

# Oilfield Explosives Safety

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# Oilfield Explosives Safety

## 1 Scope

This publication is applicable to chemical explosives used as an energy source to do work in oil- and gas-producing operations, and more specifically to explosives intended for use inside a wellbore. The purpose of this recommended practice (RP) is primarily to prevent the inadvertent initiation of these explosives at the wellsite but also includes some recommendations for safe and secure storage and transportation and handling, as well as requirements for design and manufacture of selected equipment.

Additionally, there are five annexes included as part of this RP that provide important guidance:

- Annex A: Critical Safety Equipment for Operations;
- Annex B: Explosive Arming and Disarming Safety Critical Fundamentals—Electric Detonators;
- Annex C: Recommended Safety Equipment and Processes;
- Annex D: Stray Voltage Worksheet;
- Annex E: Wellsite Audit Checklist;

With the exception of Annex A, these annexes have been provided as reference material; they are not intended to replace the full text of this document but rather are provided as supplemental information. Operating companies and/or service companies may establish more comprehensive and exhaustive materials, as they deem appropriate for their particular situation(s).

While some chemicals intended for various nonexplosive applications can prove explosive when misused (such as lithium batteries), it is not the intent of this RP to address these materials.

## 2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies.

IME Safety Library Publication 20 <sup>1</sup>: *Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (Blasting Caps)*

MIL-DTL-23659F <sup>2</sup>, *Detail Specification: Initiators, Electric, General Design Specifications for*

U.S. DOL Title 29 <sup>3</sup>, CFR Part 1910.119, *Process Safety Management of Highly Hazardous Chemicals*

VG 95378-11:2014 <sup>4</sup>, *Electromagnetic Compatibility (EMC)—Electromagnetic Compatibility of Electroexplosive Devices (EED)—Part 11: Test Procedure for Proof of Immunity to Disturbance of EED Towards Pulses of Electrostatic Discharge*

<sup>1</sup> Institute of Makers of Explosives, 1212 New York Ave, NW, Suite 650, Washington, DC 20005, [www.ime.org](http://www.ime.org).

<sup>2</sup> U.S. Department of Defense, 1400 Defense Blvd, Washington, DC 20301, [www.everyspec.com](http://www.everyspec.com).

<sup>3</sup> U.S. Department of Labor, 200 Constitution Ave, NW, Washington, DC 20210, [www.dol.gov](http://www.dol.gov).

<sup>4</sup> German Institute for Standardization (DIN), Saatwinkler Damm 42/43, 13627 Berlin, Germany, [www.din.de](http://www.din.de)

## 3 Terms, Definitions, and Abbreviations

### 3.1 Terms and Definitions

For purposes of this document, the following terms and definitions apply.

#### 3.1.1

##### **adiabatic heating**

An increase in the temperature of a material without addition of heat.

EXAMPLE When the pressure of a gas is increased.

NOTE This can happen in pressure control equipment that has not been purged of air properly and pressure is introduced rapidly.

#### 3.1.2

##### **armed explosive device**

A loaded explosive device to which the detonator or initiating device has been secured mechanically and/or electromechanically and is ready for use.

#### 3.1.3

##### **arming**

The process of mechanically and/or electromechanically attaching a detonator or initiator to a loaded explosive device.

#### 3.1.4

##### **auto ignition**

A spontaneous activation or initiation of a device containing explosive components, caused by elevated temperature or the rapid application of pressure when a seal is breached.

NOTE Auto ignition can produce a variety of reactions including detonation and deflagration that can also be time dependent. Depending on the chemical reaction, the auto ignition can lead to an event whereby the rate of activation increases over time, because the detonation or deflagration occurs after the initial activation.

#### 3.1.5

##### **ballistic arming**

The act of mechanically configuring components in an explosive train such that initiation of the detonator or igniter will allow initiation of the next explosive component in the train to occur.

#### 3.1.6

##### **bullet perforating gun**

A perforating gun using propellant-driven hardened steel bullets to penetrate the casing, cement, and formation.

NOTE Their use has been largely supplanted by jet perforators, but they are still in limited use.

#### 3.1.7

##### **cable safety circuit**

An integral portion of the electric wireline unit that opens the electric wireline cable to prevent the application of current and resistively shunts the conductor to the cable armor.

#### 3.1.8

##### **cathodic protection system**

A method of corrosion control utilizing an impressed DC current, making the protected structure a cathode, thus minimizing or eliminating corrosion.

**3.1.9****chemical cutter**

A downhole tool used to sever tubular goods in pipe recovery operations, utilizing the chemical reaction of bromine trifluoride ( $\text{BrF}_3$ ) with ferrous metals to sever well tubulars.

**3.1.10****critical safety equipment**

The minimum equipment required to conduct an explosives operation safely.

NOTE Refer to Annex A.

**3.1.11****detonator**

An initiating device that produces a strong shockwave output to detonate a secondary explosive. See electric detonator and percussion detonator.

