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## Revision Memo

06/04      General revision to be consistent with ExxonMobil experience. Detailed revision Memo provided as APPENDIX 4 at the end of this section

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## 1 SCOPE

This section describes the basic principles and procedures for the evaluation of overpressure potential in plant equipment, and for the selection, design and specification of appropriate pressure relieving facilities. The design of closed pressure relief valve and flare headers is included in this section, but blowdown drums and flares are covered under [DP XV](#), [DP XV-D](#) and [XV-E](#), respectively.

## 2 REFERENCES

### 2.1 DESIGN PRACTICES

|                        |                                                       |
|------------------------|-------------------------------------------------------|
| <a href="#">DP II</a>  | Design Temperature, Design Pressure and Flange Rating |
| <a href="#">DP X-A</a> | Pumping Service Design Procedures                     |
| <a href="#">DP X-F</a> | Positive Displacement Pumps                           |
| <a href="#">DP XIV</a> | Fluid Flow                                            |

### 2.2 GLOBAL PRACTICES

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| GP 03-02-01, | Sewer Systems                                      |
| GP 03-02-04, | Pressure Relieving Systems                         |
| GP 03-03-02, | Suction and Discharge Piping for Centrifugal Pumps |
| GP 03-03-07, | Inlet and Exhaust Piping for Steam Turbines        |
| GP 03-06-03, | Utility Connections to Piping and Equipment        |
| GP 03-15-01, | Pressure Relief Valves                             |
| GP 03-12-01  | Valve Selection                                    |
| GP 05-03-01, | Pressure Testing of Unfired Pressure Vessels       |
| GP 07-01-01, | Fired Heaters                                      |
| GP 07-02-01, | Industrial Boilers                                 |
| GP 08-01-01, | Cooling Towers                                     |
| GP 09-07-03, | Vents for Fixed Roof Atmospheric Storage Tanks     |
| GP 14-03-01, | Fireproofing                                       |
| GP15-01-01,  | Instrumentation for Fired Heaters                  |
| GP15-07-02,  | Protective Systems                                 |
| GP 18-10-01, | Additional Requirements for Materials              |

### 2.3 OTHER REFERENCES

1. Exxon Blue Book.
2. ASME - Section I, Power Boilers.
3. ASME - Section VIII, Pressure Vessels.
4. ASME B31.3, Process Piping.
5. API RP-520, Sizing, Selection and Installation of Pressure Relieving Devices in Refineries - Part I: Sizing and Selection (7th edition, 2000); Part II: Installation (4th edition, 1994).
6. API RP-521, Guide for Pressure Relieving and Depressuring Systems (4th edition, 1997).
7. API RP-526, Flanged Steel Pressure-Relief Valves (5<sup>th</sup> edition, 2002).

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### 3 DEFINITIONS

#### Accumulation

Accumulation is the pressure increase over the maximum allowable working pressure or design pressure (in psi or kPa) of the vessel during discharge through the pressure relief valve, expressed as a percent of that pressure. (See definition of Design Pressure.)

#### Back Pressure

**Back Pressure General** - Is the pressure on the discharge side of a pressure relief valve. Total back pressure is the sum of superimposed and built-up back pressures.

**Superimposed Back Pressure** - Is the pressure at the outlet of the pressure relief valve while the valve is in a closed position. This type of back pressure comes from other sources in the discharge system; it may be constant or variable; and it may govern whether a conventional or balanced valve should be used in specific applications.

**Built-up Back Pressure** - Is the increase in pressure at the outlet of a pressure relief device that develops (typically due to friction but also static) as a result of flow through the discharge system after the pressure relief valve opens.

#### Balanced Pressure Relief Valve

A pressure relief valve which is designed to minimize the effect of back pressure on its performance characteristics.

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### Balanced Bellows Pressure Relief Valve

A balanced pressure relief valve that incorporates a vented bellows as the means for minimizing the effect of back pressure on the performance characteristics: *opening* pressure, closing pressure, lift and relieving capacity.

### Blowdown

Blowdown is the difference between the set pressure and the reseating pressure of a pressure relief valve, expressed as percent of set pressure.

### Closed Discharge System

This is the discharge piping for a PR valve which releases to a collection system, such as a blowdown drum and flare header. However, a closed system can also be a process vessel or other equipment at a pressure lower than the set pressure of the PR valve.

### Cold Differential Test Pressure

The cold differential test pressure (in psig or kPa gage) is the pressure at which the valve is adjusted to open on the test stand. This cold differential test pressure includes the corrections for service conditions of superimposed back pressure and temperature.

### Combustible

Liquid with a flash point at or above 100°F (38°C) and handled at more than 15°F (8°C) below its flash point.

### Common Cause Failure Mode

A coincident failure in two or more similar elements of a system caused by a single event. An example of a common cause failure mode is the simultaneous failure of two independent level instruments due to freezing of the process fluid in the instrument leads when exposed to low ambient temperatures.

### Conventional Pressure Relief Valve

A conventional pressure relief valve is a closed-bonnet spring-loaded pressure relief valve that has the bonnet vented to the discharge side of the valve and is therefore unbalanced. The performance characteristics, i.e., opening pressure, closing pressure, lift and relieving capacity, are directly affected by changes in the back pressure on the valve.

### Design Capacity

The capacity used to determine the required area of a relief device based on the limiting contingency.

### Design Contingency

An abnormal condition including maloperation, equipment malfunction, or other event which is not planned, but is foreseen to the extent that the situations involved are considered in establishing equipment **design conditions**.

### Design Pressure

**Design pressure** is the pressure in the equipment or **piping** under consideration at the most severe combination of coincident pressure, temperature, liquid level and **vessel pressure drop** expected during service, which results in the greatest required component thickness and the highest component rating (e.g., highest **ASME B16.5** flange class). More than one set of design conditions should be specified if the most severe pressure, temperature, liquid level and **vessel pressure drop** will not occur at the same time.

For **pressure vessels**, it is the pressure at the top of the vessel. Maximum liquid level and **vessel pressure drop** (if appropriate) should also be specified. **Design pressure** is equal to or less than the **maximum allowable working pressure**.

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### Double or Multiple Contingency

Two or more independent, unrelated, abnormal events that, if they occurred simultaneously or within a restricted short time interval, could result in an emergency. Double or multiple contingencies are normally not considered in the setting of design conditions or the design of overpressure protection facilities. However, it is the responsibility of the designer to consider **common cause failure modes** which might reasonably apply. Examples of common cause failure modes include potentially fouling conditions, low winter temperatures or off normal operations, that might cause simultaneous failure of process control and protection systems. Another example is the failure to close of two identical check valves in series. In such circumstances, the designer may need to provide designated "**safety critical**" protection, such as instrument purge or heating, safety valve inlet/outlet line tracing, independent types of instrument sensors, use of different types of check valves when two check valves in series are used to minimize back flow, etc

### Emergency

An interruption from normal operation in which personnel, equipment or the environment may be affected.

### Fire Risk Area

A process plant is subdivided into fire risk areas, each of which is the maximum area which can reasonably be expected to be totally involved in a single fire. Fire Risk Areas are established by the provision of access ways or clear spacing at least 20 ft (6.1 m) wide on all sides with drainage to catch basins located within the fire risk area. This is used to determine the combined requirement for pressure relief due to fire exposure and should not be confused with the areas used to determine fire water and sewer capacities, which are defined as plot subdivision areas in [DP XV-I](#), *Fire Fighting Facilities*.

### Flammable

Liquid with a flash point below 100°F (38°C) or a liquid with a flash point at or above 100°F (38°C) but handled within 15°F (8°C) of its flash point.

### High Integrity Protective System (HIPS)

An arrangement of instruments and other equipment, including sensors, logic controllers and final control elements used to isolate or remove a source of pressure from a system or to trip a shutdown or depressuring device such that the design pressure and/or temperature of the protected system will not be exceeded. Typical HIPS applications include load reduction to existing flare systems and the protection of systems where conventional protective systems such as pressure relief valves have proven to be unreliable or impractical. By definition, a HIPS is a safety critical system and must be independent from all other control schemes and from shutdown systems whose failure can lead to an event requiring HIPS activation. Functionally, a HIPS must provide equal or lower (better) unavailability on demand than a typical pressure relief valve. To ensure that this criterion is met, a HIPS should be specified to meet Safety Integrity Level (SIL) 3 or better. Safety Integrity Levels are defined elsewhere in this section.

### Intermediate - Time pressure Allowance (for piping only)

Per **ASME B31.3**, an increase of not more than 20% above the **design pressure** or the allowable stress for pressure design at the temperature of the increased condition. It is permitted for a maximum of 50 hours at any one time and for less than 500 hours per year, provided the additional restrictions in [DP II](#) are met.

### Maximum Allowable Working Pressure (MAWP)

For pumps and compressors, see [DP X-A](#) and [DP XI-A](#).

For **pressure vessels**, per the **ASME Code**, **MAWP** is the maximum (gauge) pressure permissible at the top of a vessel in its normal operating position at the designated coincident temperature and liquid level specified for that pressure. **MAWP** does not apply to **piping**. **MAWP**:

1. May be determined for more than one designated operating temperature and coincident liquid level, using for each temperature the applicable allowable stress value.
2. Is the least of the values for the internal or external pressure for any of the pressure boundary parts.

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- Is based on calculations using nominal thickness exclusive of allowances for corrosion and exclusive of thickness required for loadings other than pressure for every element of a vessel.
- Is assumed to be equal to the **design pressure** for all cases in which calculations were not made to determine the value of the **MAWP**.
- May, in final vessel construction be higher than the **design pressure**, due to the selection of thicker plates or plates with a nominal thickness greater than required in order to use a standard size.

#### Open Disposal System

This is discharge piping of a PR valve, which releases to the atmosphere either directly or via a collection system (which could include a K.O. drum).

#### Operating Pressure

The operating pressure is the gauge pressure to which the equipment is normally subjected in service. A process vessel is usually designed for a pressure which will provide a suitable margin above the operating pressure, in order to prevent leakage of the relief device. For the relationship between normal operating pressure and design pressure, reference should be made to [DP II, Design Temperature, Design Pressure and Flange Rating](#). Where it is necessary to raise operating pressure above the design operating basis, to avoid premature opening of a PR device, the **maximum** operating pressure can be related to the pressure relief valve set pressure (see *Set Pressure*). Where a spring-loaded pressure relief valve is used (either conventional or bellows type), up to 50 psig (345 kPa) set pressure, the maximum operating pressure shall be at least 5 psig (35 kPa) lower than the set pressure. For spring-loaded PR valves set above 50 psig (345 kPa), the maximum operating pressure shall be not more than 90% of set pressure. For a pilot operated pressure relief valve, the maximum operating pressure shall be not more than 95% of set pressure at or above 50 psig (345 kPa) and set pressure less 2.5 psig (17 kPa) below 50 psig (345 kPa). For pressure relief valves on low-pressure tankage, the valve manufacturer shall be consulted for appropriate set versus operating pressure limits.

#### Overpressure

Overpressure is the pressure increase over the set pressure of the relieving device during discharge. It is the same as accumulation when the relieving device is set at the maximum allowable working pressure of the vessel. It is also used as a generic term to describe an emergency which may cause the pressure to exceed the maximum allowable working pressure.

#### Pilot-Operated Pressure Relief Valve

A pilot-operated pressure relief valve is a PR valve that has the major flow device combined with and controlled by a self-actuated auxiliary pressure relief valve. This type of valve does not utilize an external source of energy and is balanced if the auxiliary PR valve is vented to the atmosphere.

#### Pressure Relief Device

A device actuated by inlet static pressure and designed to open during an emergency or abnormal condition to prevent the rise of internal fluid pressure in excess of a specified value. The device may also be designed to prevent excessive vacuum. The device may be a pressure relief valve, a non-reclosing pressure relief device or a vacuum relief valve.

#### Pressure Relief Valve

This is a generic term applying to relief valves, safety valves or safety relief valves. It is commonly abbreviated to "PR Valve."

#### Rated Capacity

The capacity a pressure relief device can pass when fully open at accumulated pressure. This rate is greater than or equal to the design capacity. The relationship between rated and design capacity is determined by the following ratio: (design capacity / required area) = (rated capacity / selected area).

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### Relief Valve

A relief valve is an automatic pressure-relieving device actuated by the static pressure upstream of the valve, and which opens in proportion to the increase in pressure over the opening pressure. It is used primarily for liquid service.

