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GP 44-70

Overpressure Protection Systems

Group Practice

**BP GROUP
ENGINEERING TECHNICAL PRACTICES**

Foreword

This revision of Engineering Technical Practice (ETP) Group Practice (GP) GP 44-70 consists of only one addition as 9.5.e and is indicated by a bar in the margin. This revision recommends periodic revalidation of the relief system design and was inadvertently omitted in the 26 October 2009 revision. Revisions to the 3 April 2006 version were more extensive, were not indicated by a bar in the margin, but included the following:

- Amendments to the scope of this GP.
- Update of normative references in accordance with BP Group and segment defined ETPs.
- Clarification on documentation requirements.
- Additional guidance on designing overpressure protection for a burst tube condition in a shell and tube heat exchanger.
- Additional guidance on best practice for designing pressure letdown stations, including assumptions on bypass valve positions and controls.
- Clarification on the use of series check valves to minimise reverse flow scenarios and potential overpressure of equipment.
- Several amendments and clarifications from the original version within the document.

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1. Scope

- a. This GP provides practice for selection, design, and installation of overpressure protection systems and protection against overpressure of pressurised systems (up to the relief device discharge flange), in new plants and facilities in the list provided below:
 1. Hydrocarbon processing plants, including refineries, natural gas installations, and chemical plants.
 2. Steam and/or power generating plants and ancillary equipment.
 3. Terminals, including jetty and loading facilities.
 4. Offshore installations, including floating production systems.
 5. Petroleum production facilities, including well pads and crude oil and gas gathering centres.
 6. Main transmission pipelines, flowlines, and associated equipment.
 7. Storage installations.
 8. Vacuum systems and systems relieving at pressure less than 1 barg (14,5 psig).
 9. Utility systems.
 10. Components of drilling systems on BP operated platforms in which the drilling rig is an integral part of the facility or mobile drilling rigs that are owned or operated by BP.
 11. Ships, vessels such as a Floating Production Storage Offload (FPSO) and road/rail tanks where the system is a special purpose-built facility that would normally be considered a processing plant. This GP does not apply to other ships, vessels or road/rail tanks.
- b. This GP may also be used for assessment and modification of existing plants and facilities in the list above.
- c. This GP applies the general requirements, as outlined in GP 48-03, for the use of layer of protection analysis (LOPA) to define applicable safety instrumented systems (SIS) for overpressure protection or avoidance of overpressure. For the analysis of overpressure systems, these requirements are based on:
 1. Use of pressure relief devices, if practical, as the main method of overpressure protection.
 2. SIS, if used, which may be an additional method of overpressure protection in most cases, and as the sole method in a limited number of cases.
- d. This GP is to be used in conjunction with the following:
 1. GP 44-80, which specifies the overall relief, vent, and depressurisation system design of which the overpressure protection is a part.
 2. ISO 4126, API Std 520, Part I, API RP 520, Part II, and API Std 521/ISO 23251, interpreting and supplementing them as necessary to provide BP requirements.
- e. This GP does not cover mobile drilling rigs or other equipment that is owned by others and assembled as required on the facility.

Although BP does not own or operate mobile drilling rigs in most circumstances, the gaps and risks against this GP should be assessed, and risks should be mitigated if these drilling rigs are being contracted.



- f. This GP does not apply to pressure relief for systems in ships or road/rail tanks, unless the system is for a special purpose built facility that would normally be considered a processing plant (e.g., floating production storage offload [FPSO] facility).

2. Normative references

The following referenced documents may, to the extent specified in subsequent clauses and normative annexes, be required for full compliance with this GP:

- For dated references, only the edition cited applies.
- For undated references, the latest edition (including any amendments) applies.

BP

GN 44-001	Relief System Design Guide.
GN 44-005	Assessment of Acoustic Induced Vibrations.
GP 30-80	Safety Instrumented Systems (SIS) - Specification and Implementation.
GP 30-81	Safety Instrumented Systems (SIS) - Operations and Maintenance.
GP 32-47	In Service Inspection and Testing of Mechanical Protective Devices.
GP 42-10	Piping Systems (ASME B31.3).
GP 44-40	Isolation of Equipment for Maintenance and Emergency.
GP 44-80	Relief Disposal and Depressurisation Systems.
GP 48-02	Hazard and Operability (HAZOP) Study.
GP 48-03	Layer of Protection Analysis (LOPA).
GP 48-04	Inherently Safer Design (ISD).

American Petroleum Institute (API)

API RP 14C	Analysis, Design, Installation, and Testing of Basic Surface Safety Systems for Offshore Production Platforms.
API Std 520, Part I	Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries, Part I - Sizing and Selection.
API RP 520, Part II	Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries, Part II - Installation.
API Std 521	Pressure-relieving and Depressuring Systems.
API Std 526	Flanged Steel Pressure Relief Valves.
API Std 2000	Venting Atmospheric and Low-Pressure Storage Tanks: Nonrefrigerated and Refrigerated.
API Std 2510	Design and Construction of LPG Installations.

American Society of Mechanical Engineers (ASME)

	ASME Boiler and Pressure Vessel Code (ASME Code).
	ASME Boiler and Pressure Vessel Code Section I - Power Boilers.
	ASME Boiler and Pressure Vessel Code Section VIII - Rules for Construction of Pressure Vessels Division 1.
	ASME Boiler and Pressure Vessel Code Section VIII - Rules for Construction of Pressure Vessels Division 2 - Alternative Rules.
ANSI/ASME B16.5	Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24.
ANSI/ASME B31.3	Process Piping.
ASME PTC 25	Pressure Relief Devices.



British Standards Institute (BSI)

BS EN 1473	Installation and equipment for liquefied natural gas. Design of onshore installations.
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Energy Institute (EI)

IP 9	Model code of safe practice Part 9: Liquefied petroleum gas. Vol. 1. Large bulk pressure storage and refrigerated LPG.
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International Electrotechnical Commission (IEC)

IEC 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems.
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International Organization for Standardization (ISO)

ISO 4126	Safety devices for protection against excessive pressure.
ISO 4126-2	Safety devices for protection against excessive pressure - Part 2: Bursting disc safety devices.
ISO 4126-6	Safety devices for protection against excessive pressure - Part 6: Application, selection and installation of bursting disc safety devices.
ISO 10418	Petroleum and natural gas industries - Offshore production installations - Basic surface process safety systems.
ISO 23251	Petroleum, petrochemical and natural gas industries - Pressure-relieving and depressuring systems.