**3.1.12****detonator safety tube**

A tubular vessel used to contain the detonator during electric arming, designed to contain the fragments and most of the blast, should the detonator inadvertently function.

**3.1.13****downhole power source**

Any downhole equipment that could potentially transmit electrical power unintentionally to an explosive device before or after intentionally attempting to fire it.

**3.1.14****downhole tractor**

A motive conveyance system powered by electric or electro-hydraulic means to deploy tools, equipment, and perforating guns in horizontal or highly deviated wells.

**3.1.15****drop bar initiation**

An initiation system for TCP systems utilizing a gravity drop bar to initiate a percussion detonator.

**3.1.16****electric arming**

The electrical attachment of an electro-explosive device to a source of electrical power prior to energizing the circuit.

**3.1.17****electric detonator**

A detonator designed to be initiated by electric energy.

**3.1.18****electrically armed before ballistically armed****EBBA**

The electrical attachment of an electro-explosive device to a source of electrical power, prior to the mechanical attachment or alignment of all the elements of an explosive train.

**3.1.19****essential safety systems**

Those systems that are critical to maintaining a safe working environment as well as critical for the safe completion of explosives operations.

**3.1.20****explosive materials**

A solid or liquid substance or mixture of substances capable of undergoing a rapid chemical reaction, without the participation of external reactants such as atmospheric oxygen.

**NOTE** Explosive materials are generally classified as low or high explosives. Low (or deflagrating) explosives are used primarily for the generation of gas to do useful work. The reaction rate is subsonic. High (or detonating) explosives are used in articles such as shaped charges, severing tools, and jet cutters, and produce extremely powerful shock waves to do useful work. The reaction rate is supersonic.

**3.1.21****explosive trainee**

A person directly involved in explosives operations who has successfully completed the training described in 15.3.2 and who works under the direct supervision of an explosive user.

**3.1.22****explosive user**

A person who has successfully completed the training described in 15.3.3.

**3.1.23****explosive user in charge****EUIC**

The explosive user responsible for all explosive operations at the wellsite and who has successfully completed the training described in 15.3.4.

**NOTE** Responsibilities include the safe arming and disarming of explosive systems.

**3.1.24****failure mode and effects analysis****FMEA**

A systematic method using inductive reasoning to analyze single points of failure and their effects or consequences on the system.

**3.1.25****firing windows**

The preprogrammed parameters established in memory-type trigger tools, which define an upper and/or lower limit for each of the applicable parameters.

**NOTE** The parameters can include time, temperature, pressure, acceleration, or combinations thereof. The trigger is in safe mode until wellbore conditions are within the firing windows. When conditions for all firing windows have been met, the tool will apply power to an electric initiator or open a path for well fluid to act on a percussion detonator.

**3.1.26****formation tester**

A tool run on wireline for the purpose of pressure measurement and the extraction and identification of formation fluid samples.

**3.1.27****gun loading area**

A cordoned off area at a worksite or within a gun loading shop used for the loading/downloading and preparation of explosive components, such as those used in perforating guns.

**3.1.28****gun loading shop**

A fixed or mobile workshop used for the loading/downloading and preparation of explosive components, such as those used in perforating guns.

**3.1.29****HazMat employee**

Any person that performs any function subject to the hazardous materials regulations involving the transportation of hazardous materials in commerce.

EXAMPLE Packaging, offering for transport, signing and completing HazMat goods declaration.

NOTE Synonymous with dangerous goods employee, a phrase used internationally.

**3.1.30****high-volume/high-pressure pump**

A pump that produces high flow rates and is capable of producing high pressures.

**3.1.31****hydraulic and pressure actuated firing head**

An initiation system utilizing hydraulic or downhole pressure to percussively initiate an explosive system.

**3.1.32****igniter**

An initiating device that produces a deflagration or flame output leading to ignition of a propellant.

NOTE Used in setting tools, sample takers, chemical cutters, etc.

**3.1.33****independent third-party organization****ITPO**

An organization able to demonstrate the competence and capability to test and certify equipment to specific design criteria and the manufacturer's specifications and claims.

**3.1.34****initiator**

A detonator or an igniter, used to begin a chemical or mechanical process such as an explosion, chemical release, or pyrotechnic initiation.

**3.1.35****isolation barrier**

An electrical or ballistic feature that blocks the transmission of electrical or explosive energy to the next component in the tool string.

**3.1.36****jet cutter**

A downhole explosive device used to sever well tubulars in pipe recovery operations.

NOTE A jet cutter uses the action of an explosive shaped charge to generate a radial cut, producing separation of the tubular.

**3.1.37****linear cutter**

A downhole explosive device used to sever well tubulars in pipe recovery operations utilizing the action of a linear explosive shaped charge to produce an axial cut across a tool joint, resulting in separation of the tubulars at the tool joint.

**3.1.38****loaded explosive device**

A mechanical device to which the explosive components have been inserted or attached, with the exception of the initiating device (see unarmed).

