CANADIAN ASSOCIATION OF PETROLEUM PRODUCERS

BEST MANAGEMENT PRACTICES

Facility Flare Reduction

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The Canadian Association of Petroleum Producers (CAPP) represents 150 companies that explore for, develop and produce natural gas, natural gas liquids, crude oil, oil sands, and elemental sulphur throughout Canada. CAPP member companies produce more than 95 per cent of Canada's natural gas and crude oil. CAPP also has 130 associate members that provide a wide range of services that support the upstream crude oil and natural gas industry. Together, these members and associate members are an important part of a $100-billion-a-year national industry that affects the livelihoods of more than half a million Canadians.

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Overview

Flaring is a combustion process used to dispose of natural gases (sweet gas, sour gas, acid gas or other hydrocarbon vapour) through a vertical stack. Facilities in the oil and gas industry may routinely flare small volumes of natural gas that are technically difficult and uneconomic to conserve. Flaring is also an important safety measure, used to safely dispose of natural gas that would otherwise pose a hazard to workers, nearby residents and facility equipment during non-routine occurrences like emergencies, process upsets, equipment failure and power failure conditions. Flaring is recognized as an important issue for the upstream oil and gas industry for health, safety and environmental impacts, as well as conservation of energy resources.

Recognizing these concerns, the Canadian Association of Petroleum Producers (CAPP) asked the Clean Air Strategic Alliance (CASA) to form a flaring task group. The CASA Flaring and Venting Project Team was formed in 1997, consisting of industry, government, and environmental non-government organizations. The CASA Flaring and Venting Project Team established a solution gas management framework with reporting and conservation requirements that came into effect in 1998 with updates on the management framework done on a regular basis. These requirements have led to a significant reduction in solution gas flaring (71.9% reduction from the 1996 baseline or an actual volume reduction from 1340 x 10^6 to 376 x 10^6 m^3/year at the end of 2005). CASA continues to review the success of flare reduction programs in Alberta, and is expected to modify targets to drive further reductions. This Best Management Practice (BMP) is a direct outcome of a CASA recommendation.

The long-term industry objective is to eliminate routine flaring and minimize non-routine flaring. Although BMP modifications in procedures and design can reduce the frequency of non-routine flaring, emergency flaring is still the most fail-safe operational measure available to prevent equipment overpressure, catastrophic equipment failure and loss of human life. However, flaring simply because it is convenient to do so or because it has been a long-standing industry operating practice is unacceptable.

In Alberta, the Alberta Energy and Utilities Board (EUB) has designated permissible flare volumes depending on facility size and type in order to provide facilities with an operational buffer in the event of unforeseen flare events, as shown in Table 1. These allowable flare volumes must not be used as justification for delay or inaction to address chronic or known flaring causes or as justification to be used as "flare up to" limits. Facility operators and designers should use this BMP as a means to reduce flare volumes.

Table 1: Allowable Flare Volumes for Alberta Oil and Gas Facilities

Facility Type	Inlet Gas Rate Per Year	EUB Regulation[1]	Allowable Flare Volume[2]
Gas plant first year operation	< 1.0 10^9 m^3	D060, 5.2	1% of raw gas receipts
Gas plant	< 1.0 10^9 m^3	D060, 5.2	0.5% of raw gas receipts
Gas plant	> 1.0 10^9 m^3	D060, 5.2	Greater of: 0.2% of raw gas receipts or 5.0 10^6 m^3/year
Gas battery		D060, 4.2	Notify EUB Field Centre if: Flare event > 30 x 10^3 m^3 or > 4 hours in duration
Oil and bitumen battery solution gas flaring		D060, 2.5	Unique per site based on economic analysis[3]

[1]EUB Directive 060: Upstream Petroleum Industry Flaring, Incinerating and Venting (November 16, 2006)
[2]Excludes flared acid gas and fuel gas used for flare pilot and flare purge
[3]Sites with volumes >900 m^3/day require economic analysis for conservation

In addition to the limits in Table 1, gas plants must not exceed six major flare events in any consecutive six month period (6 in 6). As per EUB Directive 060 Section 5.3, major flare events are defined as:

- 100 10^3 m^3 or more per event for plants with approved inlet capacity of > 500 10^3 m^3 /d
- 20% of plant design daily inlet or more per event for plants with approved inlet capacity of 150 to 500 10^3 m^3/d
- 30 10^3 m^3 or more per event for plants with approved inlet capacity of < 150 10^3 m^3/d

This BMP provides design and operating staff with a recommended approach to identify routine and non-routine flare sources and quantities, and assesses the opportunity for reduction of flare volumes and frequency at their operated facilities. The guidance provided in this BMP can also apply to routine and non-routine venting.

Since this BMP is applicable to the upstream oil and gas industry Canada-wide, it is the responsibility of the facility operator to ensure compliance with current flare volume limits set by the respective provincial authority. In the event that flare limits have not been established for other provincial jurisdictions, the values in Table 1 shall be used as guideline quantities.

By identifying flare sources and gaps between facility design and BMP design principles, design staff will be able to identify equipment and process modifications necessary for reducing flare volumes and frequency for both existing and new facilities. Similarly, operations staff will be able to identify new operating practices needed for flare reduction by reviewing current flare sources and identifying gaps between current operating practices and BMP operating practices.

This BMP is applicable to all upstream oil and gas facilities. For the purpose of this BMP, facilities will include:

- Oil and bitumen batteries
- Gas batteries
- Oil processing plants
- Compressor stations
- Gas plants

Each facility is unique in terms of types of processes, equipment, age of design, products, complexity and level of support staff. For this reason, the Flare Reduction Plans (FRPs) developed using this BMP process will also be unique such that the most beneficial options for each facility are identified and implemented first.

This BMP is also applicable if an incinerator is used instead of a flare for disposal of the gas.

Throughout this document, the use of the words 'must', 'shall', 'required', 'recommended' and 'should' are to be interpreted as follows:

- Must, shall or required: specified action or item is a regulated requirement
- Recommended: specified action or item is a recommended practice
- Should: specified action or item is a good practice

This BMP is based on current available technology, current regulatory requirements and accepted industry practices. As technology advances, the BMP will be updated and there will be more opportunities for routine and non-routine flare reduction.

Although the BMP process outlined in this document may be used to achieve compliance with regulated design, operating and air quality requirements, its main focus is on continuous improvement. As technologies improve and the price of energy increases, operators should re-evaluate the feasibility of reducing flaring beyond regulatory requirements on a continuous basis.

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Glossary

Acid gas: Waste gas produced as a by-product of sour gas sweetening. Usually contains CO_2 and H_2S with very little or no hydrocarbon vapour.

AENV: Alberta Environment. Environmental regulatory body in Alberta.

BDV: Blow Down Valve. Used to depressurize piping or equipment to a lower pressure.

BMP: Best Management Practice.

CAPP: Canadian Association of Petroleum Producers.

CASA: Clean Air Strategic Alliance (of Alberta).

CO_2E: Carbon Dioxide Equivalent. All greenhouse gas emissions may be converted to an equivalent mass of carbon dioxide using published 100 year global warming potential (GWP) factors. For example, 1 tonne of methane (CH_4) is equivalent to 21 tonnes of CO_2E and 1 tonne of nitrous oxide (N_2O) is equivalent to 310 tonnes of CO_2E.

Compressor station: Facility used to compress and re-compress gas to meet pipeline (sales or gathering) requirements. Gas dehydration is sometimes part of the facility.

Emergency flaring: Flaring that is required to avoid possible human injury or property loss resulting from explosion, fire or catastrophic equipment failure. Piping and equipment systems are depressurized during emergency flaring.

ESDV: Emergency Shut Down Valve. Valve used to isolate the facility from inlet feed and outlet discharge. An ESDV can be activated automatically (via process computer) or manually.

EUB: Energy and Utilities Board (of Alberta).

FCV: Flow Control Valve. An automatic valve used to control a process stream at a certain constant flow rate. Usually pneumatically operated.

Flare baseline year: For facilities in operation in 2005, the flare baseline year is 2005. For new facilities in operation after January 1, 2006, the flare baseline year is the first year of operation.

Flare event: The occurrence of flaring at a given facility.

Flare source: The origin of the flared gas. The point at which gas is discharged into the flare piping system.

FMS: Flare Management Strategy. Procedural and design methods (for a given facility) used to reduce or eliminate the effects of flaring on health, safety and the environment.

FRP: Flare Reduction Plan. Involves the determination of flare properties and flare reduction assessment in order to develop operational procedures and design changes that are economic and technically feasible and will result in reduced flare volumes or frequency at a given facility.

Fugitive emissions: Small, unintentional vapour emissions (to the atmosphere) from valves, fittings, compressor and pump seals, joints and other equipment.

Gas battery: Facility used to de-water, meter, process and compress wellhead gas of which the primary product is natural gas.

Gas plant: Facility used to process natural gas gathered from wellheads, gas batteries, compressor stations or other gas plants. Processes may include: hydrocarbon liquid extraction, gas sweetening, sulphur recovery, dehydration and compression.