ISO 23251 has adopted API Std 521 in its entirety. Therefore, these documents are identical.

ISO 28300	Petroleum, petrochemical and natural gas industries - Venting of atmospheric and low-pressure storage tanks.
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National Fire Protection Association (NFPA)

NFPA 30	Flammable and Combustible Liquids Code.
NFPA 59A	Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG).

3. Terms and definitions

The technical terms used in this GP have the meanings defined in API Std 521/ISO 23251. For the purposes of this GP, the following terms and definitions also apply:

Corrected test pressure

Hydrostatic test pressure multiplied by the ratio of stress value at design temperature to stress value at test temperature.

Disposal system

A system that conducts the relieved fluid to a location where it can be safely discharged. Disposal systems may terminate in an atmospheric vent, a combustion device, such as a flare tip, or other specialised treating equipment.

High pressure (HP)/low pressure (LP) interface

A piping component (valve, flange, orifice plate, etc.) in which the upstream operating pressure is higher than the downstream maximum allowable working pressure (MAWP). Less obvious situations



could include reverse flow through pumps, hydraulic power recovery turbines or check valves, drains to closed drain systems, or heat exchanger tube failures.

Joule-Thomson effect

The temperature change of a gas or liquid that is forced through a valve or restriction while kept insulated such that no heat is exchanged with the environment.

Letdown station

A flow restriction in which the upstream operating pressure is greater than the downstream design pressure. Letdown stations normally consist of an arrangement of control valves, manual valves, and/or orifice plates. Choke valves in Exploration and Production (E&P) operations are letdown stations. Letdown stations can be permanent (e.g., fixed piping) or temporary (e.g., hoses).

HP/LP interfaces are letdown stations, including the following:

- a. Reverse flow through pumps, check valves, or compressor recycle valves.
- b. Drains from process systems to closed drain systems, across which an HP/LP interface exists.

Pressure limiting instrumentation

Instrument systems that minimise the size or frequency of relief loads by automatically adjusting process conditions if they tend toward a relief situation. One example of pressure limiting instrumentation is an SIS (described in 6.5).

Pressure vessel

Vessel used for an integrated operation in petrochemical facilities, refineries, gas plants, oil and gas production facilities, and other facilities.

Probability of failure on demand (PFD)

Probability that a system will fail to perform a specified function on demand.

Reliability analysis

Mathematical technique for assessing, in probabilistic terms, performance of a component, system, or plant.

Relief device

Any device (mechanical or instrumentation) that acts automatically and reliably to relieve material upon pressure rise. "Relief device" normally refers to pressure relief valves and bursting discs, but explosion hatches, water seals, buckling pin devices, and pressure/vacuum breather valves are other devices that meet this definition.

Safeguarding process flow diagram

Process flow diagram that illustrates major relief and flare system design features, including relative relief devices, SIS devices, emergency shutdown valves (ESDVs), blowdown valves (BDVs), relief headers, knockout drums, and flares.

Safety instrumented function (SIF)

Safety function with specified integrity level that is necessary to achieve functional safety by putting process to a safe state or maintaining it in a safe state under predefined conditions. SIF is implemented using SIS.



Safety instrumented system (SIS)

Instrumented system used to implement one or more SIF. SIS is composed of sensors, logic solvers, and final control elements. An emergency shutdown (ESD) system is a specific example of an SIS.

The term high integrity protection system (HIPS), as used in API Std 521, can be assumed to be SIS for the purposes of this GP.

Safety integrity level (SIL)

Numerical representation of the integrity required and capability of SIF. SIL addresses hardware reliability and capability to avoid systematic faults. SILs for SIFs operating in demand mode are defined for hardware reliability in terms of PFD (see IEC 61511 and IEC 61508). See GP 48-03 for details of SIL levels.

4. Symbols and abbreviations

For the purpose of this GP, the following symbols and abbreviations apply:

BDV	Blowdown valve.
Cg	Valve sizing coefficient for gas.
CHAZOP	Computer HAZOP.
CSC/CSO	Car sealed closed/car sealed open (normally applies to isolation valves).
Cv	Valve sizing coefficient.
CV	Control valve.
CVP	Capital value process.
EA	Engineering authority.
ESD	Emergency shutdown.
ESDV	Emergency shutdown valve.
FB	Full bore.
FMEA	Failure mode and effects analysis.
HAZID	Hazard identification.
HAZOP	Hazard and operability (study).
HEM	Homogenous equilibrium model.
HIPS	High integrity protection system.
HP	High pressure.
I/O	Input/output.
IFC	Issued for construction (typically P&IDs).



IFD	Issued for design (typically P&IDs).
IM	Integrity management.
ISD	Inherently safer design.
LNG	Liquefied natural gas.
LO/LC	Locked open/locked closed valves.
LOPA	Layer of protection analysis.
LP	Low pressure.
LPG	Liquefied petroleum gas.
LR	Long radius.
MAWP	Maximum allowable working pressure.
MBP	Marked burst pressure.
MCC	Motor control centre.
MOC	Management of change.
MP	Major projects.
NGL	Natural gas liquids.
P&ID	Process and instrument diagram.
PCHE	Printed circuit heat exchanger.
PFD	Probability of failure on demand.
PLC	Programmable logic control.
PORV	Pilot operated relief valve.
PSV	Pressure safety valve.
QRA	Quantitative review analysis.
RO	Restriction orifice.
SBP	Specified burst pressure.
SDV	Shutdown valve.
SIF	Safety instrumented function.
SIL	Safety integrity level.
SIS	Safety instrumented system(s).
SME	Subject matter expert.



SPU	Strategic performance unit.
SR	Short radius.
TA	Technical authority.

5. Philosophy

5.1. Review of overpressure scenarios

- a. A systematic review shall be conducted to review overpressure scenarios for equipment and HP/LP interfaces.

A full facility HAZOP (performed in accordance with GP 48-02) may be required. The facility HAZOP should incorporate the overpressure requirements as defined within this GP.

- b. During design of overpressure protection systems, the preferred order of techniques employed should be as follows:
1. Elimination or reduction in magnitude and frequency of overpressure cases through the application of ISD principles in accordance with GP 48-04.
Application of ISD principles can result in a system design pressure above the maximum pressure that can be generated under relieving conditions, therefore eliminating the need for a relief device. The assumed conditions on which this is based need to be fully documented such that subsequent changes can be assessed.
 2. Installation of mechanical relief devices to relieve excess pressure and protect equipment from overpressure.
 3. Application of SIS to limit relief loads.
 4. Application of SIS to protect equipment from overpressure.

