

**PROBLEMY MECHATRONIKI**  
**UZBROJENIE, LOTNICTWO, INŻYNIERIA BEZPIECZEŃSTWA**

ISSN 2081-5891



12, 4 (46), 2021, 83-104

**PROBLEMS OF MECHATRONICS**  
**ARMAMENT, AVIATION, SAFETY ENGINEERING**

## **Constructional Aspects for Safe Operation of 120 × 570 mm Ammunition**

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*Received: April 28, 2021; Revised: May 27, 2021; Accepted: July 14, 2021 /  
Published: December 30, 2021*

DOI 10.5604/01.3001.0015.5991

**Abstract.** This paper provides a characteristic of the design of 120 × 570 mm tank ammunition with particular reference to the cartridges in service in the Polish Army. The presentation of the design and technological details was primarily focused on emphasising their influence on the phenomena occurring or likely to occur during the process of ammunition operation, and to a much lesser extent related with the reference of the characteristics of the performance of the ammunition. Due to the sheer bulk of this subject matter, this paper narrowed the issues of ammunition primarily to the aspects of entry into service, transport, storage, and operation of the specified ammunition cartridges. During these operational stages, there was major focus on the issues of ammunition safety and reliable performance.

Note that these aspects are not exhaustive for the topic; this paper also serves as an introduction to a future paper which will deal with safety issues during combat operation using the 120 × 570 mm tank ammunition cartridges.

**Keywords:** 120 × 570 mm tank ammunition, operation of ammunition, safety of ammunition handling

## 1. INTRODUCTION

The acquisition of the Leopard 2A4 tanks in 2002-2003 with optional equipment and technical and material resources was accompanied by the handover of certain production lots of 120 × 570 mm ammunition cartridges from the Bundeswehr stock. This included the DM33A2 live APFSDS-T (sub-calibre penetrator) versions, the DM48 practice sub-calibre penetrator, and the DM18A1 multi-purpose practice cartridge. The Polish Army had already been using in 125 mm 2A46 tank cannon ammunition with semi-combustible cartridge case, but the technical solutions applied in these munitions and the method of firing were considerably different from those applicable to the 120 × 570 mm ammunition cartridges. A significant difference here was also the introduction of dedicated, Bundeswehr-sourced practice ammunition to the Army's fire units; the ammunition allowed practice shooting complete with the specifics of live ammunition [1, 2], unlike the 125 mm ammunition cartridges which had been in service in the Polish Army. Moreover, the firing with the practice sub-calibre ammunition revealed it caused much less wear on the tank cannon bores than live sub-calibre ammunition [2, 3].

The emergence of munitions with characteristics somewhat different from those of the tank cannon ammunition already in service – and thus imposing different performance requirements – necessitated defining new operating principles for the Bundeswehr-sourced munitions. In the first stage of introduction of the new ammunition patterns, the solutions which had been applied in the Bundeswehr were adopted, including translation of the operating manual and other special documentation [4, 5, 6]. However, in not in all cases did the translations fully reflect the essence of the specifics of the operation of the ammunition types. Subsequently, following the introduction of domestically designed and manufactured ammunition into service, the translated reference materials were supplemented by provisions formulated specifically for the domestic products [7, 8]. Bearing in mind that it is the adopted design solutions that significantly determine the requirements, including those concerning safety, and the further part of this paper will characterise the construction of the ammunition in more detail. The further sections deal with the impact of the solutions adopted in individual ammunition components on the potential and real hazards which may arise in the course of operation.

## 2. DESIGN CHARACTERISTICS OF THE 120 × 570 mm TANK AMMUNITION

The design of the 120 × 570 mm ammunition is based on its interaction with a cannon cartridge chamber uncommon in other types of weapon. The position of the ammunition cartridge is fixed by the metal case base with another point of support within the chamber being the projectile's sealing ring and the bourrelet (Fig. 1). This solution features a cartridge chamber to cartridge case clearance, which may exceed 2 mm along the diameter (Fig. 1).

For most of the length of the ammunition cartridge it does not touch the walls of the cartridge chamber, hence the case can be made of a combustible material. Depending on the brand of the propellant used, projectile type, and cartridge assembly technology, the cartridge case consists of a one or two parts bonded together (Fig. 2). The combustible cartridge case is a composition of nitrocellulose, cellulose and other components which are wet-milled, compressed, and impregnated. Finally, the cartridge case is coated with a varnish. To reduce the risk of ignition, the nitrocellulose cartridge case is sealed from above with a case adapter made of cellulose and is virtually incombustible when the cartridge is fired. In some cartridges, the case adapter may also be made of plastic. The case adapter shape conforms to the specific projectile type assembled into the cartridge (Fig. 2).

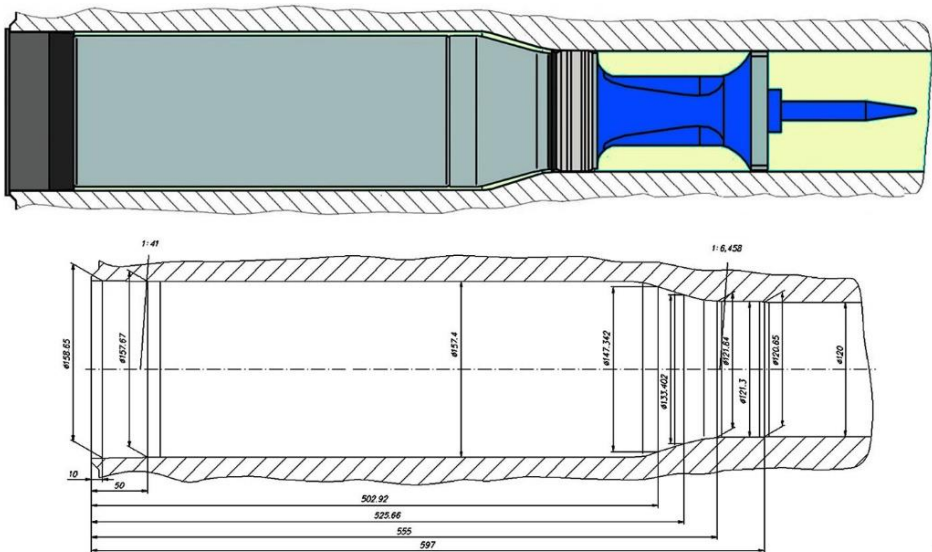


Fig. 1. Interaction of the 120 × 570 mm cartridge with the cannon cartridge chamber (top view – [proprietary work]) vs. the Rh-120 tank cannon cartridge chamber dimensions (bottom view – [9])

