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Special Effect Pyrotechnics MANUAL

EDITION 3
2014

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About this manual

The purpose of this safety manual is to assist users in understanding the *Explosives Regulations, 2013* (the Regulations) as they relate to special effect pyrotechnics and for the safe sale, use and storage of special effect pyrotechnics.

This manual also provides a guide to the authorities having jurisdiction (AHJs) to assist them in approving special effect pyrotechnic events.

It is the responsibility of all sellers and users of special effect pyrotechnics to ensure compliance with the Regulations and the *Explosives Act* (the Act), as well as all applicable provincial and municipal laws and by-laws. This manual does not constitute legal advice.

If you have questions about the specifics of the legislation, contact the Explosives Safety and Security Branch. If you require assistance in the interpretation of the legislation, including the Regulations, and its potential application in specific circumstances, contact your legal advisor. This manual is not intended to replace the Act or the Regulations. Reference should always be made to the official version of the Act and Regulations (available at <http://laws-lois.justice.gc.ca/eng/acts/E-17/index.html>).

Authority under the Act and the Regulations

Although this manual is available to inspectors appointed under the Act, they will apply and enforce the Act and the Regulations based on the facts as they find them during their inspections. This manual does not affect their enforcement and compliance discretion in any way.

List of Authorized Explosives

Any explosive that is to be imported into or manufactured, transported, possessed or used in Canada must appear on the List of Authorized Explosives or be allowed by a permit, certificate or special authority issued by the Explosives Regulatory Division for special tests or product trials.

Note

- Explosives include propellants, ammunition, fireworks, model rocket motors and toy pistol caps, as well as blasting explosives.

- A testing protocol is established for authorization and classification of Class 1 (Explosives), and this testing helps to establish the United Nations classification.

Following a review of submitted specifications for the product, this testing protocol may be initiated if further assurances are required or if the product is new in the field. Testing is used to determine the safety of the product and conformity with the manufacturer's specifications.

These tests establish criteria for storage, transportation and general use of the product.

Special effect pyrotechnics

Special effect pyrotechnics (called pyrotechnics in this manual) include type F.3 explosives. The following types of explosives are also included if they will be used to produce a special effect in a film or television production or a performance before a live audience:

- fireworks accessories (type F.4)
- black powder and hazard category PE 1 black powder substitutes (type P.1)
- smokeless powder and hazard category PE 3 black powder substitutes (type P.2)
- initiation systems (type I) (e.g. blasting accessories)
- blasting explosives (type E.1) (e.g. detonating cord)
- special purpose pyrotechnics (pyrotechnics that are combined at the site of impending use with a flammable liquid, solid or gas to produce a custom-made pyrotechnics special effect)

To use pyrotechnics safely and responsibly, you need a basic understanding of three things:

- how pyrotechnics work
- how to use and handle pyrotechnics
- related laws and regulations

Audience

This manual has been developed for

- people wanting to work in the pyrotechnic special effects industry as pyrotechnicians
- existing pyrotechnicians
- companies engaged in the sale or distribution of pyrotechnics
- performers who work with pyrotechnics
- authorities having jurisdiction, i.e. fire chief or fire protection officer (one of these will be the AHJ in most cases)
- designated representatives for event approval or site inspections: police forces, including explosives disposal units (EDUs) or equivalent, and provincial/territorial occupational health and safety organizations

What this manual addresses

This manual provides guidance about the Act and the Regulations and addresses

- sale, purchase, storage, use and disposal of all pyrotechnics as used in the performing arts, including
 - indoor or outdoor performances
 - live performances, as well as those produced without an audience (e.g. a closed production)
 - theatrical, musical or similar productions
 - videotaping, audiotaping or filming of any movie, television, radio or private performance
 - rehearsals
 - product trials and evaluations
 - any event using pyrotechnics

What this manual does not address

The guidance provided by this manual does not apply:

- to consumer fireworks (F.1), unless they are used in conjunction with pyrotechnics
- to display fireworks (F.2), unless they are used in conjunction with pyrotechnics
- where pyrotechnics are prohibited by provincial/territorial law or regulation, or municipal or city by-law. You must abide by that prohibition.
- in jurisdictions having pertinent and more stringent standards, regulations and requirements

Note

You must comply with the laws and regulations of other jurisdictions, even when they differ from the Act and the Regulations. You must also continue to comply with the Act and the Regulations. As a rule of thumb, comply with the most stringent regulation.

It is the responsibility of the pyrotechnician in charge to be aware of all relevant authorities, such as occupational health and safety or municipal bodies and ensure that all regulations and directions are followed.

- where the pyrotechnic special effects used are not defined as explosives under the Act. These include flame special effects such as
 - hand-held burning devices (e.g. lighters, alcohol wands)
 - small fires used to create a theme, compressed gas or liquid flame generators (e.g. propane flame bar, flame-breathing dragon)

If consumer or display fireworks are used in conjunction with, or at, pyrotechnic special effects events, contact the ERD for further guidance.

Flame special effects

For direction on flame special effects (flammable liquids, gases and solids) that are not defined as explosives under the Act, contact your AHJ. As a guide, you can consult the National Fire Protection Association (United States) document NFPA 160, *Standard for the Use of Flame Effects Before an Audience*. Provincial/territorial and municipal standards may apply.

Note This manual does apply to flame special effects used with pyrotechnics and/or detonating cord (a high explosive) to fabricate special purpose pyrotechnics, for example,

- a fireball effect made up of black powder (as an igniting/lifting/dispersing charge) with fuel oil placed in a plastic bag (turkey bag) and situated on top of the black powder charge. Ignition is normally accomplished with an electric match placed into the black powder.

Terminology

To add clarity, the following terms are used in this manual.

Pyrotechnician: The term “pyrotechnician” includes special effect pyrotechnics technicians, lead pyrotechnicians, lead technicians, special effects coordinators (SEC), and similar terms. It is also used as a generic term to refer to all classes of pyrotechnicians as set out in the Regulations.

Classes of pyrotechnicians: Where the manual refers to a class of pyrotechnicians, the actual class name is capitalized and in italics: *Pyrotechnician*, *Senior Pyrotechnician*, *Special Effects Pyrotechnician* and *Visitor Pyrotechnician*.

Article: The pyrotechnic article that produces the effect, and includes

- *igniters and initiators*
- *authorized pyrotechnics*
- *black and smokeless powder*
- *detonating cord and associated articles*
- *special-purpose pyrotechnics*

Device: The physical configuration in which the *pyrotechnic special effect article* is employed or situated (e.g. a concussion mortar, supporting framework for *pyrotechnic articles* such as a gerb fan, a truncated-pyramid mortar used to situate and direct a *special-purpose pyrotechnic* fireball, etc.)

- The term can also include the pyrotechnic *articles*, depending on the usage (e.g. cable cutter) and by industry convention (e.g. a spark-producing device, which is actually an *article* by the above description).

Cap: The unit of measure within the pyrotechnic industry for standard, mixed, two-component powder. “One cap” means “one cap full,” using the cap from the largest plastic bottle (bottle labeled “B”).

Effect: The resultant flame, sparks, heat, light, noise, concussion and/or mechanical action produced from the functioning of any *pyrotechnic special effect article*.

Equipment: All associated electrical and mechanical items or systems (e.g. controller, wiring, zip cord, test instruments).

Site (Location): A specific or general place for the filming of scenes or shoots.

Venue: A specific public location where live performances take place (theatre, night club, coliseum).

Types of pyrotechnic special effect products

The primary types or groups of pyrotechnic special effect products cited in this manual are listed and described as follows.

Authorized pyrotechnics or pyrotechnics (F.3)

- pyrotechnic *articles* (e.g. electric matches, squibs, mines, gerbs and saxons), including two-component or pre-mixed powders (e.g. airburst, concussion or flash powder) that have been tested and authorized (approved) for sale and use in Canada

Igniter

- an *article* typically producing a short-duration flame or flash (i.e. an electric match), generally used for the ignition of fuses, *pyrotechnic articles* (including powders), *black* and *smokeless powder*, and possibly flammables
- In certain applications, squibs are used for ignition as well.
- A *squib* differs from an electric match in that the squib contains an electric match as well as a pyrotechnic base charge.

Initiator

- *articles* that are manufactured for a purpose other than simple flame ignition (e.g. various strength squibs, spark-producing *devices* and bullet hits)
- items that are used to initiate (detonate) *detonating cord* and other *pyrotechnic special effect articles*

Black powder

- used to make up explosive charges (e.g. *black powder* lifters)

Smokeless powder

- used in flame projectors to produce a vertical column of flame up to 3 metres (m) high

Detonating cord (*a commercial high explosive*)

- a flexible cord containing powerful high explosives (PETN) with the explosive load expressed in grams per metre (g/m). The velocity of detonation (VOD) is approximately 7000 metres per second (m/s) (25 000 kilometres per hour [km/h]).
- The diameter of detonating cords ranges from 3 millimetres (mm) to 15 mm, with core loads (quantity of PETN per metre length of cord) of 1 to 85 g/m, respectively.
- initiated by commercial detonators or high-strength squibs that do not produce shrapnel themselves
- used in the film and television industries to
 - disperse and ignite flammable liquids, gases and solids
 - shear off metal or destroy small objects such as car axles and beams
 - create instant openings through doors or walls (destruction or rapid entry)

Note The word “det-cord” is used as an abbreviation for detonating cord throughout the manual. The words “det-cord and associated articles” are used as a simplification throughout the manual.

Note **Det-cord** and **associated articles** are allowed for use by *Special Effects Pyrotechnicians* who hold the fireworks operator certificate for *Special Effects Pyrotechnician – detonating cord*.

Special purpose pyrotechnics

- Special purpose pyrotechnics means pyrotechnics that are combined with a flammable liquid, solid or gas to produce custom-made special effects.

Right to appeal

You have the right to request a review of decisions of the Chief Inspector of Explosives (CIE) regarding suspensions or cancellations of certificates.

Prior to cancelling or suspending a certificate, the CIE will notify the certificate holder, in writing, of the decision to be made and provide an opportunity for the certificate holder to provide reasons why the certificate should not be suspended or cancelled.

Should the CIE suspend or cancel the certificate after the opportunity to provide reasons has passed or after reasons not to suspend or cancel have been given, the certificate holder may request a review of the CIE’s decision to suspend or cancel.

Requests for reviews must be made in writing and should be addressed to the Minister of Natural Resources, in care of the CIE, and must be made within 15 days after the CIE has given the certificate holder notice of the decision.

Amendments and revisions

This manual will be amended and updated to account for changes in technology, law and practice. We welcome your comments and recommendations. The ERD will communicate major changes in policy and direction to the industry through bulletins, directive letters or newsletters. Notification of any upcoming changes will be posted on the ERD Web site at erd.nrcan.gc.ca.

Chapter 1. Certification

1.1 Users with a certificate

Pyrotechnics is a wide and varied field. A theatre technician reproducing a lightning strike during a stage play, a pyrotechnician lighting up a rock concert, a *Special Effects Pyrotechnician* destroying structures in a film scene – all of these may use pyrotechnic special effects, which requires certification under the Regulations.

In view of the varied backgrounds and experience of pyrotechnicians, the wide spectrum of pyrotechnic special effect articles and devices, differing physical situations and types of activities, pyrotechnic special effects certification is divided into five fireworks operator certificates (FOCs):

- *Pyrotechnician*
- *Senior Pyrotechnician*
- *Special Effects Pyrotechnician*
- *Special Effects Pyrotechnician – detonating cord*
- *Visitor Pyrotechnician*

1.1.1 Pyrotechnician

If you hold an FOC (*Pyrotechnician*), you may use

- explosives classified as type F.3 and fireworks accessories that have been authorized for use by a *Pyrotechnician* or *Visitor Pyrotechnician*. The articles that are authorized for use by the *Pyrotechnician* will be designated with the letter "P" on the List of Authorized Explosives.
- smokeless powders
- explosives classified as type F.3, fireworks accessories and black powder, but only under the direct supervision of a *Senior Pyrotechnician* or *Special Effects Pyrotechnician*
- special purpose pyrotechnics for the film and television industry, but only under the direct supervision of a *Special Effects Pyrotechnician*
- special purpose effects that use initiation systems and detonating cord for the film and television industry, but only under the direct supervision of a *Special Effects Pyrotechnician* who holds an FOC (*Special Effects Pyrotechnician – detonating cord*)

To obtain an FOC (*Pyrotechnician*), you must complete, sign and send the following to the ERD:

- Form F17-01
- photo of the applicant taken within the previous 12 months. A digital photo is acceptable. (See Form F17-01 for details regarding the photo.)
- initial certification fee

In addition, you must successfully complete the Special Effect Pyrotechnics Safety and Legal Awareness Course before you can be certified as a *Pyrotechnician*. The ERD offers the course periodically, depending on demand, at various locations throughout Canada. To register for a course or obtain information, contact the ERD or your local vendor.

