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Analysis of Temperature and Relative Humidity Variations in the Large-Caliber Ammunition Containers of NATO and Eastern Concept Depending on the Change of Seasons

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Abstract

The design and materials used for large-caliber ammunition containers significantly effect on its shelf-life, safety and functional reliability during the handling and storage process. All ammunition containers should protect the ammunition in the required operating environment during extreme weather conditions, in terms of water resistance and protection from corrosion and fungi, and ammunition inside of the container needs to withstand all shocks caused during handling and transport. There are significant differences in the design, construction and materials used for the containers of NATO concept and ammunition containers of Eastern concept. The basic differences between these two concepts are reflected in the degree of protection of ammunition during extreme changes in temperature and relative humidity in ammunition storage and inside of containers. The NATO concept of ammunition container is consisted of outer and inner lining, where outer lining is usually made of wood or steel sheet. The inner lining protects the contents from the influence of environmental parameters (temperature, relative humidity). The Eastern concept of a large-caliber ammunition containers usually does not have an inner lining. The aim of the experimental research carried out in four different containers, was to identify and analyze the degree of variations in temperature and relative humidity in ammunition containers of NATO and Eastern concept during the storage, depending on the change of seasons. Using a Tiny tag Plus TGIS-1580 data logger, the changes in temperature and relative humidity were measured, inside and outside of ammunition magazine, inside the ammo box and inside of fiber container. Experimental research showed large influence of the design of outer and inner lining of ammunition containers on the variation of environmental parameters. Since the ammunition is expensive and tends to have a longer shelf life, it is necessary to implement NATO concept of ammunition containers on ammunition packaging of the Eastern concept

Key words

Ammunition, Shelf-life, Storage, Measurement, Packaging, Fiber container, Environmental parameters

1. INTRODUCTION

At the end of 20th century, drastic changes were made in political and military relations between the great powers in the World, resulted in the number of a new conflicts, some of which continued to last with varying intensity. These conflicts are characterized by a mass use of large caliber ammunition, where ammunition is transported by all available means of transport (road, air, sea, rail etc.), stored in the open air or earth covered magazines, on different climatic and geographical locations. In such conditions, it is extremely important to know and respect all parameters that can affect the shelf-life of ammunition, and to ensure that ammunition and explosives (AE) are fully ready and safe for potential transport, handling and use of the same.

One of the main and most influential parameters that affect the safety of AE and its storage, are environmental parameters, because temperature and relative humidity of the air in ammunition magazine have significant impact on the condition and overall life of ammunition. Climatic changes, through large oscillations of daily temperatures and relative humidity, whose values deviate from the set of safety standards, directly effect on the process of ammunition performance degradation, performance of propellants in propellant charges, explosives in warheads and pyrotechnic components and igniter systems.

The issue of ammunition maintenance is a very important and every effort should be made to ensure safe conditions prevail in the process of storage and transportation, because factors as higher temperature, rain, dampness and humidity can cause enormous damage to AE in a very short time [1]. If the manufacturers' environmental conditions are not met, the performance of explosives will be unpredictable and the safety will be reduced [2]. From financial side, aspect of ammunition storage is significant, since about 50 % of the total costs for the process through which the ammunition goes (design, production, storage and demilitarization), is necessary for AE storage. But more often the importance of adequate storage is being neglected. Unfavorable condition for AE storage, with significant temperature fluctuations and high relative humidity for a longer period of time, can also cause a drastic shortening of ammo life and the need to use it as quickly as possible. The service life of such ammunition in the new real storage conditions is no longer as prescribed by the manufacturer. The issue of maintaining such ammunition has become essential. The need for periodic inspection and inspection of ammunition has become one of the vital activities of modern Armies focused not only on safety, reliability and performance functionality, but also on issues of operational status of ammunition in low-intensity wars.

1.1. The effects of air temperature and relative humidity on ammunition

Ambient air temperature does not necessarily mean that is also the temperature of ammunition, temperature of explosive substances in warheads, rocket motors or propulsion charges in cartridge. This is particularly the case when the ammunition is stored and used in dessert areas, where solar radiation significantly increases local temperature on some parts of ammunition [3]. Storage of AE on air temperature of 60 or 70°C in dessert has totally different effect than storage in the magazine at 15 °C temperature in Central Europe [4]. Experience from the use of ammunition in the combat conditions showed that if ammunition prepared for combat use, stored outdoors for a longer time, under the strong influence of solar radiation, it can in some cases reach temperature on lancer up to 100°C or ammunition inside of tanks and armored fighting vehicles without air conditioning can reach 90°C [3].

