the igniter’s charge (black powder) inside the metal tube. Flame and propellant gases from igniter’s charge burn the cellulosic plug and flow out through the open side of metal tube starting the combustion process of propellant charge. In this ignition system the combustion process of propellant charge starts from the front and moves towards the bottom of the metal case (f), inversely than in original artillery rounds with bottom ignition system.

Figure 3. Frontal ignition system: (a) piezoelectric pressure sensor, (b) barrel, (c) propellant charge, (d) cellulosic cap, (e) impact igniter, (f) metal case, (g) metal tube filled with black powder, (h) cellulosic plug.
3. **Shooting tests**

To determine the igniter’s charge position influence on ballistic parameters of the artillery rounds three different models of ignition system in variable configuration with propellant charge were prepared:

1. Bottom ignition system with NDT-3 18/1 nitroglycerin 1 – channel propellant
2. Bottom ignition system with 15/7 nitrocellulose 7 – channel propellant
3. Centric ignition system with NDT-3 18/1 nitroglycerin 1 – channel propellant
4. Centric ignition system with 15/7 nitrocellulose 7 – channel propellant
5. Frontal ignition system with NDT-3 18/1 nitroglycerin 1 – channel propellant

During each shot the muzzle velocity of the projectiles and the pressure of the propellant gases were measured (with piezoelectric pressure sensors and crushers in the same time). Details and obtained results were presented in the tables 1 – 5 and figures 4 – 8.

**Table 1.** Tests results for bottom ignition system (original) with NDT-3 18/1 nitroglycerin 1 – channel propellant.

| Shot No. | Propellant | Mass of propellant charge (kg) | Mass of black powder (kg) | Maximum pressure CRUSHER (MPa) | Maximum pressure PIEZOELECTRIC SENSOR (MPa) | Muzzle velocity of projectile (ms⁻¹) | Shot duration (s) |
|----------|------------|--------------------------------|---------------------------|------------------------------|--------------------------------------------|-------------------------------------|------------------|
| 1        | NDT-3 18/1 | 5.54                           | 0.075                     | 293.0                        | 347.6                                      | 897.0                               | 0.0080           |
| 2        | NDT-3 18/1 | 5.54                           | 0.075                     | 288.1                        | 334.8                                      | 897.1                               | 0.0092           |
| 3        | NDT-3 18/1 | 5.54                           | 0.075                     | 292.8                        | 345.8                                      | 899.4                               | 0.0084           |
| 4        | NDT-3 18/1 | 5.54                           | 0.075                     | 289.7                        | 341.7                                      | 902.9                               | 0.0086           |
| 5        | NDT-3 18/1 | 5.54                           | 0.075                     | 294.6                        | 339.0                                      | 899.1                               | 0.0080           |
|          | Average    |                                |                           | 292.6                        | 341.8                                      | 899.1                               | 0.0084           |

**Table 2.** Tests results for bottom ignition system (original) with 15/7 nitrocellulose 7 – channel propellant.

| Shot No. | Propellant | Mass of propellant charge (kg) | Mass of black powder (kg) | Maximum pressure CRUSHER (MPa) | Maximum pressure PIEZOELECTRIC SENSOR (MPa) | Muzzle velocity of projectile (ms⁻¹) | Shot duration (s) |
|----------|------------|--------------------------------|---------------------------|------------------------------|--------------------------------------------|-------------------------------------|------------------|
| 1        | 15/7       | 4.5                            | 0.075                     | 276.0                        | 305.6                                      | 841.1                               | 0.0088           |
| 2        | 15/7       | 4.8                            | 0.075                     | 295.3                        | 368.7                                      | 882.3                               | -                |
| 3        | 15/7       | 4.8                            | 0.075                     | 297.1                        | 357.2                                      | 879.6                               | 0.0084           |
| 4        | 15/7       | 4.8                            | 0.075                     | 296.5                        | 354.9                                      | 881.0                               | 0.0080           |
| 5        | 15/7       | 4.8                            | 0.075                     | 302.0                        | 361.9                                      | 879.9                               | 0.0086           |
|          | Average from shots 2 - 5 | 297.5                           | 360.7                     | 880.7                        |                                            |                                     | 0.0083           |
Figure 4. Example pressure graph for bottom ignition system with NDT-3 18/1 nitroglycerin 1 – channel propellant.

