

Level 4 Ordnance, Munitions and Explosives Technician

Knowledge Test Study Guide

for Apprentices



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1. **My Level 4 Ordnance, Munitions and Explosives Technician Apprenticeship**

The Ordnance, Munitions and Explosives (OME) Technician Apprenticeship, is for someone who will contribute to preparing and setting up an OME processing area and equipment, OME inventory activities, undertaking inspection of OME to determine serviceability, preparing OME for processing and storage tasks in line with instructions and operating procedures and the design and operation of OME by preparing explosive compositions and devices for a variety of reasons, including testing and evaluating, storing, processing and disposal. As such, they can support other technical experts in chemical science working with volatile materials, manage and conduct tasks in a laboratory, workshop or storage facility, assess risks and make considered judgements on the performance and characteristics of explosives as well as undertaking activities to award free from explosive (FFE) certification. In doing so, they must work in a safe and environmentally sound manner, potentially within a hazardous environment, following approved safe systems of work.

It will typically take up to 18 months to complete the apprenticeship, although the exact duration will be dependent on your previous experience.

This apprenticeship has been designed to provide access to development opportunities for as wide a range of individuals as possible. This includes individuals who are at the start of their career in OME and who wish to take their first steps into professional design and development of explosive substances and articles. It is also appropriate for those already in roles who may already have developed practical experience but who wish to develop their theoretical understanding of explosive materials, development and testing processes and safety. At the start of their learning, apprentices may choose to register as a Student Member of the Institute of Explosives Engineers with the opportunity to change their status to that of a Technical Member of the Institute of Explosive Engineers (TIEpE) on completion of the qualification, to support their professional career development and progression.

Each training provider has developed its own apprenticeship programme and has mapped it to the outcomes required in the standard.

The complete apprenticeship standard is available here:

<https://www.instituteforapprenticeships.org/apprenticeship-standards/ordnance-munitions-explosives-technician-v1-0>

2. End-Point Assessment

In order to award the qualification you will be required to prove your competence in a number of ways. This provides you with opportunities to demonstrate your competence across the whole range of outcomes and is designed to be fair in its approach by matching the assessment style with the realities of using your new knowledge, skills and behaviours in the workplace.

The assessment approach is critical, being robust, challenging and testing, and will ensure that apprentices meet the knowledge, skills and behaviour outcomes as defined in the Standard¹, whichever Training Provider is delivering the Apprenticeship, and whichever Independent Assessment Organisation undertakes the End Point Assessment.

The End Point Assessment will test the entire Standard, and be undertaken as follows:

- assessment of knowledge through a test using scenarios, questions and responses
- assessment of practical competency through observation of performance
- assessment of competency through competency based interview
- assessment of portfolio of evidence
- continuing Professional Development Log reviewed and professional discussion/question and answer session²

Your line manager will decide when you are ready to be assessed at each stage based on your demonstrated knowledge and performance in your workplace but you will be able to prepare for the assessments using this study guide at any time.

¹Institute for Apprenticeships and Technical Education / Ordnance, Munitions and Explosives Technician / Standard ST0833 Dated 02/12/20

²The Ordnance, Munitions and Explosives Technician Apprenticeship Assessment Plan ST0384/AP02 Revised 24/10/17

3. About my end-point assessment knowledge test

The knowledge test is the first stage in the process of end point assessment once you have conducted the required On-Programme Assessment and been judged as suitable to progress at the Gateway to End Point Assessment. The test focuses on the underpinning knowledge of commonly used basic theories and methodologies that you will require to perform effectively in your role based on accepted industry norms.

The 40 multiple-choice questions will be made up of:

- 30 multiple-choice questions that should have 4 options of which 1 will be correct.
- 10 multiple-choice questions which will be based on two given scenarios, 5 questions will be asked per scenario which will still require the apprentice to select 1 option from a choice of 4. These questions ensure the apprentice can demonstrate that they can identify which knowledge or learning is appropriate for the given situation. The given scenario will be up to 150 words long based on a true to life OME scenario. For example, the scenario testing K15 might summarise a quality management system, with the 5 multiple-choice questions asking respondents to identify key activities required in these throughout the OME lifecycle. For K9 the scenario may describe the principles that underpin OME with the 5 multi-choice questions based on the concepts and components for a given explosive effect.

4. Marking / Grading

Your knowledge test will be marked by a single assessor, with significant occupational and teaching experience of leadership and management, and who is qualified to level 5 (or equivalent). The assessments are weighted equally in their contribution to the overall grade.

Assessment method 1 (Practical demonstration)	Assessment method 2 (Interview)	Assessment method 3 (Knowledge test)	Overall grading
Pass	Fail	Fail	Fail
Fail	Fail	Pass	Fail
Fail	Pass	Fail	Fail
Pass	Pass	Pass	Pass
Distinction	Pass	Pass	Pass
Pass	Distinction	Pass	Pass
Pass	Pass	Distinction	Pass
Distinction	Distinction	Pass	Pass
Pass	Distinction	Distinction	Pass
Distinction	Pass	Distinction	Pass
Distinction	Distinction	Distinction	Distinction

Table 1. Overall EPA grading. Source: The Ordnance, Munitions and Explosives Technician Apprenticeship Assessment Plan

End-Point Assessment Evidence	Maximum Mark	Minimum Pass Mark	Distinction
Knowledge Test	40	20	32

Table 2. EPA marking. Source: The Ordnance, Munitions and Explosives Technician Apprenticeship Assessment Plan

5. How to use this study guide

This study guide is based primarily on the Health and Safety executive (HSE) Explosive Regulations 2014, the overarching legislation and best practice guide for all matters relating to working with explosives in the civilian sector, and the Defence Safety Authority's DSA 03.OME Part 2 which supersedes Joint Service Publication (JSP) 482, the Defence Code of practice for In-Service and Operational Safety management of OME. This guide also contains extracts from appropriate technical papers, articles, websites and industry journals and there are links to the National Occupational Standards (NOS) finder website that provide an excellent source of basic principles relating to working with OME.

This guide has been written to mirror the functional areas specified in the apprenticeship standard. They are presented in the same sequence as the standard in order to facilitate your study and to help you keep track of what you have done at any point in your learning journey. Not all functional areas required for the qualification are covered in this guide as much of the knowledge you require and especially the practical application of it, is best gained in the workplace so we have not covered all of in this guide. As your End Point Assessors it is our duty to ensure that you are sufficiently prepared through your own study to attempt the assessments and that is how you should use this guide.

Each section begins with a short summary of the subject and then presents a range of popular or widely accepted models or theories on each area, with explanations or references to legislation, policies or authority documents. Suggested reading, mostly links to websites or articles are provided at the end of each section to allow you to look deeper into each subject and find the method of explanation and depth that suits your own preference.

5. To make sure you are studying all the required topics you should check the Learning Outcomes and Assessment Criteria that your training provider uses, by referring to the qualification specification document (it may be called a guide or syllabus). The document will state not only the Learning Outcomes and Assessment Criteria but add detail to assist your studies. If you have not yet seen this document you should request it from your training provider. If there are no Learning Outcomes you should refer to the Knowledge, Skills and Behaviours (KSB) specified in the Apprenticeship Standard. The complete apprenticeship standard is available here:

<https://www.instituteforapprenticeships.org/apprenticeship-standards/ordnance-munitions-explosives-technician-v1-0>

The document is a guide only; it is designed to assist you in your study by introducing the subjects and signposting you to useful sources of information. The information in it represents the basic underpinning knowledge and a start point for the research you will require not only to pass the assessments but more importantly, to work as an OME technician, and you should conduct as much research as possible based on the signposting provided by this guide. You can choose to follow all the suggested links and others that will become apparent during your research and gain a broad view of the subject area, or focus on particular areas, but you must remember to study what the Assessment Criteria or KSBs suggest will be in the assessment. Links to the three main authority references are below but there are links to the relevant sections in the appropriate sections of this guide.

HSE: <https://www.hse.gov.uk/explosives/index.htm>

DSA: <https://www.gov.uk/government/publications/dsa03-ome-part-2-in-service-and-operational-safety-management-of-ome>

NOS: <https://www.ukstandards.org.uk/NOS-Finder#k=explosive%20substances%20and%20articles>

6. What knowledge requirements will be in the knowledge test?

The apprenticeship standard sets out 15 functional areas that must be taught. These have been developed as the Learning Outcomes for the purposes of designing training to meet your learning needs, as mentioned above. The Learning Outcomes for the whole qualification are designed to cover the functional areas shown in Table 3 below:

K1	To set up, conduct, shut down and supervise OME processes in accordance with relevant H&S, environmental and explosives regulations Such as, Explosives Regulation 2014 and JSP482.
K2	The health, safety and environmental and other statutory legislation, regulations and safe working practices and procedures governing OME, such as, Risk assessments, HAZID, hazard logs, hazard reviews, ALARP principles, safety cases and their implications for the area of work.
K3	The fundamentals of protective equipment and clothing, safe handling, movement and use of OME, encompassing hazard divisions, hazard types, compatibility groups, mixing rules and fire divisions.
K4	The basic concepts and theory of OME engineering/material science, including the chemical properties of explosives, abnormal stimulus, compatibility testing, hazard testing, risk assessment and engineering controls.
K5	The principles and differences of coaching and mentoring including how to conduct the chosen option.
K6	The principles of Continuing Professional Development (CPD) and how the National Occupational Standards (NOS) can determine required CPD interventions.
K7	The limits of individual responsibility and knowledge as well as that of the team and where to seek advice when required.
K8	The processes for assessing, analysing and interpreting technical information to determine the serviceability of the OME products or plant such as: recognising signs of damage and deterioration and propose solutions in order for safe actions to be taken.
K9	The principles underpinning OME concepts and components for a given explosive effect including knowledge of initiators, initiation systems, explosive trains, explosive substances and articles.

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K10	The range and choice of resources, equipment and materials used within OME processes and their application and constraints.
K11	The principles of explosives classification, OME inventory activities and licensing requirements, conditions and restrictions.
K12	The principles related to the safe preparation of ordnance munitions and explosives for specified tasks.
K13	OME disposal processes, including associated environmental factors and regulation.
K14	The process for ensuring the workplace is safe and free from explosive hazards.
K15	The requirements of a Quality Management System and the key activities required by this (such as inspection and QA regimes) throughout the OME lifecycle.