Recommended temperature in the storage should be in the range 5 do 25°C. In the situation of storing AE for a longer period, it is necessary to take into account the temperature values are not the same during summer and winter period, and there are differences in daily values. Temperature values, lower and higher than standard, can have a very negative effect on the structure and performance of AE in the storage. Very low temperature are not as objectionable as higher ones, but explosive that contain nitroglycerin can become dangerous at very low temperature or it can change physical properties of material of which explosive is composed. Higher air temperature can intensify degradation reaction of certain components inside of explosive matters and reduce ballistic performance or cause chemical degradation of material and appearance of gases causing cracks of propellant [5]. Increasing the temperature for about 10°C above the recommended temperature of 25°C, can generally speed up chemical reactions by 2 to 3 [6].

Impact of the humidity can be very complex and significantly depends on the air temperature. Higher relative humidity can cause ammunition damage and lower humidity causes static electricity for some type of stocks. The penetration of moisture through the hermetic systems in complex projectiles can cause failures of the functions of vital components, causing chemical reactions in ignition systems based on aluminum and magnesium. In ammunition packaging systems or in the case of poor packaging, the free moisture released during the daily temperature cycle can cause long-term corrosion of the metal components of the ammunition and thus reduce the functional capability of the ammunition in combat use. The physical effects of the influence of temperature changes during diurnal temperature cycling and high temperatures in the warehouse can cause the appearance of high stress states and the appearance of cracks in the zones of contact of explosive matter with the ammunition structure [5].

Contemporary research of the impact of environmental parameters on the condition of ammunition have shown that it is no longer enough to read the temperature once a day, but it is necessary to continuously monitor the temperature and humidity inside the ammunition packages. In this way, the precise data, necessary for estimating the remaining life of ammunition, are obtained [5]. This is based on significant deviations in the measurement of real air temperature during the daily cycle in comparance to the measurement of a long-term mean temperature over time for a given storage location. In addition, a very important factor is the monitoring of temperature and humidity within the ammunition packages themselves, as this provides more accurate data necessary to estimate the remaining life of the ammunition.

Since ammunition may deteriorate or become damaged unless it is correctly stored, handled and transported, with the result that it may fail to function as designed and become dangerous for storage, transport and use [5, 7], therefore it is important to know environmental conditions where the ammunition is stored, considering important parameters as actual atmospheric parameters outside the magazine over a longer period of time, parameters inside the magazine, efficiency of natural ventilation in the magazine and variation of temperature and relative humidity inside the package of ammunition. The design and used materials of the packages can significantly influence on the ability to reduce the impact of external influences of environmental factors.

1.2. The importance of ammunition package

Ammunition packaging is a crucial factor in maintaining the integrity of ammunition. It represents a key safety measure in the process of handling, storing and transporting ammunition until the moment of the use on the battlefield. The design and materials of the ammunition container significantly effects on its service life, safety and functional reliability during the handling and storage process [2]. NATO and Eastern (China, Russia) ammunition container concept is the mostly used in the world. But there are significant differences in design approach, construction and used materials between these two concepts.

The basic differences between these two concepts are reflected in the degree of protection in extreme changes of temperature and relative humidity in magazines (during the change of seasons) and the ability to absorb shocks during handling and transport. The NATO concept of a large-caliber ammunition container implies that the container contains an outer coating that protects the contents during the transport, handling and storage process. The outer cladding is usually made of wooden materials or sheet steel, and more recently of reinforced plastic. Internal linings protect the contents from the effects of the environment (temperature, relative humidity) and have additives that prevent displacement and absorb the effects of shock and vibration. The inner linings are in the form of fiber containers or made of composite plastic materials. The Eastern concept of a large-caliber ammunition containers usually did not have an inner lining, larger ammunition was placed in wooden crates with very primitive accessories to prevent the movement of ammunition. There were packaging designs where the ammunition was loaded into special metal containers and then together with the projectiles into wooden crates (125 mm tank ammunition). In a recent years, the situation has changed and the packaging of the Eastern concept ammunition has been improved. Theoretically, all ammunition containers should protect the ammunition in an extreme weather conditions in demanding operational environments, it should be waterproof and resistant to corrosion and fungi, and allow the ammunition inside the container to withstand all shocks caused by handling and transport.

