FIRE AND EXPLOSION HAZARD MANAGEMENT

AN INDUSTRY RECOMMENDED PRACTICE (IRP) FOR THE CANADIAN OIL AND GAS INDUSTRY

IRP VOLUME 18 – 2006

SANCTION JANUARY 2007

Drilling and Completion Committee

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This IRP is a set of best practices and guidelines compiled by knowledgeable and experienced industry and government personnel. It is intended to provide the owner, operator, and contractors with advice regarding the specific topic. It was developed under the auspices of the Drilling and Completions Committee (DACC).

The recommendations set out in this IRP are meant to allow flexibility and must be used in conjunction with competent technical judgment. It remains the responsibility of the user of the IRP to judge its suitability for a particular application.

If there is any inconsistency or conflict between any of the recommended practices contained in the IRP and the applicable legislative requirement, the legislative requirement shall prevail.

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PREFACE

PURPOSE

The purpose of this IRP is to improve worker safety by providing industry with:

- a more thorough understanding of fire and explosion hazards;
- a process for identifying such hazards; and
- effective methods for managing these hazards.

AUDIENCE

The recommendations in this document apply to oil and gas operations where the potential for fires and explosions from air-hydrocarbon mixtures exist.

The intended audience includes:

- company personnel at the management, project engineer, supervisory, and worker levels; and
- personnel in all associated support services.

SCOPE AND LIMITATIONS

The scope of this IRP includes:

1. **Industry training and awareness**
    - An overview of the current safety and energy regulations relevant to fire and explosion safety.
    - Responsibilities for individuals, organizations, and the industry with regard to preventing fire and explosion incidents.
    - A content profile for use as the foundation for educating industry personnel about managing fire and explosion safety.

IMPORTANT: Each employer is responsible for providing training on how its employees should apply this IRP to its activities. This training needs to be designed for the different levels of employees within the organization.

2. Methodology for hazard management and assessment

- A method for developing a fire and explosion hazard management process.
- A method for assessing potential fire and explosion hazards at the field level.
- Guidance for determining when a field-level hazard assessment is insufficient and a more detailed risk assessment is needed.
- Guidance for selecting and implementing appropriate control methods.
- Guidelines for the development of written, site-specific fire and explosion prevention plans.
- Guidance for effective communication of fire and explosion hazards, controls, and prevention plans.

Limitations

A variety of compelling reasons made it impractical and unrealistic to develop prescriptive design, operating, and maintenance procedures in this IRP. These included:

- the wide variety of operations and circumstances which can create air-hydrocarbon mixtures;
- the dynamic nature of fire and explosion systems, equipment, procedures and personnel;
- the difficulty of knowing exactly what substances and conditions exist in some situations; and
- the science needed to prove conclusively what is safe and unsafe may not exist for specific operations.

METHOD OF DEVELOPMENT

The recommendations in this document are based on the research of industry incidents in Western Canada which have happened and could happen again. These incidents revealed the need for training and a systematic approach focused on improving safety relative to fires and explosions.

To develop appropriate recommendations, the IRP 18 committee completed a comprehensive investigation in cooperation with the University of Calgary Department of Chemical and Petroleum Engineering, which included:

- A detailed assessment of more than 40 fire and explosion incidents;
- The review of more than 500 text books, papers, articles, and other technical references related to fire and explosion safety; and
- Interviews with more than 50 oil and gas industry personnel with fire and explosion incident experience.

Research Information Available

Information gathered as supporting research for IRP 18, has been made available for industry reference on the internet at www.firesandexplosions.ca, included are:

- Detailed technical research; and
- The analysis and documentation of more than 40 relevant case studies.

Ongoing Research

Research pertinent to this IRP continues in conjunction with the University of Calgary Department of Chemical and Petroleum Engineering.

REVISION HISTORY

Edition	Sanction Date	Scheduled Review Date	Remarks and Changes
1	TBD	2 years after approval	This is the first edition of IRP 18. The content was developed by the IRP 18 committee, a subcommittee of the Drilling and Completions Committee (DACC).

IMPLEMENTATION

The recommendations in this document affect a number of other IRPs, and alignment is required.

The Enform Training Council will need to examine the development of the basic and advanced level training as specified in this Industry Recommended Practice.

SANCTION

The following organizations have sanctioned this document:

Alberta Energy and Utilities Board
BC Oil and Gas Commission
Canadian Association of Oilwell Drilling Contractors
Canadian Association of Petroleum Producers
Alberta Employment, Immigration and Industry
Intervention and Coil Tubing Association
Petroleum Services Association of Canada
Small Explorers and Producers Association of Canada

ACKNOWLEDGEMENTS

Western Canada’s upstream oil and gas industry has paid a high price for the information relevant to this IRP; people have been killed or injured and billions of dollars worth of equipment has been damaged.

This IRP was developed by a subcommittee of the Drilling and Completions Committee (DACC), the IRP 18 Development Committee. This subcommittee was made up of knowledgeable and experienced industry and government personnel. The individuals listed below are recognized for their significant contributions to this IRP.

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The University of Calgary Department of Chemical and Petroleum Engineering was retained to assist with the research which forms the basis of this document. **Dr. Raj Mehta** and **Matt Ursenbach** oversaw this research which was completed by the engineering students listed below.

Students	Year
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Jeff Olson	2004
Eric Lottermoser, Deanne Van Dam, Maryann Youseff	2003

OTHER ACKNOWLEDGMENTS

The committee would like to recognize the contribution of a large number of people who played an important role in the development of this document. Notable contributions were made by: Rod Loewen, Workers' Compensation Board of BC; Bob Brownlee, Calfrac Well Services; Don Battenfelder, Calfrac Well Services; Bill Groves, Clean Well Tools; Scott Marshall, Colter Production Services Inc.; Ed Strickland, EnCana Corporation; Brian Green, Enform; Murray Sunstrum, Enform; Craig Marshall, Ensign Energy Services Inc.; Dave Fennell, Imperial Oil Ltd.; Jim Holmberg, ExxonMobil Canada; Dennis McCullough, Alberta Energy and Utilities Board; Jim Reid, Alberta Energy and Utilities Board; Kyle Makofka, High Arctic; Stephen Pleadwell, ESP Safety Resources; Christien Venardos, Key Safety and Blowout Control; Larry McPherson, Live Well Service; Lyle Schnepf, Lonkar Services Ltd.; Emerson Vokes, Lonkar Well Testing Ltd.; Daryl Sugden, Nabors Production Services/Swabtech; Ron Green, Pure Energy; Bill Thomas, Precision Energy Services; Bob Ross, Saskatchewan Labour; Steve Lemp, Schlumberger; Dave Todd, Shell Canada; Al Vallet, Snubco; Stu Butler, Weatherford Canada; Scottie Hannah, Weatherford Canada; Matt Deady, Wespro Production Testing.

DEFINITIONS AND ABBREVIATIONS

Competent: In this document, competent means that a person is adequately qualified, suitably trained, and has sufficient experience to safely perform work without supervision or with only a minimal degree of supervision.

Controls: In this document, controls mean equipment or actions applied to reduce the frequency or the severity of injury or loss due to an unplanned fire or explosion.

Critical Risk Factors: Operational conditions that significantly increase the probability of a fire or explosion.

Employer: In this document, this term means any company that has one or more employees at the wellsite. This includes ‘drilling contractors’ and ‘service companies’ or as commonly known in the industry - 'sub-contractors'. It also includes any small contractors or businesses that have one or more people doing work at the wellsite whether they are employees, owner operators or self-employed workers.

Engineering Certifications: Documents stamped, signed and otherwise “certified by a professional engineer” as per the applicable Occupational Health and Safety Act, Regulations and Codes.

Energy–Ignition Source: Any source of energy or heat that has the potential to ignite an explosive or flammable mixture.

Expanded Fire Triangle: The fire triangle is a fire fighting theorem which states that for fires and explosions to propagate, they must have access to fuel, an oxygen source, and sufficient energy. The expanded fire triangle discussed in this IRP, recognizes that there is a broader range of fuel-hydrocarbon, oxygen-air, and energy- ignition sources that must be considered in fire and explosion hazard management.

Fire and Explosion Hazard: A situation, condition or thing that may cause an undesirable consequence including danger to the safety or health of workers. Fire and explosion hazards are those situations or conditions created by the potential combination of a fuel source, an oxygen source, and source of ignition.

Fire and Explosion Hazard Management (FEHM): FEHM refers to actions, procedures, plans, and policies used by organizations and individuals to prevent and/or limit the exposure to unplanned fires and explosions.

Fire and Explosion Prevention Plan (FEPP): A documented hazard assessment that addresses planned activities which have the potential to ignite an oxygen-air and fuel-hydrocarbon mixture. The plan must identify the conditions that have the potential to cause a fire or explosion as well as the control measures in place to negate that potential. Employers may choose a documented process effective for them for the FEPP or refer to the prevention plan template provided in this IRP.

Flammable Substance: (a) a flammable gas or liquid; (b) the vapour of a flammable or combustible liquid; (c) dust that can create an explosive atmosphere when suspended in air in ignitable concentrations; or (d) ignitable fibres.

Fuel–Hydrocarbon Source: Any "flammable substances" with the potential to create an explosive atmosphere when combined with oxygen or air including:
(a) a flammable gas or liquid; and
(b) the vapour of a flammable or combustible liquid.

Hazardous Operations: In this document, hazardous operations are situations where all three parts of the fire triangle co-exist in the same time and space with the potential to create a flammable or explosive mixture. In particular, those operations where any of the critical risk factors identified in SECTION 18.4.3, pg. 23 are present.

Hypergols: When a fuel and an oxidizer react so rapidly on being mixed at room temperature that combustion starts immediately without an outside ignition source. The term, hypergolic reaction, originated with rocket propellants. Similar chemical reactions have caused accidental fires in the oil and gas industry.

Inerting: A purging process where the replacement gas or liquid is inert, or noncombustible and incapable of supporting combustion.

Manufacturer's Specifications: The written specifications, instructions or recommendations of the manufacturer of equipment or supplies, that describe how the equipment or supplies are to be erected, installed, assembled, started, operated, handled, stored, stopped, calibrated, adjusted, maintained, repaired or dismantled, including a manufacturer's instruction, operating or maintenance manual or drawings for the equipment as described in the Alberta Occupational Health and Safety Act, Regulations and Code.

Operator or Owner: The licensee of the wellsite is the owner and usually the prime contractor unless this responsibility has specifically been assigned to another party by written agreement, and the owner has taken steps to ensure that the assigned party is capable of fulfilling all the duties and responsibilities required of a prime contractor. When a well has more than one owner, the owner who is assigned as the operator has the responsibilities of prime contractor. Generally this is the licensee of the well. The terms 'operator' or 'owner' will have this meaning throughout this IRP.

Oxygen–Air Source: Sources of oxygen, which when combined with a fuel, have the potential to create an explosive mixture at the operating pressures and temperatures. This may include:

- Air
- Oxidizing chemicals
- Membrane-generated nitrogen (which may contain varying levels of oxygen, systems must be operated at an appropriate purity level to avoid potential explosive mixtures).

Prime Contractor: When workers from two or more employers are working at a wellsite, one party must be identified as the one with overall responsibility for safety, and the co-ordination of all employers carrying out the planned work at that wellsite. In Alberta, this party is known as the 'prime contractor' and this term will be used throughout this IRP. In other jurisdictions, this specific term may not be used but the legislation has similar requirements and responsibilities for this function (also see Operator or Owner definition).

Process Safety Management: Beginning in the mid-90s, American industries with processes involving highly hazardous chemicals were required by OSHA (29 CFR 1910.119) to conduct formal process hazard analyses, and have a process safety management program. The standard's purpose is to prevent or minimize the consequences of the catastrophic release of designated, highly hazardous chemicals.

Purge: The act of removing the contents of a pipe, pipeline, vessel or container, and replacing it with another substance. A purge out-of-service replaces hydrocarbons with safer contents; a purge into service displaces air with another substance to avoid creating an explosive atmosphere when hydrocarbons are introduced.

Risk: The chance that a hazard, left uncontrolled, may result in an injury or loss; in the case of this IRP, due to a fire or explosion. The term risk involves perception, consequence, and frequency or probability.

Supervisor: In this IRP, the term supervisor refers to the person directly responsible for the supervision of the work and workers of a specific employer at the wellsite. Examples of supervisors include: rig manager, driller, truck push, frac crew supervisor, logging supervisor, drill stem tester, power tong operator, cementing supervisor. In addition, the term wellsite supervisor is used to describe those individuals who represent the operator or prime contractor at the wellsite. The wellsite supervisor is generally responsible for directing all employers at the wellsite. The wellsite supervisor is therefore the representative of the prime contractor at the wellsite.

Well Construction Operations: In this document, well construction operations refer to the broad range of well planning and engineering activities including all drilling, completion, and well servicing operations.

Well Program: A well program is a written document that outlines the planned activities for drilling, completing or servicing a well.

ABBREVIATIONS

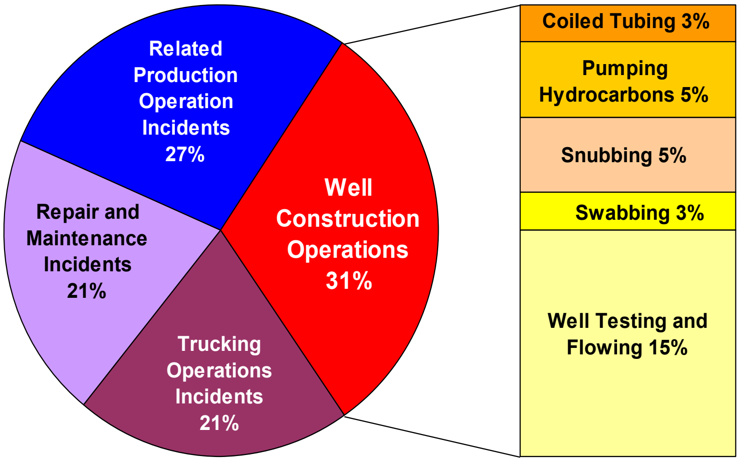
AGA – American Gas Association
API – American Petroleum Institute
ASTM – American Society for Testing and Materials
CAODC – Canadian Association of Oil Drilling Contractors
CAPP- Canadian Association of Petroleum Producers
CSA – Canadian Standards Association
DACC – Drilling and Completions Committee
DACUM – Developing a Curriculum
EUB – Alberta Energy and Utilities Board
FEHM – Fire and Explosion Hazard Management
FMEA - Failure Modes and Effects Analysis
FTA - Fault Tree Analysis
HAZOP – Hazard and Operability Study
ICoTA – International Coiled Tubing Association
LEL – Lower Explosive Limit
MSDS – Material Safety Data Sheets
MIE – Minimum Ignition Energy
NFPA – National Fire Protection Association
OHS – Occupational Health and Safety
OGC – Oil and Gas Handbook
OGR – Oil and Gas Regulations
OSHA – Occupational Safety and Health Administration (USA)
PHA – Process Hazard Analysis
PSAC – Petroleum Services Association of Canada
SEPAC – Small Explorers and Producers Association of Canada
UEL – Upper Explosive Limit
UKOOA – United Kingdom Offshore Operators Association
WHMIS – Workplace Hazardous Materials Information System
WHS – Workplace Health and Safety

18.1 RATIONALE AND QUICK REFERENCE GUIDE

18.1.1 RATIONALE

This IRP was prepared to provide industry with an improved understanding of fire and explosion mechanics, and organizations with more effective strategies for managing fire and explosion risks. The recommended actions were developed in response to conclusions drawn from the research and investigative work conducted on behalf of the IRP 18 committee. **FIGURE 1** below, shows the types of operations where fire and explosion incidents occurred in the case studies reviewed during this process.

Figure 1: Types of Fire and Explosion Incidents Reviewed



The conclusions that follow shaped the committee's recommendations and are provided to inform the understanding of those applying this IRP.

- **A "One Size Fits All" solution does not exist**

Based on the investigative work completed, the committee determined that the identification of general equipment or procedural requirements that could be universally applied to reduce or prevent fire and explosion incidents is not realistic.

- **Site-specific strategies are needed**

More specifically, because of the large variety of work tasks and equipment being used, it is difficult to identify prescriptive measures that would effectively and reliably eliminate the hazard for the full range of circumstances that could be encountered. It is clear that to be effective, solutions must be site specific and must consider the type of operations, the equipment being utilized, the substances being handled, and the training and experience of the workforce.

- **Improved training and awareness are required**

Based on the evidence, the single most significant factor in the case studies evaluated was the overall lack of awareness of the fire and explosion hazards. Committee members were consistently surprised that the workers involved in the incidents did not recognize and respond to some of the very obvious warning signs. This led to the conclusion that industry personnel at all levels must be equipped to ask sensible questions, and question assumptions about the sources of fire and explosion hazards.

Personnel must be aware of the expanded fire triangle (See FIGURE 7, pg. 21) and use their knowledge of it to recognize hazardous situations, and take the appropriate steps. Knowledge alone, however, will not raise the level of safety. Better understanding must also lead to the improved design of equipment and procedures.

Human errors also figured prominently in the incidents analyzed despite the extensive regulations already in place. Recognizing that human errors will inevitably continue, this IRP emphasizes better methods of catching and modifying potential errors rather than increasing the number of rules to follow.

- **The dynamic nature of operations must be considered in the assessment of fire and explosion hazards, and in the choice of controls**

The basic elements of the fire triangle – fuel, energy, oxygen – remain constant. However, there is virtually always something new and different in every circumstance. This is because of the dynamic nature of the fire and explosion systems, equipment, procedures, and people involved. In some cases, it can be difficult to know exactly what substances and conditions are at play. Two similar situations with only slight differences may evolve into considerably different states. Such is the case with situations involving both time and space. Given this, the accurate monitoring of complex systems may well be impossible; making the reliance on one method of control inappropriate and unlikely to eliminate fire and explosion events. A multi-faceted approach to the choice of controls is more prudent.

- **High levels of uncertainty require larger margins of safety**

The potential combinations of fuel-hydrocarbons, oxygen-air, and energy-ignition are highly complex making exact predictions of what is safe and unsafe difficult and often impractical. The science needed to prove conclusively if combinations near explosive limits will be safe, is not yet available.

The level of risk accepted by an organization should, therefore, be informed by the following factors:

A. What current science tells us. (For this IRP, it is imperative that those at all levels understand FIGURE 7: EXPANDED FIRE TRIANGLE, pg. 21, and then apply their knowledge of it.)

B. The judgments and value-commitments of those deciding acceptable risk levels.

It follows that situations with an elevated level of uncertainty require a larger margin of safety, as shown in FIGURE 3: SIMPLIFIED RISK ASSESSMENT PROCESS, pg. 7. More detail about factors that should be taken into account in assessments is provided in SECTION 18.3, pg. 5.