Table 3. Level 3 Ordnance, Munitions and Explosives Technician apprenticeship knowledge requirements.

Not all the functional areas are tested in the knowledge test. The functional areas that are covered in the knowledge test are shown in the table 4 below:

K3	The fundamentals of protective equipment and clothing, safe handling, movement and use of OME, encompassing hazard divisions, hazard types, compatibility groups, mixing rules and fire divisions.
K4	The basic concepts and theory of OME engineering/material science, including the chemical properties of explosives, abnormal stimulus, compatibility testing, hazard testing, risk assessment and engineering controls.
K9	The principles underpinning OME concepts and components for a given explosive effect including knowledge of initiators, initiation systems, explosive trains, explosive substances and articles.
K11	The principles of explosives classification, OME inventory activities and licensing requirements, conditions and restrictions.
K12	The principles related to the safe preparation of ordnance munitions and explosives for specified tasks.
K15	The requirements of a Quality Management System and the key activities required by this (such as inspection and QA regimes) throughout the OME lifecycle.

Table 4. Level 3 Ordnance, Munitions and Explosives Technician apprenticeship knowledge exam functional areas³.

³The Ordnance, Munitions and Explosives Technician Apprenticeship Assessment Plan ST0384/AP02 Revised 24/10/17

6.1 Explosive engineering and material science

Knowledge criteria: K4. The basic concepts and theory of OME engineering/material science, including the chemical properties of explosives, abnormal stimulus, compatibility testing, hazard testing, risk assessment and engineering controls.

6.1.1 Chemical properties of explosives

What is an explosive?

There are various definitions of what an explosive is, and they vary according to context and audience. According to the Explosive Regulations 2014, an explosive substance is a solid or liquid substance (or mixture of substances) which is in itself capable by chemical reaction of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings.

Pyrotechnic substances are included even when they do not evolve gases. A pyrotechnic substance is a substance or mixture of substances designed to produce an effect by heat, light, sound, gas or smoke or a combination of these as the result of non-detonative self-sustaining exothermic chemical reactions. All explosive substances are made up of an oxidant (is a substance that has the ability to oxidize other substances such as hydrogen peroxide) plus some kind of fuel.

An explosive article is an article containing an amount of one or more explosive substances such as a munition, actuating charges such as those in a vehicle passenger airbag, and detonators or 'blasting caps'.

NOTE: The word 'explosive' can have different meanings and interpretations. Reference to 'an explosive' or 'explosives' is commonly understood to mean substances or articles in Class 1 of the scheme of the UN Recommendations on the Transport of Dangerous Goods that is, those which are intentional explosives or have properties which when assessed under the test procedure of the Manual of Tests and Criteria place them in UN Class 1. The description 'explosive' can, however, be used to describe a property and as such it encompasses a wider range of substances than just those in UN Class 1. The Global Harmonized System (GHS) requires that classification is based on intrinsic properties and the word 'explosive' in that context can be used to describe the property of a substance i.e. its ability to explode, as well as referring to a substance or article that has been designed to have explosive

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properties. This can lead to confusion and difficulty but in the above definition 'explosive' refers to explosion hazard of substances and articles and is not limited to those which would be placed in Class 1 of the UN scheme⁴.



Suggested reading

<https://en.wikipedia.org/wiki/Explosive#:~:text=the%20carbon%20dioxide.-.Chemical%20composition,or%20grain%20dust%20and%20air>

<https://theconversation.com/five-of-the-most-explosive-non-nuclear-chemicals-ever-made-72702>

<https://www.ilo.org/legacy/english/protection/safework/ghs/ghsfinal/ghsc1528.pdf>

6.1.2 Characteristics of an explosion

Detonation

When an explosive substance functions it decomposes rapidly in a detonation; there is a rapid release of heat and rapidly expanding gasses that have sufficient force (pressure) to overcome confining forces such as rock, a container, the target or other items in their path. The energy released by the detonation produces four basic effects; fragmentation; displacement; ground vibration; and blast. The fragmentation caused is a result of the shattering effect or 'brisance' of an explosive event.

The blast wave can often be seen as a rapidly widening ripple in the air around the explosion site. When an explosion occurs there will be the initial 'positive' wave that starts at the centre of the explosive and travels outwards. The effect the wave has is determined by the speed at which it moves between or through any materials affected (known as propagation).

The explosive detonates at a speed according to the properties of its chemical composition. The detonation travels through the entire mass of the explosive material in a wave, the speed of which is known as the 'Velocity of Detonation'.

⁴United Nations International Labour Organisation, Globally Harmonized System for the Classification and Labelling of Chemicals (GHS), Section 15

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The greater the Velocity of Detonation, the greater the over-pressure created by the blast wave. This over-pressure results in a negative wave that then travels back towards the centre of the original explosion. The sudden rise in pressure, which creates the shock effect (blast wave) decreases with distance from the explosion centre. Eventually the blast wave decays to an acoustic wave traveling at the speed of sound in air (about 738 mph, 330 m/s) which is why observing an explosion usually results in a delay between seeing the 'flash' and hearing the 'bang'. The flash to bang time is entirely dependent on distance but is affected by external factors such as air humidity.

Deflagration

Low explosives can achieve their explosive effect without detonation. A process known as deflagration is created when the combustion zone of a rapidly burning fire propagates at a velocity that unlike a detonation, is slower than the speed of sound. However, the explosive effects are still powerful and are affected or increased by factors such as confinement that assist the build-up of pressure until it is sufficient to overcome the confining forces in the same way as a detonation.



Suggested reading

<https://onlinelibrary.wiley.com/doi/pdf/10.1002/9781118903117.app3#:~:text=The%20blast%20wave%20generated%20by,returns%20to%20its%20ambient%20value.&text=The%20shock%20pressure%20rise%2C%20Ps,distance%20from%20the%20explosion%20center>

6.1.3 Detonation of an explosive

Sensitivity

During production, storage, transport, and similar activities, explosives are frequently exposed to various external stimuli such as friction, impact, heat, etc. The ability of an explosive to react to these stimuli, resulting in either combustion or detonation, is defined as its sensitivity. This particular property of explosives might be a key factor in determining the practical applicability of a given explosive.

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Due to the complexity of the initiation phenomenon, there is no absolute indicator of the sensitivity as expressed, for instance, by the minimum initiation energy. The energy required for the initiation of an explosive depends not only on the chemical nature of the explosive and on a number of physical parameters, but also on the kind of initial stimulus and the nature of energy transfer to the explosive. Thus, the total amount of the initiation energy may vary considerably. It could be generally stated that an even distribution of externally applied energy through the whole explosive volume is not suitable for a successful initiation. A high concentration of energy in time and in explosive volume is the necessary precondition for a successful initiation. The energy required for the initiation of reactions of decomposition can be applied in the form of - thermal impulses (flame, spark, heating, etc.), mechanical impulses (impact, friction, projectile impact, etc.), shock wave, etc.

Classification of explosives

Some explosives detonate more easily than others. This is the basis of the classification into two types- high explosives and low explosives. High explosives can be divided further into primary and secondary explosives. This distinction can be made based on the fact that primary explosives can be detonated by a heat source such as a resistance bridge wire, while secondary explosives are those which will only detonate when in contact with, or close proximity to another exploding charge. However- it may be possible, given the right conditions for any explosive to detonate when subjected to a thermal source but conversely most explosives can also burn without detonation. Some high explosives are so sensitive that they do not need a booster charge but will react to the initiation on their own, these are known as 'detonator sensitive' explosives.

Sensitivity therefore refers to the ease with which an explosive can be initiated by design.

It may be possible to detonate an explosive accidentally by subjecting it to an energetic stimulus that creates the conditions required to cause detonation. This would be referred to as abnormal stimulus and is most commonly assumed to be caused by shock or impact- usually dropping, or by heat; due to friction or the creation of a hot-spot such as exposure to an electrical wire. It has been shown that the time between impact and detonation is faster than between creation of a hot-spot and detonation, due to the time required to create a hot-spot of sufficient intensity to cause detonation. Friction, Impact or shock usually causes unplanned detonation in solid explosives, whereas hot-spot induced detonation is more

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likely in gases or liquid explosives such as nitro-glycerine.

Sensitiveness therefore refers to the ease with which an explosive can be initiated by accident.



Suggested reading

<https://www.icheme.org/media/12121/xi-paper-12.pdf>

<https://pubs.acs.org/doi/abs/10.1021/cr60215a003>

https://link.springer.com/chapter/10.1007/978-1-4612-0797-9_2

<https://www.hse.gov.uk/comah/sragexp/srag-explosives.pdf>

<https://royalsocietypublishing.org/doi/10.1098/rspa.1948.0108>

Detonators

Detonators are devices that contain a few grams of explosive that are placed on, against, or into the main explosive charge (a blasting agent). The two most commonly used detonators are electric and non-electric or Igniferous, which we will explain here.

Non-electric Detonators

Non-electric, Igniferous or 'flash' detonators. In mining and demolition, high explosive charges are initiated by detonators in carefully timed sequences to minimize vibration and damage to surrounding structures and control rock breakage and throw or 'kick out'. Introduced in the 1860s, the first detonators were called blasting caps or caps (names still used synonymously with detonator). They were capsules of mercury fulminate which initiated a charge of nitro-glycerine. Mercury fulminate detonators were widely replaced due to their extreme sensitivity. Contemporary simple non-electric detonators contain a small quantity of primary explosive (often lead azide) which, once ignited by a fuse, ignites the more powerful base charge of a secondary explosive (an additional low explosive may be used between the fuse and the primary explosive).

6.1 Electric Detonators

A straightforward electric detonator contains a matchhead and a high resistance bridgewire buried in a low explosive. An electric current from an external power source heats the bridgewire which ignites the matchhead which in turn initiates the low explosive, which then initiates the primary explosive. Newer detonators use a faster-acting and lower energy-demanding semi-conductor bridge. Often another controlled volume of low explosive is placed between the matchhead and the primary charge. This burns for a specified period introducing a delay (from a few milliseconds to a few seconds) into the detonator. However, any low explosive delay device (syn. delay electric igniter) introduces imprecision because the chemicals are affected by moisture, temperature, and time. High precision delay electric detonators implant the matchhead directly into the primary explosive and control the delay with an integrated circuit within the detonator. Even more precise electric detonators use a capacitor to discharge an extremely strong current through a thin bridgewire embedded directly into the secondary explosive. The bridgewire is rapidly heated, evaporates, and explodes to initiate the charge. These also have the advantage of being extremely insensitive to all but strong electrical discharges, thus improving safety.