5.2. Safety instrumented systems (SIS)

- a. Apart from SIS of sufficient integrity (designed for SIL in accordance with 6.5), no automatic relief limiting systems (e.g., pressure sensor that triggers shutoff of heat source) shall be used as alternatives to the provision of pressure relief devices as described in this GP.
- b. Installation of SIS as described in 6.5 in place of pressure relief valves shall comply with SIS requirements across the entire lifecycle.

The following points should be considered if applying SIS as an alternative or supplement to relief devices or to minimise the rate or duration of atmospheric discharge:

- *Generally, use of SIS moves a facility away from ISD. SIS have multiple components and potential for common mode failures and systematic faults.*
- *What appears on a P&ID and basic logic diagram to be a straightforward trip system can, if fully engineered, result in a complex system. For example, closing an ESDV between a high pressure vessel and a low pressure vessel upon loss of level in the high pressure vessel or increased pressure in the low pressure vessel can require additional instruments for reliability and a requirement to regularly test the ESDV closure time.*
- *Any savings in the cost of plant, relief valves, and rupture disks need to be offset against the capital cost of SIS, associated test facilities, the ongoing cost of maintenance, and routine proof testing of the system.*



- *Instrumentation on which the safety of the plant depends (SIL 1 and higher integrity) needs to be clearly identified and distinguished from all other instrumentation, including trips. This identification should appear in documentation (e.g., the register of safety critical devices) from design through operation.*

5.3. Pressure settings

- a. Relief devices or overpressure protection shall be set at or lower than the design pressure or MAWP of the weakest component in the system being protected, unless allowed otherwise by code.

For example, SIS should be set to allow sufficient response time between the shutdown action being initiated and the isolation of the pressure source.

- b. Occasionally, a relief device may be set lower than maximum design pressure to direct the valve discharge to a preferred location. However, adequate spread between operating pressure and set pressure of the relief device shall be maintained to prevent valve leakage or premature opening.

5.4. Closed relief system

- a. As the primary option, relief flow should be routed to a closed system (e.g., flare) or back into the process. If atmospheric relief is selected, the hazards associated with atmospheric relief should be assessed, and the overpressure reduction should be combined with a reduction in venting volumes by the use of SIS in accordance with 6.5.
- b. SIS devices may be used to minimise relief to a closed relief system provided the SIS complies with 6.5.
- c. Design of closed systems (e.g., flares) in which multiple pressure relief devices and/or blowdown valves/vent valves are connected shall comply with GP 44-80.
- d. For some installations, design, installation, and testing of overpressure protection systems may comply with API RP 14C or ISO 10418. However, use of these standards does not negate the need for LOPA.

LOPA should be used as the primary means of establishing the adequacy of an overpressure protection system design and then checks against API RP 14C or ISO 10418, if applicable, to meet regional requirements. If LOPA identifies a higher level of protection than required by local codes, the higher level of protection should be applied to the design.

API RP 14C requires that each safety system normally consist of two levels of protection to prevent or minimise the effects of an equipment failure within the process. API recommends using different or independent types of protection. The first or primary method of protection is normally instrument based, while the secondary method is usually provided by self acting devices, such as relief valves or rupture discs.

ISO 10418 incorporates API RP 14C but also allows use of the risk based approach for specification of safety protective systems in accordance with IEC 61508 as an alternative to specific requirements of API RP 14C.

6. Design practice

6.1. General

- a. A systematic examination of all modes of operation, including startup, shutdown, trip, and maintenance, shall be made to identify failures capable of creating overpressure.



- b. Apart from their normal operating mode, process units can have a range of other operating conditions that are either necessary for maintenance or occur as a result of upsets. Operating conditions (as applicable) to be considered shall include the following:
1. Normal and emergency shutdown.
 2. Pressure and tightness testing.
 3. Prestartup and startup.
 4. Manual operation as a result of automatic control system failure or deactivation.
 5. Alternate operating modes from original design (e.g., change in controller set point, turndown, or turnup).
 6. Catalyst conditioning.
 7. Catalyst regeneration/passivation, etc.
 8. Depressuring.
 9. Removal of inventory from unit.
 10. Gas freeing.
- c. Establishment of relieving loads shall include consideration of common modes of failure, such as electrical, instrument control system, mechanical, human, and procedural.
- d. Relief rates, together with the relieving temperature and composition, should be calculated by performing heat and mass balance calculations for relieving conditions. This should include such factors as:
1. Reflux drum emptying or flooding.
 2. Dryout of column sections, causing loss of circulating reflux.
 3. Change of duty in air cooled exchangers due to different temperature differentials.
 4. Change in latent heat and boiling temperature due to increased pressure and change in composition.
 5. Initial gas flow during startup of shut in oil wells.
- e. Methods of calculation shall be defined at an early stage of the design.
- Rigorous prediction of relief conditions within a distillation tower is difficult. For example:*
- *With regard to normal base composition, the raised temperature at relief pressure may so reduce heat transfer that reboil ceases. Designers may then only provide for the smaller fire relief load resulting from liquid vaporisation. This principle of “stall out” is potentially hazardous, because once reboil falls away, tower tray contents of volatile material could dump and “chill” the base contents such that reboil is reestablished.*
 - *In an upset condition, fractionation could be impaired and concentration profiles could differ markedly from normal conditions. Base compositions could markedly affect the temperature driving force and, hence, vaporisation rate, even beyond design.*
- f. A specialist in relief sizing for runaway reaction kinetics should be consulted to assist in overpressure protection analysis of reaction systems. This analysis should include:
1. Too much reactant, wrong composition.
 2. Too much catalyst and/or promoter.
 3. Overfilling, insufficient ullage for expansion.



4. Loss of agitation.
5. Loss of cooling.
6. Failure to terminate the reaction.
7. Loss of control.

Those processes (mainly petrochemical) that require the addition of catalyst or chain termination agents have very specific and difficult to calculate relief situations if either too much or too little of these agents is added or the temperature control mechanisms fail to perform properly.