### Remote Contingency

An abnormal condition which could result in exceeding **design pressure** at the coincident temperature, but whose probability of occurrence **is** so low it is not considered as a **design contingency**. **Note that temperatures above the design temperature may also be permitted under remote contingency conditions.**

### Rupture Disc Device

A rupture disc device is actuated by inlet static pressure and is designed to function by the bursting of a pressure-retaining diaphragm or disc. Usually assembled between mounting flanges, the disc may be of metal, plastic, or metal and plastic. It is designed to withstand pressure up to a specified level, at which it will fail and release the pressure from the system being protected.

### Safety Critical Device

A Safety Critical Device is any device (mechanical, pneumatic, hydraulic, electrical, or electronic), system or sub-system whose failure to operate properly may result in loss of containment leading to possible explosion, fire, or uncontrollable release of hazardous material. Such events may result in:

- Fatalities/serious injuries to personnel, or impact on the public
- Major/extended duration or serious/significant resource commitment to address a potential environmental impact.
- A larger or smaller community disruption
- A corporate or regional financial impact.

Safety Critical Devices should be tested and maintained as part of a formal program designed to ensure that they will achieve the required level of availability and reliability during their life cycle. For safety critical alarms, written instructions should be provided to enable the operator to respond adequately to the alarm.

Excluded from SCDs are those devices whose only consequence of failure is an environmental exception (reporting). This does not obviate the need for reporting environmental incidents. Also excluded from the SCD category are business critical devices whose consequence of failure is purely economic (e.g., custody transfer). Reliable operation of such devices is covered by other appropriate equipment strategies.

The term "**safety critical**" is usually applied to instrumentation, but any device may qualify as **safety critical** if its failure could lead to serious consequences. For example, heat tracing systems (steam or electric) used to prevent plugging of pressure relief devices due to solidification of process fluids are considered **safety critical** and should be identified as such. Check valves can also be **safety critical** under certain conditions. Table 2 in [DP XV-A](#) lists some examples of **safety critical** check valve applications. Other examples of **safety critical** devices include restriction orifices that limit the flow rate to a pressure relief device and Emergency Block Valves (EBVs).

### Safety Critical Instrument

Any instrument, electrical, electronic or analytical device or system whose failure to operate properly may result in one or more of the following:

- A serious threat to the safety of plant personnel or the community through loss of containment and subsequent explosion, fire or personnel exposure to hazardous materials
- Serious equipment damage with associated safety risk to plant personnel or the community
- A serious environmental or industrial hygiene risk to plant personnel or the community.

The term **Safety Critical Instrument** is equivalent to the term **Safety Instrumented System (SIS)** in **ISA-S84.01** and to the term **Protective System** in **GP 15-07-02**.

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**Safety Critical Instruments** are a subset of **Safety Critical Devices**.

### Safety Integrity Level (SIL)

One of three possible discrete levels used to characterize the reliability of instrument-based safety systems as prescribed in ISA S84.01. SILs are defined in terms of Probability of Failure on Demand (PFD). The PFDs for various SIL levels are as follows:

| SAFETY INTEGRITY LEVEL (SIL) | PROBABILITY OF FAILURE ON DEMAND (PFD) |
|------------------------------|----------------------------------------|
| SIL-1                        | $0.01 < \text{PFD} \leq 0.1$           |
| SIL-2                        | $0.001 < \text{PFD} \leq 0.01$         |
| SIL-3                        | $\text{PFD} \leq 0.001$                |

### Safety Relief Valve

An automatic spring-loaded pressure relieving device suitable for use either as a safety valve or a relief valve, depending on application. It is used for vapor/gas service or for liquid service.

### Safety Valve

An automatic spring-loaded pressure-relieving device actuated by the static pressure upstream of the valve and characterized by a rapid full opening or pop action. It is used for vapor or gas service.

### Set Pressure

The set pressure (expressed as psig or kPa gage or other increment above atmospheric pressure) is the inlet pressure at which the pressure relief valve is adjusted to open under service conditions. For a relief or safety relief valve in liquid service, the set pressure is to be considered the inlet pressure at which the valve starts to discharge with a significant volume under service conditions. For a safety or safety relief valve in gas or vapor service (including two-phase and supercritical conditions), the set pressure is to be considered the inlet pressure at which the valve pops open under service conditions.

### Short-Time Pressure Allowance (for piping only)

Per **ASME B31.3**, an increase of not more than 33% above the **design pressure** or the allowable stress for pressure design at the temperature of the increased condition. It is permitted for a maximum of 10 hours at any one time and for less than 100 hours per year, provided the additional restrictions in [DP II](#) are met.

### Single Risk

The equipment affected by a design contingency.

### Spring Pressure

The spring pressure is equal to the set pressure minus the superimposed back pressure for a conventional PR valve. For a balanced pressure relief valve, the spring pressure equals the set pressure.

### 1.5 Times Design Pressure Rule

Equipment design per the ASME Code Section VIII, Division 1, is considered to be adequately protected against **overpressure** from **remote contingencies** if the maximum pressure during the remote contingency event can not exceed the proof test pressure, or 1.5 times the **design pressure** whichever is lower.

Equipment designed per the ASME Code Section VIII, Division 2, is considered to be adequately protected against **overpressure** from **remote contingencies** if the maximum possible pressure can not exceed the proof test pressure, or 1.25 times the **design pressure** whichever is lower.

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In addition, the maximum membrane stress in the equipment should not exceed the yield strength for the equipment material at the actual metal temperature experienced by the equipment during the **remote contingency** under consideration.

#### 4 SUMMARY OF SPECIFIC EXXON MOBIL REQUIREMENTS

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This section presents a summary of specific requirements that apply to ExxonMobil facilities. These requirements are based on ExxonMobil's interpretation of the broad principles contained in API Recommended Practices RP 520 and RP 521 and reflect ExxonMobil experience and overpressure protection philosophy. Additional background information for these requirements can be found elsewhere in [DP XV-C](#). The intent of this summary is to expedite access to this information by Contractors and other practitioners engaged in the front-end design of process facilities for ExxonMobil affiliates and licensees. **THIS SUMMARY DOES NOT RELIEVE THE USER FROM THE RESPONSIBILITY OF COMPLYING WITH ALL OF THE REQUIREMENTS OF DP XV-C AND API RECOMMENDED PRACTICES RP 520 AND RP 521. IN CASE OF CONFLICT BETWEEN THIS SUMMARY AND THE MAIN BODY OF DP XV-C, THE MAIN BODY OF DP XV-C GOVERNS.**

1. The simultaneous occurrence of two or more abnormal situations (**double** or **multiple contingencies**) need not be considered in the design of overpressure protection facilities.
2. No credit may be taken for operator intervention in preventing a potential overpressure incident..
3. No credit may be taken for the actions of process control or **safety critical instruments** other than **High Integrity Protective Systems (HIPS)** in preventing a potential overpressure incident.
4. The following basis should be used to determine the maximum flow rate arising from failure of a control valve in the fully open position:

| Type of Contingency | Flow Basis for Control Valve                                                                                                                                                                                     | Flow Basis for Bypass Valve                                                                                      |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
| Design              | Installed flow coefficient ( $C_v$ )<br>Upstream pressure = maximum operating pressure<br>Downstream pressure = 1.1 x MAWP of downstream system.                                                                 | 50% of $C_v$ of control valve at its normal operating position.<br>Pressure drop same as that for control valve. |
| Remote              | Installed flow coefficient ( $C_v$ )<br>Upstream pressure = maximum operating pressure<br>Downstream pressure = 1.5 x MAWP of downstream system or proof test pressure of downstream system, whichever is lower. | Installed flow coefficient ( $C_v$ ).<br>Pressure drop same as that for control valve.                           |

5. Under certain conditions, failure of a control valve in the open position may result in vapor blow-through into a system that is initially filled with stagnant (non-flowing) liquid. This situation may arise, for example, during the startup of certain hydrodesulfurization or hydroconversion units equipped with high-pressure liquid-vapor separators that feed the liquid to lower-pressure stripping towers. When this happens, the pressure in the downstream piping and equipment may temporarily approach that of the equipment upstream of the control valve as the liquid contained in the downstream system is accelerated. For such systems, the pressure-temperature rating of the piping and the design pressure of the equipment (vessels, exchangers) downstream of the control valve shall be determined as follows:
  1. Determine the extent of piping and equipment that could be **TOTALLY** filled with stagnant (non-flowing) liquid immediately before the control valve fails open.
  2. For any piping that could be **TOTALLY** filled with stagnant (non-flowing) liquid, specify a pressure-temperature rating such that the maximum operating pressure of the equipment upstream of the letdown valve does not exceed the short-term allowable pressure for the selected pressure-temperature rating at the operating

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temperature of the upstream system. The short-term allowable pressure is typically 133% of the maximum continuous pressure allowed for a given pressure-temperature rating.

- For any equipment (vessels, exchangers) that could be TOTALLY filled with stagnant (non-flowing) liquid, specify a design pressure such that the maximum operating pressure of the equipment upstream of the letdown valve does not exceed "C" times the design pressure, where "C" is the multiplier applied to design pressure to obtain hydrostatic test pressure per **GP 05-03-01**.

When the application of these guidelines results in an unreasonable increase in the cost of downstream equipment or piping, the following alternatives may be considered:

- Perform a dynamic analysis of the downstream system to determine the peak pressures as a function of time and downstream distance from the letdown valve. In some cases it may be possible to address the concern by specifying a maximum opening and/or closing rate for the control valve.
  - Consider modifying the configuration of the downstream piping and equipment or the startup sequence such that only a minimal amount of piping and equipment is 100% filled with stagnant (non-flowing) liquid whenever vapor blow-through is a credible scenario.
  - Provide a pressure relief device immediately downstream of the pressure letdown valve set at the maximum allowable working pressure of any piping or equipment located between the pressure letdown valve and the next piece of downstream equipment protected by a pressure relief device. This pressure relief device should be sized for the maximum vapor flow rate that can pass through the fully open control valve.
- The following basis should be used to determine the residual cooling capacity of air-cooled exchangers upon failure of the cooling air supply or control mechanisms:

| Type of Failure                                                      | Residual Cooling Capacity                                                                                                                                                                                                     | Type of Contingency                                                                                                                                                                                                                                                                       |
|----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Loss of the fan in a single fan unit.                                | 10% of the design capacity for condensers, 30% of the design capacity for coolers.                                                                                                                                            | Design                                                                                                                                                                                                                                                                                    |
| Loss of one fan in a multi-fan unit                                  | Assume one other fan is shutdown for maintenance.<br><br>Use 10% of the design capacity for condensers, 30% of the design capacity for coolers, applied over the surface area served by the two fans assumed to be shut down. | Design                                                                                                                                                                                                                                                                                    |
| Loss of all fans                                                     | 10% of design capacity for condensers, 30% of design capacity for coolers.                                                                                                                                                    | Remote if caused by mechanical failure of the fans.<br><br>If caused by loss of electric power, the contingency may be a design contingency or a remote contingency, depending on how loss of electric power is defined. See <a href="#">Utility Failure as a Cause of Overpressure</a> . |
| Failure of one set of automatic or manual louvers in closed position | No residual cooling capacity over the affected surface area.                                                                                                                                                                  | Design                                                                                                                                                                                                                                                                                    |
| Failure of all automatic louvers in the closed position.             | No residual cooling capacity over the affected surface area.                                                                                                                                                                  | Remote                                                                                                                                                                                                                                                                                    |
| Failure of all manual louvers in the closed position                 | This contingency need not be considered.                                                                                                                                                                                      | Not credible.                                                                                                                                                                                                                                                                             |

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7. Internal equipment blockage by collapsed internals such as bed supports or outlet collectors, or by plugging of packed beds by coke, scale or catalyst fines may be treated as a **remote contingency**. Blockage of fractionating towers by collapsed trays need not be considered.
8. Unless prohibited by local codes, the presence of a manual block valve in a single relief path for a vessel or group of vessels is acceptable only if **all** of the following conditions are satisfied:
  - a. The valve is car-sealed in the full open position (CSO) and painted a distinctive color (normally yellow).
  - b. The block valves must be line size full port hand-operated ball, gate or plug valves
  - c. If the block valve is a gate valve, it shall be installed with the stem oriented at or below the horizontal.
  - d. In the event of accidental closure of the block valve the maximum pressure reached in the protected equipment does not exceed 1.5 times its MAWP or its proof test pressure, whichever is lower. This condition need not be satisfied in the case of CSO isolation valves at the inlet or outlet of a pressure relief device intended to allow removal of the pressure relief device for maintenance, since inadvertent closure of such a valve will not result in an immediate overpressure event, and closure of such valves is controlled by administrative procedures. For the same reason, this condition need not be satisfied in the case of CSO isolation valves installed in flare headers to allow isolation of individual branches during plant turnarounds.