Electro-explosive device

An electric detonator is just one type of item that can function due to the input of electrical energy. This is done deliberately when detonation is required. However, other types of items are also susceptible to RF radiation, induced electromagnetic energy or electrostatic electricity as emitted by a mobile telephone, pager or powerful radio communication device. Any such vulnerable item is collectively referred to as an electro-explosive device or EED.

Explosive substance characteristics

Different types of explosives have different characteristics based on their chemical make-up and the environmental factors around them. It is important to understand the specific characteristics of any explosive substance you might be about to work with. Although some of the properties of the substances may be marked on the packaging you should conduct further research into some of the most common materials and their unique properties.

6.1

It is worth researching the following groups of explosives:

- **Metal powders** – Metal powders are commonly added to explosive formulations to modify the blast behaviour. Although velocity of detonation is typically reduced compared to the neat explosive, the metal provides other benefits. Aluminium powder, homogeneously distributed throughout the explosive material increases the overall energy output and high-density metals may enhance momentum transfer to a target. However- they pose a risk related to their production of hydrogen when in contact with water.
- **Phosphides** – substances including Phosphorus are hard, brittle, high-melting, and chemically inert. They usually have the appearance of a metal and have high thermal and electrical conductivities. Most significantly they will produce phosphine gas on contact with water.
- **Phosphorous** – specific risks including the spontaneous ignition of white phosphorous in air if not immersed in water.
- **Nitrates** – these act as oxidisers as they concentrate the amount of oxygen available to the explosive, increasing the power of the blast.
- **Azides** – when heated they decompose rapidly to produce large volumes of nitrogen gas.
- **Peroxides** – chemicals containing weak and unstable oxygen-oxygen bonds. This means they are very unstable and prone to spontaneous detonation.

6.1.4 Explosive compatibility

As with all highly energetic substances, explosives are not perfectly stable - their safety and functional features change during ageing. The extent of chemical instability strongly depends on the chemical structure of the explosive - aromatic and aliphatic nitro compounds, secondary nitramines, and organic azides are relatively stable, whereas aliphatic nitrate esters suffer from much lower stability. The rate of ageing of an explosive can be strongly accelerated by incompatibility reactions between the explosive and contact materials. Stability and compatibility of explosives can be investigated with numerous test methods.

6.1 Explosive Regulations 2014

The UK regulations state that chemicals and materials incompatible with the explosives used or with each other must be identified and either kept to the minimum necessary for the safe operation of the explosives facility, or completely segregated from the explosives.

The conditions for safely mixing explosives with incompatible materials should be known and controlled.

The nature of any incompatibilities will depend on the chemical interactions between different materials, but in general, explosives and propellants are often found to be incompatible with such substances as acids, alkalis, strong oxidising or reducing agents, sulphur, phosphorus and strong amines. Water and moisture can be incompatible with some of the ingredients of explosives and can affect the sensitivity of explosives.

Materials intended for use in the construction of an explosive article, process equipment or in packaging likely to be in contact with explosives or propellants can also exhibit chemical incompatibility with the explosives they are in contact with or contain.

Steps to prevent accidental contact between incompatible materials should be taken, and should include:

- **Quality control systems** – to detect contaminants
- **Moisture prevention** – measures to keep explosives dry
- **Compatibility testing** – testing should include not only chemicals that may come into contact with each other but also the equipment and any construction materials. Tests may include:
 - thermal stability tests
 - vacuum stability tests
 - contact tests
- **Cleaning tools** – after every job to prevent transfer
- **Drainage** – a system to keep incompatible waste separate and constructed from suitable materials
- **Solid waste** – preventing it from entering the drainage system

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Indicators

If two substances are incompatible they may exhibit any or all of the following:

- colour change
- gas emission
- smoke
- heat



Suggested reading

<https://aip.scitation.org/doi/pdf/10.1063/1.5044962#:~:text=Metal%20powders%20are%20commonly%20added,the%20metal%20provides%20other%20benefits.>

<https://emergency.cdc.gov/agent/sodiumazide/basics/facts.asp>

<https://royalsocietypublishing.org/doi/10.1098/rspa.1951.0153>

<https://www.legislation.gov.uk/ukxi/2014/1638/contents/made>

6.1.5 Hazard testing

In any environment where explosives are manufactured, tested, processed or stored there are potential hazards that may cause an explosion not linked to the explosives in use but present a significant risk in terms of initiating the explosives either by combustion (leading to deflagration) or propagation (the wave of detonation passing from the first explosion into other sensitive materials which in turn explode). The types of tests that may need to be conducted include:

- dust cloud explosibility parameters (Kst, Pmax)
- dust cloud ignition limits (LOC, MEC)
- auto-ignition temperature (MAIT)
- minimum ignition energy (MIE)
- dust layer ignition temperature (MIT)
- gas explosibility parameters (Kmax, Pmax, LFL, UFL, LOC) at ambient and elevated temperature/pressure
- liquid auto-ignition temperature, burning velocity.

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Dust hazard

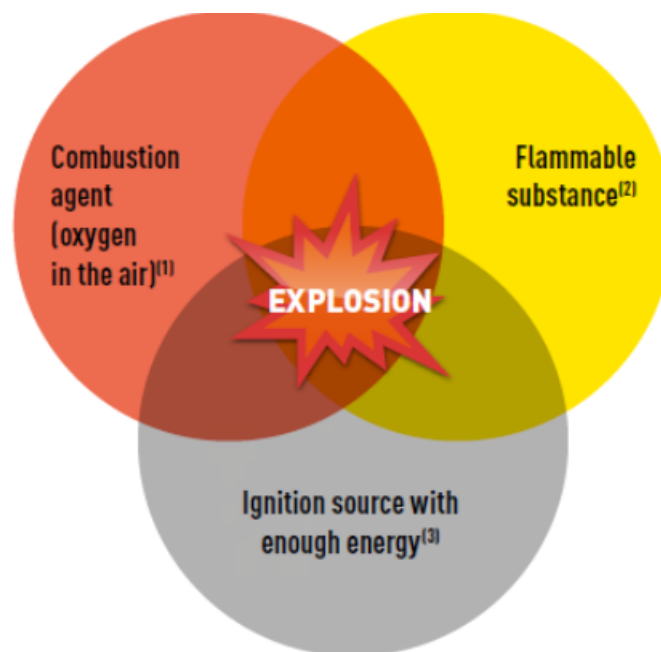
- The most significant explosion hazard is dust. There are a number of clinical tests that can be carried out to determine the presence of hazardous dust in an establishment and what type of dust it is as well as the likelihood of it igniting. KSt and Pmax are considered two of the most important parameters to characterize dust material combustibility.

Cross-cutting safety measures

Cross-cutting safety measures (i.e. measures that address more than one duty) are implemented to ensure the safe manufacture and storage of explosives. Some safety measures are particularly important because they reduce the risk of an explosion being initiated, and limit the consequences in the event of an initiation. These safety measures are:

- appropriate training and competence
- safe systems of work and working practices
- high standards of housekeeping
- providing and maintaining appropriate mounds and traverses
- effective stock management
- segregating explosives presenting different likelihoods of initiation (or different hazard types)
- segregating explosives operations from other activities
- safely handling and transporting explosives on site.

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- (1) Optimal conditions: pressure, concentration.
- (2) Gas: Methane, Acetylene, Hydroge; Dusts: Wood, flour, sugar, aluminum, carbon; Vapor: Ethyl alcohol, Acetone.
- (3) High temperature, mechanical or electrical arc and spark, static electricity, lightning, wrong use

Figure 1: The conditions required for an explosion



Suggested reading

<https://www.hse.gov.uk/explosives/er2014-commercial-manufacture-and-storage-of-explosive-articles-and-substances.pdf>

6.1.6 Risk assessment

There are many risks associated with the storage, handling transport and processing (everything from the development to the disposal) of explosives. In order to sufficiently protect people, property and infrastructure detailed risk assessment of all intended activity must be carried out. Each location and facility will have its own specific risks, processes, characteristics and measures that will affect the results of the risk assessment and it must not be assumed that risk assessments covering one site will be totally suitable for any other.

6.1

In accordance with Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) employers are legally required to identify risks and implement suitable control and mitigation measures. The types of issues and risks (pre-cursors) that are present include, but are not limited to:

- friction
- impact
- ignition by flame
- ignition by spark
- ignition by heat
- ignition by radio frequency energy (RADHAZ/HERO)
- electrostatic discharge
- inadequate procedures
- inadequate supervision
- inadequate identification and labelling of substances or articles
- poor maintenance of any vehicles, explosive items or equipment used in ANY stage of the process
- ignition of solvent vapour, dust or reaction by-product
- chemical incompatibility, not limited to explosive materials
- exudation/Sublimation and consequential contamination of explosives
- inadequate removal of explosive material
- lack of knowledge of presence of explosive material requiring disposal or destruction
- lack of knowledge of the properties of explosive materials
- inappropriate confinement of possible explosive effects
- poor control of equipment requiring treatment, modification or disposal at facilities outside of process areas.

Risk reduction and ALARP

The General Assembly requested the United Nations to develop guidelines for adequate ammunition management. In response, the International Ammunition Technical Guidelines (IATG) were developed in 2011 and the UN SaferGuard Programme was established. Within this programme a system of risk levels were developed to assist organisations and agencies that store or process explosives to do so in the safest possible manner. The United Nations established the International Ammunition Technical Guidance (IATG) as a set of guidelines to further detail the risks and measures associated with the storage and

6.1

handling of ammunition, known as 'stockpile management'. Within the IATG, the tasks and activities necessary for safe, efficient and effective stockpile management equate to one of three risk levels. These are indicated within each IATG as either LEVEL 1, LEVEL 2 or LEVEL 3, dependent on the degree of complexity of each task or activity. The UN SaferGuard website provides a number of online tools that allow assessment of risks and determination of the risk level. The questions in the assessment tool are a useful reference and can be used as a checklist for identifying areas of concern in any facility that stores or processes ammunition. The online tool can be found here:

<https://www.un.org/disarmament/un-saferguard/risk-reduction-process-levels/#:~:text=Within%20the%20IATG%2C%20the%20tasks,of%20each%20task%20or%20activity.>

Having established the level of risk present in a facility it is necessary to implement all means possible to reduce the risk to the lowest acceptable level. ALARP is short for 'as low as reasonably practicable'. SFAIRP is short for 'so far as is reasonably practicable'. The two terms mean essentially the same thing and at their core is the concept of 'reasonably practicable'; this involves weighing a risk against the effort, time and money needed to control it weighed against the likelihood of a risk materialising and the impact of it if it does occur. Thus, ALARP describes the level to which workplace risks are controlled.