NOTE Sometimes used interchangeably with charged explosive device.

**3.1.39****lockout**

A positive mechanical locking device used to prevent the inadvertent energizing of equipment. Examples are key switches and single point safety switches.

**3.1.40****low-volume/high-pressure pump**

A pump that produces low flow rates, but is capable of producing high pressures.

**3.1.41****lubricator**

A device mounted on the wellhead used to introduce tool strings, chemicals, instruments, and perforating guns into a well under pressure.

**3.1.42****management of change****MOC**

A change control process that is implemented to safely manage variation in people, organization, practices, procedure, equipment, or materials in the approved plan or guideline.

**3.1.43****maximum allowable working pressure****MAWP**

The pressure that is not to be exceeded during a particular operation.

**3.1.44****misfire**

The failure of an armed explosive device to properly function (e.g. detonate) when subjected to the proper impulse for firing, either mechanically or electrically.

**3.1.45****misrun**

The failure to achieve the objective of a run into the well, which may or may not involve a misfire.

**3.1.46****no-fire**

The maximum stimulus level at which an initiator will not fire with a probability of 0.999 at a confidence level of 95 %, as determined by test and computation.

**3.1.47****no-fire current**

The maximum DC current applied for 5 minutes at which an initiator will not fire with a probability of 0.999 at a confidence level of 95 % as determined by test and computation.

**3.1.48****no-fire voltage**

The maximum DC voltage applied for 5 minutes at which an initiator will not fire with a probability of 0.999 at a confidence level of 95 %, as determined by test and computation.

**3.1.49****non-resistorized hotwire detonator**

A detonator with a low resistance bridge wire used to initiate a primary explosive.

**NOTE** These devices typically have an overall resistance of one to two ohms. These devices shall not be used for oilfield explosive operations.

**3.1.50****non-standard rig down procedures**

Rig down procedures that are not usually followed when retrieving wireline tools from the wellbore.

NOTE This can occur during abnormal operations, or when it is suspected that a ballistic device did not detonate (e.g. disarming an ungrounded perforating gun on surface).

**3.1.51****pentaerythritol tetranitrate****PETN**

A highly explosive organic compound belonging to the same chemical family as nitroglycerin and nitrocellulose.

**3.1.52****percussion detonator**

A detonator designed to be initiated by mechanical impact.

**3.1.53****phase transition temperature**

The temperature at which the onset of a change in the crystal structure of a material takes place.

**3.1.54****power safe device****PSD**

A device installed on a wireline tool string between the wireline and the detonator, which permits downhole arming and disarming of the detonator.

**3.1.55****pre-determined wellsite test pressure**

The pressure at which the equipment is tested, prior to introducing wellhead pressure to the pressure control equipment string.

NOTE This is done to ensure the equipment will function properly when wellhead pressure is applied.

**3.1.56****primary explosive**

A highly sensitive explosive material or pyrotechnic mixture that is more sensitive than PETN to flame, friction, impact, or electrostatic discharge.

**3.1.57****quick test safety sub**

A component of the pressure control equipment that breaks apart and allows for the pressure testing of that specific connection, thereby alleviating the need for a full pressure test of the pressure control equipment that has remained unbroken.

NOTE This is accomplished by applying hydrostatic pressure equal to that of the initial wellsite pressure test between two elastomeric seals.

**3.1.58****regulations**

Any prescribed local, state, or federal rule or ordinance pertaining to the subject at hand.

**3.1.59****safety meter**

A test instrument with built-in current limiting features that is approved for use in measuring electrical resistance or conductivity in an explosive blasting circuit.

NOTE Commonly referred to as blasting ohmmeter, blasting multimeter, blasting galvanometer.

**3.1.60****safety sub**

The top section of the gun below the firing head that does not contain shaped charge perforators.

NOTE Safety subs are used in TCP gun strings.

**3.1.61****secondary explosive**

An explosive material or pyrotechnic mixture that is equivalent to, or less sensitive than pentaerythritol tetranitrate (PETN) to flame, friction, impact, or electrostatic discharge.

**3.1.62****select fire perforating gun system**

A method of sequentially firing a number of perforating guns in a gun string after relocation of the gun string to perforate a number of intervals in a single run.

**3.1.63****setting tool**

A mechanical downhole device activated by an electro-explosive initiator in conjunction with a gas-generating propellant charge.

**3.1.64****severing tool**

A downhole tool used to sever thick-wall well tubulars in pipe recovery operations.

**3.1.65****sidewall sample taker**

A ballistic or mechanical tool used to extract and retrieve formation core samples from the sidewall of the wellbore.

**3.1.66****single point safety switch****cable safety switch**

A single keylock safety switch with a properly secured single key that isolates all power from the wireline prior to attachment of an explosive device.

**3.1.67****spudding**

The intentional act of repeatedly lowering a tool string rapidly to overcome, dislodge, move, or displace an obstruction.