2. AIM AND METHODOLOGY OF RESEARCH

The aim of the experimental research which was performed in four different ammo containers, is to identify and analyze the degree of variations in temperature and relative humidity values, measured in NATO and Eastern concept ammunition containers during changes of seasons [7].

Ammo containers were stored in the Earth Covered Magazine (ECM), located on geographical area surrounded by forest and mountains, and it was not under direct influence of the Sun. Due to it, it was characterized with periodical intense changes in temperature and relative humidity. Containers were located next to the wall of magazine, 5 m from the entrance door. Magazine does not have HVAC system for an indoor climate control and the ventilation is natural. It has two front openings for air entry and one air outlet. Within the ammunition magazine, four types of ammunition packaging were placed, which differ in the design of the outer and inner packaging and the used materials for the packaging structure. Measurements performed during all four seasons made it possible to monitor changes in temperature and relative humidity in the storage area of ECM, inside the outer packaging and inside the inner containers.

Measurement of temperature and relative humidity was performed with Tiny tag Plus Intrinsically Safe Dual Channel Temperature / Relative Humidity (-40 to + 85°C / 0 to 100% RH) by Gemini Data Loggers (UK) Ltd, which provide continuous monitoring of temperature and relative humidity within hazardous storage areas and during transport of hazardous substances. Data loggers are powered by batteries and can continuously measure changes in atmospheric parameters 24 hours a day, seven days a week, 12 months a year.

Data logger TGP-4500 Tiny tag with dual channel for measuring temperature and humidity (-25 to + 85°C / 0 to 100% RH) has a high resolution and accuracy of data reading, waterproof (IP 68) and designed for outdoor use and industrial applications. The TGP-4500 sensor was placed in the entrance area of the ECM. Data logger TGIS-1580 Tiny tag with special safety with double channel for measuring temperature and humidity (-40 to + 85°C / 0 to 100% RH) is an ATEX certified data logger for use in hazardous areas, as which are ammunition depots. TGIS-1580 data loggers were placed inside ammunition magazines, inside crates, fibers and metal cylindrical containers to measure changes in temperature and humidity.

Measurements of air parameters with data loggers were performed every 20 min. The obtained results of daily maximum and minimum parameters values, differences between daily maximum and minimum air parameters and mean parameter values for each measurement day were identified and processed. Parameters of temperature and relative humidity in ECM represent the basis for comparison with the data inside the ammunition packaging.

3. RESULTS OF EXPERIMENTAL RESEARCH

Throughout the research period, environmental parameters in front of and inside the magazine were measured. Measurement results were processed in the way that the average daily values of temperature and relative humidity were determined for a clearer comparative analysis.

Over a period of one year of research, the difference between the maximum and minimum values of daily temperature changes in front of the ammunition magazine ranged from a few degrees Celsius to 27°C. In the winter, the lowest temperatures were down to -19°C and the highest in summer up to 34 °C (Figure 1a). During the research period, the relative humidity was higher most of the time, often up to 100 % (Figure 1b).

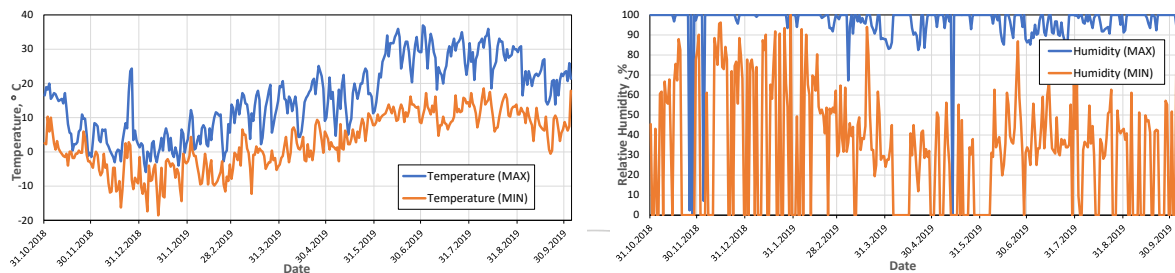


Figure 1. (a) Measured temperature values on the site of analyzed ECM

(b) Measured relative humidity values on the site of analyzed ECM

Characteristics of the magazine, as earth covered concrete structure, and the existing concept of natural ventilation system, had influence on measurement results. Average temperature in the magazine for considered measurement period, in the winter ranged up to 5°C, while in summer period it reached maximum 18°C. The deviations of daily maximum and minimum temperatures in the magazine did not exceed a few Celsius degrees (Figure 2a).