In bringing a new process from pilot plant to full scale, designers may attempt to tailor the process such that it can become self controlling to a large degree. Even so, some or all of the upsets listed can cause excessive vapour generation, resulting in overpressure. As far as practical, the design temperature and pressure of the equipment should be such to contain or suppress these reactions. This may not be possible, and relief or high integrity SIS may be necessary.

The list of potential upsets in 6.2 is not exhaustive. A thorough knowledge of the process and its reaction kinetics is vital to identify the potential upsets such that a safe plant can be designed. Such knowledge should include:

- *Knowledge of reaction kinetics and equipment that adds the reactants should enable a simulation to be performed to determine the amount of excess material that needs to be relieved.*
 - *From design of the catalyst addition system, it should be possible to identify how much excess catalyst could be added from a single failure scenario. The reaction kinetics should then enable a simulation to be made of the result and the quantity and properties of excess material to be removed.*
 - *A loss of agitation reduces cooling, allowing exothermic reactions to accelerate. It may also allow local high concentrations of reactants with side reactions or local heating. Pilot plant studies are typically required to quantify the scale of relief needed in this situation.*
 - *A loss of cooling results in the reaction occurring at a higher temperature. Pilot plant work should identify the results of this situation and the appropriate response. The most likely actions that are required are quenching or depressuring. Either of these solutions requires SIS.*
- g. Relief devices that only protect piping systems may be set above the design rating of the piping in accordance with GP 42-10.
- This is a common approach in refineries that, however, may not be allowed by other regulating agencies (Minerals Management Service).*
- h. For internal explosion or runaway chemical reactions, if an ISD is not practical and if pressure relieving devices cannot protect against the situation, special requirements for emergency depressuring, halting reactions, or otherwise preventing/controlling these situations shall be provided by SIS in accordance with GP 48-03, GP 30-80, and GP 30-81.

6.2. Causes of overpressure

- a. Causes of overpressure to be considered in relief design shall include those listed in API Std 521/ISO 23251 and [GN 44-001](#).

The list of causes in API Std 521/ISO 23251 is not exhaustive. Therefore, good engineering judgment is required in considering each potential cause of overpressure. Further considerations for the potential causes of overpressure are listed in b.



- b. The following list supplements the causes referenced in a, but the list shall not preclude a detailed review of all other overpressure possibilities:

1. Power failure
 - a) Local power failure (local to equipment protected by a single PSV).
 - b) Complete power system failure within a unit or the entire facility.
 - c) Individual substation failure affecting all electrical equipment fed by a single substation.
 - d) Individual MCC failure affecting all electrical equipment fed by a single MCC.

Failure of an electrical subsystem often creates a larger relief case than total electrical failure.

2. Cooling or reflux system failures - local unit, plant wide. Partial cooling water failure shall not be assumed, i.e., complete cooling water failure shall be assumed if applicable.

In a cooling water distribution system, some exchangers are mounted in elevated positions. Upon the loss of some of the cooling water pumps, the change in the pump head/flow relationship can result in starving the elevated exchangers of water and loss of all cooling. Similarly, some hot exchangers may have insufficient flow to prevent boiling, which can cause vapour lock.

The loss of electricity and/or steam may lead to a cooling water failure, depending on the power utility being used for the rotating equipment supplying the cooling water or refrigerant utility. This should be reviewed as part of the cascading effects.

3. Boiler feedwater failure.

Boiler feedwater may be used as a cooling medium in some installations.

4. Multiple valve failure, open or closed.

There are some circumstances for which the potential for simultaneous failure of multiple valves needs to be considered. For example, if multiple production wells feed a common downstream system and if there is a sufficient number, two or more wells could fail to be isolated. LOPA is used to assess the probability and consequences of failure.

5. Inadvertent valve operation, control valve failure, or valve opening from a higher pressure source.
6. Failure of automatic controls. The instrumentation TA or appropriate SME should be consulted for consideration of the following issues:
 - a) Potential failure of instrument systems, including SIS.
 - b) For modern instrument systems that may rely on distributed shared loop systems, potential for simultaneous failure of more than one control loop.
 - c) Capability of a distributed control system to introduce means for otherwise unrelated control systems to be driven simultaneously to a dangerous position.
 - d) Operation of controllers in manual mode or with alternative set points to the original design basis.

Distributed control systems can be subject to failures that result in more than one controller failing simultaneously (e.g., node freezing or I/O card failure). Under these circumstances, it is better to design the control elements to failsafe (i.e., split I/O amongst different cards).



7. Gas breakthrough (blowby). Gas breakthrough shall be specifically addressed as a relief case (see 7.2).

Gas breakthrough is a condition that can occur if the liquid from a gas/liquid separation passes to a lower pressure system. If the liquid level is lost, gas can pass into the lower pressure system. Since a much greater volume of gas can pass through a control valve or manual valve than the liquid for which the valve was sized, the lower pressure system downstream of the HP/LP interface could be overpressured due to high rate gas flow (relative to the liquid design case).

8. Blocked or closed outlet(s).

Blockage could also result from plugging with solids (e.g., wax, hydrates, ice buildup).

9. Equipment failure (including pump, air cooled exchanger fan, or compressor trips and shutdowns).

10. Reverse flow (e.g., check valve failure).

- a) A reverse flow relief scenario is defined as when a feed pump or compressor to a gas/liquid system stops and the high pressure gas/liquid can reverse flow into the lower pressure system.
- b) If a single check valve is used on the discharge stream, full backflow shall be considered, and the settle out pressure should be appropriately defined.
- c) Typically, a dynamic analysis of the process system is required to be performed to evaluate the “settle out” case.

It is normally less of a problem if the system is liquid only, since very little material needs to be relieved, but calculations need to be performed to verify this.

11. Partial utility failure and/or interaction between utilities.

Partial utility failure cases include the loss of one part of the utility system. This can be the total or partial loss of one voltage on electrical systems or one arm of a piped utility. It often produces a larger relief case than a total utility failure.

12. Changes in feedstock or other process condition changes.

For example, the wellhead shut in pressure may increase if a gas column can be formed in the well bore, displacing liquids and reducing the hydraulic head loss.

Another case to consider is retrofitting gas lift to production wells, as the gas lift system may be able to generate higher pressures than the production risers and manifolds were originally designed for.

13. Properties of process fluids under relief conditions that are different from normal operation.

For example, blockages may occur due to freezing or hydrate formation.

