



VIETNAM
AGEING STUDY
MANAGEMENT OF EXPLOSIVE
REMNANTS OF WAR (MORE)

GENEVA INTERNATIONAL CENTRE FOR HUMANITARIAN DEMINING (GICHD)

The Geneva International Centre for Humanitarian Demining (GICHD) works towards reducing risks to communities stemming from explosive ordnance, with particular focus on mines, cluster munitions, other explosive remnants of war and ammunition storage.

The Centre helps develop and professionalise the sector for the benefits of its partners: national and local authorities, donors, the United Nations, other international and regional organisations, non-governmental organisations, commercial companies and academia. It does so by combining three distinct lines of service: field support focused on capacity development and advice, multilateral work focused on norms and standards, and research and development focused on cutting-edge solutions.

Based at the Maison de la paix in Geneva, the GICHD employs around 70 staff members from 23 different countries. This makes the GICHD a unique and international centre of expertise and knowledge. Our work is made possible by core contributions, project funding and in-kind support from more than 30 governments and organisations.

Acknowledgements

The GICHD wishes to thank the main contributors to this report: Colin King and David Hewitson, Fenix Insight Ltd; Sn Col Tuan (retired), GICHD consultant, Hanoi; Len Austin and Lee Moroney, Golden West Humanitarian Foundation; Vietnam National Mine Action Center; The Vietnamese Institute of Propellants, Hanoi; The International Centre, Hanoi; Vietnamese Ministry of Defence; Quang Tri Province People's Committee; Quang Tri Provincial Military Command; Quang Tri Mine Action Center; BOMICEN (Technology Centre for Bomb and Mine Disposal); Norwegian People's Aid.

This report was managed by Rob White, GICHD Advisor, and commissioned by the U.S. Department of State, Bureau of Political and Military Affairs - Weapons Removal and Abatement.

GENEVA INTERNATIONAL CENTRE FOR HUMANITARIAN DEMINING

Vietnam ageing study - Management of explosive remnants of war (MORE),

GICHD, Geneva, 2019

ISBN 978-2-940369-77-5

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2019

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INTRODUCTION TO AGEING

Every conflict leaves behind explosive remnants of war (ERW) in lesser or greater quantities depending upon the nature and duration of the conflict and the types and quantities of weapons used. How ERW are dealt with reflects local circumstances and conditions, as well as the influence of international humanitarian law (IHL), the availability of resources and prioritisation choices made by governments, international institutions and agencies. In many cases an initial period of proactive effort is followed, sooner or later, by the adoption of more reactive policies and practices. The duration of the transition period varies from country to country, but in every case a situation eventually arises when the ERW that remain are treated as “residual”. In many locations where ERW are found, the items have been exposed to the outdoor environment for many years. The effect of this “ageing” on munitions has not been researched to any extent, and most information on ageing is anecdotal, rather than systematically compiled. Additional information and a robust methodology are required to enable evidence-based planning decisions.

Accurate information on ageing is critical in designing a programme that delivers value for money and addresses those areas with the greatest need as quickly as possible. The protracted nature of clearance activities means that the problem is quite complex: victim rates change over time, munitions age, populations migrate and variable conflict patterns mean that not all contaminated areas are known. In order to have a national clearance programme which is fit for purpose, these variables need to be considered when planning a holistic clearance effort. Improvements to global understanding of the mechanisms, significance and implications of ageing in ERW provide opportunities for other

mine action programmes to benefit from the lessons learned, in establishing studies into the ageing of components and compounds of improvised mines and other ERW.

This report presents the results of a pilot study conducted in 2018 and provides comment on the technical ageing of ERW found in Vietnam, to determine the effect of time and surrounding environment on the probability of detonation and functionality, on a limited number of target items.

The aim of the pilot study was to contribute to increased confidence and efficiency in mine action prioritisation, planning and risk management decision-making within the mine action programme in Vietnam, by providing information on the effects of and approach to ageing. The authors recognise that the sample of munitions is not large, so summaries and recommendations should be taken as cautious and indicative. This report provides a narrative on the background to the approach to ageing of munitions, the process of the field work/cutting of the munitions, and a description of findings from the analysis of the explosive content by Fenix Insight Ltd and the Weapons Technical Centre, Military Technical Academy, Hanoi, the details of which can be found in the annexes to this report.

APPROACH TO AGEING OF MUNITIONS

The majority of the weapons used during the Vietnam conflict originate from the Cold War era. Much of the ammunition was manufactured in the 1950s and 60s and has remained undisturbed since it was deployed. With the exception of some landmines, most of these munitions were built with a shelf life of a very few years. They were expected to be maintained in protective storage and designed to function on, or shortly after, deployment yet they have now been exposed to the outside environment for decades.

This prolonged exposure is well beyond any anticipated design consideration and until Fenix Insight Ltd began undertaking ageing studies, the consequences were largely unknown. In the absence of reliable data, the subject has been dominated by popular myth and speculation, with a widespread assumption that unexploded ordnance (UXO) becomes more dangerous as it ages. Even experienced explosive ordnance disposal (EOD) personnel use emotive terms such as “unstable” and “volatile” to express their expectation of increased risk, yet there is little reliable evidence to support this misconception. In fact, recent analysis by Fenix suggests that the vast majority of ordnance becomes safer within this timescale.

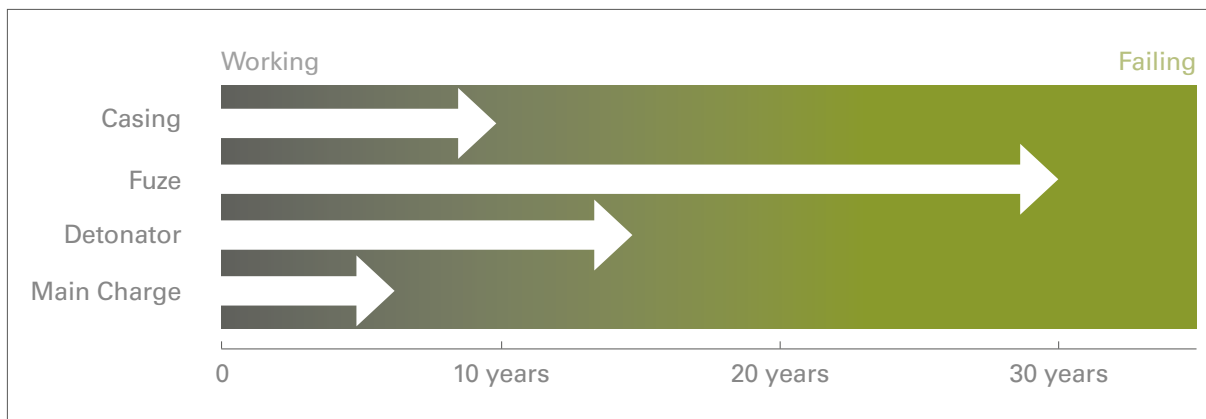
All explosive munitions contain multiple assemblies and energetic materials that are critical to their function and the majority of these are vulnerable to degradation. In most cases, the failure of any critical component will lead to the item becoming incapable of working as designed. To make an analogy, there is no expectation that a 1960s car, camera or typewriter, abandoned in the open for decades, would remain operational. Similarly, it is inevitable that munitions - manufactured from vulnerable materials - will also fail. Some have already done so, while many others are nearing the end of their functional life.



Whether abandoned or expended, Cold War era ammunition throughout the world is suffering from the effects of ageing



Some munitions are barely recognisable, and evidence suggests that many are no longer functional



Critical components transition from full functionality to failure at different rates

The inability of a system to function as designed does not necessarily make it safe; in rare instances, it may lead to the creation of a new and unintended means of initiation. Examples include the release of a mechanism by a weakened component, or a chemical interaction leading to the formation of a sensitive compound. In these exceptional cases, the alternative hazard will be temporary, but the degree and duration of the new risk may be difficult to establish.

THE RELEVANCE OF AGEING FOR THE MANAGEMENT OF RESIDUAL ERW

MORE is all about understanding risk, primarily considering the potential for interaction between people and ordnance. The people concerned may be the local communities farming the land, machine operators and builders involved in development projects, or specialist operators from clearance agencies. Wherever their activities coincide with the location of abandoned or unexploded munitions, the potential for an accident to occur is likely to depend heavily on the condition of the item encountered.

Studying the effects of ageing is key to evaluating the hazard posed by munitions and, importantly, understanding the future “residual” risk as the ammunition continues to age.

WHAT IS AFFECTED?

Ageing causes changes to every form of explosive ordnance, from small, simple munitions such as landmines and grenades to large and complex weapons such as cluster bombs and missiles. Almost every type of material is affected, from pyrotechnic compositions and explosive compounds to plastic casings and metallic components. In addition to changes within individual components, such as rusting of steel or hardening of rubber, materials may react with one another to create unforeseen chemical effects.



The hardening of rubber and rusting of steel have changed the characteristics of this PMN mine



A sectioned fuze mechanism from an Mk 82 bomb, blocked by the build-up of oxidised aluminium

Animal activity and accidental human interaction (such as contact with farming implements) may weaken or break casings, while external influences (such as the ingress of silt or root structures) also interfere with mechanisms.

In weapons where stored electrical energy is needed for initiation, self-deactivation is inevitable. While military-grade batteries may last for decades, most commercial cells will degrade within a year or two at the most.

The findings are also relevant for improvised explosive devices (IEDs), with strong evidence to suggest that the effects of ageing occur much faster in most IEDs than in conventional weapons. Many IEDs use flimsy casings, low-grade commercial batteries and water-soluble explosive mixtures, all of which are prone to rapid deterioration.

WHERE ARE AGEING MUNITIONS FOUND?