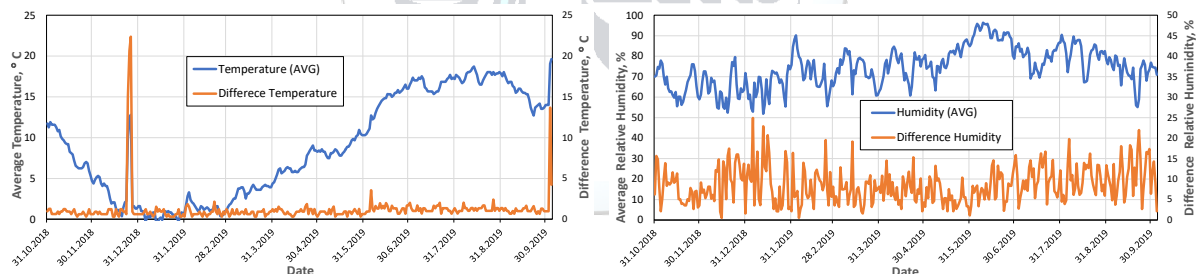


Figure 2. (a) Average temperature in ECM

(b) Average relative humidity in ECM

Average daily relative humidity for a measurement period was in the range 55-95 %, while in some parts of the day, relative humidity value reached up to 100 % (Figure 2b).

First measurement packaging, cartridge propelling 105 mm L35, was consisted of metal box, where inside were placed two cylindrical plastic containers (Figure 3, left). Plastic container was consisted of brass cartridge case, electric igniter and five incremental charges (Figure 3, right).



Figure 3. Cartridge propelling 105 mm, L35, packaging

Measurement results of air parameters inside of metal box and plastic container for Cartridge propelling 105 mm L35 are shown on the Figure 4. Character of temperature changes in a metal box and in plastic container is similar to temperature changes inside of ECM. Variations of daily temperature values inside of both packages were up to 4°C, in comparance to the temperature in ECM.

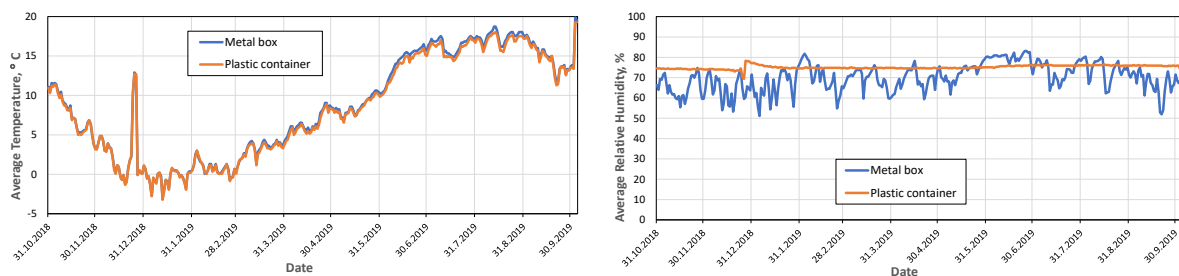


Figure 4. (a) Measured temperature values in Cartridge Propelling Packaging 105 mm, L35

(b) Measured relative humidity values in Cartridge Propelling Packaging 105 mm, L35

Relative humidity inside of the metal box was lower by 15 % in comparance with relative humidity inside of ECM. Character of relative humidity variations inside the metal box during measurement period was similar to variation of relative humidity inside of magazine because metal box of this package has several openings on its structure and there was air circulation through openings. In the case of a plastic container, there is a sealing system that prevents air penetration from the metal box to the inside of plastic container and there were no significant changes in the relative humidity in comparance to the parameters, at the time of closing the container. The variations of relative humidity was up to 3% (Figure 4b). More precisely, the relative humidity at the time of closing the plastic container remained "frozen" in comparance to the initial state.