14. Effect of a very large capacity source (such as a wellhead or long pipeline)

- a) The HP/LP interface shall be considered between a large high pressure inventory that feeds a system of smaller capacity designed for lower pressure (e.g., a subsea flowline or interfield pipeline feeding a topsides production manifold and separator).
- b) In these circumstances, it may not be feasible to provide a relief system of sufficient capacity to accommodate the case in which the high pressure system is suddenly deisolated (e.g., through failure open of the main ESDV).



- c) In this case, it may be necessary to provide mechanisms for safely depressuring the upstream source to a low enough pressure prior to startup with appropriate SIS and procedural controls.
- d) If SIS is used in lieu of mechanical devices, a detailed dynamic analysis should be performed to ensure that the downstream system will be protected, given that there is a delay between high pressure switch activation and closure of the isolation valve.

6.3. Relief limitation by design

6.3.1. ISD measures

At an early design stage in the project, ISD measures as defined in GP 48-04, and further defined for overpressure protection below, shall be considered. Some of the ISD design measures that can be used are:

- a. Design of vessels and equipment for pressure containment, rather than relying solely on relief devices to limit pressure.
- b. Reducing the source pressure in upstream supply.
For example, minimising wellhead supply pressure to a receiving facility.
- c. Increasing the differential between operating pressure and the pressure at which the pressure relief device operates or a control valve discharges to flare.
For example, increasing the design pressure to allow a higher relief device set pressure would accommodate pressure fluctuations that would otherwise cause excessive gas flaring or would eliminate an overpressure scenario (e.g., overfilling).
- d. Independent subdivision of utilities, either imported and/or generated onsite (e.g., power, steam, compressed air), to decrease (although it may not preclude) the likelihood of a total utility failure.
- e. Provision of two or more electrical feeders or generators to a site or part of a site. Electrical feeders and generators shall be rated, connected, and protected such that failure of any single element does not interrupt continuity of supply from other sources.
- f. Consideration of layout for external fire conditions.
An ISD approach should consider the layout of the facility to mitigate the effects of external fire from pool fire or jet fire from the facility equipment, as well as from adjacent facilities.

6.3.2. Basic design measures

At an early design stage in the project, the following methods to limit or reduce the likelihood of pressure relief should be considered as good practice in reducing overpressure loads but shall not be used as credit if sizing the pressure relief system:

- a. Design, selection, and protection of control equipment and other service systems to minimise the potential for simultaneous failure of otherwise independent systems.
- b. Use of auxiliary sources of power, such as diesel engines or steam turbines, to provide cooling water, instrument air, electrical power, etc., under emergency conditions.
- c. Provision of automatic reacceleration schemes for electric motor drivers, the loss of which may give rise to overpressure conditions. These schemes may reaccelerate motors simultaneously or sequentially, depending on the capability of the power supply.
- d. Use of the same utility for cooling as for heat supply (e.g., steam or steam/hydraulic drivers for air cooled exchangers and reflux pumps) in which steam driven feed pumps and reboiler pumps or steam heated reboilers are used.



- e. Consideration of the effect on relief systems in selecting process and auxiliary drivers.
- f. Provision of cooling water standby tanks to ensure a period of water supply, normally 30 min.

6.4. Assessment of overpressure scenarios

- a. Identification of all possible failure modes that could lead to an overpressure scenario, and these probabilities and consequences shall be the responsibility of a design team. In addition to HAZID and HAZOP, other formal procedures, such as LOPA, QRA, and FMEA may be applied, as deemed necessary.
- b. The potential for failure of major utilities and services with multiple drivers (e.g., cooling water, refrigerant) should be determined, assuming that any one machine could be down for maintenance.

For example, power may be generated via an electric supply base and diesel driver power backup. A total power failure occurs if the diesel drive is down for maintenance when the electric supply fails.

- c. API Std 521/ISO 23251, Section 4.2, provides requirements that shall be followed in coincident failure situations.

Coincident failure scenarios are sometimes referred to as “double jeopardy” however care should be exercised to ensure the failure modes are completely independent.

- d. Coincident failure shall be considered, if the result of a common mode failure or a process dependency. For example:
 - 1. There may be conditions in which fluids are particularly hazardous or the consequences of failure are of such magnitude that the norm of not considering two unrelated and coincident failures may not be appreciated.
 - 2. In such cases, hazards should be quantified to determine the relief loads that need to be considered.

Care needs to be taken in considering simultaneous failures. Often, two apparently unrelated events can have a common mode failure, and it is possible for a latent failure to remain undetected prior to initiation of the second event.

For example, in a system that has an inlet line with two pressure regulators and no means of determining the failure of either pressure regulator, one of the pressure regulators may have an undetected latent failure that is assumed to have occurred. As a result, the simultaneous failure of both pressure regulators should be considered.

- e. Cascading events
 - 1. Cascading events should be included in considering coincident failures.
 - 2. If there are process connections from one part of a unit to another part of the same or another unit, the need for overpressure protection due to an upset on one causing an overpressure on the other should be addressed.
 - 3. This shall particularly be examined for all cases in which gas generated in one process is supplied to another.

Utility systems, such as fuel gas, often have pressure controllers from the generating equipment that open if the pressure rises. If a major upset occurs in the generating vessel, large quantities of gas can be discharged at a much higher pressure than the downstream equipment design pressure. This case is normally recognised in the generating equipment, and appropriate relief is normally included. However, the downstream equipment can still be overpressured if its design pressure is lower.



The same problem occurs anywhere material is taken as a product of one part of a unit to provide feed for another.

A particularly difficult problem arises if a liquid overfill condition can occur on the generating equipment for which gas is the normal product. In such a case, liquid knockout facilities are required in the transfer system, unless SIS is provided against this eventuality.

- f. Maximum discharge pressure of a fluid driver during an overpressure event should account for effects of that event on suction pressure of the fluid driver.

For example, consider a system in which fluid is being pumped from an upstream vessel into a downstream vessel. A closed outlet for the downstream vessel is expected to result in overfilling of the upstream vessel. Therefore, the suction pressure of the fluid driver should be based on an elevated pressure in the upstream vessel.

- g. If multiple interconnected vessels or equipment are protected by a common relief device, the following criteria shall be used in accordance with ASME Boiler and Pressure Vessel Code Section VIII Division 1 Appendix M and/or ASME Boiler and Pressure Vessel Code Section VIII Division 2 Part 9 as appropriate:

1. An open relief path shall be maintained between interconnected vessels and their protective device (i.e., no intervening valves [automatic or manual] are permitted).

