

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 ¹: *Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (Blasting Caps)*

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

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

VG 95378-11:2014 ⁴, *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*

¹ Institute of Makers of Explosives, 1212 New York Ave, NW, Suite 650, Washington, DC 20005, www.ime.org.

² U.S. Department of Defense, 1400 Defense Blvd, Washington, DC 20301, www.everyspec.com.

³ U.S. Department of Labor, 200 Constitution Ave, NW, Washington, DC 20210, www.dol.gov.

⁴ German Institute for Standardization (DIN), Saatwinkler Damm 42/43, 13627 Berlin, Germany, 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 (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 ₃	bromine trifluoride
CO ₂	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 ₂ 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, 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 ^[1], IME SLP 17 ^[2], and the ATF Publication 5400.15 ^[3].

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 ^[4] and IME SLP 17 ^[2] 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 (EUIIC). 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 ^[1].

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 ^[10], 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;

- b) cover the anchor body (independent of severing head) as soon as it is connected to the cable, while on surface and during the retrieval until pressure has been bled off;
- c) be made of aluminum;
- d) be of sufficient thickness to provide effective deflection or containment;
- e) be open on both ends;
- f) have an ID adequate to pass over the severing head or anchor body; and
- g) have a means for positively securing to the severing head or anchor body.

Field modifications shall only be made to chemical cutters if written approval has been received from the equipment manufacturer.

6.12 Pressure Testing of Wellhead Pressure Control Equipment

6.12.1 Exposure of Explosive Devices to Pressure

Exposure to pressure has the potential to cause explosive devices to auto-initiate. Wellsite pressure testing of wellhead pressure control equipment (WHPCE) should be completed prior to inserting any explosive device into the WHPCE. WHPCE shall never be tested to a pressure exceeding its maximum allowable working pressure (MAWP). MAWP is the pressure at which the equipment was tested at the wellsite prior to the job. Every time the pressure control equipment is disconnected, the MAWP is reset to 0 psi until the connection that was broken is retested.

6.12.2 Use of Quick Test Safety Subs

A quick test safety sub can be used to retest the integrity of the breakout connection of the WHPCE. This device safely and effectively facilitates the retesting of the one connection regularly broken in the WHPCE string following the introduction of the explosive device. The design of this device safely applies hydrostatic pressure only between two elastomer seals, avoiding the application of hydrostatic pressure to the explosive device, the WHPCE, or both.

Alternatively, a wireline safety ball valve may be used, which will also eliminate the need to pressurize the explosive device. When the ball valve is opened, the flow path through the valve has a smooth ID allowing the travel of wireline tools through it.

6.12.3 Pressure Testing Equipment Containing Explosive Devices

6.12.3.1 General

Before proceeding, the pressure-testing procedure shall be reviewed by all personnel involved in the pressure control and perforating operation.

Caution—Exposure to pressure has the potential to cause explosive devices to self-initiate.

Although not recommended, if the equipment outlined in 6.12.2 cannot be used and the WHPCE is tested with an explosive device inside, special precautions shall be taken.

Explosive devices shall not be exposed to any greater pressure for any extended period of time than is necessary prior to their deployment into the well. The explosive device shall be deployed into the well immediately after the pressure test has been completed.

The WHPCE should be loaded with a nonvolatile liquid prior to testing the WHPCE to the predetermined wellsite test pressure.

The wellsite pressure test should be accomplished using a dedicated low-volume/high-pressure test pump with redundant calibrated pressure gauges and adequate overpressure protection. Alternatively, the use of a device designed to limit the volume of fluid introduced into the WHPCE, such as a choke manifold, is acceptable.

A low-volume/high-pressure pump is the preferred type of pump for pressure testing as it lowers the risks of adiabatic heating and the overpressurization of equipment. The high-pressure system pump is capable of achieving the test pressure after the high-volume pump has filled the WHPCE with test fluid.

The wellsite test pressure of the WHPCE shall not exceed 80 % of the pressure rating of the explosive device.

6.12.3.2 Effects of Adiabatic Heating

6.12.3.2.1 General

If wellsite pressure testing is performed with high-volume/high-pressure pumps, adiabatic heating can occur. This can result in a significant increase in temperature within the WHPCE due to rapid pressurization of compressible fluids or gases. This temperature increase is localized and occurs in the area where the wireline enters the grease head. The resulting temperature can be sufficiently high such that the wireline suffers substantial damage to the cable armors and/or conductors. This creates an increased potential for an unintentional pull-off and/or tool failure.

Adiabatic heating-induced wireline cable conductor damage can result in an ungrounded explosive device at surface. This is potentially catastrophic. Basic explosives safety procedures require all explosive devices to be grounded.

Recovering the ungrounded or unattached explosive device requires nonstandard rig down procedures and exposes the wireline crew to additional hazards.

Several possible solutions to this problem can be used, alone or in combination, and may completely eliminate or greatly reduce risk.

6.12.3.2.2 Use of Vents

The use of a vent can release compressible fluids or gases in the WHPCE as the equipment is being filled with test fluid. These devices can be operated remotely to release pressure and mitigate the adiabatic effect caused by compressing the trapped compressible fluid or gas during the pressure test. Vents have limitations, and using one with a high-volume/high-pressure pump might not allow sufficient venting to prevent adiabatic heating. Vents can help; however, they cannot be relied on to eliminate this problem.

6.12.3.2.3 Use of Test Pumps

The use of a properly sized test pump for WHPCE pressure testing is preferred to avoid the effects of adiabatic heating. This should be a dedicated low-volume/high-pressure test pump with redundant calibrated pressure gauges and adequate overpressure protection.

If using a larger high-volume/high-pressure pump, the use of a choke to restrict the output of the pump into the pressure control string is required. This reduces the rate at which the lubricator fills to test pressure. Similarly, redundant calibrated pressure gauges and adequate overpressure protection is recommended. The use of a combination high-volume/low-pressure and low-volume/high-pressure pump system is recommended. Most of the fluid volume should be filled up at low pressure and high volume, then low volume should be provided at a high pressure.

High-volume, high-pressure pumps are used during wireline pump down and fracturing operations. Their use is discouraged for pressure testing WHPCE. Rapid “bull heading” of the equipment with test fluid will promote adiabatic heating and can quickly overpressure the WHPCE’s maximum allowable working pressure, unless adequate overpressure protection is used, such as a choke manifold or a pressure relief valve. Fill rates are calculated based upon the equipment ID and volume, taking the fluid vent capability into consideration. When using a high-volume/high-pressure pump, a typical fill rate is 80 liter/minute (21.1 US gallon/minute) at 400 psi maximum. However, the preference is to use a low-volume/high-pressure pump.

6.12.4 Equalization of Well Pressure

When preparing to deploy explosive devices into a well under pressure, the pressure equalization should be accomplished using well pressure or an appropriate low-volume/high-pressure pump. The pump should be equipped with adequate over-pressure protection or a device designed to limit the volume of fluid introduced into the WHPCE, such as a choke manifold. The pressure used to equalize the WHPCE shall not exceed 80 % of the pressure rating of the explosive device while at surface.

When equalizing the WHPCE to well pressure, regardless of which method used, it is safer to raise the WHPCE pressure slightly above the existing wellhead pressure first. This prevents well fluid surging into the pressure control equipment and pushing the tool string into the top of the lubricator. If there is no other option than introducing wellhead pressure via the swab valve, then a typical fill rate is 80 liter/minute (21.1 US gallon/minute) at 400 psi maximum followed by a buildup rate of 1000 psi/minute, but these rates shall be calculated based upon the equipment ID and volume, taking the fluid vent capability into consideration.

6.12.5 Safety of Personnel

Only competent personnel essential to the operation shall be involved in the use of WHPCE. During wellsite pressure testing or equalization of WHPCE containing explosives, all personnel shall be located at least 23 m (75 ft) from the equipment under test, if the work environment allows. If this cannot be achieved, they shall shield themselves behind a structure to prevent being struck by debris in the event of a failure of the explosive device or WHPCE.

7 Downhole Equipment

7.1 Introduction

This section describes recommended features and minimum requirements for downhole equipment to ensure personnel safety.

7.2 Primary Explosives

Primary explosives are only permitted in electric and percussion initiators. They shall not contain any exposed primary explosive.

7.3 Detonators and Initiating Devices

7.3.1 Pull Strength

Electric detonators and initiators shall be designed and manufactured to withstand at least 7 lbf (31 N) pull applied between the detonator body and the lead wires.

Caution—Do not field test this capability since pulling wires from a detonator or initiator body can cause detonation.

7.3.2 Drop Height Requirement

Electric and percussion detonators and initiators shall be designed and manufactured to withstand a drop, without firing, of at least 4.6 m (15 ft) onto a steel plate supported by concrete.

7.3.3 Electrostatic Resistance

Electric initiators used in the oilfield shall be capable of passing the pin-to-case and pin-to-pin electrostatic tests described in MIL-DTL-23659F or VG 95378-11. Each production lot shall be tested.

7.3.4 Impact Resistance of Percussion Initiators

Percussion style initiators that will not be exposed to well fluids or pressure shall be designed with a minimum 2 ft-lb no-fire level. Percussion style initiators that will be exposed to well fluids or pressure shall be designed with a minimum 5 ft-lb no-fire level. Impact force shall be applied in the normal firing configuration. The minimum no-fire impact level shall have a probability of not firing of 0.999 at a confidence level of 95 % as determined by test and computation.

7.3.5 Temperature and Pressure Rating

Specifications for the temperature and pressure rating of detonators that will be exposed to the wellbore shall be based on tests that involve the simultaneous application of temperature and pressure.

7.3.6 Electric Detonators

7.3.6.1 General

Warning—Non-resistorized hotwire detonators (i.e. detonators with internal resistance of less than 50 ohms) shall not be used in wellsite applications.

Electrically initiated detonators used for perforating shall have characteristics and features that put them in one of the following three groups.

7.3.6.2 Group 1

Group 1 detonators shall have the following features and characteristics:

- a) Detonators of this group may contain some primary explosive.
- b) Overall resistance of the detonator shall be greater than or equal to nominal 50 ohms.
- c) Detonators of this group shall have a no-fire current of at least 200 mA. The detonator manufacturer may also rate the detonator for a higher no-fire current if the design and testing support a higher value.
- d) Detonators of this group might be sensitive to RF energy. Users shall follow the guidance of IME SLP 20 to setup an RF transmitter exclusion distance when utilizing a detonator of this group.

7.3.6.3 Group 2

The following features and characteristics apply to Group 2 detonators:

- a) Detonators of this group may contain some primary explosive.
- b) Detonators of this group shall have a no-fire voltage of at least 25 V ac/dc.

- c) Detonator RF sensitivity to each single transmitter of frequency and power identified in IME SLP 20 shall be evaluated. The detonator manufacturer shall publish tables of safe distances for each individual transmitter type. These tables shall be formatted similar to those published in IME SLP 20 for 50 ohm detonators (Group 1 detonators). The manufacturer may also provide a method for calculating the safe distance for an environment of multiple transmitters at varying distances.
- d) Manufacturers shall provide the user with a sample calculation of RF exclusion distances for multiple RF transmitters.
 - The sample calculation should include 100 handheld transmitters of 5 W output at 144 Mhz or higher (use the frequency from this range to which the particular detonator design is most sensitive) plus 20 mobile transmitters of 200 W output at 144 Mhz or higher (use the frequency from this range to which the particular detonator design is most sensitive). All 5 W transmitters are at the same distance. All 200 W transmitters are at the same distance.
 - In evaluating detonator RF energy sensitivity, the manufacturer shall consider the detonator antenna configuration with the greatest sensitivity to the frequency being evaluated. Potential oilfield detonator antenna systems are discussed in IME SLP 20.
 - There are many different wellsite environments. The user will need to determine the safe RF distance for their particular wellsite RF environment using the tables provided by the detonator manufacturer. The calculation can be performed following the technique used by the manufacturer for the example situation described above.
- e) Detonators of this group should be designed such that any single point of failure within the detonator does not result in an unintended initiation when the detonator is exposed to environmental stimulus up to the environmental limits specified for this detonator group. This characteristic should be evaluated by performing a systematic analysis of failure modes (such as FMEA).
- f) These safety-related features and characteristics shall be tested and validated by an ITPO, and the manufacturer shall make the results available to users upon request.

7.3.6.4 Group 3

The following features and characteristics apply to Group 3 detonators:

- a) Detonators of this group shall not contain primary explosives.
- b) Detonators of this group shall have a no-fire voltage of at least 120 V ac/dc.
- c) Detonators of this group shall be immune to RF energy emitted by each transmitter of frequency and power output identified in IME SLP 20, including marine transmitters.
 - In evaluating detonator RF energy sensitivity, the manufacturer shall consider the detonator antenna configuration with the greatest sensitivity to the frequency being evaluated. Potential oilfield detonator antenna systems are discussed in IME SLP 20.
 - Group 3 detonators shall not require an RF transmitter exclusion zone. The detonator shall not initiate by RF energy when the detonator and/or the associated system is exposed to levels up to a level specified by the manufacturer.
 - When the detonator and/or the associated system are exposed to levels above the specified level, the detonator shall not initiate due to this stimulus but shall fail safe when it fails.
 - A detonator that has failed safe shall retain all safety characteristics of Group 3 detonators.

- d) Detonators of this group shall be designed such that any single point of failure within the detonator does not result in an unintended initiation when the detonator is exposed to environmental stimulus up to the environmental limits specified for this detonator group. This characteristic should be evaluated by performing a systematic analysis of failure modes (such as FMEA). This analysis shall include evaluation of RF energy pickup by all components of the detonator.
- e) These safety-related features and characteristics and testing thereof shall be validated by an ITPO, and the manufacturer shall make the results available to users upon request.

7.3.7 Attachments to Detonators

Any detonator attachment (fireset, switch, etc.) that changes the characteristic of the overall detonator/attachment assembly can change the group the combination falls into. The detonator and attachment combination shall satisfy all the requirements of the group it is intended to meet including testing and evaluation.

7.3.8 Manufacturing Quality Control Program

Manufacturers shall have a documented manufacturing quality control program for detonators and attachments (fireset, switch, etc.) that ensures the uniform quality of their products with respect to features required by this document.

7.3.9 Igniters

Igniters shall be treated like detonators when applicable.

Propellant-activated sidewall sample takers and bullet perforating gun designs do not lend themselves to the incorporation of initiators meeting the requirements of 7.3.6. These tools should have a minimum of 50 ohms resistance in the downhole firing circuit and either:

- a) a feature that prevents electrical connection to the initiating device prior to running in the hole,
- b) a ballistic interrupter that can be deactivated after the cable head has been connected to the tool, or
- c) another equivalent safety feature.

Operation of these devices should be determined to be safe through prior review by and agreement between the service company and operating company.

7.4 Selective Firing Perforating Gun Systems

7.4.1 Description

Selective electrically fired perforating gun systems are made up of individual guns connected into a string and fired sequentially, one at a time, from the bottom up. These gun strings can include two or more guns connected together. The guns are electrically separated and individually fired using selective switches. When a switch is activated, it creates an electrical path from the gun's shooting wire to the switch's detonator wire.