18.1.2 QUICK REFERENCE GUIDE

FIGURE 2 on the following page, provides a quick reference guide to the recommendations in this IRP. These include:

- Defining a Fire and Explosion Strategy and Training Personnel;
- Assessing Fire and Explosion Hazards;
- Preparing Written Fire and Explosion Prevention Plans; and
- IRP 18 Implementing Fire and Explosion Prevention Plans.

Figure 2: Quick Reference Guide IRP 18

Defining Fire and Explosion Strategy and Training Personnel

- ☐ Identify operations management team. Assign responsibilities:
  - Employer (18.3.3 pg. 9)
  - Prime Contractor (18.3.4 pg. 13)
  - Supervisor (18.3.5 pg. 13)
  - Worker (18.3.6 pg. 15)
- ☐ Provide workers with required training specific to fire and explosion hazards. **Training must be applied to all steps that follow.** (18.3.3.2 pg. 10; Appendices B & C)
- ☐ Management planning: Identify scope of operations and any applicable regulations. (18.2 pg. 5; Appendix A)
- ☐ Evaluate potential levels of risk (18.3 pg. 5) and develop an appropriate fire and explosion management process. (Figures 3 and Figure 4, pgs. 7, 8)

Assessing Fire and Explosion Hazards for Planned Operations

- ☐ Identify hazardous operations at the job planning and design stage. Identify need for written plans/procedures.
- ☐ Assess potential for critical risk factors (18.4.3 pg. 23)
- ☐ Complete 'field' assessment to identify potential for all parts of fire triangle to co-exist (Figures 3,6,7,10 pgs. 7, 18, 21, 33)
  - Fuel–Hydrocarbon sources (18.4.4.1;18.4.4.2 pg. 26)
  - Oxygen–Air sources (18.4.4.3 pg. 27)
  - Energy–Ignition Sources (18.4.4.4 pg. 27)
- ☐ Identify need for formal, operation-specific risk assessment (18.4.6 pg. 29)

Choosing Controls and Preparing Written Fire and Explosion Prevention Plans

- ☐ Choose the appropriate control methods (18.5 pg. 32)
- ☐ Identify other factors affecting control decisions and address as required. (18.5.1.5 pg. 38)
- ☐ Develop a written fire and explosion prevention plan. (18.6.2 pg. 41; Figure 12 pg. 42; 18.6.3 pg. 43)
- ☐ Confirm acceptability to proceed with operations. Review & confirm fire & explosion hazards and control requirements.

Implementing Fire and Explosion Prevention Plans and Monitoring Effectiveness

- ☐ Communicate fire & explosion prevention plan:
  - When to communicate (18.7.1.2 pg. 45)
  - Identification of stakeholders (18.7.1.3 pg. 45)
  - What to communicate (18.7.1.4 pg. 46)
  - How to Communicate (18.7.1.5 pg. 47)
- ☐ Implement fire & explosion prevention plan including chosen control measures. Apply training. (18.6.3 pg. 43)
- ☐ Monitor effectiveness of plans & controls (18.6.3 pg. 43)
- ☐ Recognize & respond to warning signs & changing conditions. Adjust plans accordingly. (18.4.5 pg. 28)
- ☐ Report, investigate close calls & incidents.(18.7.1.6 pg. 48; 18.7.2, pg. 49)

18.2 REGULATORY AND INDUSTRY REQUIREMENTS

Fires and explosions in the upstream oil and gas industry cause death, serious injuries, and substantial property damage. Many rules based on knowledge, experience and proven practice are in place to help prevent these dire consequences.

As background to the development of this recommended practice, more than 40 fire and explosion incidents were collected and analyzed. In several cases, human suffering and financial loss could have been prevented had existing regulations been followed. Every organization involved in the upstream oil and gas industry is responsible for ensuring its knowledge of and adherence to the most current applicable legislation, regulations, guides and standards, wherever it conducts operations.

Regulatory compliance, however, only represents a starting point for improved safety regarding fires and explosions. The real need is for a constructive means of ensuring that practical improvements and preventative measures are adopted.

APPENDIX A, pg. 51, provides information about regulatory requirements. The appendix includes a summary of applicable regulations, codes, and standards relevant to fire and explosion safety.

18.3 ORGANIZATIONAL AND INDIVIDUAL RESPONSIBILITIES

An ongoing dialogue between management, engineering personnel, field staff, and contractors is critical to fire and explosion safety

The stakes with respect to fire and explosion hazards are always high and many of the field-level decisions urgent. A cooperative effort is needed between oil and gas companies and service providers to effect the changes outlined in this IRP. This makes an ongoing dialogue between management, engineering personnel, field staff, and contractors critical. This dialogue needs to recognize the levels of uncertainty, the value-commitments, and the legitimacy of the perspectives of everyone involved. Fire and explosion safety must be the joint responsibility of management, field, and contract personnel.

18.3.1 EVALUATING POTENTIAL LEVELS OF RISK

It is the responsibility of all employers involved in upstream oil and gas operations to evaluate potential levels of risk with respect to fire and explosion hazards and determine how to effectively manage them. It is strongly recommended that such discussions be endorsed at the highest levels of the company as they will drive the business approach to fire and explosion hazard management.

Key considerations include:

- Operations must be considered hazardous when the three sides of the fire triangle exist in the same time and space creating a flammable or explosive mixture. Before such operations begin, it is important to determine what plans and controls are required for the work to proceed safely.

- Within the same company, different operations will have different potential levels of risk. This will require different levels of planning and control to manage the respective risks effectively. The key consideration is whether the proposed controls will reduce the initial risk to a point where operations can proceed safely with confidence.

- Potential risk levels will influence the types of controls chosen for work activities and the need for site-specific fire and explosion prevention plans. A simplified risk assessment process is described in FIGURE 3, pg. 7. This diagram highlights the relationship between the Expanded Fire Triangle FIGURE 7, pg. 21, the critical risk factors, and the recommendations for managing fire and explosion hazards. It is not intended to replace a company's internal risk assessment.

- Employers should be able to articulate these risk levels and show how they are being communicated to those involved in planning and executing the work. More importantly, if challenged, a company should be able to defend its level of planning and the types of controls applied to operations where fire and explosion hazards exist.

- Employers must ensure that those involved in all levels of an operation are aware that the responsibility for maintaining the required controls, which mitigate the risks, applies to every role in the operation. The outcome needs to be that workers understand the true nature of the fire or explosion hazards so that they are prepared to take the measures needed to address the real risks.

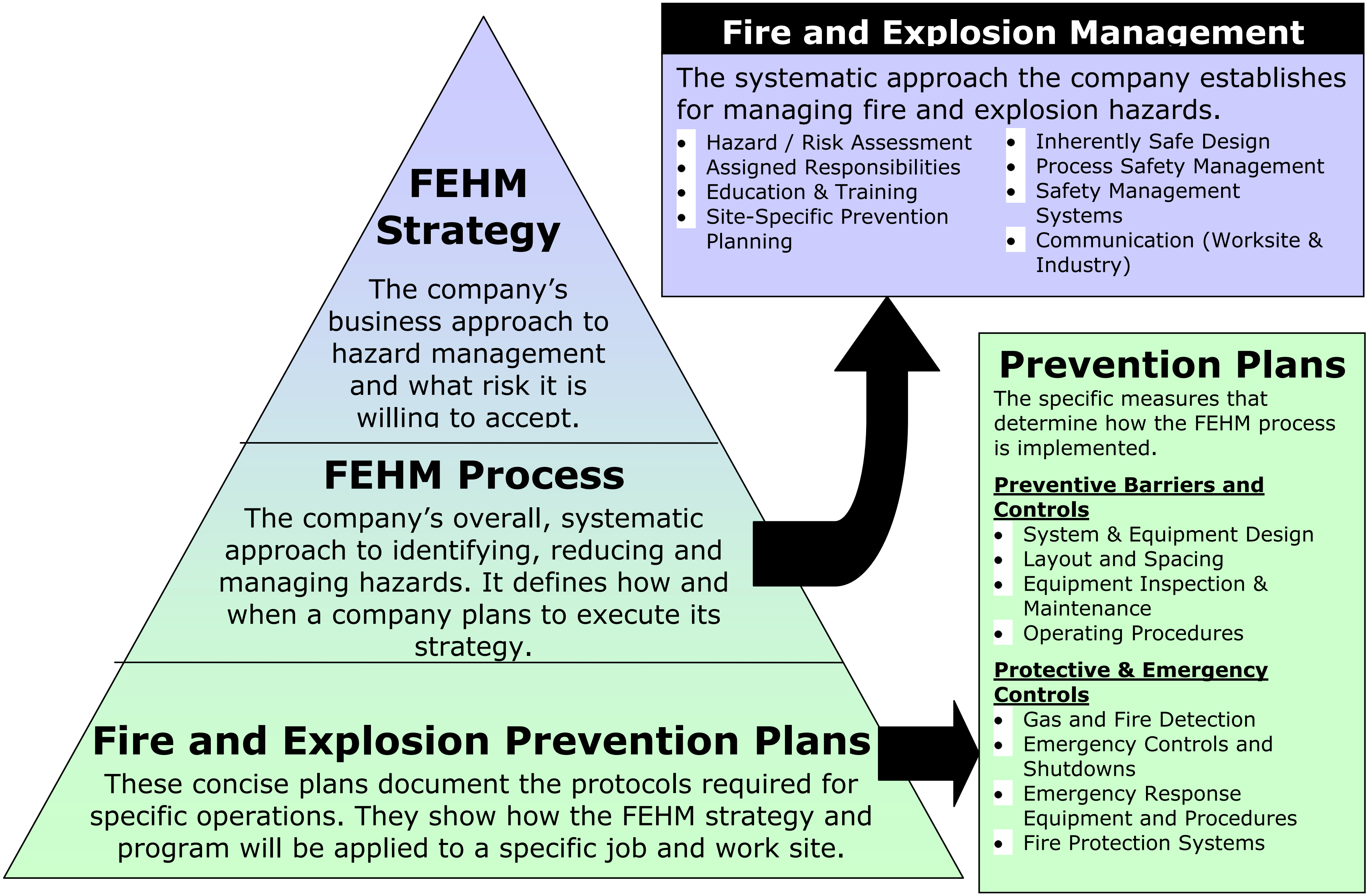
FIGURE 4: FIRE AND EXPLOSION HAZARD MANAGEMENT PROCESS on page 8 shows the different components of a fire and explosion hazard management approach.

Figure 3: Simplified Risk Assessment Process*

Conditions	Risk Level	Procedures Required
• Confident that all potential air OR fuel sources eliminated. • Operations are well understood. • Personnel are trained per IRP 18 and are experienced. • Significant history of safe operations exists under nearly identical circumstances.	**Improbable** 🟢	• Incorporation of FEHM content in current safety procedures, including pre-job safety meetings and hazard assessments. • Work-site and equipment inspections. • Worker qualification reviews. • Alertness for barriers/controls failure.
• Fire triangle may exist; confident that critical risk factors don't. • Operations are well understood. • Personnel are trained and experienced.	**Possible** 🔻	Those above, plus: • Reusable FEHM-specific hazard assessments. • Alertness for changing conditions/ingredients. • MSDS/TDG document review. • Safe work permits.
• Fire triangle may exist. • One or more critical risk factors may be present. • Well conditions/ operations not well understood. • New or poorly understood operations/ technologies. • History of incidents under similar circumstances.	**Probable** 🛑	Those above, plus: • Detailed, site-specific FEHM plans prepared prior to operations. • Documented risk assessment completed. • Documentation available to all at the work-site.

* This diagram highlights the relationship between the Expanded Fire Triangle, FIGURE 7, pg. 21, the critical risk factors, and the recommendations for managing fire and explosion hazards. It is not intended to replace any company's internal risk assessment process.

Figure 4: **Components of a Fire and Explosion Hazard Management Process**



FEHM Strategy

The company's business approach to hazard management and what risk it is willing to accept.

FEHM Process

The company's overall, systematic approach to identifying, reducing and managing hazards. It defines how and when a company plans to execute its strategy.

Fire and Explosion Prevention Plans

These concise plans document the protocols required for specific operations. They show how the FEHM strategy and program will be applied to a specific job and work site.

Fire and Explosion Management

The systematic approach the company establishes for managing fire and explosion hazards.

- Hazard / Risk Assessment
- Assigned Responsibilities
- Education & Training
- Site-Specific Prevention Planning
- Inherently Safe Design
- Process Safety Management
- Safety Management Systems
- Communication (Worksite & Industry)

Prevention Plans

The specific measures that determine how the FEHM process is implemented.

Preventive Barriers and Controls

- System & Equipment Design
- Layout and Spacing
- Equipment Inspection & Maintenance
- Operating Procedures

Protective & Emergency Controls

- Gas and Fire Detection
- Emergency Controls and Shutdowns
- Emergency Response Equipment and Procedures
- Fire Protection Systems

18.3.2 IDENTIFYING, COMMUNICATING, AND ADHERING TO RESPONSIBILITIES

The complex issue of fire and explosion prevention is the responsibility of everyone involved in an upstream oil and gas operation including owners, contractors, supervisors, and workers.

For on-site operations to proceed safely, roles and responsibilities need to be clearly defined, communicated and followed **within each organization** and **between each of the organizations** involved with fire and explosion prevention. Each organization on site needs to consider who could be affected by its activities and should be informed before hand about the associated hazards, and afterwards about situations encountered during implementation.

With respect to fire and explosion safety, this means that:

- Those planning, designing, and managing specific operations must be aware of the potential hazards and ensure appropriate plans and controls are developed, communicated, and followed with respect to their operation.
- Those supervising on-site operations must be aware of the plans and controls developed, and capable of communicating and implementing them. Supervisors must be trained to recognize fire and explosion hazards, and to react appropriately to scope changes and warning signs. On-site supervisors may need to develop additional hazard control plans for specific tasks not identified in the project plan.
- Those executing the work must be trained to recognize fire and explosion hazards and have sufficient knowledge to deal with them. Workers need to participate in pre-task hazard identification and control meetings.

The specific corporate, prime contractor, supervisory, and worker responsibilities are addressed in **SECTIONS** 18.3.3, 18.3.4, 18.3.5, and 18.3.6**.**

18.3.3 EMPLOYER RESPONSIBILITIES

This section of the IRP outlines the steps every employer must consider when addressing the health and safety of its employees who work where fire and explosion hazards exist. These responsibilities apply to all employers involved in such upstream oil and gas operations. The size of the company and the role it plays in the work undertaken does not change these responsibilities; they apply equally to all parties involved.

18.3.3.1 MAKING PERSONNEL AWARE OF THIS IRP

> *You can't solve problems with the same level of knowledge that created them.*
> *Albert Einstein*

Employers must ensure that personnel planning, implementing and executing operations with fire and explosion hazards, are aware of this IRP.

18.3.3.2 TRAINING PERSONNEL IN FIRE AND EXPLOSION HAZARD MANAGEMENT

Employers must provide training to personnel involved in operations where fire and explosion hazards exist, this includes:

- staff planning, designing, and managing the scope of work;
- supervisory staff; and
- workers.

Training is essential for petroleum industry personnel so that they are better equipped to address fire and explosion hazards. Two training levels are recommended and outlined in the chart below.

- Training must be geared to the employee's responsibilities and experience level.
- This IRP encourages companies to develop and deliver customized training compliant with these requirements.
- All training programs must assess the participants' knowledge of required content on course completion.

Training Level and Audience	Summary of Requirements
Basic Entry Level Workers	• Emphasis on understanding the expanded fire triangle. • Analysis of relevant fire and explosion case studies. • Introduction to control methods and jobsite communication.

Advanced
Planners, Designers, Managers, and Supervisors
	• Emphasis on understanding the expanded fire triangle.
	• Analysis of relevant fire and explosion case studies.
	• Guidance on:
	  • Preparation of fire and explosion prevention plans.
	  • Identification and implementation of appropriate control methods.
	  • Identification of changing conditions and strategies for managing change.
	  • Strategies for effective jobsite communication.

It is important to ensure a standard foundation for personnel training, therefore, the following core information must be referenced when developing worker training:

- APPENDIX B, pg. 58 provides training developers with a recommended outline for a curriculum or DACUM to address the expectations identified in this IRP.
- APPENDIX C, pg. 60 provides more details regarding specific fire and explosion training requirements.
- **Technical Information re the Expanded Fire Triangle and Case Studies available through** www.firesandexplosions.ca**. These two subject areas are critical.** A review of case studies will give participants an understanding of why training is important; studying the expanded fire triangle will give them a better understanding of oxygen sources and how they can be introduced, hydrocarbons and their properties, and the variety of possible ignition sources. With this knowledge workers will be better equipped to understand on-site hazards and management personnel will be better equipped to write their own prescriptive measures for the work they direct.

Additional safety and technical training may be required to ensure workers have the necessary background information to work safely (e.g., H_2S Alive, manufacturers' procedures for using gas detection equipment, etc).

18.3.3.3 ESTABLISHING A FIRE AND EXPLOSION HAZARD MANAGEMENT (FEHM) PROCESS

It is the responsibility of every employer to ensure their workers safety. One method of meeting this obligation, regarding fires and explosions, is the establishment of a Fire and Explosion Hazard Management (FEHM) process. Such a systematic approach should document how the company will evaluate potential risk levels, and cover the life cycle of the operations undertaken. The process should also be monitored and evaluated for effectiveness, and revised as necessary.

The four stages of a Fire and Explosion Hazard Management Process are:

1. Managing fire and explosion risks and training personnel.
2. Assessing fire and explosion hazards for planned operations.
3. Choosing controls and preparing Fire and Explosion Prevention Plans (FEPP) as needed.
4. Implementing FEPPs, monitoring effectiveness, and revising as needed.

FIGURE 5: STAGES OF A FIRE AND EXPLOSION HAZARD MANAGEMENT PROCESS, pg. 12 illustrates the different phases of this process.

18.3.3.4 ASSESSING SUPERVISOR COMPETENCY

The employer is responsible for assessing and ensuring the competency of their supervisors.