**3.1.68****surface pressure control equipment**

Equipment that contains well fluids at the surface and prevents their escape into the surrounding environment.

NOTE 1 Typically, surface pressure control equipment consists of a permanent structure such as a wellhead or surface tree.

NOTE 2 Also referred to as a well-barrier element.

**3.1.69****switch**

A device used to selectively route power to a particular initiator.

**3.1.70****thermal decomposition**

A temperature-driven chemical reaction due to thermal exposures, which can introduce out-gassing and heat.

**3.1.71****thermal runaway**

A self-sustained thermal decomposition or reaction that is generally not possible to stop, even when the heat source is removed. Explosion and detonation hazards exist in thermal runaway situations.

**3.1.72****thermally overexposed explosives**

Explosives that have been exposed to temperatures above the manufacturer's published time-temperature exposure limits.

**3.1.73****top drive**

A hydraulic or electric motor driving the rotary motion of the tool string from the swivel.

NOTE Used in place of a rotary table, kelly, and kelly bushing.

**3.1.74****trigger**

A downhole electronic device containing an integral power source which, under a specific set of conditions or stimuli, will apply power to an electric initiator or open a path for well fluid to act on a percussion detonator.

**3.1.75****unarmed**

A loaded explosive device without an initiating device attached.

**3.1.76****unintentional pull-off**

The accidental separation of the wireline cable from the fishing neck that is affixed to downhole wireline tools.

**3.1.77****wellhead pressure control equipment****WHPCE**

Additional equipment connected to the well or tree used during well intervention under pressure.

EXAMPLE Wellhead adapter flange, wireline valve, pump-in sub, quick test safety sub, tool trap, lubricator, tool catcher, ball check valve, grease injection head, stuffing box, and line wipers.

**3.1.78****wireline safety ball valve**

A ball valve designed for high-pressure conditions that can hold pressure from both directions.

**3.2 Symbols and Abbreviated Terms**

|     |                                                                                      |
|-----|--------------------------------------------------------------------------------------|
| ac  | alternating current                                                                  |
| ATF | (Bureau of) Alcohol, Tobacco, Firearms (and Explosives), officially designated BATFE |
| AWG | American Wire Gauge                                                                  |

|                            |                                                                  |
|----------------------------|------------------------------------------------------------------|
| BHA                        | bottom hole assembly                                             |
| BrF <sub>3</sub>           | bromine trifluoride                                              |
| CO <sub>2</sub>            | carbon dioxide                                                   |
| CO                         | carbon monoxide                                                  |
| CWOP                       | complete well on paper                                           |
| dc                         | direct current                                                   |
| EBBA                       | electrically armed before ballistically armed                    |
| ERG                        | Emergency Response Guidebook                                     |
| ESD                        | electrostatic discharge                                          |
| ETD                        | electronic time delay                                            |
| EUIC                       | explosive user in charge                                         |
| FMEA                       | failure mode and effects analysis                                |
| H <sub>2</sub> S           | hydrogen sulphide                                                |
| HMX                        | octogen or octohydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine      |
| HNS                        | hexanitrostilbene                                                |
| I                          | current                                                          |
| IEEE                       | Institute of Electrical and Electronics Engineers                |
| IME                        | Institute of Makers of Explosives                                |
| ITPO                       | independent third-party organization                             |
| MOC                        | management of change                                             |
| PETN                       | pentaerythritol tetranitrate                                     |
| PHMSA                      | Pipeline and Hazardous Materials Safety Administration           |
| POOH                       | pull out of hole                                                 |
| PSD                        | power safe device                                                |
| PSM                        | process safety management                                        |
| PTD                        | pyrotechnic time delay                                           |
| R                          | resistance                                                       |
| RDX                        | hexogen or hexahydro-1,3,5-trinitro-s-triazine                   |
| RF                         | radio frequency                                                  |
| RP                         | recommended practice                                             |
| SDS                        | safety data sheet                                                |
| SIT                        | system integration test                                          |
| SLP                        | The Institute of Makers of Explosives Safety Library Publication |
| SWA                        | stop work authority                                              |
| t                          | time                                                             |
| T                          | temperature                                                      |
| TCP                        | tubing-conveyed perforating                                      |
| V                          | volts                                                            |
| WHPCE                      | wellhead pressure control equipment                              |
| $\beta \rightarrow \delta$ | HMX crystalline phase transition                                 |

## 4 General

### 4.1 Application

Operating companies and/or service companies may establish more stringent and additional policies and procedures, as they deem appropriate for their particular situation(s).