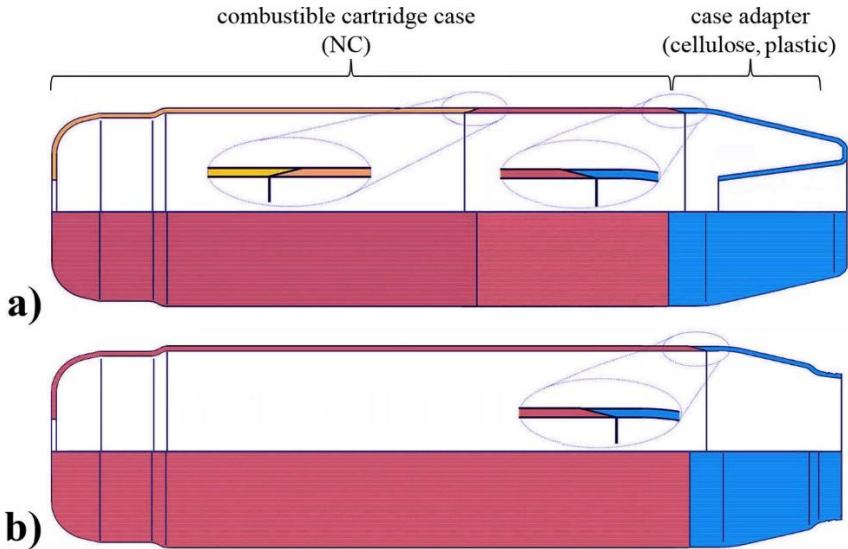


Fig. 2. The structures of the 120×570 mm combustible cartridge cases, showing the number of adhesive bonds [2 in a) and 1 in b)] and the shape of the case adapter [for APFSDS-T type projectiles in a) and for HE or MP type projectiles in b)] [10]

The small wall thickness of the combustible cartridge case demands high rigidity of the shell, which is ensured by a special pressing process based on longitudinal bracing ribbing (Fig. 3b) and adhesive bonding over the diagonal contact surfaces (Fig. 2). The method of joining the case components shown in Fig. 2 is most commonly found in 120 mm tank cannon cartridges, but other methods exist. German-made tank cannon ammunition most often uses a shell case with the design shown in Fig. 2b, although the DM11 cartridge, for example, given the type of propellant used and its distribution within the case, has the design shown in Fig. 2a. The cartridges manufactured to date in Poland uses combustible cases as shown in Fig. 2a.

It is also worth noting that the rounds manufactured by Mesko S.A. Pionki Plant (Poland) use components of combustible cartridge cases sourced from Nitrochemie Aschau GmbH, a supplier of the same cases for Rheinmetall Waffe Munition GmbH, a large German ammunition manufacturer.

In addition to the required stiffness of the cartridge, an important feature of the cartridge should be its resistance to various in-operation exposure environments. In order to prevent shock damage to the cartridges, “elastic” joints are used between the combustible cartridge case portion, the metal case base and the projectile. For the cartridge case base, it is firmly fixed with allowance for movement of the individual components in relation to each other by using a joint based on a chrome-silicon steel spring disc fixed in place by a circlip secured within the case fitting (Fig. 3a and 3b).

A characteristic feature of this joint is that the metal part of the case features a rubber compound ring cured over the metal part; the rubber compound is resistant to short-term high-temperature shocks. The ring dimensions and shape were chosen to provide a press-fit connection of about 4 mm with the bottom part of the combustible cartridge case (Fig. 3a). The use of this joint can protect the whole cartridge against the ingress of moisture during normal operation. At the same time, the joint provides considerable flexibility thanks the deformability of the bottom of the lower part of the combustible cartridge case, which returns to its original shape when no longer loaded; this is thanks to the elastic effect of the retaining spring disc held by the circlip (Fig. 3b).

The top part of the cartridge is joined to the projectile by adhesively bonding the cellulose case adapter fastened to the projectile into the combustible cartridge case (Fig. 3c). This joint can be produced either by screwing the case adapter to the projectile body or by bonding and/or curing the projectile within the case adapter (Fig. 3c). The use of these joints facilitates retention of the required stiffness of the cartridge while providing the cartridge with relatively high deformability without failure. It is also important to maintain the hermetic seal of the cartridge case interior and isolate the adverse effects of ambient conditions (humidity in particular) from the igniting charge and propellant charge inside of the case.

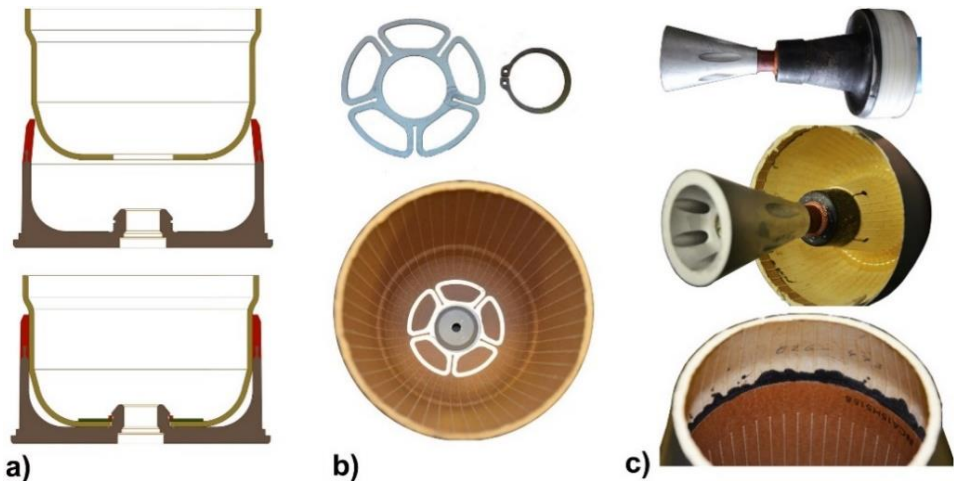


Fig. 3. The method of fastening the 120 × 570 mm combustible cartridge case to the metal case base (a); the fasteners and the view of the joint between the combustible and metal parts of the case shown from the inside of the cartridge (b); example fastening of the projectile within the case adapter, inclusive of the adhesively bonded joint between the cellulose case adapter and the nitrocellulose shell case (c)