Suggested reading

<https://safetyculture.com/checklists/dsear/>

<https://www.hse.gov.uk/pubns/indg370.htm>

<https://www.hse.gov.uk/managing/theory/alarpglance.htm>

<http://www.eig2.org.uk/wp-content/uploads/2012/09/Guide-on-Risk-Assessment-.pdf>

<https://s3.amazonaws.com/unoda-web/wp-content/uploads/2019/05/IATG-01.20-Index-of-Risk-Process-Levels-V.2.pdf>

https://www.hse.gov.uk/research/hsl_pdf/2005/hsl0558.pdf

6.1 6.1.7 Engineering controls

The Hierarchy of hazard control is a system used in industry to minimize or eliminate exposure to all forms of hazards. It is a widely accepted system promoted by numerous safety organizations. It is most commonly represented by a triangle resting on its point to depict a scale rising from the least to the most effective method of control.

The term 'engineering controls' refers to any physical measures that may be built in to a site to mitigate the effects of an explosion and any of the hazards associated with one such as blast, fragmentation, projected effect or thermal hazard. Engineering controls involve making a physical change to the workplace and may be based on distance or on measures such as mounds, barricades or safety screens.

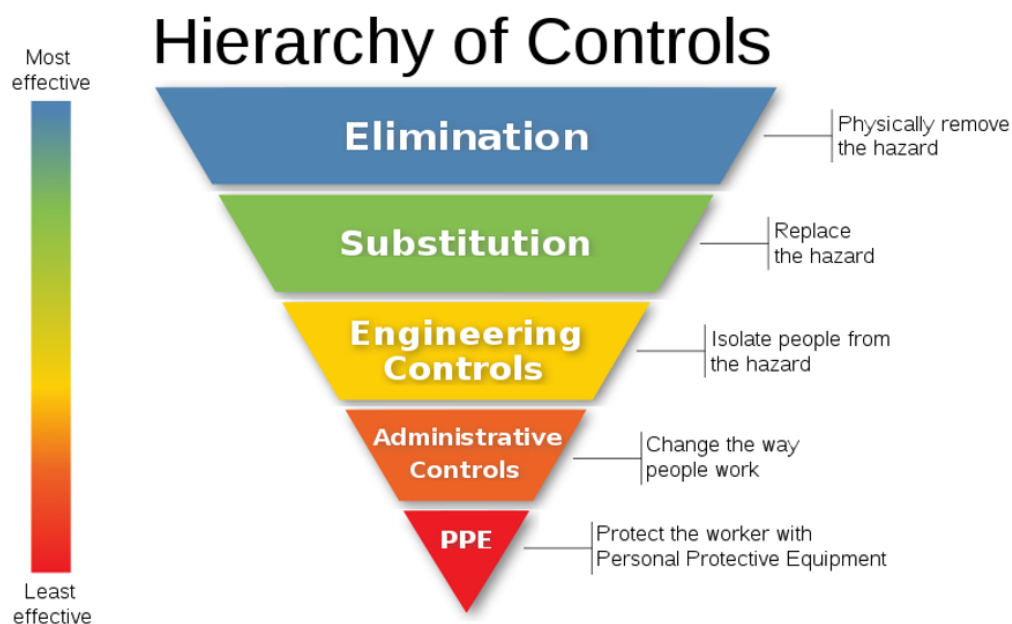


Figure 2: NIOSH Vector version: Michael Pittman

6.1

Passive v active controls

An active control measure is one that is put in place and employs a system or mechanism that constantly works to prevent an incident occurring. Passive controls are those that are in place but only come into play when an incident occurs and are also referred to as mitigation measures. Examples of control measures include:

Active 'Controls'	Passive 'Measures'
Fume extractors	Earth mounds
Machinery guards	Barricades
'Dead man's switch'	Vehicle crumple zones
	Personal Protective Equipment (PPE)

Table 5. Explosive storage facility controls and measures

6.2 Creating an explosive effect

Knowledge criteria: K9. The principles underpinning OME concepts and components for a given explosive effect including knowledge of initiators, initiation systems, explosive trains, explosive substances and articles.

6.2.1 Initiators and Initiation systems

To begin the detonation process there must be an initiation. The explosive substances used for the task are known as initiator explosives and are the most sensitive substances. The term 'initiator' should not be confused with the 'detonator' as described below. Initiation, or causing the initiator explosive to detonate can be achieved by a number of means including:

- Electrical – use of a bridgewire to rapidly create the extreme heat required
- Igniferous – initiation via the introduction of a flame or spark
- Chemical – introduction of highly volatile, reactive chemicals that when mixed with others, create the reaction that leads to initiation
- Mechanical – use of an impact or friction mechanism to impart sufficient shock or heat to initiate the main charge.

The primary safety considerations in the formulation, manufacture, and use of explosives are that they must never explode prematurely but always explode when desired. Often this balance is achieved with an insensitive main charge being initiated by the smallest possible amount of a more sensitive explosive. This concept is expanded to that in which a series of decreasingly sensitive explosives is ultimately sufficient to initiate an insensitive main charge. The sensitivity of explosives to initiation provides a common means of classification:

Primary high explosives. Also referred to as initiator explosives, those most sensitive to heat, shock, electric spark, friction, and impact. They are usually high explosives such as the fulminates and lead azide, although lead azide may be sensitized with a small amount of lead styphnate.

6.2

Secondary high explosives, those that do not easily go from deflagration to detonation, do not initiate electrostatically with ease, and require larger shocks to detonate. They include nitrocellulose, PETN (commonly used as the fill for detonating cord), Torpex (a more powerful version of RDX) and desensitized nitro-glycerine.

Tertiary (Low) explosives, are those most difficult to detonate. They include extremely powerful high explosives like RDX and HMX.

Other explosives may be added to sensitize certain components or add a time delay. Any number of combinations can be employed to achieve the desired function, power, speed, reliability, timing, and safety of a system.



Suggested reading

<https://en.wikipedia.org/wiki/Explosive>

6.2.2 Explosive trains

A detonation is achieved when an explosive reaches the point in time at which it changes state from either a solid or liquid into high pressure gasses. To control the occurrence of the final, main detonation it is necessary to create a sequence of events based on the decreasing sensitivity of the components used to begin the process and result in that detonation. Within a detonator as described above, there is what is known as an explosive train (also known as the initiation train). Each explosive substance is chosen for its sensitivity and its ability to initiate the next component in line. Regardless of whether the detonator is an electric or Igniferous one, it will start by initiating a very small amount of highly sensitive 'initiator' primary explosive which in turn will transfer the effect to a slightly larger amount of high explosive referred to as the booster. If this is then placed in or against a larger quantity of much more stable low explosive, it will be sufficient to initiate that low explosive and create the desired explosive effect.

6.2

The low explosive is the final component in the whole explosive train. An explosive train consists of three parts:

- **Primary components** – the most sensitive part of the explosive train consisting of the initiator which is made up of the fuze, primer and detonator (which is a mini explosive train in its own right as stated above)
- **Secondary components** – booster to increase the wave of detonation to a state in which it will initiate the main, lower sensitivity charge (such as detonating cord or a small charge)
- **Tertiary components** – main charge such as TNT, PETN or ANFO.

The inherent safety resulting from the use of insensitive, low explosive as the larger quantity of explosive is how safety can be engineered into the process.



Suggested reading

https://en.wikipedia.org/wiki/Explosive_train

<https://app.knovel.com/web/toc.v/cid:kpEDHESET7/viewerType:toc/>

6.2.3 Utilising explosive effects

Explosive power can be harnessed to achieve a number of effects on the intended 'target'. The explosive power is not limited to the transfer of blast energy into or through adjacent materials and can be greatly enhanced by the application of some simple principles.

Shaped charges

One of the most common uses of explosive power is to create a shaped charge. Different shapes create varying effects but most of them are based on the simple precept that forming a concave face in the explosive charge will focus the explosive energy and blast created during detonation. The variations in effect are summarised here.

6.2

Misznay-Schardin

Also known as the Munroe Effect is caused because the explosive blast expands directly away from, and perpendicular to, the surface of an explosive. Unlike the blast from a rounded explosive charge, which expands in all directions, the blast produced by an explosive sheet expands primarily perpendicular to its plane, in both directions. However, if one side is backed by a heavy or fixed mass, most of the blast (i.e. most of the rapidly expanding gas and its kinetic energy) will be reflected in the direction away from the mass. If the exposed face of the explosive is curved away (concave) from the target the effect is more concentrated still.

Conical charge

The Misznay-Schardin effect can be harnessed further by the addition of a metal plate to the curved face of the explosive. The added plate must be softer or more malleable than the explosive container, as the blast will follow the line of least resistance. This will focus the blast further, the high temperature causing the plate to become a molten fragment often referred to as a jet or 'slug'. The velocity, temperature and blast associated with this effect results in the fragment penetrating the target material in a narrow focused area roughly the size and shape of the face of the charge. The addition of a metal plate is extremely effective but if the plate is formed into a cone it concentrates the effect, penetrating a thicker target but resulting in a much smaller hole. A comparison of the effects of shaped charges is shown below. This effect is most commonly harnessed in portable anti-tank weapons and those types of weapons are known as High Explosive Anti-Tank (HEAT) munitions.