Unexploded ordnance and ammunition stockpiles throughout the world are undergoing the effects of ageing. Although the focus of this study is Vietnam, it draws upon data gathered from studies in many other countries. Similarly, many of the findings gained in Vietnam will be relevant to regions and weapons elsewhere. A number of local factors, such as climate and soil type, will affect the rate at which critical components age, yet the eventual effects are largely the same.



The characteristics of abandoned and unexploded weapons throughout the world are changing. The Vietnam study will contribute to our understanding of how they are affected by ageing

WHO SHOULD BE INTERESTED, AND WHY?

The implications of ageing are important to every group engaged with, or affected by, explosive ordnance. Examples of interested parties and the relevance of munition ageing are:

Stakeholder	Priority	Questions relevant to ageing
Government agencies and policymakers	Need to understand the nature of the residual risk in order to manage it effectively	Is it necessary to clear each and every deep-buried bomb in a region, if evidence indicates that they pose a negligible threat? What level of residual risk will remain in the long term?
Donors	Seeking to prioritise tasks and make the most effective use of funds	Which types of munition, in which areas, present the greatest and most immediate threat, and therefore justify the funding of clearance programmes?
Clearance agencies	Need to identify munitions and understand the risks in order to select appropriate clearance techniques	Are the munitions still recognisable? Can high-risk munitions, formerly requiring special procedures and equipment, be cleared using normal techniques once they have degraded?
Researchers and equipment developers	Seeking to plug gaps in existing detection and disposal capabilities, while exploring new opportunities created by changing characteristics	The rusting of ferrous components may make metal detection more difficult, but will explosive leaking through degraded cases increase the potential for chemical detection?
Builders and developers	Concern about the potential for an accident during excavation and construction work	Is a site survey needed before work begins? Should plant operators be given additional training? Is an on-site EOD capability needed?
Affected communities	Need to be able to recognise munitions. May have lived with the threat for decades, and are already aware of its changing nature, but need guidance on safe activities	Farmers were forbidden from removing UXO from their fields, but had little alternative. Given the low accident rate during encounters with degraded ordnance in recent years, should the question of "self-help" options be revisited?



The effects of ageing may affect clearance priorities, while operators need to be trained and equipped to deal with the changing threat



Communities must know which locations and activities are safe, while their leaders should understand the long-term residual risks

HOW WILL WE LEARN MORE?

The investigation examined live ammunition from former battlefields, where it has been abandoned or failed to explode. Once the ordnance has been recovered, it will be disassembled or cut open remotely, so that experts can examine the materials, mechanisms and explosives inside. These will be compared to their original condition in order to see how and why they have changed. The ability of the weapon to cause harm will be assessed and, where possible, tested under safe conditions.

For the initial “pilot study” a small number of munitions will be selected so that the process can be tested. This will include a variety of weapon categories (such as grenades, mines and bombs), so that different materials, casing thicknesses, fuze types and explosives are represented. Every step of the process will be risk assessed and strictly controlled to minimise the danger, while collecting as much data as possible. The team responsible for the work has conducted many such examinations and works to international environmental, quality and safety standards (ISO).

The findings from the pilot study will help to prioritise and direct further research, which may be expanded to a wider variety of weapon types within Vietnam. The findings will be published in the form of a report, along with presentations to key stakeholders and decision makers.



Munitions will be disassembled, or cut remotely, using well-established techniques



Analysis will include comparing recovered weapons with items in their original condition

IN SUMMARY

In Vietnam, as in many other countries, abandoned and unexploded ordnance is undergoing major changes as a result of the ageing process. These effects are critical to recognition, detection and clearance techniques and, most importantly, to the residual risk they pose. Yet, despite their importance to stakeholders at every level, very little is understood about the long-term effects of ageing on ammunition. This study will make a substantial contribution to knowledge in this important area and enable better, more informed, decision-making within the management of residual explosive remnants of war.

AMMUNITION CUTTING

BACKGROUND

The management of residual explosive remnants of war (ERW) programme relies on an accurate understanding of the risk posed by ageing explosive ordnance. ERW include unexploded ordnance (UXO) and abandoned explosive ordnance (AXO). However, there has been hardly any research into the effects of ageing, and therefore very little reliable data is available.

Much of the ordnance used in Vietnam was produced in the 1950s, 60s and 70s, with some originating from the Second World War. Most has remained untouched and vulnerable to the local environment, for more than 40 years.

There is no doubt that the ageing of munitions causes a number of significant changes, ranging from differences in external appearance, to variations in functionality.



A Vietnamese soldier from BOMICEN sets up a cut on a US Mk 82 aircraft bomb

The primary aim of the cutting programme is to enable the internal examination of ordnance, in order to understand the changes that have occurred, and help gain an accurate assessment of the risk it poses. In many instances, this would not be possible by any other means. Non-intrusive methods of examination, such as X-ray, do not yield anything approaching the same level of detail as visual inspection.

Although a cutting system has been available in Vietnam for some time, various administrative and training issues have prevented its use. A pilot study was therefore needed to revive a host-nation capability for ordnance cutting.

AIMS

The work in December 2018 had three major aims:

- To provide training to host-nation staff in the operation of cutting equipment, in order to allow future work to be conducted by local personnel.
- To cut and assess a small sample of munitions, in order to demonstrate a variety of techniques and provide some baseline data for future work.
- To increase confidence, among the host-nation agencies and other stakeholders, that this type of operation could be conducted safely and successfully in Vietnam.

LIMITATIONS

The initial study was constrained by the following factors:

- The cutting technique is best suited to larger hard-cased ordnance, such as mortar bombs, projectiles and aircraft bombs. Small items such as grenades and submunitions are far more difficult to cut into.
- Despite a wish list comprising a wide range of ordnance, the programme could only use ammunition recovered by clearance non-governmental organisations in the preceding weeks. At the time of the mission, a fairly limited selection of items was available.
- The specialists from Golden West Humanitarian Foundation and Fenix were only available in-country for a period of one week.

PRELIMINARY ACTIONS

COORDINATION

A large number of stakeholders and contributors had to coordinate in order to allow the project to proceed. These included:

- Geneva International Centre for Humanitarian Demining (GICHD)
- Province Military Command (PMC)
- Vietnamese Ministry of Defence
- Quang Tri military command
- Vietnam National Mine Action Center (VNMAC)
- BOMICEN (Technology Centre for Bomb and Mine Disposal)
- Quang Tri regional authorities
- Norwegian People's Aid (NPA)
- Golden West Humanitarian Foundation (GWHF)
- Fenix Insight Ltd (Fenix)

Arranging facilities, timings and activities between this number of agencies involved a substantial coordination effort and added significant complexity to the programme.

There were also a number of administrative and logistical actions required, including crucial permissions that needed to be obtained, before the project could get underway. These had resulted in a previous mission, planned for August 2018, being aborted. Each issue was systematically addressed and overcome by Senior Colonel (Sn Col) Tuan and the major stakeholders, in order to allow the work to proceed.

EQUIPMENT

The cutting programme involved the use of the following key equipment:

- Mobile cutting system (MCS) consisting of a trailer-mounted bandsaw and generator
- Generator (for administrative area)
- Monitoring camera
- Lifting frame
- Chain lifting block and tackle
- Truck with HIAB crane

All of this equipment had to be moved to the site and installed in preparation for the mission.



The bandsaw of the mobile cutting system

ADDITIONAL EQUIPMENT

In addition to the host-nation equipment listed above, the following items were provided by GWHF:

- Drone (with still/video camera)
- Additional static video camera
- Hand tools
- Reconnaissance kit (including tape measure, brushes, marker pens etc., for use during exploitation)



A GWHF drone was used for monitoring cuts and provided excellent additional imagery

PERSONNEL

The personnel on-site included the following:

- Advisor/coordinator: Sn Col Tuan (retired)
- VNMAC (including Mr Thanh and Major Penh)
- BOMICEN (6 EOD personnel)
- GWHF: Len Austin and his interpreter were responsible for providing training on cutting methods
- Fenix Technical Director, Colin King, was responsible for exploitation work
- Province Military Command: 6 personnel, including drivers, security and general duty personnel, and crane operators



The site was well prepared by the time GWHF and Fenix arrived

FACILITIES

Work was carried out at an NPA site, which had been examined by Sn Col Tuan and approved for purpose by all relevant authorities. The site was large enough to safely accommodate all cutting, exploitation and disposal activities.

Preparation for the visit was excellent, with separate enclosures built from tents and sandbag walls (although these were too low to provide complete protection).

The site incorporated secure storage for smaller ordnance items and had a generator to provide power and lighting in each enclosure.

The main site access road had become impassable due to flooding, but an acceptable alternative route was found.

ORDNANCE

The munitions consisted of a mixture of UXO (recovered from clearance operations) and AXO (from storage).

All items were unitary high explosive (HE) stores of US and Russian origin, including mortar bombs, artillery projectiles and air-delivered bombs. Some of the munitions were fuzed and some were not; all of the fuzes present were mechanical impact types, with most having been heavily damaged on impact.

The mortars and projectiles were stored in secure holding areas on-site. Each had been labelled. The aircraft bombs were brought from remote storage sites, as required.



Smaller items of UXO and AXO were stored on-site in secure concrete bays

SEQUENCE OF EVENTS

MONDAY 3 DECEMBER

Soon after their arrival, Sn Col Tuan accompanied the GWHF and Fenix teams on an initial visit to the work area. Here, they met representatives from BOMICEN and VNMAC and together viewed the site, assessed the ordnance and examined the MCS. Some preliminary actions (such as mixing cutting fluid and repositioning protective works) were explained and implemented before the start of work the following morning.