The FOC (*Pyrotechnician*) will be valid for five years from the date of issue.

1.1.2 Senior Pyrotechnician

If you hold an FOC (*Senior Pyrotechnician*), you may use

- explosives classified as type F.3 and fireworks accessories, black powder and smokeless powders
- special purpose pyrotechnics for the film and television industry, but only under the direct supervision of a *Special Effects Pyrotechnician*
- initiation systems and detonating cord for the film and television industry, but only under the direct supervision of a *Special Effects Pyrotechnician* who holds an FOC (*Special Effects Pyrotechnician – detonating cord*)

To obtain the FOC (*Senior Pyrotechnician*), you must

- have acted as a pyrotechnician for two years
- be able to safely use explosives that are classified as type F.3, and propellant powder

The FOC (*Senior Pyrotechnician*) will be valid for five years from the date of issue.

To apply for the FOC (*Senior Pyrotechnician*), you must complete, sign and send the following to the ERD:

- Form F17-02
- photo of the applicant taken within the previous 12 months. A digital photo is acceptable. (See Form F17-02 for details regarding the photo.)
- three letters of recommendation. The letter must show that the applicant is able to safely use explosives classified as type F.3 and propellant powder.
- a copy of the applicant’s work journal that includes
 - the date and place of each pyrotechnic event at which the applicant worked and the types of explosives used
 - the capacity in which the applicant acted at each pyrotechnic event (i.e. pyrotechnician in charge or crew)
 - the name of the applicant’s supervisor at each pyrotechnic event
- fee to upgrade the certificate

1.1.3 Special Effects Pyrotechnician

If you hold an FOC (*Special Effects Pyrotechnician*), you may

- assemble at the site of use and use special purpose pyrotechnics, the explosives classified as type F.3, fireworks accessories, black powder and smokeless powders
- use initiation systems and detonating cord for the film and television industry, but only under the direct supervision of a *Special Effects Pyrotechnician* who holds an FOC (*Special Effects Pyrotechnician – detonating cord*)

To obtain the FOC (*Special Effects Pyrotechnician*), you must

- have acted as a *Senior Pyrotechnician* for two years
- be able to safety use explosives that are classified as type F.3, propellant powder and special purpose pyrotechnics

The FOC (*Special Effects Pyrotechnician*) will be valid for five years from the date of issue.

To apply for the FOC (*Special Effects Pyrotechnician*), you must complete, sign and send the following to the ERD:

- Form F17-02
- photo of the applicant taken within the previous 12 months. A digital photo is acceptable. (See Form F17-02 for details regarding the photo.)

- three letters of recommendation from supervisors. The letter must show that the applicant is able to safely use explosives classified as type F.3 and propellant powder and special purpose pyrotechnics.
- A copy of the applicant's work journal that shows the
 - date and place of each pyrotechnic event at which the applicant worked and the types of explosives used
 - capacity in which the applicant acted at each pyrotechnic event (i.e. pyrotechnician in charge or crew)
 - name of the applicant's supervisor at each pyrotechnic event
- fee to upgrade the certificate

1.1.4 Special Effects Pyrotechnician – detonating cord

If you hold a FOC (*Special Effects Pyrotechnician – detonating cord*), you may

- assemble at the site of use and use special purpose pyrotechnics, explosives classified as type F.3, fireworks accessories, black powder and smokeless powders
- use initiation systems and detonating cord for the film and television industry

To obtain the FOC (*Special Effects Pyrotechnician – detonating cord*), you must

- have acted as a *Special Effects Pyrotechnician* for two years
- be able to safely use initiation systems and detonating cord

The FOC (*Special Effects Pyrotechnician – detonating cord*) will be valid for five years from the date of issue.

To apply for the FOC (*Special Effects Pyrotechnician – detonating cord*), you must complete, sign and send to the ERD

- Form F17-02
- photo of the applicant taken within the previous 12 months. A digital photo is acceptable. (See Form F17-02 for details regarding the photo.)
- three letters of recommendation from supervisors. The letter must show that the applicant is able to safely use explosives initiation systems and detonating cord.
- a copy of the applicant's work journal that shows the
 - date and place of each pyrotechnic event at which the applicant worked and the types of explosives used
 - capacity in which the applicant acted at each pyrotechnic event (i.e. pyrotechnician in charge or crew)
 - name of the applicant's supervisor at each pyrotechnic event
- fee to upgrade the certificate

High explosives other than initiation systems and detonating cord

Contact provincial/territorial authorities regarding the use of high explosives other than initiation systems and detonating cord.

1.1.5 Visitor Pyrotechnician

If you are based outside of Canada and you plan to purchase, store, use and destroy pyrotechnics in Canada, you must obtain an FOC (*Visitor Pyrotechnician*).

If you hold an FOC (*Visitor Pyrotechnician*) certificate, you may use

- explosives classified as type F.3 and fireworks accessories that have been authorized for use by a *Pyrotechnician* or *Visitor Pyrotechnician*. Articles that are authorized for use by the pyrotechnician will be designated with the letter “P” on the List of Authorized Explosives.
- smokeless powders
- explosives classified as type F.3, fireworks accessories and black powder, but only under the direct supervision of a *Senior Pyrotechnician* or *Special Effects Pyrotechnician*
- special purpose pyrotechnics for the film and television industry, but only under the direct supervision of a *Special Effects Pyrotechnician*, and special purpose effects that use initiation systems and detonating cord for the film and television industry, but only under the direct supervision of a *Special Effects Pyrotechnician* who holds an FOC (*Special Effects Pyrotechnician – detonating cord*)

To apply for the FOC (*Visitor Pyrotechnician*), you must complete, sign and send the following to the ERD:

- Form F17-03
- photo of the applicant taken within the previous 12 months. A digital photo is acceptable. (See Form F17-03 for details regarding the photo.)
- a copy of the applicant’s resume specifying the pyrotechnic events at which they used pyrotechnics, and the people and organizations that held pyrotechnic events for whom they worked
- a list of the pyrotechnics events in which the applicant plans to participate in Canada and their dates
- the name, telephone number and fireworks certificate number of the pyrotechnician in charge for each event
- certificate fee

1.1.6 Authority having jurisdiction

Authorities having jurisdiction (AHJs) and members of agencies associated with pyrotechnic displays (an agency member may also be an AHJ) may attend the Special Effects Pyrotechnics Safety and Legal Awareness course.

However, if they want to work on pyrotechnic displays as *Pyrotechnicians*, they must meet the regulatory requirements for certification.

1.1.7 Pyrotechnic logbook

If you are the pyrotechnician in charge, you must keep a record of the pyrotechnic event. The record must be kept in a logbook that provides your name and the number and expiry date of your fireworks operator certificate. The logbook must be kept for two years after the date of the last entry. The record must include

- a copy of the plan prepared for the event
- a copy of the AHJ's approval to hold the event
- the name and address of every person who worked at the event under the supervision of the pyrotechnician in charge
- a description of any unusual occurrence, the number of misfires and how each misfire was dealt with

It is recommended that you keep a pyrotechnic logbook, journal or work record even when you are not the pyrotechnician in charge. This logbook also serves as an individual detailed account of a pyrotechnician's activities or employment history within the industry and is needed for certain certifications. Some provinces/territories have this requirement for all users of pyrotechnic special effects.

- This document should be maintained in a manner befitting the pyrotechnician and employment situation. For example, record the necessary information in something such as
 - a durable, waterproof, surveyor-style notebook
 - individual pages kept in a three-ring binder (the pages may be blank or formatted to your needs)
 - an electronic journal with a PDF of hard copy documents

Standardized forms as used by certain union and trade groups can also be used if they meet the above guidelines.

You will need this pyrotechnic journal or logbook to demonstrate your experience and past activities to

- the ERD (when attempting to advance to a higher level of certification)
- the AHJ (when applying for event approval, permits or permission)
- explosives disposal unit (EDU) members (or equivalent) or consultants who might be overseeing the events, scenes or shoots
- unions or trade associations
- producers, managers and property owners
- insurance representatives
- prospective employers within the industry

1.1.8 Possession of certificate

If you as a pyrotechnician are purchasing, handling, setting up, operating or disposing of pyrotechnic special effects, the pyrotechnic certificate should be in your immediate possession at all times and available for inspection by the AHJ, ERD or other relevant authorities.

1.1.9 False or misleading information

Under Section 19 of the Act, anyone who submits false or misleading information – for example, in a pyrotechnic journal or letter of reference – is in contravention of the Act and can be prosecuted. Pyrotechnic special effects certification may also be refused, suspended or cancelled as a result.

1.2 Users without a licence or certificate

1.2.1 Flash cotton, flash paper, flash string and sparkle string

If you do not hold a fireworks operator certificate or licence, you may purchase, store and use flash cotton, flash paper or sparkle string in accordance with the following conditions.

Storage

No more than 200 g of flash cotton, 1 kilogram (kg) of flash paper, 200 g of flash string and 200 g of sparkle string may be stored at any one time.

You must store the flash cotton, flash paper, flash string or sparkle string in a dwelling or a storage unit and ensure that the following requirements are met.

When pyrotechnics are stored in a dwelling, they must be stored away from flammable substances and sources of ignition, in a manner that protects them from theft and ensures that access is limited to people authorized by the user.

When pyrotechnics are stored in a storage unit,

- The storage unit must be located in a dry place, away from flammable substances and sources of ignition.
- The storage unit must be constructed and maintained to prevent unauthorized access and to protect the contents from weather.
- If the storage unit is a container, it must not impede exit in case of fire.
- If the storage unit is not a container, all exits must be kept unobstructed.
- Any shelving in the storage unit must be made from non-sparking material (for example, wood or painted metal).
- Propellant powder, fireworks accessories and other pyrotechnics must be stored separately from one another (for example, on different shelves or separated by a wooden partition).
- Any spill, leakage or other contamination in the storage unit must be cleaned up immediately.
- Precautions must be taken that minimize the likelihood of fire in or near the storage unit.
- A sign that displays the words “Danger – Fire Hazard/Risque d’incendie” in letters at least 10-centimetres (cm) high, along with letters or a symbol at least 10-cm high indicating that smoking is prohibited, must be posted on the storage unit in a clearly visible location.

1.2.2 Percussion caps and propellant powder used in historical re-enactments

If you do not hold a fireworks operator certificate or licence, you may purchase, store and use percussion caps and propellant powder if the caps and powder are purchased for the use of original or reproduction firearms (including cannons) in an historical re-enactment.

To purchase percussion caps and propellant powder for use in a historical re-enactment, you must

- have written consent of the local AHJ to hold the re-enactment or be under the supervision of a person who has received such consent
- have experience in the safe use of explosives in historical re-enactments and have completed a course on such use certified by the Minister of Natural Resources or be under the supervision of a person who has such experience and has completed such a course

Storage

You must store the percussion caps and propellant powder in a dwelling or a storage unit and ensure that the following requirements are met:

- Percussion caps must be stored in their original packaging.
- The maximum quantity of propellant powder that may be stored at any one time in a single detached dwelling or in a storage unit that is attached to such a dwelling is 25 kg, of which no more than 5 kg may be black powder.

The maximum quantity of smokeless powder that may be stored at any one time in a dwelling other than a detached dwelling or a storage unit attached to such a dwelling is

- 20 kg, if all the smokeless powder is in containers that hold no more than 1 kg
- 5 kg, if any of the smokeless powder is in a container that holds more than 1 kg

Smokeless powder must be stored in its original container or in small arms cartridges.

The maximum quantity of black powder that may be stored at any one time in a dwelling other than a detached dwelling or a storage unit attached to such a dwelling is

- 1 kg, if the black powder is in containers
- 3 kg, less any amount that is in containers, if the black powder is in small arms cartridges or black powder cartouches

Black powder must be stored in its original container, in small arms cartridges or in black powder cartouches.