Second measurement packaging for mortar ammunition 20 mm, HE, M62, was consisted of wooden box, were two fiber containers with ammunition were placed (Figure 5). Fiber container is made of craft paper and from the outside, it is impregnated with a layer of asphalt varnish in order to protect it from moisture penetration.



Figure 5. Mortar ammunition 120 mm, M62, packing

Temperature and relative humidity variations of Mortar ammunition 120 mm, M62 are shown on the Figure 6. Intensities of temperature changes inside of wooden box and fiber container were similar to the character of temperature changes in the ECM during measurement period. Daily variations of relative humidity in the wooden box in comparance with relative humidity in the magazine had lower intensity by about 10 %, with a certain delay in reaction due to the process of heat transfer through the structure of packaging.

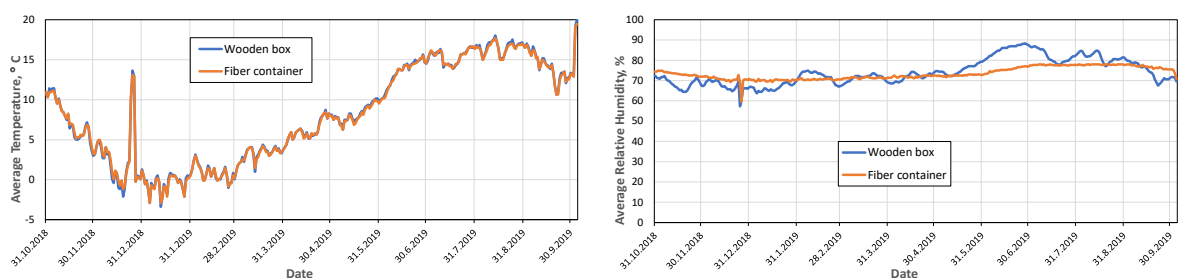


Figure 6. (a) Average temperature values in the packaging for Mortar ammunition 120 mm, HE, M62

(b) Average relative humidity in the packaging for Mortar ammunition 120 mm, HE, M62

Relative humidity changes in fiber container had minor variations over the time in relation to changes in wooden box, due to the outside waterproof layer of asphalt varnish on the fiber container surface (Figure 6b). Initial parameters of relative humidity in the moment of installation of ammunition in the fiber container, and after closing the lid with a hermetic coating, retained same in the container. Resulting small variations of relative humidity inside of fiber container are the result of temperature changes and ability of material inside of fiber container to absorb and release moisture.

Third measurement packaging for tank ammunition 125 mm, APFSDS-T, M88, was consisted of wooden box, in which were two metal containers placed (Figure 7). One container contained a projectile 125 mm, APFSDS-T, M88 with additional propelling charge, and in second container, main propelling charge was placed.



Figure 7. Tank ammunition 125 mm, APFSDS-T, M88, packaging

Variations of temperature and relative humidity inside of ammunition 125 mm, APFSDS-T, M88 are shown on the Figure 8. Intensity of temperature changes inside of wooden box and metal container during daily cycles was similar to temperature changes in the ECM. There are significant differences in the character of daily variations of relative humidity inside of wooden box, in comparance to relative humidity variations inside of ECM, characterized with more intensive variations. Relative humidity averagely ranged between 70% and 80%.

Measurement results of relative humidity in the metal container had slightly variations during entire research period in comparance to the changes in wooden box. Variations of relative humidity were for about 25 % lower compared to the relative humidity of wooden box. Metal container practically “freezes” the state of air from the aspect of relative humidity in the moment of installation of ammunition and closing the container.

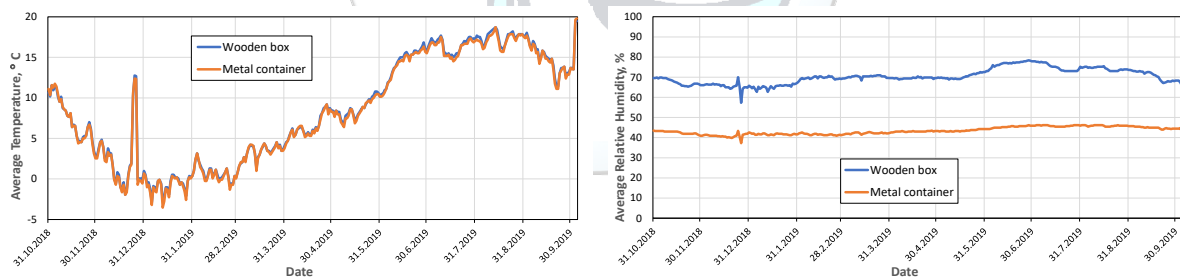


Figure 8. (a) Average temperature values in packing for ammunition 125 mm, APSDFS-T, M88