TUESDAY 4 DECEMBER

The first working day began with a safety briefing from VNMAC and an explanation of the proposed activities, with the cutting of smaller calibre live munitions commencing soon after. As each cut was completed, sections of the munition were moved across to a separate enclosure for exploitation. Cutting and exploitation of mortars and projectiles continued throughout the day, with the involvement of the BOMICEN operators being steadily increased.

WEDNESDAY 5 DECEMBER

Quang Tri Province Military Command provided two US Mk 82 (500 lb) bombs, a Russian mortar bomb and two Russian artillery projectiles. These items were cut and the explosive fillings of the Mk 82 bombs were burned out.

THURSDAY 6 DECEMBER

The morning was devoted to positioning and cutting a US Mk 84 (2,000 lb) bomb; the bomb casing and other explosive items (from exploitation) were then burned out. At the end of the mission, an out-brief was given by Mr Thanh of VNMAC, with additional comments by all major contributors to reinforce key points.

CUTTING TRAINING

Cutting began on the smallest items first (81 mm mortar bombs), with technical and procedural approaches demonstrated and explained at every stage. Work progressed quickly up through larger calibre artillery projectiles, eventually moving on to the Mk 82 bombs.

Though somewhat limited, the available selection of ordnance provided a good introduction to the use of the MCS, and the carrying out of cutting operations. Throughout the training, responsibility was gradually transferred to BOMICEN and PMC engineers, so that they were performing most of the actions by the end of the second day, including the cutting of an Mk 82 bomb.

The cutting of fuzes, and the Mk 84 bomb, provided opportunities for GWHF to demonstrate more difficult and specialist operations.



Soldiers from BOMICEN gradually assumed greater responsibility, and conducted the cutting of the second Mk82 bomb virtually unaided

DISPOSAL TRAINING

Disposal was centred on open burning (OB) rather than the open detonation (OD) techniques more familiar to BOMICEN. The advantages of OB over OD include:

- Low noise level
- Absence of air and ground shock
- Fewer stores required
- Fewer storage, accounting and security issues
- Avoidance of metallic contamination
- Availability of residual scrap metal

The principles of initiation and safe separation were explained, together with the use of large munition burns to destroy or detonate small items (such as fuzes).

Despite the extensive use of OB, it was pointed out that there may also be a need for some demolition by OD during these programmes.



The burned-out carcass of the Mk 84 bomb as it cooled. Note that the fuze in the nose section (to the right) has been deliberately initiated using the heat of the burn, in order to render it safe

EXPLOITATION

Exploitation work was kept completely separate from cutting training, with sections taken across to a remote enclosure.

As each section arrived, it was allocated a serial number and photographed. Visual examination, and a limited amount of further disassembly was then carried out, with detailed photography of relevant observations.

Work was conducted on a single munition section at a time and kept to a 1-person risk.

Time and facilities were limited, allowing only for a superficial examination of the ammunition sections. Nevertheless, the ability of the process to provide accessible samples was clearly proven, and there were a number of interesting findings.



Cut munitions were taken to a separate tent, well away from all other activity, for examination

EXPLOSIVE ANALYSIS OF TNT, TETRYL AND COMPOSITION H6 SAMPLES

Previous ageing studies and weapons exploitations programmes have determined that the secondary explosive found in recovered munitions is usually serviceable. This conclusion is based largely on visible characteristics such as appearance and physical integrity, often reinforced by burning small samples, or by larger scale open detonation and open burning. However, until now, there has been little opportunity to conduct rigorous scientific testing.

The Vietnamese Institute of Propellants offered this programme a unique opportunity to analyse and record the precise physical and chemical properties of explosives extracted from recovered warheads. Although there was no expectation of finding the materials to be inoperative, small changes in characteristics, such as melting point and sensitivity, might indicate continuing trends in the degradation of the materials. If so, these changes could have significant implications for long-term residual risk.

PHYSICAL CHARACTERISTICS

- The report concludes that degradation due to ageing has resulted in minor changes in the physical characteristics of all 3 explosive types.
- The result is that some of these characteristics now fall outside the relevant military standards. These standards are regularly updated according to the Law on Regulations and Standards of Vietnam. Each type of explosive has a standard for determining quality criteria and testing methods. The Vietnamese TCVN / QS standards use to evaluate TNT explosive samples in the report as the latest version was updated in 2018.
- Characteristics such as melting temperature and moisture content are set for military utility, but small changes are unlikely to have any adverse consequences in UXO or AXO in terms of performance as military weapons.

STABILITY

- The thermal stability and 'quality' of all 3 explosive types is still good; they are considered appropriate for safe storage and therefore pose no greater risk of accidental detonation from overheating than explosives meeting current standards.
- However, impact sensitivity for TNT is higher than the military standard. This may increase the possibility of accidental initiation under the following circumstances:
 - During violent disturbance, such as pile driving or quarrying;
 - When using low-order (deflagration) EOD techniques.

POWER

- The lead cylinder compression tests show that all 3 explosive types have retained their original explosive energy. This means that:
 - The minor effects of degradation, such as melting temperature and moisture content, have made no discernible difference to the destructive potential of the weapons;
 - Tetryl boosters will remain capable of initiating the main fillings (particularly considering the observation that the sensitivity of the TNT and Composition H6 samples had slightly increased).

FURTHER WORK

As the report states these findings do not allow extrapolation, but they do provide some data points that can be added to during subsequent research in order to answer the following questions:

- How will these changes progress in future years?
- Are they linear?
- Do they have limits?
- Can we compare with other known examples?

FINDINGS

Exploitation findings are summarised below, with more detailed observations in Annexes A – G.

APPEARANCE

An obvious conclusion is that the appearance of ordnance changes as it ages.

Painted markings are often obscured or lost altogether during impact, with even the most superficial corrosion worsening the effect.

With many casings looking similar, the loss of markings means reliance on less obvious signatures for identification, some of which will be known only to ammunition experts.

However, as the ageing process continues, even these signatures are gradually eliminated. Identification becomes even more difficult if the shape has changed significantly, through the loss of a key recognition feature, such as a tail assembly.

The consequence is that it is has already become difficult to identify some types of UXO. This problem will inevitably get worse as the ageing process continues to obscure, alter and destroy key features.

The deterioration or detachment of key components may also make risk assessment harder.

For example, on projectiles, the engraving on a driving band normally gives a clear indication of whether or not the munition has been fired. If this band is absent for any reason (copper bands are often removed for their scrap metal value) it may be more difficult to establish the projectile's status (fired or unfired), and therefore the risk it poses.

Similarly, the tail of a mortar bomb may give the only clear indication of whether the munition has been fired.



Paint and markings are among the first identification features to be lost as the casing corrodes



The loss of key identification features can make identification far more difficult



A projectile with the driving band removed

CASINGS

Most ordnance is steel-cased and therefore vulnerable to corrosion. Since rusting relies on the presence of air and water, the immediate environment can significantly affect the rate of decay. One projectile may be found preserved virtually as-new, while another of a similar type and age may be heavily corroded.

The expansion and rough surface of rust and other metal oxides may lead to the loss of identification features and can also make it hard to determine the precise calibre.

On thick casings, the corrosion is normally superficial, with a substantial layer of unaffected metal beneath the surface. However, thinner casings, and those subjected to particularly harsh conditions, may deteriorate to the point where they can no longer support their contents.



The corrosion of thick steel casings is normally superficial, but may make it hard to measure the calibre

MAIN CHARGES

Most of the ordnance used in Vietnam is based on common military high explosives such as TNT and RDX (often combined into mixtures such as Composition B). These are known to remain stable over relatively long periods, particularly where they are supported and protected by their casing.

Distortion of the munition on impact may crack the filling, but this alone is unlikely to significantly affect its characteristics. Cracking does, however, present a larger surface area to water and other contaminants entering the filling. This may lead to accelerated deterioration and the leaching of potentially toxic compounds into the surrounding environment.

A number of explosive samples were sent for laboratory analysis, in order to confirm their types and establish whether any significant changes had taken place.



Explosives such as Composition B remain stable for long periods, but may crack on impact

BOOSTERS

Many of the munitions used in Vietnam use high explosive boosters, which are normally composed of pressed TNT or Tetryl. Both of these explosives are relatively stable and remain capable of detonation for many years.

Boosters tend to be well protected by the outer casing and are often found intact. However, being near the nose or tail of the munition, they are often exposed to water. While both have very low solubility, they can partially dissolve during prolonged exposure. Tetryl is a toxic compound and may contaminate the surrounding environment.

Boosters are often contained in thin aluminium casings; these are often found corroded into an expanded white oxide, which may penetrate nearby fuze structures.



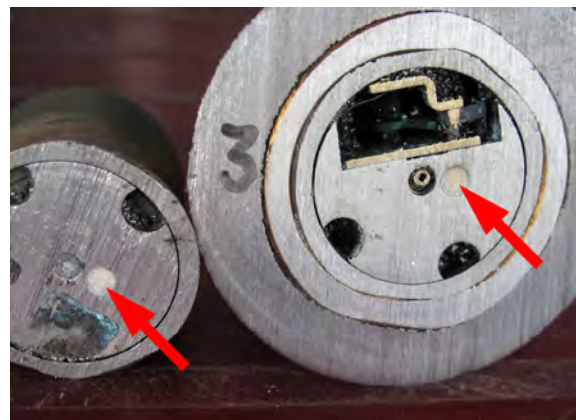
A pressed booster from a US artillery projectile, still in exceptionally good condition

DETONATORS

During the cutting of some munitions, detonators within the fuzes were sliced through. GWHF regularly cuts through live detonators, which only initiate if there is a technical problem with the cut (such as a defective blade, absence of cutting fluid or unexpected movement of the sample being cut).

The cut detonators revealed primary explosive that appeared to be in good condition, but no formal testing was conducted to confirm their condition.