The design and composition of the propellant charge is the final distinctive element that sets the 120 × 570 mm tank cannon cartridges apart from other ammunition types. The adoption of specific solutions is a derivative of the required cartridge quality parameters and it also depends on the available material resources. This primarily concerns to the type of propellants, which should ensure the appropriate combustion gas supply characteristics. A projectile of a certain mass must be propelled to the required velocity, while the propulsion must operate at the lowest possible pressure values, which directly translates into a barrel service life that is strictly dependent on the pressure of combustion gases [3]. In the case of the first domestic 120 × 570 mm cartridges, the propellant charge included as many as three types of Polish propellant compositions (Fig. 4a): 15/1 TR wa (single perforated, high-nitric) propellant and two types of multiperforated (seven) propellant: 9/7 and 12/7 wa (high-nitric). The weight of the third propellant was specified for each production lot after a process of “balancing” the charge (which means achievement of the required ballistic parameters for the propellant lots used to make the ammunition). This procedure also resulted in the three-piece cartridge case design, which facilitated the case filling with different types of propellant. In late 2011, a modification was implemented to abandon the 12/7 wa propellant composition in favour of the 9/7 propellant; this resulted in minor changes to the structure of the propellant charge (Fig. 4b). The propellant charge was still be ignited with a bagged igniter pad made of D1 low-explosive black powder (approx. 60 g), with the bag being a rigid cotton cloth (NAM 14/2). To secure a more reproducible (simultaneous) ignition of the propellant charge, it was necessary to use a tubular stick propellant bundle which “transmitted” the flame towards the granulated propellant charge in the top part of the cartridge. Sewn onto the igniter pad was a bagged flash reducing agent, consisting in WTCh-20 single perforated granular single-base propellant. This solution reduces the flash effect accompanying the shot. The abandonment of the traditional bagged igniter pad in favour of an igniting primer contained in a sleeve [11] allowed approximation of the Polish cartridge design to the most common methods of propellant charge ignition applied for the 120x570 mm ammunition.

The use of only one grained propellant type, into the body of which a nitrocellulose sleeve with the igniting charge comprising a fine-grained stick low explosive is inserted (Fig. 4c), makes it possible to simultaneously ignite a higher number of the grains than in the previously applied ignition method. In the constructions described so far, a characteristic solution is the use of a cardboard cylinder which retains the cotton cloth of the bag; both components retain the propellant charge located in the bottom of the combustible cartridge case. The propellant which fills the top of the case is separated so from the remainder of the charge by a “barrier” of sorts.

The resulting gap between the two parts of the propellant charge should not be so large that it impedes the “simultaneity of ignition”, thus providing reproducible progress of the combustion process.

This applies more to possible interference with the flame transmission from the bottom layer of the granulated explosive (Fig. 4c), as the ability to ignite the charge in the top of the case using a stick propellant (Fig. 4a and 4b) is better.

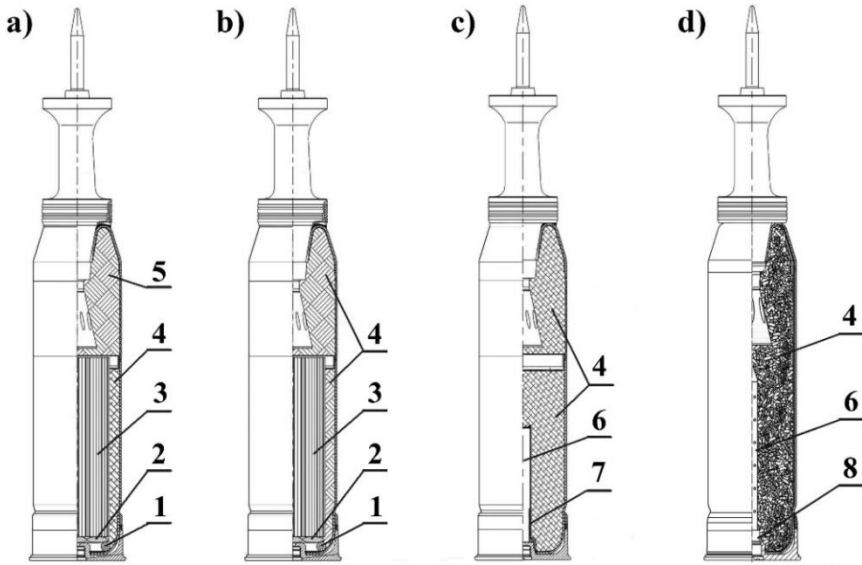


Fig. 4. 120 × 570 mm cartridges with the propellant charge which comprises: (a) three propellant types and an igniting charge of black powder; (b) two propellant types and an igniting charge of black powder; (c) one propellant type and an igniting charge in a nitrocellulose sleeve; (d) one propellant type and an igniting charge in a metal sleeve; 1 – flash reducing agent, 2 – cotton-bagged black powder-based igniter pad, 3 – tubular stick propellant, 4 – granulated propellant, I, 5 – granulated propellant, II, 6 – igniting charge, 7 – igniter nitrocellulose sleeve, 8 – igniter metal sleeve [11]

Probably the most commonly used propellant charge ignition method in the 120 × 570 mm ammunition is the one illustrated in Fig. 4d. It has been present in the DM63A1 ammunition sourced for the Polish Army since 2019. When using a single granulated propellant type, it is much easier to simultaneously ignite a larger volume of the charge with the igniting charge encased by a metal sleeve located deep in the propellant, and where no physical barrier separating the different parts of the charge exists. The use of the metal sleeve to contain the igniting charge is primarily due to the fact that the primer and the sleeve form a single component module (Fig. 4d).