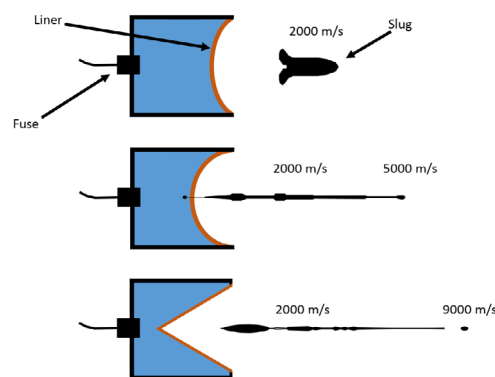


Figure 3. The effects of dish-shaped and conical shaped charges

6.2 High Explosive Squash Head (HESH)

This is not a form of shaped charge but is based on the principle of delaying detonation of the main charge until the explosive has been pressed and spread against the target.

HESH rounds are thin metal projectiles filled with plastic explosive and a delayed-action base fuze (in the rear). The plastic explosive is 'squashed' against the surface of the target on impact and spreads out to form a disc or 'pat' of explosive. The base fuze detonates the explosive milliseconds later, creating a shock wave that, owing to its large surface area and direct contact with the target, is transmitted through the material. This wave transmission causes material on the opposite side to flake away or 'spall'.

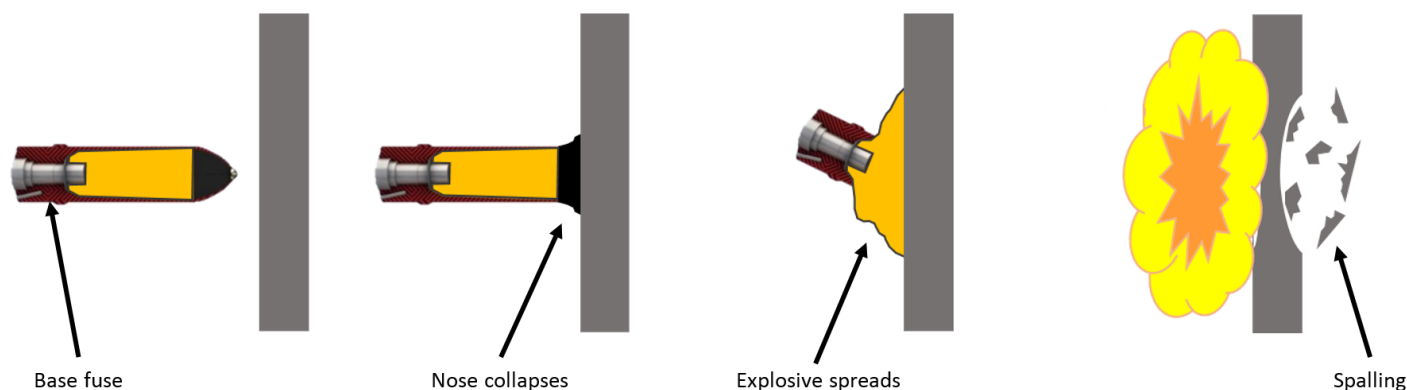


Figure 4. The sequence of functioning of a HESH munition



Suggested reading

HESH v HEAT: <https://www.youtube.com/watch?app=desktop&v=Uhz3w8-PSI8>
<https://www.sciencedirect.com/topics/engineering/shaped-charge#:~:text=A%20shaped%20charge%20is%20usually,shape%2C%20as%20shown%20in%20Fig.&text=The%20explosive%20charge%20is%20often,Figure%2025.3>
<https://www.diva-portal.org/smash/get/diva2:643824/FULLTEXT01.pdf>
<https://apps.dtic.mil/dtic/tr/fulltext/u2/600273.pdf>

6.3 Explosive classification

Knowledge criteria: K11. The principles of explosives classification, OME inventory activities and licensing requirements, conditions and restrictions.

6.3.1 Dangerous goods classification

The United Nations devised a system for classifying dangerous goods. The UN Globally Harmonized System of Classification and Labelling of Chemicals (GHS) states clearly the classification criteria that enables identification and marking of all explosive materials. It is an established, internationally agreed and has been used extensively around the world for a long time.

The classification system was originally used for making transportation of dangerous goods safer. The principles have, however, also been applied by many nations as the basis for a simplified consequential hazard and risk assessment for the storage of ammunition.

The system comprises:

- Hazard Divisions (HD) including sub-divisions
- Compatibility Groups (CG)
- and, when these are combined together: Hazard Classification Codes (HCC)

Hazard Divisions indicate the type of hazard to be expected primarily in the event of an accident involving a quantity of ammunition. The Hazard Division (HD) for a particular explosive or type of ammunition shall be determined by its performance and test results according to Part I of the Manual of Tests and Criteria of the UN Recommendations on the Transport of Dangerous Goods.

6.3

The divisions are articulated numerically. This UN system covers all sorts of dangerous goods from chemicals to medical waste (there are nine (9) top-level classes in all). The Number for Explosives is '1'. This is then subdivided into explosives that present different types of hazard for example '1.1' or '1.2'.

The Hazard Divisions are most often seen marked on orange diamonds on packaging. These diamonds usually include the Compatibility Group, thus showing the complete Hazard Classification Code. The picture of the box of Plastic Explosive has an orange diamond on it. This shows that this is HD 1.



Packaging will generally have a number of other markings on it, all providing information. There are 6 Hazard Divisions for Class 1 Goods: 1.1, 1.2, 1.3, 1.4, 1.5 and 1.6.

Note: There is also an additional category, which covers unstable explosives. There is no pictogram or HD for this type of ammunition, as unstable explosives are not allowed to be transported.

Compatibility Groups are designed to minimise the risk of storing items together that will either increase the risk of an accident or, for a given quantity, the magnitude of the effects of such an accident. The Compatibility Groups are articulated alphabetically, for example 'C' or 'D'

Note: The application of the Hazard Division and Compatibility Group does not take into account the probability of an incident. It assumes that if it can happen it will, and when it does, it identifies the extent of the hazards.

6.3

6.3.2 Hazard classification

Explosives are without doubt, dangerous goods within the terms of international definitions. However- to clarify to a potential user of such items, how they are expected to behave, those substances classed as dangerous are classified further. The classification of dangerous goods used in the UK is the European Agreement concerning the International Carriage of Dangerous Goods by Road 2017, known as the ADR or 'Orange Book'. Hazard type defines and describes the nature of the hazard arising from an explosive in manufacture and storage conditions.

Hazard type	Definition (regulation 2 ER2014)	Explanation
Hazard Type 1	An explosive which, as a result of, or as a result of any effect of, the conditions of its storage or process of manufacture has a mass explosion hazard	A mass explosion is one in which the entire body of explosives explodes as one
Hazard Type 2	An explosive which, as a result of, or as a result of any effect of, the conditions of its storage or process of manufacture has a serious projectile hazard but does not have a mass explosion hazard	
Hazard Type 3	An explosive which, as a result of, or as a result of any effect of, the conditions of its storage or process of manufacture has a fire hazard and either a minor blast hazard or a minor projection hazard, or both, but does not have a mass explosion hazard	i.e. those explosives which give rise to considerable radiant heat or which burn to produce a minor blast or projection hazard
Hazard Type 4	An explosive which, as a result of, or as a result of any effect of, the conditions of its storage or process of manufacture has a fire or slight explosion hazard, or both, with only local effect	i.e. those explosives which present only a low hazard in the event of ignition or initiation, where no significant blast or projection of fragments of appreciable size or range is expected

Table 6. European Agreement explosive Hazard Type definitions

6.3

Hazard type represents the potential behaviour of the explosives in the form in which they are manufactured or stored. This means that explosives do not have inherent hazard types that can be automatically ascribed without consideration. Hazard type will be dependent on:

- the quantity of explosives
- the types of explosives
- the loading density
- packaging (if any) or containment
- the presence of barriers or other controls that will prevent rapid communication of an event between explosives;
- orientation
- how an event involving the explosives might progress or degrade any controls

How explosives of different hazard type can affect their surroundings can also depend on the orientation of any packaging, additional confinement or building that they are in.

Determination of hazard type

For those explosives being kept as packaged for carriage, and that have been classified, there will generally be a direct correlation between the UN hazard division (HD) assigned them on classification for transport and the hazard type (HT) they should be allocated for storage, i.e.

- UN HD 1.1 = HT 1
- UN HD 1.2 = HT 2
- UN HD 1.3 = HT 3
- UN HD 1.4 = HT 4

Explosives that have been assigned, on classification, the UN HD 1.5 and 1.6 will need to be considered in detail and on a case-by-case basis before a hazard type can be allocated.

6.3 Hazard markings

The combination of the 'Hazard Division' and the 'Compatibility Group' results in an alpha-numeric 'Hazard Classification Code' for each item and type of ammunition and explosives. The make-up of a UN Hazard Classification Code (HCC) = HD + Sub-division + CG. For example '1.1D' or '1.4S'.

These codes, or a similar national system, are critical to the safe storage and movement of ammunition and explosives and provide warning information for first responders in the event of an accident or incident.

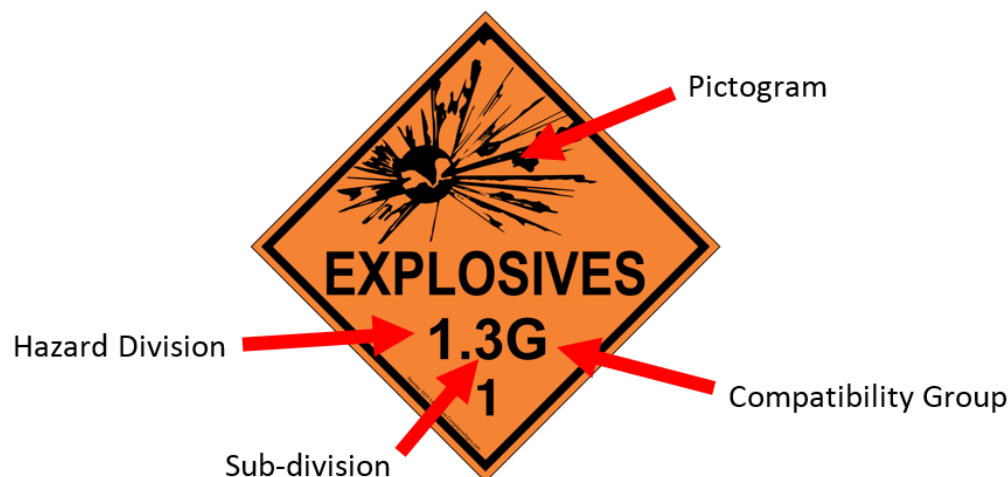


Figure 6. UN Hazard classification label

These codes, or a similar national system, are critical to the safe storage and movement of ammunition and explosives and provide warning information for first responders in the event of an accident or incident.