Small explosions, heard during burning, confirmed that the primary explosive was still capable of detonation when sufficient energy was available, but not whether the detonators would be capable of fulfilling their role as part of the explosive train.



Cutting this M524 mortar fuze, demonstrated the ability to pass through live detonators without setting them off

FUZE MECHANISMS

Most mortars and projectiles are fitted with nose fuzes, which are usually partially damaged or destroyed on impact. Even slight damage will allow water to enter, which accelerates the degradation process affecting most metals and explosive initiators.

This can lead to several modes of failure in mechanical fuzes, including: the inability of the mechanism to generate sufficient energy to cause initiation (e.g. a rusted spring); the physical blockage of movement by damage, the presence of foreign matter (such as silt), or the build-up of oxidised material from within the fuze; the initiator to be less receptive to input energy (e.g. a damp igniter). After prolonged exposure to water, a combination of these failure modes tends to render fuzes inoperative.



A sectioned M48A1 fuze from an M107 projectile

A brief examination of the fuzes, as shown here, appears to support this finding. However, a good deal of further analysis would be needed in order to establish more detailed conclusions on the failure mechanisms of individual weapons, and their implications for residual risk.

OTHER COMPONENTS

A variety of other sub-assemblies and components were revealed during the cutting process, such as:

- Propellant cartridges
- Primers
- Additional energetic material
- Fuze adaptors
- Plugs
- Seals

The ability to visualise the presence, location and condition of these components can play an important part in assessing the overall risk from the munition.



Cutting allows the visualisation of internal components, such as this incendiary pellet

CONCLUSIONS – THE PROJECT

- The project was highly successful. It achieved the technical objectives, demonstrating cutting techniques on a variety of ordnance, and greatly increased confidence in this technique within host-nation agencies.
- The project was more complex than it might have appeared. It required the coordination of many agencies, the securing of several permissions and considerable logistical effort to prepare facilities and equipment. Overcoming these hurdles is a testament to the skill of all involved, but particularly of Sn Col Tuan, and Len Austin of Golden West.
- Once all of the administrative and logistical challenges had been met, the project achieved high productivity within a short time frame. This demonstrates how much can be achieved by an MCS, once the preparatory effort has been made.
- The project demonstrated, to all participants and observers, the value of cutting in order to visualise internal ammunition structures. Most of those present had never seen the internal components of live ammunition, and were fascinated by what they saw.
- Although no training was provided in the formal exploitation process, the participants clearly grasped the value of cutting, for both the disposal and assessment of ammunition.
- The project was conducted without incident or injury. However, there was the potential for accident and room for improvement with regards safety (see below).

SAFETY

During explosive ordnance disposal (EOD) operations, there is a tendency for inexperienced operators to fixate on explosive risks, while sometimes overlooking contextual hazards. In particular, the movement of heavy items (the Mk 82 and Mk 84 bombs) had the potential to cause serious injury. Within a risk matrix (scoring “likelihood” against “consequence”) this would probably have been assessed as a higher risk than that of an explosive event.

Risk factors included lifting gear of unknown quality and strength, the presence of large numbers of people confined in small spaces, language differences and the natural enthusiasm of all participants to issue loud, conflicting suggestions and instructions simultaneously.

Operators regularly placed limbs, or their entire body, under heavy suspended weights, and placed hands and fingers into pinch points. Many had no personal protective equipment (PPE) such as gloves and helmets.

Unexploded and abandoned ordnance is handled routinely in Vietnam, and incidents involving the movement of ammunition are extremely rare. However, the condition of the ordnance was unknown (which is what the exploitation process would aim to examine). Within a risk matrix, the potential “consequence” of multiple fatalities should lead to the “control” of using as few operators as possible during the movement of suspect ammunition. This is simply the application of the ALARP (as low as reasonably practicable) principle.



While explosive risks were well-managed, people were sometimes in danger from mechanical injury

CONCLUSIONS – EXPLOITATION

- The level of exploitation performed here was cursory. This was due to major limitations on time, ammunition types, facilities and equipment. No further disassembly or cutting could be performed, and no testing of mechanisms or energetic materials was possible.
- Nevertheless, within the limitations outlined above, the work was successful. A number of different cut munitions were presented, examined and photographed.
- The project demonstrated the feasibility of running exploitation in conjunction with a cutting programme, although even the most superficial examination cannot keep pace with the output of a well-run MCS.
- Findings from exploitation were broadly in line with expectations and observations from previous work. They reinforce the conclusion that most types of ammunition present a lower risk of accidental detonation as they age, because the means of initiation tends to become non-functional, even though the explosive charge remains viable.
- Many questions remain to be answered about the changing characteristics of ammunition components, their ability to function, and the possibility of new, alternative initiation mechanisms that might arise as a result of ageing.

RECOMMENDATIONS

The following actions are recommended:

1. **Continued work.** Further ordnance cutting and exploitation should continue to build on the foundation laid with this pilot programme. This work should:
 - a. Incorporate different ammunition types, such as grenades, rockets and submunitions.
 - b. Focus on initiation systems:
 - the condition and status of the intended fuzing system
 - the possibility of new initiation mechanisms arising as a result of the ageing process.
 - c. Develop new protocols to optimise the productivity and cost-effectiveness of the work.
2. **Safety.** An enhanced safety programme should be integral to any further work, and should incorporate:
 - a. Training - to raise awareness of both explosive and non-explosive hazards; to explain risk assessment, risk treatment, the need for regular reviews and the principle of continual improvement.
 - b. PPE - the provision and systematic use of eye protection, gloves, helmets etc.
3. **Explosive analysis.** As part of the effort to understand residual risk, further laboratory support is required for the analysis of explosives; particularly primary explosives. These will need to be transported, analysed and tested, which may require the development of new protocols.
4. **Mentoring.** Expert advice, assistance and oversight should be made available to Vietnamese agencies during the evolution of the programme.

ANNEX A: M374

DESCRIPTION

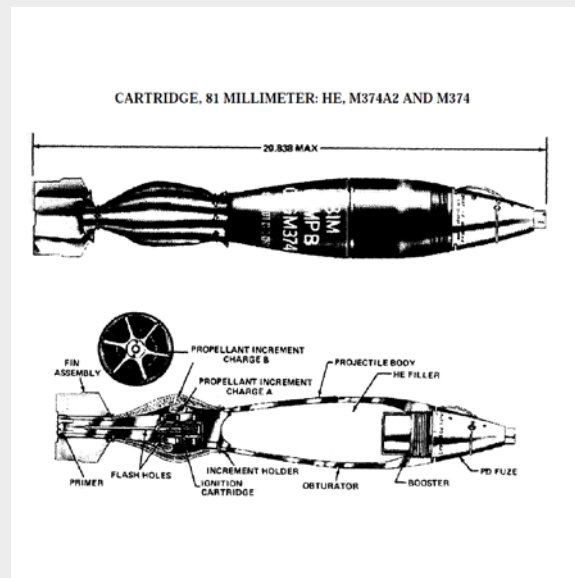
The M374 is a US 81 mm mortar bomb intended for use with smooth-bore mortars. The steel-cased HE warhead accepts various fuzes, the most common being the M524 and M526 point-detonation (PD) mechanical fuzes.

Recovered mortars typically have the main charge and booster intact, with some or all of the external fuze assembly (the portion projecting beyond the steel warhead casing) missing or severely damaged during impact.

The tail assembly contains a primer and an ignition cartridge which, along with the external propellant charges, are expended during firing and will not be present on unexploded examples. The tail assemblies of these UXO mortar bombs, therefore, contained no hazardous energetic components.

Each of the mortar bombs was cut perpendicular to the longitudinal axis. At least two cuts were made, to reveal the base of the fuze and the main explosive filling, but several mortar bombs were cut in multiple locations.

During this pilot study there was no expectation of detailed fuze analysis, and besides, the size of the MCS bandsaw combined with the small diameter of the M374 mortar, made longitudinal cuts impractical. Nevertheless, some fuze cuts were made, allowing some opportunity for observations to be made.



The US M374 81 mm mortar bomb



Cuts through one of the M374 mortar bombs



OBSERVATIONS

APPEARANCE



The appearance of these mortars can vary significantly, depending on damage and effects of ageing. There are still enough signatures for an experienced operator to make an identification, but these will continue to diminish



The tail assembly is an important identification feature, but even among the small number examined, these ranged from near original to completely absent. In some cases, the alloy was severely corroded, altering the shape and appearance

CASING



Cutting shows that rust on even the most heavily degraded steel casing is relatively superficial, and that the side wall remains extremely robust



Water entering the casing through the fuze well has caused corrosion of the inner assemblies, causing a build-up of expanded rust and aluminium oxide

MAIN CHARGE



Sample #1 shows virtually no degradation while the internal corrosion, caused by the ingress of water into sample #2, has cracked and discoloured the main charge



Despite cracks and cosmetic changes to the explosive, the Composition B (RDX/TNT) filling in all M374 mortar bombs was otherwise unchanged. While stable, it is capable of detonation if subjected to extreme heat, shock or friction

FUZING



M524 fuze. The external portion of the fuze is normally damaged on impact, and may be missing altogether. The alloy fuze body is vulnerable to degradation

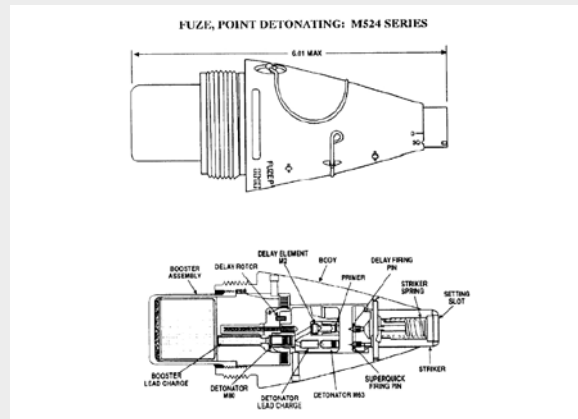


It is not unusual for the external portion of the fuze to be missing altogether. However, detonators may still remain within the section hidden by the casing