For vessels where two or more parallel relief paths exist, see [Item 16](#).

9. Heat exchanger tube rupture or leakage shall be considered as a **remote contingency**. Overpressure protection of the low pressure side need not be provided if the **proof test pressure** of the low pressure side, including attached piping and interconnected equipment is equal to or greater than the **design pressure** of the high pressure side. If this condition is not satisfied, overpressure protection may be required unless it can be shown that the relief capacity through the piping and equipment connected to the low pressure side is sufficient to prevent the pressure in the low pressure side from exceeding the proof test pressure.
10. **Liquid overfilling of vessels** as a source of overpressure shall be considered a **design contingency** unless **both** of the following conditions are satisfied:
  - a. Vessel is equipped with a **safety critical**, independent high-level alarm.
  - b. The liquid hold-up above the high level alarm is sufficient to provide a minimum of 30 minutes operator response time after activation of the alarm before an overpressure condition develops. The hold-up time is calculated assuming liquid continues to enter at its maximum expected flow rate with no liquid outflow.

When both of these conditions are satisfied, liquid overfill is considered a **remote contingency**.

If **in addition** to satisfying the above conditions, the vessel is equipped with a **safety critical**, independent high-level cut-out that will shut down all the liquid feeds into the vessel, then liquid overfill need not be considered as a potential source of overpressure (principle of not designing for double contingencies takes precedence over principle of not relying upon instrumentation to prevent overpressure). For this criterion to apply, it is necessary that the high-level cut-out be independent of both the process control level instrumentation and the **safety critical**, independent high-level alarm and that there be no **common cause failure mode** that could lead to the simultaneous loss of both the **safety critical** high-level alarm and the **safety critical** high-level cutout. In addition, the **Safety Integrity Level (SIL)** of the system as a whole must be 3 or higher.

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11. Equipment must be protected against potential overpressure caused by **reverse flow through check valves**. The following scenarios shall be considered.

| Scenario No. | Number of Check Valves in Series | Potential Overpressure Scenario                                                                                                                                                                                                                                                                                                                                                                                                              | Type of Contingency |
|--------------|----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| 1            | 1                                | <b>Partial failure of check valve.</b><br><br>Assume failed check valve behaves as a restriction orifice with a diameter equal to 1/3 the nominal diameter of the check valve. Use this basis for reverse flow of liquid, vapor and liquid followed by vapor.                                                                                                                                                                                | Design              |
| 2            | 1                                | <b>Total failure of check valve.</b><br><br>Calculate reverse flow rate (liquid and/or vapor) as if the check valve were not there.                                                                                                                                                                                                                                                                                                          | Remote              |
| 3            | 2 or more                        | <b>Partial failure of one check valve.</b><br><br>Failed check valve behaves as a restriction orifice with a diameter equal to 1/3 the nominal diameter of the check valve. Each of the remaining check valves in series is assumed to behave as a restriction orifice with a diameter equal to 1/10 the nominal diameter of the check valve.                                                                                                | Design              |
| 4            | 2 or more                        | <b>Total failure of one check valve.</b><br><br>Failed check valve is ignored. If only two check valves in series are installed, assume the second check valve fails partially open and calculate back flow per Scenario 1. If more than two check valves in series are installed, assume that each of the remaining check valves behaves as a restriction orifice with a diameter equal to 1/10 of the nominal diameter of the check valve. | Remote              |
| 5            | 2 or more                        | <b>Two or more check valves in series fail fully open.</b><br><br>This contingency need not be considered.                                                                                                                                                                                                                                                                                                                                   | Not credible.       |



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12. Check valves in a pressure relief path are acceptable as long as they meet **all** of the following conditions:
  1. The valve opens in the pressure relieving direction.
  2. The check valve is in a normally flowing line (i.e., normally open).
  3. The valve is of the swing-check or wafer (where acceptable per **GP 03-12-01**) type with no external actuation or damper mechanism.
  4. The pressure drop is included in the system analysis
13. Flow meter orifice plates are permissible in a pressure relief path, except PR valve inlets, outlets or flare headers, provided that the required relief flow can be passed without exceeding the upstream MAWP plus the applicable accumulation (if any) permitted by the design Code.
14. Flame arrestors and detonation arrestors are not permitted in a pressure relief path.
15. Demisting screens (typically, crinkled wire mesh screens) are permitted in a pressure relief path as long as the following conditions are satisfied:
  - a. Service is non-plugging
  - b. Screen is secured in accordance with **GP 05-02-01** to minimize risk of dislodgment.
16. When two or more parallel flow paths exist between the protected equipment and the pressure relief device, and one or more of the flow paths can be individually blocked, credit may be taken for the capacity of the remaining open flow path(s) for overpressure protection. The following guidelines apply:
  - a. If blocking one of the parallel flow paths causes the equipment pressure to exceed 1.5 times the MAWP or the proof test pressure, whichever is lower, either the block valves shall be removed or a pressure relief valve shall be provided to protect the equipment.
  - b. If blocking two parallel flow paths causes the equipment pressure to exceed 1.5 times the MAWP or the proof test pressure, whichever is lower, either the block valves shall be removed or a pressure relief valve shall be provided to protect the equipment. This guideline recognizes that any two parallel paths could be blocked simultaneously due to operator error. For example, an operator could mistakenly block the inlets and/or outlets of two parallel paths instead of the inlet and outlet of one path, or block an open path before opening a previously isolated path.
  - c. If neither condition (a or b) applies, two options are available:
    1. The inlets and outlets of all of the parallel flow paths shall have their isolation block valves car-sealed open (CSO), OR
    2. Determine the minimum number of parallel flow paths, N, that must remain open to prevent the protected equipment pressure from exceeding its MAWP, and car-seal open the isolation block valves of N+1 paths. If this option is selected, there must be a **safety critical** written procedure or mechanical interlocks to ensure that at least N+1 parallel paths have their isolation valves CSO at all times



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17. Maximum allowable **accumulation** for all **design contingencies** shall be as follows unless local codes specify otherwise:

| Vessel Type                                    | Type of Contingency  | No. of PR Valves in Parallel | Allowable Accumulation, % of MAWP                                                                    |
|------------------------------------------------|----------------------|------------------------------|------------------------------------------------------------------------------------------------------|
| Fired boiler<br>(ASME Section I)               | Any                  | Any                          | 6                                                                                                    |
| Unfired Pressure Vessel<br>(ASME Section VIII) | Design (except fire) | 1<br>2 or more               | 10 or 3 psi (20.7 kPa)<br>(whichever is greater)<br>16 or 4 psi (27.6 kPa)<br>(whichever is greater) |
|                                                | Fire                 | Any                          | 21                                                                                                   |

- For equipment designed to codes other than ASME Sections I or VIII, consult EMRE's Mechanical Engineering Section.
18. The maximum superimposed back pressure for non-discharging PR valves during a maximum system release (from either single or multiple valve releases under a design contingency) shall be as follows:

For spring-loaded, conventional PR valves:

$$P_{si(max.)} = 0.826 C P_s - P_d$$

For balanced bellows and pilot operated valves:

$$P_{si(max.)} = 0.50 C P_s$$

Where:

$P_{si(max.)}$  = Maximum superimposed back pressure

$P_{set}$  = Pressure relief valve set pressure

$P_d$  = Differential spring pressure

$C$  = Multiplier applied to design pressure to obtain hydrostatic test pressure per **GP 05-03-01**, dimensionless

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19. For a **design contingency** (including fire), the **built-up back pressure** for conventional spring-loaded pressure relief valves shall not exceed the following:

| Vessel Type                                    | Type of Contingency  | No. of PR Valves in Parallel | Allowable Built-Up Back Pressure, % of MAWP                                                          |
|------------------------------------------------|----------------------|------------------------------|------------------------------------------------------------------------------------------------------|
| Fired boiler<br>(ASME Section I)               | Any                  | Any                          | 6                                                                                                    |
| Unfired Pressure Vessel<br>(ASME Section VIII) | Design (except fire) | 1<br>2 or more               | 10 or 3 psi (20.7 kPa)<br>(whichever is greater)<br>16 or 4 psi (27.6 kPa)<br>(whichever is greater) |
|                                                | Fire                 | Any                          | 21                                                                                                   |

For a **remote contingency**, the maximum allowable **built-up back pressure** for conventional spring-loaded pressure relief valves shall be:

$$P_{b(max.)} = 0.173 C P_{set}$$

Where:

$P_{b(max.)}$  = Maximum built-up back pressure

$P_{set}$  = PRV set pressure

$C$  = Multiplier applied to design pressure to obtain hydrostatic test pressure per **GP 05-03-01**, dimensionless

20. For a **design contingency** (including fire), the **total back pressure** for balanced bellows pressure relief valves shall not exceed 50% of set pressure. For total back pressures in excess of 30% of set pressure for valves in vapor service or 15% of set pressure for valves in liquid service, a **back pressure correction factor** shall be applied as recommended by the manufacturer or as obtained from [Figure III-2B](#) or [Figure III-4](#). For pilot operated PR valves, the **total back pressure** shall not exceed 75% of set pressure.

For a **remote contingency**, the maximum allowable **total back pressure** for balanced bellows and pilot operated pressure relief valves shall be:

$$P_{b(max.)} = 0.50 C P_{set}$$

Where:

$P_{b(max.)}$  = Maximum built-up back pressure

$P_{set}$  = PRV set pressure

$C$  = Multiplier applied to design pressure to obtain hydrostatic test pressure per **GP 05-03-01**, dimensionless

The **back pressure correction factor** for balanced bellows pressure relief valves for a **remote contingency** may be obtained from [Figure III-2B](#) or [Figure III-4](#) using the **effective set pressure** in place of the **set pressure** in the calculation of % **Gauge Back Pressure**. The effective set pressure is defined as follows:

$$P_{se} = C P_{set} / (1 + \text{Allowable Accumulation, \%})$$

Where:

$P_{se}$  = Effective set pressure

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$P_{set}$  = Actual set pressure

C = Multiplier applied to design pressure to obtain hydrostatic test pressure per **GP 05-03-01**, dimensionless

21. The maximum allowable frictional pressure drop between the protected equipment and the pressure relief valve inlet flange is 3% of set pressure for set pressures equal to or greater than 50 psig (345 kPa gauge) and 5% of set pressure for set pressures less than 50 psig (345 kPa gauge) for all **design contingencies** including fire. For **remote contingencies**, the maximum allowable frictional pressure drop between the protected equipment and the pressure relief valve inlet flange is 4% of set pressure for set pressures 50 psig (345 kPa) or higher and 7% for set pressures lower than 50 psig (345 kPa). The pressure drop limitations include only frictional losses and do not include static head or the effects of fluid acceleration.
22. The inlet and outlet frictional pressure drops for individual PR valves shall be calculated using the PR valve **rated capacity** for releases that are partially or totally vapor at PR valve inlet conditions except for fire contingency. For releases that are 100% liquid at PR valve inlet conditions and for fire contingencies, the PR valve **design capacity** may be used to calculate inlet and outlet piping frictional pressure drops.
23. Frictional pressure drop in closed PR valve discharge collection systems that collect the discharge from two or more PR valves shall be calculated using the sum of the **design capacities** for all the PR valves that discharge simultaneously for the contingency under consideration.
24. The maximum permissible flow velocity at any point of the PR valve discharge piping is 75% of sonic velocity, regardless of whether the PR valve discharges to atmosphere or to a closed system. Flow velocity is calculated at the **design capacity** of the PR valve.
25. The minimum permissible exit velocity for the atmospheric discharge of **flammable vapors** is 100 ft/sec at 25% of the **rated capacity** of the PR valve or at the minimum anticipated relief load, whichever is greater. If this criterion cannot be met with a single PR valve installation, consideration should be given to specifying two or more PR valves with individual discharge risers and staggered set pressures, or dispersion calculations should be done to verify that a flammable mixture will not be present at potential sources of ignition downwind from the point of discharge.
26. **Calculation of relief rates for fire**  

The wetted surface used to determine the heat absorption will be calculated according to API 521, with the following additions:

  - a. For horizontal vessels any wetted surface located above 25 ft (7.5 m) but below the vessel centerline will be added to the area used.
  - b. For vertical vessels located entirely above 25 ft (7.5 m), only the area of the bottom head will be used. If the vessel is supported by a full skirt extending all the way to the ground and the skirt has no more than one opening which does not exceed 20" (500 mm) diameter, the area of the bottom head may be excluded regardless of its elevation above grade.
  - c. In all cases, the expanded volume of the liquid should be used. The expanded volume of the liquid includes the thermal expansion of the liquid from its initial temperature to its boiling point at the accumulated pressure of the vessel.
  - d. For air cooled exchangers, see [APPENDIX 1](#).