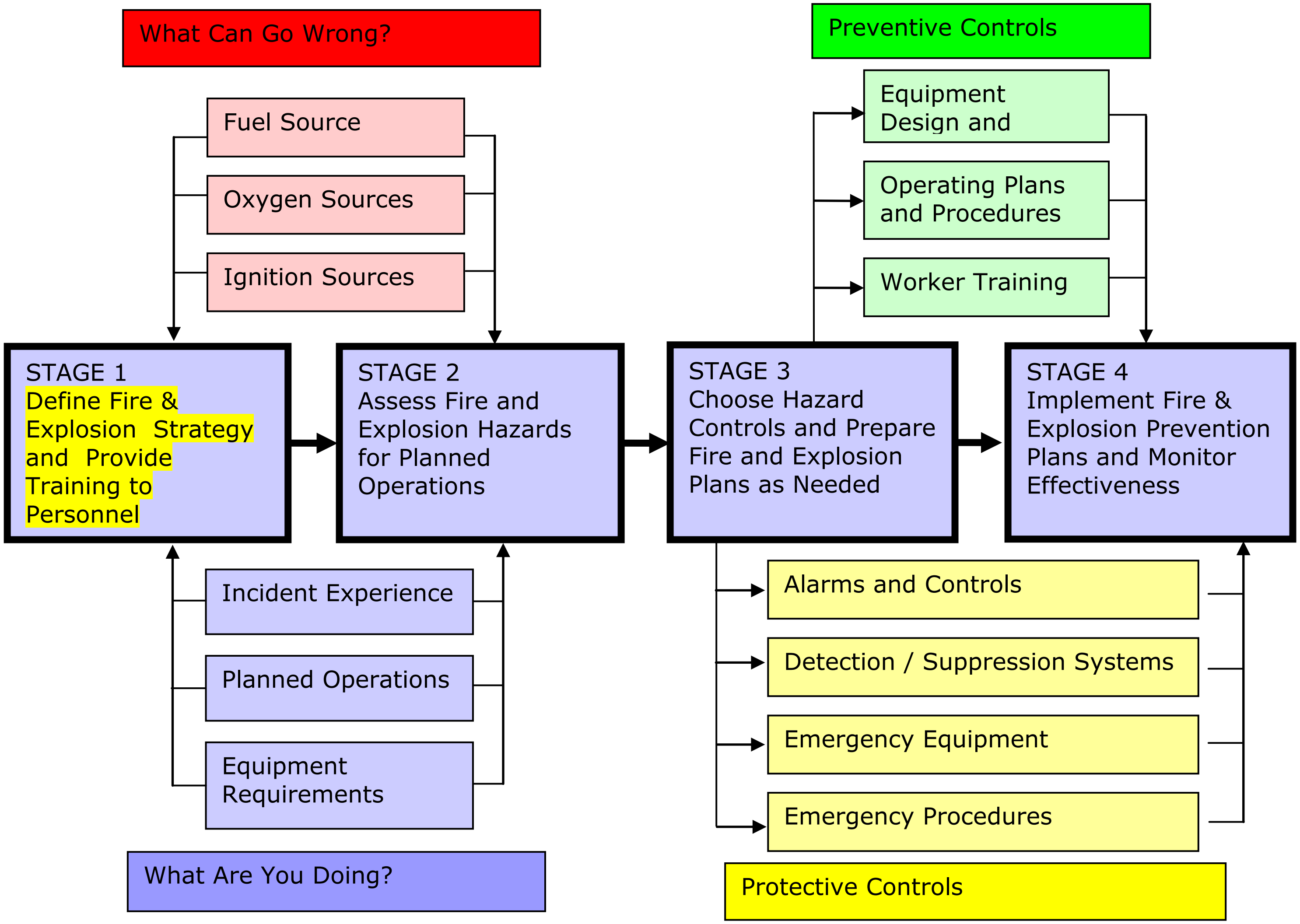
18.3.3.5 MONITORING POLICY & PROCEDURE COMPLIANCE

Employers should consider establishing processes to monitor compliance with their fire and explosion hazard management requirements.

18.3.3.6 SUPPORTING THOSE WHO IDENTIFY UNSAFE WORK

The employer is responsible for creating a climate that encourages everyone involved with an operation to identify and report unsafe work. Senior executives and management need to support and communicate this attitude throughout the organization. Those on the front lines are often in the best position to identify unsafe situations while those in the front office are often in the best position to influence attitudes. Whatever approach is taken, those exposed to the dangers should feel confident that their concerns will be communicated, taken seriously, and addressed appropriately.

Figure 5: **Stages of a Fire and Explosion Hazard Management Process**



18.3.4 PRIME CONTRACTOR RESPONSIBILITIES

In some jurisdictions, legislation requires that a prime contractor be appointed when there are two or more employers working on the same jobsite. The prime contractor must be aware of the supervisory requirements outlined in SECTION 18.3.5 and ensure that those that apply to the prime contractor or his on-site representative are addressed.

The prime contractor/prime contractor's representative is responsible for coordinating the fire and explosion hazard management activities of all contractors employed on the worksite based on the prime contractor's FEHM process.

Specifically, the prime contractor/prime contractor's representative must clearly indicate before work begins:

- any pre-existing hazards (i.e., reservoir fluid properties, air in the wellbore, etc);
- when fire and explosion prevention plans are required;
- who is responsible for developing, communicating, implementing, and monitoring such plans, when required; and
- how the activities of multiple contractors will be coordinated.

The prime contractor/prime contractor's representative must ensure that any operation-specific prevention plans prepared by individual contractors are implemented, and that the equipment provided is adequate to complete the work safely.

18.3.5 SUPERVISORY RESPONSIBILITIES

This section outlines the on-site responsibilities of field supervisors.

18.3.5.1 TAKING FIRE AND EXPLOSION TRAINING

It is the responsibility of supervisors to ensure that they have taken the advanced fire and explosion hazard management training.

18.3.5.2 IMPLEMENTING HAZARD IDENTIFICATION AND CONTROL ACTIONS

The supervisor must ensure that all workers under his supervision are informed of the expected hazards and required controls on the site, before work begins.

The supervisor is responsible for ensuring that on-site fire and explosion hazards are identified and appropriate control actions taken for all operations he supervises.

Specifically the supervisor must ensure that he or those charged with identifying hazards and control actions:

- conduct a fire and explosion hazard assessment involving the workers affected whenever possible;
- eliminate hazards where possible and ensure appropriate controls are in place to mitigate hazards that cannot be eliminated;
- develop and document site-specific fire and explosion prevention plans based on the requirements of the employer's FEHM process;
- communicate fire and explosion prevention plans to all workers on site before work begins and make the plans available on site;
- ensure the workers affected by the identified hazards are informed of them and the methods used to eliminate or control them;
- ensure workers are familiar with the safe operation of the controls in use;
- inform workers about changes in either work scope or operating conditions that may increase the potential for fires and explosions;
- ensure the protective equipment required is available, functional and most importantly, that workers know how to use it; and
- develop emergency response procedures based on the hazards identified.

18.3.5.3 Confirming Workers Fire and Explosion Training

The supervisor is responsible for confirming the fire and explosion training of those under his supervision. Should the supervisor determine that a worker has not been trained, one of the following actions must be taken:

- A trained replacement found;
- A trained worker assigned to work directly with the worker in question; or
- Training provided as detailed in this IRP.

18.3.5.4 Challenging Workers Not Doing the Right Thing

The supervisor is responsible for challenging workers not taking the necessary precautions to prevent fires and explosions.

18.3.5.5 Creating an Environment Where Workers are Willing to Report Unsafe Work

It is the supervisor's responsibility to create an environment where workers are willing to report unsafe work conditions or activities. Those exposed to the significant dangers inherent where fire and explosion hazards exist, should feel confident that their concerns will be taken seriously, addressed appropriately and taken into consideration for the duration of the operation, and ideally for future similar work.

18.3.6 WORKER RESPONSIBILITIES

This section refers to individuals working where fire and explosion hazards exist. To reduce the likelihood of a serious fire or explosion, every worker must take personal responsibility for their own safety and the safety of their co-workers.

18.3.6.1 TAKING AND APPLYING FIRE AND EXPLOSION HAZARD MANAGEMENT TRAINING

Workers are responsible for taking and applying the basic level of fire and explosion hazard management training. The investigation of more than 40 fire and explosion incidents revealed that the most significant contributing factor was the lack of awareness of fire and explosion hazards. Obviously, deaths and life-altering injuries could have been prevented if individual workers had had a better understanding of the dangers of working where fire and explosion hazards exist.

The nature of hydrocarbons, the variety of conditions, and the broad scope of work activities all contribute to the complexity of the problem. The ability to improve fire and explosion safety depends on increasing awareness of the potential fire and explosion hazards amongst all those involved in planning, implementing, and executing work where these hazards exist.

18.3.6.2 CARRYING OUT SITE-SPECIFIC FIRE AND EXPLOSION PREVENTION PLANS, PROCEDURES, AND CONTROLS

Workers are responsible for carrying out the plans, procedures, and controls that apply to their specific tasks. As directed, they are responsible for participating in pre-task hazard assessments, and the preparation and communication of fire and explosion preventions plans. Workers must ensure that they understand any instructions received about such plans, procedures, and controls.

In particular, workers need to be aware of the site-specific issues including:

- Fire and explosion hazards including potential fuel, oxygen, and energy sources;
- Conditions that could create an explosive atmosphere;
- Controls including equipment and procedures;
- Situations that require the updating of the hazard assessment, such as a change in the scope of work, personnel using new skills, or an emergency; and
- Procedures for emergency response including the type of equipment, the on-site personnel qualified to operate the equipment, and the individual protective equipment they require in an emergency.

18.3.6.3 REPORTING FIRE AND EXPLOSION HAZARDS

Workers are required to report any fire and explosion hazard immediately to their jobsite supervisor, who is responsible for taking appropriate action. It is the combined awareness and vigilance of all on site that serves as the most effective means to prevent serious injury, loss of life, and property damage due to fires and explosions.

18.4 IDENTIFYING AND ASSESSING POTENTIAL FIRE AND EXPLOSION HAZARDS

Section 18.4 outlines a step-wise process for identifying and assessing operations with potential fire and explosion hazards, at both the **planning and field levels**.

18.4.1 ASSESSING PLANNED OPERATIONS

Section 18.4.1 provides steps those planning, designing, and managing the scope of work should consider when assessing operations for fire and explosion hazards.

Hazard assessments are a key requirement of occupational health and safety regulations in every jurisdiction. This IRP recognizes that many companies have established hazard assessment processes including but not limited to the following:

- job safety assessment (JSA) or job hazard assessment (JHA)
- safe work permit systems;
- pre-job safety meetings with specific consideration to hazard review; and
- detailed operations inspection programs which emphasize fire and explosion hazards.

Where such processes are in place, companies may only need to review them to confirm that the hazard identification and assessment recommendations in this IRP are addressed.

18.4.1.1 REVIEWING AND CONFIRMING SCOPE OF WORK

Prior to a field assessment, the entire scope of work must be reviewed by those planning, designing, and managing the program to ensure that all operations are considered when determining which facets require close scrutiny due to the potential for fires and explosions.

18.4.1.2 IDENTIFYING HAZARDOUS OPERATIONS PRIOR TO FIELD ASSESSMENT

For the purpose of this IRP, hazardous operations are those where the three parts of the fire triangle co-exist. While a list has been provided in SECTION 18.6.1, pg. 41, the onus is on those conducting the initial review to determine operations with this potential. Such operations must be clearly identified to trigger close scrutiny of the chosen methodology, and to alert field personnel of the need for site-specific fire and explosion prevention plans.

18.4.1.3 EVALUATING CAPABILITIES OF CONTRACTORS AND WORKERS

The capabilities of the contractors and workers needs to be considered as part of the review of planned operations. Methods and controls should be chosen with this important factor in mind. For example, more controls may be necessary if less experienced personnel are involved. Please note that this IRP requires personnel involved with planning, supervising, and executing operations where fire and explosion hazards exist to have taken fire and explosion hazard management training (See APPENDIX C, pg. 60 for training guidelines.)

18.4.1.4 CONFIRMING SUITABILITY OF METHODS, EQUIPMENT AND TOOLS TAKING INTO ACCOUNT CRITICAL RISK FACTORS

Those reviewing planned operations should confirm the suitability of the methods, equipment and tools chosen taking into consideration the critical risk factors outlined in SECTION 18.4.3, pg. 23.

18.4.1.5 IDENTIFYING ADDITIONAL MEASURES REQUIRED TO REDUCE RISK

Following the assessment of the planned operations, a final review of factors contributing to the potential risk of fires and explosions should be done to identify any additional measures required to eliminate or reduce them.

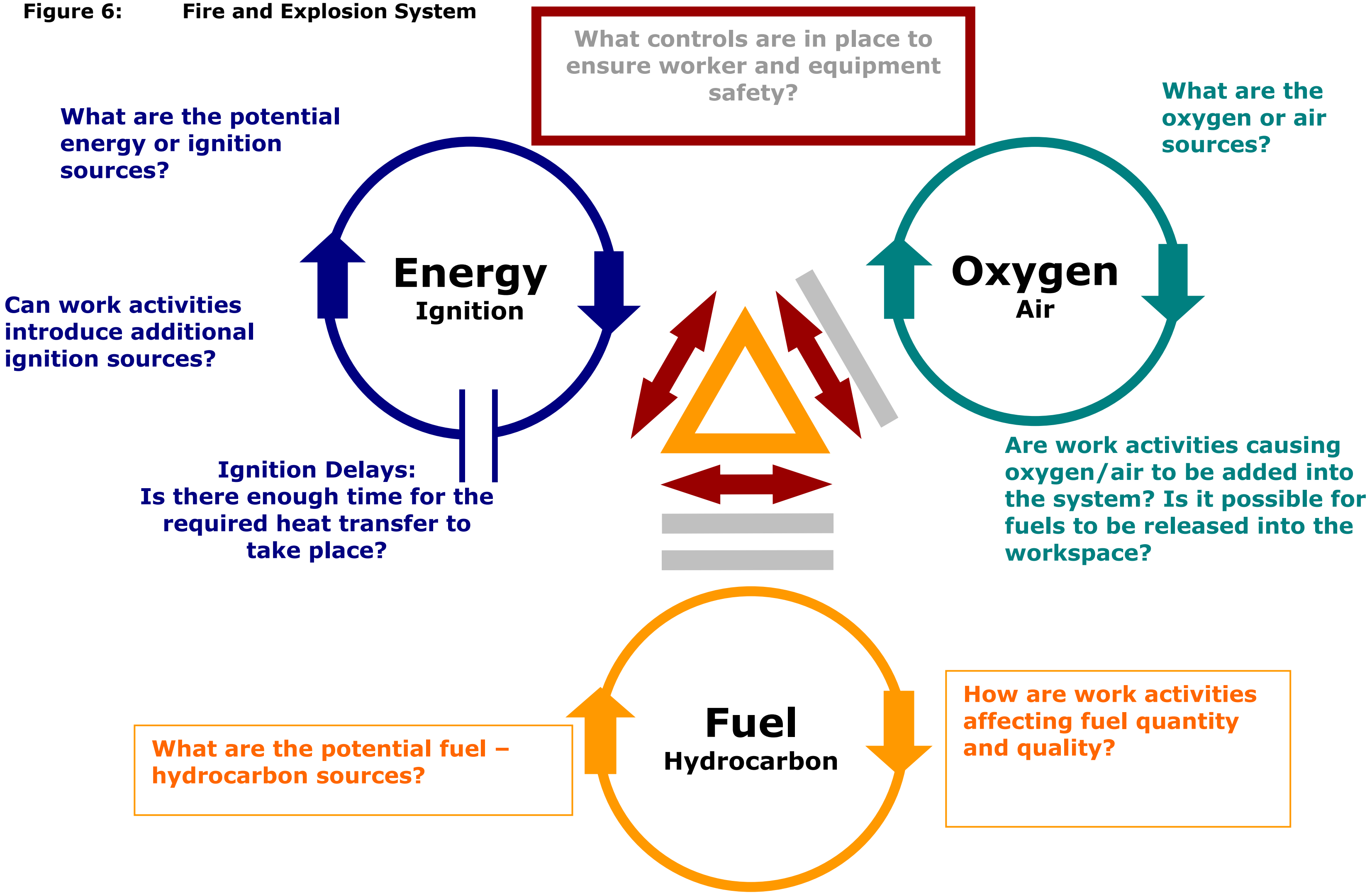
18.4.1.6 VERIFYING WORKSITE CONDITIONS AND ASSESSING POTENTIAL FOR CONDITIONS TO CHANGE

Among the reasons why those responsible for planning, designing, and managing operations must regularly verify worksite conditions are:

- Confirmation that the design considerations used in planning operations were and continue to be accurate, especially in situations where critical risk factors exist; and
- The need to regularly assess the potential for conditions to change.

FIGURE 6: FIRE AND EXPLOSION SYSTEM, pg. 18 outlines an approach for identifying factors that could take operations outside the safe range.

Figure 6: **Fire and Explosion System**



What controls are in place to ensure worker and equipment safety?

What are the potential energy or ignition sources?

What are the oxygen or air sources?

Can work activities introduce additional ignition sources?

Ignition Delays:
Is there enough time for the required heat transfer to take place?

Are work activities causing oxygen/air to be added into the system? Is it possible for fuels to be released into the workspace?

What are the potential fuel – hydrocarbon sources?

How are work activities affecting fuel quantity and quality?

Points to Remember

1. Anytime all three sides of the fire triangle can co-exist, there is real potential for a fire or explosion.
2. There are critical risk factors that increase the probability of a fire and explosion significantly. (See 18.4.3)
3. The system is dynamic and circumstances change over time. As a result, safe situations may become unsafe.

18.4.2 EXPANDED FIRE TRIANGLE

The fire triangle in FIGURE 7, pg. 21 shows the three critical components required for combustion. It is widely understood that to remove the potential for a fire or explosion, one of the three sides of this triangle must be eliminated. Given the nature of upstream oil and gas operations, this is not as simple as it seems:

1. There is always potential for flammable/combustible substances to be present. More importantly, their properties can vary based on history and operating conditions.
2. There is a wide range of oil and gas operations with an equally wide range of circumstances where oxygen-air can be combined with fuels. The accidental release of hydrocarbons into a work area is an ongoing concern. As is the planned or accidental entry of air into a closed system.
3. There is a wide range of energy-ignition sources. Some ignition sources, such as static electricity, adiabatic compression (dieseling effect), and/or sudden decompression, are not well understood and are even more difficult to identify and control.

The ability to develop effective solutions for improving industry safety depends on training which results in a better understanding of these elements. A fire triangle with expanded parameter lists is therefore provided. The fire triangle should be used to guide the identification of potential fuel, oxygen, and energy sources.

It is important to remember that even though all sides of the fire triangle co-exist, there is not 100 per cent certainty that a flammable mixture will ignite; the 'ingredients' need to be present in the right amounts and in the vicinity of each other. Conducting an operation on the basis that is has been completed safely numerous times previously without incident can provide a false sense of security. Factors to consider include:

- **Upper and Lower Explosive Limits**: The mixture must be within the explosive range. If the mixture is below the Lower Explosive Limit (LEL) or the above the Upper Explosive Limit (UEL), no ignition will take place. The LEL and UEL are affected by the chemical nature of the fuel, the fuel concentration, the oxygen concentration, and the presence of any diluents such as inert gases.

- **Minimum Ignition Energy (MIE):** The most important variable is the minimum level of energy required to ignite a flammable mixture. The critical risk factors discussed in SECTION 18.4.3, pg. 23 can significantly affect the MIE, frequently increasing the probability of ignition. Temperature and pressure as well as relative humidity have key impacts on the MIE requirements.