M524 FUZE



An M524 fuze, cut through the delay rotor and detonator. While many internal fuze structures remain intact, vulnerable components degrade to form expanded oxidation products (arrows); these often fill voids and seize mechanisms

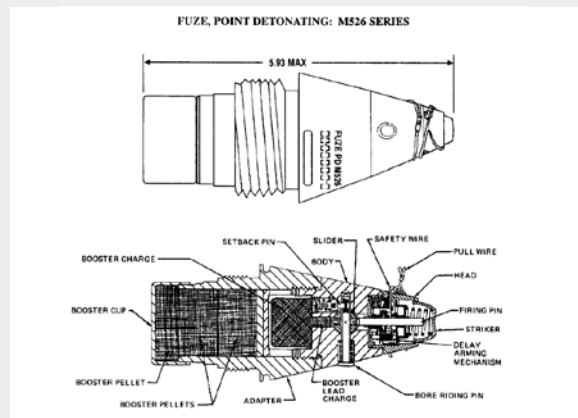


M524 fuze

M526 FUZE

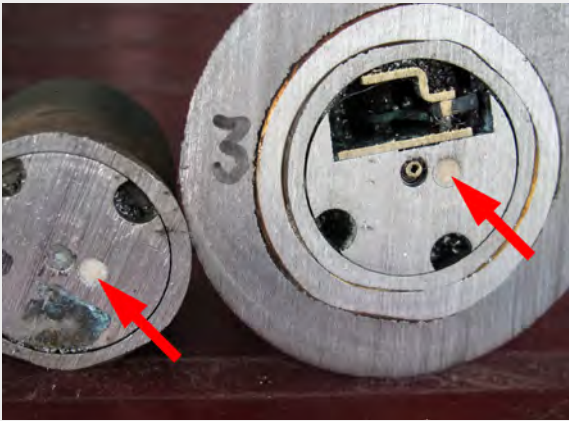


This M526 fuze was remarkably undamaged, with just the ballistic cap missing to expose the firing pin. Further investigation would be needed to establish the viability of the fuze



M526 fuze

OTHER OBSERVATIONS



This image illustrates the ability of the MCS to cut straight through a live detonator without initiating it



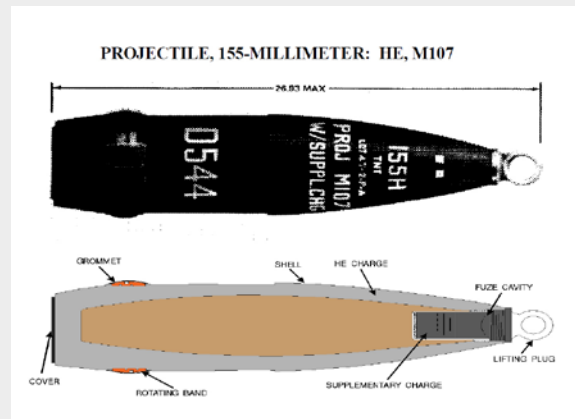
Alloys can degrade rapidly under some conditions, with the expansion of oxidised material disguising the original shape, and complete loss of material in some instances

ANNEX B: M107

DESCRIPTION

The M107 is a US 155 mm artillery projectile. The unitary steel-cased HE warhead is filled with Composition B and uses a booster pellet made from pressed TNT. Various nose fuzes can be fitted, but the most common is the M48 series of point-detonation mechanical fuzes.

Recovered projectiles typically have the main charge and booster intact, with some or all of the external fuze assembly (the portion projecting beyond the steel warhead casing) missing or severely damaged during impact.



The US M107 155 mm projectile

Engraving of the copper driving bands towards the rear of the casing gives a clear indication that the projectile has been fired. If the driving band remains smooth, then the projectile is unfired and the fuze (if fitted) is very unlikely to be armed.

Two M107 155 mm projectiles were cut perpendicular to the longitudinal axis, with one cut being made near the base of the fuze (to reveal the booster) and another further back along the casing to view the main charge.

A longitudinal cut was made through a fuze, mainly to demonstrate the technique, but also allowing an opportunity for observation.



The engraved driving band on the left hand projectile (#8) clearly shows that it has been fired. The driving band on the right-hand projectile (#9) has been removed, probably for its scrap value

OBSERVATIONS

APPEARANCE



What appears to be a plug in the nose of projectile #8 is actually the remains of an M48A1 fuze



The impact of projectile #7 has removed most of the fuze body

CASING



Cutting shows that the rust on the surface of projectile #8 is superficial and that the casing is in good condition



The surface of projectile #7 is heavily pitted. Nevertheless, a substantial proportion of the casing thickness remains

MAIN CHARGE

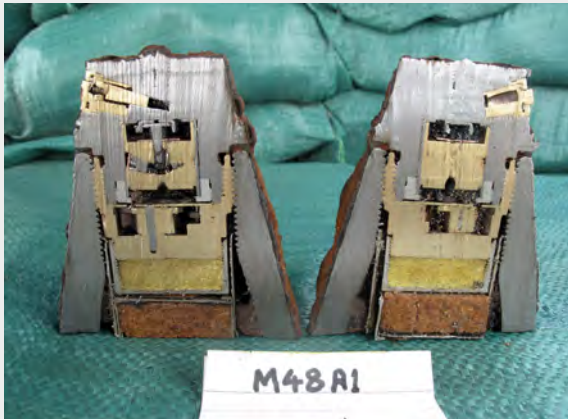


The main charge of the projectile shows no obvious signs of degradation. The pattern seen in the explosive is produced as the molten filling cools

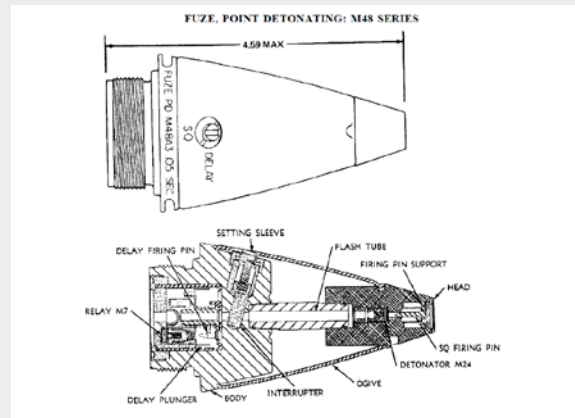


The pressed TNT boosters also remain in good condition

M48A1 FUZE



A section through the fuze from projectile #8 shows that many of the internal components remain relatively undamaged. Further analysis would be needed to establish whether the fuze would be capable of functioning as a result of moderate impact, or other foreseeable action



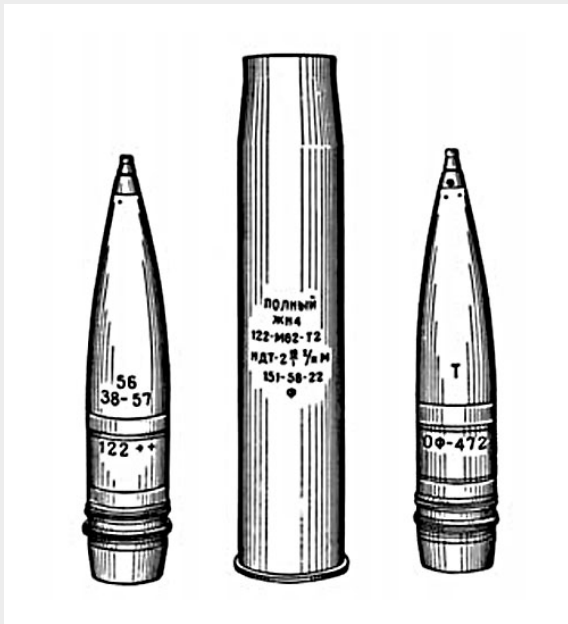
M48 series fuze

ANNEX C: OF 472 AND OF 482

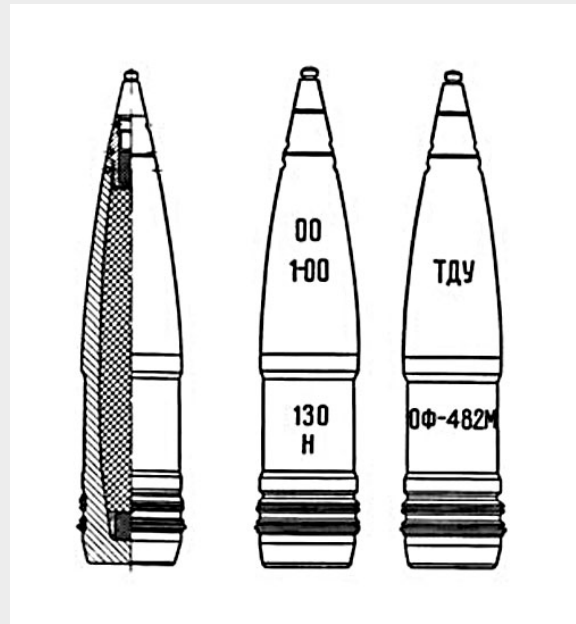
DESCRIPTION

The OF 472 is a Russian 122 mm artillery projectile with a steel-cased HE warhead that is normally filled with TNT. The OF 482 is similar in design, but has a calibre of 130 mm. In Russian designation, the letters "OF" indicate that the projectile has a combined blast and fragmentation effect. Various point-detonation mechanical nose fuzes can be fitted.

Two recovered (unexploded) OF 472 projectiles were examined, along with two unfired OF 482 projectiles.