Long strings of many guns can be time-consuming to arm and assemble. This presents the desire to build the string up before the wireline operation begins to improve wellsite efficiency. This is especially desirable when perforating is a small part of a much more complex well service operation. Most selective systems do not permit the efficient installation of the detonator after the string is built up and connected to the wireline cable at the wellhead. Wellsite explosive procedures generally require the wireline head to be electrically connected to the gun before installing the detonator. For selective systems, it is permitted to install detonators that will be connected to switches that will block their electrical path to shooting power prior to connecting the cable head to the gun string. However, prior to the

connection of the detonator, the status of protective features built into the system shall have been confirmed. These features prevent unintended electrical power on the wireline cable from passing to the detonator upon connection of the cable head to the gun string.

Mechanical and electronic switches are commonly used in these applications. The characteristics and corresponding procedural requirements for each type are described below.

7.4.2 Mechanical Switches

7.4.2.1 General

Mechanical switches are typically installed in a pressure bulkhead between two guns. The switch is actuated by an abrupt pressure increase in the gun below it. When actuated the switch completes an electrical connection between the wireline cable and the detonator of the gun above the switch.

7.4.2.2 Features and Characteristics

The following features and characteristics apply to mechanical switches:

- a) Voltage, temperature, and pressure ratings of the switch shall be specified by the manufacturer.
- b) The voltage rating of the switch should meet or exceed the maximum output voltage of the surface shooting panels with which they are intended to be used or be designed, such that the overvoltage failure mode isolates the input voltage from the output to the detonator. When a power supply can exceed the rating of a switch that fails in an unsafe mode, a power safe device (PSD) shall be placed in line at the top of the gun(s) and is electrically before the bottom-most switch in the string.
- c) The default state of the switch shall isolate the detonator's electrical input connection point from the gun shooting wire connection point.
- d) The switch's intended applications, installation procedures, and requirements shall be documented by the manufacturer and these shall be made available to the user.
- e) There are two main types of mechanical selective switches as follows:
 - Dual diode mechanical selective switches. These only allow the use of two explosive devices.
 - Polarity sensitive (positive or negative) diode mechanical selective switches. These shall be used alternatively in a multi-gun string.

7.4.2.3 Selection Criteria

Selection criteria for using mechanical switches are as follows:

- a) Users shall select a switch to match the requirements of the detonator used.
- b) Users shall select a switch rated for the maximum output voltage of the shooting power supply.
- c) Users shall select switches rated for the temperature and pressure at which the gun will be used.
- d) Users shall install switches following the manufacturer's documented procedure.
- e) Switches shall be electrically checked as per the manufacturer's instructions to confirm switch position (state) prior to installation of the switches into the gun.

- f) Users shall check to confirm isolation between the switch's detonator connection points to the gun's through wire (shooting line) after installation into the gun.
- g) Users shall check gun through wire (shooting line) end-to-end continuity and isolation from ground after installation into the gun.

7.4.2.4 Arming Procedures

7.4.2.4.1 General

Unless the use of ballistic interrupts is allowed (see 7.5) then detonators should be installed into a selective firing gun string immediately prior to their use. When guns containing mechanical switches are being assembled into a gun string, detonators may be installed in all guns except the bottom gun in the string before the cable head is attached. When using mechanical switches, the bottom-most gun in the string will be the first gun in the electrical path to the shooting power source. The first gun in the electrical path to the power source (the bottom gun) shall be electrically armed after the cable head has been attached. If a dual diode switch is used, the first two guns (explosive devices) in the circuit shall be electrically armed after the cable head has been attached to the string.

7.4.2.4.2 Installing Detonators While Assembling the Gun String (Except Bottom-most Gun)

The following procedure shall apply for installing detonators in all but the bottom-most gun while assembling a gun string.

- a) Prepare the site for arming following all relevant procedures of 10.1.
- b) Apply the precautions of 10.4.1 through 10.4.5 when installing detonators while assembling a mechanical switch-enabled selective gun string.
- c) Install detonators (except for the bottom-most gun) in accordance with 10.6.5 c) through 10.6.5 f).
- d) Check the insulation between the switch's detonator connection point and the gun's shooting wire using a safety meter in accordance with 10.6.5 g) through 10.6.5 i). Repeat the process for the next gun in the string until detonators have been installed in all except the bottom-most gun.

Warning—Unless otherwise approved by the gun system manufacturer and the detonator manufacturer, selective firing guns that have had detonators installed shall remain at a safe distance from RF sources in accordance with 10.1.3.

7.4.2.4.3 Arming the Bottom-most Gun

When arming the bottom-most gun, all steps of Section 10 shall be followed.

The bottom-most gun in a selective gun string which incorporates mechanical switches shall be armed after attaching the wireline cable head and immediately prior to running the gun string into the well.

Caution—When a dual diode switch is used, the bottom two guns shall not be armed until the cable head has been attached. When the bottom device is a setting tool, refer to 14.1.

7.4.2.4.4 Misfired Gun Strings/Unfired Guns

When retrieving a misfired gun string, the bottom-most unfired gun shall be immediately disarmed prior to removing the cable head. When using a dual diode, disarm all unfired guns connected to the dual diode prior to removing the cable

head. All other unfired guns shall be inspected through the port to identify potential flooding before disconnecting the head. If flooding is detected, disarm all of the remaining unfired guns prior to removing the cable head.

When disarming unfired guns, follow the disarming procedure described in 10.6.5 and 10.6.6.

7.4.3 Electronic Switches

7.4.3.1 General

Electronic switches are typically installed in the cavity of the hollow carrier gun or adapter between two guns. There will typically be an electrical feed-through in a pressure bulkhead between the two guns. A switch is actuated by a dedicated electrical signal from the shooting control system at surface. When actuated, the switch completes an electrical connection between the wireline cable and the detonator connected to the switch.

Switches that contain electronic components for polarity sensitivity but use a mechanical mechanism for gun selection (such as a “dart” or “rotary electromechanical” systems) are considered mechanical switches and should follow the procedures in 7.4.1.

7.4.3.2 Features and Characteristics

The following features and characteristics apply to electronic switches:

- a) Voltage, temperature, and pressure ratings of the switch shall be specified by the manufacturer.
- b) The voltage rating of the switch shall meet or exceed the maximum output voltage of the surface shooting panel with which the switch is designed to operate. Alternatively, the switch shall be designed such that the overvoltage failure mode isolates the input voltage from the output to the detonator. When a power supply can exceed the rating of a switch that fails in an unsafe mode, a PSD shall be placed in line before the first switch in the string.
- c) The default state of the switch shall isolate the switch's detonator input connection point from the gun shooting wire connection point.
- d) Electronic switch surface test units shall comply with surface test unit output limits set in 6.9.
- e) The switch's intended applications, requirements, and installation and testing procedures shall be documented by the manufacturer, and these shall be made available to the user.

7.4.3.3 Selection Criteria

Selection criteria for using electronic switches are as follows:

- a) Users shall select a switch to match the requirements of the detonator used and to withstand the maximum output of the source of power. When using a power supply that can exceed the rating of a switch that is capable of failing in an unsafe mode, a PSD shall be placed in line before the first switch in the string.
- b) Users shall select switches rated for the temperature to which the gun will be exposed.
- c) Users shall install switches following the manufacturer's documented procedure.
- d) Switches shall be electrically checked as per the manufacturer's instructions to confirm switch condition and state prior to installation into the gun.

- e) Users shall check to confirm isolation between the switch's detonator connection point and gun through wire (shooting line) upon installation into the gun. This check shall be performed per the manufacturer's procedures.
- f) Users shall complete all other assembled gun electrical checks specified by the switch manufacturer.

7.4.3.4 Arming Procedures

7.4.3.4.1 General

Detonators should be installed into a selective firing gun string immediately prior to its use. When guns containing electronic switches are being assembled into a gun string, detonators may be installed in all guns except the top-most gun in the string before the cable head is attached. When using electronic switches, the detonator of the top-most gun in the string is the first gun in the electrical path to the shooting power source. The first gun in the electrical path (the top gun) to the power source shall be electrically armed after the cable head has been attached. See Annex B and Annex C for more information on arming procedures and equipment.

7.4.3.4.2 Installing Detonators While Assembling the Gun String

With the exception of the top-most gun, the following procedures shall apply when installing detonators while assembling the gun string:

- a) Prepare the area for arming following all relevant procedures of 10.1.
- b) The precautions of 10.4.1 through 10.4.5 apply when installing detonators while assembling an electronic switch-enabled selective gun string.
- c) Procedure to install detonators, follow 10.4.6 c) through 10.4.6 f).
- d) Then check the gun string wiring and switch using the switch surface tester or as specified by the manufacturer.
- e) Then follow 10.4.6 g) through 10.4.6 i).
- f) Repeat the process for the next gun in the string until detonators have been installed into all but the top-most gun.

Warning—Unless otherwise approved by the detonator manufacturer, selective firing guns that have had detonators installed shall remain at a safe distance from RF sources in accordance with 10.1.3.

7.4.3.4.3 Arming the Top-most Gun

A detonator shall not be attached to the top-most electronic switch until after the cable head has been attached to the gun string. This should be performed immediately prior to running the gun string into the well.

When arming the top-most gun, all steps of Section 10 shall be followed.

As an alternative, the wireline cable head may be attached to the gun string with all the detonators installed, provided there is an additional electronic switch, or PSD, or alternative physical or electrical barrier between the top-most detonator and the cable head. The additional barrier shall be capable of withstanding the output of the surface unit power sources. If an electronic switch is used, this additional barrier shall not be directly connected to a detonator at any time. The barrier shall be used once, unless its manufacturer specifies otherwise.

7.5 Detonators with Ballistic Interrupts

7.5.1 Ballistic Interrupt Hardware

7.5.1.1 General

Some electric and percussion detonators are designed to include or be combined with a ballistic interrupt safety feature. The interrupt feature is a physical barrier designed to prevent the detonator output from initiating the detonating cord or next explosive component in the explosive train.

7.5.1.2 Interrupt Design Features and Characteristics

Interrupt design features and characteristics are as follows:

- a) The detonator and interrupt barrier shall be engineered to function as an integrated assembly.
- b) The interrupt barrier design shall be tested and validated to stop the detonation transfer, and the testing setup shall accurately reflect the actual configuration under which the device will be used. One of the following tests shall be used.
 - 1) Receiver witness test—with the interrupters properly installed between the two explosive components, fire a minimum of six tests. To validate the design there shall be no observed damage whatsoever (from fragment hits, detonation pressure, shock or heating) on the face of the receiver explosive component. A soft-surface witness receiver that is nonexplosive may be used instead of the explosive receiver for easier examination. If there is any damage at all, the design may still be validated for no detonation by a statistical inference test.
 - 2) Statistical inference test—validate that there is no detonation transfer with a minimum reliability of 0.999 and a 95 % confidence as determined by a statically significant number of tests, supplemented by computation.
- c) If the fit, form, or function of the barrier design changes, the validation test shall be repeated.
- d) The manufacturer shall provide documentation to the users that identifies the following:
 - 1) the compatible explosives components;
 - 2) specifications, including:
 - systems or devices for which the interruptible detonator has been designed and tested;
 - reliability of interrupt mechanism;
 - the maximum and minimum operating temperature; and
 - a procedure for reinstalling the interrupt (if applicable) after being run in the well;
- e) The interrupt barrier mechanism shall have features to retain the barrier in the safe position under normal handling and transportation conditions.
- f) The interrupt barrier mechanism shall require a deliberate action to remove the interrupt barrier from the detonation path (to ballistically arm the detonator). It shall be designed to survive shock and vibration levels experienced during normal perforating gun handling and transportation.
- g) Installation and removal of the interrupt barrier shall not require forces that could damage the detonator or the receptor.
- h) The interrupt mechanism and detonator combination should be designed to prevent incorrect user assembly.

7.5.2 Detonator/Interrupt Assembly Installation into the Gun

7.5.2.1 General

If classification of the detonator/interrupt assembly and gun by local authorities permits transportation, the installation may be performed in a gun loading shop away from the wellsite. Should there be need to install a detonator/interrupt assembly at the wellsite, all normal wellsite procedures shall be followed (see Section 10).

Detonators with interrupts shall be used only in gun systems or other explosive devices which have the characteristics and features that the detonator/interrupt manufacturer specifies as important to the correct functioning of the detonator/interrupt subassembly.

The detonator and interrupt barrier mechanism shall be designed to be combined together. Use only combinations of detonators and interrupters that are specified by the manufacturer as suitable to be combined. A detonator having holes through the body of the detonator does not necessarily mean it is intended as an interruptible detonator.

While detonators and their interrupt barrier mechanisms appear simple, they include complex design work and some have been approved by regulatory authorities for their transportation. Any changes made by the user can make them ineffective, and consequently invalidates transportation approval. Do not substitute or modify components.

Guns with detonators and interrupts shall comply with all federal and state regulations governing transportation and other activity. Most countries outside the U.S. do not allow transportation of guns with detonators with or without interrupts.

7.5.2.2 Gun Loading Shop Preparation of Ballistic Interrupts for Electric Detonators

Before removing the required detonators from their storage magazine, the gun loading shop and surrounding worksite shall be prepared as follows:

- a) Discontinue all electric welding operations unless the manufacturer of the electric detonator or initiator specifies that stopping such activities is unnecessary.
- b) Exercise precautions to prevent RF hazards. Warning signs shall be posted and other appropriate measures taken so that RF emitters will be shut off when within hazardous distances of a work area where detonators are handled. See IME SLP 20 and IEEE C95.4-2002 ^[11] for the recommended distances for posting signs and shutting off radio, radar, cellular telephone, and pager RF transmitting units.
- c) The gun loading shop shall be designed so that no stray voltages are present. Prior to each work session, check for stray voltages (ac and dc) between all possible discharge points in the work area; for example, a workbench to building structure, etc. If any stray voltage is measured, find and eliminate it at its source.
- d) Verify that all conductive fixtures in the work area are grounded (workbenches, floormats, building structures, etc.).
- e) Remove or shut down, for the duration of the operation, any electrical sources in the gun loading shop work area. Any electrical sources that could inadvertently be switched on again shall be locked out or tagged out.
- f) Ensure that appropriate measures are in place to prevent ESD, for example static discharge bars at all entrances to the gun loading shop. All personnel shall wear conductive or anti-static clothing, electrostatic dissipative footwear, etc. Be aware that people moving and materials rubbing together can develop significant levels of electrostatic charge if appropriate measures aren't taken to prevent them.

7.5.2.3 Gun Loading Shop Detonator Installation Procedure

7.5.2.3.1 Detonators may be installed in all guns except the bottom gun in the string. The bottom gun in the string is the first gun in the electrical path to the shooting power source. The first gun in the electrical path to the power source shall be electrically armed after the cable head has been attached at the wellsite. If a dual diode switch is used, the first two guns (or setting tool and first gun in a “plug and perf” gun string) in the circuit shall be electrically armed after the cable head has been attached at the wellsite. When using electronic switches, the first gun in the electrical path may be the top gun in the string, which then requires the detonator be excluded.