Hazard: Anything that can cause harm to human health, the environment, property, facility, products and reputation. Hazards present a danger and require careful management to minimize risk.

HazOp review: Hazard and Operability review. A detailed operational and process design review which identifies and analyzes hazardous plant operating conditions brought on by instrument failure, process control failure, utility failure or operator error.

LCV: Level Control Valve. An automatic valve used to control the liquid level within a process vessel. Used to initiate and stop the discharge of liquid from a vessel. Usually pneumatically operated.

LHV: Lower (or net) Heating Value. The amount of heat liberated when a given volume of hydrocarbon is burned. Typical units are MJ/m^3. For gross heating value (GHV), the water produced by the combustion is in liquid form, while for LHV, the water is in the gaseous state. LHV is used for flaring dispersion calculations.

MW: Molecular Weight. Typical units are kg/kg-mol.

Non-routine flaring: Flare events that are intermittent and infrequent and are the result of conditions outside normal steady state plant process and equipment operations. Examples include: PSV overpressure, loss of electrical power, process upset, operation error, equipment de-pressure for maintenance, plant startup and shutdown, etc.

Oil battery: Facility used to de-water and de-gas wellhead oil emulsion where the primary product is crude oil.

PCV: Pressure Control Valve. An automatic valve used to control a process stream at a certain constant pressure. Usually pneumatically operated.

PID: Piping and Instrumentation Drawing. A precise schematic representation of all equipment, processes, instrumentation, piping and valves associated with a particular facility.

Planned maintenance flaring: The intentional de-pressurization of processing facilities to the flare in order to provide safe working conditions for the maintenance of process equipment or piping systems.

PRV: Pressure Relief Valve. Also known as Pressure Safety Valve (PSV). A self-actuating valve designed to open automatically once its set pressure is reached (at its inlet). This valve will automatically close once its upstream or inlet pressure reaches 90% of its set pressure.

Purge gas: A fuel gas or non-condensable inert gas added to the flare piping system in order to evacuate and prevent air from entering the flare system. The use of adequate purge gas prevents flame burn-back and explosion risk inside the flare system.

Risk: The possibility of danger. Risk is a measure of both consequence and likelihood (i.e., probability) of an undesired event.

Routine flaring: Continuous or intermittent flaring that occurs on a regular basis due to normal operation of a plant process. Examples include: glycol dehydrator reboiler still vapour flaring, storage tank vapour flaring, flash tank vapour flaring, solution gas flaring, etc.

sm^3: Standard cubic metres. Vapour volume calculated at 15 ^oC and 101.325 kPa (absolute).

Solution gas: Hydrocarbon gas originally in solution (i.e., dissolved in) with the produced oil at the wellhead. This gas comes out of solution when the oil pressure is reduced significantly (approximately atmospheric conditions).

Sour gas: Natural gas containing H_2S (hydrogen sulphide) and CO_2 (carbon dioxide). For air dispersion modelling purposes, sour gas is defined as having an H_2S content of at least 1% (mole percent). The EUB classification of sour gas can be below 1% depending on site specific health and safety hazards.

Sweet gas: Natural gas containing no or trace amounts (less than 10 ppm) of H_2S.

Upset flaring: Occurs when one or more process parameters fall outside the allowable operating or design limits, resulting in potential off-spec product. Upset flaring can be isolated to specific plant equipment or process and stops when normal process parameters are achieved.

Venting: The direct release of natural gas or process vapour into the atmosphere.

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1 Use of Best Management Practice (BMP)

This BMP will serve as a process or framework to be used by design and operating staff to identify feasible options for the reduction of flare volumes and frequency at their operated facilities. Sections of the BMP are briefly described below.

Section 2 Flare Management Strategy provides a discussion of the regulatory elements of developing a facility flare management strategy and introduces the concept of continuous improvement in flare reduction. Flare reduction and continuous improvement are discussed in detail in subsequent sections.

Section 3 Determine Flare Properties provides guidance on locating actual and potential flare source events, classification of the flare source as routine or non-routine, quantification of flare volume and duration, and determining flare causes.

Section 4 Flare Reduction Assessment provides guidance on identifying and assessing options to reduce flaring, and includes identifying gaps between current design/operation versus BMPs, economic assessments of reduction projects, and the prioritization, implementation and documentation of reduction projects.

Section 5 BMP Design Considerations provides guidance on design considerations to prevent, reduce or partially eliminate routine and non-routine flare volumes and frequency.

Section 6 BMP Operating Considerations provides guidance on operating considerations to prevent, reduce or partially eliminate routine and non-routine flare volumes and frequency.

Appendix A Flare Quantification Requirements provides guidance on quantifying all sources of flares.

2 Flare Management Strategy

The primary objective of this BMP is to provide a process for enabling facilities to reduce flare volumes and events with an overall Flare Management Strategy (FMS). Although it is recognized that flare stacks are an essential part of safe facility design and operation, all operators are expected to work towards the elimination of routine flaring and reduction of non-routine flare events when economically and technically feasible.

Figure 1 outlines the recommended steps for developing a FMS for a specific facility. There are three main elements in the systematic approach:

1) Design and Operating Compliance
2) Sour Flare Air Dispersion Modelling
3) Flare Reduction and Continuous Improvement

The three elements are integral to each other and critical to the success of a FMS.

Developing a Flare Reduction Plan (FRP) is an essential part of the overall FMS for a facility. As shown in Figure 1, the two main steps in developing a facility FRP are:

1) Determine Flare Properties
2) Flare Reduction Assessment

2.1 Design and Operating Compliance

All flare systems must be designed and operated in accordance with all applicable engineering and safety standards. These include (but are not limited to):

- American Petroleum Institute (API) Recommended Practice 521: Guide for Pressure-Relieving and Depressuring Systems.
- API Recommended Practice 520: Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries.
- API Recommended Practice 537: Flare Details for General Refinery and Petrochemical Service.
- ASME BPV (American Society of Mechanical Engineers Boiler and Pressure Vessel) Code: Section VIII, Division 1 – Design and Fabrication of Pressure Vessels
- ASME B31.3: Process Piping Design
- Alberta Boilers Safety Association (ABSA) Safety Codes Act and Pressure Equipment Safety Regulations (PESRs)
- Forest and Prairie Protection Regulations AR 135/72
- EUB Directive 038: Noise Control Directive User Guide
- EUB Directive 060: Upstream Petroleum Industry Flaring, Incinerating and Venting
- Occupational Safety and Health Association (OSHA) requirements

- ANSI / ISA – S84.01: Application of SIS (Safety Instrumented Systems) for the Process Industries
- IEC (International Electrotechnical Commission) 61555: Functional SIS for the Process Industry Sector
- SIL (Safety Integrity Level) analysis (as per ANSI / ISA – S84.01 and IEC 61508)
- PHA (Process Hazard Analysis)
- HazOp Review
- Canadian Standards Association (CSA) C22.1 Electrical

Compliance with the above is required in order to ensure safety of personnel, prevent equipment damage and minimize risk hazard. All facilities must demonstrate (to regulatory bodies) compliance to all applicable engineering and safety standards and capability to meet all regulatory operating requirements prior to facility start-up and operation.

2.2 Sour Flare Air Dispersion Modelling

Facilities must meet the requirements set forth in the Alberta Ambient Air Quality Objectives (H_2S and SO_2 for sour gas flaring) and the *Environmental Protection and Enhancement Act (EPEA) – Substance Release Regulation* (opacity or black smoke), both issued by Alberta Environment (AENV).

Air dispersion modelling must be done in accordance with *AENV Air Quality Model Guideline* (March 2003 as amended) and *Emergency/Process Upset Flaring Management: Modelling Guidance* (March 2003 as amended) and EUB Directive 060 Section 7.12. All dispersion modelling must reflect worst case operating parameters, representative natural gas compositions, maximum license limits, local meteorology and surrounding topography unique to the facility being modelled.

2.3 Flare Reduction and Continuous Improvement

This BMP provides the framework or process for achieving flare reduction. Although this process may be used to achieve compliance with regulated design, operating and air quality requirements, its main focus is on continuous improvement.

As technologies improve and the price of energy increases, operators should re-evaluate the feasibility of reducing flaring beyond regulatory requirements on a continuous basis.