6.3

In order to maximise the safe storage, transport and handling of explosive compounds, substances and articles there is an international pictogram-based marking system shown below. This facilitates at-a-glance identification of a substance or article in its packaging.

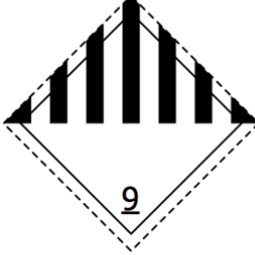
				
1-Explosives	2.1-Flammable gases	2.2-Non-toxic and non-flammable gases	2.3 Poison gases	3-Flammable liquids
				
4.1-Flammable solids	4.2-Spontaneously combustibles	4.3-Dangerous when wet	5.1-Oxidizers	5.2-Organic peroxides
				
6.1-Poison	6.2-Infectious substances	7-Radioactive	8-Corrosive	9-Miscellaneous dangerous substances

Figure 7. Hazardous goods labels

6.3

In the case of explosives the sub-divisions and their warning sign pictograms are as follows:

Hazard Classification Sign	Definition	Hazard Classification Sign	Definition
	Mass explosion hazard		Projection hazard Small fragments - short range No mass explosion hazard
	Severe projection hazard No mass explosion hazard		Sympathetic explosive reaction Burns on bullet impact Burns in heating tests
	Severe projection hazard Large fragments – long range No mass explosion hazard		Fire hazard Minor projection hazard Minor blast hazard No mass explosion hazard

Table 6a. UN Hazard Division 1. Explosive classification labels

6.3

In the case of explosives the sub-divisions and their warning sign pictograms are as follows:

Hazard Classification Sign	Definition	Hazard Classification Sign	Definition
	Mass fire hazard Thermal radiation hazard Minor projection hazard Minor blast hazard No mass explosion hazard		Mass explosion hazard May mass explode in fire
	Fire hazard Burns sporadically Minor projection hazard Minor blast hazard No mass explosion hazard		No mass explosion hazard
	No significant hazard Fire or projection hazard	NO SIGN? TRANSPORT NOT PERMITTED	Any explosive in an unstable condition
NOTE: * SHOWS WHERE A COMPATIBILITY GROUP INDICATOR WILL BE: A, B, C, D, E, F, G, H, J, K, L, N, S			

Table 6b. UN Hazard Division 1. Explosive classification labels

6.3

Fire divisions

There are six fire divisions. These equate to the Hazard Divisions.

Each Fire Division has a symbol that represents it. A fire division number is shown on each symbol.

These are shown in the table below.

The symbol should be indicated during storage and transportation. This is to allow fire-fighting personnel to recognise the fire hazard when approaching the scene of an incident, accident or unplanned event such as a fire, crash or impact etc. based on the general expected behaviour of the items. For a fireman its primarily related to what he can expect to occur after high temps or a lengthy period of fire on or in the marked building or vehicle. Hazard Division symbols may also be used for this purpose.

Fire Division	Symbol	Remarks	Fire Division	Symbol	Remarks
1.1		Presents a possible mass explosion hazard if the substance reaches sufficient temperature or is ignited.	1.4		Presents no significant hazard- is unlikely to make any existing fire worse.
1.2		Presents a fragmentation or projection hazard if the substance reaches sufficient temperature or is ignited and is able to deflagrate.	1.5		Fire Division 1 symbol used because of the similar fire-fighting hazards.
1.3		Presents a fire hazard- will contribute to the intensity and/or duration of any existing fire.	1.6		Fire Division 2 symbol used because of the similar fire-fighting hazards.

Table 7. UN Fire division symbols

6.3 Transport of explosives

The Competent Authority of a Contracting Party to ADR must assign the classification of explosive materials before they can be transported by road within Great Britain. The process involves assessing an explosive to determine whether or not there is a danger of fire/explosion that would jeopardise safe transport in terms of:

- thermal stability i.e. the response to heat and flame.
- sensitiveness towards mechanical stimuli i.e. the response to impact and friction.
- response to dropping an unpackaged article, packaged article or packaged substance from a height of 12 metres.

The final stage of the process is to assign the explosive to – or exclude from – Class 1 of the UN classification scheme for the transportation of dangerous goods by assessing its behaviour in terms of:

- mass explosion of a single package.
- propagation potential towards other packages or from a non-packaged article to another.
- mass explosion, dangerous projections, radiant heat, violent burning or other dangerous effect when packages are involved in a fire.
- hazardous effects outside the package arising from accidental ignition or initiation of contents.

An explosive assigned to Class 1 is given an appropriate UN Serial Number, hazard division and compatibility group, depending on its composition, type, and hazard.

A Competent Authority is a body designated or recognised to carry out duties under transport of dangerous goods regulations. In Great Britain:

- HSE is the Competent Authority for the classification of non-military explosives.
- Military explosives, i.e. explosives under the control of and/or in connection with the execution of contracts for the Secretary of State for Defence are classified by the Explosives Storage and Transport Committee (ESTC) of the Ministry of Defence.

Once the Competent Authority (CA) has agreed the classification, it issues a Competent Authority Document (CAD). The CAD is a document detailing the classification assigned to an explosive, or group of explosives, by a CA. Copies of relevant CADs should be kept by all duty holders under ADR, in a form that is easily understood by CA inspectors and be available on demand.

6.3



Suggested reading

https://unece.org/fileadmin/DAM/trans/danger/publi/ghs/GHS_presentations/English/phys_haz_e.pdf
https://www.chemsafetypro.com/Topics/TDG/Class_1_Dangerous_Goods.html
https://www.chemsafetypro.com/Topics/TDG/Dangerous_Goods_Reference_Resource.html
<https://www.hse.gov.uk/explosives/licensing/hazard-classification.htm>
<https://www.hse.gov.uk/explosives/classification/index.htm>
https://www.unece.org/fileadmin/DAM/trans/danger/publi/unrec/rev16/English/02E_Part2.pdf
<https://www.osha.gov/dsg/hazcom/ghsguideoct05.pdf>
<https://www.hse.gov.uk/chemical-classification/labelling-packaging/hazard-symbols-hazard-pictograms.htm>
<https://www.hse.gov.uk/cdg/manual/classification.htm>
https://www.chemsafetypro.com/Topics/TDG/Dangerous_Goods_Classification_Symbols.html

6.3.3 OME inventory activities

Stock control

Any person or organisation intending to hold quantities of explosives must implement an effective stock management system. The primary concerns are safety and security and this can be ensured if stocks are controlled. Basic OME stock accounting starts with the use of stock tally cards that record all relevant information about the type of OME in each stack and also allows for editing when any amount of that item is issued, received or returned. The fundamental requirements of a stock management system (Page 22 of ER 2014) are:

- Recording of what items are held and where they are in the facility (room, shelf, locker etc.).
- Rotation of stock to ensure oldest stock used first.
- Safe stability and serviceability of shelving, stacks and packaging.
- Accurate shelf-life records and monitoring.

6.3

- Routine planned assessment of stock for damage, shelf-life or other issues.
- Incompatible stores are not co-located in the facility. Information is available to emergency services/ first responders.
- Adherence to explosive licence limits.
- Compliance with regulatory requirement to record holdings of 'relevant explosives'.
- A system for identifying and reporting losses of 'relevant explosives'.
- Recording of all movements of explosives in and out of the facility for use, transport or disposal.



Suggested reading

<https://www.hse.gov.uk/pubns/priced/l150.pdf>

<https://iexpe.org/forum/explosives-magazine-stock-control/>

<https://www.ukstandards.org.uk/PublishedNos-old/COGESA7.13.pdf#search=explosive%20substances%20and%20articles>

6.3.4 Licensing requirements

With certain exceptions a licence is required for the manufacture or storage of explosives. Licencing depends on the quantity of explosive that is required to be stored or whether or not there will be manufacturing of explosives on site. A summary of the main questions that must be considered by an organisation before applying for a licence are listed below.

Is the organisation/site indenting to conduct any of the following:

- Manufacture of explosives.
- Manufacture and storage of any quantity of explosives at Office for Nuclear Regulation (ONR) regulated sites.
- Storage of more than 2000 kg of explosives.
- Manufacture and storage of Ammonium Nitrate Blasting Intermediate (ANBI).
- Storage of any quantity of explosives on the surface of a mine, whether in a building or not.
- Storage of any quantity of explosives within a port or harbour area.
- Storage of up to 2000 kg of explosives if some of the explosives are either smokeless powder, or percussion caps.

6.3

- Storage of up to 2000 kg of explosives if some of the explosives are a relevant explosive that requires an explosives certificate.
- Ammunition prohibited to be acquired by the firearms Act 1968-97.
- Storage by a person who is a registered firearms dealer.
- Storage of up to 2000 kg of other explosives (including fireworks and small arms ammunition) the acquisition of which is NOT regulated or prohibited by virtue of the firearms Act 1968-97 where separation distances can be met, none of which requires an explosives certificate.
- Storage of up to 2000 kg of explosives where separation distances in Regulation 27 and schedule 5 cannot be met.
- Handling explosives in a port or harbour area.
- On-site mixing.

Further information on these can be found on the HSE website here: <https://www.hse.gov.uk/explosives/licensing/how-to-apply.htm>

HSE issues licenses for manufacturing activities and larger explosives storage facilities but may not grant a licence for a manufacturing facility or store until the local authority has given its assent. Stores holding less than two tonnes of explosives are either licensed by the local authority or the police, HSE licences stores that are located in a mine or harbour.

6.4 Safe preparation of OME for specified tasks

Knowledge criteria. K12. The principles related to the safe preparation of ordnance munitions and explosives for specified tasks.