When the percussion caps and propellant powder are stored in a dwelling, they must be stored away from flammable substances and sources of ignition in a manner that protects the pyrotechnics from theft and ensures that access to them is limited to people authorized by the user.

When the percussion caps and propellant powder are stored in a storage unit,

- The storage unit must be located in a dry place, away from flammable substances and sources of ignition.
- The storage unit must be constructed and maintained to prevent unauthorized access and to protect the contents from weather.
- If the storage unit is a container, it must not impede exit in case of fire.
- If the storage unit is not a container, all exits must be kept unobstructed.

- Any shelving in the storage unit must be made from non-sparking material (for example, wood or painted metal).
- Propellant powder, fireworks accessories and other pyrotechnics must be stored separately from one another (for example, on different shelves or separated by a wooden partition).
- Any spill, leakage or other contamination in the storage unit must be cleaned up immediately.
- Precautions must be taken that minimize the likelihood of fire in or near the storage unit.
- A sign that displays the words “Danger – Fire Hazard/Risque d’incendie” in letters at least 10-cm high, along with letters or a symbol at least 10-cm high indicating that smoking is prohibited, must be posted on the storage unit in a clearly visible location.

If you are planning to manufacture the charges, you may need to obtain a manufacturing certificate or licence. Contact the ERD for further information.

1.2.3 Pyrotechnics used in student training

If you are registered in a college or university course on special effects pyrotechnics that is certified by the Minister of Natural Resources, you may use any pyrotechnics that your supervisor is authorized to use, during your training and while under the direct supervision of a holder of the FOC (*Senior Pyrotechnician* or *Special Effects Pyrotechnician*).

1.2.4 Requirements when using pyrotechnics

You must follow the manufacturer’s instructions when using pyrotechnics.

Do not use any pyrotechnics if they show signs of deterioration such as discoloration or a vinegary smell. You must not use an electric match to ignite flash cotton, flash paper, flash string or sparkle string.

Chapter 2. Sale and storage of pyrotechnics

Notes

2.1 Sale

A seller may purchase, store and sell pyrotechnics if they hold a licence. To obtain a licence to sell pyrotechnics, contact your local ERD regional office.

A seller must

- store their pyrotechnics in the magazine specified in their licence
- not store igniters in the same magazine as other pyrotechnics unless the igniters are an integral part of the pyrotechnics
- not put the pyrotechnics on display for sale

A seller must not sell pyrotechnics to a buyer unless the buyer is authorized:

- by their licence to acquire the type of pyrotechnics to be sold
- by Part 17 of the Regulations to acquire the type of pyrotechnics to be sold
- by their FOC to use the type of pyrotechnics to be sold

A seller must not sell more pyrotechnics to a licenced buyer than the buyer is authorized by their licence to store. Also, a seller must not sell more pyrotechnics to an unlicensed buyer, including a holder of an FOC, than the buyer is authorized to store by Part 17 of the Regulations.

Before selling pyrotechnics, the seller must require the buyer to establish their identity.

A seller must keep record of every sale of pyrotechnics for two years after the date of the sale. The record must include the following information:

- buyer's name and address
- number and expiry date of the buyer's licence and fireworks operator certificate, as applicable
- type and trade name of each pyrotechnics article sold, the quantity of each type sold and the name of the company as it appears on the List of Authorized Explosives
- short description of the effects of any explosives article sold
- container size of any propellant powder sold
- date of sale

2.2 Storage

A user may purchase and store pyrotechnics if he/she holds the FOC required for the use of the pyrotechnics to be acquired.

If you plan to store more than the amount described below, you must obtain a licence from the ERD. Contact your local ERD regional office to apply for a licence.

You can store up to 500 electric matches and 25 kg gross mass of other pyrotechnics at any one time.

The maximum quantity of propellant powder that may be stored at any one time in a single detached dwelling or in a storage unit that is attached to such a dwelling is 25 kg, of which no more than 10 kg may be black powder.

2.2.1 Smokeless powder

The maximum quantity of smokeless powder that may be stored at any one time in a dwelling other than a detached dwelling or a storage unit attached to such a dwelling is

- 20 kg, if all the smokeless powder is in containers that hold no more than 1 kg
- 5 kg, if any of the smokeless powder is in a container that holds more than 1 kg

Smokeless powder must be stored in its original container or small arms cartridges.

2.2.2 Black powder

The maximum quantity of black powder that may be stored at any one time in a dwelling other than a detached dwelling or a storage unit attached to such a dwelling is

- 1 kg, if the black powder is in containers
- 3 kg, less any amount that is in containers, if the black powder is in small arms cartridges or black powder cartouches

Black powder must be stored in its original container, in small arms cartridges or in black powder cartouches.

2.2.3 Pyrotechnics stored in a dwelling

When pyrotechnics are stored in a dwelling, they must be stored away from flammable substances and sources of ignition in a manner that protects the pyrotechnics from theft and ensures that access to them is limited to people authorized by the user.

The written plan must be kept for two years after the date of the pyrotechnic event.

The AHJ may also require more information as part of the approval process.

At the production site or venue, the pyrotechnician should have copies of the following available for inspection:

- written plan as submitted to the AHJ for approval
- written approval of the AHJ

3.1.1 Disconnection of smoke sensors

If the performance requires the disconnection or bypassing of smoke sensors or any other safety or fire protection equipment, the pyrotechnician should

- Discuss the feasibility of obtaining permission from the AHJ to disconnect or bypass the smoke detectors prior to or during the event approval process.
- Arrange for a person approved by the AHJ – a “fire watch” (not necessarily from the fire department) – to be on site during all rehearsals and performances, if required by the AHJ, and fulfill any other requirements.
- Obtain permission of the property owner or agent.
- Reactivate all safety equipment as soon as possible after the performance or shoot.

3.1.2 Demonstration before the event

The AHJ may request that the pyrotechnician perform a representative demonstration or dry run of the production to judge further whether the event can be performed safely. The AHJ may consider that a demonstration is necessary for reasons including

- The AHJ is unfamiliar with the pyrotechnician or the planned effects.
- There is a need to determine the ventilation capabilities of the venue for the smoke produced.
- The AHJ is uncertain of how the functioning of the pyrotechnics might affect the audience, performers, crew, pyrotechnicians, venue or site.

Note Under the *Criminal Code of Canada* (Section 79), pyrotechnicians must also fulfill the “duty of care” or possibly face the consequences of non-compliance. Contact your legal advisor for further guidance.

3.2.1 Liability insurance

If you are participating in any form of pyrotechnic event (e.g. an airburst employed at a high school dance), you may be required by the AHJ to have liability insurance for at least \$1 million:

- The AHJ may not approve your event without proof that you have sufficient liability insurance.
- In some situations, the management of the venue or the company contracting for the pyrotechnic services may arrange insurance coverage. In such cases, make sure that you
 - verify your coverage with the broker
 - confirm the deductible in the event of a claim
 - obtain written confirmation of the above two points
 - know what your policy covers

3.2.2 Invalidating your insurance

Your insurance may be invalidated if you

- fail to follow the explosives regulations and/or accepted operating procedures referred to in this manual
- engage in any other illegal or unapproved activities

Note If you have all the information required on the form except what pertains to the pyrotechnician (because none has yet been hired, arrived, etc.), you may, if the AHJ agrees,

- Submit the application and documentation for conditional approval.
- Follow this up by supplying the AHJ with the required information on the pyrotechnician (including the pyrotechnician’s signature on the form) no less than 24 hours before the event or in a timeframe and manner agreed to by the AHJ.

4.4 Alcohol and drugs

Safety requires a clear head. It is an offence to use or handle pyrotechnics or devices while under the influence of intoxicating beverages, narcotics or prescription or non-prescription drugs that can impair judgment.

4.5 Fire prevention measures

Adequate fire prevention measures and facilities, equipment and personnel for fighting fire and administering first aid must be present at the site during the pyrotechnic event.

4.5.1 Fire evacuation plan

For all events involving pyrotechnics, you must

- Be knowledgeable of the fire evacuation plan (which must take the audience into account).
- Ensure that staff understand and are aware of the plan's pertinent points (e.g. the location and availability of exits).
- Ensure that an emergency contingency plan (what to do if things go wrong), which generally applies to film shoots, is drawn up for locations that have no fire evacuation plan.

4.5.2 Fire extinguishers

When you are preparing, loading or firing pyrotechnic special effects, ensure that

- at least two pressurized water, Class 2-A extinguishers and two Class 10-BC extinguishers are located within 15 m of the pyrotechnic special effects and equipment
- the fire extinguishers are accessible and maintained in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*
- all pyrotechnicians are trained to use the fire extinguishers
- fire extinguishers remain on site until all pyrotechnics have been fired, stored or disposed of in a safe manner

Note Pyrotechnic articles and compositions cannot be extinguished by A:B:C- multi-purpose fire extinguishers or small quantities of water:

- Pyrotechnic compositions contain their own source of oxygen and do not need "air" to burn.
- Extinguishers are used to control and extinguish the surrounding fire or the possibility of a fire starting.
- In some circumstances, water can cool the article or device and retard the pyrotechnic effect.

Subsequent meetings must be held if the event is changed in a way that increases the likelihood of harm to people or property created by the use of the pyrotechnics.

The pyrotechnician in charge should conduct staging dry runs to demonstrate timing, spacing and safety parameters and to demonstrate the pyrotechnics to inexperienced performers in conjunction with the dry runs.

4.8 Danger zone

A danger zone must be established, taking into account the properties of the pyrotechnics to be used, how they will be positioned, the manufacturer's instructions, the weather conditions if the pyrotechnic event is to be outdoors and the likelihood of harm to people or property created by the use of the pyrotechnics.

4.8.1 Establishing the danger zone

General distances to audience and performers

To establish the distance from the pyrotechnics to the audience, you should use the greatest of the following three distances:

- 5 m
- the distance recommended by the manufacturer
- twice the pyrotechnics' fallout radius

Performers should maintain the greater of the following two distances:

- distance recommended by the manufacturer
- twice the pyrotechnics' fallout radius

Note that these distances do not necessarily apply to effects positioned on a performer's body, including hand-held articles.

A 1.2-m corridor should be maintained between the spectators and the stage. In some locations (e.g. night clubs), this may not be possible, but exit or escape routes must nevertheless be adequate for the venue, kept clear and sanctioned by the AHJ.

4.8.2 Concussion mortars

Concussion mortars must be well-secured, separated from the audience, performers and support personnel by at least 8 m, and barricaded (where required, to guard against shrapnel).

4.11 Devices

A device for containing pyrotechnics must be

- designed and manufactured to prevent fragmentation or distortion of the device
- designed and manufactured to prevent or contain fragmentation of the pyrotechnics
- mounted to prevent any change in position or direction when used
- positioned and secured in a manner that minimizes the likelihood of harm to people or property
- kept in good condition

4.12 Damaged articles

Pyrotechnics that are damaged, leaking, damp or contaminated must not be used.

Defective pyrotechnics should be returned to the vendor for disposal.

4.13 Removing pyrotechnics from storage

When removing pyrotechnic articles and devices from storage, select products according to

- precedence – Articles in storage the longest, or with the oldest date stamp, if indicated, should be used first.
- quantity – Remove only what you need for one event.

Note Never carry or place pyrotechnic special effects in your clothing. Instead, use a small carrying container. Once you have removed pyrotechnic articles from storage (or set them up for operation), never leave them unattended.

4.14 Timing: Lower the exposure

Be sure to set up and position the articles as close as possible to the start time of the rehearsal, performance or film shoot.

4.15 Mixing two-component powder

Two-component powder must be mixed:

- in strict accordance with the manufacturer's instructions
- in an area restricted to public access
- one unit at a time, by using the entire contents of both bottles

- only in the manufacturer’s designated equipment

Do not mix or use two-component powder that is “time expired.”

- Immediately initial and date all bottles of powder that you mix. Initial and date pre-mixed powders as soon as you open them.
- Never “mix and match” powders.

In addition,

- Use powders only with manufacturer-approved equipment.
- Be very cautious of concussion powder, and pay close attention to mortar specifications. Use of incorrect concussion powder and mortars could lead to catastrophic results because of the different velocities of the powders.