Figure 1: FACILITY FLARE MANAGEMENT STRATEGY

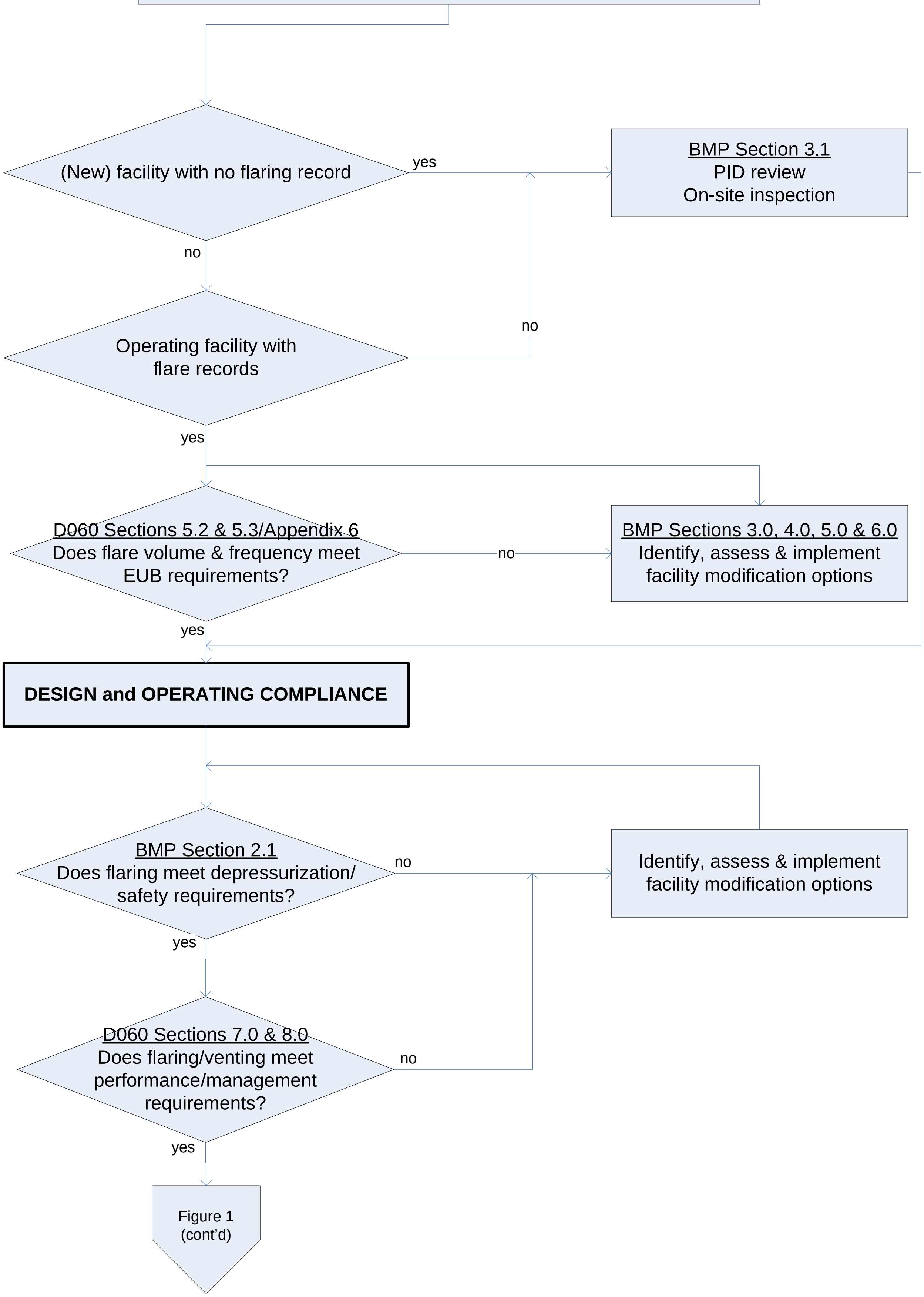
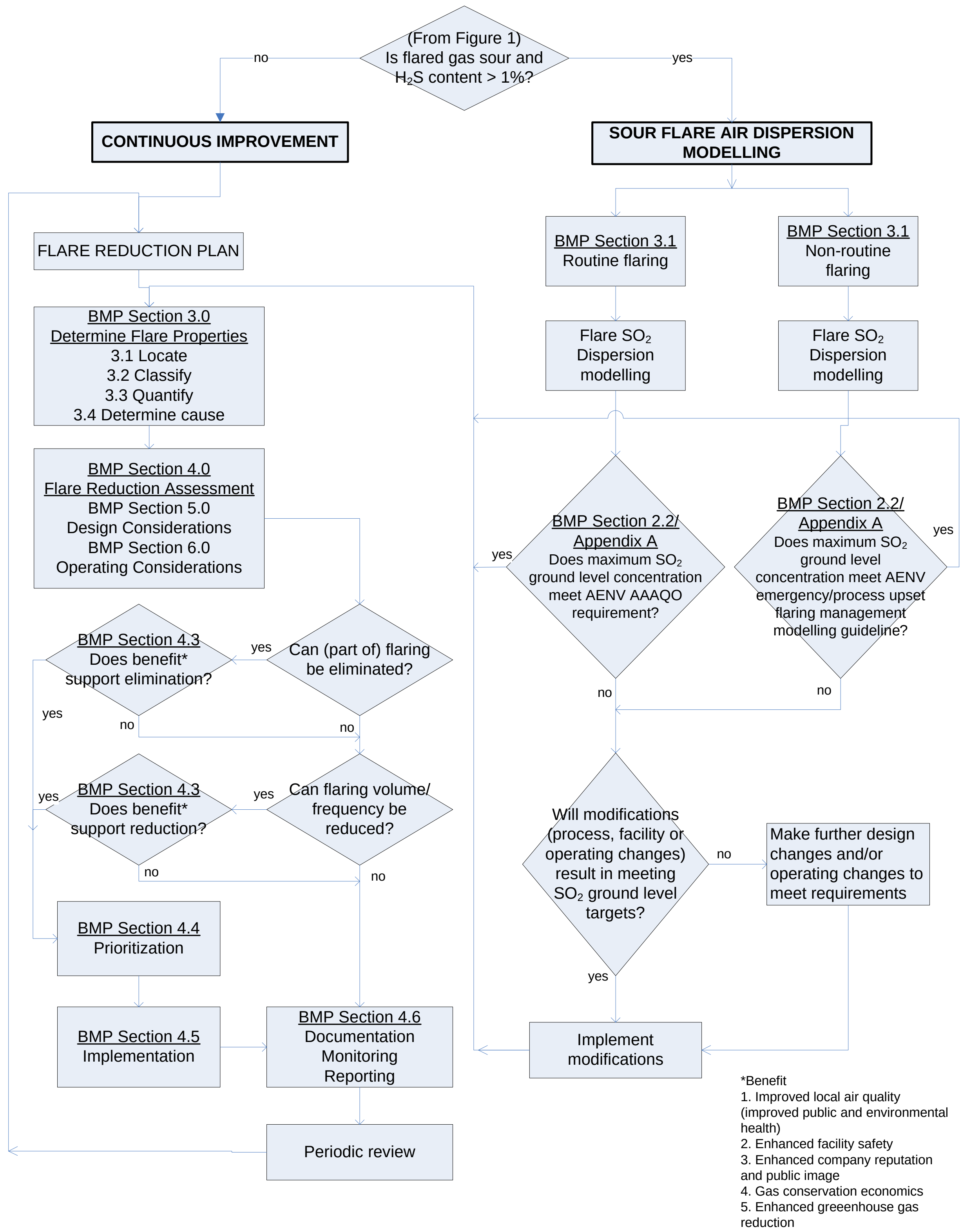


Figure 1(cont'd): FACILITY FLARE MANAGEMENT STRATEGY



3 Determine Flare Properties

In the development of a FRP, flare properties should be determined first for actual flare events and then for potential flare events. By investigating and implementing the BMP to actual flare events first, immediate reductions in flaring will be evident.

Determining flare properties for actual and potential flare events will involve the following four tasks:

1) Locate flare sources
2) Classify flare sources (routine and/or non-routine)
3) Quantify flare events (rate, duration and volume) and flare baseline year volume
4) Determine cause of flare events

3.1 Locate Flare Sources

In order to facilitate the reporting and determination of flare causes and volumes, flare sources must be located at each facility. Table 2 lists typical routine and non-routine flare source locations at various facilities. The sources listed in Table 2 are typical but not all-inclusive. It is the responsibility of the facility operator to identify any unique flare sources at their facility.

Table 2: Typical Facility Flare Source Locations (Routine and Non-routine)

Facility Type	Process/Equipment	Routine Flare Source[1]	Non-routine Flare Source[2]
Oil battery	Inlet separator	PCV	PRV
	Treater	PCV	PRV
	Gas line PRV seat leakage	PRV	
	Process vessel liquid drains		LCV, BDV
	Crude or condensate storage tank	PCV, Vent	
	Vapour recovery compressor	PCV	PRV
	Equipment isolation: maintenance		BDV
	Gas pipeline pigging		BDV
Gas battery	Inlet piping		ESDV
	Inlet separator	PCV	PRV
	Gas line PRV seat leakage	PRV	
	Process vessels containing vapours	PCV	PRV
	Process vessel liquid drains		LCV, BDV
	Compressor suction scrubber	PCV	PRV
	Fuel gas scrubber	PCV	PRV
	Compressor discharge		PRV
	Compressor valve seals/distance piece	PCV	Vent
	Fired line heaters		PRV
	Equipment isolation: maintenance		BDV

Facility Type	Process/Equipment	Routine Flare Source[1]	Non-routine Flare Source[2]
	Gas pipeline pigging		BDV
Gas plant	Inlet piping		ESDV
	Inlet separator	PCV	PRV
	Gas line PRV seat leakage	PRV	
	Process vessels containing vapours	PCV	PRV
	Process vessel liquid drains		LCV, BDV
	Compressor suction scrubber	PCV	PRV
	Fuel gas scrubber	PCV	PRV
	Compressor discharge		PRV
	Compressor valve seals/distance piece	PCV	Vent
	Equipment isolation: maintenance		BDV
	Glycol reboiler flash tank	PCV	
	Amine reflux accumulator	PCV	
	Gas pipeline pigging		BDV
	LPG storage vessels	PCV	PRV
	Gas sweetening: off-spec product		FCV
	Amine flash tank or vessel	PCV	PRV

[1]Blank cells indicate that there typically are no routine flare sources for this process/equipment.
[2]Blank cells indicate that there typically are no non-routine flare sources for this process/equipment.