6.4.1 Storage

Separation distances

Separation distances can apply to all types of Dangerous Goods classes, and the required dispersal or other tactically-protective spacing they require, not just OME. The term 'separation distance' refers to a generic term for the minimum permissible distance between a potential explosion site (PES) and an exposed site (ES). That means the physical distance required between any facility that is used to either process or store explosive items and any civilian population or critical infrastructure that is not otherwise protected. Any organisation that stores explosives at a site must ensure that the relevant separation distance is maintained. Separation distances are calculated according to several factors:

- The Net Explosive Quantity of an item: How much actual explosive is in an article, not the total weight of the item.
- The location where the explosive is stored or processed – the building characteristics.
- The Hazard Type of the explosive in question.

Quantity Distances

Quantity distances (QDs) are licensing calculations linking the Net Explosive Quantity (NEQ) of an item to protective distances according to DSA03 and IATG. The NEQ, also known as net explosive content (NEC) or net explosive weight (NEW), of a quantity or consignment of OME or similar products is the total mass of the contained explosive substances, without the packaging, casings, bullets etc. It also includes the mass of the TNT- equivalent of all contained energetic substances. The UN IATG website features an online calculator tool that enables rapid calculation of the mandatory quantity distances. The tool can be found here:

<https://www.un.org/disarmament/un-safeguard/map/>

6.4

Provided that the explosives are stored in a safe and suitable place, with all due precautions for public safety, there are some exceptions to having to maintain separation distances and these include:

- Stores holding small quantities of explosive, i.e. 100g or less.
- Stores holding 5 kg or less of a combination of shooters powders and model rocket motors.
- Stores holding 30 kg of shooters powders or less and/or up to 300 g of percussion caps, subject to certain conditions.
- Stores holding up to 200 detonators and 5 kg of water-based explosive and detonating cord; or 5 kg of water-based explosive or detonating cord, subject to certain conditions.
- Stores used by the police to keep no more than:
 - 4 kg of explosives for use for operational purposes including the training of dogs used for the detection of explosives.
 - Up to 30 kg of explosives kept for ordnance disposal or explosive means of entry and associated activities.

Note: If and of the explosives listed above are being kept with small arms ammunition, any separation distance required due to the presence of small arms ammunition will continue to apply.

Some other stores will not be subject to the separation distance requirements of the regulations. They are stores:

- Other than those where HSE or ONR have granted a licence under regulation 13(6), where the only explosives being kept are desensitised explosives.
- Licensed by HSE or ONR where the local authority has given its assent to the grant of the licence or where, in certain circumstances assent was not required for the grant of the licence.
- Controlled by the Ministry of Defence.

Stores controlled by contractors on establishments owned or controlled by the Ministry of Defence are not exempt from the separation distance requirements.

Separation distances also apply to the storage of explosives even when a licence is not required and to stores operated by organisations which are exempt from the licensing requirements. This includes any stores operated by local authorities and police forces not detailed above.

6.4 Buildings that are not normally occupied

Where the presence of people within a building on an explosives site is transient and that building would be a protected place of Class F, then for the purposes of applying separation distances, that building may be considered to be not normally occupied or unoccupied when it is being used by the people who are engaged in the site's explosives activities.

Examples of such unoccupied buildings could include toilets, changing rooms and switch-rooms. The requirements of regulation 26 of ER2014 would however mean that duty holders will need to take account of the risks posed by such buildings in deciding where it might be appropriate to locate their stores and also have systems in place to ensure that appropriate measures have been taken to protect people using those facilities from the effects of a fire or explosion.

Buildings that are not on the explosives site and which are only occupied for a few minutes per day, such as:

- Stores which are only occupied whilst goods are removed or deposited.
- Stock sheds in farms only occupied for a few minutes per day to feed and water the stock.
- Should be treated as being occupied or inhabited and appropriate separation distances should be applied.

Mixing rules

Having considered how an ammunition nature might respond in the event of unplanned stimulus – in effect if an incident occurs at the site which affects the ammunition, we have seen that each item should be allocated a letter to denote its 'Compatibility Group'.

Allocating each explosive a Compatibility Group means, in theory, ammunition may be stored like with like. This also means that it is only permitted and safe to store ammunition that is definitely incompatible in a separate location.

However, it is possible to compromise by mixing ammunition of different Compatibility Groups, if it is known that they can be stored together.

6.4

To be 'acceptable' it must be possible to store the ammunition in a manner which reduces the probability of an accident, and also reduces the severity of an accident if one does occur. This essentially means reducing the risk.

Why is the ability to store different ammunition types together important? If it were possible, all ammunition would be stored and transported separately, without being in proximity to different types of ammunition. However, there are practical constraints on this, mainly the available space for storing everything.

The answer to what CG can be stored or mixed with other CG lies in the 'Mixing Rules'. Conventional ammunition should be stored in accordance with these mixing rules. This table is in the IATG, specifically at IATG 01:50. Note that this applies to 'fixed' ammunition storage sites, for example a base ammunition depot, or similar. For ease of reference the items that can be mixed are represented in a table:

Compability Group	A	B	C	D	E	F	G	H	J	K	L	N	S
A	x												x
B		x		x (1)	x (1)	x (1)							x
C			x	x	x	(2)	(3)					x (4)	x
D		x (1)	x	x	x	(2)	(3)					x (4)	x
E		x (1)	x	x	x	(2)	(3)					x (4)	x
F		x (1)	(2)	(2)	(2)	x	(3)						x
G			(3)	(3)	(3)	(3)	x						x
H								x					x
J									x				x
K										x			
L											(5)		
N			x (4)	x (4)	x (4)							x (6)	x (7)
S		x	x	x	x	x	x	x	x			x (7)	x (6)

Table 8. IATG Compatibility Group mixing table

6.4



Suggested reading

<https://www.hse.gov.uk/pubns/priced/l150.pdf>

<https://www.hse.gov.uk/explosives/er2014-commercial-manufacture-and-storage-of-explosive-articles-and-substances.pdf>

<https://www.hse.gov.uk/explosives/licensing/how-to-apply.htm>

6.4.2 Safe handling

Many substances create dust or vapours that are not only harmful to health but present a fire or explosion hazard. In order to create the safest working environment possible a number of directives have been passed. These are explained in this section.

ATmosphère EXplosibles (ATEX)

ATEX is an abbreviation of the French term, describing the equipment or use of a product within an explosive atmosphere. The ATEX certification is mandatory across Europe and involves all stages from the manufacture, through to the installation and use of the equipment.

There are two parts which can be defined as:

- **DIRECTIVE 2014/34/EU**

This is a directive that ensures safety in the workplace by providing direction on standards of manufacture and quality that apply to equipment and protective systems used for working with explosives. It also applies to all equipment used in or related to explosive atmospheres, such as electrical and non-electrical equipment, components and safety devices, and the control and adjustments necessary for the safe operation of this equipment and protective systems. It also defines the essential requirements for the safety and health for all manufacturers of the equipment or systems.

6.4

Devices falling within the scope of the European Directive are identified by a marking plate on which the logo appears:

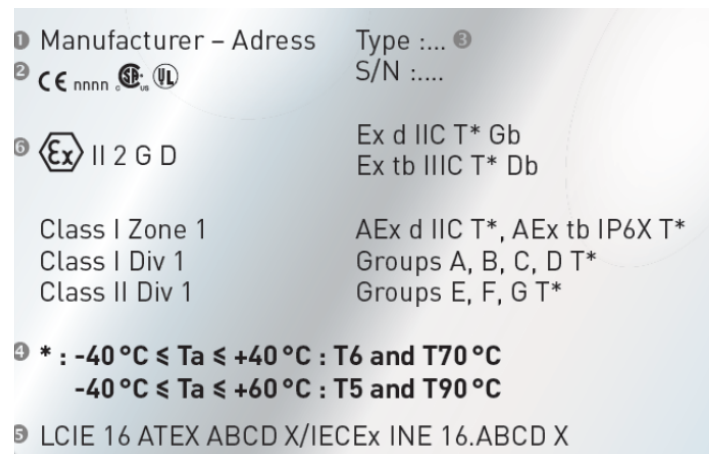


Figure 8. Example ATEX compliant equipment marking plate

1. Manufacturer identification:

Name and/or trademark

Address.

2. Conformity to all relevant European directives and/or North American standards.

3. Product type.

4. Temperature class.

5. The certificate number endings:

- none: OK to use without specific recommendations.
- X: equipment with special condition(s) for safe use.
- U: component (complementary certification needed for use).

6. The Ex hexagon logo – Marks products in the scope of directive 2014/34/EU and in compliance with ERSH.

Directive 2014/34/EU marking:

II: Equipment group = surface industry.

2: Equipment category.

G D: Gas or Dust atmosphere.

6.4

This Directive requires:

- For products: a type certification, a declaration of conformity and an instruction manual, allowing to affix the marking.
- For the manufacturers: a quality assurance system audited annually by a notified body, and the appointment of an authorised person referred to as the 'Ex-Proof responsible person'.

Main standards applied

- IEC/EN 60079-0: Products for use in explosive gas atmospheres - General rules.
- IEC/EN 60079-1: Explosive atmospheres - Part 1: Equipment protection by flameproof enclosures "d".
- IEC/EN 60079-7: Explosive atmospheres - Part 7: Equipment protection by increased safety "e".
- IEC/EN 60079-31: Explosive atmospheres - Part 31: equipment protection against ignition of dust by enclosure "t".

DIRECTIVE 1999/92/EC

The 1999/92/EC Directive aims to improve the safety and health protection of workers potentially at risk from explosive atmospheres. In order to do this it puts in place four simple rules which state that the employer shall:

- Prevent the formation of explosive atmospheres or if this is not possible, prevent ignition of explosive atmospheres.
- Assess the specific risks arising from explosive atmospheres and to draw up and keep up to date an explosion protection document.
- Classify places where explosive atmospheres may occur into zones.
- Mitigate the harmful effects of an explosion to protect the health and safety of workers (install appropriate equipment, take organizational measures such as staff training etc.).

6.4 International Electrotechnical Commission Explosive (IECEx)

The aim of this voluntary scheme is to facilitate the international flow of electrical equipment intended to be used in potentially explosive atmospheres and thus avoiding multiple national certifications and at the same time ensuring an appropriate level of safety. The IECEx certification scheme allows the manufacturers of “Ex-proof” equipment to obtain a Certificate of Conformity that would be accepted in Member States in which this certification scheme is recognised.