4.16 Handling powders

All loose compositions, including mixed or unmixed two-component powders, pre-manufactured powders, and black and smokeless powders, must be handled:

- in a restricted area with only authorized people present
- with non-sparking tools
- so as to avoid friction and impact
- on a clean and uniform surface or table (clean up all spills immediately)
- with no smoking in the area
- in accordance with the following precautions against the risk of static discharge:
 - Avoid wearing static-producing synthetic clothing or material.
 - Ground yourself frequently by touching the table, articles and all equipment to equalize potential.

4.17 Special precautions

Do not confuse black powder, as used in black powder lifters, with modern smokeless powder, as used in flame projectors. The consequences of such confusion could be disastrous.

All mixing and loading of compositions, as well as the fabrication and placement of devices should, if possible, be carried out by one pyrotechnician. Having only one person perform these tasks will improve safety and quality control by

- eliminating “double loading” and uncharged devices
- reducing the instance of incorrect fabrication, especially when assembling special-purpose pyrotechnics

4.18 High heat, open flames and smoking

High heat and open flames must never be close enough to pyrotechnic articles and devices to present a hazard. With respect to smoking, you are responsible for ensuring that

- Smoking is prohibited by anyone in the magazine and preparation area and on the stage or location.
- “No Smoking” signs are posted.

Note Smoking that may be required as part of the performance can take place at a safe distance from pyrotechnic articles if it is approved by the pyrotechnician.

4.19 Friction, static and impact

Friction, static and impact can also accidentally set off pyrotechnic articles and powders. Treat all articles with caution and maintain a clean, orderly and controlled working area.

4.20 Sympathetic communication: sparks, heat and shock

To minimize the risk of having sparks or heat initiate an adjacent article or device,

- Lightly cap open devices with a fire-resistant material (e.g. aluminum foil).
- Take care to secure the capping material so that it will neither be projected into the air nor confine the effect.

To lessen the chance of shock from an adjacent article (e.g. concussion mortars) causing accidental sympathetic ignition, separate and/or barricade the articles.

4.21 Sensitivity of electric matches, squibs and detonators

In addition to being subject to accidental firing through spurious electrical mechanisms, all igniters and initiators (e.g. electric matches, squibs and detonators) are extremely sensitive to impact, friction and heat. In fact, they may be even more sensitive to these factors than the powders they ignite. When handling these articles, never allow your attention to wander from the task at hand.

4.22 Fallout precautions

Articles and devices must be positioned and test fired so that fallout (or the resultant effect) cannot

- come into contact with other (unprotected) pyrotechnics or flammable materials
- burn surfaces, injure people or damage property

Note Lights or signals are often used to warn of an imminent firing.

4.23 Airbursts

If airbursts are positioned over an audience, performers or support personnel, ensure that

- The support rigging is fire-resistant.
- The airbursts are situated away from other unprotected pyrotechnics and flammable materials.
- The minimum required fallout distance is maintained. Some venues will not accommodate airbursts because of
 - ceiling height
 - ventilation requirements

Note Airbursts are sometimes mounted well above the stage or audience where they cannot be seen by the pyrotechnician. In such cases, use spotters and consult with the AHJ for direction.

4.24 Line or grid rockets

Line or grid rockets are, in essence, thrust-producing gerbs that normally produce a scream, whistle or crackling effect. They are attached to aircraft cable tightly strung across a venue such as a large nightclub or coliseum. Ensure that

- There is a safe fallout distance to the audience.
- Proper rigging equipment is employed (consult or employ an approved rigger if necessary).
- Cable is rigged securely to supporting members.
- Rockets cannot separate from the cable leader (firmly secured and taped).
- Rockets will not burn adjacent material or rigging on initiation (e.g. nylon rope, burlap).
- Rockets can be safely “caught” at the far end of the cable so that they do not fly off the cable or continue to openly discharge.

4.25 Bullet hits

Body hits (positioned on a person)

- are specifically designed to produce a sharp explosion
- may be mounted in an indentation on a custom metal receptacle with a leather backing to direct the explosion outward from the performer (the receptacle can be mounted over soft material for the performer's further protection)
- can be covered with a plastic bag containing simulated blood

In addition,

- Clothes that cover the article should be cut or weakened.
- Precautions must be taken to ensure that the audience, performers and support personnel are protected from possible sparks, shrapnel and debris.

Bullet hits positioned in or on surroundings

- must be mounted in or on a surrounding wall, floor, ceiling, structure or prop
- must be suitably covered or protected
- must be staged so as to ensure that the audience, performers and support personnel are protected from possible sparks, shrapnel and debris

Note If you as a performer activate the bullet hit yourself, make sure you use a two-step ignition procedure.

4.26 Spark-producing devices

Spark-producing devices (SPD) are often used to simulate the production of sparks, as in an electrical short circuit or a bullet ricochet:

- Ensure that the SPD is mounted in or on a surrounding wall, floor, ceiling, structure or prop (or firmly secured to a performer, in some cases).
- Take precautions to ensure that the audience, performers and support personnel are protected from the sparks or possible shrapnel and debris.

Chapter 5. Electric firing

Notes

5.1 Equipment

Use only devices and associated equipment that are specifically designed and manufactured to electrically activate pyrotechnic special effects. It is understood that the *Special Effects Pyrotechnicians* may need to use equipment (such as nail boards, clunker boxes, and one-shot buttons) that are not available commercially.

5.2 Controllers and cables

Commercial controllers (panels, firing boards) that activate the articles or devices are typically designed with a built-in test circuit, keyed interlock and fire buttons. They are manufactured to activate from four to thousands of effects, depending on the unit and corresponding cost.

A transformer or rectifier is built into either the controller or the pod that holds the article to

- reduce the voltage from 110 volts (V) to under 36 V
- rectify the alternating current (AC) to direct current (DC) because AC current can cause igniters and initiators to malfunction

Connection to the effects is accomplished by various lengths of cable and connectors referred to as "XLR:"

- The cable connection is made with either three- or four-pin connectors:
 - Zip connectors (with alligator clips) are sometimes used to connect to the leg wires of igniters or initiators.
- Some systems use interchangeable audio-type XLR cables, which can create a hazard:
 - Label, mark or colour code the cables so that they are easily distinguished from other wiring.
- When connections are made to the controller, the controller must shunt (short circuit) the wiring or cables (see Section 5.12.1).

5.3 Wireless controllers

A wireless controller must be equipped with a keyed interlock and a second firing mechanism (as required on conventional units).

Prohibited equipment includes

- consumer frequency transmitter and receiver units (e.g. used to unlock car doors and open garage doors)
- infrared units

Note **Exercise extreme caution** if you are contemplating custom designing or manufacturing this type of equipment or using existing products and apparatus. Do not do so if you do not have sufficient skill or training.

5.4 Power sources

Consumer

- 110 volt AC transformed/rectified to under 36 V and DC current

Batteries

- Keep batteries encased and the terminals protected.

Generators, power or light poles

- If you are using these sources, equip the line with a breaker switch with a rating that matches the supply.

Connections and care

- Keep the controller separate and secure from the firing circuit until it is necessary to connect it (wire in).
- Never leave the controller unattended when it is connected to a power source.
- Keep the key in your possession.

5.5 Pre-show inspection

Inspect and test all electrical equipment before you bring it to the site. You are responsible for making sure that your equipment is

- safe
- functional
- compatible
- of sufficient capacity for the effects

5.9 Circuit testers

Test all circuits (igniters, initiators and the connected wiring or cables) for continuity by using the tester normally built into the controller or a separate, hand-held instrument. The separate unit may be an ohmmeter or a simple continuity tester similar to the instrument contained within a typical controller.

Keep all personnel clear of the pyrotechnic devices when testing circuits. If a test system is malfunctioning, there is always a danger that testing can cause igniters and initiators to activate the articles or devices.

Remember Safe methods and equipment reduce risk, but provide no guarantees.

5.10 Continuity testers

A continuity tester verifies that there is a complete circuit when the test light on the controller or the separate test unit lights up. However, the test light will also activate if

- The electric match (or initiator) is faulty (dead-short across the bridge wire).
- There is a short-circuit in the connecting wiring.

The “light” simply verifies that current is flowing through a circuit, which could include a faulty electric match or damaged (shorted) wiring.

5.11 Blasting ohmmeter

A blasting ohmmeter tests for resistance within the circuit (e.g. electric match and wiring) and indicates the resistance in ohms. It produces a sensing current of approximately 0.025 amperes (A), much below what is needed to initiate electric matches, squibs or detonators.

The approximate resistance of the circuit being tested can be calculated for the number of electric matches (or initiators) in the circuit and length of attached wiring or XLR cables. This calculated figure (the total resistance in ohms) must match the resistance indicated when the circuit is tested with a blasting ohmmeter. If it does not match, the circuit is faulty.

This test for resistance is a definitive determination of the integrity of the circuit.

Notes

- Specifications on resistance (in ohms) for the igniters or initiators and the attached wiring or XLR cables can be obtained from the manufacturers, distributors or instruction sheets.

5.12.3 Radio frequency energy from mobile transmitters

Any transmitter (e.g. cellphone, two-way radio, pager, wireless microphone, radio, TV, radar) can produce electromagnetic fields (RF) powerful enough to activate an igniter or initiator such as electric matches, squibs, SPD, bullet hits or detonators.

- Do not carry any transmitter on your person when handling pyrotechnics and related wiring.
- If at all possible, keep transmitters away from the site when igniters, initiators, primed pyrotechnic special effects and associated wiring are being handled or are in place.
- Post hazard signs or guards to bar transmitters from the site:
 - If it is not possible to ban common, low-wattage, high-frequency, consumer transmitters (e.g. cellphones, two-way radios, pagers, wireless microphones) from the venue or site, make sure that they are separated from igniters, initiators and associated wiring by a distance of at least **4 m**.

Note Certain two-way radios and other consumer transmitters require a distance greater than 4 m, depending on their power and operating frequency.

- For recommended distances between initiators and any transmitters of various power (watts) and frequencies, see the bulletin SLP 20: *Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators*, Appendix 5, Table 3, issued by the Institute of the Makers of Explosives.

Other hazards associated with cellphones and two-way radios include

- exposed battery-charging terminals, if they come into contact with the igniter, initiator or associated wiring
- aerials that accidentally come into contact with the wiring, especially if the aerial and/or wiring is frayed or damaged

5.12.4 Transient electrical currents

Transient electrical currents (stray currents) from diverse sources travelling through working surfaces (e.g. steel stages, scaffolding and rigging) can also cause articles and devices to fire unexpectedly. Keep the igniters, initiators and associated wiring shunted.

- These currents are also a factor when working outdoors where spurious electrical currents travelling through the ground can cause premature ignition.

5.16 Final site check

Special effects pyrotechnics should only be fired when

- There is a clear line of sight from the firing controller to the articles and devices.
- All necessary steps have been taken to ensure that the articles and devices will function properly, remain stationary and are clear of flammables.
- All people are on their marks and safely clear of the devices and fallout.
- Weather conditions are still favourable, and no other circumstance has occurred that could increase the likelihood of harm to people or property.
- If black powder charges or det-cord are used,
 - Make certain that effects in the scene or shoot are being used in conformity with adequate, observed safety distances.
 - Ensure that preliminary warning signals, if appropriate, have been sounded (consult with the AHJ and/or other applicable agencies).

Note Safe functioning may be aided by

- using spotters, disablers, warning signals and/or a dedicated communication system for the pyrotechnicians (and possibly the performers)
- stage markings and warning lights for the performers and pyrotechnicians

Remember The pyrotechnician is always responsible, and can be held liable, for

- any incident or accident that occurs as a result of the pyrotechnic and/or explosive effect
- activities related to the use of pyrotechnics (e.g. mixing, loading, positioning, wiring)

Chapter 6. Special-purpose pyrotechnics

Notes

6.1 General

Special-purpose pyrotechnics are used primarily in the film and television industry to simulate real-life events such as violent explosions. The articles are typically fabricated from any combination of authorized pyrotechnics or compositions, black and smokeless powder, and/or detonating cord **in conjunction with** flammable fuels (diesel, gasoline, propane, napalm, etc.), and/or gases and solids (e.g. benzoic peroxide, coffee whitener, naphthalene). Depending on the materials employed, the articles or devices can be activated by electric matches and initiators up to soft-shell or commercial detonators.