OF 472 122 mm projectile



OF 482 130 mm projectile



OBSERVATIONS

APPEARANCE



As with the M107, the absence of the driving band on the right-hand projectile makes it harder to determine whether the projectile has been fired



Markings, showing the designation and filling, are still just visible on the projectile surface that was lying uppermost. These would soon be lost with continued ageing

CASING



Rusting has made little impression on the thick steel casing, although water may still enter via the fuze well



Impact has bent the casing of projectile #6, crushing the filling and allowing water to permeate throughout

MAIN CHARGE



The main charge of cast TNT is slightly porous, and has allowed some water ingress over a prolonged period



The crushed and discoloured filling of projectile #6; it is not known whether this would affect its performance

OTHER OBSERVATIONS



A section through the base of a 130 mm OF 482 projectile showing (left, from the outside moving inwards) the copper driving band, the thick steel casing of the base section and the lower extremity of the main charge, with embedded aluminium-based incendiary pellet

This section, once again, demonstrates the utility of cutting in order to visualise components, and their relationship to one another. For example, diagrams - or even X-rays - might not reveal that the incendiary pellet is often off-centre.

ANNEX D: 160 MM F-853U MORTAR

DESCRIPTION

The F-853U is a Russian 160 mm mortar bomb with a distinctive tear-drop shaped body. The HE warhead is made from steel and normally filled with TNT. In Russian designation, the letter “F” indicates that the mortar bomb primarily has a blast effect, although the steel casing will inevitably produce fragmentation as well.

The mortar bomb examined (allocated #12 during exploitation) was fitted with a point-detonating mechanical nose fuze, which appeared to be in relatively good condition. The tail fin assembly was missing.

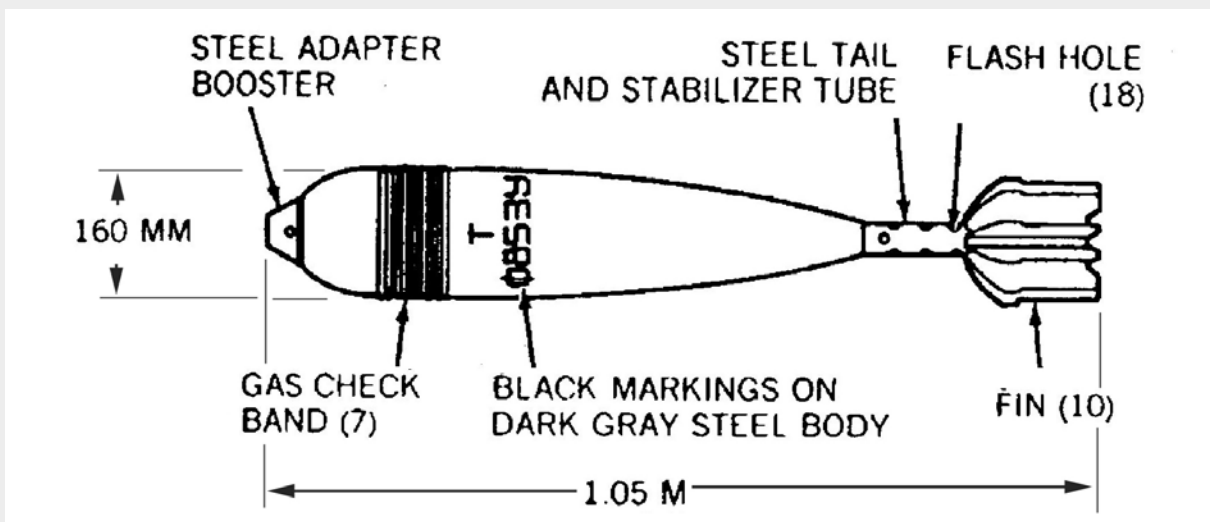


Diagram of the F-853U



The F-853U mortar bomb presented for cutting. The body shape is distinctive enough to allow for identification despite the absence of the tail assembly; however, the missing tail makes it harder to establish whether the mortar bomb was unfired or unexploded

OBSERVATIONS

APPEARANCE

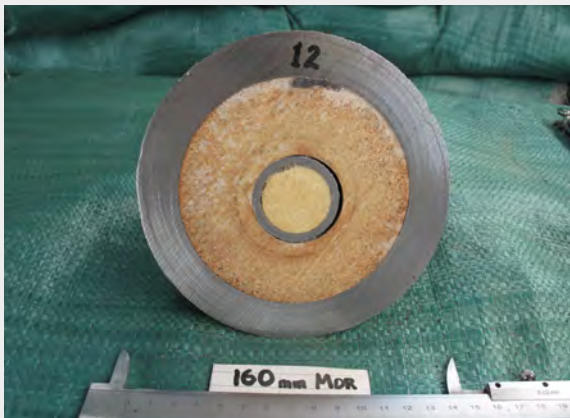


Despite the presence of caked-on mud, the body of the mortar bomb was in relatively good condition. No markings were visible



Most of the fuze was present, but damage would almost certainly have permitted water to enter. The fuze was not cut, so no internal analysis could be made

CASING



The steel casing was in good condition and showed only superficial corrosion



The booster cup, which is also made from steel, showed remarkably little corrosion

MAIN CHARGE



The main charge (cast TNT) and the booster were in good condition



There was no evidence of water ingress at this cut point, and no corrosion visible on the inside of the casing

ANNEX E: MK 80 SERIES BOMBS

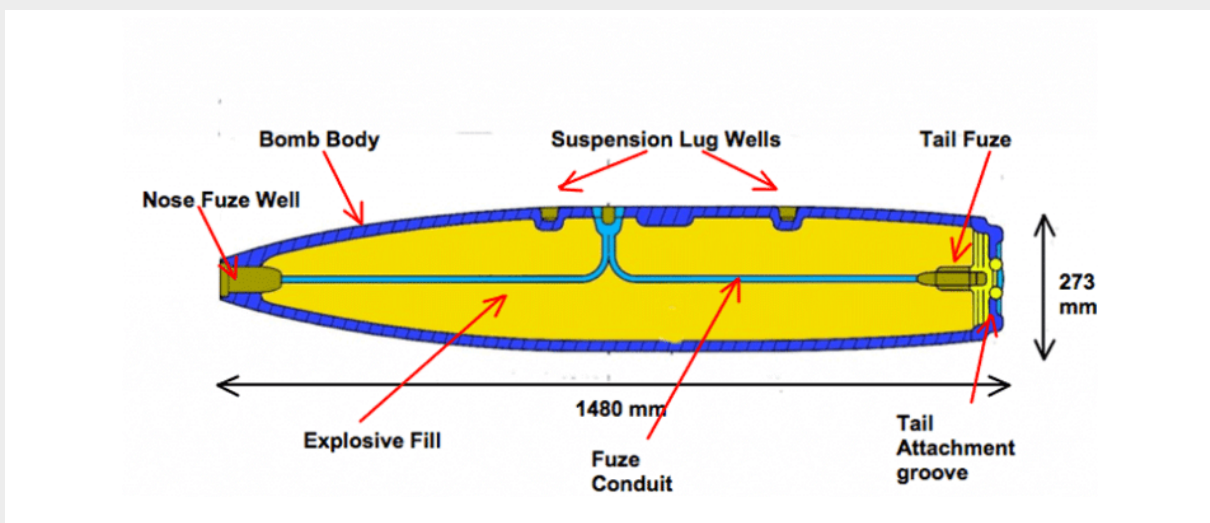
DESCRIPTION

The US Mk 80 series are general-purpose low-drag aircraft bombs. They have steel casings designed to offer a good compromise between blast and fragmentation. There are four bombs in the series: Mk 81, Mk 82, Mk 83 and Mk 84, with nominal weights of: 250, 500, 1,000 and 2,000 lb (approximately 114, 227, 454 and 909 kg) respectively.

The bombs are modular, accepting a range of fuzes and tail units depending on the intended role. Tails include fixed conical units, folding fins from the "Snakeye" series, parachutes, and air-inflatable retarders (AIR) sometimes known as "ballutes". The bombs have fuze wells in the nose and tail, and a charging well positioned on the top surface between the two suspension lugs. Two conduits run through the bomb, connecting the charging well to the nose and tail fuze wells. Suspension lugs on the Mk 81, 82 and 83 are 356 mm (14 inches) apart, while those on the Mk 84 are 762 mm (30 inches) apart; most bombs also have a lifting lug well between the suspension lugs.

The bombs can accept a wide variety of fuzes, though most of those used in Vietnam were mechanical impact types. Some fuzes are specifically for use in either the nose or tail, while other fuzes can be used in either or both. For example, among the most common types, the M904 impact fuze is used in the nose, while the M905 impact fuze is used in the tail.

During the mission, cuts were made on two Mk 82 (500 lb) bombs and one Mk 84 (2,000 lb) bomb; each of these incorporated an M904 impact nose fuze, but no tail fuze. Due to limitations of time and equipment, none of the fuzes were cut and only a superficial examination was made of each nose section.