For example, a heat exchanger having an upstream check valve and a downstream control valve could potentially be isolated from an interconnected downstream vessel. The control valve could close during an overpressure scenario, either by design or by operator error, regardless of its failure position upon loss of instrument air. Therefore, this exchanger cannot be protected by a relief device located on the downstream vessel.

2. If manual block valves are located in a normally flowing process line and if they are only used for equipment isolation and maintenance, the flow path between the equipment and its protective device shall be maintained open by:

- a) Locking or sealing open the intervening block valve(s).

Valve controls can include mechanical interlocks (other than seals or locks) that prevent the valve from being closed, instrumented interlocks (e.g., permissives) that prevent the valves from being closed out of sequence, or three way valves to prevent the flow being blocked without another flow path being simultaneously opened.

- b) Identifying the valves in relief and overpressure system design documentation.
c) Closing the valves by permit or procedure only and including the isolation procedure in plant operating instructions.
d) If manual block valves are installed around an exchanger for maintenance, the exchanger shall be vented and drained immediately after it has been isolated. If this is not practical, a relief device should be installed to protect the exchanger.

Manual block valves are permitted if fire is the only scenario and the vessel is immediately drained upon closure of the manual block valves.

- e) If the option of venting and draining is adopted, a warning notice should be installed which states that the exchanger shall be vented and drained immediately after being isolated.
3. If closure of the valve (due to mechanical failure or human error) can result in pressures exceeding the corrected test pressure, either of the two following shall occur:
a) The block valve(s) shall be eliminated.



- b) A pressure relief device shall be installed that protects the equipment from overpressure due to closure of the valve(s).

This clause does not apply to the isolation of pressure relief devices, which is covered in 10.6.2.

- h. Credit shall not be taken for automatic controls acting to prevent an overpressure situation, unless they meet the requirements required for SIS (see 6.5).

This assumption is implicit in API RP 14C, as the relief or blowdown system is only called on to operate if both the normal process control and the protective instrumentation have failed.

- i. To address the issues of I/O card failure and inadvertent operation of control devices that have multiple inputs, a process control loop failure assessment shall be performed as follows:

1. For any system with more than one output, an analysis should be performed to determine all reasonably foreseeable failure modes or common cause component failures that may result in more than one output going to the nonfailsafe state and potentially producing unacceptable process relief loads.

See IEC 61508 for control system electrical supply reliability.

2. Relief loads that could arise from these failures should be determined. If relief loads exceed design capability, it may be possible to reassign system outputs to reduce the relief load.

GN 30-401 provides guidance on performing a computer or control HAZOP (CHAZOP) that addresses failures of control and safety system elements which could cause concurrent process hazards.

- j. Credit shall only be taken for an operator intervention in accordance with GP 48-03 to determine if the operator, in conjunction with other layers of protection, can be relied upon to address the overpressure scenario (e.g., liquid overfill).

Operator intervention may be considered if the onset to overpressure is long enough (10 min to 30 min after alarm) to allow operators to respond effectively in mitigating the event and if the scenario does not cause the release of flammable, toxic, or otherwise hazardous fluids directly to atmosphere. See GP 44-80 and GN 44-001 for decision trees and additional guidance on operator intervention.

- k. Since piping and equipment design takes into account both temperature and pressure, the possibility that departures from the normally expected operating temperature range may occur during emergencies should be recognised.

Pressure relief systems may not provide adequate protection if conditions are outside equipment design temperatures (high or low). Typical examples are overheating due external fire, exothermic reaction, and autorefrigeration due to the presence of light hydrocarbons. Temperature limiting or emergency depressurising systems may also be required. Refer to GP 44-80.

In these circumstances, the allowable stress of construction materials may be so much reduced that failure occurs at pressures below the set pressure of the relief device.

The hazards of autorefrigeration are that the materials of construction may be embrittled by the resultant low temperature or that plugging could occur due to freezing fluids.

- l. Overpressure protection design shall be based on the maximum expected throughput for an individual process component or process system. Consideration should be given to



variations in normal operating flow rates while avoiding significant oversizing of pressure relief devices.

- m. Relief devices protecting unfired process boilers (waste heat boilers) that are designed in accordance with ASME Boiler and Pressure Vessel Code Section VIII (or another pressure vessel design code) shall be consistent with that design code.
- n. Dynamic simulation
 - 1. Calculation of the quantity to be discharged under relief conditions normally assumes a steady state condition.
 - 2. If it is estimated that this assumption is overly conservative, a dynamic simulation should be performed to determine the required relief capacity.
 - 3. Reference should be made to the requirements of API Std 521/ISO 23251 if using dynamic simulation as a method for determining the relief rate and specifically, the need for:
 - a) Sensitivity analysis.
 - b) Matching of the dynamic model with a steady state calculation.
 - c) Use of conservative assumptions.

Dynamic simulation of transient overpressures can often reduce the size of a relief device. The results from simulations can be very sensitive to starting assumptions and the manner in which some system components have to be modelled. Therefore, attention needs to be paid to the quality of information and the methodology used in any model.

6.5. Pressure limiting and safety instrumented systems (SIS)

- a. SIS intended to avoid or limit pressure relief (also known as HIPS) may be a viable approach to overpressure if compared to conventional protection methods using mechanical devices, such as relief valves.
- b. GP 48-03 shall be followed in the application of LOPA, and the SIS arrangement shall comply with the appropriate SIL in accordance with GP 30-80 and GP 30-81.

Examples of such circumstances for which this approach may be justified are:

- *If there is no practical location to which relief can be discharged.*
- *For protection against internal explosion.*
- *For protection against uncontrolled chemical reaction.*

SIS typically consists of instruments, final control elements (e.g., valves, switches), and associated logic designed to prevent overpressure. SIS generally works by limiting source pressure into the system and often does not provide actual pressure relief.

This design approach to process instrumentation and SIS is based on guidance given in API Std 521/ISO 23251 and ASME Boiler and Pressure Vessel Code Section VIII Division 1.