Notes

- If the flammable liquids, gases or solids are used alone, without any pyrotechnic or high explosive material, the effect is considered to be a “flame special effect.”
- Because special-purpose pyrotechnics are not authorized explosives, they cannot be legally transported and must be made up on site.

6.2 Fabricating special-purpose pyrotechnics

To fabricate special-purpose pyrotechnics for the film and television industry, you must

- use authorized pyrotechnic products
- be certified in the *Special Effects Pyrotechnician* class or directly supervised as specified in this manual
- exercise due care at all times
- obtain accurate information on the probable behaviour of the fabricated special-purpose pyrotechnics by
 - testing
 - experience
 - consulting with other pyrotechnicians and/or competent authorities

6.3 Fireball effects

Typical fireball effects are made up of

- an igniter or initiator
- black powder lifter charge (and possibly detonating cord using an appropriate initiator)
- flammable liquid
- (in some cases) a fine particulate, flammable solid (e.g. coffee whitener, benzoic peroxide)

Proven dangers include

- dispersion of the flammable powders into a dust cloud (where proper combustion is not obtained), which sometimes causes detonation and structural damage to the surroundings and large areas of broken windows
- power lines shorting to one another or arcing to the ground because of the smoke and heat produced, sometimes resulting in downed power lines

Remember Take all possible precautions and keep personnel clear!

6.4 Detonating cord

6.4.1 General description

- Detonating cord is a commercial high explosive primarily used in the mining, quarrying and road construction industries to initiate other high explosives or to connect a series of charges.
- It is a round, flexible cord with an outer braided textile wrap and inner explosive composition of PETN (pentaerythritol tetranitrate) or RDX (cyclotrimethylenetrinitramine).
- Cord diameters range from 3 to 15 mm, with core loads (quantity of PETN per metre length of cord) ranging from 1 to 85 g/m, respectively.

6.4.2 Properties

- very strong with an average tensile strength of over 100 kg and pliable at exterior working temperatures
- high velocity of detonation (VOD) for all types of cord – 7000 m/s (25 000 km/h). Compare this speed with that of black powder, which, when confined, deflagrates at a maximum of 300 m/s.

- in packaged form, relatively stable and insensitive to normal shock and friction
- water-resistant
- not susceptible to stray currents

6.4.3 Characteristics

- Detonating cord can be initiated by commercial or soft detonators (high-strength squibs) that do not produce shrapnel.
- On initiation, an extremely loud report or “crack” is produced, typically much louder than the main charge (if any), including commercial high explosives. Keep this in mind when using det-cord in public areas:
 - Atmospheric conditions can also magnify the sound level and range of travel.
- In a fire situation, a roll of detonating cord can cross over to detonation, while strands of cord will typically burn if not confined.

6.4.4 Uses

- Det-cord will destroy, shear, fracture, propel, make depressions or holes, and vapourize various materials and liquids.
- With det-cord, you can create more “useful” enhanced or spectacular effects. It can be combined with other pyrotechnic powders, materials and various liquids for instant vapourization, dispersion, hotter fires and guaranteed ignition.

6.4.5 Selection

The choice of cord depends on

- surroundings
- activity
- energy required

The lightest cord will easily shatter any glass, while heavier core loadings will instantly shear trees, cut off car doors and hoods, blow out tires, and create holes in buildings and doors (rapid entry).

6.4.6 Preparation

- Prepare the cord on a clean, smooth, non-sparking surface.
- Use only non-sparking tools.
- When cutting cord, use a straight knife:
 - Never employ scissor-type cutters, which create a shearing action (friction).
- Be aware that, over time, PETN can be deposited in the grooves carved into a surface from the cutting operation.
- Always tape the ends of the cord after cutting so as to not lose composition.
- Clean up the preparation area as soon as you are finished.
- Be careful during cutting or fabrication not to dislodge the core composition. Under normal conditions and handling, it is relatively insensitive in packaged form. However, loose core composition can be initiated by friction or impact, especially if it has been contaminated.
- If it is necessary to join pieces of cord, make a tight, conventional square knot, then wrap it with tape:
 - You can connect separate lengths of cord running in different directions with a taped clove hitch.

6.4.7 Initiation

- If shrapnel is not a consideration, initiate with commercial detonators.
- Attach detonators to the cord according to the manufacturer's instructions.
- It is recommended that double initiators be used with the detonators pointing down the line – not toward the cut end.
- Avoid loops, sharp kinks or angles that direct the impulse of the cord back toward the oncoming line of detonation.

6.4.8 Peculiar hazards

- Do not mistake detonating cord for safety fuse or "tape fuse" (used to make up a simple igniter, igniter cord, or detonator assembly), or shock tubing (Nonel, Streaks).
- Do not use detonating cord as a fastener (as in the packaging of gifts) or as an article of clothing (e.g. a "rope tie").

6.7 Black powder lifters: Consult the EDU

If black powder lifters or explosive charges (detonating cord) – and possibly associated flammables – are used in a scene or effect, it is recommended that the AHJ require the pyrotechnician to have an EDU member or explosives consultant present.

6.8 Explosive charges

There are no tables, formulas or computer programs that can precisely determine the effects of an explosive charge on people or things. Data that exist apply only to unconfined, spherical, open-air charges and are therefore of limited relevance to the pyrotechnics industry and of small use to the AHJ in determining safety distances.

There is, however, a relative system of danger zones from which separation distances have been derived. These distances are to be regarded as approximations and are for guidance only. However, they do provide a baseline that, when combined with education and experience, may assist the pyrotechnician in estimating safe distances from explosive charges.

For all the effects that you plan to fire, use the following three categories as a starting point for developing special precautions and safe distances:

- Red Zone or Danger Zone: Prohibited access
- Shatter Zone: Window breakage
- Green Zone: General protection

6.9 Red Zone: Prohibited access

A Red Zone is an off-limits area or a closed location surrounding an explosive device. Only pyrotechnicians are allowed in the Red Zone while the charge is being prepared or placed. The pyrotechnician is required to

- Establish a Red Zone before the positioning of an explosive charge.
- Keep the Red Zone free of all people from the time the charge is placed until the *Special Effects Pyrotechnician* gives the “all clear” after the shot.

The comparative rule-of-thumb formula for the perimeter or radius distance is

$$\text{Distance (m)} = 7 \times \text{quantity}^{1/3} \text{ (kg)}$$

For example, a 0.5-kg charge would require a Red Zone radius or perimeter distance of 6 m.

6.10 Shatter Zone: Window breakage

The Shatter Zone perimeter delineates the area in which the overpressure produced (5 millibars or 150 decibels) is sufficient to break residential windows.

The comparative rule-of-thumb formula is

$$\text{Distance (m)} = 65 \times \text{quantity}^{1/3} \text{ (kg)}$$

For example, a 0.5-kg charge would require a safety distance of 50 m. This does not take shrapnel or fragments into account.

6.11 Green Zone: General protection

For protection against shrapnel, fragments and/or projected material that can be propelled much farther than the actual blast effect perimeter, the Green Zone is a minimum suitable comparative distance or perimeter that must be maintained between the explosion and unprotected personnel.

The comparative rule-of-thumb formula is

$$\text{Distance (m)} = 120 \times \text{quantity}^{1/3} \text{ (kg)}$$

Correspondingly, the minimum comparative distance to be maintained between unprotected personnel and a 0.5-kg charge is 95 m.

6.12 Numbers for the Red, Shatter and Green zones

Remember three comparative numbers – 7, 65 and 120 – multiplied by the cube root of the quantity, correspond to the Red (danger) Zone, the Shatter Zone, and the Green (safe) Zone, respectively.

Note Because the formulas incorporate a cube root (mass of the charge), they are not linear and cannot be divided or multiplied for different quantities to obtain accurate minimum distances.

6.13 Distances from other vulnerable features

You can calculate the comparative distances for other vulnerable features – vehicle windshields (uncoated), brick or concrete walls, and plaster walls – by using the following formulas:

$$\text{Shatter vehicle windshields: } D \text{ (m)} = 10 \times Q^{1/3} \text{ (kg)}$$

$$\text{Crack concrete or brick walls: } D \text{ (m)} = 19 \times Q^{1/3} \text{ (kg)}$$

$$\text{Crack plaster walls: } D \text{ (m)} = 34 \times Q^{1/3} \text{ (kg)}$$

Note All of the above rule-of-thumb formulas and figures are relative and are not meant to be regarded as actual safety-distance determinations. The actual distances applied and approved could be greater or less, depending on the particular situation.

6.14 Filming

The three main formulas (Red, Shatter and Green Zone) for determining comparative safety distances indicate that you must

- film remotely

and/or

- take the following precautions (depending on the distance from the blast):
 - camera “hides” provided
 - Lexan™ sheets employed
 - ear and eye protection worn
 - fire blankets and other safety equipment provided

6.15 Explosives inside structures

If you use a special-purpose pyrotechnic (including black powder) inside a structure, you must ensure that

- Gas mains are shut off and purged.
- Flammables are removed from the structure.
- Fire-fighting measures are in place and sprinkler systems (if available) are operating and can be shut off.
- The appropriate agencies have been notified and, where necessary, permission has been obtained.
- The minimum safe quantity of explosive material is used.
- You have taken adequate precautions against shrapnel and other hazardous debris being blown from the building.
- Exits are – or can be – lit for the rapid evacuation of personnel in the event of a mishap.
- Safety distances are adequate.
- An emergency contingency plan has been drawn up by the pyrotechnician and instituted.

6.16 All show, no go: Use no more charge than the job requires

The world of pyrotechnic special effects, especially in the film industry, is one of illusion. Effects are supposed to simulate phenomena or events that occur in “real life:” noise, light, fire, explosions, bombings, accidents, infernos and disasters. However, “real life” often pales in comparison to some of the situations modern pyrotechnicians are able to create. An actual vehicle bombing, with its small puff of grey smoke, makes dull viewing compared with the spectacular fireball of a staged car bomb.

The quality of an illusion, however, should not be regarded as proportionate to the size of the effect. Larger pyrotechnic or explosive items increase the danger to the public, employees and structures. The educated and safe pyrotechnic artist tries to limit the use of energetic materials, employing the smallest possible charge for the most effective result. In the words of a North Vancouver pyrotechnician, the best pyrotechnic execution is

“All show, no go.”

(The largest visual effect incorporating the smallest explosive charge.)

6.17 Duds and misfires

- Before any support personnel enter the production area, make sure that all pyrotechnic articles or explosives have functioned.
- If you know of or find duds or misfires, before approaching, wait at least
 - 10 minutes (min) for effects initiated directly by an igniter or initiator with no fuse or other pyrotechnic transfer or delay in the ignition train
 - 30 min for all fused or fuse-delayed articles and devices
- Precautions must be taken to minimize the likelihood of harm to people and property from misfired pyrotechnics.
- Return the articles or devices to a separate storage magazine for future disposal. (See Chapter 8)
 - This will not always apply to the film industry, which often uses special-purpose pyrotechnics that cannot be returned to storage or even moved; they must be employed in place.

6.18 Firefighters

The use of film special effects sometimes require firefighters to be present. In such cases, before firefighters are permitted to approach the area, the *Special Effects Pyrotechnician* must determine whether all charges have functioned and that the location and surroundings are safe.

6.19 High explosives

Contact the ERD (erd.nrcan.gc.ca) for specific requirements related to the purchase and storage requirements of detonating cord and associated articles (detonators, cable cutters and exploding bolts).

Chapter 7. Post-event procedures

Notes

7.1 Disabling the devices

Immediately after each performance, pyrotechnicians must

- Disarm the controller.
- Keep the key in their possession.
- Ensure that the area or location where pyrotechnics were deployed is safe.

7.2 Duds and misfires

- Before any support personnel enter the production area, make sure that all pyrotechnic articles or explosives have functioned.
- If you know of or find duds or misfires, before approaching, wait at least
 - 10 min for effects initiated directly by an igniter or initiator with no fuse or other pyrotechnic transfer or delay in the ignition train
 - 30 min if the firing was initiated by other means

Note Manufacturers may require longer wait times.

- Pyrotechnics that are damaged, leaking, damp or contaminated must not be used. Return the articles or devices to a separate storage magazine for future disposal or dispose of them according to the procedures described in Chapter 8.