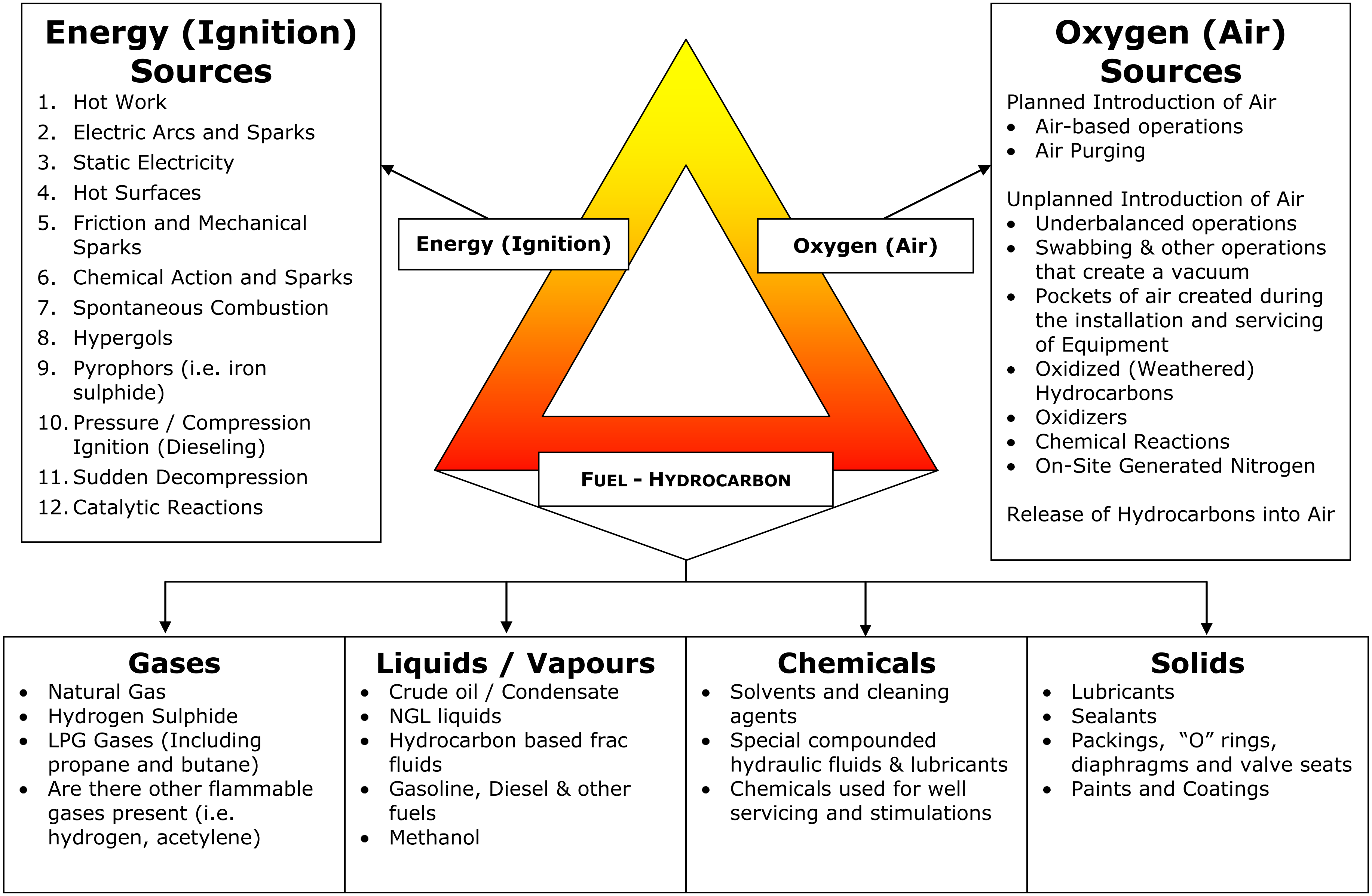
- **Other Important Properties of Flammable Substances**: In addition to the flammability limits, every flammable substance has a number of important physical characteristics that affect worker safety. These include: vapour pressure, flashpoint, fire point auto-ignition temperature. These are normally detailed in the Material Safety Data Sheet for a substance.

- **Available Ignition Energy:** The level of energy associated with the ignition source must also be considered. The ignition source must have sufficient temperature, be of sufficient size, and be applied for a sufficient length of time for ignition to occur. An ignition source with a high level of energy has an increased probability of igniting. FIGURE 8: FACTORS AFFECTING IGNITABILITY OF FLAMMABLE MIXTURES, pg. 22 depicts these relationships.

- **System Geometry:** This is the most complex issue and explanations of it cannot be simplified. Key considerations include: vessel/piping size, wall material, flow velocity and turbulence, and other physical factors that can affect the ignitability.

For the reasons listed above, it is important to heed any warning signs and near misses. Attention is required because small events signal that the right components co-exist but conditions are not yet perfect. A more serious event may be imminent.

Figure 7: Expanded Fire Triangle



Energy (Ignition) Sources

1. Hot Work
2. Electric Arcs and Sparks
3. Static Electricity
4. Hot Surfaces
5. Friction and Mechanical Sparks
6. Chemical Action and Sparks
7. Spontaneous Combustion
8. Hypergols
9. Pyrophors (i.e. iron sulphide)
10. Pressure / Compression Ignition (Dieseling)
11. Sudden Decompression
12. Catalytic Reactions

Oxygen (Air) Sources

Planned Introduction of Air

- Air-based operations
- Air Purging

Unplanned Introduction of Air

- Underbalanced operations
- Swabbing & other operations that create a vacuum
- Pockets of air created during the installation and servicing of Equipment
- Oxidized (Weathered) Hydrocarbons
- Oxidizers
- Chemical Reactions
- On-Site Generated Nitrogen

Release of Hydrocarbons into Air

Gases

- Natural Gas
- Hydrogen Sulphide
- LPG Gases (Including propane and butane)
- Are there other flammable gases present (i.e. hydrogen, acetylene)

Liquids / Vapours

- Crude oil / Condensate
- NGL liquids
- Hydrocarbon based frac fluids
- Gasoline, Diesel & other fuels
- Methanol

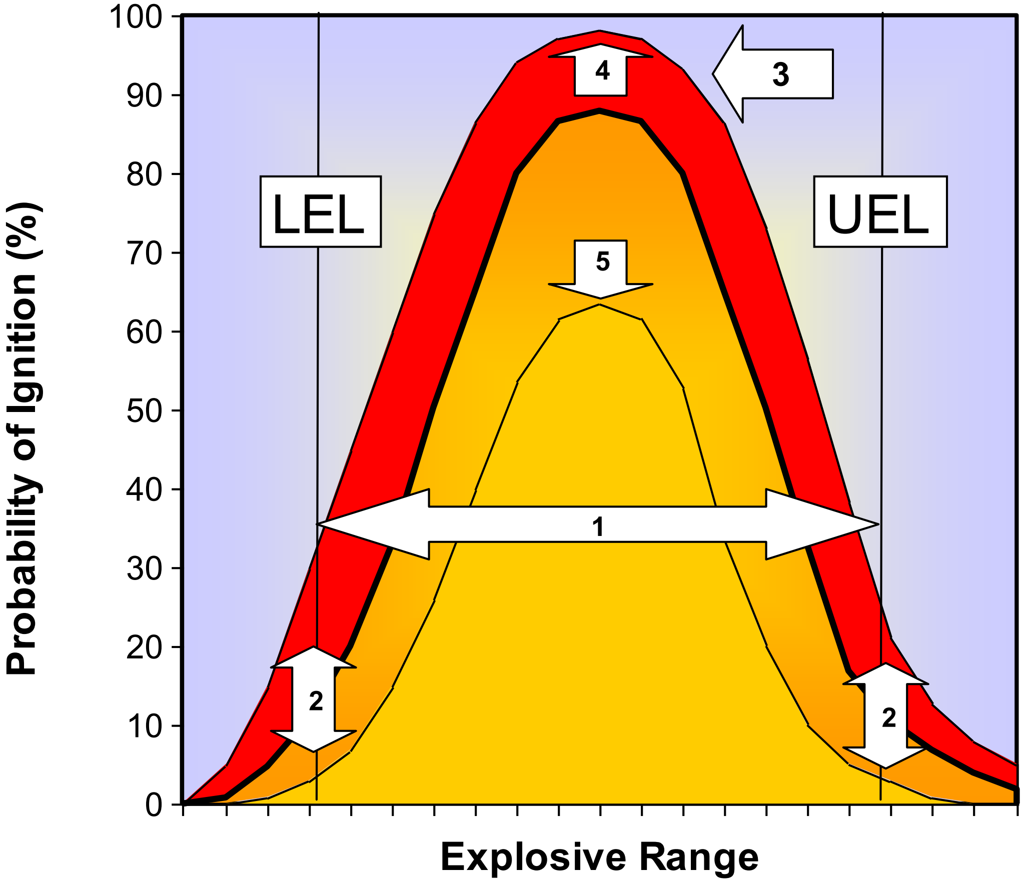
Chemicals

- Solvents and cleaning agents
- Special compounded hydraulic fluids & lubricants
- Chemicals used for well servicing and stimulations

Solids

- Lubricants
- Sealants
- Packings, "O" rings, diaphragms and valve seats
- Paints and Coatings

Figure 8: **Factors Affecting Ignitability of Flammable Mixtures**



This graph illustrates the impact of the various risk factors on a flammable mixture and does not represent an actual substance.

1. The explosive limits (LEL/UEL) can vary significantly for different substances. The wider the explosive encelope the greater the probability of encountering the right conditions for a fire or explosion.

2. The Probability of ignition of a mixture may not be zero even below the estimated LEL or above the UEL depending on a number of factors including the exact properties of the mixture, nature of the ignition sources, and the presence of any critical risk factors.

3. Even at ideal conditions, the probability of a fire or explosion is not 100% as illustrated by the gap at the top of the graph.

4. The introduction of the critical risk factors can significantly expand the explosive range increasing the probability of a fire or explosion over the entire range of the explosive envelope as represented by the red band.

5. Low energy ignition sources can reduce the probability of ignition of an explosive mixture as illustrated by the line inside the explosive range.

18.4.3 CRITICAL RISK FACTORS

The following discussion summarizes the most significant factors affecting fire and explosion hazards. Each one has a critical affect on fire and explosion safety and requires careful consideration in operational and control decisions.

Because operation-specific variables make it impossible to prescribe controls that will work effectively in every circumstance, companies must do the homework necessary to evaluate whether or not planned control measures will be effective.

If the factors identified below exist, a site-specific fire and explosion prevention plan may be required to effectively manage potential fire and explosion hazards.

1. **Presence of liquid hydrocarbons and other flammable liquids**

   The fire and explosion hazard for operations containing liquid hydrocarbons and other flammable liquids increases significantly when compared to pure methane gas. Critical risk factors include:

   - Displacing highly flammable hydrocarbon liquids with air is **not** a recommended practice.
   - Liquid hydrocarbons in general (both light hydrocarbons such as condensates and heavy hydrocarbon liquids) represent a significant risk as they, in contact with oxygen form oxidized hydrocarbons which may be highly unstable.
   - Potential for liquids to exist in an aerosol form. This significantly increases volatility and the potential for ignition by low-grade ignition sources (i.e., static electricity).
   - Increased potential for the build-up of significant static charges. Hydrocarbons are an insulating fluid; they have very low electrical conductivity. As they flow through piping (i.e., flow into tanks and tank trucks) they can cause the build up of electric charges. More importantly, these types of static build-up only dissipate slowly over time.
   - Monitoring equipment is calibrated to detect specific substances, typically natural gas (mainly methane). A monitor calibrated for methane will be highly inaccurate if used to detect atomized liquid hydrocarbons or liquid hydrocarbon vapours or other gaseous hydrocarbons.

   ▪ Licensees and service providers need to be aware of EUB SAFETY BULLETIN 2003-02. (See www.eub.gov.ab.ca)

2. **Presence of hydrogen sulphide (H_2S)**

   The introduction of air-oxygen into 'systems' containing H_2S should be avoided altogether.

   - H_2S may cause the formation of pyrophoric iron sulphides, a potential ignition source.
   - The presence of H_2S will widen significantly the explosive limits of a mixture increasing the potential for a fire or explosion at a lower oxygen level.
   - Streams containing H_2S cannot be released to atmosphere due to the potential for worker exposure and off-lease odours.

3. Addition of hydrocarbon-based workover fluids

Fire and explosion hazards can increase significantly in systems where hydrocarbon-based fluids are added in particular drilling, completions, and workover operations. Critical risk factors include:

- Potential for liquids to exist in an aerosol form, which significantly increases volatility and the potential for ignition by low-grade sources (i.e. static electricity).
- Air-hydrocarbon contact (i.e. liquid hydrocarbons stored at atmospheric temperatures and pressures) can result in the absorption of air-generating oxidized hydrocarbons such as hydroperoxides, aldehydes, ketones, etc. Increased temperatures and pressures, may decompose some of these highly unstable, explosive compounds (such as hydroperoxides – auto-ignition). The University of Calgary continues to research this issue.
- The use of air and oxidizing chemicals in the presence of liquid hydrocarbons can create a significant hazard.

4. Fluid mixtures with different chemical properties

- Mixing fluids with different chemical properties such as solvents and chemical additives can result in unique fluids with significantly different properties than either of the original fluids. The combined fluid may have an unknown and possibly greater potential, for fires or explosions.
- Monitoring equipment must be calibrated for the hydrocarbons being detected.

5. Elevated operating pressures and temperatures

- Increased temperatures and pressures significantly expand the explosive envelope increasing the potential for a fire or explosion.
- Monitoring equipment is calibrated to operate at atmospheric temperatures and pressures and will be highly inaccurate when used under higher temperature and pressure conditions.
- Detailed information on this topic is available in references used for this IRP and on the www.firesandexplosions.ca website.

6. Potential for rapid pressure or temperature changes

- When air-hydrocarbon mixtures undergo rapid pressure or temperature changes, up or down, the fire and explosion hazard increases. Work procedures are required to ensure that any such changes are managed. For example, when equalizing pressure between tubing and casing or between the wellbore and servicing equipment.
- Temperature changes affect fluid properties. For example, increases can cause a liquid to vapourize, and overload the gas handling capability of a system. Decreases can cause a liquid to solidify or form a slush that affects fluid handling systems.

- It is recommended that consideration be given to controlling the rate of temperature and pressure changes to eliminate/reduce the potential fires or explosions due to adiabatic compression, static spark or increased volatility due to temperature increase.

7. **Flowing explosive mixtures into 'closed' systems**
   - The use of air should be restricted to operations where the well can be safely vented into an open system such as a rig tank or drilling sump.
   - Flowback of potentially explosive mixtures into closed systems that have not been purged or inerted is highly dangerous (e.g., P-tank, pressure vessel, connecting piping, flare stack) and is **not** a recommended practice. The danger lies in the flare as an ignition source and the potential for explosive forces (detonation versus deflagration).This also applies to BOP type equipment. Some equipment may need to be redesigned to enable effective purging or inerting.
8. **Pre-existing trapped air**
   - If the possibility exists that air was purposely or inadvertently introduced into the wellbore during a previous or ongoing operation, the well should be inerted or purged where possible. For example, the flowback of a low pressure, dry-formation well could be considered a form of purging. (See EUB SAFETY BULLETIN 2005-02 for reference.) If purging is not possible, specific plans will need to be developed.
   - Systems containing trapped air need to be inerted or purged to eliminate the potential for an explosive mixture.
   - Wells should be purged as soon as possible at the lowest flow, pressure, and temperature conditions possible. Purging requirements for surface equipment will depend on equipment design, the substances being purged, and the purge medium.
   - For surface piping systems, the American Gas Association publication: *Purging Principles and Practice* provides guidelines for developing safe purging procedures (see BIBLIOGRAPHY, pg. 65).

18.4.4 ASSESSING POTENTIAL FIRE AND EXPLOSION HAZARDS

This section covers the first step of a field-level assessment of fire and explosion hazards, which is the identification of potential fuel-hydrocarbon, oxygen-air, and energy-ignition sources based on the expanded fire triangle (see FIGURE 7 pg.21). The assessment is the responsibility of the supervisor. The OHS Code in some jurisdictions states that assessments must be written and that workers must be involved in conducting worksite hazard assessments.

There need to be several results from this action.

1. **Identification of the on-site sources** which could combine to create a fire or explosion.
2. **Identification of critical risk factors** (see SECTION 18.4.3, pg. 23).
3. **Identification of changing job scope or operating conditions** which could increase the possibility of these sources combining. This involves considering how the components are affected by different conditions such as temperature, pressure, exposure to air etc.

18.4.4.1 FUEL-HYDROCARBON SOURCES: IDENTIFYING AND DOCUMENTING HAZARDS

It is recommended that the steps outlined below be taken before any work begins. Fuel and hydrocarbon sources on the work site need to be identified and the properties of each understood and considered by those responsible for the fire and explosion hazard assessment. At a minimum, those identifying fuel hazards should consider the questions below taking into account the list of fuels in the expanded fire triangle (See FIGURE 7, pg. 21).

Step 1: Identify and document fuels/hydrocarbons

A. Which operations require or will encounter fuels/hydrocarbons?
B. What are the properties of these fuels/hydrocarbons and how do they potentially create a fire and explosion hazard?
C. How can these properties be confirmed? How can they be measured?
D. How are these properties affected by surface versus downhole operations?
E. Are there fuels/hydrocarbons present now? Were fuels/hydrocarbons present at any time previously? If so, could residual amounts still be present?
F. Have the fuels/hydrocarbons been removed? What evidence is this based on?
G. Do operations involve adding fuels/hydrocarbons?
H. If fuels/hydrocarbons are present, what form are they in? Can they change? How?
I. Is there something unique about the state and/or types of fuels/hydrocarbons that may make them more or less dangerous?

Step 2: Determine and document hazards based on responses to Step 1.

Step 3: Consider the fuel-hydrocarbon hazards identified in the fire and explosion prevention planning process.

18.4.4.2 ASSESSING CONTROLLED FUEL RELEASES AND POTENTIAL FOR UNCONTROLLED RELEASES

If a controlled release of hydrocarbons is planned as part of the scope of work, this should automatically trigger the need for a fire and explosion prevention plan for the specific operation. It is also critical to consider the potential hazard should an uncontrolled release of fuels or hydrocarbons into the work environment occur.

18.4.4.3 OXYGEN SOURCES: IDENTIFYING AND DOCUMENTING HAZARDS

It is recommended that the steps outlined below be taken before any work begins. If the use of oxygen is planned as part of the scope of work, this should automatically trigger the need for a fire and explosion prevention plan for the specific operation.