In the Polish solution, the adapted G UW-7-120 (EZA-1) primer is a separate component screwed into the bottom of the steel case base, while the nitrocellulose sleeve is attached to the primer socket (Fig. 4c).

The final difference in the ignition method concerns the form of the igniting charge. Cotton-bagged igniter pads are based on loose low explosive, black powder (Fig. 5b). This is also the form of fine single perforated propellant with which the nitrocellulose sleeves are filled. The charge filling the metal sleeves is most usually a compacted igniting mixture in the form of more or less elongated rods (Fig. 5a).



Fig. 5. Examples of propelling charge initiating components in the  $120 \times 570$  mm cartridge: a – DM132 igniter, integrated with a metal sleeve for the igniting charge in the form of compressed rods; b – G UW-7-120 (EZA-1) igniter and the igniting charge with the flash reducing agent packaged in a cotton bag with black powder

The operating safety of a particular type of projectile is closely related to the explosive material with which the projectile is filled. In this respect, there are no significant differences in the operating requirements for the 120 mm tank cannon ammunition and other artillery ammunition which uses structurally similar projectile types. Therefore, this paper will not focus on any in-depth analysis of the effects of the projectile design on the operating safety of these munitions.

### 3. AMMUNITION TESTING

In order to determine the quality parameters of ammunition, detailed testing is carried out on its individual characteristics. In the case of the  $120 \times 570$  mm cartridges, there are documented specifications of requirements and test procedures both at the allied level [9, 12] and the level of their national implementations [13, 14]. This does not mean, however, that all test results are available for the munitions in service in the Polish Army.



This is due to a number of different reasons, which mainly include the type of tests performed (product lifetime) and how and when the munition is sourced.

The cartridges released by the Bundeswehr together with the first batch of the Leopard 2A4 tanks have already undergone type tests and some of the technical useful life extension tests; hence, the detailed results are available in Germany. The situation is slightly different for new-production sourced munitions. In alliance relations, the document which certifies that a product meets the specified requirements is the declaration of conformity, although obtaining one is not the same as gaining access to all the results obtained during the testing of a product. Therefore, most of the experience in the specifics of the 120 × 570 mm tank cannon ammunition was gained during domestic work conducted during the development, implementation and in-operational testing of the cartridges. With that said, a number of important and practical findings [15, 16] were only made after a fatal accident in 2015. However, despite the clarification of the accident details, there still remain a number of ambiguities or outright myths in this area, and the resulting information, which is important to the operating safety of these munitions, has still to be published sufficiently.

In order to refer to the experience in testing of the 120 mm tank cannon ammunition, it should be noted that at the stage of development of the Polish counterpart of the ammunition (the first production batches were from 2005), applicable national standards have not yet been approved (standards [13, 14] were introduced in 2006). However, even based on the NATO documents [9, 12] there would also be problems in attempting the comprehensive testing of the ammunition. This is due to the fact that all these works [9, 12, 13, 14] lack detailed specifications concerning the performance of numerous procedures; instead, the documents refer to a number of other, more detailed documents. When work on this ammunition was undertaken in Poland nearly twenty years ago, some of the referenced documents might not have been available to the ammunition manufacturer and testing authority. This was especially true for a number of International Test Operations Procedures (ITOP) and U.S. military standards (MIL-STD). However, the introduction of new cartridge versions or subsequent production lots of the in-service ammunition had already been tested against these standards.

The factors outlined above and the initial reluctance of the Polish Ministry of Defence to participate in the Munitions Safety Information Analysis Center (MSIAC), which operates under the aegis of NATO, contributed to the fact that a certain amount of operational experience had to be gained during the process. The following are examples of experiences which, either during testing or in service conditions, contributed to the modification of the ammunition and improving its operational safety.

### 3.1. Release of black powder dust by prolonged vibrations

The quality acceptance procedures for each type of ammunition provide for testing based not only on the standards dedicated to the particular ammunition type but also on generic documents, such as those included in the series of Polish military standards from NO-06-A101 to NO-06-A108. One of the mandatory inspections of military technical assets is the testing of resistance to simulated transport conditions. The combination of the duration and intensity of exposure to transport conditions is intended to ascertain whether the tested cartridge exposed to these heavy conditions will maintain its operating safety and combat readiness.

In the case of the domestic 120 × 570 mm ammunition cartridges, an example of these tests exists where it was only after a number of iterations that a potential hazard was discovered. This applied to the igniting charge (low-explosive igniter pad) encased in a cotton bag (Fig. 5b). The black powder it contained was exposed, along with the entire cartridge, to the action of vibration. Although the containment for the igniting charge is made of a very dense fabric (NAM 14/2 is used to make water-proof raincoats, for example), there was evidence of a very fine powder being released from the bag. Since the fine powder is friction-sensitive and the low explosive at the bottom of the case is a good friction element when exposed to vibration (Fig. 4a and Fig. 4b), it was ignited during the tests.

This case is “unusual” in that such compositions of black powder, igniting charge have been widely used for decades and continue to see applications in artillery munitions. Numerous tests, including testing the resistance to unfavourable transport conditions using a vibrating table, have so far revealed no indication of such a hazard. This incident demonstrates that the operating process of munitions is not a closed set of prohibitions and mandatory activities; new circumstances can always arise that can have a significant impact on the operating safety and may also necessitate changes in the cartridge design. The resulting revision of the igniting charge to nitrocellulose-sleeved version with fine-grain tubular propellant (Fig. 4c) not only improved the operating safety of the new ammunition lots, but, together with the change in propellant type, improved its ignition repeatability. It is also important that the abandonment of the black powder contributed to the elimination of hydrogen sulphide from the thermal decomposition products of the propellant charge, whose characteristic unpleasant smell was noticed by the crews of the Leopard 2 tanks.