Fire Risk Areas are established by the provision of access ways or clear spacing at least 20 ft (6.1 m) wide on all sides with drainage to catch basins located within the fire risk area. They are used to determine the combined requirement for pressure relief due to fire exposure. The selection of single fire risk areas within a plant or unit must consider the design of the drainage system and the equipment layout. These should be selected to limit the extent of the fire risk area to no more than 5000 ft<sup>2</sup> (500 m<sup>2</sup>). However, the extent of the fire risk area must be based on the actual drainage pattern and the actual spacing that is available and may result in areas greater than 5000 ft<sup>2</sup> (500 m<sup>2</sup>).

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## 5 BASIC DESIGN CONSIDERATIONS

This section discusses the principal causes of overpressure in refinery and chemical plant equipment and describes design procedures for minimizing the effects of these causes. Overpressure is the result of an unbalance or disruption of the normal flows of material and energy that cause material or energy, or both, to build up in some part of the system. Analysis of the causes and magnitudes of overpressure is therefore a special and complex study of material and energy balances in a process system.

Although efforts have been made to cover all major circumstances, the designer is cautioned not to consider the conditions described as the only causes of overpressure. Any circumstance that reasonably constitutes a hazard under the prevailing conditions for a system should be considered in the design.

Overheating above design temperature may also result in overpressure, due to the reduction in allowable stress. A pressure relief valve cannot protect against this type of contingency. Thus, to provide some degree of protection, safety **critical instrumentation**, depressuring and fireproofing should be considered. Reference should be made to the section on chemical reactions.

### 5.1 CONTINGENCY BASIS FOR DESIGN

The cost of providing facilities to relieve all possible abnormal situations simultaneously would be prohibitive. Every abnormal situation arises from a specific cause or contingency. The simultaneous occurrence of two or more abnormal situations, or contingencies (i.e., a double contingency) is unlikely. Hence, generally an abnormal situation which can arise only from two or more unrelated contingencies (e.g., the simultaneous failure of both a control valve in the open position and cooling water, or the failure of an exchanger tube at the same time a control valve fails closed) is normally not considered for sizing safety equipment. Contingencies, including external fire, are considered as unrelated if there is no process, mechanical, or electrical inter-relationship between them, or if the length of time elapsing between possible successive occurrences of these contingencies is sufficient to separate their effects.

Every unit or piece of equipment must be studied individually and every contingency must be evaluated. The safety equipment for an individual unit is sized to handle the largest load resulting from all possible design contingencies. When analyzing any contingency, one must consider all directly related effects which may occur from that contingency. For example, should an air failure also cause a control valve in a cooling circuit to close, then both the air failure and the loss of cooling in that circuit are considered as part of the same contingency.

Likewise, if a certain abnormal situation would involve more than one unit, then all affected units must be considered together. An example of this is the use of a stream from one unit to provide cooling in a second unit. Loss of power in the first unit would result in loss of this cooling in the second unit, and thus must be considered as part of the same contingency.

In analyzing the system to identify all design contingencies that may occur and the resulting relief requirements (and overpressure protection system design), no credit may be taken for operator intervention in preventing a potential overpressure incident. However, operator intervention may be relied upon to classify a liquid overfill scenario as a **remote contingency** as described under [LIQUID OVERFILL AS A CAUSE OF OVERPRESSURE](#). No credit may be taken for the actions of process control or **safety critical instrumentation** other than **High Integrity Protective Systems (HIPS)** as the final protection layer in **preventing** a potential overpressure incident. Credit for **safety critical instrumentation** may be taken, however, in reducing the demand rate to a pressure relief device provided as the final protection layer, as described in the following paragraph.

**Safety Critical Instruments** (other than **HIPS**) meeting the requirements of **GP 15-07-02, Protective Systems** may be considered in the design of certain components of the relief system, such as the flare collection header, blowdown drum, seal drum and flare tip, as a means to reduce the simultaneous load to the flare in a contingency involving multiple pressure relief devices as described in [APPENDIX 2](#). However, credit may not be taken for **safety critical instruments** (other than **HIPS**) in determining the need for or the required relief capacity of individual pressure relief devices.

When taking credit for **HIPS** or **safety critical instrument systems** as described in the preceding paragraph, the designer must confirm that the dynamic response of the system as a whole, including sensing elements, transmitters control valves and the protected system as a whole (vessels, heat exchangers, fired heaters, piping, etc.) is adequate to prevent the protected system pressure from reaching the relief device set pressure. Where warranted, a rigorous dynamic simulation of the system as described in [APPENDIX 2](#) should be performed. Unless a rigorous dynamic

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simulation shows otherwise, it shall be assumed that the residual heat input from fired heaters following activation of the main fuel cut-out is 10% of the design heat duty.

The equipment judged to be involved in any one emergency is termed a "single risk." The single risk which results in the largest load on the safety facilities in any system is termed the "largest single risk" and forms the design basis for the common collection system, such as the flare header, blowdown drum and flare. The emergency which results in the largest single risk on the overall basis may be different from the emergency which forms the basis for each individual piece of equipment.

While generally only a design contingency is considered for design purposes, there may be situations where two or more simultaneous contingencies should be taken into account, e.g., if there is some remote interrelationship between them, and pressures or temperatures developed could result in catastrophic failure. Such remote contingencies are also considered, but the "1.5 Times Design Pressure" rule may be applied in this situation. (See the discussion of this rule under [DESIGN PROCEDURE, PART I.](#))

Overpressure which may occur at normal or below normal pressures, as a result of reduced allowable stresses at higher than design temperatures, are also evaluated and appropriate protective features applied in the design. For example, such conditions may result from chemical reactions, startup or upset conditions. Likewise, low metal temperature must be considered, such as from autorefrigeration, to make sure that brittle fracture conditions do not develop.

## 5.2 APPLICATION OF CODES AND STATUTORY REGULATIONS

The basis for design overpressure described in this section is related to the ASME Boiler and Pressure Vessel Code and ANSI B31.3, Code for Petroleum Refinery Piping. Compliance with these codes is a requirement, or is recognized as the equivalent of a requirement in many locations. In the United States, the ASME Code is now mandatory since it is a requirement under the Occupational Safety and Health Act. Where more stringent codes apply, the local requirements must be met. Therefore, local codes must be checked to determine their requirements. For example, some countries do not permit the use of block valves underneath pressure relief valves, unless dual valves with interlocks are installed. Also, in some cases, 21% accumulation under fire exposure conditions is not permitted, and accumulation allowed may be lower than the ASME Code (for example no increased accumulation when multiple PR valves are used). The affiliate for which the design is intended is usually the best source of information on local codes.

## 5.3 SUMMARY OF PRESSURE RELIEF DESIGN PROCEDURE

The essential steps in the design of protection against overpressure which are covered in detail in other parts of this section are summarized below:

### 5.3.1 Consideration of Contingencies

- 1) All contingencies which may result in equipment overpressure are considered, including external fire exposure of equipment, utility failure, equipment failures and malfunctions, abnormal processing conditions, thermal expansion, startup and shutdown, and operator error.
- 2) For each contingency, the resulting overpressure is evaluated and the need for appropriately increased design pressure (to withstand the emergency pressure) or pressure-relieving facilities to prevent overpressure (with calculated relieving rates) is established. Also, see [DP II](#).
- 3) If a contingency consequence is indeterminate (e.g. compressor may or may not trip, or operators may or may not intervene), each possibility should be analyzed and the relief flow determined for the worse case.

### 5.3.2 Selection of Pressure Relief Device

From the range of available pressure relief valves and other devices, selection is made of the appropriate type for each item of equipment subject to overpressure. Instrumentation, check valves, and similar devices are generally not acceptable as means of overpressure protection.

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### 5.3.3 Pressure Relief Device Specification

Standard calculation procedures are applied to determine the size of the pressure relief device (usually a pressure relief valve) required for the maximum relieving rate, together with other information necessary to specify the device.

### 5.3.4 Design of Pressure Relief Device Installation

Finally, the pressure relief device installation is designed in detail, including location, sizing of inlet and outlet piping, valving and drainage, selection of open or closed discharge, and design of closed discharge system to a flare or other location.

### 5.3.5 Summation and Documentation of Contingencies

The Design Specification should include a tabulation of all major contingencies considered, together with their relief requirements. Such a tabulation is helpful to assure that all contingencies have been considered and for selecting the contingency which sets the design of the collection system. It is also necessary and invaluable for future analysis of the overpressure protection system. An example of a tabulation sheet is included as [Table I-1](#).

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## 6 DESIGN PROCEDURE, PART I: CONSIDERATION OF CONTINGENCIES AND DETERMINATION OF RELIEVING RATES

S

### 6.1 INTRODUCTION

The first step in the design of protection against overpressure is to consider all contingencies which may cause overpressure, and to evaluate them in terms of the pressures generated and/or the rates at which fluids must be relieved.

All unfired pressure vessels designed to the ASME Code Section VIII **must** be protected by pressure relieving devices that will prevent accumulation (of excessive pressure) within the vessel exceeding 10% of the design pressure or 3 psi (20.7 kPa), whichever is greater, (16% or 4 psi (27.6 kPa), whichever is greater, if multiple PR devices are used) unless the design pressure of the vessel equals or exceeds the maximum pressure that could be developed. When the excess pressure is caused by an external fire, 21% accumulation is permitted (if allowed by local codes).

Fired pressure vessels are covered by the ASME Code Section I (Power Boilers), which requires pressure relief devices to prevent accumulation exceeding 6%.

The following unfired steam generators are considered as unfired pressure vessels, and maximum accumulation should be specified in accordance with the ASME Code, Section VIII (unless prohibited by local codes).

- 1) Evaporators and heat exchangers in which steam is generated.
- 2) Vessels, e.g., waste heat boilers, in which steam is generated incidental to the operation of a processing system containing a number of pressure vessels, such as are used in chemical and petroleum products manufacture. (Equipment which may fire a supplemental fuel should be considered as a fired pressure vessel.)

The design contingency basis for these considerations, as well as a means for tabulating and documenting the various contingencies considered, is described under [BASIC DESIGN CONSIDERATIONS](#). The types of contingencies which should be considered, together with guidelines for evaluating them, are detailed in the remainder of this part of [DESIGN PROCEDURE, PART I](#).

Selection of design pressure for equipment is covered in [DP II, Design Temperature, Design Pressure and Flange Rating](#). Design for overpressure protection in most cases consists of providing pressure relief devices sized to handle the calculated relieving rates necessary to prevent emergency pressures from rising above the design pressure (plus allowable accumulation).

As an alternative means of protection, it is economical in some cases to specify an increased equipment design pressure which will withstand the maximum pressure that can be generated, without relieving any contained fluids. Also, in some cases, the cost of the collection system can be reduced by specifying higher design pressures which will permit a higher back pressure in the collection system. See [DP II](#).

For remote contingencies, the "1.5 Times Design Pressure Rule" is applicable.

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**"1.5 Times Design Pressure Rule"** - The additional load caused by the remote contingency (to which the "1.5 Times Design Pressure Rule" is applied) need not be considered in calculations of flare and PR valve radiant heat levels. For situations where the relief area calculated for the remote contingency on the basis of the "1.5 Times Design Pressure Rule" exceeds the relief area calculated for the limiting design contingency, or when the remote contingency is the only overpressure scenario applicable to a pressure relief valve, the required PR valve relief area should be set equal to the relief area calculated for the remote contingency based on applying the 1.5 Times Design Pressure Rule. The relief flow rate reported in the specification sheet should be set equal to the calculated capacity of a pressure relief valve having an effective relief area equal to the required relief area calculated above at the Code allowable accumulation.

- ♦ In addition, since the intent is to keep the vessel pressure no higher than the proof test pressure, the pressure drop between the vessel and the location of the PR valve (including inlet line losses) must be taken into account. For some equipment, the "1.5 Times Design Pressure Rule" may not apply. The yield stress must be reviewed based on the actual condition (physical and operational) of the equipment. See the paragraph entitled *Overpressure Caused by Abnormal Temperature* for additional information on this topic.