Suggested reading

<https://marechal.com/marechal/en/p-ex-zones.html>

<https://www.rayteclad.com/blog/what-is-the-difference-between-atex-iecex-certification/>

6.4.3 Destruction and disposal

Choice of method

Destruction of any explosives is a dangerous activity and the method of disposal or destruction must be chosen with care. A simple set of questions that must be answered is here:

1. Are the explosives safe to transport and use as is? If they are, then reasonably practical disposal methods such as disposal by use or a legal sale or transfer to another person should be considered before destruction is chosen as the disposal method.
2. Would the explosives be safe to transport and use if reworked? If it would be reasonably practicable to rework explosives requiring disposal then the balance of risks between reworking and destruction should be reconsidered.
3. If the explosives require disposal because they have failed to meet a prescribed quality standard, can the explosives be used legally in an environment where that failure to meet the quality standard will not have a materially detrimental impact on safety, health or the environment?
4. If the explosives require disposal because they have become life-expired can the explosives be re-lifed or requalified.
5. Is the nature of the explosive such that particular specialist competence and/or equipment will be required for the safe disposal of the explosives and is this competence and/or equipment available?

6.4

6. Is there a recognized method or scheme in place for the disposal of the particular explosive? For example schemes are in place for the disposal of time expired flares and other life-saving pyrotechnics.

If, after answering all of the above questions, the answer remains destruction as the most suitable method of disposal it is accepted that it can be conducted in one of four ways:

- Burning
- Detonation
- Dissolution of dissolving with a solvent
- Chemical destruction

In some cases a combination of the above may be suitable but careful selection and preparation of the site and resources is necessary to reduce all risks to ALARP. The HSE document 'Guidance for the Safe Management of the Disposal of Explosives' at the 'eig2' link below provides detailed information on this subject. The processes and procedures required to conduct these methods are hazardous, complex, require special training and equipment, and are not described in this guide.

Certified free from explosives (CFFE)

Any items that have been involved in the storage, handling or processing of explosive substances, on completion of the work, must be checked and certified as being free from any residue, particles or parts of item that may present an ongoing explosive hazard. This is known as certified free from explosives (CFFE). The system is designed to minimise the hazards faced by persons outside of the explosive storage and handling regime such as those receiving scrap, servicing machinery or using explosive training aids.

The task of inspecting and certifying items as CFFE is to be regarded as an explosive process and conducted in a licenced building or site whenever possible. It is accepted that activities often involve more than one item or types of item and in that case, when conducting the CFFE process there must be separate areas for the following:

- Articles and packages awaiting CFFE.
- Processing the articles and packages.

6.4

- Isolation of live articles found during the inspection (this area should be suitably positioned and protected whenever possible to minimise the hazard from the live articles).
- Articles and packages that have been CFFE 9essential that these items do not mix with un-checked items once certified or the process is void and the hazards remain).

Competencies

The only persons authorised to conduct CFFE are the following:

- Persons trained on the items requiring inspection or with proven experience with that type, especially concerning ammunition types.
- Authorised by a senior manager (usually in a military context this will be a Unit Commanding Officer or a delegated authorised subordinate officer).

So, within an explosives workshop, laboratory or processing organisation the type of persons who may be suitable to conduct CFFE, depending on the type of explosives, items or substances in question, include:

- Graduates of this qualification with practical experience of the items to be inspected.
- Graduates of the Level 6 Ordnance, Munitions and Explosives professional (integrated degree).
- Graduates of the Level 7 Ordnance, Munitions and Explosives specialist (integrated degree).

Within a military environment, depending on the nature of items, explosives and ammunition being inspected (most usually packaging or items of fired ammunition), the following persons are permitted to conduct CFFE:

- Ammunition Technical Officer (ATO)
- Ammunition Technician (AT)
- Demolition Safety Officer (DSO); now superseded by Explosive Safety Officer (ESO)
- Stage 3, 4 or 5 live firing Range Safety Officer (RSO)
- Resources specialist with Ammunition Storemen qualification

6.4 The CFFE process

As a guide, the following activities must be conducted:

1. All packages, articles and items are inspected and a thorough examination carried out to ensure that they are free from explosives or explosive residue/dust. This is to include the removal and inspection of all internal packing fitments and furniture, although they can be subsequently replaced if required.
2. Hazard Classification Code markings, Supplementary Symbols, Proper Shipping Name and UN Serial Number details if present are to be removed or obliterated from packaging or containers as part of the CFFE process. Obliteration can be in the form of simple use of paint to obscure them.
3. Once packages have been subject to the CFFE process they must be sealed. The senior manager is responsible for ensuring that there is a management system to ensure that these arrangements are put in place and remain so until dispatch of the items.
4. When any live explosives are found to be present in any package, article or part of a consignment that have been Certified as Free From Explosives it is known as a violation. The facts are to be reported so that an investigation can be carried out to prevent a recurrence. The report must be accompanied by copies of all documentation concerning the consignment. Similarly the discovery of contamination by other hazardous substances or items certified as being free from contamination, must also be reported.

Best practice is that a certificate (a simple form identifying the items as free from explosives or residue), preferably signed, dated and stamped should be inserted or fixed to the items or packaging to complete the process. The UK MOD uses a standard format, which can be found in either of the first two links below although other organisations should use their own similar document. The names and roles of persons in an organisation who are authorised to conduct CFFE should be listed in the organisation policy relating to explosive handling and storage.

6.4

For detailed explanations and guidance on the disposal process the HSE document 'Guidance for the Safe Management of the Disposal of Explosives' at the 'eig2' link below is essential reading.



Suggested reading

<https://www.gov.uk/government/publications/dsa03-ome-part-2-in-service-and-operational-safety-management-of-ome>

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/892794/DSA_03_OME_PART_2_JSP_482_CH_27_Nov_19_-_mod_gov_uk.pdf

http://www.eig2.org.uk/wp-content/uploads/disposal_guide.pdf

<https://www.hse.gov.uk/comah/background/comah15.htm>

6.5 Quality Management Systems

Knowledge criteria: K15. The requirements of a Quality Management System and the key activities required by this (such as inspection and QA regimes) throughout the OME lifecycle.

6.5.1 Key activities

The Health and Safety executive has issued a number of high level 'Success statements'. The idea is that if each of the strategic criteria are met, there will be safe system in place in which explosive related accidents will not happen. The statements are divided into two categories – safety and security. They cover the following topics:

Safety provisions

There must be policies, procedures and systems in place to address the following:

- fire and explosion measures during manufacture and storage
- cross-cutting safety measures (i.e. measures that address more than one duty)
- staff Competence
- safe systems of work and working practices
- housekeeping
- mounds, traverses and barriers
- stock management
- segregating explosives presenting different likelihood of initiation
- segregating explosives operations from other activities
- safely transporting explosives on site
- preventing fires and explosions
- general precautions
- management arrangements
- cross-cutting safety precautions
- impact and friction
- pressure
- chemical incompatibility
- maintenance systems
- measures to limit the extent of a fire or explosion
- protecting people from the effects of a fire or explosion
- limiting the numbers of people in explosives areas
- engineering controls
- provision of personal protective equipment
- emergency procedures
- separation distances

6.5

- protecting explosives from sources of ignition
- naked lights and flames
- heat and temperature
- electrical, electrostatic and electromagnetic energy
- mechanical sparks
- discarding and disposal of explosives and decontamination of explosive-contaminated items
- discarding and disposal of explosives
- decontamination of explosive plant and equipment
- vacating an explosives site
- prohibitions relating to specific pyrotechnics substances and articles

Success statements - security provisions

There must be policies, procedures and systems in place to address the following:

- security requirements
- unauthorised Access
- prohibitions concerning the transfer of relevant explosives
- restrictions on prohibited persons
- unique identification of civil explosives
- attribution of manufacturing site codes for civil explosives
- records in relation to relevant explosives
- records in relation to civil explosives
- reporting loss
- prohibitions in relation to unmarked plastic explosives.



Suggested reading

<https://www.hse.gov.uk/explosives/statements-of-success.htm>

6.5 6.5.2 The Fundamentals of a Quality Management System

ISO 9001 builds on seven quality management principles

Customer focus

Meeting and exceeding customer needs is the primary focus of quality management and will contribute to the long-term success of your enterprise. It is important to not only attract but also retain the confidence of your customers, so adapting to their future needs is key.

Leadership

Having a unified direction or mission that comes from strong leadership is essential to ensure that everyone in the organization understands what you are trying to achieve.

Engagement of people

Creating value for your customers will be easier if you have competent, empowered and engaged people at all levels of your business or organization.

Process approach

Understanding activities as processes that link together and function as a system helps achieve more consistent and predictable results. People, teams and processes do not exist in a vacuum, ensuring everyone is familiar with the organization's activities, and how they fit together will ultimately improve efficiency.

Improvement

Successful organizations have an ongoing focus on improvement. Reacting to changes in the internal and external environment is necessary if you want to continue to deliver value for your customers. This is of paramount importance today when conditions evolve so quickly.

Evidence-based decision-making

Making decisions is never easy and naturally involves a degree of uncertainty, but ensuring your decisions are based on the analysis and evaluation of data is more likely to produce the desired result.

6.5 Relationship management

Today's businesses and organizations do not work in a vacuum. Identifying the important relationships you have with interested parties such as your suppliers – and setting out a plan to manage them – will drive sustained success.



Suggested reading

<https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100373.pdf>

<https://www.qualio.com/blog/the-9-core-elements-of-a-quality-management-system>

<https://quality.eqms.co.uk/blog/what-is-the-purpose-of-a-quality-management-system>

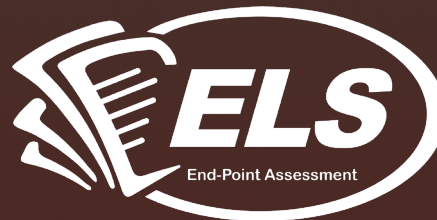
<https://global.oup.com/uk/orc/busecon/business/combe/student/mcqs/ch06/>

7. Conclusion

Remember that this study guide is not intended to provide all the answers. It is a collection of signposts to assist you in your studies and you should explore each subject fully to provide you with the underpinning knowledge you will need to be an effective Ordnance Munitions and Explosives Technician.

As your End Point Assessment Organisation it is our intention for you to be fully prepared for the assessments so please follow the suggested links and read as much as you can.

Good luck.



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