- c. SIS shall only be used as the sole means to provide final protection against overpressure if all of the following conditions have been satisfied:
 - 1. There are compelling engineering or commercial reasons that the equipment cannot be protected by conventional pressure relief devices.
 - 2. The appropriate EA has approved the use of SIS as follows:



- a) For operating facilities, the appropriate EA (operations or site) shall be responsible for ensuring LOPA planning, conduct, documentation, and resolution of action items.
- b) For projects, the project EA shall be responsible for ensuring LOPA planning, conduct, documentation, and resolution of action items.
- 3. The closed system designed for receipt of relief valve discharges has been sized by taking credit for the operation of automatic pressure limiting instrumentation to reduce the relief load. Consideration for design of the relief system should be given to SDV leakage rate and dynamic response of the shutdown system.
- 4. There is operations competence and capability to construct and maintain the SIS to the required standard.
- 5. The system application and design complies with GP 48-03, GP 30-80, and GP 30-81.
- d. Pressure limiting and temperature limiting SIS may, if appropriate, include automatic actuation of the following:
 - 1. Feed or pipeline transmission pump or compressor trips.
 - 2. Fuel shutoff valves.
 - 3. Reboiler heating medium bypasses and shutoff devices.
 - 4. Fired reboiler shutdown and heating medium circulating pump trips.
 - 5. Pressure and temperature limiting systems to protect reactors.
- e. A philosophy of automatic turndown may be applied to allow time for effective operator action to avoid both the operation of relief devices and widespread shutdown.
- f. The set points of any pressure limiting SIS, preceded by alarms, as required, should be below the lowest design pressure in the system under consideration to be effective.
- g. API Std 520, Part I, should be consulted for typical set point tolerances and the spread required between operating and set pressure of relief devices.
- h. Sufficient design margin, taking account of control system response and process dynamics, shall be applied in selecting a set point. Design margin shall be defined to allow for:
 - 1. Tolerance of set pressure of the relief device under actual working conditions.
 - 2. Setting of any trip switch or amplifier and its switching differential.
 - 3. Setting of the prealarm and its switching differential.
 - 4. Maximum operating pressure under normal process conditions.
 - 5. Time required for the SIS to fully complete its protective function in relation to process dynamics.

Valve closing time is usually the limiting factor.

6.6. Reverse flow

- a. Overpressure resulting from reverse flow from a high pressure system shall be considered. No credit shall be taken for the presence of a single check valve or steam trap in a line. The following shall be considered:
 - 1. Two check valves in series may be used as a means of overpressure protection, provided that the application and subsequent reliability and maintenance complies with GP 48-03. The installation of two check valves shall not be the sole means for isolation of low and high pressure sources. A positive means of isolation of the line shall be installed for maintenance.



If two check valves are used to prevent overpressure, these components become safety critical elements. Therefore, performance standards need to be developed and a means of proving their integrity provided.

2. Two dissimilar check valves in series used for overpressure protection shall only be used in clean, nonvibrating, nonpulsating services and shall be periodically maintained and tested to improve reliability by eliminating common mode valve failures.
3. If two check valves are used as a means of overpressure protection, their use shall be clearly documented in design, included in a register of safety critical equipment (e.g., the relief and overpressure dossier), and be subject to approval by the appropriate EA.
4. If the reliability of two check valves in series cannot be ensured, the reverse flow leakage rate shall be based on calculated flow through a single orifice with a flow area equal to 10% of the largest check valve flow area.

As this presumes two failures, one check valve fails open completely, and the second check valve fails open partially.

5. Orientation of check valves shall ensure that the check valves can function reliably in accordance with manufacturer recommendations.
- b. If there is only a single check valve, complete failure of the check valve shall be considered for the applicable overpressure scenario definition. In this case, the reverse flow rate shall be based on the full orifice diameter within the check valve, assuming complete failure.
 - c. The requirement for additional isolation to prevent ongoing leakage raises the following practical issues that shall be considered for the overall level of protection to be considered satisfactory:
 1. If some leakage is tolerable, a LOPA should be performed in accordance with GP 48-03 to identify issues involved and sensitivities of key assumptions.
 2. If a detailed analysis shows that manual isolation is not a practical option, consideration should be given to automatic isolation or an alternative means of protection as follows:
 - a) Circumstances that require additional manual isolation shall be clearly identified and agreed with operating personnel. This additional manual isolation shall be readily identifiable in the field, and the requirement for isolation shall be clearly identified in operating procedures.
 - b) System design shall ensure that it is safe for field personnel to make required manual isolations. The rate of pressurisation of the low pressure system shall be sufficiently slow such that a dangerous level of pressure is not reached within the timescale for effective isolation.
 - c) Assessment of the timescale for isolation shall take into account the likely circumstances of the initiating event (e.g., a total power failure) and the alarm loading and work load on field personnel at the time. The human factor aspects of the situation shall be considered, including the potential for the isolation step to be omitted.
 - d) Any manual isolation valve that is required to supplement the check valves shall be maintained in good working order. An actuated isolation valve should be used, unless the manual valve is located in an area that is protected against effects of fire or blast overpressure and potential escalation.
 - e) Any manual isolation valve shall be accessible in all foreseeable situations (e.g., if the cause of reverse flow was a fire that could lead to a pump being shut



down, the isolating valve would need to be accessible), unless the consequences of any reverse flow were judged to be far less than the initiating event.

- f) Consideration of the potential consequences of failure (either the failure of the isolation valve to open or close) should be made. While catastrophic failure of a vessel is always a very serious event, if the consequences are particularly severe, a higher standard may be warranted.
- g) Consideration should be given to the implications of assumed leakage rates on the inspection regime of check valves and whether simple visual inspection is sufficient or a higher standard of testing (e.g., periodic leak testing) is required.

6.7. Vacuum relief

- a. The potential need for vacuum relief on vessels and systems shall be considered for all modes of operation (e.g., purging, startup, shutdown, thermal contraction, condensing).

The potential for vacuum occurring usually only arises if deviating from normal operating conditions, such as preparing for maintenance in draining and purging activities (e.g., steamout).

- b. The ISD (preferred) method of vacuum protection is to design pressurised equipment for full vacuum, if practical.
- c. For low pressure equipment and other instances for which designing for full vacuum is not practical, protection may be provided by vacuum relief systems or gas (noncondensable) blanketing systems from a high reliability supply source using a protective system in accordance with GP 48-03.

If there is a risk of flammable mixture formation inside the equipment, vacuum relief devices may not be preferred.

- d. Under some circumstances, such as maintenance activities, procedural protection may be adequate to prevent vacuum conditions. Basis of protection shall be included in documentation required in 9.4.