### 3.2. Manufacturing errors

It is important to note that ammunition inspections include different categories of tests that allow inspection of all cartridges in a lot or a representative sample of them only.

This, among other things, is the basis for the principle accepted in engineering that a certain margin of non-conformity is allowed per ammunition lot.

The adopted and approved (and therefore effective in the Polish Army) tactical and technical assumptions for the 120 × 570 mm ammunition [17] require at least 98% operational reliability of the propellant charge. This means that a maximum of 2 cartridges out of 100 can be defective. From a combat readiness point of view, this is a fairly high percentage of acceptable failures, but this fraction is actually lower by one order of magnitude – and often by more than two orders of magnitude.

Disintegration of the cartridge is an example of a potentially hazardous failure. The defective adhesive bonding of individual components of the combustible cartridge case (Fig. 6) was identified, for example, in 6 cases out of just over 10,000 rounds of a domestic practice sub-calibre ammunition.



Fig. 6. Example of defective ammunition: as a result of a defective adhesive bonding process, the cartridges were partially (see right) or completely disintegrated (see left) [courtesy: Polish Armed Forces Support Inspectorate]

These defects were not detected during testing by the manufacturer and the defective ammunition cartridges were released to a defence user. Although the discovered failures represent less than 0.06% of the total population of ammunition used (which is more than 33 times below the specified limits), if each such defect were to surface during combat use in adverse conditions, there could be potentially six health hazards or deadly conditions for the tank crew. This is due to the possibility of exposures during tank ammunition firing which could initiate the propellant spilled from the failed cartridge.

Measures implemented by the manufacturer to improve the process of shell adhesive formulation and its time-limited use, as well as a new quality control method, helped eliminate the risk of these defects in later production lots of the ammunition.

The importance of maintaining the cartridge design consistency is evidenced by the actions of the US Army, which for a number of years has been ordering both practice and live cartridges filled with the propellant contained in additional cotton bags. Depending on the design of the projectile, the propellant type used and its distribution inside of the cartridge, there may be one to several cotton bags with the propellant (Fig. 7). This approach, the result of many years of experience with the  $120 \times 570$  mm ammunition, makes it possible to drastically reduce the impact of, or even avoid, the hazards associated with a cartridge disintegration.



Fig. 7. Examples of the 120 mm U.S. tank cannon ammunition provided with various designs of cotton bags for the propellant charge (highlighted in green):

- (a) M830A1 HEAT round; (b) M830 HEAT round; (c) M1028 canister cartridge;
- (d) M829A2 APFSDS-T round; (e) M829A4 APFSDS-T round; (f) M865 practice sub calibre round; (g) IM HE-T (Insensitve Munition High Explosive-Tracer) high explosive cartridge [18]

The above examples show that the continuous checks on the characteristics of ammunition are important to maintain the required level of operating safety of ammunition. The absence of some of the tests or their inadequacy in relation to the exposures involved could lead to a risk to the tank crews using these munitions. The results obtained during the checks should drive detailed analyses and possible changes in the cartridge design.

## 4. COMBUSTIBLE CARTRIDGE CASE DEFORMATION

The peculiarity of the 120 × 570 mm tank ammunition cartridges is that they feature a combustible portion of the case, made of a composition of nitrocellulose, cellulose and other components, wet-milled, compressed, and impregnated, and finally coated with varnish.

With a shell case wall thickness of 4 mm, it is impossible to achieve the stiffness and strength in this case design to prevent deformation under in-service conditions. It is therefore important to understand the acceptable limit magnitudes of exposures age and their effect on the serviceability of exposed munitions.

### 4.1. Combustible cartridge case non-roundness

The long-term storage of ammunition, so characteristic of ensuring continuous combat readiness of armed forces, adversely affects the performance of many of ammunition cartridge components. One such undesirable influence is the constant effect of the propellant charge on the combustible cartridge case. The restraint is provided by the cartridge handling container at the metal case base and the projectile, which results in that most of the cartridge case length is unsupported inside the container. The considerable weight of the propellant and its permanent effect on the cartridge case causes deformation of the shell case during operation due to being off-centre on the cross-section (Fig. 8).

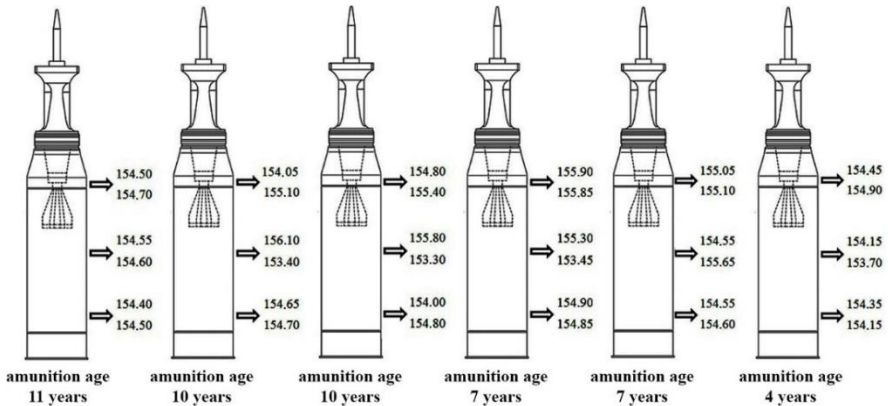


Fig. 8. Locations of measurements and the dimensions, specified in mm, of the combustible cartridge case outer diameters for the 120 × 570 mm tank cannon cartridges

An analysis of the data in Fig. 8 suggests that the greatest ovalization occurs at the location furthest from the cartridge support points inside the handling container.

A measurement of the diameters near the bonded joint of the cartridge case showed that significant stiffening of the cartridge was achieved there, resulting in lower deformability. It should be emphasised here that the data shown in Fig. 8 represent the results of measurements in two perpendicular planes, which did not mean that these were always the largest or smallest actual diameters. Thus, the measurement taken for the oldest ammunition cartridges tested, which were 11 years old, may also be subject to error.