More detailed methods of tracing flaring to its sources for actual flare events include:

- Process computer alarm annunciation
- Flow indication via flow transmitters or flow recorders
- High pressure alarm annunciation
- Ultrasonic testing for flow indication in piping
- Piping isolation and leak testing to confirm pressure relief valve (PRV) or control valve seat leakage to flare
- Flare gas sampling/analysis to determine process origin
- Documentation of maintenance procedures and date/time of maintenance releases to flare
- Documentation of operator initiated releases to flare (flare log, etc.)

Since new facilities will not have historic logs of flare events, it is recommended that a FRP analysis of potential flare events be conducted prior to facility start-up. This exercise will help identify both design and operating gaps that may be modified to prevent excessive flaring during the plant start-up and subsequent process operation. Operating facilities with poor documentation of flare events and volumes may have to follow the same procedure.

The identification of potential flare source locations can be determined through a review of as-built piping and instrumentation drawings (PIDs) or on-site inspections. All process piping discharging into the flare header should be followed back to determine their origin. For example, process drains discharging into the flare knock-out vessel could also be a potential for flare in the events of: a failure of one or more low liquid level alarms in the process vessels; drain valve leakage; or operator error with respect to manually operated liquid drain valves.

3.2 Classify Flare Sources

Each individual flare source must be classified as either routine or non-routine. This classification is important in order to determine the method of flare reduction and the priority of flare reduction options.

Routine flare sources are the result of piping and process control design configurations within a facility and are intentional, expected and are considered normal under steady state plant process and equipment operation. Examples of routine flaring include (but are not limited to):

- Separator or treater off-gas flaring (PCV)
- Tank vapour flaring
- Glycol dehydrator still vapour flaring
- Compressor distance piece vapour flaring
- Normal operation pressure control valve (PCV) and flow control valve (FCV) discharge
- Waste acid gas or sour gas flaring

Routine flare source volumes can increase substantially due to changes in process or unexpected events, such as failure of instruments/controls/equipment or operator error. Although it is still a routine flare source, the event can be classified as a non-routine flare event. Flare sources must not be confused with flare events.

Non-routine flaring, as per EUB Directive 060, includes intermittent and infrequent events such as planned maintenance, process upsets and emergencies. It can be defined as all flare events outside normal steady state plant process and equipment operations. Non-routine flaring can be generalized into three categories as defined below:

- Emergency - Safety controls within the facility/plant to depressurize equipment to protect the safety of personnel/public on or near the facility. Emergency flares are designed scenarios and the objective is to depressurize the facility as quickly as possible. Examples include: emergency depressuring via PRV or PCV; equipment pressure relief caused by fire, etc.
- Upset - Process conditions where the facility is outside its normal operating envelope and flaring is required to bring the production back under control. Examples include: process start-up (release to flare) to stabilize process flow or pressure; process upset leading to off-spec product; loss of process control

due to electrical power outage; loss of instrument air; improper operation of manual or automatic blowdown valves (to flare); equipment failure (valve, instrument, engine, etc.); pipeline depressuring due to hydrate blockage; liquid unloading at well startups, etc.

- Planned maintenance - These are known, scheduled events that are planned. Examples include reducing the pressure by drawing down the sour gas before purging equipment with fuel gas or nitrogen prior to flaring, start-up and shutdowns. Air quality management plans may be developed based on the dispersion modelling. Examples include: maintenance depressuring of compressors or process vessels; pipeline depressuring for inspection, etc.

3.3 Quantify Flare Events

In order to establish the priority of implementing flare reduction or elimination options, the flare volume from each flare source from an actual flare event or potential flare event must be determined. Flare volume determination of routine flare events are simpler to calculate and can be predicted more readily than non-routine flare events. This is because routine flares are:

- Based on steady state process operation
- Readily metered or measured
- Accurately calculated using mass balance equations
- Usually for a known time frame and known process parameters

On the other hand, non-routine flare volumes can best be estimated or calculated during or after the actual flare event since they are often time dependent and there are many variables involved. The duration of non-routine flare events is very important for SO_2 dispersion modelling. The average rate is modelled and is simply the volume divided by the duration. The variables associated with non-routine flaring include:

- Length of time the inlet process valve was open on a process overpressure situation
- Length of downtime for required utilities (electricity or instrument air)
- Length of time required to identify which process to isolate on a control system or instrument failure
- Length of time required to identify and isolate a failed valve/component
- Whether a failed component can be automatically or manually isolated
- Whether the event was caused by operator error

Even with the presence of a total flare gas meter, flare gas volume estimation will still be required to allocate flare volumes to individual flare sources if more than one flare source releases to flare during a specific flare event.

If a facility's actual total continuous flare volume is significantly higher than the estimated total from each individual flare source, this could signify valve seat leakage into the flare system. Valve seat leakage may be detected using flow detection/measurement instruments or gas tracers.

Methods for estimating flare volumes can be found in CAPP publication #2002-0009 entitled "Estimation of Flaring and Venting Volumes from Upstream Oil and Gas Facilities". Appendix A.1 of this document discusses flare volume measurement and reporting requirements.

The amount of air emissions from a flare event or source should also be considered when prioritizing flare reduction options for a facility's FRP. Appendix A.2 of this document discusses methods of calculating air emissions from flaring.

3.4 Determine Cause of Flare Events

The determination of the cause of flaring is an important factor in choosing the appropriate flare reduction option for each flare event. All major flare events must be investigated in order to determine and mitigate the root cause of the flare event. EUB Directive 060 Sections 4.1 (gas battery) and 5.3 (gas plant) state that licensees must investigate and correct repeat non-routine flare events. In addition, EUB Directive 060 Section 10.4 requires that logs be kept to describe each non-routine flare incident and changes implemented to prevent future non-routine events of a similar nature from occurring in the future.

Although the initial reason why a particular non-routine flare event occurred may be obvious, the determination of the root cause of the event usually involves investigation or engineering analysis of the events leading up to the actual flare event. For example, the initial reason for a PRV to open (to flare) is overpressure, but the cause of the overpressure could be one of many possibilities. Overpressure within a facility process results from an imbalance or disruption of the normal flows of material and/or energy such that a buildup of material and/or energy is caused in some part of the system. Examples of the causes of overpressure include:

- Blocking-in the discharge of a process or process equipment
- Thermal expansion of a liquid or vapour within a confined volume
- Check valve failure (does not close)
- Power failure
- Instrument air failure
- Heat exchanger tube failure
- Control valve failure
- Valve leakage
- Infrequent pipeline pigging resulting in large slugs of liquids being sent to the plant's inlet separator and stabilizer causing capacity overload.

Methods to determine causes of non-routine flaring (for each flare source or flare event) include, but are not limited to:

- PID hazard and operability (HazOp) procedure/design review
- Flare incident investigation (operation and process control review)

A HazOp review involves an operational and engineering analysis of potential causes and consequences of process control failure, equipment failure, instrument failure and operator error associated with critical facility processes.

A flare incident investigation involves an analysis of the operating events, process parameters (flow, pressure and temperature) and process alarms leading up to the non-routine flare event.

Table 3 lists some (not all) causes of non-routine flaring.

Table 3: Example Causes of Non-routine Flaring

Non-routine Flare Source	Cause
Separator PRV	Downstream block valve closed
	Inlet PCV failure
	PRV valve seat leakage
	PRV setting incorrect
	Inlet PCV setting incorrect
	Separator exposed to fire/flame impingement
Tank vapour losses (with VRU)	VRU (vapour recovery unit) compressor failure
	Gas blanket PCV failure
	Tank exposed to fire/flame impingement
Compressor discharge PRV	Electrical power outage
	Instrument air failure
	Downstream FCV shut: off-spec product
	Downstream compressor failure: high vibration
Amine system sour gas inlet PCV	Downstream sulphur recovery unit down
	Acid gas injection compressor failure
	Tail gas incinerator failure
	Amine foaming (in contactor tower)

Routine vapour discharges to the flare are incorporated into a facility's design for process control (pressure or flow control) or for the destruction of a non-recovered vapour source. Reasons for routine flaring are usually technical or economic limitations at the time of process design. Although elimination of routine flaring may not be justified at all facilities, the reduction or minimization of routine flaring can sometimes be achieved through minor changes in operating procedures or process control optimization. This will be discussed in more detail in Sections 5 and 6 of this document.