At a minimum, those identifying oxygen hazards should consider the questions below taking into account the list of oxygen sources in the expanded fire triangle (see FIGURE 7, pg. 21).

Step 1: Identify and document oxygen-air sources

A. How can oxygen-air be combined with a fuel?
B. How could a fuel source be released to an oxygen-air containing atmosphere?
C. Will oxygen-air be deliberately combined with a fuel source?
D. Can oxygen-air be inadvertently introduced into a closed system containing a fuel source?
E. Can the fuels-hydrocarbons contain or be exposed to chemicals or products that are potential oxygen sources such as: weathered hydrocarbons, chemical additives, ester-based greases or on-site generated nitrogen?

Step 2: Determine and document hazards.

Step 3: Consider the oxygen-air hazards identified in the fire and explosion prevention planning process.

18.4.4.4 ENERGY-IGNITION SOURCES: IDENTIFYING AND DOCUMENTING HAZARDS

It is recommended that the steps outlined below be taken before any work begins. Possible energy-ignition sources need to be identified and the properties of each understood and considered by those responsible for the fire and explosion hazard assessment. As a minimum, those identifying hazards should consider the questions below taking into account the list of energy-ignition sources in the expanded fire triangle (see FIGURE 7, pg. 21).

Step 1: Identify and document energy-ignition sources

A. Have all obvious sources such as open flames, sparks, heat sources been identified?
B. Have non-obvious energy sources been considered, such as pressure increases (also known as the dieseling effect), sudden depressurization, static discharge, and chemical reactions?
C. Have all classified areas been identified, as per the Canadian Electrical Code? Does the equipment to be used meet electrical code requirements?
D. If there is the potential for low-grade ignition sources (i.e. static charges), will there be sufficient energy to ignite a flammable mixture?

Incidents show that it is extremely difficult to account for all possible energy-ignition sources on a work site. For this reason, the elimination of ignition sources should not be used as the only basis for safety.

Step 2: Determine and document hazards

A. What operations could create non-obvious energy sources such as changes in operating pressures and static electricity through equipment movements?

B. What is the potential for changing conditions to affect minimum ignition energy as shown in FIGURE 8, pg. 22. For example: Static charges may not have enough energy to ignite a dry gas mixture because of the high minimum ignition energy. However, if liquid hydrocarbons are introduced, the minimum ignition energy is significantly reduced, making it important to consider static electricity as an ignition source.

Step 3: Consider the energy-ignition hazards identified in the fire and explosion prevention planning process.

18.4.5 RECOGNIZING AND RESPONDING TO WARNING SIGNS AND SCOPE CHANGES

The analysis of case studies done as background to this IRP showed that **many of the incidents could have been avoided if warning signs had been better understood and communicated so that appropriate action could have been taken.**

The **most significant warning sign was found to be when work activities did not go as planned** - no matter how minor the change may have seemed at the time. For personnel to better recognize and respond to warning signs the following steps should be considered.

Step 1: Personnel on site should be made aware of potential warning signs and instructed to communicate promptly with their supervisors when things do not go as planned.

Step 2: When plans deviate, the following responses should be considered, and the most appropriate actions taken:

- Redo the hazard assessment taking new information into account;
- Revise operational plans accordingly;
- Communicate information as required; and
- **Repeat the actions above until the work can be completed without varying from the 'adjusted' plans.**

Job Scope Changes and the Need for Hazard Re-evaluation: Why High-risk Operations Seldom Go Wrong

Many of the incidents reviewed for this IRP were considered routine operating and maintenance activities. In contrast, incidents during operations normally considered to be high-risk activities, were infrequent. It was learned that such activities are usually conducted without serious incident because those involved know what is planned, how the operation should unfold, and that work must be suspended and the hazards re-evaluated whenever activities deviate in any way from the planned operations.

18.4.6 CONSIDERING THE NEED FOR A FORMAL RISK ASSESSMENT

This section discusses the steps to take if the initial assessment of some or all planned operations indicates that the risk levels warrant conducting a more formal risk assessment.

18.4.6.1 IDENTIFYING THE NEED FOR AN OPERATIONS-SPECIFIC RISK ASSESSMENT

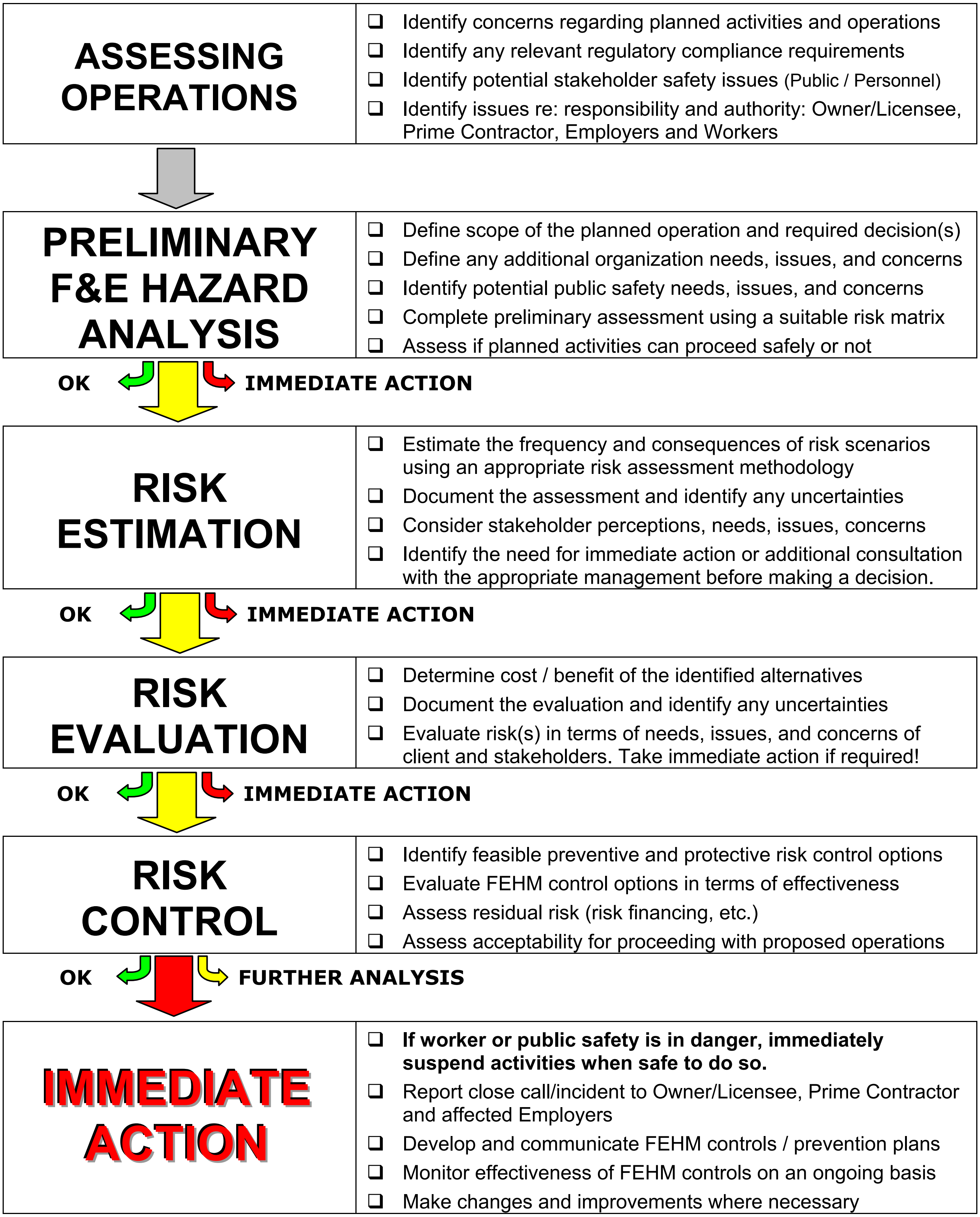
Risk is present in most oil and gas activities. Before risk can be managed, it must be analyzed. In many cases, the risks are obvious and a field-level assessment will adequately identify the potential fire and explosion hazards so that appropriate controls can be put in place. In other cases, the risks may be less obvious, especially when operations are highly complex. In such cases, a comprehensive risk analysis should be considered in order to accurately identify the potential hazards so that effective plans and procedures can be put in place to address them.

FIGURE 9, pg. 30 shows the recommended model for assessing fire and explosion risks. This model is based on the principles found in the Canadian Standards Association document, *CSA Q850 – Risk Management: Guideline for Decision Makers.*

Based on the investigation of fire and explosion incidents, it is possible to identify factors that should trigger the need for comprehensive risk assessments. These include:

1. The use of new, unproven technologies;
2. The use of proven technologies in previously untried circumstances;
3. Operations with previous fire and explosion incidents; and
4. Operations in which one or more of the employers have no experience.

Figure 9: Fire and Explosion Risk Management Model



ASSESSING OPERATIONS

- ☐ Identify concerns regarding planned activities and operations
- ☐ Identify any relevant regulatory compliance requirements
- ☐ Identify potential stakeholder safety issues (Public / Personnel)
- ☐ Identify issues re: responsibility and authority: Owner/Licensee, Prime Contractor, Employers and Workers

PRELIMINARY F&E HAZARD ANALYSIS

- ☐ Define scope of the planned operation and required decision(s)
- ☐ Define any additional organization needs, issues, and concerns
- ☐ Identify potential public safety needs, issues, and concerns
- ☐ Complete preliminary assessment using a suitable risk matrix
- ☐ Assess if planned activities can proceed safely or not

OK | **IMMEDIATE ACTION**

RISK ESTIMATION

- ☐ Estimate the frequency and consequences of risk scenarios using an appropriate risk assessment methodology
- ☐ Document the assessment and identify any uncertainties
- ☐ Consider stakeholder perceptions, needs, issues, concerns
- ☐ Identify the need for immediate action or additional consultation with the appropriate management before making a decision.

OK | **IMMEDIATE ACTION**

RISK EVALUATION

- ☐ Determine cost / benefit of the identified alternatives
- ☐ Document the evaluation and identify any uncertainties
- ☐ Evaluate risk(s) in terms of needs, issues, and concerns of client and stakeholders. Take immediate action if required!

OK | **IMMEDIATE ACTION**

RISK CONTROL

- ☐ Identify feasible preventive and protective risk control options
- ☐ Evaluate FEHM control options in terms of effectiveness
- ☐ Assess residual risk (risk financing, etc.)
- ☐ Assess acceptability for proceeding with proposed operations

OK | **FURTHER ANALYSIS**

IMMEDIATE ACTION

- ☐ **If worker or public safety is in danger, immediately suspend activities when safe to do so.**
- ☐ Report close call/incident to Owner/Licensee, Prime Contractor and affected Employers
- ☐ Develop and communicate FEHM controls / prevention plans
- ☐ Monitor effectiveness of FEHM controls on an ongoing basis
- ☐ Make changes and improvements where necessary

18.4.6.2 COMPLETING DETAILED PROCESS HAZARD ANALYSES (PHA) WHEN APPROPRIATE

There are a number of well established Process Hazard Analysis (PHA) methods described below. Those choosing the methodology should consider:

- the scope and complexity of the planned operations;
- the degree of risk associated with those operations; and
- the complexity of the prevention plan needed to provide an acceptable safety level.

The methods most commonly used include:

- **Hazard and Operability Study (HAZOP**): This is the most rigorous and formal of the PHA options. It is used when the changes undertaken are very large or complex. The technique can be very time-consuming and requires the involvement of key personnel.
- **What-if Analysis**: Compared to a HAZOP, this approach is less structured. It involves a review team using a series of what-if questions to identify the hazards associated both with the change and the proposed recommendations. Due to its lack of structure, this method requires an experienced team to be successful.
- **Checklist**: The checklist approach is used for many Management of Change analyses because it can generate useful results in a short period of time.
- **Failure Modes and Effects Analysis (FMEA):** This method focuses on analyzing equipment performance by evaluating how equipment could fail, and the consequences. It is generally used for large and/or complex items such as compressors and high pressure vessels. It is appropriate for Management of Change reviews where new equipment will be installed or where radical changes are being made to items already in use.
- **Fault Tree Analysis (FTA):** This is a formal, rigorous method for evaluating the risk of system failures. With quantitative data, it can be used to calculate the probability of failures occurring. This approach is most appropriate for the analysis of large systems and is not often used for Management of Change modifications.

These methods are discussed in more detail in *CSA Standard Q634-M – Risk Analysis Requirements and Guideline.*

18.5 CHOOSING APPROPRIATE CONTROL METHODS

18.5.1 DETERMINING THE NEED FOR FIRE AND EXPLOSION CONTROLS

When determining the need for fire and explosion controls, the main questions to be answered are:

1. Does a hazard or threat exist? Can the fire triangle be completed?
2. What can be done to reduce the hazards? What fire and explosion controls are required?

The identified hazards and the controls need to be examined relative to the energy-ignition, oxygen-air, and fuel-hydrocarbon sources found in each specific oil and gas operation. Consideration should also be given to any emergency preparedness measures that may be required should barriers and controls fail. This review should take place before work begins to ensure that any controls needed to deal with such failures have been put in place.

The potential for hydrocarbon releases into the atmosphere, and the introduction of oxygen-air into a ‘closed‘ system warrant special attention as it is almost impossible to control the resulting explosive mixtures in such circumstances.

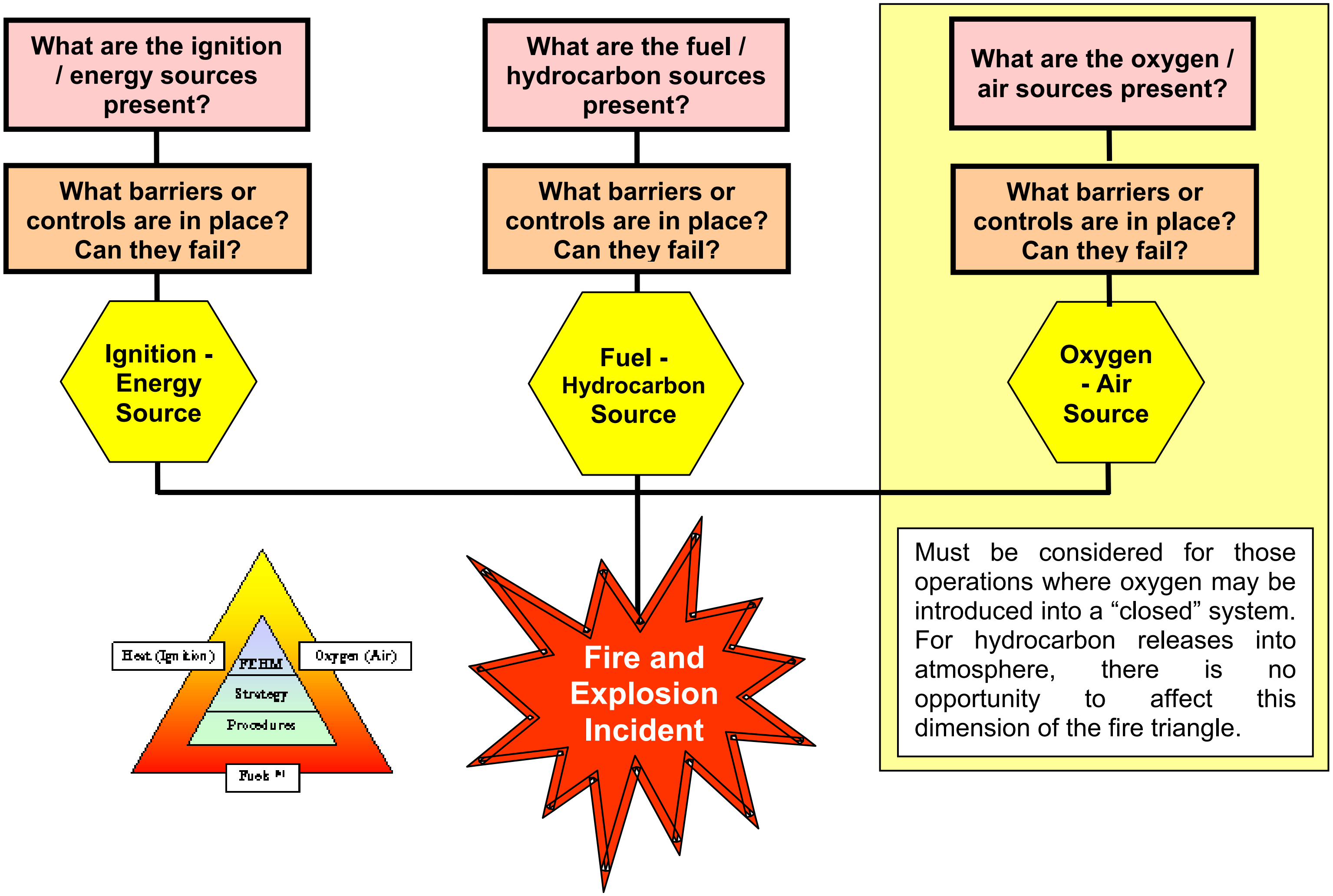
FIGURE 10: ASSESSING THE POTENTIAL FOR A FIRE OR EXPLOSION on page 33, illustrates these concepts.

18.5.1.1 STAGES OF CONTROL APPLICATION

Controls should be considered at three critical points during the life cycle of operations.

- **Preoperational design stage.** The greatest opportunity to analyze hazards and design ways to avoid, control or eliminate them exists before operations begin. By designing with fire and explosion hazard management in mind, costly redesigns, retrofits, and replacements can be avoided.
- **Operational stage.** After work has begun, operations can be made safer through a process of continuous improvement. This involves retrofitting to address hazards identified during operations. This is accomplished by identifying, and evaluating hazards as they become evident and working to control or eliminate them before they cause injury, death or damage.
- **Post-incident stage.** After an incident has occurred, safety can be improved by investigating the hazards related to the incident, determining the causal factors, and reviewing the possible impact of design decisions on the incident. This information can then be used to improve future designs and eliminate the factors that led to the incident.

Figure 10: Assessing the Potential for a Fire or Explosion



Must be considered for those operations where oxygen may be introduced into a “closed” system. For hydrocarbon releases into atmosphere, there is no opportunity to affect this dimension of the fire triangle.

18.5.1.2 TYPES OF CONTROLS

There are three widely recognized types of hazard controls, each with different functions. They are listed in the order of their effectiveness, with engineering controls being more dependable than those that rely solely on human behaviour.