Examples where the "1.5 Times Design Pressure Rule" may apply (i.e., normally considered remote contingencies) are:

- 1) Contingencies which have some remote interrelationship and which could develop pressures or temperatures sufficient to cause catastrophic failure, or result in a large release of toxic or light hydrocarbon material.
- 2) Abnormal events, such as:
  - a. Heat exchanger tube failure.
  - b. Inadvertent closure of a CSO valve except for CSO valves used to isolate pressure relief devices for maintenance or to isolate individual branches in flare systems for which accidental closure is considered non-credible.
  - c. Inadvertent opening of a CSC valve.
  - d. Plugging of a fixed bed reactor catalyst bed (some local codes consider catalyst bed plugging as a contingency that requires normal pressure relief valve protection).
  - e. Collapse of reactor outlet collector causing total obstruction of flow.
  - f. Installation of a rupture disc upside down.
  - g. A control valve failing open with its bypass fully open.

## S 6.2 FIRE AS A CAUSE OF OVERPRESSURE

Equipment in a plant area handling flammable or combustible fluids is subject to potential exposure from an external fire, which may lead to overpressure resulting from vaporization of contained liquids. This hazard may exist even in items of equipment containing nonflammable materials.

### 6.2.1 Equipment to be Protected

All vessels must be protected from overpressure. In addition, all vessels subject to overpressure by fire must be protected by PR valves, with the following exceptions:

1. If allowed by the applicable pressure vessel code, fire may be excluded as a contingency for PR device sizing for a vessel which normally contains no liquid, since failure of the shell from overheating would probably occur even if a PR valve were provided. Examples are fuel gas knockout drums and compressor suction knockout drums where a liquid level is not maintained. Some jurisdictions require pressure relief valve protection for "dry drum" situations. If a PR valve is required (or desired) for "dry drum" conditions, the sizing procedure contained in [APPENDIX 1](#) may be used. However, it should be recognized that a pressure relief valve will only prevent the pressure from rising above the allowable accumulation and will not necessarily prevent (although it may delay) vessel failure due to overheating. In these cases, consideration should be given to the use of non-reclosing devices such as a rupture pin valve, rupture disc or fusible plug, since such devices will depressure the vessel upon actuation and reduce the risk of vessel failure due to overheating. Refer to [APPENDIX 1](#) for additional information on protecting dry vessels against overpressure due to external fire.

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2. Typically, drums and towers 2 ft (.6 m) and less in diameter, constructed of pipe, pipe fittings or equivalent, do not require PR valves for protection against fire, unless these are stamped as coded vessels. This exception is based on the fact that piping is not provided with protection against overpressure from this contingency. PR valves are required on such vessels, however, if overpressure can result from contingencies other than fire.
3. Interconnected vessels may be treated as one unit for pressure relief purposes during a fire (and also other contingencies) if the piping and valving between them meet applicable criteria as described in this Design Procedure.
4. Except for special situations, (or unless required by local codes) pressure relief devices are not individually provided for fire exposure of piping. Special situations which may require individual pressure relief device include congestion and substandard spacing, or unusually large equipment with normal liquid holdup over 1,000 gallons (4 m<sup>3</sup>) or which represents over 15% of the total wetted surface of the system to which it is directly connected for pressure relief.
5. Fire exposure overpressure protection for filters: Filters are typically designed to be blocked off from the process flow for periods of time and remain filled with liquid. Therefore, filters that can be blocked off should be provided with PR valves to protect them against fire exposure unless the filter falls in either of the following categories: 1) the filter is made of pipe sections 24 in. (0.6 m) or less in diameter, or 2) the filter contains a non-flammable fluid, is not located within the diked area of a tank, and is located at least 20 ft (6 m) in all directions from all sources of hydrocarbon or potential fire locations. The piping exception is a result of the ANSI code not requiring protection for piping (and by extension of equipment made from piping sections) and accessories such as strainers. Note that filters made of low melting alloys require special consideration since they require additional protection, such as fireproofing.
6. Fire exposure overpressure protection for heat exchangers: In general, heat exchangers do not need a separate PR valve for protection against fire exposure since they are usually protected by PR valves in interconnected equipment or have an open escape path to atmosphere via a cooling tower or tankage. This is true even if the heat exchanger has a manual block valve between it and the PR valve since it is not expected that this valve will be closed by operators during a fire incident. However, in situations where a fail-close control valve or an EBV could isolate the heat exchanger from the PR valve providing protection against fire exposure, a separate PR valve to protect the exchanger may be required. Although experience shows that the usual consequence of such a scenario is relatively benign and is typically limited to a relatively small leak related to gasket failure, each situation should be assessed individually to determine whether or not a pressure relief valve is required to manage the risk. The risk assessment should consider, among other things, the requirements of local codes, the mechanical design features of the exchanger, the volume, toxicity and flammability of the contained fluid and the likely consequence (minor leak or catastrophic breach of the pressure containing envelope). In the absence of a favorable risk assessment, a pressure relief valve should be provided.

Fire exposure protection for heat exchangers that are provided with blocks and bypasses to permit cleaning while the rest of the unit is operating, present a special situation. Again, interconnected equipment usually provides the required overpressure protection but these exchangers are expected to be occasionally isolated from the system. In this case, one of two options is available to provide protection: installing PR valves or relying on operating procedures. If the operating procedure option is used, this operating procedure must direct the operators to drain all liquid from the exchanger immediately upon isolating it from the system and maintaining the exchanger "dry" during the period of time it is isolated from the PR valve that would normally provide protection. To increase the probability that this operating procedure is followed, a caution sign in accordance with **GP 03-02-04** shall be permanently placed at the block valves of all exchangers not equipped with a permanently open bypass.

Fire exposure overpressure protection for air-cooled exchangers is discussed in [APPENDIX 1](#).

7. Another special situation involves vessels filled with both a liquid and a solid (such as molecular sieves or catalysts). In this case, the behavior of the vessel contents normally precludes the cooling effect of liquid boiling. Hence rupture discs, fireproofing and depressuring should be considered as alternatives to protection by PR valves.

#### 6.2.2 Determination of Relieving Rate and Risk Area

In calculating fire loads from individual vessels, assume that vapor is generated by fire exposure and heat transfer to contained liquids at operating conditions. The calculation procedure is covered in [APPENDIX 1](#). For determining PR valve capacity for several interconnected vessels, each vessel should be calculated separately, rather than determining the heat input on the basis of the summation of the total wetted surfaces of all vessels. Vapors

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generated by normal process heat input on compression, etc., are not considered. No credit is taken for any escape path for fire load vapors other than through the PR valve (which may be a common relief valve for more than one connected vessel), nor is credit allowed for reduction in the fire load by the continued functioning of condensers or coolers.

In order to determine the total vapor capacity to be relieved when several vessels are exposed to a single fire, a processing area may be divided into a number of smaller single fire risk areas by increased spacing. See [DEFINITIONS](#) for definition of a fire risk area.

Plant layout should be designed in accordance with the spacing standards (see [DP XV-G](#)) and must include accessibility for fire fighting. The fire risk areas for the purpose of overpressure protection are established by the provision of accessways or clear spacing at least 20 ft (6.1 m) wide on all sides, which permit fire fighting attack into all parts of the area and which limit the spread of fire. Clear space under pipebands, if more than 20 ft (6.1 m) wide, is considered as acceptable separation between fire risk areas. The selection of single fire risk areas within a plant or unit must, in addition, consider the design of the drainage system and the equipment layout.

When a fire occurs, it is assumed that all fluid flow to and from the fire risk area has been stopped and that major machinery within the fire risk area, such as compressor fitted with remote shutdown facilities, are stopped. Credit is not generally given to flow out of the normal process channels, since they are also generally closed during the emergency.

The total fire load is calculated for each fire risk area and used in the determination of the largest single risk release. Where the size of a closed discharge header is set by the fire relieving capacity requirement, advantage may be taken of reducing the requirement by providing fireproofing or insulation on vessels with large liquid inventories, as described in [DP XV-H](#) and covered by [APPENDIX 1](#).

If a situation occurs which involves more than one fire risk area simultaneously (such as an entire Refinery or Chemical complex), it would be classed as a remote contingency event, and the "1.5 Time Design Pressure Rule" may be applied. See [DESIGN PROCEDURE, PART I, INTRODUCTION](#).

### 6.2.3 Protection of Vessels from Fire Exposure, in Addition to Pressure Relief

Pressure relief valves cannot protect a vessel that becomes locally overheated on an unwetted surface, although they do prevent the pressure from rising beyond accumulation pressure. However, in such a case the vessel may be effectively protected against failure by either one of two methods for mitigating the effect of fire:

1. **The Reduction of Pressure by Depressuring** - The reduction of pressure in a vessel exposed to fire has the advantages of not only reducing the metal stress to a value that will not result in failure, but also of reducing markedly the quantity of fuel that might feed the fire should failure occur. This depressuring can be achieved by use of rupture discs or instrumented emergency depressuring (vapor blowdown) systems (described in [DP XV-F](#)). When over pressure protection is only required because of fire exposure, rupture discs should be considered.
2. **An Effective Limitation of the Heat Input** - Application of firewater from fixed and mobile fire fighting facilities is the primary method of cooling equipment which is exposed to fire. These facilities are described in [DP XV-I](#). Further protection by fixed water deluge or spray systems, or fireproofing, is applied in areas of particularly high fire risk, as described in [DP XV-I](#) and [XV-H](#), respectively. However, in sizing PR valves, no credit is taken for reduced heat input due to application of cooling water, since it cannot be considered 100% effective in all fire conditions.

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## 6.3 UTILITY FAILURE AS A CAUSE OF OVERPRESSURE

### 6.3.1 General Considerations

Failure of the utility supplies (e.g., electric power, cooling water, steam, instrument air or instrument power, or fuel) to refinery plant facilities will in many instances result in emergency conditions with potential for overpressuring equipment. Although utility supply systems are designed for reliability by the appropriate selection of multiple generation and distribution systems, spare equipment, backup systems, etc., the possibility of failure still remains. Possible failure mechanisms of each utility must, therefore, be examined and evaluated to determine the associated requirements for overpressure protection. The basic rules for these considerations are as follows:

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1. Interruptions of utility supply are considered only on a design contingency basis, i.e., corresponding to a failure of a single component of the generation or distribution system of one utility. Consideration must, however, be given to the direct effect of one utility on another. If a supply failure in one utility system, as a result of a design contingency, results in a complete or partial loss of another inter-related utility, then the dual failure must be considered. For example, in a plant where electricity is generated by steam turbine generators, loss of steam production will cause direct loss of power.
2. Failure is considered both on a local basis, i.e., loss of utility supply to one item of equipment (e.g., electric power to a pump motor) and on a general basis, i.e., loss of supply to all consuming equipment in a process unit if it can occur as a result of a design contingency (e.g., cooling water to all coolers and condensers). For the purpose of these pressure relief design considerations, a process unit is defined as one which meets all the following criteria:
  - a. It is segregated within its own clearly identifiable battery limits boundary.
  - b. It is supplied with each utility through one or two independent laterals from an offsite header.
  - c. It constitutes a complete processing function.
3. For a process unit with its own segregated and self-contained closed PR discharge system, only a utility failure to that unit need be considered for the purpose of sizing the safety facilities. However, when two or more units share a closed disposal system (e.g., a common blowdown drum and/or flare), the design procedure must include consideration of the potential for a design contingency resulting in utility supply failures to more than one of the units. Although such refinery-wide or plant-wide utility failures are not always used as a basis for sizing the safety facilities, they must be evaluated. This entails the evaluation of reliability of generation and distribution systems and requires good engineering design and the inclusion of adequate backup features. Examples of such backup features are included in the discussion of each utility contingency. In designs where all pressure relief valves discharge into a closed collection system, because of environmental restrictions, a total failure of one utility deserves more careful consideration since there are no atmospheric releases which would tend to relieve the load on the closed system.
4. Evaluation of the effects of overpressure attributable to the loss of a particular utility supply must include the chain of developments that could occur and the reaction time involved. In situations where fluid flow stops due to failure of its utility supply, but is in parallel with equipment having a different energy source, credit may be taken for the unaffected and functioning equipment to the extent that operation is maintained and the operating equipment will not trip out due to overloading.

For example, consider a cooling water circulating system consisting of two parallel pumps in continuous operation, with drivers having different and unrelated sources of power. If one of the two energy sources should fail, credit may be taken for continued operation of the unaffected pump, provided that the operating pump would not trip out due to overloading. Similarly, credit may be taken for partial continued operation of parallel, normally operating instrument air compressors and electric power generators which have two unrelated sources of energy to the drivers.

Backup systems which depend upon the action of automatic cut-in devices (e.g., a turbine-driven standby spare for a motor-driven cooling water pump, with PLCI control) would not be considered an acceptable means of preventing a utility failure for normal pressure relief design purposes, even though their installation is fully justified by improved continuity and reliability of plant operations.