Section through the US Mk 82 GP bomb.
All of the Mk 80 series bombs share a similar structure



The appearance of typical nose-fuzed Mk 82 bombs before deployment

OBSERVATIONS

APPEARANCE



The Mk 84 bomb, along with two Mk 82 bombs, being delivered to the site. All of the bombs were fitted with an M904 nose fuze and no tail fuze. Tail assemblies were missing, as is often the case; these tend to become detached as the bomb enters the ground

CASING AND MAIN FILLING



Cutting the nose section, complete with fuze, of an Mk 82 bomb. While most Mk 80 series bombs found in Vietnam will have a superficial layer of rust, the thick steel casing is unlikely to be penetrated for many years to come



As expected, the explosive filling of the Mk 82 and Mk 84 bombs remained in good condition, protected by the thick steel casing. The explosive is likely to remain viable as long as the casing remains intact

ANNEX F: GOLDEN WEST REPORT

From 3-7 December 2018, Golden West Humanitarian Foundation (GWHF) personnel provided technical support for the management of residual ERW (MORE) programme sponsored by the GICHD. The planning of this operation was provided by the GICHD, Senior Colonel Tuan (retired), and Major Penh (VNMAC and former BOMICEN explosive ordnance disposal (EOD) technician) with the mobile cutting system (MCS) provided by BOMICEN (purchased through the US State Department WRA), along with 6 BOMICEN EOD personnel (to operate the MCS and handle the munitions to be processed) and 6 Quang Tri province Provincial Military Command sappers (to set up the site, operate the 2 trucks, generators and provide security). Colin King, Fenix Technical Director, was there to exploit the cut munitions. A vehicle was provided by Golden West.

On Monday 3 December NPA range located in Quang Tri province near the coast was visited.

The site was established at the NPA range which had all the necessary safety distances. VNMAC, together with the local PMC, had created sandbag emplacements for the MCS, a safety bunker, along with other sandbagged emplacements for other activities and storage of munitions. The MCS was tested and found to be in fine working condition. The munitions scheduled for processing the day after were presented:

- 2 x USSR OF 482 130 mm (filled with 3.6 kg of TNT) unfired projectiles
- 2 x USSR OF 472 122 mm (filled with 3 kg of TNT) unfired projectiles
- 2 x US M107 155 mm (filled with 6.62 kg of TNT) projectiles, both which had been fired, one was missing the nose fuze, while the other had a damaged M48 PD fuze
- 8 x US M374 series 81 mm (filled with 1 kg of Composition B) mortars; the US M374 mortars included those with no fuze, 2 x M524 PD fuzes, 1 x M525 PD fuze, and 1 x M519 PD fuze





The dirt road initially used was made serviceable due to the trucks going to and from the site during the set-up operation, whilst we walked 2 km to the site; another route, although a bit longer, was found for the following few days.



The mobile cutting system was set up in a sandbagged bunker area with the hoist and generator. The Wi-Fi camera system was very unreliable so another camera system with hardwire and LCD screen will be bought, as a replacement. This will be presented to VNMAC (estimated cost is US\$ 200).



View of the cutting area and overall drone view of the range. VNMAC, BOMICEN and PMC sappers did an excellent job of following safety distances and having the site set up prior to our arrival

On Tuesday 4 December, we were able to process all of the 8 x 81 mm mortars, 2 x 155 mm projectiles, 1 x 130 mm projectile, and the 1 x 122 mm projectile. We made 3 cuts each on the US M374 fuzes, as well as a cross-section cut on an M525 PD fuze, and a base cut of the USSR OF 482 130 mm showing the TCU located in the base of the projectile. Both of the US M107 155 mm projectiles were cut 3 times, exposing the booster cups and Composition B filler.



View of the 8 x US M374 81 mm mortars prior to cutting



Before and after a cut of the M374 81 mm mortar



Views of the cut of the US M525 PD fuze and the booster cup section of the M374 81 mm mortar; note the damage and expansion due to corrosion of the aluminum of the fuze



The base cut of the OF 482M 130 mm projectile showing the TCU incendiary plug embedded within the TNT filler. Also pictured is the M107 155 mm projectile with the cut at the booster cup and its HE filler



Drone view of the cutting of the M107 155 mm projectile; image on the right shows the result of the cut of the M48 series PD fuze that was on the fired M107 155 mm projectile

On Wednesday 5 December, we received from the Quang Tri PMC, 2 x US Mk 82 500 lb bombs, 1 x USSR F-853U 160 mm mortar, and 2 x USSR OF 472 122 mm projectiles. We were able to cut all the items and conducted a burnout of the 2 x US Mk 82 500 lb bombs.



Cutting of the USSR F-853U 160 mm mortar with the GVMZ-7 PD fuze



Hoisting the Mk 82 500 lb bomb onto the MCS, a single 1-ton hoist with chain was used



Hoisting and setting in place the Mk 82 500 lb bomb for cutting; note the use of the bomb cradle to help support the bomb as well as keeping the hoist cables connected while cutting. Each of the Mk 82 500 lb bombs had a crushed M904 PD fuze and there was no tail fuze in either one. We cut between 20 cm and 25 cm so that the booster cup was not cut through and still allowed us to make the cut large enough for the burnout process



Drone view of the cutting of the Mk 82 500 lb bomb; image on the right shows the cut nose section. The cut took 12 minutes



Removing the two pieces of the Mk 82 500 lb bomb after the cut

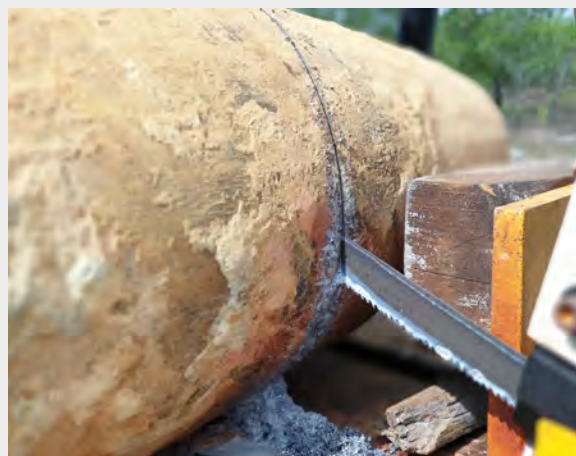


Burning out the main bodies of the 2 x Mk 82 500 lb bombs; the burnout lasted 22 minutes

On Thursday 6 December, the PMC brought out the Mk 84 2,000 lb bomb which had an M904 series PD fuze but no tail fuze. A cut was successfully made, the nose fuze section was separated from the main body, and a burnout process on both the body and the nose fuze was achieved (and destroying the M904).



Prepping the Mk 84 2,000 lb bomb for cutting; note the use of 2 x 1-ton chain hoists and a table with sandbags to hold the bomb in place. It was important to make the bomb stable even when finished with the cut, so that it would not damage the cutter by moving or pinching the blade.



Front view of the cutting of the Mk 84. It was important to keep the bomb straight and as even as possible so as not to damage the cutter or the blade; image on the right shows the cutting blade with the metal lubricant evenly distributed throughout the length of the blade while cutting; the cut took 50 minutes due to the 22 mm thickness, and the slow drop and blade speed settings that we used for the cut.



Wooden blocks were used to help hold the nose in place with the cutter clamps, as well as changing the angle of the clamps to help hold the nose steady; image on the right shows the body being slowly removed from the cutter after the successful cut



Drone and GoPro footage of the cut was taken



After the cut, the Mk 84 2,000 lb bomb was burned out along with the nose section containing the fuze; the Mk 84 bomb contains 429 kg of either Tritonal or H6 filler (this particular bomb contained Tritonal) and it took 40 minutes to burn out; the nose fuze detonated as required during the burnout. The image on the right shows the intense heat on the inside of the bomb casing even after the burn; note the bomb section that was cut off, containing the M904 nose fuze which was destroyed during the burnout process, to the right of the body.



Conclusion: we successfully cut and burned out all of the following items:

- 8 x US M374 81 mm mortars
- 2 x US M107 155 mm projectiles
- 2 x USSR OF 472 122 mm projectiles
- 2 x USSR OF 482 130 mm projectiles
- 1 x USSR F-853U 160 mm mortar
- 2 x US Mk 82 500 lb bombs
- 1 x US Mk 84 2,000 lb bomb

All of these items were destroyed using the cut and burnout process and did not require any demolition operations, which are a cause of concern for local residents due to the extreme noise and danger of fragments from detonations. The resulting burned out casings can also be used as training aids when welded together. The MCS is an economical and safe process to destroy munitions.

ANNEX G: ASSESSING QUALITY OF EXPLOSION SAMPLES FROM UXO

SAMPLES AND CHARACTERISTICS

NO	NAME OF SAMPLE	SYMBOL	AMOUNT	CHARACTERISTICS
1	TNT explosive from 155mm projectile	Ph155	1	Dark yellow
2	TNT explosive from 155mm projectile	Ph155 pitted	01	Dark yellow, with many small holes
3	TNT explosive from 160mm mortar	Co 160	01	Light yellow
4	Comp H6 explosives from bomb MK-82	Comp-H6	01	Gray
5	Tetryl explosive from the 155mm exploitation station fuse	Tetryl Ph155	01	Yellow
6	Tetryl explosives from the mortar explosion station fuse 160mm	Tetryl Co 160	01	Yellow

METHOD AND TESTING EQUIPMENT

Conduct experiments to determine the quality criteria of explosives according to standardized methods, specifically:

- Determination of moisture content, insoluble matter in acetone, RDX, TNT, Wax, oil rust by analytical methods.
- Determination of melting temperature on SP-10 and DSC Diamond devices (Figure 1), sample volume of about 20 mg, measuring accuracy to 0.1°C.



Figure 1. Differential calorimeter scanning device DSC Diamond (USA).

- Determination of the burning temperature on DT-400 device (Figure 2), capable of heating to 400°C with accuracy of 0.10°C. Install SP1 temperature (start measurement) and SP2 (end of measurement) so that the explosive temperature of the explosion is between SP1 and SP2 and higher than SP1 by about 250°C, heating speed of 5°C / min. The weight of each sample is about 0,15 g, the sample is contained in a heat-resistant glass test tube.



Figure 2. Flammable (burning) temperature determination device DT-400 (Germany).

- Determination of vacuum heat resistance on the Stabil Vacuum tester (Figure 3) at 100°C continuously for 48 hours, the sample volume per test is about 2gr



Figure 3. Vacuum stability tester (Czech) determines chemical stability under vacuum thermal stabilization method:

- Picture above: control unit of heating mode and computer;

- Picture below: heating block and test tubes containing sample + pressure sensor.