7.5.2.3.2 The following conditions apply when performing the detonator installation procedures in the gun shop:

- a) If the manufacturer does not provide the detonator with the interrupt barrier installed, the barrier should be installed at the first opportunity, but in any event shall be installed before attaching the detonator to the detonating cord.
- b) Detonators shall be handled one at a time.
- c) No more than 10 loose detonators (out of the original packaging) should accumulate in the work area at any one time.
- d) Detonators in the original packaging should be at least 1 m (3 ft) from detonators not in their original packaging.
- e) When a gun loading shop contains more than one gun loading area where detonators are being handled or installed into guns, these work areas should be separated by at least 1 m (3 ft).
- f) Detonator lead wires shall be kept in the configuration as supplied by the manufacturer until immediately prior to installation.
- g) Only personnel essential to the detonator/interrupt installation process shall be in the gun loading shop during the installation process.
- h) All personnel shall be clear from the line of fire of the perforating gun when installing the detonator.
- i) Detonators shall not be installed during an electrical storm, or if an electrical storm is anticipated within 30 minutes.
- j) Remove only enough detonators from the magazine to address the work at hand.
- k) Detonators shall be separated from secondary explosives until assembled in the gun.

7.5.2.3.3 When connecting the detonator to the explosive device, the following shall apply:

- a) Remove the detonator from its storage container and verify that it is shunted.
- b) Place the detonator in a detonator safety tube, and check it with a safety meter or other device as specified by the detonator manufacturer (refer to 6.8, 6.9, and 10.2.3). Re-shunt the detonator wires after checking the resistance.
- c) Verify that no voltage exists between the points of connection in the gun to which the detonator wires will be attached.
- d) It is best practice to connect the detonator wires to the gun wires before connecting the detonator to the cord. However, in some gun systems this may not be possible due to the compact nature of the gun system design. When an approved electrical barrier (e.g. electronic or mechanical switch) has been installed in the gun, preventing connection to the gun shooting wire (confirmed by a safety meter check), the detonator may be attached to the gun detonating cord before the detonator wires are connected. No matter the sequence, verify that the interrupt mechanism is properly installed and activated before attaching the detonator to the cord.

- e) Unshunt the detonator wires immediately prior to making the detonator electrical connections to the gun wiring.
- f) Complete the assembly of the gun or device, taking care not to pinch, crush, or impact the explosive components or wiring.

7.5.2.4 Gun Loading Shop Preparation of Ballistic Interrupts for Percussion Detonators

These devices are typically used for tubing-conveyed perforating (TCP) applications and may be activated by thermal and/or pressure exposure in the borehole.

Care shall be exercised in the correct selection of the interrupt device for the given downhole conditions using the manufacturer's selection procedures.

7.5.3 Wellsite Operational Concerns

7.5.3.1 The interrupt barrier should remain in place as late in the process as is practical to maximize the protection it provides. When practical, the detonator interrupts should not be removed until the cable head has been attached to the gun string and all the detonators in the gun string have been electrically connected to their switch output contact or lead. Interrupts should be removed from guns immediately before the gun string is rigged up.

7.5.3.2 When a gun has been ballistically armed by removing the interrupt but has misfired, or will not be used, the interrupt shall be reinstalled or the gun disarmed by removing the detonator.

7.5.3.3 An interrupt barrier shall not be reinstalled in an unfired gun unless the manufacturer's instructions define how reinstallation should be done.

7.5.3.4 If the manufacturer does not provide a procedure to reinstall an interrupt, the gun shall be disarmed by removing the detonator.

As a result of changes due to rough handling, a misfire, or gun flooding, reinstalling the interrupt into the gun after it has been run in the well can be more hazardous than removing the detonator. On inspection, if the interrupt and/or detonator components appear damaged or are inaccessible, the gun should be disarmed by removing the detonator rather than attempting to reinstall the interrupt.

When retrieving thermally activated TCP percussion ballistic interrupts from a well, care shall be taken to allow the time for the ballistic interrupt to return to its safe state.

7.6 Downhole Firing Systems

7.6.1 Design Criteria

7.6.1.1 General

The design criteria in 7.6.1.2 and 7.6.1.3 shall apply to all of the firing systems.

7.6.1.2 Drop Survival

Tools shall not initiate when dropped in a manner simulating accidental dropping of the explosive tool from a height of not less than 9.1 m (30 ft) in air onto a 25 mm (1 in.) thick steel plate supported by concrete.

7.6.1.3 Trapped Pressure Relief

Tools shall be designed such that, upon retrieval from the wellbore, internal trapped pressure can be safely bled down. All threaded connections shall incorporate a feature that allows trapped pressure to be vented.

7.6.1.4 Capacitive Discharge Systems

Capacitive discharge systems shall be designed such that the capacitor is discharged to below 50 % of the minimum required firing voltage within 60 seconds.

7.6.1.5 Non-electric Downhole Firing Systems

Non-electric downhole firing systems shall be designed to include one of the following:

- a) requirement of at least two independent actions to allow function of the detonator/initiator on or near surface;
- b) incorporation of at least two independent safety features that prevent inadvertent functioning;
- c) a combination of such actions and safety features—categories of acceptable actions and features are:
 - mechanical designs that physically restrict or limit those actions required to cause functioning,
 - mechanical designs that cause the detonation train to cease, and
 - pressure activation.

7.6.2 Slickline Perforating Systems

7.6.2.1 General

This section addresses self-contained devices that are generally conveyed by slickline but can also be conveyed by other means such as coiled tubing, electric wireline, sucker rod, tubing, or in some cases dropped from surface. These devices of one of the following three types, based on how they are initiated:

- a) by mechanical or hydraulic means using a percussion initiator;
- b) by battery-operated electronics using a percussion initiator; or
- c) by battery-operated electronics using an electric initiator.

7.6.2.2 Mechanical/Hydraulic or Battery-operated Electronics using Percussion Initiator

The design shall incorporate at least two independent safety features that prevent inadvertent functioning, or that have a combination of actions and safety features such as:

- a) mechanical designs that physically restrict or limit those actions required to cause functioning;
- b) mechanical designs that cause the detonation train to cease (i.e. detonation interrupt device);
- c) pressure activation that exceeds a preset value;
- d) a safety feature to prevent explosive device initiation by an accidental over-pressurization, if utilizing a firing head that will be exposed to pressure while at surface.

7.6.2.3 Electronic using Electric Initiator

7.6.2.3.1 General

These are battery-operated memory-type or surface-controlled tools, or a combination of both (triggers), which initiate a downhole explosive device according to either firing windows (which can include time, temperature, pressure, acceleration, or combinations thereof) or surface-initiated commands.

- a) The trigger design shall incorporate at least two independent purpose-designed safety features or barriers, placed between the energy source and the attached explosive components.
- b) Downhole firing systems that require an electrical connection to be made to the detonator while on or near the surface shall be designed to allow for electrically arming before ballistically arming (EBBA).
- c) The tool design shall facilitate a wellsite check to establish that there is < 0.25 V and < 25 mA output from the initiator connections.

7.6.2.3.2 Trigger Assessment

Prior to service introduction, the following safety-related features and characteristics shall be tested and validated by a systematic analysis of failure modes (such as FMEA) performed by an ITPO, with said assessment as a minimum:

- a) confirmation of no single-point failure within the trigger system or separate isolation barrier that can cause or permit any surface panel or trigger voltage to be applied to an armed explosive device;
- b) inclusion in the assessment of trigger systems with internal isolation barriers and battery-powered release devices if they are integral to the trigger;
- c) confirmation that the design and control mechanisms for safety features or barriers are separate and independent, such that no single failure mode or mechanism can simultaneously render both inoperative (for example, a failure mode that permits through-conduction);
- d) confirmation that the requirement of 7.6.2.2 a) is fulfilled.

The manufacturer shall make the results available to users upon request.

7.7 Other Downhole Equipment

7.7.1 Downhole Power Source

Any downhole power source shall incorporate at least two independent safety features that prevent inadvertent functioning when used in combination with an initiator.

7.7.2 Power Safe Devices

7.7.2.1 General

A relatively high percentage of surface detonations are related to electric power being inadvertently applied to the gun system. A PSD that provides a barrier between the cable head and gun system until the gun string is safely downhole can reduce the likelihood of this type of incident occurring. A PSD should ensure unit power is blocked as intended but permit shooting through the PSD when needed. It should be used with every electrically-initiated gun system.

Warning—Use of a PSD shall not replace any other recommended safety practices of this document.

7.7.2.2 Requirements of a Power Safe Device

The following apply to PSDs:

- a) The device shall not have a single point of failure that will allow power to the gun system.
- b) A FMEA shall be performed and the results made available for review by the user.
- c) A PSD shall be rated above the voltage of the maximum output of any power supply within the logging unit.
- d) A PSD shall be user-testable to confirm proper operation. The tester shall not be capable of initiating the detonator.
- e) The PSD shall not be tested on the surface with the unit shooting panel when the PSD is connected to an armed gun string.
- f) The state of a PSD (open/safe or closed/fire) shall be verifiable from the surface prior to coming out of the hole.
- g) The default state of the PSD shall isolate the gun string from the wireline cable head.
- h) Voltage, current, temperature, and pressure ratings of the PSD shall be specified by the manufacturer.
- i) Equipment maintenance and usable life shall be specified by the manufacturer.

7.7.2.3 Maintenance of a Power Safe Device

Power safe devices shall be maintained and inspected in accordance with the manufacturer's recommendations. Equipment that is past the usable life shall not be used.

7.7.3 Trapped Pressure Relief

Tools shall be designed such that, upon retrieval from the wellbore, internal trapped pressure can be safely bled down. All threaded connections shall incorporate a feature that allows trapped pressure to be vented.

7.8 Special Provisions for Shallow Operations

Certain operations may require explosive services at depths shallower than 61 m (200 ft). If well conditions permit, the explosive device should be lowered to at least 61 m (200 ft) before restoring power and continuing with the operation. Shallow explosive operations may require extra safety precautions to protect against fluids being ejected from the well. Pack-offs may be used, and personnel shall be cleared from the drill floor.

Such operations can require an MOC or similar process control with management approval before operations can continue.

7.9 Electric Downhole Tractors

7.9.1 Equipment

Downhole tractors are considered a downhole power source and are operated at voltages that can unintentionally fire an armed explosive device (7.7.1). As such, during operations in which a tractor's passenger tools comprise one or more explosive device, at least two purpose-designed isolation barriers shall be installed between the tractor electrical circuitry and the attached armed explosive device(s). No component of an attached armed explosive device may be considered one of the two required isolation barriers.

7.9.2 Isolation Barriers

Each isolation barrier itself shall have the following features at a minimum:

- a) The ability to block a voltage of at least 110 % of the maximum output voltage of the tractor's surface power supply or the tractor itself. Blocking higher voltages is desirable to increase the margin of safety and should be pursued in any future barrier designs.
- b) Inclusion of a mechanism to confirm, on surface, the barrier's status (isolated or through-connected).
- c) Be independent of the other barriers such that they cannot be functioned simultaneously by user error.
- d) The ability to detect a barrier failure to an unsafe mode through either standard operating procedures (documented tool operation/servicing) or via direct feedback from the isolation barrier (telemetric self-diagnosis/interrogation). The failure of any isolation barrier shall be reported to the equipment operator.

7.9.3 Isolation Barrier Assessment

Prior to service introduction, each isolation barrier shall undergo an FMEA by an ITPO with said assessment as a minimum. The manufacturer shall make the results available to users upon request.

The manufacturer shall confirm that no single-point failure within the tractor system or separate isolation barrier equipment shall cause or permit any surface panel or tractor voltage to be applied to an armed explosive device. Tractor systems may have internal isolation barriers, and some may also include battery-powered release devices that shall be included in the safety assessment if they are integral to the tractor.

The manufacturer shall confirm that the design of isolation barriers and their control mechanisms are separate and independent so that no single failure mode or mechanism can simultaneously render the isolation function of both isolation barriers inoperative (for example, a failure mode that permits through-conduction).

The barrier assessment shall verify each isolation barrier meets the requirements of 7.9.2.

8 Time Delays

8.1 Description

There are two primary types of time delays for sequencing of explosive events: pyrotechnic and electronic.

The pyrotechnic time delay (PTD) uses a chemical reaction to provide a time delay and is typically initiated by mechanical stimulus. The PTD is used to provide a delay between initiation and detonation. Additional PTDs may be run in tandem to produce an extended time delay between initiation and detonation. The PTD shall be considered a percussion initiator.

The electronic time delay (ETD) is typically initiated by mechanical stimulus and then uses hardware, firmware, and/or software to provide a time delay before initiating the rest of the explosive train. The ETD is used to provide a manufacturer-programmed timer circuit delay between mechanical stimulus and electrical stimulus to a detonator. The ETD shall be considered an electric initiator.

8.2 Design Features and Requirements

Delays shall meet the applicable requirements for detonators and initiating devices in 7.3. In addition, manufacturers of delays shall provide specifications for the following:

- a) delay time at ambient temperature;

- b) temperature ratings including duration;
- c) delay time and/or range variance at temperature/time;
- d) ignition energy characteristics;
- e) output characteristics;
- f) qualified applications;
- g) special handling requirements;
- h) assembly manuals detailing the safe disarming and disassembly procedure.

Delays shall include safety and handling caps, plugs, or other protective devices until final assembly operations require their removal.

For delays with independent power sources, independent safety features shall be installed to minimize the potential for inadvertent initiation.

8.3 Safety Aspects

The requirements of Section 6, Section 9, and Section 15 shall apply when utilizing time delays.

During loading/downloading, PTDs and ETDs shall be handled as initiators, except for the following:

- a) Do not remove safety caps from time delays until assembly requires their removal.
- b) If accidental initiation occurs, evacuate all personnel to the designated safe area, and wait five times the maximum expected delay time for the assembly before returning to the scene.

8.4 Operational Considerations

8.4.1 Arming

ETDs which incorporate lead wires and electrical initiation shall be armed in accordance with the arming of electrical firing systems specified in Section 10.

8.4.2 Deployment of Devices using Time Delays

In the event of an accidental initiation, do not attempt to break lubricator or bring to surface, as the time delay may have been activated. If time allows, run in well a minimum of 61 m (200 ft) from surface or 61 m (200 ft) below the sea floor, as applicable, and wait five times maximum expected delay time for the assembly. Afterwards, return to surface and proceed with the disarming procedure.

Events that can accidentally initiate the time delay include but are not limited to:

- a) a rapid overpressure when equalizing pressure prior to running in the well;
- b) a dropped object inside the tubing; and
- c) rapid stack out while tripping in the well followed by a rapid drop.

8.4.3 Recovery of Unfired/Misfired Devices Using Time Delays

If detonation cannot be confirmed, time delays shall not be retrieved until five times the maximum expected delay time for the assembly has expired.