1. Engineering Controls: The objective of engineering controls is to eliminate or reduce the hazard. This is the preferred type of control whenever feasible. These controls relate to the design of the processes, equipment, and tools being used. They are the standards, specifications, and design criteria that apply to an operation. The basic functions engineering controls perform include:
    - Elimination: Designing equipment to minimize the release of hazardous substances.
    - Substitution: Utilizing non-hydrocarbon drilling or workover fluids, where possible.
    - Isolation: Enclosing equipment or adding emergency shutdowns to eliminate or reduce the amount of hazardous substances that will be released in the event of a failure.
    - Ventilation: Providing mechanisms for exhausting hazardous substances from the work area.
2. Administrative Controls: Administrative controls address hazards through the development and application of suitable work systems. Their effectiveness depends on the integrity of the processes used to develop them, and their proper implementation and enforcement. Examples include: work practices and procedures, on-the-job training, worker selection and supervision, etc.
3. Personal Protective Equipment (PPE): Protective equipment is "the last line of defense". PPE does not control or prevent incidents; it will only protect workers from injury should an incident occur. Examples include: respiratory protective equipment, hand and body protection including Fire Resistant Clothing (FRC), hearing protection, etc.

18.5.1.3 CONTROL PRIORITIES

To avoid, eliminate or control hazards effectively, the following priorities should be applied to control strategy decisions. For many operating situations, a combination of the five control priorities listed below may be required. Lower level priorities should not be employed until higher level priorities have been exhausted. The last three items on this list or any combination of them should not be used as the only risk reduction methods for critical hazards.

1. **Designing for minimum risk.** The top priority should be to eliminate hazards in the design process. If a hazard cannot be eliminated, the associated risk should be reduced to an acceptable level through design decisions.
2. **Incorporating safety devices.** If hazards cannot be eliminated or reduced acceptably through design, then fixed, automated, or other protective safety design features or devices should be employed. Routine checks of such devices must be required and implemented to ensure levels of protection are maintained.
3. **Providing warning devices.** In cases where the identified hazards cannot be addressed through design and/or safety devices, systems which detect hazardous conditions and warn personnel should be employed. Warning signals should be designed to help workers react promptly and correctly to a hazardous situation.

4. **Developing and implementing operating procedures and employee training programs.** Where the above methods will not eliminate or reduce hazards to an acceptable level, safe operating procedures should be developed and implemented in conjunction with safety training programs.
5. **Providing and using personal protective equipment.** Employees should be given and use personal protective equipment as a precaution to prevent injuries and illness in the event that controls fail or an emergency occurs.

18.5.1.4 GENERAL METHODS OF CONTROL

A number of fire and explosion management principles should be considered in the prevention planning process.

1. **Controlling the fuel-hydrocarbon sources:** This can be accomplished by two methods. The fuel can be physically removed or separated from any oxygen and/or ignition sources; or the fuel can be chemically affected by diluting it.

   Examples of eliminating or limiting the hazard related to fuel sources include:
   - substituting a safer substance when hazardous materials must be used by selecting those with the least risk throughout the system life cycle;
   - considering smaller quantities of hazardous materials;
   - storing hazardous materials in smaller containers;
   - controlling the accumulation of dusts, vapors, mists, etc.;
   - designing containment vessels, structures, and material-handling equipment to appropriate safety factors;
   - when removing vessels and equipment from service, purging with an inert substance to reduce the concentration of flammable substance to below its lower explosive limit (LEL); and
   - operating in conditions above the upper explosive limit (UEL).

2. **Controlling the air-oxygen sources:** Controlling the oxygen-air requires the displacement or reduction of oxygen concentrations in a ‘closed’ system to below its lower explosive limit (LEL). This involves applying an inert gas such as nitrogen or carbon dioxide. The inert gas displaces the oxygen, thereby lowering concentrations to a level that cannot sustain combustion.

   In the case of tanks and other surface equipment, this can sometimes be accomplished by providing an inert gas ‘blanket’ or applying a layer of foam to form a vapor barrier. Personnel must be aware that displacing or reducing the oxygen concentration will affect their breathing. This control method requires that personnel not enter the confined space or use breathing equipment.

   Other approaches could include:
   - when readying vessels and equipment for service, purging with an inert substance to reduce the concentration of oxygen to below its lower explosive limit (LEL);
   - isolating hazardous substances, components, and operations from other activities, areas, and incompatible materials, and from personnel;
   - locating equipment so that access during operations, maintenance, repair, or adjustment minimizes the exposure of personnel (e.g., hazardous chemicals, high voltage, electromagnetic radiation); and
   - providing warning systems that detect unwanted hazardous material releases (i.e., gas/LEL detection, fire detection, alarm systems).

3. **Controlling the energy-ignition sources:** Energy must be absorbed for it to be controlled. Combustion is an exothermic chemical reaction. If the energy emitted by the reaction can be absorbed faster than the reaction can produce the energy, then the reaction cannot be sustained. Employers are required to be familiar with the spacing requirements as defined by the Canadian Electrical Code. In addition, spacing requirements are defined in the Alberta Safety Codes Council, "Code for Electrical Installations at Oil and Gas Facilities".

   Alternatives for limiting the amount of ignition energy could include:
   - reducing actual or potential energy input;
   - conducting operations at reduced pressures;
   - using the minimum energy to reduce the viability of an ignition source (e.g., voltage, pressure, chemicals);
   - replacing hazardous operations with less hazardous operations;
   - reducing operating speed (e.g., processes, equipment, vehicles);
   - installing automatic engine air shut offs on diesel engines rather than operator-activated systems; automated systems activate when an engine 'races' thereby limiting the amount of energy created by this ignition source and worker exposure to the hazardous environment;
   - protecting stored energy and hazardous material from possible shock; and
   - adding water to prevent pyrophoric iron sulphides from drying out and igniting.

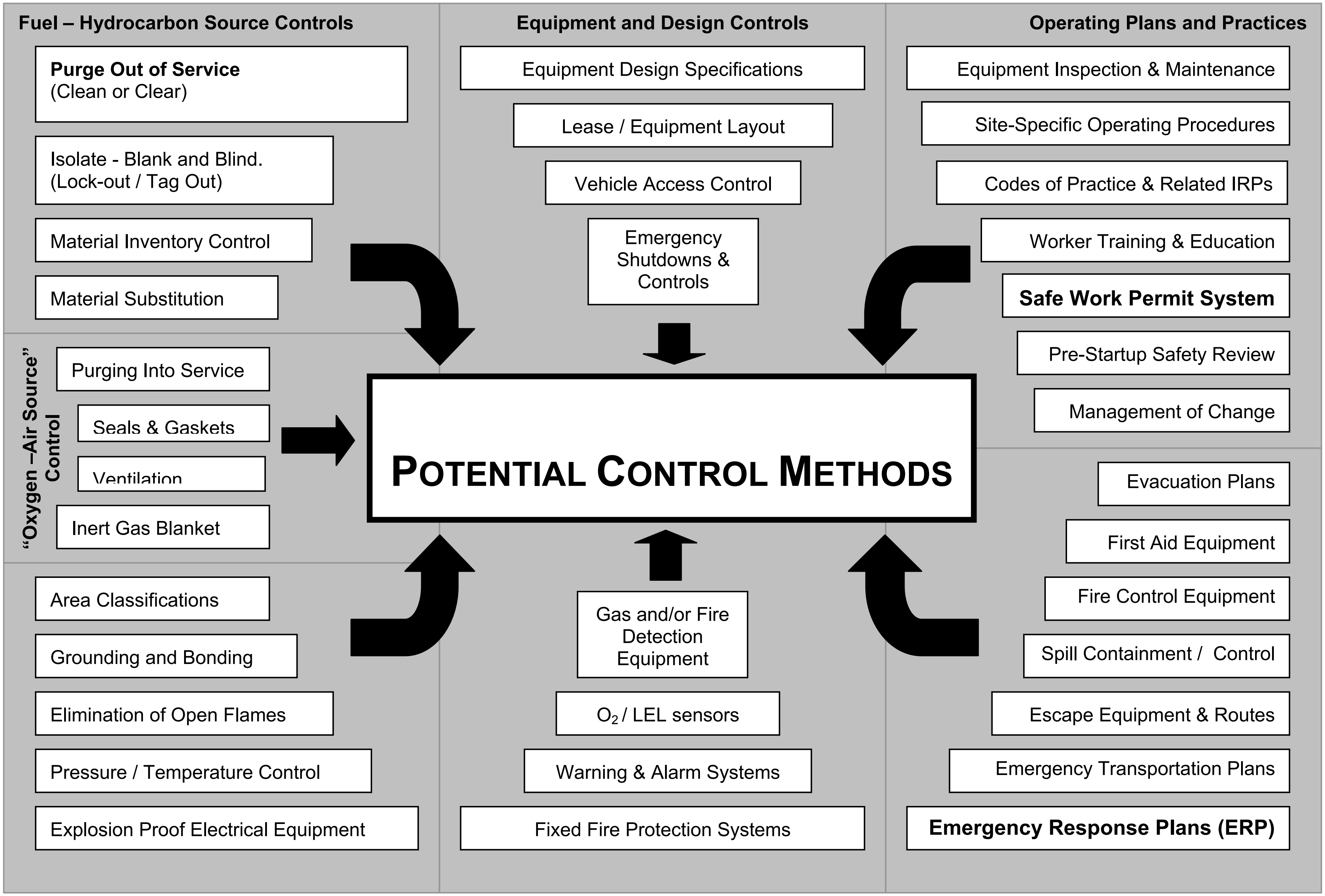
4. **Inhibiting chemical reactions:** Chemical reactions can be inhibited by introducing a chemical agent into a potentially explosive atmosphere. Certain chemical agents can interfere with reactions by absorbing the free radicals from one sequence that are needed to complete the next (i.e., dry chemical extinguishing agents used in portable fire extinguishers have this ability).

   Alternatives for inhibiting chemical reactions could include:
   - providing safety and bleed off valves;
   - reducing the burning rate (using an inhibitor);
   - using portable or fixed fire extinguishers or systems (Class A B C D); and
   - employing other special systems and extinguishing agents.

5. **Managing the fire triangle:** While not formally discussed in most safety references, another strategy for consideration involves controlling the task to maintain operations outside the explosive or flammable envelope. This is done by maintaining the fuel–oxygen mixture below the lower explosive limit (LEL) or above the upper explosive limit (UEL). This technique can **only** be considered when **all** aspects of the operation are precisely understood, and the conditions that will be encountered can be verified over the entire range of anticipated operating conditions prior to commencing operations.

FIGURE 11: POTENTIAL CONTROL METHODS, pg. 37, outlines the controls to consider for operations where fire and explosion hazards have been identified. Additional information on each of these controls is available in the references or on the fire and explosions website developed in conjunction with this IRP. See www.firesandexplosions.ca.

Figure 11: **Potential Control Methods**



18.5.1.5 OTHER FACTORS AFFECTING CONTROL DECISIONS

During the preparation of this IRP, the committee made a number of observations relative to fire and explosion safety. While difficult to quantify, these observations warrant the attention of those working to improve safety.

1. **The extreme difficulty of controlling ignition sources**

   Many incidents have shown that ignition sources turn up even though every effort has been made to remove all those that were foreseen. Because of this, the elimination of ignition sources should never be accepted as the sole basis of safety. Explosions still occur because people believe that ignition is impossible.

   The case studies highlight that the only reliable way of preventing fires and explosions is to avoid the formation of flammable mixtures. Ignition sources are so numerous and the amount of energy needed for ignition at times so small, that it is not possible to be sure that all ignition sources have been eliminated.

2. **The need for site-specific purging practices**

   The basic requirement for a successful and safe purging operation is knowledge of the principles concerning the formation, analysis and control of gas mixtures. Additional requirements include: a thorough preliminary study of the application of these principles for each situation; a well prepared procedure detailing the sequence of events; a predetermined rate of introduction of the purge medium; and verification of end-points. Finally, the steps of the procedure must be followed and carried out by capable, well-informed people.

   Purging operations should be under the direction of experienced personnel. In planning a purge, definite decisions should be made concerning:

   - What is to be purged and how it is to be isolated;
   - What purge medium is to be used;
   - How it is to be introduced and vented;
   - The method of testing and the end-point; and
   - The time and probable duration of the operation.

   All of these decisions should be included in a written plan of action.

   Any purging must be done in accordance with sound scientific principles. **The formation of flammable mixtures during purging must be minimized.**

   Carefully controlled purging of air from pipelines by direct displacement with natural gas has been practiced with the recognition that some flammable mixture has been present. Purging of natural gas from pipelines by direct displacement with air also has been practiced. At a minimum, these methods require knowledge and verification of all operating conditions and a solid understanding of the required principles and practices. These are outlined in the American Gas Association publication: '*Purging Principles and Practice'* (see BIBLIOGRAPHY).

   Balancing design and procedural improvements

   Many of the incidents leading to the development of this IRP could have been prevented by better design, and many by better operations. Good operations can sometimes compensate for poor design and vice versa, but that is not something on which to rely.

Safety by design should always be the aim but it is not always possible. Experience shows that behavioral methods can create substantial improvement in the everyday types of accidents that contributed to these incidents. However, behavioral methods should not be used as an alternative to the improvement of design or methods of working when these are reasonably practicable.

18.5.1.6 EMERGENCY EQUIPMENT AND RESPONSE PLANS

Identifying the Need for Emergency Response Plans and Procedures
The Prime Contractor / Well Licensee is required to develop and implement the appropriate emergency response plans for each worksite.
To respond to an emergency that may require rescue of a worker or site evacuation, each worksite must have an action plan in place to address how medical attention will be obtained for injured workers. The plan must be current and affected workers must be consulted. Contents of a typical plan include:

- Identification of potential emergencies
- Procedures for dealing with the emergencies
- First aid services required
- Designated rescue and evacuation workers

In addition, well licensees must have a corporate emergency response plan (ERP) in place and available at the worksite.

Considering the Need for Emergency Equipment
The types of equipment personnel must be provided with to meet specific types of fire and explosion emergencies should be determined. The equipment needs to permit quick response. It must be easy to use, especially by personnel under the stress of an emergency. It must be highly reliable and effective. It must not unduly degrade the mobility or performance of the user, or constitute a hazard itself.

The most effective locations for the emergency equipment need to be established. Equipment storage sites should be located as close as possible to where the equipment may be required.

Maintaining and Testing Required Control and Emergency Equipment
The success of any control approach requires the ongoing effective operation of both the process and the control. It is important that a scheduled maintenance program be established as part of a hazard control plan and that it be enforced.

Providing and Testing Required Emergency Response Plans and Equipment
Emergency planning is essential for avoiding severe losses to people, property, and the continuity of business. A well-developed and rehearsed emergency plan can prevent a small emergency from escalating into a catastrophe.

18.6 DEVELOPING FIRE AND EXPLOSION PREVENTION PLANS

18.6.1 CIRCUMSTANCES REQUIRING FIRE AND EXPLOSION PREVENTION PLANS

As a minimum, companies must consider developing written, fire and explosion prevention plans for the circumstances listed below. The **Critical Risk Factors** outlined in SECTION 18.4.3, pg. 23 should always be taken into consideration. Such plans may range from general guidelines for well-defined operations completed by trained, experienced personnel, to the implementation of a company's safe work permit system or in some cases to detailed site-specific procedures for non-routine operations.

Operations that require attention due to increased risks include but are not limited to:

- Where oxygen-air or oxidizing chemicals are purposely used as part of the planned operations, particularly where high pressure or hydrocarbon liquids are present;
- Where oxygen-air is likely to or can inadvertently enter a 'closed' system;
- Where there is a significant possibility that fuels-hydrocarbons may be released into the worksite (planned or unplanned); and
- Where an energy-ignition source is introduced into a potentially hazardous area.

The following list of operational examples and activities is offered for illustration purposes and is by no means exhaustive. It provides insight into when site-specific fire and explosion prevention plans may be required.

Well Construction

- Where oxygen-air or oxidizing chemicals are purposely used or inadvertently introduced in well drilling and servicing operations.
- All snubbing applications.
- All well workover applications using hydrocarbon-based fluids.

Related Production Operations

- Planning and execution of a facility turn-around.
- Start-up of new equipment.
- Preparation and/or cleaning of tanks and vessels (i.e., confined space entry).

Repair and Maintenance Activities

- Modification of vessels, equipment, piping, pipelines that have contained hydrocarbons (i.e., hot work).
- All operations involving the use of propane torches to heat or thaw systems containing hydrocarbons.

Trucking Operations

- All tank truck repairs and maintenance.
- All vacuum truck operations involving the removal of hydrocarbon fluids.

18.6.2 FIRE AND EXPLOSION PREVENTION PLAN CONTENT

Fire and explosion prevention plans need to be written site-specific or job-specific documents. These plans should be dated, reviewed, revised when necessary, kept where the work occurs, and made available to workers.

As a minimum, these plans need to:

- Describe the work to be done;
- List sources that can contribute to fire and explosion hazards
    - Fuel-hydrocarbon sources
    - Oxygen-air sources
    - Energy-ignition sources;
- List required controls;
- Confirm that workers have been trained to recognize potential fire and explosion hazards related to the planned activities, and informed about site-specific prevention plans; and
- Refer to general or site-specific emergency plans and procedures.

A fire and explosion prevention plan template is provided in FIGURE 12 on the next page.

Figure 12: Fire and Explosion Prevention Plan Template

Worksite Location:	
Date:	Prepared by:
Describe Work To Be Done	
Fire and Explosion Hazards	Do you have the components for a fire or explosion?
Fuel / Hydrocarbon Sources:	
Ignition / Energy Sources:	
Air / Oxygen Sources:	
Fire and Explosion Controls	What are you doing to prevent components from combining?
Emergency Controls	How will you respond if the conditions change?
Workers Trained and Informed	Initial
Workers have been made aware of and can recognize potential fire and explosion hazards related to the planned activities.	
Affected workers have been made aware of this fire and explosion prevention plan.	
Comments:	
Owner – Licensee Representative	Signature - Date
Contractor Representative	Signature - Date

18.6.3 IMPLEMENTING AND MONITORING THE EFFECTIVENESS OF PREVENTION PLANS

18.6.3.1 CONDUCTING A PRE-JOB HAZARD REVIEW

The purpose of a pre-job hazard review is to ensure that the planned activities will proceed smoothly and safely. It represents the last chance to catch any problems and as such should be carried out by the operations personnel who will do the work. Generally, the topics that follow need to be covered.

1. Ensuring that required hazard controls have been installed and commissioned.
2. Confirming that adequate safety, operating, maintenance, and emergency procedures are in place and have been reviewed with the appropriate personnel.
3. Confirming that all action items and recommendations from the hazard assessment and other safety reviews have been completed as required.
4. Confirming that workers have the necessary skill to conduct the work safely and that a plan to manage non-competent workers is in place.

18.6.3.2 IDENTIFYING, IMPLEMENTING AND ADHERING TO WORK PLANS AND PROCEDURES

Companies need to follow-up on work plans and procedures to ensure they are workable, and being implemented properly by those doing the work.