Figure 5. Example pressure graph for bottom ignition system with 15/7 nitrocellulose 7 – channel propellant.
Table 3. Tests results for centric ignition system with NDT-3 18/1 nitroglycerin 1 – channel propellant.

| Shot No. | Propellant | Mass of propellant charge (kg) | Mass of black powder (kg) | Maximum pressure CRUSHER (MPa) | Maximum pressure PIEZOELECTRIC SENSOR (MPa) | Muzzle velocity of projectile (ms⁻¹) | Shot duration (s) |
|----------|------------|--------------------------------|---------------------------|-------------------------------|-------------------------------------------|--------------------------------------|------------------|
| 1        | NDT-3 18/1 | 5.54                           | 0.06                      | 310.8                         | 381.5                                     | 928.4                                | 0.0076           |
| 2        | NDT-3 18/1 | 5.34                           | 0.06                      | 281.2                         | 348.9                                     | 887.6                                | 0.0080           |
| 3        | NDT-3 18/1 | 5.40                           | 0.06                      | 289.8                         | 354.3                                     | 896.9                                | 0.0074           |
| 4        | NDT-3 18/1 | 5.40                           | 0.06                      | 285.3                         | 349.0                                     | 885.1                                | -                |
| 5        | NDT-3 18/1 | 5.45                           | 0.06                      | 292.9                         | 337.2                                     | 893.1                                | -                |
|          |            |                                |                           |                               |                                           |                                      | Average           |
|          |            |                                |                           |                               |                                           |                                      | 289.3            |
|          |            |                                |                           |                               |                                           |                                      | 346.8            |
|          |            |                                |                           |                               |                                           |                                      | 892.0            |

Figure 6. Example pressure graph for centric ignition system with NDT-3 18/1 nitroglycerin 1 – channel propellant.
Table 4. Tests results for centric ignition system with 15/7 nitrocellulose 7 – channel propellant.

| Shot No. | Propellant | Mass of propellant charge (kg) | Mass of black powder (kg) | Maximum pressure CRUSHER (MPa) | Maximum pressure PIEZOELECTRIC SENSOR (MPa) | Muzzle velocity of projectile (ms⁻¹) | Shot duration (s) |
|----------|------------|--------------------------------|---------------------------|-------------------------------|--------------------------------|---------------------------------|------------------|
| 1        | 15/7       | 4.80                           | 0.06                      | 311.4                         | 339.2                          | -                               | 0.0078           |
| 2        | 15/7       | 4.80                           | 0.06                      | 309.8                         | 354.8                          | 881.8                           | 0.0083           |
| 3        | 15/7       | 4.80                           | 0.06                      | 309.4                         | 355.3                          | 881.0                           | 0.0084           |
| 4        | 15/7       | 4.80                           | 0.06                      | 297.9                         | 349.2                          | 881.6                           | 0.0080           |
|          | Average    |                                |                           | 307.1                         | 349.6                          | 881.5                           | 0.0079           |

Figure 7. Example pressure graph for centric ignition system with 15/7 nitrocellulose 7 – channel propellant.
Table 5. Tests results for frontal ignition system with NDT-3 18/1 nitroglycerin 1 – channel propellant.