9 Field Safety Procedures

9.1 Introduction

This section describes recommended procedures for the transportation of explosive devices and for their handling at the wellsite.

9.2 Transportation of Explosives

The conveyance of explosives to or from the wellsite, whether by roadway, rail, air, or water, shall follow 5.3 and all applicable regulations.

9.3 Arrival at the Wellsite

9.3.1 General

Upon arrival at the wellsite, the service company shall designate an EUIC. The EUIC shall establish a safe, controlled working environment on location for explosives operations in consultation with the operating company representative, toolpusher, and any other personnel involved.

9.3.2 Existing Wellsite Hazards

Any wellsite conditions that might contribute to a safety hazard during the handling and operation of explosive devices shall be identified and, where necessary, corrected. This should include consultation between the onsite operating company representative, contractor, and service company representatives. Consult a local weather forecast for the likelihood of lightning storms in the area.

9.3.3 Smoking Area/Open Flames

Designated smoking areas and repositories for smoking materials shall be identified and enforced. Smoking shall only be permitted within these areas, and smoking materials shall be confined to these areas at all times.

Neither open flames nor flame-producing devices shall be permitted within 15 m (50 ft) of any operation involving explosives, unless an appropriate radiant heat barrier has been installed. Local regulations shall be applied if they require the separation of flames from explosives operations to be greater than 15 m (50 ft).

9.3.4 Explosives Packaging and Identification

Explosive materials arriving at the wellsite shall be properly packaged and clearly labeled in accordance with applicable regulations (refer to 5.3.1).

9.3.5 Temporary Staging of Explosives on Location

Designated areas/facilities shall be established for the temporary staging of explosive materials, in accordance with applicable regulations. These areas should be distanced from any potential source of heat, impact/shock hazards, and living accommodation by the distance specified in the applicable regulations or in the explosives manufacturing or service company guidelines, whichever is farther.

9.3.6 Designated Gun Loading Area

Designate a gun loading area (if required) and the location at which explosive devices will be assembled.

These areas shall be located at least 15 m (50 ft) from any source of heat, such as open flame or welding operations, unless an appropriate radiant heat barrier has been installed. Local regulations shall be applied if they require the separation of flames from explosives operations to be greater than 15 m (50 ft).

9.3.7 Staging of Loaded Explosive Devices

When not in use, charged perforating guns and sidewall sampling guns shall be staged in accordance with applicable regulations.

Propellant-activated sidewall sample takers, bullet perforating guns, and select fire guns that have been ballistically armed shall not be placed on the catwalk or in any other area where logging tools are powered up.

9.3.8 Safety Meeting

The EUIC shall conduct one or more safety meeting(s) with the explosive service crew, the wellsite personnel, and supervisory staff. The purpose is to inform all personnel about the explosive operations to be performed, potential hazards, and the responsibilities of each individual.

Topics to be covered during the safety meeting(s) should include the following:

- a) general safety and potential hazards at the wellsite;
- b) activities with elevated risk;
- c) pressure, CO₂, and CO (gaseous by-products of perforating), H₂S, including confined space concerns;
- d) designated safe gathering areas in the event of an emergency;
- e) designated smoking areas;
- f) designated areas for gun loading, assembly, and explosives staging;
- g) labels and warning signs associated with the explosive materials and devices that will be used;
- h) the proximity of any RF antennas (such as mobile phones, two-way radios, and pagers), and any requirement for them to be shut down;
- i) individual responsibilities and the processes that will be followed when arming explosives devices and when opening the well;
- j) stop work authority (SWA).

A safety meeting shall also be conducted whenever wellsite personnel change, or when there is a significant change in plan, such as in the event of a misrun.

9.4 Loading or Downloading of Explosive Components at the Wellsite

9.4.1 Designated Gun Loading Area

9.4.1.1 General

Explosive components shall only be loaded or downloaded within the area designated in 9.3.5.

9.4.1.2 Using a Mobile Unit

If the designated area is a mobile unit used for the purpose of loading/downloading perforating guns (commonly referred to as a “gun loading trailer”) the unit shall meet the following requirements:

- a) There shall not be any active electrical outlets or wall sockets.
- b) Trailer wiring shall be installed to regional or international electrical codes, including grounding.
- c) If heaters, air-conditioning units, or fans are used to maintain room temperature, they shall be a permanent installation. Heaters shall not have an open flame, exposed heating element, or other potential ignition sources. Protection from contact with any heating elements shall be included.
- d) Workbench tops for gun loading shall be wood or other non-sparking material.
- e) Impact-absorbing floormats of anti-static material shall be in front of the gun loading workbenches.
- f) Workbenches and anti-static floor mats shall be electrically bonded to the trailer frame.
- g) When setup at the wellsite, the trailer frame shall be electrically bonded to the wireline unit, crane, and wellhead using grounding cables. If the trailer is remote from the wireline unit/wellhead, and the cable head will not be brought to the trailer, the trailer may be grounded to a grounding rod.
- h) Flammable materials shall not be stored in the trailer.

9.4.1.3 Work Conducted in a Mobile Unit

When working in a gun loading trailer, the following precautions shall be observed:

- a) Only safety meters for explosive use are permitted. No megohmmeter or unapproved multimeters. are allowed inside the trailer.
- b) No electric-powered hand tools shall be used inside the gun loading trailer (line or battery).
- c) Good ESD practices should be observed when loading guns and handling detonators in the gun loading trailer.
- d) RF transmitters shall be removed from the gun loading trailer when handling/installing detonators that are sensitive to RF energy (cell phones and hand-held radios are RF transmitters).

9.4.2 Warning Signs

Signs reading “DANGER EXPLOSIVES”—or equivalent—shall be prominently displayed at the perimeter of the gun loading area (refer to 6.10 and 10.1.1).

9.4.3 Personnel

Only personnel authorized by the EUIC shall be present in the gun loading area at any time during such operations.

9.4.4 Explosives Handling

The following apply for the handling of explosives:

- a) Initiators shall not be permitted within the gun loading area during the loading/downloading process, except when approved by the EUIC.
- b) Explosives shall only be removed from their packaging within the gun loading area, using tools recommended by the manufacturer. Only the quantity of explosives required for the immediate loading operation shall be unpacked. Unpackaged explosives shall not be permitted to accumulate.
- c) Only approved loading tools, approved detonating cord cutting devices, and techniques recommended by the explosive manufacturer or authorized by the service company shall be used.
- d) Attention shall be paid to proper fit during the handling and assembly of explosive devices. Parts should not be forced. Avoid impacts, pinching, crushing, and generating sparks from any source.
- e) A handling cap, plug, or other closure device shall be installed in both ends of loaded hollow carrier-type guns at all times during handling and storage. The closure device shall include a feature to relieve pressure from within the gun in case of excess heat or fire. Guns or explosive devices with exposed detonating components (such as expendable or strip guns) shall be appropriately protected from damage.
- f) As soon as loading operations are completed, loose, remnant, or unused explosives shall be repackaged in compliance with 5.3.1 for shipment from the wellsite.
- g) Loaded explosive devices shall be staged in a designated area (refer to 9.3.6).

9.4.5 Housekeeping

The loading area shall be cleaned up as soon as loading or downloading operations are completed. Separate containers shall be used for ordinary trash and explosive remnants. All explosive materials and their packaging shall be removed from the wellsite. These materials should be disposed of properly and shall not be mixed with ordinary trash.

- a) All residual explosives such as pieces of detonating cord, defective charges, or misfired detonators shall be located and packaged in proper shipping containers for transportation from the wellsite (refer to 5.3.1).
- b) All trash and debris associated with the operation such as empty explosive containers, packaging, and spent gun tubes, shall be organized and appropriately packaged for transportation from the wellsite and proper disposal.
- c) Federal, state, and local regulations should be checked to determine applicable requirements for the disposal of explosive materials, explosives packaging materials, and associated debris.

9.5 Thermally Overexposed Explosive Devices

9.5.1 Time-temperature Ratings

Published time-temperature ratings from the explosive device manufacturer should be used to determine if the explosive device is thermally overexposed.

9.5.2 Potential Hazards

There are two basic hazards associated with a thermally overexposed explosive device:

- a) Thermal runaway—thermal runaway is a dangerous condition with explosion and detonation hazards. If thermal runaway is suspected, all personnel should evacuate to a safe distance immediately for a minimum 2 hr stand-down time. Only the minimum amount of personnel should return to the area after the stand down.
- b) Pressure—out-gassing from thermal decomposition can cause pressure to build up within the explosive device. A check for internal pressure should be conducted following 10.6.5 before proceeding.

9.5.3 Recovery of Thermally Overexposed Explosive Devices

9.5.3.1 Potential Thermally Overexposed Events

Additional safety precautions shall be taken when recovering thermally overexposed explosive devices. These additional precautions shall be followed if an explosive device is overexposed to temperature and:

- a) there is a known misfire, or no firing attempt was made, or
- b) upon visual inspection of a recovered device, it becomes evident that there can still be explosive material in the device.

The service company and operating company should be aware of the potential thermal exposure conditions of explosive devices while downhole and should be prepared to take action in the event a misfire is determined upon visual inspection.

9.5.3.2 Safety Process for Thermally Overexposed Device Recovery

The actions to be taken for a thermally overexposed perforating gun are described in the following steps and the flow chart in Figure 1, but the process is applicable and should be followed for recovery of any thermally overexposed explosive device.

- a) Conduct a safety meeting, and review safety procedures.
- b) Record t_0 , the time of the last attempt to fire the explosive device or the time when recovery of the explosive device towards the surface started.
- c) Raise the gun to a region of cooler temperature, typically 61 m (200 ft) below the surface or sea floor.
- d) Wait at 61 m (200 ft) until 30 minutes has elapsed from t_0 .
- e) While waiting, prepare necessary items such as an approved infrared thermometer and/or a cup of water for the water splash test later. Identify relevant personnel trained on the proper infrared thermometer measurement techniques (avoiding scallops or reflective areas, and taking measurements at the same place on the gun body to ensure consistency).
- f) After 30 minutes since t_0 has elapsed, the gun can be retrieved to surface. If the gun fired, proceed with disarming/disassembly procedures. Otherwise, use the IR thermometer take a temperature measurement or perform a water test by splashing water over the gun.
- g) If the water boils or bubbles, or the temperature is above 100 °C (212 °F) leave the gun where it is, and clear all personnel to a safe distance.

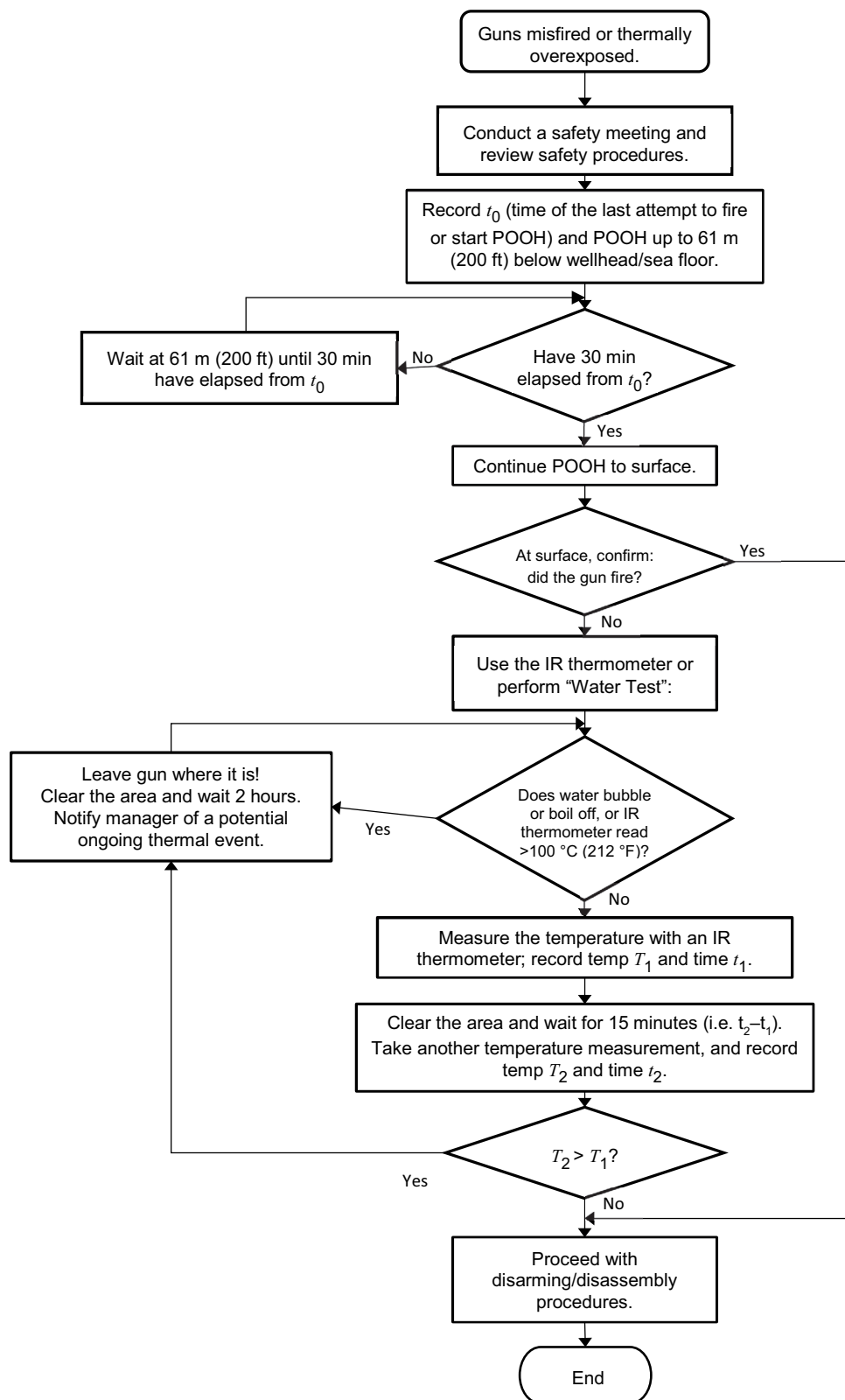


Figure 1—Flow Chart Guide for Recovery of Thermally Overexposed Explosive Devices

- h) Maintain the evacuated area for a minimum of 2 hours.
- i) Notify management of a potential ongoing thermal event.
- j) After 2 hours, verify that the temperature is below 100 °C (212 °F) by repeating the above test. If the temperature is above 100 °C (212 °F), evacuate all personnel to a safe distance for another 2 hours.
- k) Measure the temperature with an IR thermometer. Record the temperature, T_1 and time t_1 .
- l) Clear the area of all non-essential personnel, and wait 15 minutes.
- m) After 15 minutes (t_2), make another temperature measurement, T_2 , ($t_2 = t_1 + 15$).
- n) If $T_2 > T_1$, indicating a temperature increase, leave the gun where it is and clear the area. Wait 2 hours, and repeat the temperature measurement. Continue this process until a decrease in temperature is observed.
- o) If after 15 minutes the temperature has decreased, proceed with disarming/disassembly procedures.