(b) Average relative humidity values in packing for ammunition 125 mm, APSDFS-T, M88

Fourth measurement container is for propelling charge, intended for HE ammunition 155 mm. It was consisted of cylindrical metal body and a lid with a sealing system (Figure 9).



Figure 9. Propelling charge for ammunition 155mm, Metal container

Variations of temperature and relative humidity inside of packaging for propelling charge for ammunition 155mm are shown on Figure 10.

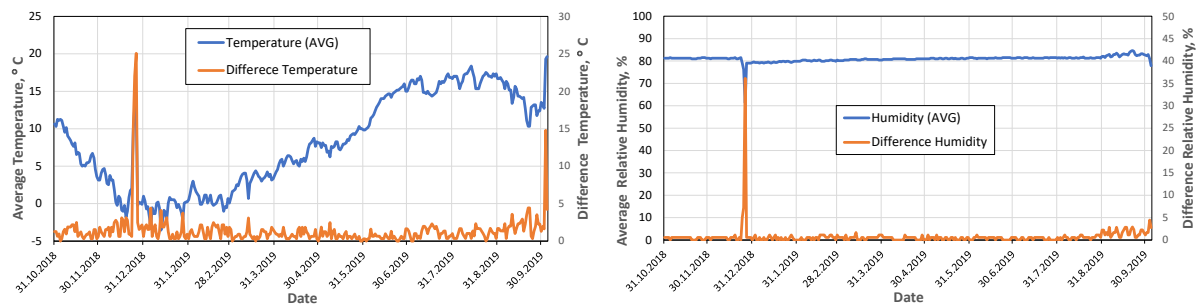


Figure 10. (a) Average temperature values in Metal Container for Propellant charge of 155 mm Ammunition

(b) Average relative humidity values in Metal Container for Propellant charge of 155 mm Ammunition

Character of the temperature changes in a metal container was similar to the changes inside of a magazine, as it was previously described for three ammo packages cases. Relative humidity in a metal container also had slightly variations as it was a case for the metal container of a third package for a tank ammunition 125 mm, APFSDS-T, M88.

By comparing the measurement results of air parameters changes for all four ammo packages, several important facts can be observed. The character of temperature changes inside all three ammo packages and metal container for propellant charge of 155 mm ammunition, during daily cycles was similar to the changes of temperature inside of magazine, during entire research period. Temperature inside of packages was for a few degrees of Celsius lower than the temperature inside ECM (Figure 11).

With metal propelling container for ammunition 155, changes of relative humidity is insignificant, because there are system for hermatization of the container, where the current condition of the air from the aspect of relative humidity is maintained until the next opening of the container (Figure 11, right).