### 4.2 Human Factors

Oilfield explosives safety incident information collected by the Independent Oilfield Forum for Advancement of Well Perforation Technology, [www.perforators.org](http://www.perforators.org), indicates that human error is the principle cause of accidents and incidents involving explosives. While API does not endorse any particular websites, there are several websites that include explosives incident databases. To promote safety and safe operations, users are encouraged to anonymously report incidents and near misses, after seeking the advice of their company's legal counsel. Two such sites are:

<http://www.perforators.org/perforating-safety/incident-list/>

<https://www.safex-international.org/safex/page-incident-information.html>

Persons who use explosives on a regular basis over a long period of time shall guard against becoming complacent and taking short-cuts in the required operations and procedures. Established procedures shall be implemented to prevent explosive accidents. It is recognized that in extremely rare and unique circumstances, deviation from these established procedures may be required for operations to progress and thus can be outside the scope of this standard. Such procedures shall be developed and implemented using process safety management (PSM) or other formal management of change (MOC) protocols to ensure that the new procedure satisfies the level of safety intended by the established procedure it replaces, and that the new procedure is properly implemented with the full knowledge and understanding of all relevant parties. This includes, but is not limited to crew rest requirements and arming and disarming procedures.

### 4.3 Attitude

The total commitment of all individuals and their respective companies is necessary to achieve the safe use of oilfield explosives. Additionally, companies are expected to maintain the same high standard of explosives safety irrespective of their geographical work locations.

### 4.4 Technical Innovation

New technologies will be developed that offer opportunities for improved safety and increased operational efficiency. These may fall within the intended scope of this RP but may not be specifically addressed in the current version. Any proposed changes to current procedures as a consequence of new technology shall include a demonstrated safe alternative. This shall include a rigorous review of potential failure points and their consequences (such as a failure mode and effects analysis [FMEA]), validated by an independent third-party organization (ITPO). Operation under such a change shall require prior review by and agreement between the service company and operating company. The base knowledge of the new technology shall be communicated to the service company by the manufacturer or engineering company.

The ITPO shall certify that the specified equipment, if used in the manner and environment described by the manufacturer, meets the stated requirements. The ITPO shall provide an assessment report detailing its findings and opinion. This report shall be peer-reviewed. The assessment report's author and reviewer shall hold an accreditation from a reputed national engineering body or equivalent (e.g. C.Eng in the UK, Eur.Eng in Europe, PE by state in the U.S.). The ITPO shall demonstrate its independence by having no directors or other controlling elements in common with the manufacturer of the specified equipment.

## 5 Transportation and Security for Oilfield Explosives

### 5.1 General

Explosives and hazardous materials are attractive to those with criminal intent. It is therefore recommended that each user establish consistent security measures. These should be routinely applied and should be adjusted as appropriate to reflect the threat levels reported by governments or other agencies. However, enhanced security measures may be required when operating in specific geographical areas or markets identified by such agencies, and each user should prepare action plans to be activated in the event of increased threat and in the event of an actual incident.

Federal, state, and local regulations pertaining to the security of explosives products must be followed in all cases. In the absence of local laws and regulations, the details provided in this section are recommended as best practices. For additional reference material, refer to IME SLP 27 <sup>[1]</sup>, IME SLP 17 <sup>[2]</sup>, and the ATF Publication 5400.15 <sup>[3]</sup>.

The responsible party for defining and implementing transportation and security measures may be the user (licensed possessor of the explosives) or their designee, or a government agency as designated by federal, state, or local law. The responsible party can change depending on the level of security and when the custody of explosive materials changes in transit.

### 5.2 Storage

#### 5.2.1 General

Explosives shall be properly secured at all times, and under the control of a person with the proper authority to possess explosives.

The purchase, import/export, storage, use, and disposal of explosive materials requires the proper licenses and permits from the appropriate governing authorities in which operations are conducted.

The loss or theft of explosives shall be reported in compliance with prevailing law.

#### 5.2.2 Packaged Explosives Storage

Except when in use, transport, or the operating process, explosives must be kept in storage facilities meeting the applicable government regulations. Storage regulations cover the following requirements: magazine construction, signage, separation distances, quantity limits, security, housekeeping, licensing, and inventory recordkeeping. IME SLP 3 <sup>[4]</sup> and IME SLP 17 <sup>[2]</sup> recommend that all explosives be stored in anti-theft magazines under lock and key and that accurate records be maintained of the explosives in storage.

Alternative storage methods may be authorized by federal, state, or local government agencies for specialty explosives, such as loaded perforating guns.

Indoor and outdoor magazines located at service company facilities and outdoor magazines located either on land or on offshore rigs shall be used for longer-term storage of explosives, such as overnight or unattended storage. Explosives should remain in their original packaging while not in use.

Day magazines should be used for short-term (i.e. duration of the job) storage of explosives intended for ready use in loading perforating guns and other explosive devices. The number of explosives stored for ready use in day magazines should be kept at a minimum. Day magazines shall be attended (within the field of vision of a responsible party), as these are generally smaller and built to a lower construction standard than magazines used for unattended storage.

Initiators and primary explosives shall be stored in a separate magazine from secondary explosives.

Explosive materials should be removed from storage, prepared for shipment, and transported to the destination without unnecessary delay. Upon arrival, they shall be unloaded into proper storage or prepared for use.