This may involve a measurement of not the smallest and largest diameters of the off-centre, but of the diameters which are offset from the smallest and largest diameters by several dozen degrees. In this case they would be of similar size in both perpendicular planes.

It is also important to note that some minor dimensional differences may be caused by the manufacturing and/or assembly processes. However, in the newest ammunition rounds, the diameters in the perpendicular planes generally differed by no more than 1 mm. A comparison of this result to the differences within 1.8 and 2.7 mm for older ammunition rounds indicates that the off-centre grows with the duration of ammunition storage. If it were possible to confirm the intensity and continuity of this process on older cartridges, it could be that after a longer period of storage or under the influence of other factors yet affecting this process, the shell case diameters would be larger than the diameter of the cartridge chamber (Fig. 1). In this case, loading to tank cannon such cartridges could be problematic to say the least, or impossible for even more deformed rounds.

As it is very difficult to periodically rotate each cartridge container (to change the “direction” of off-roundness progression) in storage during the normal operating life of the ammunition, this phenomenon must be mitigated in other ways. This can be achieved by modifying the ammunition containers so that they relieve the stress imposed by the propellant charge mass on the cartridge cases.

## **4.2. Dropped cartridge case failure**

When handling, operating, or otherwise moving ammunition, a cartridge can be dropped in or removed from the standard handling containers. As the design of ammunition handling containers significantly reduces the adverse consequences of dropping shock, this section provides examples of damage that may affect cartridges unprotected by handling containers.

The factors that have the greatest impact on the extent of cartridge damage, resulting in its non-serviceability in combat, include the height and angle of drop, the drop impact location, and the characteristics of the dropped object. For obvious reasons, a shock impact against the combustible part of the cartridge case poses the greatest risk of deformation or even bursting of the cartridge case. Example image sequences showing cartridge drops in various configurations are shown in the figures below.

Figure 9 shows the impact of a cartridge dropped from a height of about 1 meter onto a blunt edge, while Fig. 10 shows a cartridge striking the edge of a thin, hard metal plate. A drop from a height generally considered to be safe in both cases did not cause deformations of the cartridge cases which might obstruct ramming into the cartridge chamber (Fig. 15c).



Fig. 9. Impact of a 120 mm cartridge with its case adapter against a blunt edge during a drop from approx. 1 m



Fig. 10. Impact of a 120 mm cartridge with its case adapter against a sharp edge during a drop from approx. 1 m

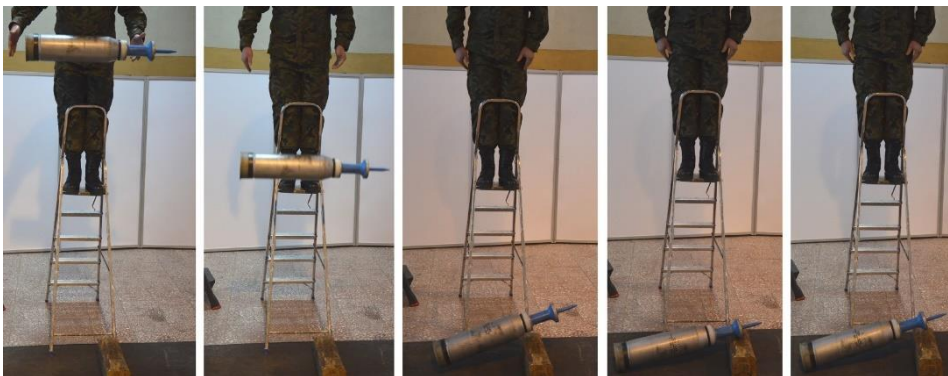


Fig. 11. Impact of a 120 mm cartridge with its case adapter against a blunt edge during a drop from approx. 2 m



This damage did not occur even during a lateral impact of the case adapter against a blunt edge after a drop from a height of 2 m (Fig. 11).

However, if an unfavourable force distribution occurs, like when hitting a hard object with the middle part of the combustible cartridge case, cartridge fracture may occur even in a drop from a height of 1 m (Fig. 12).



Fig. 12. Approx. 1 m high drop of a 120 mm cartridge with a part of the combustible cartridge case hitting a hard substrate

When a cartridge is dropped from a height of 2 meters, an oblique impact of the projectile (Fig. 13) or the metal case base (Fig. 14) caused extensive damage to the combustible part of the case (Fig. 15a and Fig. 15b). Due to the high mass of the projectile affixed within the cartridge case, the nitrocellulose cartridge case cracked in the area of maximum stress concentration, a result of the high overload from the impact of the cartridge against a hard surface.

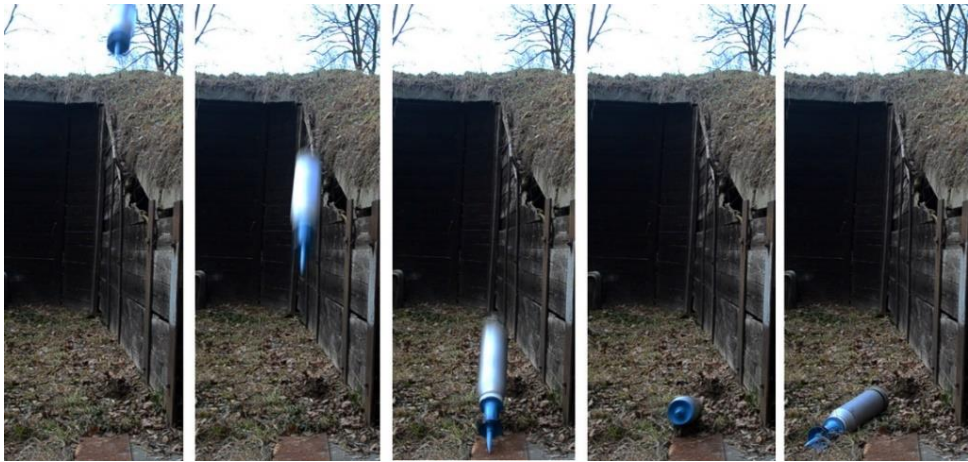


Fig. 13. Approx. 2 m high drop of a 120 mm cartridge with an oblique angle of projectile impact against a hard surface