7.3 Giving the “all clear”

After the crew has removed all pyrotechnic or explosive devices and equipment, the pyrotechnician is responsible for

- making sure that the area is completely clear
- notifying all others that the area is clear and safe

7.4 Unused pyrotechnics

All unused pyrotechnic or explosive devices and materials must be

- prepared for immediate transportation to the next destination
- stored promptly according to the instructions given in this manual (see Chapter 8) if
 - additional performances are scheduled to follow at the same location
 - transportation is scheduled for a later date

7.5 When to file an accident or incident report

In the event of an accident, incident, theft or dangerous or unusual occurrence that has (or may have) caused personal injury or unforeseen property damage, you must notify the ERD and file a written incident report as soon as circumstances permit.

An incident report form (Form F07-01) is available on the ERD Web site.

The ERD, in co-operation with the appropriate authority, may conduct an investigation of any pyrotechnics accident that resulted in bodily injury or major property damage.

Other agencies such as the AHJ and provincial/territorial occupational health and safety organizations may also require written notification. It is your responsibility to know which requirements apply.

7.6 What the accident or incident report must contain

Your report must include the following information:

- location, performance, date and time
- pyrotechnic effects involved
- description of the incident
- nature of injuries or damage
- immediate action taken
- action taken to keep the incident from happening again
- other agencies notified
- contact numbers for company officials, the pyrotechnician and assistants, as applicable
- a copy of the event approval form

Chapter 9. Transportation

Notes

9.1 Authorities

The road transportation of explosives, including all pyrotechnics and commercial high explosives, is regulated primarily by the Transportation of Dangerous Goods Directorate (TDG) of Transport Canada and partially by the ERD of Natural Resources Canada (NRCan).

9.2 Classification of explosives

The TDG derives its requirements from a classification system based on the type, potential hazard, and compatibility of pyrotechnic and high explosive materials. The following outlines the TDG classification system for road transport and has been prepared as a reference but has no legal force or effect (for a legal interpretation, consult the *Transportation of Dangerous Goods Act* and the *Transportation of Dangerous Goods Regulations*). This classification system does not apply to the storage of pyrotechnics or high explosives (for more information on these topics, see Chapter 2 or consult the ERD).

9.3 Classes of dangerous goods

Class 1 – Explosives

Class 2 – Gases, compressed

Class 3 – Liquids, flammable

Class 4 – Solids, flammable

Class 5 – Oxidizing substances

Class 6 – Poisons

Class 7 – Radioactive substances

Class 8 – Corrosives

Class 9 – Miscellaneous

9.4 Hazard divisions of Class 1

- 1.1 – Mass explosion hazard
- 1.2 – Projection hazard
- 1.3 – Fire hazard with possible minor blast or projection hazard
- 1.4 – No significant hazard beyond the package
- 1.5 – Mass explosion hazard, but much less sensitive to initiation than Division 1.1
- 1.6 – Extremely insensitive article with no mass explosion hazard

9.5 Compatibility groups

Compatibility groups refer to materials that can be transported together in the same vehicle without significantly increasing the risk of accident, ignition or magnitude of injury or damage to people or surroundings. The groups are listed as follows:

- A – Primary explosive substances (most sensitive)
- B – Detonators: articles containing a primary substance
- C – Propellant explosives (including smokeless powder)
- D – Secondary detonating explosives (including black powder, detonating cord)
- E – Explosive substances with a propelling charge
- F – Explosive substance with a propelling charge and initiator
- G – Pyrotechnic articles
- H – Explosive substance with white phosphorous
- J – Explosive substance with flammable liquid or gel
- K – Explosive substance with a toxic chemical agent
- L – Explosive substance or article presenting a special risk
- N – Articles containing only extremely insensitive detonating substances
- S – Safety explosives (one article will not initiate another and the effect is localized to the packaging)

9.6 Classification of special effect pyrotechnics

Most pyrotechnics and high explosives used in the entertainment industry are classified for transportation in approved packaging as follows:

- 1.1B (e.g. high explosive detonators, high-strength squibs)
- 1.1D (e.g. black powder, detonating cord, stick powder)
- 1.3C (e.g. smokeless powder)
- 1.3G (e.g. flash powder, smoke composition, mixed two-component powder)
- 1.4G (e.g. smoke pots, mines, gerbs, pyrotechnic cartridges)
- 1.4S (e.g. bullet hits, electric matches, squibs, blank cartridges or articles with improved packaging)

Note Classification can change to a more hazardous division and compatibility group if products are removed from their authorized packaging or the packaging is altered.

9.7 Other TDG requirements

The TDG also regulates the following for road transport:

- training requirements for anyone handling, offering for sale or transporting dangerous goods
- labeling of packaging and vehicle placarding
- documentation
- quantity limits and other requirements under which articles may or may not be transported (see Schedule 1 of the TDG Regulations)

9.8 Special provision 76

Despite Section 5.7 (reprinted in this section) of Part 5, Means of Containment (TDG Regulations), any combination of the dangerous goods shown below (by UN number) that are included in Class 1, Explosives, may be handled, offered for transport or transported in a road vehicle if

- The total quantity of all the dangerous goods included in Class 1, expressed in net explosives quantity, is less than or equal to 5 kg.
- The total number of articles of dangerous goods subject to special provision 86 is less than or equal to 100 articles.
- The operator of the road vehicle has a valid pyrotechnic card issued to the operator by the ERD of NRCan.

UN0027, UN0066, UN0094, UN0101, UN0105, UN0161, UN0197, UN0255, UN0305, UN0325, UN0335, UN0336, UN0337, UN0349, UN0430, UN0431, UN0432, UN0454, UN0499

5.7 Compatibility Groups

(1) A person must not load or transport with other explosives in the same means of transport, except for a ship, explosives that have a compatibility group letter listed in column 1 of a row in the following table unless the compatibility group letter of the other explosives is listed in column 2 of the same row:

Table – SOR/2008-34

Column 1	Column 2
A	A
B	B,S
C	C, D, E, N, S
D	C, D, E, N, S
E	C, D, E, N, S
F	F, S
G	G, S
H	H, S
J	J, S
K	K, S
L	L
N	C, D, E, N, S
S	B, C, D, E, F, G, H, J, K, N, S

9.9 Consult the TDG for further details

The full requirements surrounding the transport of explosives are too extensive and specialized to set out in this manual. The ERD recommends that you consult your local TDG inspector for particulars.

9.10 ERD vehicle requirements

The following is a summary of the ERD vehicle requirements for transportation. Consult the ERD for detailed requirements related to your specific situation:

- You must be at least 18 years old to drive a vehicle carrying explosives.
- Never smoke in or near the vehicle.
- Only crew members may accompany the vehicle.
- The vehicle must be mechanically sound and
 - able to pass a safety check
 - inspected for defects before each trip
 - fully serviced before loading

1.4 Use of explosives

The commercial use of explosives is, in most cases, a matter of provincial/territorial jurisdiction. However, the ERD is responsible for regulating the use of all types of fireworks, which includes special effect pyrotechnics.

1.5 Locations

ERD headquarters are located in Ottawa. The four regional offices are located in Ottawa, Calgary, Vancouver and Saint-Hyacinthe, Quebec.

1.6 Canadian Explosives Research Laboratory

The Canadian Explosives Research Laboratory (CanmetCERL), located just west of Ottawa, can test all fireworks, pyrotechnics, high explosive articles, devices and compositions contained in legally manufactured or imported effects, along with the articles or products themselves, primarily for authorization purposes. The CanmetCERL and the ERD are integral parts of the Explosives Safety and Security Branch of NRCan.

1.7 Authorized effects

In general, only pyrotechnic effects authorized under the Act and Regulations may be

- imported
- manufactured
- sold
- purchased
- owned
- kept and stored
- used

1.8 Unauthorized effects

You cannot lawfully manufacture, store or possess unauthorized articles. Whether such articles are permitted in other countries is immaterial. Unauthorized articles include trick fireworks and firecrackers such as

- snap caps
- champagne party poppers
- cigarette loads
- cherry bombs
- M-80 salutes
- flash crackers

Appendix 2. Background and characteristics of pyrotechnics

2.1 Word and action

The word “pyrotechnics” comes from two Greek words – *pyro* (fire) and *technic* (art) – and is often associated with fireworks. Technically, pyrotechnics is the science of materials capable of undergoing self-contained and self-sustained exothermic chemical reactions. Typically, these materials are solids and are used for the production of heat, light, gas, smoke and/or sound.

2.2 Background

Pyrotechnic effects are the earliest types of explosives known to man. The use of chemicals to produce heat, light, gas, smoke or noise originated several thousand years ago, probably in China or India.

“Greek fire,” the best known ancient firework, was reported to have been used during the Arab naval siege of Constantinople in AD 673. It contained a blend of sulphur, organic fuels, and saltpetre (potassium nitrate) that generated flames and dense smoke when ignited.

Around the 10th century, adventurous people discovered that, with the help of fire, an intimate mixture of potassium nitrate, charcoal and sulphur could produce a very impressive effect. In 1627, Kaspar Weindl fired the first commercial blast of “black powder” at the Royal Mines in Hungary, thus introducing the first high-energy composition.

2.3 Pyrotechnic compositions

Pyrotechnics are made up of compositions that burn energetically and, if confined, may explode or detonate. They are classed as low explosives, in contrast to the much more powerful high explosives such as dynamites. Pyrotechnics burn or *deflagrate*; high explosives *detonate*.

Pyrotechnic compositions contain all the oxygen necessary for a chemical reaction (and are therefore very difficult to extinguish in a firefighting situation). Principal reactants are nitrates, chlorates or perchlorates, along with a combustible material. The nature of the composition and the state of the ingredients, such as particle size, determine the reaction rate, the appearance of the flame, smoke or other pyrotechnic effect, and the noise and flash of the explosion.

Black powder (gun powder) is a versatile mixture. It is used in various granulations as a propelling charge, a source of noise, a constituent of other compositions, or as part of ignition fuses and timing systems. *Black powder* should not be confused with *smokeless powder* (propellant powder), which is a modern mixture that came into use in the late 1800s after the discovery of nitrocellulose. *Smokeless powder* generates high pressures if confined, as in small-arms ammunition.

Other compositions produce coloured flames, twinkles and smokes, and may be either loose or compacted. When compacted (pressed into cubes and pellets or rolled into spheres), these compositions are called *stars* and burn over their exposed surfaces to produce a brilliant ball of fire. Other formulations that contain powdered aluminum or magnesium react violently, causing explosions accompanied by a flash and are known as flash or concussion powders.

All pyrotechnic compositions are energetic materials. They are therefore DANGEROUS. In general, pyrotechnic compositions are sensitive to flame, spark, friction, impact and heat. All are averse to water in any form, and most are rendered completely inert by it.

Note Water may cause spontaneous reactions in a few compositions (e.g. magnesium powders).

2.4 Finished products

In contrast, finished products are much less dangerous – unless the case is ruptured and the composition leaks out. Pyrotechnic casings are made of rolled paper, plastics or aluminum. Do not tamper with manufactured articles.

2.5 Pyrotechnics versus consumer and display fireworks

Authorized pyrotechnic special effects are not the same as consumer or display fireworks, which cannot be used indoors or in close proximity to personnel and the public. The main difference is that *authorized pyrotechnics* must function the same way every time with respect to

- height
- fallout radius
- noise and light level
- concussion
- manner of firing (fast, slow, continuous, intermittent)
- quantity of smoke produced

Appendix 3. Basic chemistry of pyrotechnics

Notes

3.1 Constituents

A pyrotechnic mixture contains

- an oxygen donor (oxidizer)
- one or more fuels that burn with the released oxygen when the oxidizer is heated
- other chemicals that serve as binders and create colour, spark or other visual or audible effects

3.2 The reaction

- The heat generated by the reaction between the oxidizer and the fuel causes the other effects to occur.
- All compositions contain their own source of oxygen – *air is not necessary for combustion.*

3.3 Pyrotechnics versus high explosives

- In general, pyrotechnics deflagrate at a velocity of less than 300 m/s.
- High explosives, in contrast, detonate at velocities from 2000 to 7000 m/s.
- Compare these velocities with the following examples:
 - light: 300 million m/s
 - expansion of a nuclear fission bomb: 1 million m/s
 - 30-06 rifle cartridge: 825 m/s
 - sound: 342 m/s
 - commercial aircraft: 135 m/s
 - slap shot, baseball pitch: 40 m/s
 - vehicles on the Trans-Canada Highway: 30 m/s
 - walking: 2 m/s

3.4 Pyrotechnics: Science and art

While the chemistry of pyrotechnics is a science, the development and manufacture of effects is an art.