## S UTILITY FAILURE CONTINGENCIES TO BE CONSIDERED

The application of the above design considerations to the major utility systems for typical installations is described below.

In some cases, the loss of utility supply is not a direct cause of overpressure, but it initiates a plant upset or emergency (e.g., power failure leading to loss of tower reflux), which in turn may result in overpressure. Where necessary, reference should be made to the procedures for evaluating such upset or emergency situations and for determination of relieving rates, described later in this section.

### 6.3.2 Electric Power

1. **Normal Individual and Process Unit Basis for PR Sizing Considerations** - The following design contingencies should be considered as the basis for evaluating overpressure that can result from electric power failures:
  - a. Individual failure of power supply to any one item of consuming equipment, such as a motor driver for a pump, fan or compressor.

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- b. Total failure of power to all consuming equipment in a process unit supplied by a unit substation.
- c. General failure of power to all equipment supplied from any one bus bar in a substation servicing one or more process units. Note that some substation designs include a hierarchy of bus bars. With such an arrangement, a design contingency such as a ground fault in a higher level bus bar will result in loss of all power to the lower level bus bars.

In the case of the bus bar contingency, the basic assumption for this contingency is a ground fault in the bus bar. Thus, the impact it will have on the equipment will be affected by the design of the substation and the protective equipment provided. Some substations are designed with normally closed circuit breakers isolating adjacent bus bars, when these are fed from the same electrical feeder. When a ground fault occurs in a bus bar, these circuit breakers open, thus isolating the fault and preventing the ground fault from extending to other bus bars and perhaps causing the complete substation to fail. The basic philosophy is for the design contingency to assume that normally closed circuit breakers will function; while for the remote contingency assume that the first normally closed circuit breaker fails to isolate the fault and it extends to the adjacent bus bar. For example, if the substation is designed such that a single feeder provides power to two bus bars separated by a normally closed circuit breaker, the design contingency for this design would be the loss of power to the equipment connected to the bus bar having the ground fault; while the remote contingency would be the loss of the affected bus bar plus the adjacent bus bar assuming that one of the circuit breakers fails to function on time and the fault extends. If in the example above, the substation was designed without any circuit breaker, then the design contingency would be the loss of both bus bars.

Other substation designs use normally open circuit breakers that are meant to close upon loss of a power source to permit continued operation by obtaining power from a different source. Since this type of protection implies action by a device/instrument in order to prevent overpressure in the equipment, no credit may be taken for the potential continuation of power delivery. Hence, the contingency of loss of power to a bus and the normally open circuit breaker failing to close and reestablish power needs is evaluated as a design contingency.

During design it may not be known from which bus bar a piece of equipment will be receiving its power at the time of failure. Therefore, the combination of equipment losing power from any single bus bar fault which results in the highest release rate should be used as the design basis for this contingency. Alternatively, the design specification must specify the arrangement of equipment within the available bus bars.

For units in which spared equipment is supplied from different bus bars in the same substation, loss of any one bus bar will, on average, result in loss of power to one-half of the equipment. Hence, for the design of a closed system, such as a blowdown or flare header system, a release equal to one-half of the release for the worst combination of equipment loss can be assumed as a design contingency as long as the worst case (100% of the load for the worst combination of equipment loss) is the basis for design as a remote contingency to which the "1.5 Times Design Pressure Rule" is applied.

2. **Consideration of Plant-wide or Refinery-wide Power Failure** - The following general power failures on a plant-wide scale must be considered.
  - a. Failure of purchased power supply to the plant or refinery.
  - b. Failure of internally generated power supply to the plant or refinery.
  - c. Total power failure in any one major substation. (Usually considered a remote contingency to which "1.5 Times Design Pressure Rule" is applied.)

As discussed under *General Considerations* above, adequate backup features must be included to reduce the probability of such major failures to an acceptably low level and balanced against the consequences, should such failures occur. The following backup arrangements are normally required as a minimum:

1. Two or more feeders for purchased power.
2. Two or more parallel generators with a spare backup where power is generated in the plant or refinery.
3. More than one fuel to boilers generating steam for turbine generators.
4. Automatic load shedding arrangements to maintain supply preferentially to critical consumers.
5. Secondary selective power distribution systems. (In these systems, the substations used have two busses, each supplied by a normally-closed incoming line circuit breaker and connected together by a normally-open bus tie circuit breaker. The dual sources normally divide the load in non-parallel operation. Upon failure of one source, the substation is isolated from the failed source and the de-energized bus section is connected to the source remaining in service. This "transfer" of load should be automatic and all motors connected to the bus bar must be provided with re-acceleration.)

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### 6.3.3 Cooling Water

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- Normal Individual and Process Unit Basis for PR Sizing Considerations** - The following design contingencies should be considered as the basis for evaluating overpressure that can result from cooling water failures:
    - Individual failure of water supply to any one cooler or condenser.
    - Total failure of any one lateral supplying a process unit which can be valved off from the offsite main.
  - Consideration of Plant-wide or Refinery-wide Failure** - The following general cooling water failures must be considered:
    - Failure of any section of the offsite cooling water main.
    - Loss of all the cooling water pumps that would result from any design contingency in the utility systems supplying or controlling the pump drivers.
    - Loss of all the fans on a cooling tower that would result from any design contingency in the utility systems supplying or controlling the fan drivers.

In the case of partial loss of the cooling water system due to a design contingency, the cooling water will be lost earlier to elevated users, such as condensers. These users may contribute disproportionately more to the safety release than the users to which cooling water is still available. In this instance, the actual safety release will be somewhat greater than a release proportional to the quantity of cooling water lost but lower than total loss of cooling water. To evaluate this situation three options are available:

- Assume that partial loss of cooling water, as a design contingency, results in the same safety release rate as total loss of cooling water.
- Determine, based upon a detailed analysis of the system configuration, where cooling water will flow upon partial loss of water, and the resulting safety release rate from each piece of affected equipment.
- Design for partial loss as a design contingency and total loss as a remote contingency if a significant portion of the plant PR valves discharge to a closed system, and option 1 results in an oversized closed system. When this design contingency becomes controlling (i.e., sets size of all or part of the closed system) an acceptance basis to reduce the size of the closed system is to design it assuming that partial loss of cooling water results in a safety release proportional to the amount of capacity lost. For example, loss of one-half of the cooling water capacity due to the loss of one-of-two 50% pumps results in a flare system load equal to one-half of the load caused by complete failure of the cooling water system. To balance this optimistic basis, the closed system must be designed in a manner somewhat more conservative than usual, as follows:
  - Design for loss of cooling water causing a safety release proportional to the amount of loss as a design contingency.
  - Design for total cooling water system failure as a remote contingency to which the "1.5 Times Design Pressure Rule" is applied to all PR valves blowing.
- Design the closed system such that other protected equipment not involved in the cooling water contingency cannot be overpressured by more than the "1.5 Times Design Pressure Rule," even during a total cooling water failure.
- Design each flare lateral to accommodate the largest possible release up to the total design release rate. Since it may be impractical to determine through which laterals the releases which make up the total are coming from, the design of flare laterals must presume that any one lateral could be at its maximum possible load up to the total design rate. For example consider a closed system consisting of two laterals, A and B. During a total cooling water system failure the PR valve releases add up to 140 klb/hr (18 kg/s) in Lateral A and 60 klb/hr (7.5 kg/s) in Lateral B, for a total load of 200 klb/hr (25 kg/s). To design for a partial loss of 50% of the cooling water system, the design release is one-half of the total or 100 klb/hr (12.5 kg/s). Lateral A is designed for its full release up to the design release or 100 klb/hr (12.5 kg/s). Similarly, Lateral B is designed for 60 klb/hr (7.5 kg/s) while the sections of closed system header downstream of the juncture of the two laterals is designed for 100 klb/hr (12.5 kg/s). These sizes would be compared to sizes developed from other contingencies to select actual lateral size.

As discussed under *General Considerations* above, adequate backup features must be included to reduce the likelihood of a major failure. As a minimum, all of the following should normally be provided:

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1. Multiple cooling water pumps with different type drivers and automatic cut-in of the spare pump. The motors must be designed to avoid overloading over the full range of the pump operating curve and as a result of the automatic cut-in.
2. Holdup in the sump of a cooling tower should be specified as per [DP XXVII](#) of the Design Practices. An independent low water level alarm set at the minimum holdup level should also be provided. This should provide sufficient warning so that corrective steps can be taken by operating personnel. Without such an alarm, makeup water failure may not be apparent.
3. Secondary selective power supply to cooling tower fan motors.
4. Adequate instrumentation and alarms to give warning of potential cooling water system failures, such as a low pressure alarm on the makeup cooling water supply header.

The safety system load associated with the total loss of any of the independent systems could be considered under the remote contingency rules if the design complies with Items 1 through 4 above.

Application of the following should also be considered, in appropriate cases:

1. Multiple cooling water systems to reduce the size of the releases in case of total system failure. For example, to reduce the impact of total cooling water loss, independent multiple cooling water systems could be provided. These independent systems would supply different sections of the plant.
2. Cross-connected or looped distribution headers, to gain the added spare capacity of multiple cooling water systems.

#### 6.3.4 Steam

1. **Normal Individual and Process Unit Basis for PR Sizing Considerations** - The following design contingencies should be considered as the basis for evaluating overpressure that can result from steam failures:
  - a. Individual steam failure to any one item of consuming equipment (e.g., turbine drivers, reboilers, strippers, ejectors, etc.).
  - b. Total failure of any one lateral supplying a process unit which can be valved off from the offsite main.
2. **Consideration of Plant-wide or Refinery-wide Failures** - The following general steam failures must be considered:
  - a. Failure of any section of the offsite steam main.
  - b. Loss of any one steam generator.
  - c. Loss of purchased steam in any one supply line.

As discussed in *General Considerations* above, the probability of these major failures must be reduced by backup features, such as the following:

- a. Multiple boilers with spare capacity fired by multiple fuels.
- b. Adequate control and alarm systems, automatic load shedding arrangements, etc.

#### 6.3.5 Instrument Air

1. **Normal Individual Process Unit Basis for PR Sizing Considerations** - The following design contingencies should be considered as the basis for evaluating overpressure that can result from an instrument air failure:
  - a. Loss of instrument air supply to any one individual control instrument or control valve. It is assumed that the correct air failure response occurs. In the case of "remain stationary" control valves, it is assumed that the drift action to the fully opened or closed position takes place. Failure of automatic controls is covered under [EVALUATION OF OVERPRESSURE RESULTING FROM EMERGENCY CONDITIONS, AND DETERMINATION OF RELIEVING RATES](#) later in this section. Note that these latter considerations include failure of any control valve to both the opened and the closed position.
  - b. Loss of instrument air from a valved sub-header as well as total failure of any one valved lateral supplying a process unit from the offsite main: The correct air failure response of instruments and control valves is assumed. Consider "remain stationary" valves as drifting to either the fully opened or closed position, depending on the direction of the actuator.
2. **Consideration of Plant-wide or Refinery-wide Failures** - The following general instrument air failures must be considered:

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- a. Failure of any section of the offsite instrument air main.
- b. Loss of flow through any one set of instrument air dryers.

As discussed under *General Considerations* above, the probability of these major failures must be reduced by appropriate backup features. Both of the following should be considered as minimum requirements:

- a. Multiple air compressors with different drivers and automatic cut-in of the spare machine.
- b. Spared instrument air drying capacity.

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#### 6.3.6 Instrument Power

Instrument power failures are evaluated on a basis similar to that described for a power failure.

Included in the considerations for PR sizing should be the failure of power supply to all instruments in and controlled from a single bus bar. Reliability features should include secondary selective power supply to control rooms, with emergency generator or battery backup for critical instruments and control computers. Critical controls should be able to continue operation independently of control computers.

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#### 6.3.7 Fuel

Fuel supplies to boilers, fired heaters, gas turbine and engine drivers, etc., are designed with features such as multiple fuel gas sources, propane vaporizer backup, and a liquid fuel surge tank, to promote reliability. The failure of any one fuel to a process unit or utility generation facility is used as the basis for evaluating a potential overpressure.

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#### 6.3.8 Other Utilities

Failure of other utilities, such as inert gas to seals and purge systems, or compressed air (when used by the process) may in some cases determine pressure relief requirements. These cases are evaluated on a design contingency failure basis similar to the above.