Calculation of the required inflow rate to prevent vacuum can prove problematic, as it is usually a result of a transient effect. Conservative assumptions should be made concerning heat transfer and compositions to ensure that the system is robustly designed.

- e. The following causes of vacuum inside storage tanks could result in potential loss of containment and/or a spill and should be considered:
 1. Changes in ambient conditions causing contraction of a trapped vapour due to lowering of the temperature of a closed vessel containing a volatile liquid below its atmospheric boiling point.
 2. Pumping out a vessel at a rate faster than the liquid can be replaced with gas or vapour.
 3. Gravity emptying.
 4. Condensation of vapour.

This may occur following a steamout operation.

6.8. Cold service

- a. Liquid condensation and/or solids formation
 1. If autorefrigeration or Joule-Thomson cooling causes low temperatures (below minimum rated temperature for the downstream piping and equipment), consideration shall be given for liquid condensation and/or solids formation in released vapours



(e.g., letdown from high pressure gas service or low temperature storage of LNG or LPG, fluorocarbons, or other low boiling materials).

2. In these cases, the pressure relief device and depressuring valve (if used) shall be constructed of materials suitable for the minimum temperature encountered.
3. Refer to GP 44-80 for more detailed guidance.
4. Additionally, potential blockage and/or liquids accumulation should be considered in the design for these services.

A temperature check is most likely needed for relief conditions involving autorefrigeration or liquids or gases at high pressures. A temperature check is not required for overpressure cases due to heat input from external fire.

- b. Any nonflammable, nontoxic liquefied gas (e.g., CO₂) capable of forming solid particles on discharge should be vented directly to atmosphere at a safe location with minimal piping downstream of the pressure relief device. Refer to GP 44-80 for detailed guidance on vent systems and dispersion modelling.

The formation of solid particles could result in erosion and/or blockage of piping downstream of relief valves.

- c. Pressure relief for CO₂ is a specialised area, and further advice should be sought before proceeding with the design. The pressure relief device should be constructed of materials suitable for this service.

BP has participated in research over recent years to better understand the behaviour of CO₂ and connected systems under relief and emergency depressurisation situations. Under some circumstances (e.g., if the depressuring or relief rate is too high), there is a risk of vessel failure due to rapid cooldown and embrittlement.

- d. If autorefrigeration or Joule-Thomson cooling through a pressure relief valve is anticipated, heating and insulating of the valve should be considered to minimise leakage caused by the valve failing to reclose completely.

6.9. External fire condition

- a. Pressure relief devices shall be provided for the fire relief condition on vessels and equipment that could be subjected to a sustained external fire. Calculation methods shall comply with API Std 521/ISO 23251.
- b. For pressure equipment (i.e., design pressure greater than 1,0 barg [15 psig]), a heat input rate of 66,2 kW/m² (21 000 Btu/hr ft²) should be used if adequate drainage and firefighting capability are provided in accordance with API Std 521/ISO 23251. If adequate drainage and/or firefighting are not provided, a heat input rate of 108,8 kW/m² (34 500 Btu/hr ft²) shall be used.

Generally, the lower heat input rate of 66,2 kW/m² (21 000 Btu/hr ft²) is applied to vessels and equipment located within the process area.

See GN 44-001 to determine when drainage and firefighting capability are considered adequate.

- c. For low pressure storage tanks (i.e., design pressure less than or equal to 1,0 barg [15 psig]), requirements in API Std 2000 or ISO 28300 shall be used.

Consult API Std 2000 or ISO 28300 for appropriate requirements relating to liquid level and height of wetted surface area.

- d. For all spherical storage vessels, regardless of drainage or firefighting capability, a heat input rate 108,8 kW/m² (34 500 Btu/hr ft²) shall be used.



Consult API Std 521/ISO 23251 for additional requirements for fire relief for spheres.

- e. For column bases, the level of the wetted surface should be based on the normal liquid level, plus a level equivalent to the liquid on all the trays or internal packing, on the assumption that the liquid will be dumped into the base of the column. If there are total trapout trays, this should be modified.
- f. Pressure vessels should not be assumed to be liquid full, unless that is the normal operating condition (e.g., shell and tube heat exchangers that contain liquid streams). The liquid level used in the wetted surface area determination for vessels may be based on either:
 - 1. High level alarm set point.
 - 2. Maximum operating level.
- g. The relief rate shall be determined at the relieving conditions, taking account of changes in latent heat, composition, etc., due to elevated pressure and temperature.
- h. Fire relief
 - 1. Pressure relief devices that protect vessels during an external fire (including liquid full vessels) should be sized assuming all vapour venting (i.e., adequate disengagement of the liquid and vapour occurs).
 - 2. However, fire relief design for vessels containing reactive or foamy fluids and/or vessels in which the pressure relief device inlet is connected below liquid level shall size the relief device based upon incomplete vapour/liquid disengagement (i.e., two phase or flashing flow).
 - 3. The relief rate should be determined on the basis that the equipment is isolated. It may be acceptable to take credit for open outlets but only if it is possible to ensure that the outlets will remain open and have adequate capacity during a fire (e.g., it is normal practice for emergency responders to isolate lines and equipment).
- i. Vessel failure
 - 1. Vessels may fail due to sustained exposure to high temperature from the flame/fire plume and/or thermal radiation for the following cases:
 - a) Gas or vapour filled vessels.
 - b) Vessels in which the fluid can reach or exceed thermodynamic critical conditions (dense phase fluid).
 - 2. In these cases, vessel will fail due to overtemperature rather than overpressure, so a pressure relief device is generally ineffective.
 - 3. Deluge, fireproofing, emergency depressurisation, or other system mitigation should be provided to protect against vessel rupture due to overtemperature for large equipment that is subject to external fire.

Fire mitigations, such as deluge, fireproofing, and/or emergency depressurisation, should be designed to resist flame impingement, blast overpressure, and other dangerous environmental conditions that may exist in an emergency.
- j. All bunded areas (curbed or diked) with storage tanks or equipment storing combustible liquids shall be considered potential fire zones (refer to NFPA 30).
- k. A closed system for the fire relief case shall be sized to handle simultaneous discharge from all pressure relief devices that are judged to be affected. Refer to [GN 44-001](#) for additional guidance on fire zones as follows:
 - 1. Fire zone shall be determined by reference to the plot plan, making allowance for adjacent roads, bund (dike) walls, curbed areas, firewalls, and drainage conditions.