OXYGEN + FUEL = **HEAT** + reaction products (solid, liquid or gas)

HEAT = Light, colour, sparks, whistle, rapport, smoke and propulsion

3.5 Ignition

Ignition occurs when sufficient external energy interacts with the pyrotechnic composition. This energy can be in the form of flame, sparks, high temperature (hot wire), impact or friction.

Typical means of igniting pyrotechnic devices include

- flame or spark (fuse)
- electric current, producing heat or a flash (electric match)
- impact (percussion primer)
- friction (safety match)

3.6 Propagation

Propagation of the reaction occurs when the heat generated by the initial ignition continues in the composition itself (an exothermic reaction).

- energy input to pyrotechnic mixture = broken chemical bonds
- new chemical bonds form = energy is released
- released energy is
 - lost to the surroundings
 - transferred to the composition in sufficient quantity to yield a self-propagating reaction

3.7 Requirements

Pyrotechnic devices must

- produce the desired effect
- be safe to manufacture
- be chemically stable (in transportation, storage and use)
- have low hygroscopicity (tendency to absorb moisture from the air)
- have low toxicity
- have a moderate production cost

3.8 Basic pyrotechnic principles

Several key factors affect the performance of pyrotechnic compositions. Even if two identical formulas are used to manufacture a pyrotechnic mixture, the effects produced can be quite varied. The reasons for this include

Water or moisture

- One of the oldest sayings in the field of pyrotechnics is “keep your powder dry.” Water absorbs heat when it vaporizes. Powder that has a high moisture content can be difficult to ignite and may produce a dangerous dud. Water can sensitize certain compositions, such as magnesium powder.

Extent of mixing

- A poorly mixed blend of oxidizer and fuel may burn quite slowly (if at all), while the same mixture blended to a high degree of homogeneity will tend to be quite reactive when ignited.

Particle size

- Pyrotechnic mixtures made from oxidizers and fuels of small particle size (high surface area) will tend to be considerably more reactive than compositions made from coarser chemicals, even if the same percentages and mixing methods are used.

Confinement (through packaging or pyrotechnic mass)

- Unlike high explosives, pyrotechnic mixtures show a sharp increase in burn rate when they are confined and ignited. Also, the burn rate of a mixture tends to increase as the surface area of the burning material increases. On ignition, gases and heat are produced. If the gases are held long enough in the vicinity of the burning front, the heat will act on the gases and, if the gases cannot escape, the pressure increases. The increased pressure elevates the reaction rate and establishes a vicious circle, whether it is in a paper tube, steel pipe or a quantity of pyrotechnic composition approaching the critical mass.

3.9 Common pyrotechnic ingredients

Oxidizers

- ammonium perchlorate, barium nitrate, potassium chlorate, potassium nitrate, potassium perchlorate, and strontium nitrate

Fuels

- elemental: boron, carbon, phosphorus, silicon and sulphur
- organic compounds: natural gums, plastics, polymers and starch
- metals: aluminum, magnalium, magnesium and titanium

3.10 Noise effects

Report or noise effects and concussion powders

- typically contain potassium perchlorate or nitrate oxidizers, and aluminum

Whistle effects

- usually made of potassium perchlorate, sodium salicylate or sodium benzoate

3.11 Coloured flames and sparks

The show-related applications of pyrotechnic mixtures are infinite, but usually involve the production of coloured flames or sparks. The common colour and spark-producing chemical groups for fireworks-type reactions are listed in the following table

Colour	Chemical group
Red	Strontium salts
Green	Barium salts
Yellow	Sodium salts
Blue	Copper salts
White	Antimony salts or aluminum powder
Amber sparks	Charcoal or iron particles
Gold sparks	Iron or iron titanium alloy
Silver sparks	Titanium, aluminum or magnesium

Appendix 4. Fireworks categories

4.1 Consumer fireworks (F.1)

Outdoor, low-hazard recreational fireworks such as showers, fountains, golden rain, Roman candles, volcanoes, sparklers, and caps for toy guns

4.2 Display fireworks (F.2)

Outdoor, high-hazard recreational fireworks such as display shells, bombshells, large wheels, barrages, bombardos, waterfalls and mines

4.3 Pyrotechnic special effects (F.3)

These effects are created through the firing of pyrotechnic, propellant and explosive materials and devices, and are used by the entertainment industry for indoor and outdoor performances. Examples include bullet effects, flash powders, smoke compositions, gerbs, lances and saxons.

4.4 Fireworks accessories (F.4)

For practical reasons, this manual also regards black and smokeless powder, as well as special-purpose pyrotechnics, as part of this category. Special-purpose pyrotechnics are pyrotechnics and compositions, black or smokeless powder, and/or commercial high explosives used in conjunction with flammable liquids (diesel, gasoline, propane, napalm, etc.) and gases and solids to produce a one-of-a-kind pyrotechnic effect.

Appendix 5. Minimum separation distances for personal communications devices

The minimum distances that must separate pyrotechnics from mobile transmitters and cellphones, including amateur and citizen's bands, are listed in Table 1. These distances are excerpted from the bulletin SLP 20: *Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators*, which is published by the Institute of Makers of Explosives.

Table 1. Minimum separation distances for personal communications devices

Minimum separation distances (in metres, rounded off after conversion from feet)					
Transmitter power (watts)	MF 1.9–3.4 MHz fixed, mobile, marine	HF 28.0–29.7 MHz amateur	VHF 35–36 and 42–44 MHz public use, 50–54 MHz amateur	VHF 35.0–36.0 MHz amateur, 150.8–161.6 MHz public use	UHF 450–470 MHz public use, cellphones above 800 MHz
	Distance (metres)				
5	10	22	19	7	4
10	13	31	25	10	7
50	27	71	55	22	13
100	37	98	80	31	19
180	52	132	107	40	25
200	55	141	113	43	26
250	61	153	125	49	28
500	86	217	177	68	37
600	92	238	196	74	43
1 000	122	308	250	95	55
1 500	150	371	308	116	68
10 000	379	986	793	302	171

Notes

Glossary

Notes

Note Italicized words appear as separate entries in this glossary.

4A - 40 B:C

The numbers refer to the size rating of the fire extinguisher; the letters A:B:C refer to solids, liquids and electrical fires, respectively.

ad hoc

Situation considered on an individual and particular basis.

airburst

An effect suspended in the air to simulate outdoor aerial fireworks shells without producing potentially *hazardous debris*. The typical composition is a type of *flash powder*.

all-fire current

The minimum electrical *current* that must be applied to an *igniter* or initiator to produce 100 percent ignitions.

ampere

A unit of electrical *current* produced by 1 *volt* acting through a *resistance* of 1 *ohm*.

atmosphere

A unit of pressure equal to 101 325 *newtons* per square metre (14.5 psi).

authority having jurisdiction (AHJ)

The agency responsible in any area for granting approvals related to pyrotechnic special effects. The most common AHJ is the fire department but other agencies in various provinces/territories, cities or municipalities also serve as the AHJ (e.g. the Ministry of Labour, occupational health and safety organizations, Workers Compensation Board, Transport Canada Air, Coast Guard, a film commissioner and the EDU). It is the responsibility of the *pyrotechnician* to be aware of the AHJ(s) for the area in which the performance is to take place.

authorized (explosive, pyrotechnic)

Means any *explosive* or *pyrotechnic* that is declared to be *authorized* in accordance with the *Explosive Regulations*. *Authorized pyrotechnics* will appear as Class F.3 on the List of Authorized Explosives. The articles that are *authorized* for use by the *Pyrotechnician* will be designated with the letter "P" on the List of Authorized Explosives.

bar

A metric unit of pressure equal to 1 million *dynes* per square centimetre; 1 standard *atmosphere* or 14.5 psi.

binary material

See two-component

black match

A fuse consisting of cotton string impregnated with *black powder*; a normal burning rate is 2.5 cm/s.

black powder (gunpowder)

An intimate, ground mixture of finely powdered potassium nitrate (75 percent), charcoal (15 percent) and sulphur (10 percent). Black powder may be granular or finely ground that has unconfined velocities measured in metres per second to confined velocities of 170 to 300 m/s, depending on particle size and confinement. It has a wide variety of uses such as in *black powder lifters*. Do not mistake or substitute *smokeless powder* (as used in *flame projectors* and ammunition) for *black powder*.

black powder lifters

A soft (taped) or hard-wrapped (taped cardboard container) *black powder* charge with an *igniter*, usually fired in a *mortar* and used to simulate an *explosion*. Extra wrapping or confinement of various types will add to the subsequent *explosive* effect. No metals or rigid materials should be used to wrap or encase *black powder* (do not confine *black powder* in mortars or other firing devices). Volatile liquids and solids can be introduced for the desired effect.

blank cartridge

Bullet case and percussion primer filled with various types of *smokeless powder* or other *propellants*, but does not have a slug or projectile. The sale, possession and use of guns and ammunition is regulated under Part III of the *Criminal Code of Canada* (Firearms and Other Weapons).

blasting ohmmeter

A testing instrument used to establish the *continuity* and approximate *resistance* of electric firing circuits. It produces a sensing *current* of approximately 0.025 A, much below that needed to initiate *electric matches*, *squibs* or *detonators*.

blasting explosives

See *high explosives*.

bridge wire

A fine wire contained in an *electric match*, or *squib*, that either heats up or ignites when an electric *current* is applied.

continuity

An unbroken or low-resistance flow of electrical *current*.

critical mass

The minimum amount of energetic material that, when ignited, can cause an *explosion*, as compared with steady ignition.

cross over to detonation (transit)

In general, *high explosives* – and *pyrotechnic* compositions – will only *burn* if exposed to fire. However, if they are confined and the pressure and temperature rise, they can *detonate*.

current

The flow or rate of flow of electric charge in a circuit, expressed in *amperes*.

dangerous occurrence (unusual)

An accident or near miss caused by *pyrotechnic* or *explosives* use; also means an unexpected result or problem concerning *pyrotechnic* or *explosive* materials.

deflagration

An *exothermic reaction* in which the reaction front advances at subsonic speed (<350 m/s).

detonating cord

A flexible cord containing a powerful *high explosive* (PETN) with the *explosive* load expressed in *grams* per metre. *Velocity of detonation* (VOD) is approximately 7000 m/s (25 000 km/h).

detonation

An *exothermic* reaction in which the reaction front advances at above supersonic speed (>350 m/s) in the unreacted material. Typically, the reaction front in *high explosives* travels at more than 2000 m/s. A *detonation*, when the material is located on or near the surface of the ground, usually forms a crater.

detonator (blasting cap)

A thin metal tube containing a very sensitive primary *high explosive* used for initiating the *detonation* of other *high explosives*.

display fireworks

“*High-hazard*” recreational *fireworks* such as aerial shells, large roman candles and cakes typically used at community celebrations (Class F.2).

duty of care

Everyone who has an *explosive* substance in his/her possession or under his/her care or control is under a legal duty to use reasonable care to prevent bodily harm or death to persons or damage to property by that *explosive* substance. (Section 79, *Criminal Code of Canada*.)

dwelling (dwelling-house)

“Dwelling-house” means the whole or any part of a building or structure that is kept or occupied as a permanent or temporary residence, and includes a

- building within the curtilage of a dwelling-house that is connected to it by a doorway or by a covered and enclosed passage-way
- a unit that is designed to be mobile and to be used as a permanent or temporary residence and that is being used as such a residence. (Section 2, *Criminal Code of Canada*.)

dyne

The amount of force that imparts an acceleration of one centimetre per second per second to a mass of one gram.

electric match (e-match, igniter)

A device used to cause the ignition of *pyrotechnic* materials. It consists of two wires terminating at a *bridge wire* coated or surrounded with a small quantity of heat-sensitive *pyrotechnic* composition. When sufficient *current* is passed through the wire, the heat generated ignites the composition, producing a small burst of flame or sparks. Handle *electric matches* as you would any other *explosives*. They are sensitive to impact, friction and heat. Do not confuse *electric matches* with *squibs* or *detonators*, which are manufactured for purposes other than simple initiation by flame.

endothermic reaction

A chemical change in which there is an absorption of heat.