Causes for increases in routine flaring may include (but are not limited to):

- Changes in hydrocarbon liquid or vapour composition
- Normal wear and tear of equipment/components
- Changes in process parameters (pressure, temperature, flow)
- Changes in process control set points

It is important to understand that routine flare source volumes can increase substantially because of non-routine events, but that routine flare sources remain as routine flare sources (since they were originally designed to send vapour to the flare during normal plant operation). For example, vapour losses from hydrocarbon liquid storage tanks that are normally flared can increase substantially if:

- Any upstream vessel liquid control valves (LCVs) fail open
- Any upstream manual operated vessel drain valves are left open
- The tank gas blanket PCVs fails open
- The tank is exposed to fire/flame impingement

Table 4 lists some (not all) root causes of routine flaring.

Table 4: Example Causes of Routine Flaring

Routine Flare Source	Cause
Separator or treater PCV	Recovery for sales uneconomic
	No gas pipeline lateral within 20 km
	Gas flow intermittent and low rate (compressor sizing problem)
	Surrounding terrain unacceptable for gas pipeline
	Gas sweetening uneconomic
	Downhole injection uneconomic
Tank vapour losses (no VRU)	Recovery for sales uneconomic
	Gas flow intermittent and low rate (compressor sizing problem)
	Liquids sent to storage are non-stabilized (gas flashes off)
Glycol dehydrator vapour	Installation of flash tank uneconomic
	Installation of vapour recovery system uneconomic
	Stripping gas required to meet pipeline specification

4 Flare Reduction Assessment

Once the flare properties are determined, flare reduction options can be identified and assessed. The steps involved in this process include:

1) Identify gaps in facility design versus BMP Facility Design Considerations (Section 5)
2) Identify gaps in current operations versus BMP Operating Considerations (Section 6)
3) Determine feasibility of reduction options (economic and technical)
4) Prioritize feasible reduction options
5) Develop an implementation schedule
6) Documentation

Due to the unexpected nature of non-routine flaring, it is expected that the assessment of flare reduction options for routine flare events can be developed well before those for non-routine events. However, if historic records show that non-routine flare volumes are consistently significantly higher than routine flare volumes, then reduction of non-routine flaring should be addressed first.

Figure 1 (Section 2) shows a flow chart for this flare reduction assessment process. This process should be used to identify and document all potential flare reduction options for both routine and non-routine flare sources for actual and potential flare events.

The flare reduction assessment is a continuous improvement process and should be monitored, reviewed annually and updated. After a few evaluations, operators are expected to establish their own minimum flaring frequency and volume criteria to trigger the assessment process. It will be up to the operators to screen out the obvious flare events where the potential benefits realized do not justify the effort required to carry out the flare reduction assessment.

4.1 Identify Gaps in Operating Practices

Both flare volumes and flare events can be reduced or averted by proactive process monitoring and operator intervention for routine and non-routine flare sources. For example, by adjusting process parameters in anticipation of any process condition changes, flaring can be eliminated or minimized. Similarly, proactive operator intervention can reduce the risk of producing off-spec product and thereby reduce the risk of a major non-routine flare event.

The process of identifying gaps in current operating practices versus the BMP operating practice (Section 6) involves:

1) Documenting current operating practices associated with each facility process that contains a potential flare source
2) Comparing current operating practice with the recommended BMP operating practices

3) Identifying any required changes to current operating practices

Current operating practices should be organized in the same categories as Section 6:

- Process parameters (routine flare sources)
- Overpressure (non-routine flare sources)
- Process control (routine and non-routine flare sources)
- Equipment reliability and maintenance (routine and non-routine flare sources)
- Error (routine and non-routine flare sources)

Once new or revised operating practices have been developed, a management process should be implemented to ensure revised operating practices are being followed.

4.2 Identify Gaps in Facility Design

By incorporating appropriate system designs into facilities, both routine flare sources and non-routine flare volumes can be reduced significantly. However, not all BMP design recommendations are technically or economically viable at all facilities. For this reason, an evaluation process must also be completed as part of the procedure for optimizing a facility's design to the BMP standard.

The process of identifying gaps in current facility design versus the BMP design standard (Section 5) involves:

1) Analyzing the current design (on-site inspection or as-built PID review) associated with each facility process that contains a potential flare source
2) Comparing current facility design with the recommended BMP design standard
3) Identifying any required changes to current facility design

To facilitate the use of the BMP Design Considerations, each facility should be evaluated using the following design criteria:

- Vapour recovery
- Piping design
- Equipment sizing
- Equipment choice/specification
- Instrumentation/control

Once revised facility design changes have been identified, each design change must be evaluated, prioritized, implemented (if feasible) and documented.

4.3 Evaluate Feasibility of Reduction Options

The evaluation phase of the FRP determines if a given potential flare reduction option is technically or economically viable. The evaluation phase is intended to be applicable only to identify design changes. However, there may be instances where operating changes may not be economically viable if a particular facility is isolated and unmanned. Viability should weighed against perceived benefits and practicality of such implementation, which includes:

- Improved local air quality (improved public and environmental health)
- Enhanced facility safety
- Enhanced company reputation and public image
- Gas conservation economics
- Enhanced greenhouse gas emissions reduction

The technical evaluation of a potential flare reduction option should include analysis of whether a given technology is:

- Effective (tested and shown to achieve required results)
- Reliable (tested to operate without failure for a reasonable length of time)
- Applicable (tested and proven under similar process parameters: flow, temperature, pressure, gas composition)
- Available (mass produced or deliverable within the required project timeframe)
- Operable (can be assimilated within the facility process without a significant effect on how the facility or applicable process is operated or maintained)

An economic evaluation of all potential flare reduction options should be completed.

4.4 Prioritize Feasible Reduction Options

Once a list of feasible flare reduction options or projects has been identified for a facility, they should be prioritized such that the project with the most benefits and chance for success is implemented first. Companies should implement all economic projects no later than the next plant turnaround. Subsequent to operational technical evaluation, flare reductions achievable through operating practices should be undertaken first followed by flare reductions achievable through design changes.

The system used to prioritize the projects must be consistent, transparent and objective. Suggested elements of this prioritization may include: economic benefit, technical success, amount of reduction, environmental hazard, risk of occurrence, health and safety.

When a large number of multiple flare sources exist at a given facility, the sources should be grouped in the following categories and evaluated in accordance with the feasibility and impact to environmental health:

- Routine sour gas flare sources
- Routine sweet gas flare sources

- Non-routine sour gas flare sources
- Non-routine sweet gas flare sources

The amount of air emissions from a flare event or source should also be considered when prioritizing reduction options for a facility's flare reduction. The type and amount of emissions will depend on the composition of the flared gas. When sweet natural gas is burned, the primary emissions are carbon dioxide (CO_2) and water vapour (H_2O). Emissions may also include small amounts of unburned natural gas, products of incomplete combustion (i.e., air toxics such as PAHs) and by-products of combustion (such as NO_x). If the flared gas is sour, sulphur dioxide (SO_2) is also emitted as well as some unburned H_2S. The main emissions from acid gas combustion would be CO_2, SO_2 and H_2S as well as various products of incomplete combustion or by-products of combustion. These components have different impacts to the environment and should be prioritized accordingly.

4.5 Implementation Schedule

After the feasible flare reduction projects have been prioritized, they should be scheduled for implementation in a staged process to assure:

- Operational changes are implemented first
- Highest priority projects are implemented first
- Minimum disruption to current operations
- Adequate capital is available for implementation
- Regulatory targets or objectives are achieved

In terms of flare source classification, the order of implementation should follow this sequence:

1) Routine flaring: Operational changes
2) Non-routine flaring: Operational changes
3) Routine flaring: Design changes
4) Non-routine flaring: Design changes

4.6 Documentation

Documentation of all phases of the flare reduction assessment process is required for future audit and reference purposes. This documentation process will also be needed if it is desired to have a flare reduction project registered as a greenhouse gas emissions credit project.

The Flare Reduction Assessment documentation will include discussion of methodology, assumptions and results applicable to:

- Gaps identified in facility design versus Facility Design Considerations (Section 5)

- Gaps identified in current operations versus BMP Operating Considerations (Section 6)
- Feasibility of reduction options (economic and technical)
- Prioritization of feasible reduction options
- Implementation schedule

All documentation should follow the intent of ISO 14064-2 project documentation practices such that all documentation, statements and claims are: relevant, accurate, transparent, complete, conservative and consistent. All assumptions must be stated clearly and all conclusions must be justified with referenced data or accepted practices.

If a potential flare reduction option is not implemented, documentation of all evaluation results must be kept on-site for review and audit purposes.