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### 6.4 EQUIPMENT MALFUNCTION AS A CAUSE OF OVERPRESSURE

In addition to utility supply failures, items of equipment are subject to individual failure through mechanical malfunction. Such items include pumps, fans, compressors, mixers, instruments and control valves. The process upset resulting from such malfunctions (e.g., loss of a reflux pump) may in turn result in emergency conditions and the potential for overpressure. These contingencies should be examined and evaluated as described under [EVALUATION OF OVERPRESSURE RESULTING FROM EMERGENCY CONDITIONS, AND DETERMINATION OF RELIEVING RATES](#) in this section. In applying these rules, credit can generally be taken for pressure and temperature conditions existing under relieving or accumulated pressure conditions.

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### 6.5 PURGING / CLEANOUT

During air or hydrocarbon purging, or cleanout, facilities used for these purposes might subject the vessels to pressures beyond their design. Each operation should be individually evaluated for adequate pressure protection requirements.

Utility connections using dropout spools, blinds, or double blocks with a check valve and bleed are used to prevent contamination from backing into the utilities and contaminating these systems. When utilities are hooked up to purge or flush operating equipment, care should be taken to prevent overpressure during the purging/cleanout operation. During purging or cleanout, the possibility of failure of any valve in the system that could overpressure equipment should be considered as a design contingency and dealt with appropriately, e.g., install a pressure relief valve to protect the system or uprate the design pressure of the equipment involved. However, if permanent blinding points or break-away connections and safety **critical** procedures are provided to avoid accidental overpressuring of equipment during purging or cleanout, maloperation of valves in utility hookups may not need to be considered in evaluating pressure relief facilities. The complexity of the procedures and the frequency of their use are important factors to be addressed in this analysis.

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## 6.6 LIQUID OVERFILL AS A CAUSE OF OVERPRESSURE

PR valves are often located in the vapor space of partially liquid filled vessels such as towers, distillate drums, refrigeration flash drums, etc., which could overflow during a plant upset. In all cases, if overflow can result in a pressure above the design pressure of the vessel, the PR valve must be sized to prevent overpressure due to liquid overflow.

In analyzing liquid overflow, two general scenarios must be considered:

- Liquid outflows stop while liquid inflows continue at design flow rates.
- Liquid inflows increase above design flow rate (for example, due to a control valve failing open) while liquid outflows continue at the nominal turndown rates (typically, 50% of design). For this case, the extent of overflow possible may be limited by the upstream vessel inventory.

In determining the required relief capacity of the PR valve, credit may be taken for flow through normally open process channels that are not likely to become partially or totally blocked as a consequence of the overflow. For example, if a steam drum is balanced directly on a steam collection header without any intervening control valves, a failure of the level control valve in the full open position will eventually cause the drum to overflow, but credit may be taken up to the capacity of the steam piping to handle the combined flow of incoming water plus the design steam generation rate. If the steam piping cannot handle the resulting flow rate without exceeding the drum MAWP, then the PR valve should be sized for the difference between the incoming flow and the flow rate that can be handled by the steam piping when the drum is at its accumulated pressure. On the other hand, if there is a control valve between the steam drum and the steam collection header, the capacity credit that may be taken will depend on the response of the control valve to the upset and its capacity under these conditions. Unless the minimum relief capacity available through the control valve can be predicted with confidence, no credit should be taken for it.

**CAUTION:** The flow from the safety valve because of the overflow contingency may be two phase flow, especially if the inlet flow normally contains vapor. In the event of two phase flow, the PR valve must be designed to relieve the vapor plus liquid, minus the flow available through remaining normally open outlets, unless a dedicated PR valve is installed to specifically handle the liquid.

The overflow must be considered as a **design** contingency for PR valve sizing purposes **UNLESS BOTH** of the following are provided:

- The vessel has a **safety critical**, independent high level alarm (LHA), and
- The vessel vapor space above the independent LHA is equivalent to a 30 minute (or larger) holdup based on design liquid inlet rate and a stoppage of the liquid outflow.

If the above are provided, the overflow contingency may be considered a remote contingency to which the "1.5 Times Design Pressure Rule" is applied

It is recognized that situations may arise where protection against overpressure caused by liquid overflow by the use of a pressure relief device may not be practical, and/or may be insufficient to ensure the integrity of the facility. For example, an existing disposal system may lack the capacity to absorb the relief load, or the vessel support structure may not be capable of supporting the weight of a liquid filled vessel without risk of structural failure. In such cases, the use of a **High Integrity Protective System (HIPS)** to protect against liquid overflow may be considered as an alternative (or in addition) to a pressure relief device. The intent of such a system is to render liquid overflow a **double contingency**, which need not be evaluated in the overpressure protection analysis. Two alternative architectures for such a system are suggested:

- Provide a **safety critical**, independent high-level alarm (LHA) located such that the vapor space above the LHA is equivalent to at least 30 minutes holdup based on design liquid inlet flow rate with zero liquid outflow (this makes liquid overflow a **remote contingency**) PLUS provide a **safety critical**, independent high-level cut-out (LHCO) on all incoming feeds including start up oil (this makes liquid overflow a **double contingency**), OR
- Provide a **high-integrity, safety critical**, independent high-level cut-out (LHCO) on all incoming feeds including start up oil.

Regardless of the architecture chosen, the overall availability of the protective system must be equivalent to **Safety Integrity Level (SIL) 3** or better (99.9% or better) for the protective system to qualify as a **HIPS**. The selected system shall be designed, evaluated and installed in accordance with the criteria in **EE.137E.95**. These criteria include the need for redundancy, the need to consider the possibility of 10% leakage across the individual isolation valves and the need to confirm that simultaneous failure of the control system and the **safety critical** instrumentation

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cannot occur as a result of a **common cause failure mode** by including suitable safeguards as described under **double or multiple contingencies**. In addition, the dynamics of the **HIPS** must be evaluated to ensure that the set pressure of the PR device will not be exceeded and that surge pressures associated with the rapid closure of the isolation valves are considered in the design of upstream and downstream piping systems.

The use of a **HIPS** to eliminate the liquid overfill contingency (as described above) does not eliminate the need for a pressure relief device to protect the vessel against other potential overpressure contingencies such as fire, utility failure or operating failure. In addition, the possibility of leakage across the HIPS isolation valves must be considered in determining the required relief capacity of the PR valve protecting the vessel. To account for possible isolation valve leakage, the PR valve should have sufficient capacity to handle at least 10% of the relief load that would arise from liquid overfill without exceeding the allowable accumulation. For exceptional cases where the structural supports for a vessel are not designed for the weight of the vessel full of liquid and leakage cannot be tolerated, the use of double isolation valves with an intervening bleeder discharging to the flare (all actuated by the HIPS), should be considered.

The provision of a **safety critical** LHA and/or LH(CO) as described in the preceding paragraphs is not necessary if either of the following conditions is met:

1. The pressure relief valve protecting the vessel has sufficient capacity to handle a liquid overfill without exceeding the Code allowable accumulation (i.e. liquid overfill has been deemed a **design contingency**.) AND the pressure relief valve discharges to a closed system, OR
2. There is no credible scenario that could lead to liquid overfill. For example, the maximum pressure that can be developed by the feed system is lower than the set pressure of the pressure relief valve protecting the vessel (plus static head, if applicable).

## S 6.7 OPERATOR ERROR AS A CAUSE OF OVERPRESSURE

Operator or human error is considered a potential cause of overpressure. Contingencies of sabotage, gross negligence or incompetence are generally not considered. Gross negligence type items which generally are not included are: failure to install or remove blinds, bypassing of emergency devices, operating with closed block valves around pressure relief devices and misalignment of process flow during startup. While closing and opening of CSO and CSC valves in process streams could also be considered as gross negligence, these incidents are sufficiently severe that they must be considered, although the "1.5 Times Design Pressure Rule" may be applied in such cases. (Refer to the section on CSO valves under [EVALUATION OF PRESSURIZATION PATH IN PRESSURE RELIEF DESIGN](#) in this section.)

## S 6.8 EVALUATION OF OVERPRESSURE RESULTING FROM EMERGENCY CONDITIONS, AND DETERMINATION OF RELIEVING RATES

The following paragraphs describe a range of typical plant emergency situations which may result from utility failures, equipment malfunctions, or plant upsets, and which may result in equipment overpressure. Guidelines for the evaluation of these emergency conditions and determination of relieving rates are included. The relieving rates required for **all** valid contingencies for each PR device (and also other continuous or emergency releases into closed systems) must be documented as illustrated in [Table I-1](#).

### 6.8.1 Failure of Automatic Control

Automatic control devices are generally actuated directly from the process or indirectly from a process variable (cascade), e.g., pressure, flow, liquid level, or temperature. When the transmission signal or operating medium fails, the control device will assume either a fully open or fully closed position according to its basic design (the fail-safe position), although some devices can be designed to remain stationary in the last controlled position. Such "remain stationary" control valves will, however, drift in the direction in which the spring drives the valve and this drift must be considered if it results in a more conservative design. The failure of a process-measuring element in a transmitter or controller without coincidental failure of the operating power to the final controlled element should also be reviewed to determine the effect on the final controlled element.

However, when examining a process system for overpressure potential, one should assume that any one automatic control device could be either open or closed, regardless of its fail-safe action under loss of its transmission signal or operating medium.

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When the control valve size is established by the designer, for example selecting a  $C_v$ , it is assumed that this size valve is installed. Credit for the limiting capacity of the control valve may be taken, refer to [EVALUATION OF PRESSURIZATION PATH IN PRESSURE RELIEF DESIGN](#) in this section. If the control valve size is later increased it will be necessary to recheck the PR valve relief considerations.

Distributed Control System (DCS) failures may induce PR valve relief rates greater than individual control output failures, and should be evaluated on a case-by-case basis, taking into account all identified hardware, firmware, and software fault conditions.

1. **Instrument Air Failure or Power Failure Action** - The response of the control valve to failure of the instrument air or power supply should be selected to minimize the hazards of the resulting emergency situation. Generally, this is achieved by specifying the closure (i.e., fail close) of control valves in sources of heat input, water drawoffs and feed and product streams. Boxing-in the plant equipment in this way, on the basis that any resulting overpressure is relieved by properly designed PR valves, is considered safer than the uncontrolled dumping of plant contents into tankage and other units.  
A control valve in a heating system should generally be set to fail closed, to eliminate heat input. However, a fired heater process inlet control valve, should generally be set to fail open, to prevent overheating the process coil(s). Likewise, heat integrated circuits need careful scrutiny to determine the effect of the loss of cooling or heating. For example, a closed circuit system which is used for both heating and cooling could result in increased heat input if the flow of the stream which removes heat should fail.
2. **Control Valve System Analysis** - To evaluate system relieving capacity requirements for any design contingency (other than failure of the utility which affects valve movement), such as opening or closing of a single valve or utility failure, it is assumed that all control valves in the system which open under the contingency under consideration, remain in the position required for normal processing flow. Therefore, credit may be taken for the minimum (turndown) normal capacity of these valves, corrected to relieving conditions, provided that the downstream system is capable of handling any increased flow. While some controllers may respond correctly by increasing valve openings, capacity credit should be taken only to the extent corresponding to their minimum (turndown) normal operating position. This will avoid subjective decisions involved in evaluating response times and effects of controller settings, such as proportional band, reset, and rate action. It is also compatible with the basic philosophy that instruments may not necessarily operate or may be in the manual mode at the time of the emergency. Should the valve close under the contingency considered, no credit should be taken for relief through this valve.
3. **Failure of Individual Control Valve** - The following individual control valve failures should be included in the analysis of control systems for determination of pressure relief requirements:
  - a. Failure in the closed position of a control valve in an outlet stream from a vessel or system.
  - b. Failure in the wide open position of a control valve admitting fluid (liquid or vapor/gas) from a high-pressure source into a lower pressure system.
  - c. Failure in the wide open position of a control valve which normally passes liquid from a high-pressure source into a lower pressure system, followed by loss of liquid level in the upstream vessel and flow of high-pressure vapor. No credit is allowed for the response of the level controller which, under normal conditions, would close the control valve upon loss of liquid level, since this scenario could be caused by level controller failure. If detailed analysis indicates that flow through the wide open control valve is mixed phase, then this should be considered when determining the maximum flow through the control valve. High pressure may also be generated in the piping system as a result of liquid slugs being pushed by the vapor, hence the potential for excessive pressure from this mechanism should also be evaluated.
  - d. Failure in the closed position of a control valve in a stream removing heat from a system.
  - e. Failure in the open position of a control valve in a stream providing energy (heat) to a system.