ERD

Explosives Regulatory Division

exothermic reaction

A chemical change in which heat is released.

exploding bolts

Fastening devices that can be internally destroyed, releasing the secured object.

explosive

Anything that is made, manufactured or used to produce an explosion or a detonation or pyrotechnics effect, including anything prescribed to be an explosive by the Regulations, but does not include gases, organic peroxides or anything prescribed not to be an explosive by the Regulations.

extraneous electricity

Current that can cause the accidental initiation of igniters and initiators such as static electricity; transient currents (stray currents) produced within the earth or by man-made devices; varying electrical and magnetic fields such as lightning strike or inductance; and radio frequency (RF) energy.

firing current

The *current*, expressed in *amperes*, used to ignite or activate an *electric match*, *squib*, *bullet hit* or *detonator*.

fixed production

A production repeatedly performed in the same manner in only one location, typically a theatre setting.

fire retardant

Chemicals applied to a material to increase *resistance* to ignition or burning.

flame projector

A tube used to produce a vertical column of fire that lasts several seconds. The composition is *smokeless powder* and may contain colouring agents.

flare

An article designed to produce intense light (usually coloured) for a defined period.

flash cotton

Similar to *flash paper* but has a faster burning rate.

flash pack

Soft *black powder* charge used with flammable liquids to disperse and guarantee ignition.

flash paper

A composition made of nitrocellulose. The nitrated materials are very easily ignited and burn without solid by-products. They can be used to produce a flash or as a component in other effects.

flash pot

A device containing *flash powder*, intended to produce a flash of light and/or sparkles.

flash powder

Sensitive composition that produces a flash of light when ignited. Unlike *concussion powder*, *flash powder* does not produce a *report*. Various types are manufactured, including regular, low smoke, fast and slow sparkle, and flitter *flash powder*.

flash string

See flash paper.

FOC

Fireworks operator certificate

fuel

Anything that can burn or act as a chemical reducing agent.

gerb

An article consisting of a short, heavily walled tube filled with pressed composition. It is usually equipped with a *choke* or restricted orifice intended to produce a controlled jet or broad spray of sparks. It may also contain colour-producing materials. From the French *gerbe*: a sheaf of wheat; spray or column of water.

glitter effect

An effect that produces glowing droplets that terminate in bright yellow or white flashes.

grain

Small measure of mass (weight) in the British system.
7000 grains = 1 pound; 437.5 grains = 1 ounce; 15.43 grains = 1 gram.

gram

Measure of mass (weight) in the metric system.
1 gram = 15.43 grains = 0.03527 ounce = 0.0022 pounds.

Green Zone

Safe area beyond the minimum distance that unprotected people must keep between themselves and an open, unconfined *high explosive* or *black powder* charge.

grid rockets

See line rockets.

hangfire

A fuse or *pyrotechnic* composition that suddenly starts burning more slowly than it is supposed to; just as suddenly, it may resume burning at its normal rate. This unpredictability can be dangerous.

hazardous debris

Any potentially injurious material produced by the firing of an explosive or pyrotechnic device.

high explosives (blasting)

General term referring to any commercial *detonating explosive* as used in the construction and mining industries. *High explosives* can be manufactured in cartridge form (e.g. stick powder) or manufactured and supplied in bulk. *High explosives* can be initiated (*detonated*) by a *detonator* (blasting cap). The *velocity of detonation* (VOD) is typically between 2000 and 7000 m/s.

igniter

Any electrical device (*electric match* and possibly a *squib*) or *pyrotechnic* fuse (*igniter cord*, *black match*) used to initiate *pyrotechnic special effects* or other flammable material.

igniter cord (thermalite)

Small-diameter (1.6 mm), slow-burning cord. Two types (30 s/m and 60 s/m) are used to ignite *pyrotechnics* or flammable liquids.

inductance

Property of an electric circuit or of two adjacent circuits such that an electromotive force is generated in one circuit by a change in the *current* itself in the other circuit.

integral mortar (preloaded mortar)

A commercially produced *mortar* containing *pyrotechnic* materials and intended for one-time use.

knocker

A device used to break house and car windows, generally powered by an electrically fired *squib*.

lance

A small paper tube, roughly 1 cm by 10 cm, charged with *pyrotechnic* composition. Essentially, *lances* are small *flares* and are typically used in *set pieces*.

leg wires (lead wires)

A pair of insulated wires attached to an electrical ignition element (*bridge wire*) in an ignition article.

line rockets (grid rockets)

A *gerb*-type device having a *choke* or nozzle charged with a fast-burning composition and attached to a suspended wire for direction.

lycopodium powder

A yellow powder found in the spore cases of lycopodium plants. The fine organic material is easily dispersed into a cloud that can then be ignited by a spark or flame to produce fireball effects.

magazine

Any building, storehouse, structure or place in which any explosive is kept or stored.

maroon

A small exploding device that produces a loud noise or *report*.

millibar

Unit of atmospheric pressure equal to 1/1000 bar, 1000 *dynes* per square centimetre, or 0.014504 psi.

mine

A device, usually *preloaded*, that projects *pyrotechnic* material to a pre-determined height, producing sparks and/or flame.

mortar

A tube, pot-like or pyramid device used to direct and control the effect of various *pyrotechnic* materials.

naphthalene

White, crystalline, volatile material in a solid, flake or powdered form that gives off flammable vapours when heated. It is typically used with *black powder* bombs.

net explosive quantity (NEQ)

The actual *pyrotechnic* or *explosive* weight, excluding the packaging, wiring or cases.

newton

Unit of force that imparts to a mass of one kilogram an acceleration of one metre per second per second.

no-fire current

The maximum electrical *current* that can be applied when testing *continuity* of a circuit or article without causing an ignition or degradation of the device. For safe testing, apply no more than 20 percent of the no-fire *current*, or 0.025 *amperes*, whichever is less, and use a *blasting ohmmeter* or other approved instrument.

non-sparking tools

Implements constructed from materials (brass, copper, aluminum, wood, gun metal, etc.) that will not spark when scraped or struck.

NRCan

Natural Resources Canada

ohm

Unit of electrical *resistance*, equal to the *resistance* of a circuit in which an electromotive force of one *volt* maintains a *current* of one *ampere*.

open circuit

An electrical circuit in which there is no continuous path through which an electric *current* can flow.

out of country (Pyrotechnician)

A *pyrotechnician* who does not normally work in Canada and has not had the opportunity to follow the Canadian *pyrotechnic special effects* certification program. The *pyrotechnician* must apply for a visitor certificate.

oxidizer

Usually oxygen-rich, ionically bonded chemicals that decompose at moderate temperatures, releasing oxygen that combines with the fuel.

parallel circuit

An electrical circuit in which the *current* is split through a number of individual devices. The total *resistance* equals

$$R \text{ (total)} = \frac{1}{(1/R_1 + 1/R_2 + 1/R_3 + \dots 1/R_n)}$$

placards

Signs placed on a vehicle to indicate the nature of the cargo as required by the *Transportation of Dangerous Goods Act* and by the *Transportation of Dangerous Goods Regulations*.

preload

Articles manufactured for use that are ready to fire and do not have to be assembled.

pre-mixed powders

Pyrotechnic powders that are purchased ready for use, as distinguished from *two-component* powders that must be mixed after purchasing.

primed

An article or fuse containing an electric match or other type of initiator, including detonators.

propellant

For the purposes of this manual, a generic term including *black* and *smokeless powder*.

pyrotechnics

The science of materials capable of undergoing self-contained and self-sustained *exothermic* chemical reactions for the production of heat, light, gas, smoke and/or sound.

pyrotechnic special effects

Compositions, articles and devices created for the purpose of entertainment through the use of *explosive* materials including *pyrotechnic* and *propellant* materials. Also, *special-purpose pyrotechnics* including *pyrotechnic articles* and compositions, *black* or *smokeless powder*, and/or commercial *high explosives* used in combination with flammable liquids (diesel, gasoline, propane, napalm, etc.), and flammable gases and solids, to produce a one-of-a-kind *pyrotechnic* effect.

Red Zone

High-danger area around a *high explosive* or *black powder* charge. Once *pyrotechnicians* have positioned the charge, the *Red zone* is off limits to all. The *Red zone* periphery also serves to indicate the minimum safe distance for eardrums and protected camera operators.

Regulations, the

The *Explosives Regulations*

report

A very loud “crack” or sharp sound.

resistance

Property of a material by which it impedes the flow of electrical *current*. The unit of *resistance* is the *ohm*.

safety distances

For various quantities of *explosives*, including *pyrotechnics*, the minimum distances to be kept from all personnel and vulnerable features; generally referred to as “Quantity-Distances” in the *high explosives* industry.

safety explosives (TDG Class 1.4S)

Explosives designed so that hazardous effects are confined to individual packages, and one article cannot initiate another.

salute powder

A *pyrotechnic* mixture (a type of *flash powder*) that produces a loud *report*.

Saxon (wheel)

An effect consisting of a driver that rotates around a pivot point to produce a circular shower of sparks.

series circuit

An electrical circuit in which the *current* flows from one device to another. The total *resistance* equals the sum of *resistance* of each device:

$$R \text{ (total)} = R_1 + R_2 + R_3 + \dots R_n$$

series-parallel circuit

An electrical circuit made up of a combination of *series* and *parallel* branches. Total *resistance* equals the sum of the *series* and *parallel* branches.

set piece

A ground effect made up of small *lances*, *flares* or *gerbs*, usually of different colours, to produce an image or desired effect.

shatter zone

The area around a *high explosive* (or *black powder*) charge in which residential windows are likely to break.

shock tube (streaks, Nonel[®])

A thin plastic tube whose inside surface is finely coated with HMX and powdered aluminum. It is used to simulate lightning strikes, etc.

shunt

An intentional short-circuiting of an electrical circuit to improve safety.

silver fuse

Fuse producing a sparkling effect.

smoke

An air suspension of fine particles that have a typical size of 2.5 microns. Organic dyes can be added for coloured effects that selectively absorb portions of the visible light spectrum.

smokeless powder

A material based on nitro-cellulose and typically used as a propellant (in small arms ammunition) or in *flame projectors*. The term includes propellants with a single base (nitro-cellulose [NC] alone), double base (NC and nitroglycerin [NG]) or triple base (NC/NG/nitroguanidine). Do not confuse with *black powder*.

smoke pot

A device used to create smoke in a controlled manner.

soft detonator

A very powerful *squib* that approaches the power of a commercial *high explosive detonator*. It does not have a metal case to eliminate shrapnel being produced from it.

spark-producing device (SPD)

Electrically fired device or *squib* that produces a shower of sparks similar to electric shorting or sparks from a *bullet hit*.

special effects

A general term used in the film and television industry referring to the production of rain, wind, snow, smoke, steam and fire.

sympathetic communication

Movement of sparks, heat or sudden force from one effect to another, causing ignition and premature functioning.

tensile strength

Resistance to lengthwise stress.

transient currents

See stray currents.

transit

See cross over to detonation.

trunk line (electrical)

A wire or cable of wires running from a firing panel to the area of the effects.

turkey bag

Plastic bag containing a flammable liquid as used in *special-purpose pyrotechnic* articles.

two-component (binary)

An explosive that is formed by blending two non-*explosive* components on site. Such items are commonly shipped as separate ingredients: an *oxidizer*, typically labeled "A," and a *fuel*, typically labeled "B." These ingredients do not become an *explosive pyrotechnic* material until they are mixed. Colouring agents may be present in either of the two containers or as an additive.

unusual occurrence

See dangerous occurrence.

velocity of detonation (VOD)

The speed at which a *detonation* wave passes through a column of *explosives*, measured in metres per second (m/s) or feet per second (ft./s).

volt

Unit for measuring the difference in electric potential. A potential of one *volt* causes a *current* of one *ampere* to flow through a circuit having a *resistance* of one *ohm*.

watt

Rate of energy production equal to 1 joule/second or to the power developed in a circuit by the *current* of one *ampere* flowing through a potential difference of one *volt*.

wheel

See Saxon.

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