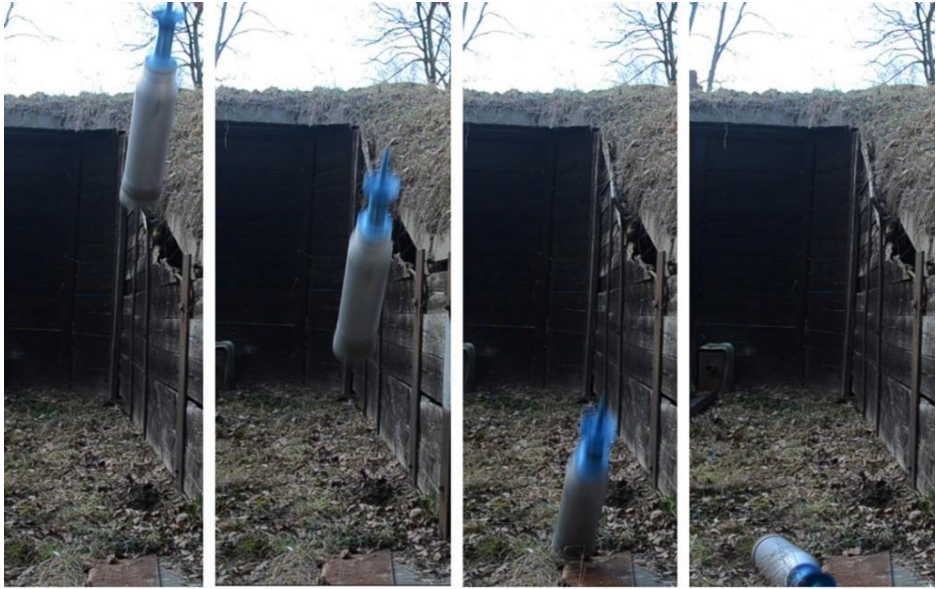


Fig. 14. Approx. 2 m high drop of a 120 mm cartridge with an oblique angle of impact metal case base against a hard surface

This is the location of the diameter necking just above the bottom engaging the metal case base and the recess for the igniter socket in the case bottom (Fig. 15a).

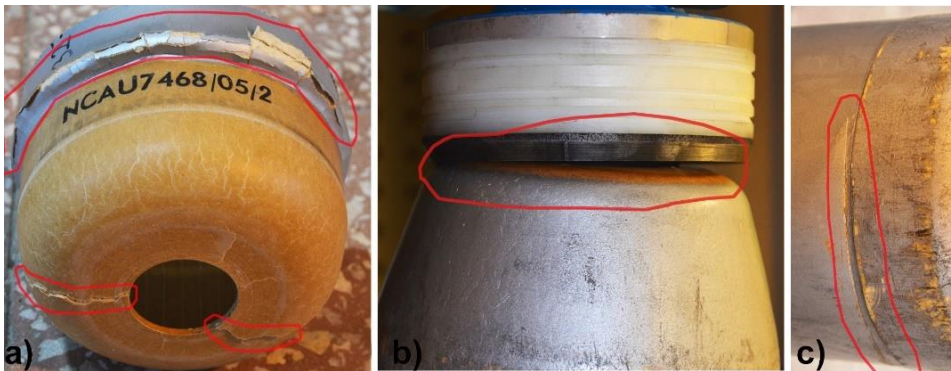


Fig. 15. Damage to a 120 mm cartridge after an oblique-impact drop from a height of 2 meters, with the impact locations: (a) metal case base; (b) projectile; (c) with the impact against a sharp edge from a 1-metre drop

A cartridge hitting a hard surface with its projectile dropped from a height of 2 meters was also exposed to significant overloads due to the large mass of the metal bottom of the case and of the propellant contained in it.

As a result of the oblique-angle shock impact of high inertial forces, the projectile, which is adhesively bonded into the case adapter, partially damaged this bonded joint. This results in a misalignment of the cartridge and a loss of concentricity between the projectile and the cartridge case (Fig. 15b).

Both the “upset” of the combustible cartridge case (Fig. 15a) and the misalignment of the projectile within the cartridge assembly (Fig. 15b) causes an irreversible failure and made round unserviceable in combat. An attempt to breech the cartridge failed, so would cause the round to become stuck inside of the cartridge chamber, rendering it unable to be rammed, preventing engagement of the breech lock, and causing great difficulty in its removal from the chamber. Given the real hazard it may cause in combat, cartridges failed in this way cannot be issued to tank crews and used for firing from a tank.

### **4.3. Impact of moisture on the combustible cartridge case material**

The industry-sourced 120 mm ammunition should be stored in handling containers which provide a hermetic seal. The containers should be unsealed just before loading into a tank. The measurements conducted by the Institute of Armament Technology at the Military University of Technology in Warsaw demonstrated that the average moisture content in the tested, hermetically sealed ammunition handling containers was slightly above 37% (with a variation of 29 to 58%). Despite being stored under the same conditions as the sealed ammunition, the cartridges prepared for use but not spent and kept in unsealed handling containers had an average moisture content of 53% (variation of 43 to 72%). The obvious conclusion is that the higher moisture content was the result of moisture ‘entrapment’ during packaging of the unspent ammunition during its preparation for use.

An experiment carried out during these measurements demonstrated the moisture present around nitrocellulose combustible cartridge case munitions is critical to their performance. After the cartridge was unsealed (where the handling container internal humidity was 29%), the cartridge and its case were exposed for 5 hours to an environment of 8°C and 77% humidity. The cartridge was sealed in a handling container for three days afterwards. When it was reopened, the humidity inside of the handling container case had increased to 58% and measurements taken at exactly the same locations showed a noticeable increase in the diameter of the combustible cartridge case (Fig. 16).