18.6.3.3 CONFIRMING WORKERS HAVE REQUIRED TRAINING AND EXPERIENCE FOR PLANNED OPERATIONS

Knowledge of the process, controls, materials used, and procedures are of significant importance in maintaining a safe operation. Appropriate training should be a part of the hazard control plan. Areas to be considered are process operation, control operation, and emergency procedures.

18.6.3.4 MONITORING WORKSITE CONDITIONS TO IDENTIFY WHEN WORK SCOPE OR OPERATING CONDITIONS HAVE CHANGED

A monitoring program is an essential component of a hazard control program. Monitoring helps to maintain the program and evaluate its effectiveness. There are two basic categories of monitoring relative to fire and explosion safety that need to be addressed.

1. Control Monitoring: Are equipment and procedures operating as expected. Are alarms and shutdowns functional?
2. Environmental Monitoring: Is the equipment monitoring the safety of the work environment in place and functioning? (e.g., LEL/H_2S etc.)

18.7 COMMUNICATING FIRE AND EXPLOSION HAZARDS AND CONTROLS

18.7.1 JOBSITE COMMUNICATIONS

The safety of oil and gas operation relies on effective communication of the hazards involved, and effective implementation of the steps required to eliminate or reduce those hazards. Those conveying such information are reminded that:

1. Communication needs to be two-way.
2. Communication should be documented (i.e. safety meeting summary).
3. Communication needs to include factual information about: the planned operations, the hazards, and the steps required to eliminate or reduce the hazards.
4. Communication between site personnel as activities progress is essential to keep the work on track according to the fire and explosion prevention plan.

This section of the IRP focuses on the communications strategies needed to effectively manage fire and explosion hazards. It is based on a review of fire and explosion incidents, where research showed that several incidents could have been prevented if warning signs had been understood and appropriate action taken promptly.

18.7.1.1 COMMUNICATION LESSONS LEARNED FROM FIRE AND EXPLOSION INCIDENTS

Effective communication about fire and explosion prevention involves getting the right information to the right people at the right time. **Equally important, it involves knowing what changing conditions or warning signs make it necessary to re-evaluate the original hazard assessment, and revise the related operational plans and communications.**

The incident review done as background for this IRP, showed that the right information usually was available on the job site. These findings suggested, however, that this information needs to be provided to workers, reinforced, and understood, if incidents are to be prevented.

The incident review revealed that:

- Fire and explosion hazard information needs to be stressed more on the job site;
- More attention must be paid to getting workers the information they need when they need it;
- Workers need to be made aware of the changing conditions or warning signs that should be reported promptly and acted upon;
- Hazard assessments and operational plans need to be re-evaluated when activities do not go exactly as planned, particularly in routine and maintenance activities;
- The results of any reassessments, such as expanded hazard identification or changes in plans, must be conveyed promptly to the right people; and
- Communication needs to take place throughout the life cycle of all operations undertaken on the site.

Improving Hazard Identification and Problem Solving

Hazard identification and problem solving form part of most companies operating plans and safety programs. Based on the research done for this IRP, attention to the following tasks during **all types of operations** will help prevent fires and explosions.

- Communicating the big picture to all – providing everyone involved with an overview of what jobs are being planned and coordinated, particularly for more complex operations involving multiple contractors.
- Implementing the following critical activities:
    - Assignment of roles and responsibilities;
    - Fire and explosions hazard identification and risk assessment;
    - Fire and explosions hazard communications; and
    - Job planning - Scheduling and coordinating activities and job tasks.

18.7.1.2 IDENTIFYING WHEN INFORMATION NEEDS TO BE COMMUNICATED

Hazard management communication should take place before work on any operation with potential fire and explosion hazards begins, and should continue through the life cycle of all operations taking place on site. If new personnel become involved, hazard management communication needs to take place before their work commences.

There are four critical stages to fire and explosion hazard management communication.

- **Preoperational Design Stage** – Communication on a company-to-company level; and communication within each company between management and operations personnel responsible for job planning and design, and field management personnel responsible for the implementation of those plans.
- **Operational Stage** – Communication between those responsible for executing different contracts; and communication on the supervisor and worker level for each different operation. **It is extremely important that information be communicated when shifts change on any operation**.
- **Change Management Stage: Job Scope Changes** – Communication on a variety of levels when operations have not gone exactly as planned.
- **Post-incident Stage** – Communication to all those directly involved about lessons learned; and broader communication to the industry through Enform.

18.7.1.3 IDENTIFYING STAKEHOLDERS

The left-side of the FIGURE 13: SAMPLE COMMUNICATION PLANNING MATRIX shows how stakeholders are identified in a matrix used by a growing number of companies to identify stakeholders, responsibilities, and information needs. The types of stakeholders will vary depending on the scope of work. Their communication needs will depend on their roles, responsibilities and involvement. Each company will need to determine how it identifies stakeholders and their communication needs. This chart is provided as a sample approach.

Figure 13 Sample Communication Planning Matrix

Hazard Communication Tool Principal Stakeholders	Hazard Assessments	Worksite Inspections	Pre-Job and Daily Safety Meetings	MSDS / TDG Information	Equipment Specifications	Work Plans and Procedures	worker Training and qualifications	Operating Standards	Emergency Response Plan
Owner/Prime Contractor Management									
Planning and Design Personnel									
Wellsite Supervisor (Company Rep.)									
Drilling and Completion Contractors									
Other Contractors and Suppliers									
Safety Support Services									
Public and Surrounding Communities									

Legend: Responsibilities & Communication Needs	
A – Approval	Approval for the task or decisions made
R – Responsible for activity	Responsibility to oversee task or make decisions
C – Consult	Consult for information or opinion on activities or decisions
P – Planning & Preparation	Involved in planning activities, decisions
M – Monitor and Verify	Monitor and verify
N – Notify	Notify of activities, decisions, changes regarding area of need
U – No Involvement	No involvement in the process

18.7.1.4 IDENTIFYING WHAT INFORMATION TO COMMUNICATE ON THE JOB SITE

Fire and explosion hazard communication on the job site should focus on a common understanding of:

- What operations are planned;
- What hazards exist;
- What controls are in place to eliminate or reduce the potential hazards; and
- What actions must be taken if things do not go as planned.

The detail different personnel require about fire and explosion hazards will depend on their roles and responsibilities. Hazard communication requires that all on-site workers be made aware of the information listed below **before** work begins:

- potential fire and explosion hazards on the job site;
- operations where a site-specific fire and explosion plan is required and will be implemented (see SECTION 18.6.1, pg. 40 for operations requiring a plan);
- control methods and how they work for the operations they execute;
- warning signs to heed;
- emergency response plans;
- availability and use of protective equipment in case of emergencies; and
- lessons learned from incidents during similar operations or from site experience.

More detailed communication needs to take place with the workers directly involved in operations where a site-specific fire and explosion plan will be implemented. It is recommended that these workers be identified before operations begin so that they can be included in safety meetings, hazard reviews, and any other activities where fire and explosion controls and protective measures are discussed.

The complexity of the operations will drive how formal communication planning and implementation needs to be. In some cases, a communication matrix may be warranted.

18.7.1.5 SELECTING APPROPRIATE COMMUNICATION TOOLS

Many of the hazard communication tools needed to adequately address the fire and explosion requirements of this IRP are likely already in place. Examples include:

- **Documented Worksite Safety Meetings:** Fire and explosion hazards and controls should be highlighted in any pre-job and daily safety meeting discussions.
- **Worksite Inspections**: The results of any worksite inspections (i.e., CAODC drilling and service rig inspections, BOP inspections etc.) should be reviewed.
- **Hazard Assessments**: Relevant hazard assessments should be reviewed with workers (e.g., Job Safety Assessments –JSA, Job Hazard Assessments –JHA).
- **Equipment Specification Reviews:** Workers need to be made aware of any specific safety features or operating/maintenance requirements relevant to completing the work safely.
- **Work Plan and Procedural Reviews**: Any applicable work procedures such as written drilling, completion and workover programs, and contractor procedures should be reviewed with those involved.
- **Material Safety Data Sheets (MSDS) Reviews** – Experience shows that MSDS sheets are seldom reviewed. When they are, toxicity is usually the focus. Product flammability needs to be emphasized with respect to fire and explosion prevention communication.

As a reminder, the checklist below outlines hazard communication requirements:

☐ Identify all hazardous chemicals and flammable products being used in the planned operations.

☐ Obtain an MSDS for each hazardous chemical or flammable product in use or stored on site. Make the MSDS readily available.

☐ Develop a labeling system for all incoming hazardous chemicals or flammable products to ensure they can be easily identified.

☐ Develop a method for communicating hazards to employees and to others. In particular, review each MSDS prior to commencing operations with an emphasis on product flammability.

☐ Inform employees of protective measures for hazardous chemicals or flammable products used in the workplace. Alert workers to any warning signs.

- **Dangerous Goods Shipping Manifests (TDG):** Shipping manifests should be obtained and reviewed with workers. Information such as explosive limits, flash point, and specific gravity should be noted.
- **Safe Work Permits:** Any required work permits should be prepared, reviewed with the workers affected and implemented (e.g., hot work, confined space entry, ground disturbances).
- **Worker Qualification Reviews:** Any specific training **or certifications** required to complete the work safely should be confirmed.
- **Hazard Alerts:** Workers should be involved with reporting job hazards. All reports should be reviewed and addressed.
- **Incident Reports:** Reports about similar operations or products as well as any relevant industry bulletins should be reviewed with workers for training purposes to help prevent similar incidents.

18.7.1.6 REPORTING, INVESTIGATING, AND COMMUNICATING FIRE AND EXPLOSION INCIDENTS

Fire or explosion incidents must be reported according to the applicable regulations, and investigated promptly and thoroughly by the companies involved. Investigation results should be conveyed to workers so that any lessons learned will reach as many workers as possible.

Background work for this IRP indicated that more effort must be made to find **all** contributing factors. It revealed that investigations frequently stopped when one root cause was identified though other factors may have contributed significantly to the circumstances. Too often, field workers were left shouldering the sole responsibility for the incident. Such an approach slows the improvement of industry safety as not all causes are brought to the fore. To advance safety, learnings need to be sought at the organizational, planning, field management, and field execution levels.

After any incident, the factors listed below need to be understood.

A. The specifics of each physical operation undertaken at the time of the incident including:

  - physical site layout;
  - equipment;
  - protection features;
  - substances involved;
  - nature of the fire and explosion hazards created by activities; and
  - mechanics of the incident.

B. The ability of operations personnel to avoid errors.

C. The range of organizational issues that may have contributed to the incident.

D. How the company’s defense systems functioned; improvements to be made.

18.7.2 INDUSTRY COMMUNICATIONS

The upstream industry is encouraged to:

- Communicate fire and explosion hazard information to the broader industry through:

  Enform
  1538 – 25th Avenue NE
  Calgary, AB T2E 8Y3
  Phone: (403) 250-9606
  Fax: (403) 291-9408

  Key communication mechanisms include:

  - Publication of fire and explosion safety alerts
  - Incorporation of current safety information into Enform training programs
  - Presentation of fire and explosion information at the Petroleum Industry Annual Safety Seminar (PIASS)
- Visit the www.firesandexplosions.ca website hosted by the University of Calgary's Centre for Innovative Technology where the following information can be found:
  - Practical technical information about fuel, oxygen, and energy sources
  - Fire and explosion hazard management strategies
  - Guidelines for assessing operational risk factors
  - General practices to help prevent fires and explosions
  - Fire and explosion case studies
- Contact the Drilling and Completions Committee (DACC) through participating industry associations to identify knowledge gaps, and technical areas requiring more research.

APPENDIX A
REGULATORY AND INDUSTRY REQUIREMENTS

A.1 REGULATORY AND INDUSTRY REQUIREMENTS

A.1.1 FIRE AND EXPLOSION REGULATIONS AND AGENCIES

In each jurisdiction, there are three principal bodies that govern the fire and explosion regulations applicable to the oil and gas industry. The requirements in this IRP are consistent with the legislation, regulations, guidelines, codes, and standards established by the responsible organizations summarized below.

1. **Occupational Health and Safety Regulators**
   These agencies have primary responsibility for fire and explosion regulations. The regulations focus on ensuring the health and safety of the workforce (e.g., Alberta Workplace Health and Safety, Workers' Compensation Board of British Columbia, Saskatchewan Labour, etc.).
2. **Energy Regulators**
   Implicitly, through guides and directives focused on well surface and sub-surface equipment standards/procedures, energy regulators mitigate fire and explosion hazards (e.g., Alberta Energy and Utilities Board, British Columbia Oil and Gas Commission, Saskatchewan Industry and Resources, National Energy Board, etc.)
3. **Government Ministries Responsible for Safety and Fire Codes**
   Nationally and provincially, appointed ministries have responsibility for overseeing fire protection and the safe design, manufacture, construction, installation, operation and maintenance of buildings, electrical systems, gas systems, pressure equipment, etc. The focus is on ensuring equipment and structures meet definitive standards designed to ensure safety and fire protection.

A.1.2 APPLICABLE INDUSTRY RECOMMENDED PRACTICES

As outlined below, a number of organizations develop recommended practices and standards that directly or indirectly address fire and explosion prevention.

1. **Enform**
   Member associations identify and develop best practices relevant to many different aspects of safety in the upstream petroleum industry.

2. **Canadian Standards Association (CSA)**
   The CSA develops a wide range of standards and specifications that apply to the safety of oil and gas operations. Regulatory agencies frequently name specific CSA standards as a requirement.

3. **Other International Organizations**
   A number of other international organizations also develop recommended practices and standards that are relevant to this industry and fire and explosion safety. The IRP18 committee reviewed pertinent documents published by the organizations listed here:
   - American Gas Association (AGA)
   - American Petroleum Institute (API)
   - American Standard for Testing and Materials (ASTM)
   - National Fire Protection Association (NFPA)

- Underwriters Laboratories (UL)
- United Kingdom Offshore Operators Association (UKOOA)

A.1.3 MANUFACTURERS' SPECIFICATIONS

Legislation, regulations, guides and standards applicable to Western Canadian upstream oil and gas operations, require the industry to be knowledgeable of manufacturers' specifications, adhere to them, and have them available on the work site.

A manufacturer's specifications are the written specifications, instructions or recommendations, if any, of the manufacturer of equipment or supplies, that describe how the equipment or supplies are to be erected, installed, assembled, started, operated, handled, stored, stopped, calibrated, adjusted, maintained, repaired or dismantled, including a manufacturer's instruction, operating or maintenance manual or drawings for the equipment.

Following manufacturers' specifications for the equipment and supplies used in the upstream industry is fundamental to the prevention of fires and explosions. Such specifications are critical to:

- suitable equipment and supply choices;
- effective training;
- proper maintenance;
- appropriate material storage and handling; and
- the correct and safe use of equipment and supplies.

A.1.4 ENGINEERING CERTIFICATIONS

Those responsible for planning and supervising upstream oil and gas industry work should be familiar with situations that require the use of certified equipment, and they should comply with all applicable regulations. Certification of equipment by a professional engineer implies that it is fit for the purpose and safe for the workers when used properly. Worker understanding of such relevant specifications is fundamental to fire and explosion prevention.

A.1.5 INCIDENT REPORTING

Regulatory agencies across Canada require the reporting of unplanned or uncontrolled explosions or fires that cause or have the potential to cause serious injuries.

Accordingly, appropriate reporting protocols must be followed in each jurisdiction. A summary of the incident reporting requirements for Western Canadian jurisdictions is included in the regulatory summary chart included in this appendix.

Industry and regulators are encouraged to continue to contribute to the understanding of this issue by sharing information about fire and explosion incidents and near misses through Enform.

A.1.5 INDUSTRY AND REGULATORY COOPERATION

This IRP encourages continued cooperation between industry and regulatory agencies. Experience shows that a strategic-based approach will advance change more rapidly and effectively than it would be possible to achieve through regulatory enforcement on a case-to-case basis.

A.2 REGULATORY SUMMARY

The chart that follows summarizes the applicable regulations, codes, and standards relevant to fire and explosion safety.

Regulatory Requirement	Alberta	British Columbia	Saskatchewan
Blowout Prevention and Control Equipment	OHS Code – Part 37 EUB Regulations Sections 8.130 - 8.143	Drilling and Production Regulations Part 7, Div 2, Sections 20 - 24	OGR Section 64
Communication of Workplace Hazards	Hazardous Products Act (Canada) Workplace Hazardous Materials Information System (WHMIS) OHS Code – Part 29	Hazardous Products Act (Canada) Workplace Hazardous Materials Information System (WHMIS) OHS Regulation – Part 5.6 & 5.7	Hazardous Products Act (Canada) Workplace Hazardous Materials Information System (WHMIS) OH&S Regulations – Part XII, Sections 322, 325 - 327
Confined Space Entry	OHS Code – Part 5 EUB Directives 36 & 37	Workers Compensation Act – Part 9.1 - 9.51 OHS Regulation – Part 10	OH&S Regulations Part XVIII, Sections 266 - 275
Control of Ignition Sources	OHS Code – Part 10	OHS Regulation – Part 23 Sections 23.6 & 23.8 BC Electrical Code Drilling & Production Regs - Part 7, Sections 59 - 62	OH&S Regulations Part XXV – Section 367
Equipment Spacing and Rig-up	OHS Code – Part 10 EUB Regs Section 8.148 EUB Directives 36 & 37 Safety Codes Act Code for Electrical Installations at Oil and Gas Facilities	Drilling & Production Regs Part 4, Div 4, Section 30 Part 7, Sections 60 - 62 Oil and Gas Handbook (OGC) Section 6 Workers Compensation Act – Sections 23.7 - 23.8	OGR Section 53