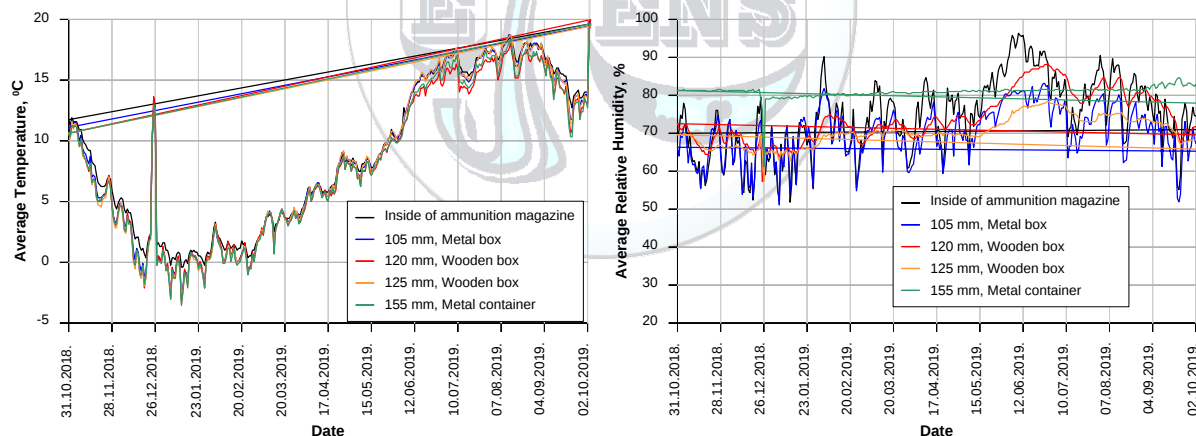


Figure 11. Comparative temperature and relative humidity air measurement data for external packaging of ammunition

Changes of relative humidity inside of plastic, fiber and metal container were less intensive in comparance with the case of ECM (Figure 12). Slightly greater variations are observed in fiber container 120 mm, M62, whose inner layer is made of craft paper which is not watertight, and then in metal container for ammunition 125 mm, APFSDS-T, which also has inner layer made of craft paper, but with a better sealing system for a metal container.

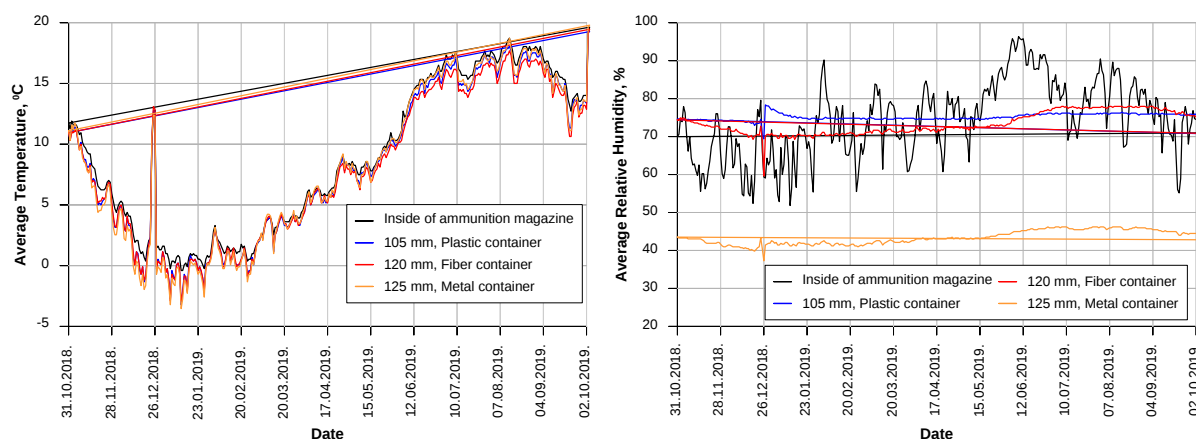


Figure 12. Comparative temperature and relative humidity air measurement data for internal packaging of ammunition

4. CONCLUSION

Based on results of measurement period of one year, it can be concluded that variations of temperature inside of outer and inner lining of ammunition packaging followed variations of temperature inside of ECM.

Changes in relative humidity inside of outer packaging that were not hermetic followed the relative humidity changes within ECM, with a certain delays in reactions. Variations of relative humidity changes were slower and with lower intensity. This is especially pronounced with the outer wooden packaging, while in the case of metal container with openings on its structure, variations of changes are more intense due to the direct contact with the air in the magazine.

Changes of relative humidity at inner packages are insensitive on changes of relative humidity inside ECM, but strongly depends on initial values of air parameters, temperature and relative humidity, at the moment of closing container, amount of component inside of container that have ability to absorb moisture and method used for container sealing.

ECMs as one of the mainly used types of magazines, very often in some cases can have moisture-intrusion problem due to its characteristic covered layers and poorly performed hydro isolation. If ventilation system is not adequate, higher values of air parameters can seriously affect safety of magazine and ammunition inside of it.

Maintenance of ammunition is crucial and every effort should be made to ensure safe conditions for storage, transport, handling and use of ammunition. Some of the most significant and influential factors to achieve that are well performed and maintained ECM with efficient ventilation system to provide adequate ventilation, well designed ammunition packaging, periodical inspection and continuous monitoring and maintenance of temperature and relative humidity at a reasonable level.

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