The increase in dimensions was found mainly at the metal case base, where a small section of the combustible cartridge case protruded outside the component and at the transition of the cylindrical case adapter part to the tapered part, above the bonded joint. In the central part of the combustible case, dimensional differences were found ranging from -0.05 to +0.15 mm in comparison to the dimensions of a cartridge removed from a sealed handling container.

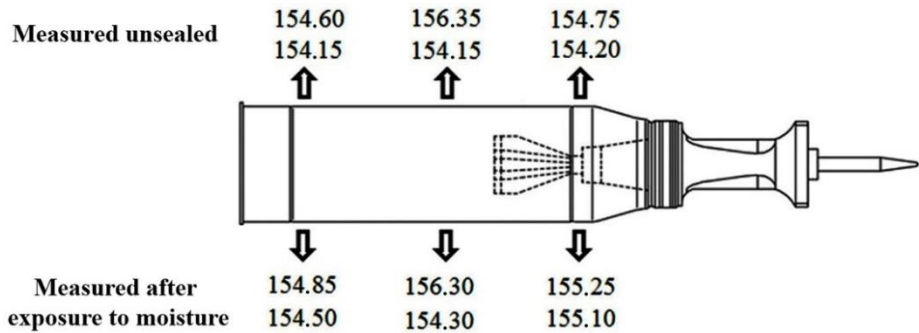


Fig. 16. Change in dimensions of a cartridge exposed to moisture

These deviations could be partly caused by to the indicating accuracy of the measuring instrument (0.05 mm of the scale interval) and the much higher susceptibility of the case to deformation where the measuring jaws were closed. Nevertheless, it is easy to see that, due to the very uniform distribution of the insulating layers of the protective coatings in this part of the case, the effect of moisture on the dimensions of the nitrocellulose combustible case was much lower than in locations where the quality of the coatings can be reduced more easily.

This applies particularly to areas where parts of the protective coatings are missing or become discontinuous in the manufacturing process (e.g., the lower section of the combustible cartridge case protruding from the seal of the metal case base, the grooves and pores where the tapered part of case adapter transitions into its the cylindrical part, etc.) or where the protective coatings are more likely to be damaged during handling or combat operations (e.g., scoring caused by rotation of the metal case base over the nitrocellulose shell case, scuffing, bumping, and scratching by contact with the handling container or other objects nearby).

The presented situation allows a conclusion that the locations of the structural component joints in the examined cartridge seem to be protected against the ingress of moisture, any damage occurring during handling into a round stowage trunk/rack or into the cannon chamber can considerably contribute to the “upsetting” of the cartridge exposed to moisture. A consequence of this may be that the dimensions of the combustible cartridge case increase to a point the round cannot be loaded into the cartridge chamber. To avoid this adverse effect, the principle of first-in first-out should be applied to previously unsealed unspent ammunition, and efforts should be made to unseal cartridges immediately before use. Proper marking of the unsealed ammunition rounds is also essential for these procedures to be effective.

## 5. CONCLUSIONS

This paper presents above characterises the most important operating aspects of the 120 × 570 mm tank cannon ammunition design used in the Polish Army. However, due to the existing differences between individual ammunition design patterns, because of differences in a given cartridge at different stages of manufacturing or because new types of cartridges for 120 mm tank cannons are sourced, this paper cannot be construed as a closed, exhaustive catalogue of commentaries. The issue of safe handling of the 120 × 570 mm cartridges is not only related to their design and the use of cartridge assembly materials with specific characteristics. A very important aspect of munitions operation is also the phenomena and events which occur or are likely to occur in the process. This involves the potential for various exposures that may pose specific safety risks during storage, transport or handling of the cartridges. The selected cases presented in this paper allow the design solutions adopted in the cartridges to be associated with the events and their possible consequences. Knowledge of the above allows a more informed operation of this type of ammunition and thus contributes to a higher safety of the process.

Another and at least equally important aspect of operating safety of the 120 mm tank cannon ammunition is the events and processes that can occur during the combat operation of the cartridges. This aspect is of such important and extent that it will be the subject of the next paper focused on the experiences acquired so far in operation of these munitions. However, it should be made explicitly clear that the cases presented in this paper have or may have a significant impact on those events that may occur during combat operations involving munitions. Due to the mutual influence of the issues that are the subject of this paper and those highlighted for the next paper, they should be treated inseparably as a more complete presentation of the operating safety of the 120 × 570 mm cartridges throughout their life cycle.

## FUNDING

The authors received no financial support for the research, authorship, and/or publication of this article.

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## Konstrukcyjne aspekty bezpiecznej eksploatacji amunicji 120 × 570 mm

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**Streszczenie.** W pracy dokonano charakterystyki konstrukcji 120 × 570 mm amunicji czołgowej ze szczególnym uwzględnieniem naboju występujących na wyposażeniu Wojska Polskiego. Ukazanie szczegółów konstrukcyjno-technologicznych jest przede wszystkim zorientowane na zaakcentowanie ich wpływu na zjawiska występujące, lub mogące się pojawić w procesie eksploatacji, a w znacznie mniejszym stopniu wiąże się z ich odniesieniem do charakterystyk użytkowych amunicji. Z uwagi na obszerność tej problematyki w niniejszym opracowaniu kwestie użytkowania zawężone zostaną przede wszystkim do obszarów związanych z wprowadzeniem na uzbrojenie, transportem, przechowywaniem oraz obsługiwaniem tych naboju. W tych etapach eksploatacji główna uwaga zostanie zwrócona na problematykę bezpieczeństwa takiej amunicji na oraz na jej właściwe działanie. Mając na uwadze fakt, że te obszary nie wyczerpują całości zagadnienia niniejsze opracowanie stanowi też wprowadzenie do kolejnego artykułu, który będzie poświęcony kwestiom bezpieczeństwa podczas bojowego użycia 120x570 mm amunicji czołgowej.

**Słowa kluczowe:** amunicja czołgowa 120 × 570 mm, eksploatacja amunicji, bezpieczeństwo posługiwania się amunicją



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