5 BMP Design Considerations

There are many potential facility design concepts that facility engineers can implement to prevent, reduce or partially eliminate routine and non-routine flare volumes and frequency. The tables in this section will assist engineering staff in the identification of opportunities relevant to a particular facility that should be evaluated for potential implementation. Although the design concepts listed may not be all-inclusive, they do provide a general indication of what types of opportunities will result in reduced flaring.

5.1 Routine Flare Sources

The facility design aspects that most affect the volume of gas flared through routine flare sources include:

- Vapour recovery (Table 5)
- Equipment sizing (Table 6)
- Equipment choice/specification (Table 7)
- Instrumentation/control (Table 8)

If these four design aspects are monitored, optimized and controlled, routine flaring can be reduced. Tables 5, 6, 7 and 8 outline design considerations for each of the above four aspects that can result in reduced routine flare volumes. Current process designs for all process streams with routine flare sources at each facility should be compared to these considerations to identify any gaps or modifications that could result in reduced flare volumes.

Table 5: Routine Flaring Design BMP: Vapour Recovery

Design Element	Consideration
Segregation	Group vapour recovery systems into sweet and sour gas systems provided sufficient volumes are available.
	Segregate vacuum system and low pressure system.
Sources	Consider collection of vapours from: hydrocarbon storage tanks, gas blanket systems, product loading, solution gas from separators, glycol flash tanks, glycol reboiler still vents, compressor seals/distance pieces, and flare system (if valve leakage and PRV leakage are excessive).
Uses	Evaluate recovery of vapour for: on-site fuel gas, product sales, on-site power generation, downhole injection.
Specification	Design/size for flexibility in flow range; i.e., provide two 50% units instead of one 100% unit.
	Provide back-up compressor to avoid down-time.
	Provide adequate inlet liquid separation and recover liquids to process.
	Determine vapour flow according to specific gas compositions and temperature/pressure of all recovered process streams.

Table 6: Routine Flaring Design BMP: Equipment Sizing

Process	Consideration
Flare system	Design in accordance with EUB Directive 060 Section 7.
General	Ensure equipment and process are sized properly for current operating conditions.

Table 7: Routine Flaring Design BMP: Equipment Choice/Specification

Process	Consideration
Gas wells	To reduce well blowdowns install plunger lift systems instead of beam lifts (for gas wells that experience liquid loading).
Flare	Install baffles in flare tip to reduce purge gas flow rate.
	Install electronic ignition in lieu of pilot gas for sweet gas flares.
	Design in accordance with EUB Directive 060 Section 7.
	Consider installation of nitrogen gas system for gas purge.
	Recover all flare knock-out liquids to process recycle.
	Consider air-assisted flare if flare gas has LHV >45 MJ/m^3 and MW >90.
Tank vapour	All liquids should be flashed to 1 psig prior to being sent to atmospheric storage tanks. Recover all flash gas.
Gas sampling	Collect gas samples at low pressure source.
Gas dehydration	Where natural gas is used for stripping, consider using nitrogen gas instead.
Gas blanketing	Where natural gas is used, consider nitrogen gas instead.
Casing gas	Install vapour recovery at wellsite and inject gas into oil gathering pipeline being routed to central facility. Remove and recover gas at central facility.
Rotating equipment	Replace or retrofit old equipment when reliability is <85%.
Sour gas sweetening	Consider acid gas downhole injection in lieu of sulphur recovery.

Table 8: Routine Flaring Design BMP: Instrumentation/Control

Process	Consideration
Flare	Adjust purge gas flow rate for ambient temperature and wind velocity (for stable flame).
	For air assisted flares, adjust air flow according to flare rate.
	Minimize pilot gas rate based on flare rate or temperature at flare tip.
	Provide automatic recovery (LCV) of flare knock-out vessel liquids.
	Install automatic fuel gas make-up to achieve minimum heating value when flaring acid gas (use flow ratio control).

5.2 Non-routine Flare Sources

The facility design aspects that most affect the volume and duration of non-routine gas discharges to flare include:

- Piping design
- Equipment sizing
- Equipment choice/specification
- Instrumentation/control

If these four design aspects are optimized, non-routine flare volumes and frequencies can be reduced. Tables 9, 10, 11 and 12 outline design considerations for each of these aspects that can result in reduced flare volumes or frequencies. Current process designs for all process streams with non-routine flare sources at each facility should be compared to these considerations to identify any gaps or modifications that could result in reduced flare volumes.

Table 9: Non-routine Flaring Design BMP: Piping Design

System	Consideration
Piping	Add piping to divert blowdown gas from maintenance activities to: fuel, low pressure source or gas recycle/recovery.
	Add piping to divert non-emergency flare gas to low pressure source such as compressor suction or gas recycle/recovery.
	Add piping (compression as necessary) to allow recycling of off-spec sales gas.
Valves	Any valves on a high pressure source discharging to a low pressure source should be double blocked and bled.
	Install a rupture disk (and pressure sensor) upstream of PRVs that have chronic seat leakage to flare, or install spare PRV and isolation valves to permit frequent servicing without shutdown.
	Where the failure of a check valve could create pressures that exceed equipment design pressures, a secondary device should be installed to prevent flow reversal.
Flare system	Avoid sending volatile or gas-laden liquids to the flare knock-out drum; instead, send to liquid recycle/recovery system.
Fire protection	Install flame resistant insulation and metal cladding (to 8 m above grade) on hydrocarbon vessels that could be exposed to flame impingement.
	Install a depressurizing system to isolate and transfer hydrocarbon liquid and vapour from vessels exposed to external fire.

Table 10: Non-routine Flaring Design BMP: Equipment Sizing

System	Consideration
General	Provide spare or redundant equipment in critical services in order to enable continuous operation (and avoid flaring) when equipment failure occurs.
Flare systems	Must be designed in accordance with API 521 (1997), API 537 (2003) and EUB Directive 060 Section 7.
Instrument air	Provide spare air compressor and sufficient air receiver/reservoir capacity in order to cycle all isolation valves at least three times.
Condensers	For fractionation towers in series, size condensers large enough to handle vapours from preceding towers should loss of heat input from preceding tower occur.
Vapour recovery	Size compressor and system according to individual stream compositions and process parameters.

Table 11: Non-routine Flaring Design BMP: Instrumentation/Control

System	Consideration
Process shutdown	Provide process or equipment isolation for emergency by using dedicated block valves as opposed to fail-closed control valves.
	The fail-safe condition (spring open, spring closed or fixed position) must ensure that overpressure risk is addressed in the event of electrical power or instrument air failure.
	Provide control logic and valving for staged/controlled facility and individual process shutdown. Block and hold in lieu of flaring (where possible).
Process control	Upon localized equipment or control failure, facility control logic should adjust process control parameters of all affected processes to the safe standby mode to prevent over-pressure in related processes until upset condition is resolved.
Temperature control	Provide high temperature alarm and heat input shutdown in situations where high temperature can produce vapour overpressure.
Aerial coolers	Louvers should fail open on process upset (provided there is no freezing risk) and fail closed in facility fire situation.
Engine surveillance	Install instruments to predict required maintenance to avoid engine failure.
Process alarms	Provide process alarms and automatic isolation in situations where operating temperatures or pressures outside intended process limits could cause runaway reactions and/or equipment overpressure/failure.
Flow control	Install automated flow control at gas batteries to prevent/reduce flaring at gas plants during times of plant through-put reduction or plant upset.
	Install automatic fuel gas makeup to achieve minimum heating value when flaring acid gas (use flow ratio control).
	Adjust purge gas rate according to wind velocity and/or flare gas rate.
	Install automatic bypass to adjacent process train or recycle loop to avoid overpressure on a blocked-in condition resulting from automatic process control/upset or off-spec product situation.

System	Consideration
Liquid drain to flare knock-out drum	Install high pressure alarm to detect gas flow/blow-by.
Plant shutdown	When bringing plant down, reduce line pressure by processing gas as far as possible. Whenever possible, use compression to lower line pressure before flaring any residual gas.

Table 12: Non-routine Flaring Design BMP: Equipment Choice/Specification

System	Consideration
Sour gas sweetening	Consider acid gas downhole injection in lieu of sulphur recovery.
Flare system	Consider air-assisted flare if flare gas has LHV >45 MJ/m^3 and MW >90.
	Consider flare gas recovery as per API 521 Section 4.4.3.1.5 if flare volumes are sufficient, are process related (not emergency related) and cannot be mitigated/reduced otherwise.
	Install flow meter to monitor daily flare volumes and detect excess routine flaring and/or low volume non-routine flaring.
Shell and tube heat exchangers	In services with high risk of tube failure, design shell and tube side of exchanger to highest pressure design specification and provide pressure alarms and automatic isolation valves.
Power supply	For facilities prone to power failure, provide auxiliary or self-generated emergency power for process control computer and critical plant control (isolation valves, PCVs, cooling pumps of which failure may cause vapour overpressure, instrument air compressor, reflux pumps, solvent/absorbent pumps).
Gas dehydration	Consider replacement of glycol dehydrators with desiccant dehydrators.
Compressor seals	Replace wet seals on compressors with dry seals.
Engine start	Install air receiver to replace natural gas engine starts.
	Design compressors to start under load.