### 5.2.3 Loaded Perforating Gun Storage

Loaded perforating guns shall be secured in a way that will prevent removal of contents and unauthorized movement of the guns.

Perforating guns in the process of being loaded or assembled at the wellsite may be held inside a gun loading area; perforating guns loaded and assembled in advance may be stored and secured outside in shipping baskets or on racks or on trailers that meet applicable regulatory requirements.

In the U.S., ATF allows loaded perforating guns to be stored outside of a locked magazine under the conditions specified in ATF Ruling 2010-7 [5]. However, local jurisdictional requirements can supersede the use of this ruling.

It is recommended that both end caps be vented to prevent pressure build up inside the gun if exposed to a fire.

### 5.2.4 Magazine Key Control

Keys to the magazines should be controlled through the explosive user in charge (EUIC). In those situations where more than one party is responsible, there should be a lockout/tag-out or similar procedure for key control. Only those authorized to access magazines shall be granted keys; for other than day boxes, there shall be a record of all individuals that have entered or opened magazines.

### 5.2.5 Recordkeeping

Accurate inventory control is an essential safety and security requirement, and can be a regulatory requirement as well.

Recordkeeping shall employ a method of keeping track of explosives in all phases of their lifecycle: receipt, storage, consumption, and disposal. This is often called “cradle to grave” tracking. The recordkeeping shall include loaded perforating guns and explosives that have “run wet” due to fluid leakage or misfire. Inventory verification should be completed at the time of every crew change.

Records shall be retained for either a minimum of five years from the date of transaction or the retention period specified by local requirements and regulations.

Hardcopy records are the norm, however in some countries computerized recordkeeping is allowed provided they meet certain criteria such as given in ATF Ruling 2007-1 [6]. The European Union (EU) enacted regulations requiring the identification and traceability of explosives for civil uses (see European Commission Directive 2008/43/EC, amended by Directive 2012/4/EU [7]). These directives require record retention for 10 years and require most individual items to have unique, readable, and scannable markings for identification and traceability.

## 5.3 Transportation

### 5.3.1 General

The transportation of explosives must be conducted in compliance with the local, national, or international dangerous goods transport regulations in effect for the mode of transport.

For example, explosives regulations for road and water transport in the U.S. are published by the Department of Transportation in 49 *CFR*, Parts 105–180 [8]. In Canada, explosives shipments by road are regulated through Transport Canada’s regulations published in the Transport of Dangerous Goods Regulations. Europe’s regulations for transporting explosives by road (European Agreement concerning the International Carriage of Dangerous Goods by Road [ADR]) and rail (Regulation Concerning the International Carriage of Dangerous Goods by Rail [RID]) are the

basis of the transport regulations for each European State. The UK implements the ADR/RID regulations through the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 and the Placing on the Market and Supervision of Transfers of Explosives Regulations 1993.

International air freight of explosives is regulated under the International Civil Aviation Organization's Technical Instructions for the Safe Transport of Dangerous Goods by Air regulations, which are implemented by most air carriers through the International Air Transport Association's Dangerous Goods Regulations. International water shipments of explosives are regulated under the IMO IMDG Code [9].

Security of explosives in transit to and from the well is critically important. Explosives are more vulnerable to loss or theft while in transportation than when properly stored at the base or wellsite. Implementing sound containment and security practices reduces vulnerability to loss or theft. The risk level for transporting explosives shall be assessed prior to beginning the transport journey. Depending on the current political or social climate, additional transport and security controls may be necessary.

### 5.3.2 Transportation Controls

All explosives shall be properly classified, packaged, marked, and labeled in accordance with the regulations under which they are being transported. The marks and labels on each explosives packaging and perforating gun body shall include the proper shipping name, UN number, net explosive weight, name and address of the shipper and consignee, and the hazard class label.

Transport documents shall accompany the shipment, such as the shipping paper, emergency response information and, if applicable, government authorizations or route plan. Moreover, in some situations transport vehicles may be required to display placarding depending on local rules and regulations and the HazMat being carried.

Loaded perforating guns should be contained completely within the bed of the truck, trailer, or tool rack/basket or in racks attached to the truck. The guns shall be secured to prevent their rolling from side to side during transport. At a minimum, the guns should be held in place by a strap or chain every 2 m (6 ft) of gun length, with at least two straps or chains. The guns should be locked to the truck, trailer or rack through the use of chains and locks or locking bars, or locked in the closed compartment of the truck. Trailers left at the wellsite should be equipped with an anti-theft device. Due to the design of some transport racks or baskets, it may be necessary to use alternate yet equivalent security methods.

Each shaped charge, if not completely enclosed in glass or metal, shall be fully protected by a metal cover after installation in the gun. Moreover, it is recommended that vented end caps be used on each end of a gun.