Warning—The time period of 2 hours is chosen as a safe time based on experience in the oilfield explosives industry. The hazard due to thermal cookoff is over, provided, of course, that the temperature at the 61 m (200 ft) depth is truly “cool.” This does not apply in special cases such as when perforating steam wells. Also, other recognized hazards such as the $\beta \rightarrow \delta$ HMX phase transition may still need to be considered when handling explosive devices at surface.

9.5.4 Special Handling of HMX Exposed to Elevated Temperature

Special attention shall be paid when retrieving any device containing HMX explosive that has been exposed to a temperature exceeding the HMX crystalline phase transition temperature. The phase change is irreversible, occurs at or above 150 °C (300 °F), and results in higher impact sensitivity. All HMX explosive devices shall be designed to prevent explosive from becoming loose during such a thermal cycle.

Any uninitiated device containing HMX explosive that is retrieved after being exposed to a temperature exceeding the transition temperature shall be handled with care. The detonator shall be removed immediately and the gun or explosive device placed in a safe area until ready for transportation. Downloading of explosives should take place at service company premises under its technical supervision.

Specific consultation shall take place between the operating company and service company whenever it is planned to expose HMX charges to temperatures approaching or exceeding the transition temperature, or whenever it is believed that charges may have been exposed to temperatures approaching or exceeding the transition temperature. Under such circumstances, operating companies and service companies are advised to review and agree to retrieval and disarming procedures prior to deployment.

9.6 Gaseous By-products of Perforating

9.6.1 Background

The generation of hazardous gases during explosive operations is to be expected and should be considered during safety planning. This pertains to any type of perforating, regardless of type of gun or conveyance method, including on jointed pipe, coil tubing, slickline, and electric line.

There are both solids and gases produced during the perforating event; some of these gases are toxic, and have the potential to reach the surface in concentrations that can pose a risk to life.

There is a direct correlation between the total amount of explosives detonated and the amount of gases that are generated. When several hundred meters (feet) of high-shot density guns are run in a well at one time, or on multiple runs, there can be a substantial amount of gases created. Table 1 lists the types of gaseous by-products and the calculated volumes that can result from explosive operations.

The gas by-product of most concern is carbon monoxide (CO), which can be generated in large quantities. There is no known way to eliminate this by-product from being produced from the perforating event, so steps should be taken to mitigate the risks at surface. CO is colorless, odorless, and tasteless and can only be detected with a detector or meter. Moreover, it is slightly lighter than air and is easily dispersed in a well-ventilated environment.

9.6.2 Calculated Gaseous By-products

Table 1—Calculated Gaseous By-products

Gas Constituent	Amount of Gas Produced per Kg of Explosive m³	Relative Percentage Produced by Volume
Nitrogen (N ₂)	0.297	35
Water Vapor (H ₂ O)	0.277	33
Carbon Monoxide (CO)	0.139	17
Carbon Dioxide (CO ₂)	0.089	11
Methane (CH ₄)	0.016	2
Hydrogen (H ₂)	0.011	1
Ammonia (NH ₃)	0.011	0.14
NOTE 1 This table is representative of HMX explosives—RDX, HNS, and PYX can exhibit slightly different amounts of gases produced, and relative percentages.		
NOTE 2 The amount of gas produced is calculated at standard ambient temperature and pressure (SATP).		
NOTE 3 The values for the amounts of each gas produced are approximate.		
NOTE 4 The Thermochemical Computer Code [12] used to produce this table above has several approximations. The most critical is that it assumes equilibrium, which in a downhole situation may not be reached. Further, the exact materials and conditions downhole cannot be predicted. These results are only for the bare explosive materials.		

9.6.3 Mitigation of Carbon Monoxide at the Surface

Depending on the depth, viscosity of the fluid, and any circulation activity, the length of time the gases take to arrive at the surface is highly variable. However, it is anticipated that the CO gas will eventually be observed at the surface, and controlled circulation procedures should result in a predictable timescale of the gas arrival. The CO shall be separated from the wellbore fluid to mitigate the CO at the surface in a controlled manner. This should be the first operation performed after fluid arrives at the surface, and should be done with the highest feasible efficiency. If the wellbore fluid is aqueous-based, that is beneficial since CO has a very low solubility in water.

Once the gas has emerged at the surface and has been separated from the wellbore fluid, it can be disposed of by several means, as indicated below. The disposal method(s) shall be determined ahead of the perforating operation.

- a) vented at a controlled rate at an elevated height above the rig floor, or in a well-ventilated area away from the rig floor (i.e. controlled release);

- b) directed through an operative gas flare system to combust the CO, converting it to CO₂;
- c) conduct a controlled mixing with air and inject through a man-portable catalyst system that converts the CO to CO₂ at room temperature.

Notwithstanding these mitigations, extreme caution shall be taken if the gaseous by-products are vented into a confined space that personnel can access.

10 Electric Line-conveyed Operations

10.1 Wellsite Preparation

10.1.1 Land Operations

Warning signs reading “DANGER - EXPLOSIVES - TURN OFF RADIO TRANSMITTERS” (or equivalent) shall be prominently displayed at the site and at all entrances and on all roadways that are within 1000 feet of the wellsite.

When using initiating devices that are insensitive to electromagnetic fields created by RF transmitters (such as those that meet the RF insensitivity of Group 3), and where permitted by local law, the portion of the sign reading “TURN OFF RADIO TRANSMITTERS” may be removed or covered.

If local regulations are more stringent, they must be followed.

In the U.S., regulations require the posting of warning signs on all roads that are within 305 m (1000 ft) of the wellsite. Those signs should read “DANGER - EXPLOSIVES - TURN OFF RADIO TRANSMITTERS” (or equivalent) on approach to the area, and they shall be posted at a distance of at least 1000 ft from the site and again at the site itself. Similarly, signs indicating that you are leaving the explosives area should be posted at 1000 ft or beyond.

When the initiating devices to be used have been certified as being insensitive to RF, the portion of the sign reading “TURN OFF RADIO TRANSMITTERS” may be removed or covered. If this is done, documentation from the manufacturer to support the certified RF insensitivity of the devices should be present at the wellsite and made available for inspection by local authorities.

NOTE 1 These requirements are taken from the Manual of Uniform Traffic Control Devices ^[13].

10.1.2 Offshore Operations

Warning procedures similar to those specified in HSAC RP 92-2 ^[14], should be prominently displayed in any restricted area where helicopter operations are anticipated.

10.1.3 Eliminating Sources of Stray Electrical Energy

10.1.3.1 The following address the elimination of stray electrical energy:

- a) Turn off electrical cathodic protection systems unless using an initiator (detonator or igniter) with no-fire voltage characteristics of Group 3, or those Group 2 initiators with a no-fire voltage greater than or equal to 100 V dc.
- b) Discontinue all electric welding operations unless using an initiator with no-fire voltage characteristics of Group 3, or those Group 2 initiators with a no-fire voltage greater than or equal to 100 V ac/dc.
- c) Precautions shall be exercised to prevent RF radiation hazards. Warning signs shall be posted and other appropriate measures taken so that radar and RF units will be shut off when within hazardous distances of explosive operations. When using Group 1 initiators, refer to IME SLP 20 and IEEE C95.4-2002 ^[11] for

recommended distances for posting signs and shutting off radio, radar, cellular telephone, and pager RF transmitting units.

NOTE IME SLP 20 tables present safe distance for a single transmitter. Refer to Part II, Section C of IME SLP 20 for the method to calculate the safe distance when more than one RF transmitter is in the vicinity.

10.1.3.2 When using Group 2 initiators, refer to the manufacturer-provided safe distance tables for the particular initiator being used. Follow the recommended distances for shutting off radio, radar, cellular telephone, and pager RF transmitting units.

NOTE Manufacturer safe distance tables present safe distance for a single transmitter. Refer to IME SLP 20 for the method to calculate the safe distance when more than one RF transmitter is in the vicinity.

When using Group 3 initiators, all RF transmitters may be left operational.

10.1.3.3 Warning—When multiple perforating guns (or explosive devices) are combined into a single gun string, the gun string shall be assumed to have the environmental sensitivity rating of the most sensitive detonator or explosive component in the string.

For example, adding a Group 2 or Group 3 detonator to a string of Group 1 detonators does not make the entire string insensitive to RF energy.

- a) Check for stray voltage between the wellhead and rig, wellhead and perforating unit, wellhead and generator skid, wellhead and rig auxiliary power source, and wellhead and barge (if applicable). If stray voltage is measured, attempt to eliminate it at its source. A stray voltage worksheet, such as shown in Annex D, may be used.
- b) Only after stray voltage has been eliminated or reduced to not more than 0.25V, shall the perforating unit, rig, and wellhead be connected together electrically with grounding/bonding cables (refer to 6.7).
- c) If the stray voltage is less than 0.25 V, or if the stray voltage is less than 0.50 V and an additional voltage measurement with a 50 ohm shunt across the inputs of the voltage meter indicates a voltage less than 0.25 V for two minutes, a Group 1 detonator is permissible.
- d) When using a detonator with unintentional firing voltage characteristics of Group 2 or Group 3, the stray voltage limit may be increased to 2.5 V and 5 V, respectively.

Warning—Stray voltages shall be resolved prior to arming any explosive device.

- e) For the duration of the operation, remove or de-energize any electrical wiring that might contact the electric wireline unit, cable, or explosive device. Top drive systems should be electrically isolated in accordance with the manufacturer's procedures.

Warning—The discharge of a static charge can result in the inadvertent initiation of a detonator or initiating device. ESD control and grounding methods shall be employed to minimize the risk of ESD, prior to handling explosive devices. The static potential between components shall be equalized before handling the detonators.

10.2 Prechecks

10.2.1 Cable Conductor Continuity

Proper insulation and continuity of cable conductors shall be verified prior to the explosive device being armed.

10.2.2 Gun Circuits

Only those circuit testing instruments specified in 6.9 shall be used when checking continuity or insulation of a gun circuit.

10.2.3 Detonators

Detonators and other electrically initiated devices shall be contained within a detonator safety tube during checking operations (refer to 6.8).

10.2.4 Checks Using Unit Power (Check Fire/Hot Check)

A check fire/hot check or any other equipment test using unit power shall not be performed if a gun or explosive device is attached to the cable head.

Warning—Mistakes that occur while performing a check fire/hot check can cause surface detonation-related fatalities.

Check fire/hot checks should be avoided whenever possible. If unit power is used to test cable head or accessory equipment, the cable head and equipment to be tested shall be in clear view of the person applying the power and should be brought into the recorder cab whenever possible. Effective verbal communications shall be established and maintained between the person applying power and the personnel in the area of the cable head and explosive devices. It is essential that the person applying the power knows with certainty, before applying the power, that no gun or explosive device is attached to the cable head.

10.3 Preparation for Explosive Device Attachment

10.3.1 Isolate the Cable

The cable circuit shall be disconnected from unit instrumentation with a positive disconnect. A single point safety switch with key lockout is the preferred method for achieving this disconnect.

10.3.2 Turn Off Instrument Panel Power

Turn off all wireline unit instrument power switches.

NOTE Safety equipment such as unit pressurization, low pressurization warning, wellhead potential monitor, H₂S warning, weight indicator, etc. may remain switched on if they operate on a separate circuit.

10.3.3 Isolate Unit Power Source

Turn off all the main circuit breaker(s) in the unit except for those required for essential safety systems (refer to Section 6).

10.3.4 Activate Current/Voltage Limiting Circuits

All electrical cable conductors shall be grounded to the unit ground through a nominal resistance of 5000 ohms (refer to 6.3.2). This should be accomplished using a single point safety switch.

10.3.5 Lock Circuits in Safe Mode

After placing the cable circuit in safe mode (following 10.3.1 through 10.3.4), the key to the lockout device shall be removed and shall remain outside the electric wireline unit until the explosive device has been introduced into the well to a minimum depth of 61 m (200 ft) below ground level or 61 m (200 ft) below sea floor.

10.4 Arming the Explosive Device

10.4.1 General

Warning—The arming and/or handling of explosives shall not be attempted on the approach of—or during—a storm. Electrical discharges can occur during rain or snowstorms and during dust and sand storms. If lightning can be seen, thunder can be heard, or weather is deteriorating rapidly (wind gusts, temperature variations, sudden precipitation, fast-forming clouds, sand storms etc.), attaching the head to the gun string, arming, disarming, and/or handling of any explosive device shall not be initiated.

Attaching the head to the gun string, performing arming procedures, and/or handling of any explosive device shall not commence until 30 continuous minutes of stabilized weather without thunder has passed.

Arming shall not be performed during the arrival of helicopters or boats at an offshore location.

Arming shall not be commenced if any of the aforementioned circumstances are expected to arise before the arming operation can be completed and the gun introduced into the well to a minimum depth of 61 m (200 ft) below ground level or 61 m (200 ft) below the sea floor.

10.4.2 Responsibility

The EUIC or a qualified designee (including an explosive user who is in the process of being trained; refer to Section 15) shall perform all explosive device arming operations.

10.4.3 Stray Voltage Check

Verify that the voltage between the wellhead and the following items does not exceed the limits specified in 10.1.3.3 b) through d):

- a) the rig;
- b) the wireline unit;
- c) the generator skid;
- d) the barge (where applicable).

Arming operations shall not proceed until the measured voltage between items a) through d) meets the specified criteria.

10.4.4 Personnel

Relocate all personnel unnecessary to the operation to a safe area. All personnel shall be clear of the line of fire of the explosive device.

10.4.5 Verify Lockout

Confirm that the key to the cable safety circuit lockout device remains outside the electric wireline unit.

Warning—An unintended surface detonation can occur, resulting from power being applied from the wireline unit. The cable safety circuit lockout device protects against this. The key shall be outside of the unit and should be in the possession of the person connecting the cable head to the explosive device, and shall remain outside of the unit until restoring power per 10.5.1.

10.4.6 Arming the Explosive Device

The following procedure shall be followed for the correct EBBA of an explosive device and is a fundamental procedure for all electrical detonators.

- a) Check the cable head to confirm zero voltage between the shooting line and ground.
- b) Check the gun string through line (shooting wire) end-to-end continuity and insulation using a safety meter.
- c) Connect the cable head and any accessory equipment to the unarmed firing subassembly, completing the electric circuit from the wireline unit to the point where the detonator will be attached.
- d) Remove the detonator from its storage container and verify that it is shunted.
- e) Insert the detonator into the electric detonator safety tube and convey to the arming area.
- f) If the detonator is to be checked, such checks shall only be made while the detonator is contained within the safety tube (refer to 6.8).
- g) Verify that no voltage exists between the points where the detonator is to be attached.
- h) With the detonator still in the safety tube, connect the detonator lead wires to the electric line circuit. The ground connector should be connected first.
- i) Remove the detonator from the safety tube and connect it to the detonating cord or device to be fired.
- j) Complete assembly of the device, taking care not to pinch, crush, or impact the explosive components or wiring.

NOTE Refer to 7.4.2.4 or 7.4.3.4 for procedures for arming a multiple gun string of a selective gun system.