- Measurement of lead cylinder compression by standard lead tools and cylinders (Figure 4), explosive dose is made in cylindrical ingot shape with diameter of 40 mm with density of 1.0 g/cm³, compressed in paper tube create detonator holes, the volume of each explosive dose of 50g, use the No. 8 electric detonator to detonate.



Figure 4. Sample explosion, lead cylinder compression measurement.

- Determination of the ability to explosion energy by the articulation pendulum (Figure 5), the explosive dose is produced in the form of cylindrical ingot 30 mm in diameter with a density of 1.0 g/cm^3 , compressed in the paper tube to create a hole of a checker. The mass of each explosive dose is 10 g, detonating the explosive dose with electric detonator No. 8.



Figure 5. Determination of the ability to explosion energy with the articulation pendulum.

- Determination of impact sensitivity on Cast hammer (Figure 6) under standard conditions (mass of 10 kg hammer, 25 cm drop height), sample weight per test of 0.05 g; Each sample carried out 25 experiments.

After dropping the hammer, the sample is considered to explode when one of the following phenomena occurs: sound, flame, smoke, pattern discolouration.

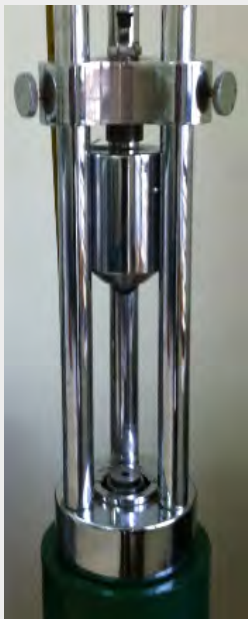


Figure 6. Equipment for determining the impact sensitivity - Cast hammer (Russia).

TEST RESULTS

1. TNT EXPLOSIVE SAMPLES FROM THE 155MM ARTILLERY SHELL (TNT PH155), TNT FROM THE 155MM ARTILLERY SHELL (TNT PH155 PITTED) AND TNT FROM 160MM MORTAR (TNT CO160)

NO	CRITERIA	TNT PH155	TNT PH155 PITTED	TNT Co160	TCVN/QS 596:2018	MIL-DTL-248D
1	Melting temperature, °C	79.5	79.0	80.0	≥ 80.20	≥ 80.20
2	Content insoluble in acetone,%	0.07	0.08	0.05	≤ 0.1	≤ 0.05
3	Oil leakage, point	5% point 5	5% point 5	5% point 5	≥ 3	-
4	Burning temperature, °C	297.3	288.8	300.8	-	-
5	Vacuum heat resistance (VTS) at 100°C and 48 hrs, cm ³ /g	0.190	0.134	0.103	-	≤ 2.00
6	Lead cylinder compression, mm	15.8	16	16.1	≥ 15.5	-
7	Ability to exploitation energy, % TNT	98.4	102.3	100	100	-
8	Impact sensitivity,%	12	12	8	≤ 8	-

Comment:

1. **Melting temperature:** The melting temperature of 03 TNT samples is lower than that of TNT level 1 (according to TCVN / QS 596: 2018) and the standard MIL-DTL-248D, proving that all TNT samples have been degraded.
2. **Content of insoluble substance in acetone:** The content of acetone insoluble substance of TNT samples meets the requirements of TCVN / QS 596: 2018, but does not meet the requirements of MIL-DTL-248D (lying value between MIL-DTL-248D and TCVN / QS 596: 2018).
3. **Oil leakage:** Oil leakage of 03 TNT samples is satisfactory for level 1 TNT according to TCVN / QS 596: 2018.
4. **Burning temperature:** The flaming temperature of the pitting TNT sample taken from the 155 mm (288.8 °C) artillery shell is much lower than the TNT sample taken from the 155 mm artillery shell (297.3 °C) and TNT taken from a 160 mm mortar (300.8 °C). This is a demonstration of the impact of environmental conditions on the quality of explosives in bombs and projectiles.
5. **Vacuum heat resistance:** Vacuum heat resistance of all 03 TNT samples is much higher than the standard MIL-DTL-248D stipulating safe storage of explosives (less than 2.0 cm³/g), proving that the above TNT explosive samples have high thermal stability, still very good quality, capable of safe storage.
- 6/7. **Lead block (Trauzl) test and pendulum test:** Results from both of these tests, for all three TNT samples, meet the requirements of TCVN / QS 596: 2018. This confirms that the energy and destructive power of these samples are the same as for newly-produced TNT, reflecting the quality and characteristics of the explosive. The differences in the pendulum test results are partly due to the inherent errors involved with this method.
8. **Impact sensitivity:** The impact sensitivity of two samples TNT taken from 155mm artillery shell does not meet the requirements of TCVN / QS 596: 2018, which partly reflects the trend of increasing risk of unsafe explosion when subject to impact impulse. With the sample TNT taken from the 160mm mortar warhead, the impact sensitivity is satisfactory according to TCVN / QS 596: 2018, but this value is in the upper limit compared to the requirement.

2. TETRYL EXPLOSIVE SAMPLES FROM THE 155MM ARTILLERY EXPLOSION STATION (TETRYL PH155) AND FROM THE 160MM MORTAR EXPLOSION STATION (TETRYL CO160)

NO	CRITERIA	TETRYL CO160	TETRYL PH155	TCOS -VN	MIL-T-339C
1	Melting temperature, °C	128.5	129.0	128.8 ÷ 129.5	128.8 ÷ 129.5
2	Content insoluble in acetone, %	0.07	0.09	-	≤ 0.1
3	Burning temperature, °C	181.7	184.3	-	-
4	Vacuum heat resistance (VTS) at 100 °C and 48 h, cm ³ /g	0.131	0.091	≤ 1.20	≤ 2.00
5	Lead cylinder compression, mm	18.2	-	-	-
6	Ability to explosion energy, % TNT	123	-	-	-
7	Impact sensitivity, %	52	48	50 ÷ 60	-

Comment:

- Melting temperature:** The melting temperature of Tetryl samples taken from the mortar explosion station 160mm does not meet the requirements of MIL-T-339C (US), which proves that the quality of Tetryl samples has been reduced. The melting temperature of the Tetryl sample comes from the 155mm artillery blast station that meets US standards.
- The insoluble substance in acetone:** The insoluble substance content of acetone of Tetryl samples meets the requirements of MIL-T-339C.
- Burning temperature:** The burning temperature of the Tetryl sample from the mortar explosion station is 160 mm (181.7 ° C) lower than that of the Tetryl model from the 155mm gun firing station (184.3 ° C), this proves that the heat stability of Tetryl was higher from the 155 mm shell bullet station.
- Vacuum heat resistance:** Vacuum heat resistance of both 02 Tetryl samples is much higher than TCQS and standard MIL-DTL-248D (less than 2.0 cm³/g), proving Tetryl samples All have high thermal stability, still very good quality, capable of safe storage.
- 5/6. Compaction of lead pillars and potential explosive energy:** These characteristics reach the equivalent value according to the tests for newly produced Tetryl.
- Impact sensitivity:** The impact sensitivity of both Tetryl samples meet the Vietnamese standards.

3. COMP-H6 EXPLOSIVE SAMPLE IN MK 82 BOMB

NO	CRITERIA	RESULTS OF TEST	MIL-E-22267A
1	Content RDX, %	-	45.1 ± 3.0
2	Content TNT, %	31.4	29.2 ± 3.0
3	Content Al, %	19.7	21.0 ± 3.0
4	Content Wax, %	-	4.7 ± 1.0
5	Moisture content, %	0.4	≤ 0.2
7	Burning temperature, °C	2078	-
8	Vacuum heat resistance (VTS) at 100 °C and 48 h, cm ³ /g	0.507	≤ 2.00
9	Lead cylinder compression, mm	21.3	-
10	Ability to exploitation energy, % TNT	1372	-
11	Impact sensitivity, %	36	-

Comment:

- 1-4. **Composition criteria:** Comp-H6 sample component still meets the requirements of MIL-E-22267A (USA).
- 5. **Moisture content:** unsatisfactory moisture content criteria according to standard MIL-E-22267A. This may be due to the influence of environmental conditions.
- 7. **Burning temperature:** equivalent in value to published research materials.
- 8. **Vacuum thermal stability:** Vacuum thermal stability of Comp-H6 explosives meets the standards.
- 9/10. **Compaction of lead pillars and potential explosive energy:** equivalent value compared with published research documents.
- 11. **Impact sensitivity:** The impact sensitivity of Comp-H6 explosive is relatively high. This is the point to note when there are mechanical impacts on this explosive.

GENERAL EVALUATION REVIEW OF THE LAB

- Explosive samples have appeared unsatisfactory compared with Vietnamese standards and US military standards.
- The strength of explosive samples still meets the requirements compared with the new explosives produced. Demonstrate that the destructive power of these explosive samples is still nearly as strong as the new compositions.
- The impact sensitivity of some explosive samples tends to be slightly higher than required. This needs to be taken into account in the course of working with bombs and mines left behind in the war.

RECOMMENDATIONS AND HINTS

The indicators identified above are not sufficient to predict the trend of changing the quality of the samples contained in bombs, bullets left after the war. Therefore, additional analyzes and aging studies are needed in order to have more comprehensive information and can predict the duration of explosives to ensure safety during storage.

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Pages 49-52: The Vietnamese Institute of Propellants

Published with the generous support of:



The U.S. Department of
State's Office of Weapons
Removal and Abatement



Australian Government
Department of Foreign Affairs and Trade

Australia, Department of
Foreign Affairs and Trade



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