Packaged explosives shall remain in their UN-certified outer packaging (i.e. manufacturer's packaging) unless an alternative packaging is authorized by the country in which they are being transported. The use of substitute or otherwise unauthorized packaging in the transport of explosive materials is illegal. Personnel involved in explosives transportation such as packaging, offering for transport, or completing transport documents, shall be deemed as Hazmat employees and correspondingly trained in accordance with applicable local or international regulations.

To enhance security, packaged explosives should be carried inside a locked compartment that is an integral part of, or permanently mounted to, a truck or trailer or carried in a locked transportation or storage container, such as a magazine that may be used for storage at the wellsite. To prevent the loss or theft of the container, it should be secured to the vehicle or trailer using a chain and lock. Containers that are not permanently attached to a vehicle are considered overpacks and shall be marked and labeled as required for any overpack.

A responsible party for the explosives should observe the loading/unloading process at both the wellsite and shipping dock. This person shall verify that explosives are unloaded/loaded correctly and shall be responsible for verifying explosive type, number, and packaging. Explosive materials staged at a marine dock should be secured in a designated area in conformance with local regulations.

### 5.3.3 Route Planning

Drivers of vehicles transporting explosives shall obtain all required documents and should establish route plans, including possible alternate routes, before departing on the journey. The route(s) should consider transport risk and should comply with local or national routing requirements. Tunnels, bridges, and high-population areas should be avoided. Stops of any significant length while en-route should be minimized. Routes, departure times, and planned stops should vary from one journey to the next.

Shipment integrity should be confirmed at each opportunity. Drivers should not discuss information related to the load or the journey with unauthorized persons. After any break in the journey, a walkaround shall be conducted to check the load to confirm shipment integrity. As a best practice, refer to IME SLP No. 27 <sup>[1]</sup>.

Vehicles transporting explosives should be parked in safe, well-lit, and designated parking locations. When possible, parking locations should be next to a wall, fence, or other stationary object to enhance security.

### 5.3.4 Communication

All vehicles transporting explosives shall be equipped with a means of two-way communication and, if possible, two-way global positioning systems (GPS) to contact company and law enforcement personnel while in transit. The route plan, in accordance with 5.3.3, should be communicated prior to departure, and regular communication with the company should be maintained, including notification of delays and arrival at destination.

When shipping by common carrier, a notification process should be established between the carrier and shipper so that the shipper is notified of any loss, damage, or theft event of the explosives while in the care of the carrier.

### 5.3.5 Breakdowns and Incidents

In the event of mechanical problems, the driver shall immediately contact the company and call for necessary third-party help. If involved in a vehicle accident, the driver shall contact law enforcement and their company. In both instances, a responsible person shall remain with the vehicle while it contains explosives. If fire threatens the cargo area containing explosives, withdraw personnel immediately and follow instructions from emergency responders. Do not fight explosives fires.

**NOTE** The Emergency Response Guidebook, Guides 112 and 114 <sup>[10]</sup>, contains additional information about potential hazards, protecting public safety, and emergency response.

Drivers of vehicles containing explosives should not stop to render aid to other vehicles. These situations should be reported to local emergency responders or law enforcement.

### 5.3.6 Common Carrier Evaluation

Only common carriers operating in compliance with local and national regulations should be chosen to transport explosives. This includes shipments to and from ports of entry and docks. To evaluate a common carrier's ability to transport explosives in a safe, secure, and legal manner, a company can check numerous sources, including national databases for the transport mode (e.g. road, water, air) to ascertain if they have the correct operating authority and required level of insurance. The carrier should be assessed on the following if an explosives shortage or damage occurs:

- a) the background checks conducted on their drivers;
- a) dangerous goods transportation training program;
- a) security measures implemented at the carrier's warehouses or dock and the procedures followed.

### 5.3.7 Return of Excess Explosive Material

All explosives shipments from the wellsite to the base must be conducted in full compliance with the applicable transport regulations.

Packaged product shall still be packaged in its UN-certified packaging, or alternate outer packaging authorized by the country in which it is being transported. Loaded perforating guns also shall be properly marked and labeled. Shipping papers shall be properly prepared for the explosives shipment by the HazMat employee.

Since the UN classification of explosives assumes that the explosive material is in original condition, operational challenges occur when there is a need to ship explosives that have been exposed to wellbore conditions, such as a misfired perforating gun. Assuring the condition of such products can be difficult at the wellsite. Excess explosive material that has been exposed to normal wellbore operating conditions and which, on visual inspection, appears to be in normal condition can be transported using usual procedures.

## 5.4 Disposal/Recycling of Spent Perforating Guns

Spent perforating gun bodies and firing heads shall be evaluated to ensure they do not contain any explosive material, prior to being shipped to a disposal or recycling facility.

The following steps shall be taken for every spent perforating gun, prior to shipment to a disposal or recycling facility.