| Shot No. | Propellant  | Mass of propellant charge (kg) | Mass of black powder (kg) | Maximum pressure CRUSHER (MPa) | Maximum pressure PIEZOELECTRIC SENSOR (MPa) | Muzzle velocity of projectile (ms⁻¹) | Shot duration (s) |
|----------|-------------|---------------------------------|---------------------------|-------------------------------|---------------------------------|---------------------------------|------------------|
| 1        | NDT-3 18/1  | 5.00                            | 0.06                      | 267.2                         | 266.4                           | -                               | -                |
| 2        | NDT-3 18/1  | 5.25                            | 0.06                      | 260.0                         | 255.0                           | 842.0                           | -                |
| 3        | NDT-3 18/1  | 5.40                            | 0.06                      | 281.9                         | 291.8                           | 878.8                           | -                |
| 4        | NDT-3 18/1  | 5.45                            | 0.06                      | 283.1                         | 299.1                           | 883.1                           | -                |
| 5        | NDT-3 18/1  | 5.45                            | 0.06                      | 277.8                         | 294.2                           | 878.9                           | -                |
|          | Average     |                                 |                           | 274.0                         | 281.3                           | 870.7                           | -                |

Figure 8. Example pressure graph for frontal ignition system with NDT-3 18/1 nitroglycerin 1 – channel propellant.
4. **Analysis of the tests results**

1. Ignition and combustion process of propellant charges with centric ignition system are unstable (jagged graph).
2. For ammunition with centric ignition system with NDT-3 18/1 nitroglycerin 1 – channel propellant have 0.14 kg less weight than propellant charges in ammunition with bottom ignition system with NDT-3 18/1 nitroglycerin 1 – channel propellant, because of lower volume of metal case in centric ignition system. In the consequence the average muzzle velocity of the projectiles of ammunition with centric ignition system is 0.8% lower than average muzzle velocity of projectiles of ammunition with bottom ignition system.
3. For both ignition systems, bottom and centric, time to reach maximum pressure of the propellant gases is the same, but the shot duration is shorter by 1ms for ammunition with centric ignition system.
4. Both ignition systems, bottom and centric, provide proper ignition and combustion process for 15/7 nitrocellulose 7 – channel propellant.
5. Average measured maximum pressure of propellant gases, for series of shots of ammunition with bottom ignition system, is higher for piezoelectric pressure sensor than for crushers and thus difficult to assess.
6. Average muzzle velocity of the projectiles of ammunition with bottom and centric ignition system are similar.
7. Time to reach maximum pressure and shot duration are the same for both types of ignition system: bottom and centric.
8. Maximum pressure of propellant gases in frontal ignition system is 10-15% lower than maximum pressure of propellant gases in bottom and centric ignition system configured with the same propellant charge (NDT-3 18/1), but the muzzle velocity of projectiles in frontal ignition system is only 1.5% lower than in the other ignition systems.
9. Shapes of pressure graphs, for frontal ignition system, are flattened and the falling part of the graphs has smaller angle of inclination, in comparison with shapes of pressure graphs for the other ignition systems with the same propellant (NDT-3 18/1).

5. **Conclusions**

Centric ignition system, in both configuration, with 15/7 nitrocellulose 7 – channel propellant and with NDT-3 18/1 nitroglycerin 1 – channel propellant, in 100 mm artillery round for BS-3 cannon, does not make qualitative change of ballistic parameters for this ammunition in comparison to bottom ignition system (original). Maximum pressure of propellant gases and muzzle velocity of projectiles are similar in both ignition systems. Very interesting results were obtained for frontal ignition system with NDT-3 18/1 propellant. Maximum pressure of propellant gases was 10-15% lower, but the muzzle velocity of projectiles was only 1.5% lower. There is also a difference in the shapes of the pressure graphs in comparison to the other ignition systems. Frontal ignition system will be tested in more configurations of propellant charges in the future.

6. **References**

[1] Sieriebriakow M 1955 *Interior ballistics* MON Warsaw
[2] Hipnarowicz K *Research on igniter and ignitor’s charge influence on ballistic parameters of artillery rounds* unpublished material from own research work