6 BMP Operating Considerations

There are numerous activities that facility operations and maintenance staff can undertake during their daily routines that can prevent or reduce routine and non-routine flare volumes and frequency. The tables in this section will assist operations and maintenance staff to identify tasks or procedures that are relevant to their particular facility that should be implemented. Although the procedures listed may not be all-inclusive, they do provide a general indication of what types of procedures will result in reduced flaring.

6.1 Routine Flare Sources

The operating elements that most affect the volume of gas flared through routine flare sources are:

- Process parameters
- Process control
- Equipment maintenance/reliability
- Error

If these four elements are monitored, optimized and controlled, routine flaring can be reduced. Tables 13, 14, 15 and 16 outline operational considerations of each of these elements that can result in reduced routine flare volumes. Current operational procedures (with respect to routine flare sources) at each facility should be compared to these considerations to identify any gaps or modifications that could result in reduced flare volumes.

Table 13: Routine Flaring Operational BMP: Process Parameters

Process Parameter	Consideration
Composition	Confirm that daily gas compositions are within design limits.
	Confirm gas stream to flare has no entrained fluids.
Temperature	Confirm daily gas temperatures are within design limits.
Pressure	At oil batteries, raise separator pressure to reduce solution gas flaring (without appreciable oil production loss).
	Confirm that daily process gas pressures are within design limits.
Flow	Confirm that daily flare gas flows are within design/expected limits.
	Record estimated routine flare flame length (to estimate flow rate).
Set points	Control process parameters (i.e., upstream pressure and temperature) to reduce the amount of flare volume created.
Documentation	Document above findings on daily operator checklist unique to facility.
	Quantify financial cost and reductions of flaring; communicate results to operations staff and management.

Table 14: Routine Flaring Operational BMP: Process Control

Process Control	Consideration
Results	Are process controls achieving required outputs? (i.e., final flow, pressure, etc.).
Flow	Adjust flare purge gas rate on-site until flame is visible at flare tip. Adjust purge gas rate if gas composition changes or excess leakage into flare occurs.
	Adjust/check glycol flow daily for gas dehydration to reflect changes in gas flow rate and water content.
	Increase gas flow rate for gas dehydration in lieu of using or increasing natural gas stripping.
	Adjust selective solvent flow (gas sweetening) to reflect changes in sour gas composition and flow rate. Achieve pipeline CO_2 spec but avoid over-processing.
Documentation	Document above findings on daily operator checklist unique to facility.

Table 15: Routine Flaring Operational BMP: Equipment Maintenance/Reliability

Process Control	Consideration
General	Maintain instruments, valves and rotating equipment on a regular schedule as per manufacturer's recommendations.
Gas dehydration	Analyze lean glycol solution regularly to determine effectiveness.
Flare	Replace flare tip when damage is visible (to reduce purge gas rate).
	Repair or replace damaged flare pilots (to reduce pilot gas).
	Resize or replace purge gas orifice plate when rate must be changed.
Valves and piping	Test for seepage/leakage into flare gas system through control valves or PRVs.
Documentation	Document above findings on daily operator checklist unique to facility.

Table 16: Routine Flaring Operational BMP: Error

Error	Consideration
Operator	Develop a training and documentation system (daily checklist) to identify and track operational considerations that affect routine flare volumes (unique to each facility).
Control logic	Check that process control settings are appropriate for new process parameters (composition, flow, temperature, pressure).
Documentation	Document any errors (operator or control) on daily operator checklist unique to facility. Describe process consequences.

6.2 Non-routine Flare Sources

Non-routine gas discharges to flare most commonly are the result of:

- Overpressure
- Process control
- Equipment maintenance/reliability
- Error

Tables 17, 18, 19 and 20 outline operational considerations for each of these elements that can result in reduced flare volumes and/or reduced flare frequency. Current operational procedures at each facility should be compared to these considerations to identify any gaps or modifications that could result in reduced flare volumes.

Table 17: Non-routine Flaring Operational BMP: Overpressure

Overpressure Cause	Consideration
High inlet pressure	Any manually operated valve discharging from a high pressure source to a lower pressure source should be tagged and car-sealed closed.
Loss of power	Keep process systems and equipment in standby mode until power reliability is confirmed.
Loss of control	Keep process systems and equipment in standby mode until control system or utility reliability is confirmed.
Process control	Keep process systems and equipment in standby mode until process upset trigger/cause has been stabilized/mitigated.
Plant utilization	Isolate and block-in (blind flange) plant equipment and process streams that are not utilized due to low production through-put.

Table 18: Non-routine Flaring Operational BMP: Process Control

Process Control	Consideration
Process upset	Where process operating parameters permit, discharge to flare philosophy should be “relieve and hold” instead of depressurization.
	Minimize acid gas and sour gas flaring by diverting gas to incinerator provided it is safe to do so. Regulators focus on the root cause of the problem/upset, not only the associated incinerator stack contraventions when investigating the incident (see CASA 2002 Recommendations).
Mitigation procedures	Develop procedures or process control logic to minimize flare volumes by diverting flows between processes during potential upset conditions. Manual procedures must be documented and operation staff trained, while control logic must be programmed into process computer.
Control settings	Adjust process control parameters for changes in operating conditions.
Flow control	Provide automatic control of fuel make-up gas for acid gas flaring.

Process Control	Consideration
Level control	Manually check vessel liquid level versus liquid level transmitter output to ensure proper level control and no gas blow through.
	Low liquid levels should be at least 0.3 m above liquid outlet nozzle.
Sour gas sweetening	Identify, monitor and document process alarms and conditions that indicate/preclude impending off-spec product condition. Mitigate effects.

Table 19: Non-routine Flaring Operational BMP: Equipment Maintenance/Reliability

Maintenance Item	Consideration
General	Maintain instruments, valves and rotating equipment on a regular schedule as per manufacturer's recommendations.
	Schedule maintenance so that multiple procedures can be performed at the same time (i.e., group tasks) to reduce the number of equipment shutdowns and start-ups.
	Purge sour gas systems with sweet gas or N_2 (for start-up) to avoid sour gas flaring.
Instrumentation	Calibrate and test operation at regular intervals as per manufacturer's recommendations.
Electrical parts	Protect/isolate electrical parts and wiring from hot surfaces, high heat radiation and vibration.
Valves and piping	If piping in place divert acid or sour gas to incinerator in lieu of flare during manual blow down.
	Use hot tap procedure for making new piping connections versus depressurizing and flaring.
	Inspect/test for tight shut-off of all block valves (to flare).
	Inspect/test for PRV seat leakage (to flare).
	Provide sufficient methanol injection in gas gathering pipelines to avoid hydrate formation.
	Monitor gas gathering and gas sales pipeline composition, temperature and pressure to initiate hydrate prevention measures.
	Monitor pressure drop versus flow rate in inlet gas gathering pipeline to detect/predict potential hydrate problem.
	Perform gas gathering pipeline pigging at regular intervals.
Compressors	Implement equipment surveillance and preventative maintenance program to achieve 97% reliability.
	Keep compressors pressurized when taken off-line for operational reasons or put on temporary standby.
	Use portable compressors to pump down (and recover) gas gathering pipeline to depressure for maintenance.
	Install static packing system to eliminate seal leakage when compressors are not operating but are still pressurized.
Documentation	Document all block valves and PRVs with seat leakage to flare.
	Record/track daily flare volumes and compare to expected routine flare volume.

Table 20: Non-routine Flaring Operational BMP: Error

Error	Consideration
Operator	Clearly mark all gas valves discharging to flare.
	Clearly mark all liquid drain valves discharging to flare knock-out drum.
	Provide training and procedures/documentation to enable an operator mitigation response time of 10 to 30 minutes (after process upset).
Control logic	Document (and provide to Operations) allowable control span/range for all facility control valves.
PRVs	Check PRV tag set pressure versus vessel design pressure before installation.

7 References

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Appendix A Flare Quantification Requirements

A.1 Flare Volume Measurement and Reporting

EUB Directive 060 Section 10 outlines the measurement and reporting requirements for flare volumes. In general, operators must be able to demonstrate that volumes of gas are accurately and consistently captured. All flare volumes greater than or equal to100 m^3/month must be reported to the Petroleum Registry of Alberta.

EUB Directive 060 Section 10.1 specifies that routine flaring exceeding 500 m^3/day must be metered with equipment suited to the source flow conditions for the required measurement points. Accurate engineering estimates may be accepted where meters are not required.

EUB Directive 060 Section 10.2 outlines the requirements for estimating flare volumes. Estimating systems must account for all gas flared from routine and non-routine sources. Estimation methods must be: based on calculations that account for volume, gas composition, temperature, initial and final pressure; consistent; documented and developed by a technically knowledgable person.

Methods for estimating flare volumes can be found in CAPP Guide entitled "Estimation of Flaring and Venting Volumes from Upstream Oil and Gas Facilities", July 2002, CAPP Publication #2002-0009.