- a) Inspect each gun after perforating to determine if all charges have detonated and compare this information with the load sheet. If there are any charges not accounted for, physically examine the gun to determine the cause and ensure any remaining explosives are addressed appropriately. If unfired explosive components or material are present, then the activities described in 10.6 shall be followed.
- b) Once it is confirmed that the spent perforating gun does not contain any explosive devices, this should be communicated to the disposal/recycling facility. Identify each gun that may have an unperforated scallop/port and advise the disposal/recycling facility of the reason, such as blank section of the gun, shot density or scallop not perforated but accounted for otherwise.

## 6 Surface Equipment

### 6.1 Introduction

This section describes recommended features and minimum requirements for surface equipment used at the wellsite during operations involving explosive devices. Critical safety equipment shall be used in accordance with Annex A.

### 6.2 Electrical Power

When using an electric wireline unit, there shall be a main power switch in the unit to control all power to the shooting system.

### 6.3 Cable Safety System

#### 6.3.1 Location

The cable safety circuit should be inside the electric wireline unit.

### 6.3.2 Safe Mode

When in safe mode, the cable safety circuit shall open all wireline cable conductors from the electric wireline unit circuits and all wireline cable conductors shall be shunted to armor through a nominal resistance of 5000 ohms. This resistance shall be provided by a minimum of two similar resistors in parallel with the net resistance being 5000 ohms.

### 6.3.3 Lockout

The cable safety circuit shall be equipped with a lockout feature when in safe mode. This may be achieved with a keylock safety switch.

### 6.3.4 Electrical Continuity

Electrical continuity shall exist from the cable safety circuit to the cable conductor, and the wiring providing this continuity shall have mechanical protection.

## 6.4 Firing System

At least three deliberate actions shall be required to fire the explosive device. At least one action shall require the use of two hands. At least one action shall involve movement of a spring-loaded switch which is normally biased to the off (safe) position.

## 6.5 Communication System

There shall be effective communications between the electric wireline unit and those areas where explosive devices are armed or disarmed.

## 6.6 Inspection and Maintenance

Equipment shall be inspected and maintained by qualified personnel in accordance with the manufacturer's recommendations and specifications.

## 6.7 Electrical Grounding/Bonding System

### 6.7.1 General

A grounding system shall positively electrically bond the electric wireline unit to the casing/wellhead/blowout preventer and the rig (sheave support system).

### 6.7.2 Cable Construction

Bonding cables shall be insulated, stranded copper conductor. Cable size shall be 10 AWG (2.5 mm / 0.102 in.) or greater.

### 6.7.3 Attachment

- a) Bonding cables shall be attached to the rig and wellhead/casing using "C" clamps, firmly secured by a pin-type screw fitting having a sharpened point.
- b) A positive electrical bond shall be provided between the electric wireline unit and the cable armor.

## 6.8 Electric Detonator Safety Tube

The electric detonator safety tube shall be a heavy-walled tube with one end closed and a cover at the other end. Each tube shall be designed to contain the fragments of the detonator in use and to mitigate the blast. In the event a blast occurs inside the electric detonator safety tube, the safety tube shall be permanently removed from service.

## 6.9 Electrical Testing Instruments

### 6.9.1 Electric Initiator Testing Instruments

The only instruments to be used when testing electric initiators and associated circuitry shall be those specifically designed and/or qualified for use with explosive devices. The test current from the meter used to perform resistance checks shall not exceed 25 mA.

If the initiation system has a critical no-fire parameter other than current, the related explosive circuit tester shall have its output limited to 10 % of that critical parameter. In no case shall current output exceed 25 mA.

### 6.9.2 Electric Switch Surface Testers

Surface testers shall be battery-powered devices for use before the cable head is attached. If rechargeable batteries are used, the tester shall not function when connected to an alternating current (ac) power line for charging.

Testers shall not be capable of activating a 50 ohm resistorized initiator. Testers shall be designed with no single point of failure that allows power to the initiator. Switch surface testers shall be resistant to interference from:

- a) electromagnetic interference (e.g. radio frequency [RF], etc.);
- b) electrostatic discharge (ESD);
- c) stray voltages.

Testers shall be inherently safe by design—the output of the tester shall be limited such that it cannot activate the initiator.

For example, surface testers shall have their output limited to 10 % of the initiator's critical no-fire parameter. When the explosive system has a critical no-fire parameter other than current, the related surface tester shall have its output limited to 10 % of that critical parameter. In no case shall current output exceed 25 mA.

The tester shall be evaluated against these requirements by an ITPO. The evaluation should include a FMEA.

## 6.10 Explosives Warning Signs (Land Operations)

Explosives warning signs shall include the words "DANGER EXPLOSIVES," or equivalent. In operations involving electric detonators, warning signs should also include the words "TURN OFF RADIO TRANSMITTERS," or equivalent. The explosives warning signs should be durable and should be visible and legible from a distance of 15 m (50 ft). Refer to 10.1.1 for additional information.

## 6.11 Chemical Cutter

Chemical cutters shall have a sleeve (also known as a protective sleeve), designed and approved by the chemical cutter manufacturer that shall:

- a) cover the severing head (independent of anchor body) for as long as the chemical cylinder is attached to it;