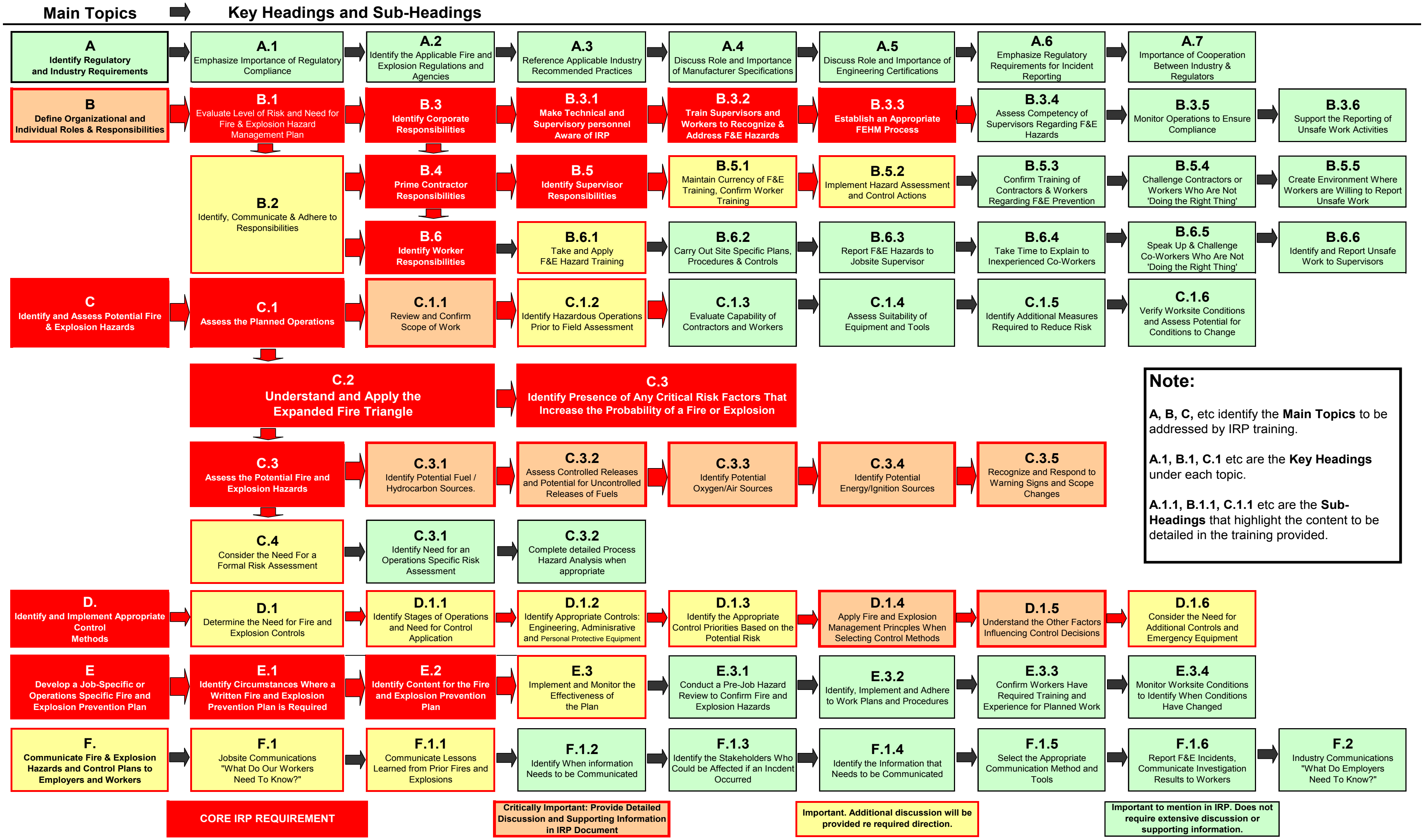
Regulatory Requirement	Alberta	British Columbia	Saskatchewan
Equipment Specifications and Inspections	OHS Code – Parts 3 and 37 EUB Directive 36 CAODC Recommended Practices	Drilling and Production Regulations Parts 23-30 CAODC Recommended Practices	OH&S Regulations Part I Section 6 and Part XXIX, Sections 414 - 438 CAODC Recommended Practices
Fire and Explosion Hazards	OHS Code – Part 10 EUB Directive 033		OH&S Regulations Part XXV Sections 359 - 374
Fluid Handling and Storage	Transportation of Dangerous Goods Regulations (TDG) OHS Code – Parts 4, 26 and 29 IRP Volumes 4, 8 and 14 Transportation of Dangerous Goods Regulation	Transportation of Dangerous Goods Regulations (TDG) OH&S Parts 5.27 to 5.35 IRP Volumes 4, 8 and 14 Transportation of Dangerous Goods Regulation	Transportation of Dangerous Goods Regulations (TDG) OHS Regulations Sections 58, 424 and 441 OGR – Section 59 IRP Volumes 4, 8 and 14 Transportation of Dangerous Goods Regulation
Hazard Identification, Assessment and Control	OHS Code – Part 2	OH&S Part 4.69	OH&S Regulations – Part III, Section 22
Locking Out and Tagging	OHS Code – Part 15	OHS Regulation – Part 10	OH&S Regulations Part X – Section 139
Maintenance and Repair of Equipment		OHS Regulation – Part 23	OH&S Regulations Part III, Section 25
Monitoring Equipment	OHS Code – Parts 10 and 37	Workers Compensation Act – Part 3, Div 17, Section 225	No regulations. However, due diligence is required.
Personal Protective Equipment	OHS Code – Part 18	OHS Regulation – Part 8	OH&S Regulations – Part VII
Purging, Venting and Inerting		OHS Regulation – Part 9,	OH&S Regulations – Part

Regulatory Requirement	Alberta	British Columbia	Saskatchewan
		Section 9.27 – 9.29	XVIII Section 273
Reporting of Fire and Explosion Incidents	OHS Act Sections 18 and 35	Workers Compensation Act – Part 3, Div 10 OHS Regulation Part 33	OH&S Regulations - Part II, Sec 8 OH&S Regulations - Part II, Sec 9.2
Rig and Wellsite Electrical	Electrical Protection Act Canadian Electric Code Part 1 Safety Codes Act Code for Electrical Installations at Oil and Gas Facilities	Electrical Protection Act Canadian Electric Code Part 1 Workers Compensation Act – Part 19 BC Electrical Code Workers Compensation Act – Section 23.6	Electrical Protection Act Canadian Electric Code Part 1 OH&S Part XXX, Sections 450 - 467 SaskPower Pub 2-035
Safe Work Procedures		Workers Compensation Act – Section 23.5	OH&S Regulations Part XXV Sections 363
Worker Training and Competency Requirements	Federal WHMIS-TDG Regulation OHS Code – Part 37, Section 751 IRP Volume 7	Federal WHMIS-TDG Regulation Drilling and Production Regulations Part 4, Div 1 & 2, Sections 23 and 29 IRP Volume 7	Federal WHMIS-TDG Regulation OH&S Regulations Part III, Section 19 Part XXIX, Section 412 IRP Volume 7

NOTE: The majority of these requirements are identified in the Safety Management and Regulatory Awareness for Wellsite Supervision training offered through Enform. Additional details can be obtained by referencing the course notes.

APPENDIX B
IRP 18 DACUM: SUMMARY DIAGRAM

IRP 18 DACUM: SUMMARY DIAGRAM



Main Topics → **Key Headings and Sub-Headings**

A Identify Regulatory and Industry Requirements → **A.1** Emphasize Importance of Regulatory Compliance → **A.2** Identify the Applicable Fire and Explosion Regulations and Agencies → **A.3** Reference Applicable Industry Recommended Practices → **A.4** Discuss Role and Importance of Manufacturer Specifications → **A.5** Discuss Role and Importance of Engineering Certifications → **A.6** Emphasize Regulatory Requirements for Incident Reporting → **A.7** Importance of Cooperation Between Industry & Regulators

B Define Organizational and Individual Roles & Responsibilities → **B.1** Evaluate Level of Risk and Need for Fire & Explosion Hazard Management Plan → **B.3** Identify Corporate Responsibilities → **B.3.1** Make Technical and Supervisory personnel Aware of IRP → **B.3.2** Train Supervisors and Workers to Recognize & Address F&E Hazards → **B.3.3** Establish an Appropriate FEHM Process → **B.3.4** Assess Competency of Supervisors Regarding F&E Hazards → **B.3.5** Monitor Operations to Ensure Compliance → **B.3.6** Support the Reporting of Unsafe Work Activities

B.2 Identify, Communicate & Adhere to Responsibilities → **B.4** Prime Contractor Responsibilities → **B.5** Identify Supervisor Responsibilities → **B.5.1** Maintain Currency of F&E Training, Confirm Worker Training → **B.5.2** Implement Hazard Assessment and Control Actions → **B.5.3** Confirm Training of Contractors & Workers Regarding F&E Prevention → **B.5.4** Challenge Contractors or Workers Who Are Not 'Doing the Right Thing' → **B.5.5** Create Environment Where Workers are Willing to Report Unsafe Work

B.2 → **B.6** Identify Worker Responsibilities → **B.6.1** Take and Apply F&E Hazard Training → **B.6.2** Carry Out Site Specific Plans, Procedures & Controls → **B.6.3** Report F&E Hazards to Jobsite Supervisor → **B.6.4** Take Time to Explain to Inexperienced Co-Workers → **B.6.5** Speak Up & Challenge Co-Workers Who Are Not 'Doing the Right Thing' → **B.6.6** Identify and Report Unsafe Work to Supervisors

C Identify and Assess Potential Fire & Explosion Hazards → **C.1** Assess the Planned Operations → **C.1.1** Review and Confirm Scope of Work → **C.1.2** Identify Hazardous Operations Prior to Field Assessment → **C.1.3** Evaluate Capability of Contractors and Workers → **C.1.4** Assess Suitability of Equipment and Tools → **C.1.5** Identify Additional Measures Required to Reduce Risk → **C.1.6** Verify Worksite Conditions and Assess Potential for Conditions to Change

C.2 Understand and Apply the Expanded Fire Triangle → **C.3** Identify Presence of Any Critical Risk Factors That Increase the Probability of a Fire or Explosion

C.3 Assess the Potential Fire and Explosion Hazards → **C.3.1** Identify Potential Fuel / Hydrocarbon Sources. → **C.3.2** Assess Controlled Releases and Potential for Uncontrolled Releases of Fuels → **C.3.3** Identify Potential Oxygen/Air Sources → **C.3.4** Identify Potential Energy/Ignition Sources → **C.3.5** Recognize and Respond to Warning Signs and Scope Changes

C.4 Consider the Need For a Formal Risk Assessment → **C.3.1** Identify Need for an Operations Specific Risk Assessment → **C.3.2** Complete detailed Process Hazard Analysis when appropriate

D. Identify and Implement Appropriate Control Methods → **D.1** Determine the Need for Fire and Explosion Controls → **D.1.1** Identify Stages of Operations and Need for Control Application → **D.1.2** Identify Appropriate Controls: Engineering, Adminisrative and Personal Protective Equipment → **D.1.3** Identify the Appropriate Control Priorities Based on the Potential Risk → **D.1.4** Apply Fire and Explosion Management Principles When Selecting Control Methods → **D.1.5** Understand the Other Factors Influencing Control Decisions → **D.1.6** Consider the Need for Additional Controls and Emergency Equipment

E Develop a Job-Specific or Operations Specific Fire and Explosion Prevention Plan → **E.1** Identify Circumstances Where a Written Fire and Explosion Prevention Plan is Required → **E.2** Identify Content for the Fire and Explosion Prevention Plan → **E.3** Implement and Monitor the Effectiveness of the Plan → **E.3.1** Conduct a Pre-Job Hazard Review to Confirm Fire and Explosion Hazards → **E.3.2** Identify, Implement and Adhere to Work Plans and Procedures → **E.3.3** Confirm Workers Have Required Training and Experience for Planned Work → **E.3.4** Monitor Worksite Conditions to Identify When Conditions Have Changed

F. Communicate Fire & Explosion Hazards and Control Plans to Employers and Workers → **F.1** Jobsite Communications "What Do Our Workers Need To Know?" → **F.1.1** Communicate Lessons Learned from Prior Fires and Explosions → **F.1.2** Identify When information Needs to be Communicated → **F.1.3** Identify the Stakeholders Who Could be Affected if an Incdent Occurred → **F.1.4** Identify the Information that Needs to be Communicated → **F.1.5** Select the Appropriate Communication Method and Tools → **F.1.6** Report F&E Incidents, Communicate Investigation Results to Workers → **F.2** Industry Communications "What Do Employers Need To Know?"

🟥 CORE IRP REQUIREMENT

🟧 Critically Important: Provide Detailed Discussion and Supporting Information in IRP Document

🟨 Important. Additional discussion will be provided re required direction.

🟩 Important to mention in IRP. Does not require extensive discussion or supporting information.

Note:

A, B, C, etc identify the **Main Topics** to be addressed by IRP training.

A.1, B.1, C.1 etc are the **Key Headings** under each topic.

A.1.1, B.1.1, C.1.1 etc are the **Sub-Headings** that highlight the content to be detailed in the training provided.

APPENDIX C
GUIDELINES FOR FIRE AND EXPLOSION HAZARD MANAGEMENT TRAINING

C.1 INTRODUCTION

Petroleum industry personnel **must be** provided training so that they are better equipped to address fire and explosion hazards. Key considerations include:

- Training is essential and must be geared to the employee's responsibilities and experience level.
- To ensure that the basis for personnel training is standardized. The following core information, **including this Appendix**, must be referenced when developing worker training:
  - APPENDIX B provides training developers with a recommended outline for developing a curriculum or DACUM to address the expectations identified in this IRP.
  - Current technical information specific to the expanded fire triangle, as well as fire and explosion case studies are available through www.firesandexplosions.ca.
- Training should be separated into two levels:

1. Advanced training for planners, designers, managers, and supervisors; and
2. Basic training for entry level workers.

- All training programs must assess the participants' knowledge of required content on course completion.

The following information is intended to provide guidelines to employers and training developers on the required competencies for each of the two training levels.

C.2 ADVANCED LEVEL TRAINING

C.2.1 IDENTIFYING POTENTIAL FIRE AND EXPLOSION HAZARDS

As a minimum, training needs to cover the following areas relative to the expanded fire triangle (see FIGURE 7, pg. 21).

1. Fuels - Hydrocarbons

Personnel need to be able to identify the presence and nature of fuels-hydrocarbons. This includes the knowledge required to answer the following questions.

- Which operations require or will encounter fuels-hydrocarbons?
- What are the properties of these fuels-hydrocarbons and how do they create a hazard?
  - Specific gravity and vapor density?
  - Flash point, ignition temperatures?
  - Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL)?
  - Phase change?
  - Toxic effects?
  - Oxidized fuels?

- How can these properties be confirmed? How can they be measured?
- How are these properties affected by surface versus downhole operations?
- Are there fuels-hydrocarbons present now? Were fuels/hydrocarbons present at any time previously? If so, could residuals still be present?
- Have the fuels-hydrocarbons been removed? What evidence is this based on?
- Do operations involve adding fuels-hydrocarbons?
- If fuels-hydrocarbons are present, what form are they in? Can they change? How?
- Is there something unique about the state and/or types of fuels-hydrocarbons that may make them more or less dangerous?

2. Oxygen-Air

Personnel need to be able to identify the presence of oxygen-air. This includes the knowledge required to answer the following questions.

- How can oxygen-air be combined with a fuel?
- How could a fuel source be released into the atmosphere?
- Will oxygen-air be deliberately combined with a fuel source?
- Can oxygen-air be inadvertently introduced to a closed system containing a fuel source?
- Can the fuels contain or be exposed to chemicals or products that are potential oxygen sources such as: weathered hydrocarbons, chemical additives, ester-based greases or on-site generated nitrogen?
- What potential exists for fuels-hydrocarbons to be released from closed systems to the atmosphere?

3. Energy-Ignition

Personnel need to be able to identify potential sources of energy-ignition. This includes the knowledge required to answer the following questions.

- Have all obvious ignition sources such as open flames, sparks, and heat sources been identified?
- Have “non-obvious” energy sources been considered such as: pressure (also known as the dieseling effect), static discharge, and chemical reactions?
- Have all classified areas been identified, as per the Canadian Electrical Code? Does the equipment to be used meet electrical code requirements?
- Is there potential for low-grade ignition sources (i.e. static charges)? Will there be sufficient energy to ignite a flammable mixture?
- What is the potential for changing conditions to affect minimum ignition energy (MIE)?
- What operations could create non-obvious energy sources such as changes in operating pressure and equipment movements?

C.2.2 FIRE AND EXPLOSION PREVENTION PLAN DEVELOPMENT

As a minimum, training must provide workers with the skills needed to develop and implement an effective plan for addressing identified fire and explosion hazards. Key considerations include the items that follow.

1. **Preparing a Fire and Explosion Prevention Plan**
   Personnel need to have sufficient skill to prepare and implement a site-specific fire and explosion prevention plan. This includes the knowledge required to answer questions such as the following:
   - Is a fire and explosion prevention plan required?
   - What are the key components for an appropriate plan?
   - How can the problems identified be fixed?
   - Have the right controls and protective equipment been selected so that work can be completed safely?
   - How should the plan be communicated and implemented?
   - Is a more formal risk assessment required?
2. **Identifying and Implementing Appropriate Control Methods**
   Personnel need to be able to identify which controls are available to reduce the risk, which control measures are appropriate, and what protective equipment may need to be put in place.

   The following topics provide questions to guide the processes that need to be covered.

   A. Can the fuel be eliminated?
   - How (exactly) do you purge the system to ensure you control the hazards?
   - How effective are the cleaning and/or purging procedures? How can you be certain?
   - What physical barriers can be utilized to prevent fuels-hydrocarbons, and oxygen-air from mixing?

   B. Can the oxygen-air be removed?
   - Is it necessary to use an inert gas to remove the oxygen-air? How can the oxygen level be confirmed?

   C. Can all potential energy-ignition sources be isolated?
   - What procedure will be utilized to prevent obvious energy-ignition sources from being in contact with the fuels-hydrocarbons?
   - What operations could create “non-obvious” energy-ignition sources such as changes in operating pressures and equipment movement?

3. Management of Change

Changing conditions can increase hazards. Personnel need to be able to identify which changes have this potential, and know how to react to such changes. This includes the knowledge required to answer the following questions.

- Are conditions static or dynamic? Could the nature or the characteristics of the energy-ignition source, fuel-hydrocarbon or oxygen-air change at any time during operations?
- Can the proximity of the fuel-hydrocarbon, oxygen-air or energy-ignition sources change?
- How can the conditions be monitored for change?
- What is the response strategy if conditions do change? What are critical deviations from the normal planned and expected operations? When should the entire risk assessment process be re-initiated?

C.3 BASIC LEVEL TRAINING

Workers should have entry-level training to make them better aware of potential fire and explosion hazards on the worksite. This training should equip the worker to understand instructions from supervisors, and assist with hazard assessments and fire and explosion hazard management plans. The training needs to address the topics that follow.

1. Expanded Fire Triangle

Workers need to understand the expanded fire triangle and how and why all three sides are needed for a fire or explosion to occur. They should be able to answer the questions that follow.

- Fuels-hydrocarbons – what is a fuel and where are they typically found on upstream petroleum sites?
- Oxygen-air – what is oxygen and why is it required for fires and explosions?
- Energy-ignition – what is it and what sources are typically found on upstream petroleum sites?

2. Controls

Workers need to have a basic understanding of the three types of controls and how they interact. This includes the knowledge required to answer the following questions:

- What are engineering controls? When and where are they typically used in the life of a project? How do they affect the site? Who uses them?
- What are administrative controls? When and where are they typically used in the life of a project? How do they affect workers? Who carries them out?
- What are protective controls? Why are they needed? How are they used effectively?

3. Communications

Workers need to know what tools are used to communicate fire and explosion hazards on the job site. The training should demonstrate how the tools are used and how they directly affect the worker.

APPENDIX D
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