In lieu of calculating/estimating non-routine total flare volumes, total plant flare volumes may be metered by installing a flow meter upstream of the facility flare stack. If a flare meter is installed upstream of the flare stack it is also advisable to meter fuel gas used for flare gas purge, pilot gas and fuel make-up. As per EUB Directive 060 Section 10, paragraph 5, fuel gas added to flare systems must be subtracted from reported flare volumes if total flare gas is measured.

Even with the presence of a total flare gas meter, flare gas volume estimation will still be required to allocate flare volumes to individual flare sources if more than one flare source is released to flare during a specific flare event.

A.2 Calculating Air Emissions from Flaring

When sweet natural gas is burned, the primary emissions are carbon dioxide (CO_2) and water vapour (H_2O). Emissions may also include small amounts of unburned fuel and air pollutants. If the flared gas is sour, sulphur dioxide (SO_2) is also emitted as well as some unburned hydrogen sulphide (H_2S). These can all be calculated using mass balance and organic chemistry theory. The amount of air emissions produced will be directly dependent on the compositions of the gas being flared and the efficiency of the combustion process.

For example, to calculate the amount of CO_2 produced when burning a natural gas mixture with the composition of: $aCH_4 + bC_2H_6 + cC_3H_8 + dC_4H_{10} + eC_5H_{12} + fCO_2$, where a to f are mole fractions, the following formula may be used (based on stoichiometry and mass balance):

$$[\eta (a + 2b + 3c + 4d + 5e) + f] \times 44.01 / 23.64 = \text{kg } CO_2/sm^3 \text{ gas flared}$$

where:

η = flare combustion efficiency (normally 0.98 unless tested otherwise)

44.01 = molecular weight of CO_2

23.64 = the volume in m^3 occupied by 1 kmole of gas at 15 ^oC and 101.32 kPaa.

The amount of CO_2 equivalent greenhouse gas emissions from unburned methane during flaring can be calculated using:

$$(1 - \eta) \times a \times 0.6784 \times 21 = \text{kg } CO_2E/sm^3 \text{ gas flared}$$

where:

0.6784 = density of CH_4 in kg/sm^3

21 = the Global Warming Potential factor for CH_4

According to research completed by Larry Kostiuk, Ph.D., P.Eng. of the University of Alberta in 2004, flare combustion efficiency for natural gas can range from 89% to 99.7%, depending on:

- Gas LHV in MJ/kg
- Gas composition
- Crosswind velocity
- Gas exit velocity (at flare stack tip)

The EUBflare spreadsheet uses Kostiuk's work to estimate the flare combustion efficiency, the CO_2E and H_2S emissions. More information on calculating greenhouse gas emissions from flaring (i.e., CO_2, CH_4 and N_2O) can be obtained from the CAPP Guide entitled "Calculating Greenhouse Gas Emissions", April 2003, CAPP Publication #2000-0004.

Information on calculating other air emissions (from flaring) such as NOx (oxides of nitrogen), CO_2 (carbon dioxide), VOCs (volatile organic compounds), particulate matter and SO_2 (sulphur dioxide) can be obtained from the CAPP Guide entitled "A Recommended Approach to Completing the National Pollutant Release Inventory (NPRI) for the Upstream oil and Gas Industry", January 2005, CAPP Publication #2005-0001.

A.3 Documentation of Flare Properties

Summary tables should be included in the documentation portion of Determine Flare Properties (Section 3). Tables A1 and A2 are examples of volume, duration and rates summary reports for actual and potential flare events and sources. Documentation of actual flare events and sources is required annually, while documentation of potential flare events/sources is only required once (provided facility piping and processes remain unchanged).

Since EUB Directive 060 Section 10 requires that all routine flare volumes (with annual average over 0.5 x 10^3 m^3/day) be measured/reported and that operator logs be kept to record data from non-routine flare events (date, time, duration, gas source/type, and volume), much of the data for actual flare events/sources documentation should readily be available.

In addition to volume summary reports, emissions summary reports should also be completed for actual and potential flare sources. Tables A3 and A4 show examples of emissions summary reports. All emissions calculations should be based on best available data. That is, if actual gas compositions are available for flared gas, these should be used to determine respective emissions quantities.

Documentation listed here for actual and potential flare sources is in addition to EUB and other regulatory documentation/reporting requirements and does not replace any existing regulatory reporting requirements. Consideration should also be given to providing rates and duration since these are required inputs for dispersion modelling.

Table A1: Example of "Summary of 2005 Actual Flare Sources: Volume Data"

Flare Source Tag #	**Process Stream**	**# of Events**	**Cause**	**Sweet or Sour**	**H_2S mole %**	**Total Flare Volume (10^3 m^3) / Duration**	**Method[1] E or M**
	Routine Flaring						
PCV501	Tank 501 gas blanket	Continuous	No VRU installed	Sweet	0.0	20.0 / day	E
PCV301	Glycol flash drum V301	Continuous	No VRU on flash drum	Sour	2.0	180.0 / day	E
PCV302	Glycol dehy V302	Continuous	No VRU on still vapours	Sour	1.0	5.0 / day	E

Flare Source Tag #	Process Stream	# of Events	Cause	Sweet or Sour	H_2S mole %	Total Flare Volume (10^3 m^3) / Duration	Method[1] E or M
	Non-routine Flaring						
PCV201	Inlet sour gas separator	3	Acid gas injection compressor failure	Sour	3.0	340.0 / 1 hr, 2 hr, 4 hr	M
BDV21	Acid gas injection compressor	3	Maintenance: vibration switch on K200	Acid	25.0	0.10 / 0.5 hr, 1 hr, 0.25 hr	E
BDV24	Engine starter gas	3	K200 re-start after maintenance	Sweet	0.0	0.01 / 0.01 hr , 0.02 hr, 0.01 hr	E

[1]Method refers to volume measurement method (Estimated or Metered)

Table A2: Example of "Summary of Potential Flare Sources: Volume Data"

Flare Source Tag #	Process Stream	Cause	Sweet or Sour	H_2S mole %	Flare Rate & Method[1] 10^3 m^3 / E or M
	Routine Flaring				10^3 m^3 / day
PCV501	Tank 501 gas blanket	No VRU installed	Sweet	0.0	0.05 / E
PCV301	Glycol flash drum V301	No VRU on flash drum	Sour	2.0	0.49 /E
PCV302	Glycol dehy V302	No VRU on still vapours	Sour	1.0	0.01 / E
	Non-routine Flaring				10^3 m^3 / day
PCV201	Inlet sour gas separator	Acid gas injection compressor failure	Sour	3.0	0.47 / E
BDV21	Acid gas injection compressor	Maintenance: vibration switch on K200	Acid	25.0	0.03 per event / E
BDV24	Engine starter gas	K200 re-start after maintenance	Sweet	0.0	0.01 / E

[1]Method refers to volume measurement method (Estimated or Metered)

Table A3: Example of "Summary of Annual Actual Flare Sources: Emission Data"

Flare Source Tag #	Process Stream	Flare Vol. 10^3 m^3	Flare Eff. η	H_2S mole %	Total CO_2E tonnes	Total SO_2 tonnes	Total H_2S tonnes	Total VOCs tonnes	Total TPM tonnes
	Routine Flaring								
PCV501	Tank 501 gas blanket	20.0	0.98	0.0	44.81	0.0	0.0	0.024	0.051
PCV301	Glycol flash drum V301	180.0	0.98	2.0	403.25	9.56	0.104	0.214	0.461
PCV302	Glycol dehy V302	5.0	0.98	1.0	11.20	0.13	0.001	0.006	0.013
	Non-routine Flaring								
PCV201	Inlet sour gas separator	340.0	0.98	3.0	761.70	27.08	0.294	0.405	0.871
BDV21	Acid gas injection compressor	0.10	0.98	25.0	0.22	0.07	0.001	0.0	0.0
BDV24	Engine starter gas	0.01	0.98	0.0	0.02	0.0	0.0	0.0	0.0

Table A4: Example of "Summary of Potential Flare Sources: Emission Data"

Flare Source Tag #	Process Stream	Flare Eff. η	H_2S mole %	CO_2E Rate	SO_2 Rate	H_2S Rate	VOCs Rate	TPM Rate
	Routine Flaring					kg / day		
PCV501	Tank 501 gas blanket	0.98	0.0	110	0.0	0.0	0.1	0.1
PCV301	Glycol flash drum V301	0.98	2.0	1,100	26.0	0.3	0.6	1.3
PCV302	Glycol dehy V302	0.98	1.0	20	0.3	0.0	0.0	0.0
	Non-routine Flaring					kg / min		
PCV201	Inlet sour gas separator	0.98	3.0	1,050	37.4	0.4	0.6	1.2
BDV21	Acid gas injection compressor	0.98	25.0	40	19.9	0.2	0.0	0.1
BDV24	Engine starter gas	0.98	0.0	20	0.0	0.0	0.0	0.0