10.5 Deploying the Explosive Device

10.5.1 Restoring Power (Exiting Safe Mode)

Only after the explosive device has been deployed to a minimum depth of 61 m (200 ft) below ground level or below the sea floor shall the circuit be switched out of safe mode.

An exception to this practice is when operating offshore in deep water. In this case, power may be restored at 61 m (200 ft) below sea level (rather than below the sea floor) provided the consequences of an unintended detonation at that depth have been properly investigated on a case-by-case basis and shown to present an acceptable level of risk, and provided that such practice has been reviewed and agreed between the service company and the operating company.

10.5.2 Deployment to Depth

The explosive device should be run to depth without undue delay but at a descent rate not exceeding any limits recommended by the manufacturer. Depth control procedures should then be completed and the device positioned ready for initiation.

Caution—Damage to tool string components and contents can occur as a result of spudding. This should be avoided as it can lead to auto-ignition, low order detonation, or flooding of the tool string. When the ability to reach total depth is in question due to an obstruction or restriction in the well, internal diameter drift descents should be performed prior to any explosive-, chemical-, or plasma-related device deployment.

10.5.3 Initiating the Explosive Device

Prior to commencing the initiation sequence, the EUIC shall verify with the operating company representative that conditions are acceptable for commencing the firing sequence.

Once the operating company representative has confirmed that conditions are acceptable, the EUIC shall inform all wellsite personnel and then initiate the device.

10.6 Recovery of the Explosive Device

10.6.1 General

Warning—An explosive device shall be treated as armed until firing has been visually confirmed. The disarming of an explosive device should not be attempted on the approach of—or during—a storm. Electrical discharges can occur during rain or snowstorms and also during dust and sand storms.

Disarming should not be performed during the arrival of helicopters or boats at an offshore location.

Disarming should not be commenced if any of the aforementioned circumstances are expected to arise before the disarming operation can be completed. The explosive device should be kept in the well at a minimum depth of 61 m (200 ft) below ground level or 61 m (200 ft) below the sea floor until it can be safely removed and disarmed. Refer to Warning in 10.4.1 for guidance on lightning storm observations.

10.6.2 Process Safety Management

To aid in the operation of retrieving thermally overexposed explosive devices or misfired explosives, a PSM methodology (such as 29 *CFR*, Part 1910.119 or equivalent) shall be used to guide a planned response. Some key elements from a PSM include:

- a) Process hazard analysis or job safety analysis—to identify worst-case scenarios and allow for a quantitative risk assessment. Refer also to API 75 ^[15] and API 75L ^[16].
- b) Operating procedures—to maintain consistency and provide clear and concise instructions to personnel.
- c) Training—to create subject-matter experts who are comfortable and knowledgeable with the processes they perform.
- d) Prestartup safety review—to document that all of the proper checks, equipment, and other requirements have been completed before starting a task.
- e) MOC—to allow for responsible flexibility to the situation as it changes.
- f) Emergency planning and response—to establish a preplanned set of actions that are used as a response to an incident.

With respect to emergency planning and response at the wellsite, some new potential hazards can be introduced during the recovery of explosive devices that have been either thermally exposed to wellbore temperatures or misfired due to unknown reasons. One set of hazards are related to thermally overexposed explosive devices (see 9.5). Other unique hazards can exist for specific explosives.

10.6.3 Retrieval to Surface

The explosive device should be retrieved at a rate not exceeding any limits recommended by the manufacturer. The explosive device should be kept in the well at a minimum depth of 61 m (200 ft) below ground level or 61 m (200 ft) below the sea floor until the following steps have been completed:

- a) Power down (reenter safe mode)—at a depth of no less than 61 m (200 ft) below ground level or 61 m (200 ft) below the sea floor, the steps described in 10.3.1 through 10.3.4 shall be followed to place the cable circuit back in safe mode and isolate unit power.
- b) Lock circuits in safe mode—after placing the cable circuit in safe mode, the key to the lockout device shall be removed and shall remain outside the electric wireline unit until the explosive device has been retrieved from the well and has been disarmed.
- c) Suspected misfire—if a full or partial misfire is suspected, the procedure detailed in 9.5 shall be followed as applicable.

See Annex B and Annex C for more information on disarming procedures and equipment.

10.6.4 Personnel

Relocate all personnel unnecessary to the operation to a safe area. All personnel shall be clear of the line of fire of the explosive device.

10.6.5 Check for Internal Pressure

Both fired and misfired tools shall be checked for any evidence of internal pressure, if applicable (e.g. when using hollow carrier guns). If internal pressure is encountered, bleed off the pressure following the service company or manufacturer's recommended procedures.

10.6.6 Disarming Misfired Devices

Misfired devices shall be disarmed immediately prior to removal of the cable head from the gun, using the reverse EBBA process so that the ballistic connection is removed first, followed by the electrical connection with the detonator in the electrical detonator safety tube, as follows:

- a) Remove the detonator from the detonating cord (or device).
- b) Put the detonator into the safety tube (refer to 6.8).
- c) Disconnect the detonator electrically from the circuit.
- d) Shunt the detonator lead wires together, then remove the detonator from the safety tube and place it into an appropriate container for transportation from the wellsite (refer to 5.3.1).
- e) Remove the cable head and transfer the gun to an appropriate area for downloading any misfired explosives (refer to 9.5.4 for discussion on special requirements for handling HMX that has been exposed to elevated temperatures).

11 Tubing-conveyed Perforating Operations

11.1 Wellsite Preparation

11.1.1 Electrical Firing

Electrical firing shall be performed in accordance with Section 10.

11.1.2 Mechanical/Percussion Firing

Warning signs reading "DANGER EXPLOSIVES," or equivalent, shall be prominently displayed at the site and at all entrances.

11.2 Preparing the Explosive Device

11.2.1 Responsibility

The EUIC or a qualified designee (including an explosive user who is in the process of being trained; refer to Section 15) shall perform all explosive device arming operations.

11.2.2 Avoiding Explosive Component Impact or Mechanical Interference

When making a vertical gun connection, the handling cap from the suspended gun should be removed first, prior to removing the handling cap from the lower gun. Immediately prior to making the connection, a check should be performed to confirm that no extraneous material or objects are present within the gun end cavities.

11.2.3 Mechanical/Percussion Firing Heads

Firing heads that will be exposed to pressure while at surface shall include a safety feature to prevent explosive device initiation by an accidental over-pressurization while at surface.

Such a feature shall not be required if the firing head is to be used in timer mode, and no explosive device will be connected while at surface (e.g. when the firing head is to be armed, deployed into the well, and latched onto an explosive device that has been previously deployed and positioned at depth).

11.2.4 Hydraulic and Pressure-actuated Firing Heads

Hydraulic and pressure-actuated firing heads that are to be connected to an explosive device at surface shall have been tested to 1.2 times the maximum surface pressure expected at any time during deployment prior to being connected to the explosive device.

11.2.5 Safety Sub(s)

To augment rig crew safety, a safety sub or blank gun section shall be installed between each gun assembly or explosive device and firing head to position the loaded portion a safe distance below the rig floor during arming and disarming operations. The minimum sub length should be 3 m (10 ft). In some cases, a longer sub is required to position the loaded assembly safely below living quarters or other occupied areas. A safety spacer may not be required when running a bottom-up firing system (refer to 11.3.4). The connection between the firing head and the safety sub should be the last connection made up when running in hole.

11.3 Arming the Explosive Device

11.3.1 Electrical Initiations Systems for Tubing-conveyed Perforating

If using an electrical initiation system for TCP, refer to 10.4.

11.3.2 Arming of Electrical Firing Systems (Non-electric Line)

When arming electrical firing systems (non-electric line), the following steps shall be followed:

- a) Eliminate sources of stray electrical energy as described in 10.1.3.
- b) Suspend all work on the rig floor and relocate all personnel unnecessary to the operation to a safe area until the explosive device has been armed and run into the well to a depth of 61 m (200 ft) or more below ground level or 200ft below the sea floor. No personnel should be present below the rig floor during arming or deployment operations. All personnel shall be clear of the line of fire of the explosive device.
- c) Remove detonator from its storage container and verify that it is shunted.

- d) Insert the detonator into the detonator safety tube and convey to the arming area.
- e) If the detonator is to be checked, such checks shall only be made while the detonator is contained within the safety tube (refer to 6.8).
- f) Verify that no voltage exists between the points where the detonator is to be attached.
- g) Secure the detonator into the firing mechanism housing, install protective devices, and convey to the explosive device assembly.
- h) Install the firing mechanism(s) at the top of the safety spacer.

11.3.3 Arming of Mechanical Firing Systems

When arming mechanical firing systems, the following steps shall be followed:

- a) Suspend all work on the rig floor, and relocate all personnel unnecessary to the operation to a safe area until the explosive device has been armed and run into the well to a depth of 61 m (200 ft) or more below ground level or 61 m (200 ft) below the sea floor. No personnel should be present below the rig floor during arming or deployment operations. All personnel shall be clear of the line of fire of the explosive device.
- b) Secure the detonator into the firing mechanism housing, install protective devices, and convey to the explosive device assembly.
- c) Install the firing mechanism(s) at the top of the safety spacer.

11.3.4 Arming of TCP Systems Which Fire Bottom Up

A firing head should not be installed at the bottom of a loaded gun assembly unless a demonstrated safe design has been developed that prevents accidental firing of the upper gun string at or near the surface during arming and disarming (following exposure to downhole conditions). Operation of an explosive system in such a configuration will require prior review by, and agreement between, the service company and the operating company.

11.4 Deploying the Explosive Device

11.4.1 Deployment to Depth

The explosive device should be run to depth at a descent rate not exceeding any limits recommended by the manufacturer. Depth control procedures should then be completed and the device positioned, ready for initiation.

11.4.2 Initiating the Explosive Device

Prior to commencing the initiation sequence, the EUIC shall verify with the operating company representative that conditions are acceptable for commencing the firing sequence.

Once the operating company representative has confirmed that conditions are acceptable, the EUIC shall inform all wellsite personnel and then initiate the device.

11.5 Recovery of the Explosive Device

11.5.1 Special Handling of HMX Exposed to Elevated Temperature

Refer to 9.5.4.

11.5.2 Drop Bar Systems

Explosive systems that use drop bar initiation shall not be brought to surface without making all reasonable attempts to retrieve the drop bar, unless a positive indication has been observed that the gun has fired.

11.5.3 Devices with Self-contained Power Sources

Explosive devices that include a self-contained power source shall be deactivated prior to being retrieved from the well, compliant with service company recommended procedures.

11.5.4 Personnel

Relocate all personnel unnecessary to the operation to a safe area before retrieving the explosive device to a depth of less than 200ft (61m) below ground level or below the sea floor. No personnel should be present below the rig floor during retrieval or disarming operations. All personnel shall be clear of the line of fire of the explosive device.

11.5.5 Check for Internal Pressure

Both fired and misfired tools shall be checked for any evidence of internal pressure, if applicable (e.g. when using hollow carrier guns). If internal pressure is encountered, bleed off the pressure following the service company or manufacturer's recommended procedures.

11.5.6 Disarm the Explosive Device

Immediately remove the firing mechanism. Proceed to break down the guns, reversing the procedure described in 11.3. Any misfired components should be placed in an appropriate container for transportation from the wellsite (refer to 5.3.1).

12 Coiled Tubing Perforating Operations

12.1 General Information

Users shall explicitly follow the equipment manufacturer's recommendation for safe transport, storage, handling, and use. Specific training is required, referencing the appropriate user's manual, specifications, company-specific procedures, and safety data sheet (SDS). Tools shall be maintained according to, and never modified outside, the manufacturer's recommended guidelines. Firing heads used for coiled tubing perforating shall be in compliance with 7.6 for downhole firing systems. Standard coiled tubing operations typically follow TCP processes (Section 11) however, when using coiled tubing with electric line installed inside the coil, electric line-conveyed processes (Section 10) should be followed.

12.2 Coiled Tubing Perforating and Simultaneous Operations (SimOps)

Deployment of explosive systems with coiled tubing carries inherent risk due to the combination of multiple services, such as pumping, coiled tubing, and perforating, which may occur at the same time. Job equipment, processes, and responsibilities shall be reviewed by and agreed upon between the service company(s) and the operating company prior to operation. This may include a complete well on paper (CWOP) and/or systems integration test (SIT).

12.3 Job Design

Jobs shall be designed such that trip/pop off valves are set in accordance with coiled tubing and TCP guidelines for their respective working pressures.

To prevent off-depth and surface gun initiation due to trapped pressure, absolute pressure firing heads shall have communication ports between coiled tubing ID and annulus, and ball drop differential pressure firing heads shall have weep holes.

12.4 Wellsite Checks

Trip/pop off valves shall be set according to pre-agreed pressures, in conjunction with the coiled tubing and perforating personnel before coiled tubing perforating assembly deployment.

Weep holes and communication ports in the firing heads shall be installed in the bottom hole assembly (BHA) and functioning properly.

12.5 Preparing the Explosive Device

During pickup and assembly, ensure that firing heads and/or exposed explosives are not contaminated with residual wellbore fluids, as this can cause misfire and require tripping live guns.

12.6 Deploying the Explosive Device

Lubricators shall not be pressure tested with pressure-activated firing heads attached to loaded guns.

The pressure on coil and wellhead shall be monitored to ensure they both are equalizing so that differential pressure is not created across the firing head that could fire guns.

The explosive device should be run to depth at a rate previously agreed between the service company and the operating company. Depth control procedures shall be completed and the device positioned and ready for initiation.

When using a differential ball drop firing head, a second ball should not be dropped after the first attempt has been made. A second ball may be allowed, given prior review and agreement between service company and operating company.

To confirm guns have fired, the volumes pumped and coiled tubing and wellhead pressures should be monitored. Be aware of nitrogen thermal effects while monitoring pressure to identify firing head activation. Additional shot detection parameters should be used to clearly identify detonation (i.e. monitor tension, use additional shot detection systems, etc.).

12.7 Recovery of the Explosive Device

If a misfire is suspected and circulation cannot be established, the BHA circulating sub (e.g. trip/pop off valve) should be activated before pulling out of the hole. If circulation cannot be confirmed with trip/pop off valve open, the BHA should be disconnected to leave guns in the hole.

When pulling out of the well, if there is any pressure on the coil when the BHA reaches surface, the pressure shall be bled in a controlled manner from the lubricator side and the coil pressure monitored to ensure that it is also bleeding off. This confirms that there is no potential differential created across the firing head. A longer time may be required to bleed the coil through weep holes if nitrogen is used.

13 Slickline Perforating Operations

13.1 Responsibility

The EUIC or a qualified designee (including an explosive user who is in the process of being trained; refer to Section 15) shall perform all explosive device arming operations related to downhole firing systems.

13.2 Field Safety Considerations

All firing devices shall have two independent features for triggering initiation, such as time and temperature, time and pressure, time and motion.

To prevent premature ignition, do not expose to surface sources of heat, pressure, friction, or impact.

Follow applicable requirements for posting safety signs, establishing a safe-work zone, and prohibiting non-essential personnel from work area and rig floor when operations are occurring (see 6.10 and 10.1.1).

Warning—Well conditions at the surface can match preprogrammed parameters, thus opening firing windows and exposing personnel and equipment to live fire conditions. Prior review and agreement between service company and operating company personnel to change one or more parameters may be required to remove this potential hazard.

13.3 Wellsite Checks

Triggers include batteries; therefore, the potential exists for electrical discharge, which can accidentally fire an electric initiator. After programming the firing windows, disconnecting from surface sources of power, and attaching the battery, perform all manufacturer-recommended checks prior to connecting to the initiator. At a minimum, perform a check to confirm <0.25 V and <25 mA leakage from the output lines going to the initiator, as measured from the assembled electrical and mechanical sections.

13.4 Recovery of the Explosive Device

The EUIC shall stop at 61 m (200 ft) below ground level or sea floor and confirm wellbore parameters are, and will continue to remain, outside established firing windows, thus ensuring the tool is in safe mode and allowing safe removal from the well.

14 Special Categories of Explosive Devices

14.1 Setting Tools

Setting tools containing gas-generating explosive power charges shall be treated in the same way as other electric line or tubing-conveyed explosive devices, except that they may be ballistically armed prior to being electrically armed. Setting tools that do not contain any gas-generating explosive components are exempt from this RP.

14.2 Cased Hole Formation Testers

Cased hole formation testers shall be treated in the same way as other electric line perforating devices (see Section 10).

14.3 Propellant Stimulation Tools

14.3.1 General Information

Propellant tools are used for the stimulation of oil and gas wells. Propellants are a mixture of fuel and oxidizer. When initiated they generate gases as a by-product of the combustion process.

Propellant tools can come in various forms, including but not limited to sleeve, tube, stick, pellet, and cartridge. Propellant sensitivity, burn rate, pressures generated, and gas volumes produced are dependent upon the specific propellant type, composition, and the specific environment where used. Propellants are inherently sensitive to temperature, pressure, friction, and shock (impact). Confinement increases sensitivity.

Liquid propellants, due to limited expertise and restricted geographical usage, are considered beyond scope of this document. Operation of an explosive system in such a configuration shall require prior review by, and agreement between, the service company and the operating company.

Users of propellant tools shall explicitly follow the manufacturer's recommendation for safe transport, storage, handling, and use. Specific product training is required, referencing the appropriate user's manual, specifications,

company-specific procedures, and SDS. Propellant and associated equipment shall not be modified outside the manufacturer's recommended guidelines.

14.3.2 Field Safety Considerations

14.3.2.1 Propellant Systems

The following shall apply to propellant systems.

- a) To prevent premature ignition, do not expose propellant surfaces to sources of heat, pressure, friction, or impact.
- b) Follow applicable requirements for posting safety signs, establishing a safe-work zone, and prohibiting nonessential personnel from work area and rig floor when operations are occurring (refer to Section 9).
- c) Follow applicable requirements for detonator arming sequence, EBBA (refer to Section 9).

14.3.2.2 Exposed Propellant Systems

Exposed propellant systems not protected by a carrier are especially susceptible to friction, so the following requirements shall be followed:

- a) To limit the friction between system OD and casing ID, run centralizer/wear rings at manufacturer recommended intervals. If not specified, run at mutually agreed intervals decided between service company and operating company.
- b) When lifting, slide propellant inside a lifting sleeve or lubricator to prevent damage and to protect personnel from exposure.

14.4 Bullet Perforating Guns

Bullet perforating guns should be treated in the same way as other electric line perforating devices, with the exception of the arming sequence described in 10.4.5, which is unnecessary because these tools are ballistically armed during assembly. The provisions in 7.3.9 apply to these tools.

14.5 Propellant-activated Sidewall Sample Takers

Propellant-activated sidewall sample takers should be treated in the same way as other electric line perforating devices with the exception of the arming sequence described in 10.4.5, which is unnecessary because these tools are ballistically armed during assembly. The provisions in 7.3.9 apply to these tools.

Propellant-activated sidewall sample takers shall not be placed on the catwalk or in any other area where electric power can be applied to logging tools.

15 Personnel Training

15.1 Introduction

This section describes the recommended minimum qualifications for personnel who participate in the storage, handling, and use of explosives at the wellsite.

15.2 Classification of Personnel

15.2.1 Explosive Trainee

An explosive trainee is a person directly involved in explosives operations who has completed the training described in 15.3.2 and who works under the direct supervision of an explosive user.

15.2.2 Explosive User

An explosive user is a person who has completed the training described in 15.3.3.

15.2.3 Explosive User in Charge

The EUIC is the explosive user responsible for safe explosive operations at the wellsite. The explosive user in charge shall be responsible for connecting detonators to explosive devices and shall therefore be trained and qualified to arm explosive devices in addition to completing the training described in 15.3.4.

15.3 Qualifications

15.3.1 Introduction

All personnel involved in explosives operations shall meet minimum age requirements as prescribed by applicable regulations or statutes governing the transportation and use of explosives. Personnel shall be deemed competent and designated by the employer. Personnel may be deemed competent upon successful fulfillment of the requirements described in this section.

15.3.2 Explosive Trainee

An explosive trainee shall have completed an orientation course prior to becoming involved in field operations involving explosives. Such an orientation course shall cover the following areas:

- a) classification of explosives used in oilfield service operations;
- b) characteristics and behavior of each class of explosive;
- c) procedures for the safe handling of explosives, including detonators;
- d) procedures for safe wellsite operations involving the use of explosive devices.

15.3.3 Explosive User

An explosive user shall have completed a minimum of six months training as an explosive trainee and shall have available on site a current document certifying the completion of training in the following areas:

- a) classification of explosives used in oilfield service operations;
- b) characteristics and behavior of each class of explosive;
- c) procedures for the safe handling of explosives, including detonators;
- d) procedures for safe wellsite operations involving the use of explosive devices;
- e) applicable laws concerning the transportation, storage, handling, and disposal requirements for each class of explosive;
- f) an annual refresher of Items a) through e) of this paragraph, including new tools and technology, assessed by a comprehensive examination.

15.3.4 Explosive User in Charge

An EUIC shall have completed a minimum of four months of experience as an explosive user and shall have available on site a current document certifying that the EUIC:

- a) is approved and designated by his company as qualified to arm and disarm explosive devices,
- b) possesses any applicable blaster's permits required by local regulations,
- c) is considered a HazMat employee by his company,
- d) has completed an annual refresher of the explosive user training as specified in 15.3.3 f).

15.4 Training

15.4.1 Provision of Training

The requirements of 15.3.2, 15.3.3, and 15.3.4 can be fulfilled by a combination of the following:

- a) service company or other employer certification based on successful completion of course work, examinations, and field assessments;
- b) industry cooperative training courses;
- c) university training courses.

15.4.2 Training Records

Service companies and other employers shall issue verifiable credentials to qualified personnel. Such credentials or equivalent individual training records should be made available on request to the operating company.

Annex A

(normative)

Critical Safety Equipment for Operations

A.1 General

Critical safety equipment is the minimum equipment required to conduct an explosives operation safely. The critical safety equipment list is subdivided into categories as basic equipment for different types of perforating jobs; however, additional equipment might be required for these jobs. The recommended safety equipment is listed in Annex C.

A.2 All Systems

A.2.1 Detonating Cord Cutting Device

Only approved detonating cord cutting devices, and techniques recommended by the explosive manufacturer or authorized by the service company shall be used.

A.2.2 Explosive System Loading Tools

Only approved tools and techniques recommended by the explosive manufacturer or authorized by the service company shall be used.

A.2.3 Detonator Crimper

Only approved detonator crimpers and techniques recommended by manufacturers of detonator attachment devices, or techniques authorized by the service company, shall be used.

A.2.4 Gun Loading Shock Absorption Material

Guns shall be loaded only in designated loading areas and should be equipped with rubber mats to prevent initiation of charges due to the impact of dropped charges.

A.2.5 Warning Signs

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).

A.3 Electrically-initiated Systems

A.3.1 Electric Detonator Circuit Testing Instruments

The only instruments recommended for use when testing electric detonators and detonator circuits are those specifically designed or qualified for checking explosives and explosives circuits. The test current from the safety meter used to perform resistance checks shall not exceed 25 mA or 10 % of the no-fire rating of the detonator in the circuit, whichever is less.

A.3.2 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 design shall be capable of containing the detonator fragments and mitigating the blast.

A.3.3 Firing System

The following apply to surface firing systems.

- a) At least three deliberate actions shall be required to fire the explosive device.
- b) At least one action shall require the use of two hands.
- c) At least one action shall involve a spring-loaded switch.

A.3.4 Electrical Grounding/Bonding System

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

A.3.5 Perforating Gun Power Safe Device (PSD)

A relatively high percentage of surface detonations are related to electric power being inadvertently applied to the gun system. A PSD that provides a barrier between the cable head and gun system until the gun string is safely downhole can reduce the likelihood of this type of incident occurring. A PSD should ensure unit power is blocked as intended but permits shooting through the PSD when needed. It should be used with every electrically-initiated gun system.

A.3.6 Firing System Safety Key

After placing the cable circuit in safe mode, the key to the lockout device shall be removed and shall remain outside the electric wireline unit until the explosive device has been introduced into the well to a minimum depth of 61 m (200 ft) below ground level or 61 m (200 ft) below sea floor.

A.3.7 Wellhead Potential Monitor

A wellhead potential monitor is a device used to detect and monitor any stray voltages that can be present around the wellhead. Other more sophisticated versions can continuously monitor the ac (50 Hz and 60 Hz) and dc voltages between the two measurement terminals. If the potential exceeds a preset threshold level, the audio alarm sounds. The audio alarm is supplemented with external flashing lights and an external alarm so that alarm can be heard on the catwalk.

A.4 Chemical Cutter Systems

Chemical cutters shall have a sleeve (also known as a protective sleeve) that shall:

- a) cover the severing head,
- b) be made of aluminum,
- c) be of sufficient thickness to provide effective deflection,
- d) be open on both ends,
- e) have an inside diameter adequate to pass over the severing head, and
- f) have a means for positively securing to the severing head.

Field modifications shall only be made to chemical cutter sleeves if written approval has been received from the equipment manufacturer.

A.5 Percussion Initiated Systems

A safety sub is a safety spacer or blank gun section, and it shall be installed between each gun assembly (or explosive device) and firing head to position the loaded portion a safe distance below the rig floor during arming and disarming operations. The minimum spacer length should be 3 m (10 ft). In some cases, a longer spacer will be required to position the loaded assembly safely below living quarters or other occupied areas. A safety spacer may not be required when running a bottom-up firing system. The connection between the firing head and the safety spacer should be the last connection to be made up when running in hole.

A safety sub may not be required when running a bottom-up firing system.

Annex B (informative)

Explosive Arming and Disarming Safety-critical Fundamentals— Electric Detonators

The following is an example text that can be posted in electric wireline units. See Section 10 for further details.

Warning—The arming and/or handling of explosives shall not be attempted on the approach of—or during—a storm. Electrical discharges can occur during rain or snowstorms and during dust and sand storms. If lightning can be seen, thunder can be heard, or weather is deteriorating rapidly (wind gusts, temperature variations, sudden precipitation, fast forming clouds, sand storms, etc.), attaching the head to the gun string, arming, disarming, and/or handling of any explosive device shall not be initiated.

Attaching the head to the gun string, performing arming procedures and/or handling of any explosive device shall not commence until 30 continuous minutes of stabilized weather without thunder have passed.

Arming shall not be performed during the arrival of helicopters or boats at an offshore location.

Arming shall not be commenced if any of the aforementioned circumstances are expected to arise before the arming operation can be completed and the gun introduced into the well to a minimum depth of 61 m (200 ft) below ground level or 61 m (200 ft) below the sea floor.

- a) The designated EUIC or a qualified designee shall perform all explosive device arming operations.
- b) Verify that the voltage between the wellhead and rig, unit, generator skid and barge (where applicable) does not exceed the limit specified in API RP 67. Do not proceed with arming operations until the measured voltage meets the specified criteria.
- c) A check fire/hot check or any other equipment test using unit power shall not be performed if a gun or explosive device is attached to the cable head.

Warning—Mistakes can occur while performing a check fire/hot check test and can result in a surface detonation.

Check fire/hot checks should be avoided whenever possible. If unit power shall be used to test cable head or accessory equipment, the cable head and equipment to be tested shall be in clear view of the person applying the power and should be brought into the recorder cab whenever possible. Effective verbal communications shall be established and maintained between the person applying power and the personnel in the area of the cable head and explosive devices. It is essential that the person applying the power knows with certainty, before applying the power, that no gun or explosive device is attached to the cable head.

Precautions shall be exercised to prevent RF radiation hazards.

All personnel shall be clear of the line of fire of the explosive device.

After placing the cable circuit in safe mode, the key to the lockout device shall be removed and shall remain outside the electric wireline unit until the explosive device has been introduced into the well to a minimum depth of 61 m (200 ft) below ground level or 61 m (200 ft) below sea floor.

Remove only enough detonators from the magazine to address the work at hand.

Connect the cable head and any accessory equipment to the unarmed firing subassembly, completing the electric circuit from the wireline unit to the point where the detonator will be attached.

Verify that no voltage exists between the points where the detonator is to be attached.

Follow "Arm the Explosive Device" using the EBBA process, as stated in API RP 67.

In the event of a delay, cancellation, or misfire, the EUIC shall initiate the misfire procedure.

Annex C

(informative)

Recommended Safety Equipment and Processes

C.1 Check Fire Test Fixture

A check fire test fixture is a device that assists the EUIC when performing the check fire/hot check procedure, previous to any run in-hole with explosives devices. The device provides test modes that simulate loads for both 50 ohm resistorized devices and other types of electric detonators; also provided are two additional modes to check the shooting casing collar locator.

C.2 Auditing

Operating companies and service companies should audit their oil and gas explosive operations to this standard.

Operating companies and service companies should have training on how to conduct an audit.

Auditing forms should be kept on file for a minimum of three years and be provided upon request. An example auditing checklist is given in Annex E.

C.3 Effective Communication System

There shall be an effective verbal communication system between the EUIC and the personnel associated with the explosive operation. Examples include, but are not limited to, direct line-of-sight person-to-person communication, radios (in conjunction with RF-safe initiators), and hardwired communication boxes.

C.4 5K Resistance Verification on “Safe”

When in safe mode, the cable circuit shall open all cable connectors from the electric wireline unit circuits, and all 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.

C.5 Infrared Thermometer (Intrinsically Safe)

An infrared thermometer (intrinsically safe) measures the surface temperature of a retrieved gun system.

Annex D (informative)

Stray Voltage Worksheet

Figure D.1 is an example worksheet that can be used to evaluate the environmental sensitivity detonators. Add the ac and dc readings (total volts) Use the same procedure for total amperes if stray current is required.

GROUND CLAMP AND WELLHEAD				AUX GROUND CLAMP AND ADDITIONAL EQUIPMENT 4			
VOLTAGE		CURRENT		VOLTAGE		CURRENT	
DCV		DCA		DCV		DCA	
ACV		ACA		ACV		ACA	
TOTAL V	0	TOTAL A	0	TOTAL V	0	TOTAL A	0

AUX GROUND CLAMP AND RIG/CRANE				AUX GROUND CLAMP AND ADDITIONAL EQUIPMENT 5			
VOLTAGE		CURRENT		VOLTAGE		CURRENT	
DCV		DCA		DCV		DCA	
ACV		ACA		ACV		ACA	
TOTAL V	0	TOTAL A	0	TOTAL V	0	TOTAL A	0

AUX GROUND CLAMP AND ADDITIONAL EQUIPMENT 1				AUX GROUND CLAMP AND ADDITIONAL EQUIPMENT 6			
VOLTAGE		CURRENT		VOLTAGE		CURRENT	
DCV		DCA		DCV		DCA	
ACV		ACA		ACV		ACA	
TOTAL V	0	TOTAL A	0	TOTAL V	0	TOTAL A	0

AUX GROUND CLAMP AND ADDITIONAL EQUIPMENT 2				AUX GROUND CLAMP AND ADDITIONAL EQUIPMENT 7			
VOLTAGE		CURRENT		VOLTAGE		CURRENT	
DCV		DCA		DCV		DCA	
ACV		ACA		ACV		ACA	
TOTAL V	0	TOTAL A	0	TOTAL V	0	TOTAL A	0

AUX GROUND CLAMP AND ADDITIONAL EQUIPMENT 3				AUX GROUND CLAMP AND ADDITIONAL EQUIPMENT 8			
VOLTAGE		CURRENT		VOLTAGE		CURRENT	
DCV		DCA		DCV		DCA	
ACV		ACA		ACV		ACA	
TOTAL V	0	TOTAL A	0	TOTAL V	0	TOTAL A	0

Blasters Meter Serial Number _____
 Blasters Meter Calibration Date _____
 Date Stray Voltage Test Performed _____
 Performed By: _____
 Employee Number _____

Figure D.1—Stray Voltage Worksheet

Annex E (informative)

Wellsite Audit Checklist

Well Site Preparation	Yes	No	N/A
Land operations —Warning signs reading “DANGER – EXPLOSIVES – TURN OFF RADIO TRANSMITTERS” (or equivalent) shall be prominently displayed at the site and at all entrances and on all roadways that are within 305 m (1000 ft) of the wellsite.			
Offshore operations —Warning procedures similar to those specified in HSAC 92–2 should be prominently displayed in any restricted area where helicopter operations are anticipated.			
Turn off electrical cathodic protection systems unless using an initiator (detonator or igniter) with no-fire voltage characteristics of Group 3, or those Group 2 initiators with a no-fire voltage greater than or equal to 100V dc.			
Discontinue all electric welding operations unless using an initiator with no-fire voltage characteristics of Group 3, or those Group 2 initiators with a no-fire voltage greater than or equal to 100 V ac/dc.			
Precautions shall be exercised to prevent radio frequency radiation hazards. Warning signs shall be posted and other appropriate measures taken so that radio and radar frequency units will be shut off when within hazardous distances of explosive operations.			
Refer to the latest edition of IME 20 and IEEE C95.4 ^[11] for recommended distances for posting signs and shutting off radio, radar, cellular telephone, and pager radio frequency transmitting units.			
Check for stray voltage between the wellhead and rig, wellhead and perforating unit, wellhead and generator skid, wellhead and rig auxiliary power source, and wellhead and barge (if applicable). If stray voltage is measured, attempt to eliminate it at its source.			
Only after stray voltage has been eliminated or reduced to not more than 0.25 V, shall the perforating unit, rig, and wellhead be connected together electrically with grounding/bonding cables.			
Stray voltages shall always be resolved prior to arming any explosives device.			
For the duration of the operation, remove or de-energize any electrical wiring that might contact the electric wireline unit, cable, or explosive device. Top drive systems should be electrically isolated in accordance with the manufacturer’s procedures.			
The discharge of a static charge has resulted in a number of incidents involving the inadvertent initiation of a detonator or initiating device. Proper electrostatic discharge (ESD) control and grounding methods shall be employed to minimize the risk of ESD, prior to handling explosive devices. Equalize the static potential between components before handling detonators.			
Prechecks	Yes	No	N/A
Cable conductor continuity —Proper insulation and continuity of cable conductors shall be verified prior to the explosive device being armed.			
Gun circuits —Only those circuit testing instruments specified in API 67 shall be used when checking continuity or insulation of a gun circuit.			
Detonators —Detonators and other initiation devices shall be contained within a detonator safety tube during checking operations.			

Figure E.1—Wellsite Audit Checklist

Checks using unit power (check fire or hot check)—A check fire/hot check or any other equipment test using unit power shall not be performed if a gun or explosive device is attached to the cable head. Check fire/hot checks should be avoided whenever possible. If unit power shall be used to test cable head or accessory equipment, the cable head and equipment to be tested shall be in clear view of the person applying the power and should be brought into the recorder cab whenever possible. Effective verbal communications shall be established and maintained between the person applying power and the personnel in the area of the cable head and explosive devices. It is essential that the person applying the power knows with certainty, before applying the power, that no gun or explosive device is attached to the cable head.			
Mistakes that occur while performing a Check Fire/Hot Check have resulted in a number of surface detonation-related fatalities.			
Preparation for Explosive Device Attachment	Yes	No	N/A
Isolate the cable circuit—The cable circuit shall be disconnected from unit instrumentation with a positive disconnect. A single point safety switch with key lockout is the preferred method for achieving this disconnect.			
Remove instrument panel power—Turn off all wireline unit instrument power switches.			
NOTE Safety equipment such as unit pressurization, low pressurization warning, wellhead potential monitor, H₂S warning, weight indicator, etc, may remain switched on if they operate on a separate circuit.			
Isolate unit power source—Turn off all the main circuit breaker(s) in the unit except for those required for essential safety systems.			
Activate current/voltage limiting circuits—All electrical cable conductors shall be grounded to the unit ground through a nominal resistance of 5000 ohms. This should preferably be accomplished using a single point safety switch.			
Lock circuits in safe mode—After placing the cable circuit in safe mode, the key to the lockout device shall be removed and shall remain outside the electric wireline unit until the explosive device has been introduced into the well to a minimum depth of 61 m (200 ft) below ground level or 61 m (200 ft) below sea floor.			
Arming the Explosive Device	Yes	No	N/A
WARNING The arming and/or handling of explosives shall not be attempted on the approach of—or during—a storm. Electrical discharges can occur during rain or snowstorms and during dust and sand storms. If lightning can be seen, thunder can be heard, or weather is deteriorating rapidly (wind gusts, temperature variations, sudden precipitation, fast-forming clouds, sand storms etc.), attaching the head to the gun string, arming, disarming, and/or handling of any explosive device shall not be initiated. Attaching the head to the gun string, performing arming procedures, and/or handling of any explosive device shall not commence until 30 continuous minutes of stabilized weather without thunder has passed. Arming shall not be performed during the arrival of helicopters or boats at an offshore location. Arming shall not be commenced if any of the aforementioned circumstances are expected to arise before the arming operation can be completed and the gun introduced into the well to a minimum depth of 61 m (200 ft) below ground level or 61 m (200 ft) below the sea floor.			
Responsibility—The designated explosive user in charge (EUI) or a qualified designee shall perform all explosive device arming operations.			
Stray voltage check—Verify that the voltage between the wellhead and rig, wellhead and unit, wellhead and generator skid, and wellhead and barge (where applicable) does not exceed the limit specified in API 67. Do not proceed with arming operations until the measured voltage meets the specified criteria.			
Personnel—Relocate all personnel unnecessary to the operation to a safe area. Ensure all personnel are clear of the line of fire of the explosive device.			

Figure E.1—Wellsite Audit Checklist (Continued)

Verify lockout —Confirm that the key to the cable safety circuit lockout device remains outside the electric wireline unit.			
Arm the Explosive Device	Yes	No	N/A
Connect the cable head and any accessory equipment to the unarmed firing subassembly to complete the electric circuit from the wireline unit to the point where the detonator will be attached. Follow the EBBA process for arming.			
Remove the detonator from its storage container and verify that it is shunted.			
Insert the detonator into the electric detonator safety tube and convey to the arming area.			
If the detonator is to be checked, such checks shall only be made while the detonator is contained within the safety tube.			
Check the gun string through line (shooting wire) end-to-end continuity and insulation using a safety meter.			
Verify that no voltage exists between the points where the detonator is to be attached.			
With the detonator still in the safety tube, connect the detonator lead wires to the electric line circuit. The ground connector should be connected first.			
Remove the detonator from the safety tube and connect it to the detonating cord or device to be fired.			
Complete assembly of the device, taking care not to pinch, crush, or impact the explosive components or wiring.			
Deploying the Explosive Device	Yes	No	N/A
Restoring power (exiting safe mode) —When the explosive device has been deployed to a minimum depth of 61 m (200 ft) below ground level or below the sea floor, the key to the cable safety circuit may be taken inside the electric wireline unit and the circuit may be switched out of safe mode.			
CAUTION When operating offshore in deep water, power may be restored at 61 m (200 ft) below sea level (rather than below the sea floor) provided the consequences of an unintended detonation at that depth have been properly investigated on a case-by-case basis and shown to present an acceptable level of risk, and that such practice has been reviewed and agreed between the service company and the operating company.			
Deployment to depth —The explosive device should be run to depth without undue delay but at a descent rate not exceeding any limits recommended by the manufacturer. Depth control procedures should then be completed and the device positioned ready for initiation.			
CAUTION Damage to tool string components and contents may occur as a result of spudding. This should be avoided as it can lead to auto-ignition, low order detonation, or flooding of the tool string. When the ability to reach total depth is in question, due to an obstruction or restriction in the well, internal diameter drift descents should be performed prior to any explosive, chemical, or plasma-related device deployment.			
Initiating the explosive device —Prior to commencing the initiation sequence, the EUIC shall verify with the operating company representative that conditions are acceptable for commencing the firing sequence. Once the operating company representative has confirmed that conditions are acceptable, the EUIC shall inform all wellsite personnel and then initiate the device.			

Figure E.1—Wellsite Audit Checklist (Continued)

Recovery of the Explosive Device	Yes	No	N/A
WARNING An explosive device shall be treated as armed until firing has been visually confirmed. The disarming of an explosive device should not be attempted on the approach of, or during, a storm. Electrical discharges can occur during rain or snowstorms and also during dust and sand storms. Disarming should not be performed during the arrival of helicopters or boats at an offshore location. Disarming should not be commenced if such circumstances are expected to arise before the disarming operation can be completed. The explosive device should be kept in the well at a minimum depth of 61 m (200 ft) below ground level or 61 m (200 ft) below the sea floor until it can be safely removed and disarmed. Refer to WARNING in 10.4 for guidance on lightning storm observations. Other safety considerations may include: a) Thermal runaway—Thermal runaway is a dangerous condition with explosion and detonation hazards. If thermal runaway is suspected, all personnel should evacuate to a safe distance immediately for a minimum 2-hour stand down time. Only the minimum amount of personnel should return to the area after the stand down. b) Pressure—Out-gassing from thermal decomposition may cause pressure to build up within the explosive device. A check for internal pressure should be conducted before proceeding. Special handling of HMX exposed to elevated temperature—Special attention shall be paid when retrieving any device containing HMX explosive that has been exposed to a temperature exceeding the HMX crystalline phase transition temperature. The phase change is irreversible, occurs at or above 150 °C (300 °F) and results in higher impact sensitivity. All HMX explosive devices shall be designed to prevent explosive from becoming loose during such a thermal cycle. Any uninitiated device containing HMX explosive that is retrieved after being exposed to a temperature exceeding the transition temperature shall be handled with care. The detonator shall be removed immediately and the gun or explosive device placed in a safe area until ready for transportation. Downloading of explosives should take place at service company premises under its technical supervision. Specific consultation shall take place between the operating company and service company whenever it is planned to expose HMX charges to temperatures approaching or exceeding the transition temperature, or whenever it is believed that charges may have been exposed to temperatures approaching or exceeding the transition temperature. Under such circumstances, operating companies and service companies are advised to review and agree to retrieval and disarming procedures prior to deployment.			
Retrieval to surface —The explosive device should be retrieved at a rate not exceeding any limits recommended by the manufacturer. The explosive device should be kept in the well at a minimum depth of 61 m (200 ft) below ground level or 61 m (200 ft) below the sea floor until the following steps have been completed:			
Power down (reenter safe mode) —At a depth of no less than 61 m (200 ft) below ground level or 61 m (200 ft) below the sea floor, the steps described in API 67 shall be followed to place the cable circuit back in safe mode and isolate unit power.			
Lock circuits in safe mode —After placing the cable circuit in safe mode, the key to the lockout device shall be removed and shall remain outside the electric wireline unit until the explosive device has been retrieved from the well and has been disarmed.			
Suspected misfire —If a full or partial misfire is suspected, the procedure detailed in API 67 shall be followed as applicable.			
Personnel —Relocate all personnel unnecessary to the operation to a safe area. Ensure all personnel are clear of the line of fire of the explosive device.			
Check for internal pressure —Both fired and misfired tools shall be checked for any evidence of internal pressure, if applicable (e.g. when using hollow carrier guns). If internal pressure is encountered, bleed off the pressure, following the service company or manufacturer's recommended procedures.			
Disarming any Misfired Devices	Yes	No	N/A
Any misfired devices shall be disarmed immediately prior to removing the cable head from the gun using the reverse EBBA process so that the ballistic connection is removed first, followed by the electrical connection with the detonator in the electrical detonator safety tube, as follows:			
Remove the detonator from the detonating cord (or device).			
Put the detonator into the safety tube.			

Figure E.1—Wellsite Audit Checklist (Continued)

Disconnect the detonator electrically from the circuit.				
Shunt the detonator lead wires together then remove the detonator from the safety tube and place it into an appropriate container for transportation from the well site.				
Remove the cable head and transfer the gun to an appropriate area for downloading any misfired explosives (refer to 9.5.4 for discussion on special requirements for handling HMX that has been exposed to elevated temperatures).				
Comments:				
Inspection performed by:		Date:		
Engineer in charge:		Date:		
Customer:				
Job:				

Figure E.1—Wellsite Audit Checklist (Continued)

Date: _____ Facility Name: _____

Inspection Conducted By: _____

Deficiency/Corrective Action Details

Item #	Deficiency Noted	Corrective Action Required	Responsible Party	Target Date	Date Corrected

Contact Manager Signature: _____

Assessor Signature: _____

Figure E.2—Deficiency/Corrective Action Details

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⁷ U.S. Department of Transportation, 1200 New Jersey Avenue, SE Washington, DC 20590, www.fhwa.dot.gov.

⁸ International Maritime Organization, 4, Albert Embankment, London SE1 7SR, United Kingdom, www.imo.org.

⁹ Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, www.ieee.org.

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