In all cases except for (3) below involving failure of a control valve in the wide open position, it is necessary to consider the effect on the relief rate of the bypass valve (if any) being partially open. This is in recognition of practical experience which indicates that operators sometimes maintain the bypass valve partially open to maintain the control valve in a controlling position. The following three scenarios must be analyzed for all fail open contingencies for control valves and the larger relief requirement used to evaluate the adequacy for overpressure protection:

1. The control valve fails wide open with its bypass valve partly open. This scenario is evaluated as a design contingency. In calculating the relieving rate for this case, the flow rate through the partly open bypass valve is calculated using a  $C_v$  for the partially open bypass valve equal to 50% of the  $C_v$  of the control valve in its normally operating position, regardless of the actual size of the bypass valve. In this analysis, it is not

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necessary to consider the maximum trim that fits into the associated control valve if it can be established that Management of Change (MOC) protocols would preclude unauthorized trim replacement. Otherwise, the maximum size trim that fits into the associated control valve (not necessarily the installed trim) must be used to calculate the flow rate. The evaluation of the flow through the control valve and the bypass should be done assuming the upstream pressure remains at the highest normal operating level, while the downstream pressure increases to 110% of the downstream system design pressure. Credit may be taken for vapor being relieved through the normal channels (if the control scheme does not bottle-up the equipment) as well as through the PR valve.

- The control valve fails wide open with its bypass valve also wide open (open 100%). This scenario is evaluated as a remote contingency. In calculating the relieving rate for this case, the actual size of the bypass valve should be used, and the flow rate through the bypass valve would be the maximum flow with the bypass fully open. (Note that some existing facilities may have bypass valves with a  $C_v$  twice as large as the associated control valve. For new designs the bypass valve should be specified with a  $C_v$  approximately equal to that of the associated control valve.) The evaluation of the flow rate through the control valve and the bypass should be done assuming the upstream pressure remains at the highest normal operating level, while the downstream pressure increases to 150% of the downstream system design pressure (or the proof test pressure, whichever is lower). Credit may be taken for vapor being relieved through the normal channels (if the control scheme does not bottle-up the equipment) as well as through the PR valve.
- The control valve fails wide open with the bypass fully closed during startup. This scenario is evaluated as a design contingency. In calculating the relieving rate for this case, assume that the downstream vessel is not yet operational. Therefore relief is only through the PR valve. In addition, the fluid in the equipment must be considered to be the startup fluid which may be significantly different from the normal fluid in the equipment.

When the "bypass" valve consists of a duplicate control valve instead of a manual throttling valve (globe valve or equivalent), the same rules apply as for the case of manual bypass valves, provided that the duplicate control valve is operated as a "standby" or "spare" for the control valve normally in service (i.e., both control valves are never in service simultaneously). However, if the level controller acts on both valves simultaneously or through a split-range arrangement, or if the failure position of both control valves is **fail-open (FO)** or **fail-hold drifting open (FH(O))**, then failure of both valves in the fully open position must be treated as a **design contingency**.

Under certain conditions, failure of a control valve in the open position may result in vapor blow-through into a system that is initially filled with stagnant (non-flowing) liquid. This situation may arise, for example, during the startup of certain hydrodesulfurization or hydroconversion units equipped with high-pressure liquid-vapor separators that feed the liquid to lower-pressure stripping towers. When this happens, the pressure in the downstream piping and equipment may temporarily approach that of the equipment upstream of the control valve as the liquid contained in the downstream system is accelerated. For such systems, the pressure-temperature rating of the piping and the design pressure of the equipment (vessels, exchangers) downstream of the control valve shall be determined as follows:

- Determine the extent of piping and equipment that could be **TOTALLY** filled with stagnant (non-flowing) liquid immediately before the control valve fails open. This situation would typically arise only during startup. During normal operation, a high-pressure liquid letdown valve will normally generate flash vapor, so that the presence of a non-flowing, 100% liquid phase on the downstream piping or equipment is unlikely.
- For any piping that could be **TOTALLY** filled with stagnant (non-flowing) liquid, specify a pressure-temperature rating such that the maximum operating pressure of the equipment upstream of the letdown valve does not exceed the short-term allowable pressure for the selected pressure-temperature rating at the operating temperature of the upstream system. The short-term allowable pressure is typically 133% of the maximum continuous pressure allowed for a given pressure-temperature rating.
- For any equipment (vessels, exchangers) that could be **TOTALLY** filled with stagnant (non-flowing) liquid, specify a design pressure such that the maximum operating pressure of the equipment upstream of the letdown valve does not exceed "C" times the design pressure, where "C" is the multiplier applied to design pressure to obtain hydrostatic test pressure per **GP 05-03-01**.

When the application of these guidelines results in an unreasonable increase in the cost of downstream equipment or piping, the following alternatives may be considered:

- Perform a dynamic analysis of the downstream system to determine the peak pressures as a function of time and downstream distance from the letdown valve. In some cases it may be possible to address the concern by specifying a maximum opening and/or closing rate for the control valve.

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2. Consider modifying the configuration of the downstream piping and equipment or the startup sequence such that only a minimal amount of piping and equipment is 100% filled with stagnant liquid whenever vapor blow-through is a credible scenario.
3. Provide a pressure relief device immediately downstream of the pressure letdown valve set at the maximum allowable working pressure of any piping or equipment located between the pressure letdown valve and the next piece of downstream equipment protected by a pressure relief device.

When analyzing such individual control valve failures, one should consider the actions of other control valves in the system in accordance with Item 2, **Control Valve System Analysis**. However, the PR valve must be sized to handle the peak flow condition calculated from the various possible contingency scenarios for control valves.

4. **Special Capacity Consideration** - Although control devices, such as diaphragm-operated control valves, are specified and sized for normal operating conditions, they are also expected to operate during upset conditions, including periods when pressure relieving devices are relieving. Valve design and valve-operator capability must be selected to ensure operation of the valve plug in accordance with control signals during abnormal pressure conditions. When wide discrepancies exist between normal and emergency conditions, the higher valve-actuator pressure requirements should be covered in the Design Specification.

When determining pressure relief requirements, one should calculate the capacities of control valves at the temperature and pressure that occur during the relieving conditions, since these are in many cases significantly different from capacities at normal operating conditions. Downstream equipment must be analyzed under relieving conditions.

5. **Evaluation of Pressurization and Escape Path** - Reference should also be made to [EVALUATION OF PRESSURIZATION PATH IN PRESSURE RELIEF DESIGN](#) and [EVALUATION OF ESCAPE PATH IN PRESSURE RELIEF DESIGN](#) later in this [PART I](#) of the Design Procedure, for further discussion of control valves as a factor in pressure relief design.

#### 6.8.2 Cooling Failure in Condenser/Cooler

In addition to the general failure of cooling water discussed under [UTILITY FAILURE AS A CAUSE OF OVERPRESSURE](#), failure of cooling water flow to each individual condenser or cooler must be considered. Normally, no credit is taken for any residual cooling in a shell and tube condenser after the cooling stream fails, because it is time-limited and dependent on physical configuration of piping.

1. **Total Condensing** - The relief requirement is the total incoming vapor rate to the condenser. If desired, credit may be taken for reduced relieving rate, when recalculated at a temperature corresponding to the new vapor composition at the PR valve set pressure plus overpressure, and heat input prevailing at the time of relief.  
In the case of a fractionator, the overhead accumulator surge capacity at normal liquid level is typically limited to less than 10 minutes. Therefore, if the duration of cooling failure exceeds normal liquid holdup time, reflux is lost and the overhead composition, temperature, and vapor rate from the tower may change significantly. Hence, for many designs loss of a significant portion of tower overhead condensing capacity should be evaluated as loss of reflux. Also, the vapor load at the time of relief may be reduced below the normal operating rate, due to the higher pressure, which may suppress vaporization at the time of the overpressure. Pinchout of a reboiler is such a situation. In such a case, maximum steam process design conditions should be used, rather than the maximum steam pressure which could exist under pressure relieving conditions of the steam system.
2. **Partial Condensing** - The relief requirement is the difference between the incoming and outgoing vapor rates at relieving conditions. The incoming vapor rate should be calculated on the same basis as stated in Item 1. For a tower, if the reflux is changed in composition or rate, the incoming vapor rate to the condenser should be determined for the new conditions.

#### 6.8.3 Air Fin Exchanger Failure

Loss of air fin exchanger capacity may result from fan failure, inadvertent louver closure, pitch control failure, or variable speed motor driver failure.

1. **Fan Failure** - The effect of fan failure on heat transfer capacity will depend on the configuration of fans and tube bundles. For pressure relief design, the design contingency failure of one fan is considered. (Failure of all fans, that would result from a general power failure, would be included under utility failure considerations.) When two or more fans are provided, it is assumed that one other fan is shut down for maintenance at the time of failure.

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Credit may be taken for continuing heat transfer as a result of natural convection. As a guide, this may be taken as 10% of design capacity for condensing service and 30% of design capacity for cooling service, applied over the area of tube bundle normally cooled by the fans that are shut down or failed. Thus, for an air-cooled condenser having two fans, the residual cooling capacity upon loss of one fan would be 10% of design (one fan assumed to be shut down for maintenance or operational reasons at the time of failure). For an air-cooled condenser equipped with four fans, the residual cooling capacity upon loss of one fan would be 55% of design (two fans running at their full capacity provide 50% of the total cooling capacity, while one shut down fan and one failed fan each provide 2.5% of the total cooling capacity by natural convection. Additional credit for natural convection cooling may be taken if supported by engineering calculations.

2. **Louver Failure** - Inadvertent louver closure may result from automatic control failure or mechanical linkage failure. The effect on heat transfer will depend on the degree of restriction to air flow in the closed position and the configuration of louvers in relation to tube bundles (e.g., louvers might not be installed over all tube bundles in a given service). For pressure relief design, the design contingency closure of one set of louvers is assumed. (Failure of all louvers, that would result from a general instrument air or power failure, would be included in utility failure considerations.) No credit may be taken for continuing heat transfer due to natural convection, since the closed louvers would interfere with free air circulation.
3. **Pitch Control Failure** - For the purpose of pressure relief design, the fan pitch position that result in the least air flow (therefore least cooling) is assumed as a design contingency. Credit may be taken for continued cooling at this air flow.
4. **Variable Speed Motor Driver Speed Control Failure** - Failure of the driver speed control may result in a significant loss of cooling depending on the last speed of the fan. For the purposes of pressure relief design, the speed that results in the least air flow (therefore least cooling) is assumed as a design contingency. Credit may be taken for continued cooling at this air flow.

#### 6.8.4 Special Conditions in Closed Circuit

Where heating or cooling is used in a closed loop circuit (e.g., hot oil and refrigeration system), consideration must be given to overpressure conditions that might occur on loss of fluid flow, loss of heat input or loss of heat removal.

#### 6.8.5 Reflux Flow Failure

In some cases, failure of reflux (e.g., pump shutdown or valve closure) will cause flooding of the condenser, which is equivalent to PR valve capacity required for total loss of coolant. Compositional changes caused by loss of reflux may produce different vapor properties, which affect the relieving capacity. Usually, a PR valve sized for total tower overhead will be adequate for this condition, but each case must be examined in relation to the particular components and system involved.

#### 6.8.6 Pumparound Flow Failure

The relief requirement is the vaporization rate caused by an amount of heat equal to that removed in the pumparound circuit. The latent heat of vaporization would correspond to the temperature and pressure at PR valve relieving conditions. "Pinchout" of steam heaters may be considered, if appropriate. When pumparound duty is high, or the feed to the fractionator is highly superheated (e.g. FCCU and Coker fractionators), loss of a pumparound may cause a significant reduction in tower cooling and result in dry-out of the tower. Therefore, the potential for dry-out should be evaluated. The relief load due to fractionator dry-out is usually the sum of all the vapor feeds entering the fractionator plus any stripping steam or reboiler vapor (where applicable).

#### 6.8.7 Absorbent Flow Failure

In a unit where large quantities of inlet vapor may be removed in the absorber, loss of absorbent could cause a pressure rise to relief pressure, since the downstream system may not be adequate to handle the increased flow. In such cases, the effect of this additional vapor flow into downstream equipment must be analyzed.

#### 6.8.8 Loss of Heat in Series Fractionation System

In series fractionation, i.e., where the bottoms from the first column feeds into the second column and the bottoms from the second feeds into the third, it is possible for the loss of heat input to a column to overpressure the following

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column. Loss of heat results in some of the light ends remaining with the bottoms and being transferred to the next column as feed. Under this circumstance, the overhead load of the second column would consist of its normal vapor load, plus the light ends from the first column. If the second column does not have the condensing capacity for the additional vapor load, excessive pressure could occur.

#### 6.8.9 Abnormal Process Heat Input

The required capacity is the maximum vapor generation rate at PR valve relieving conditions, including any noncondensibles produced from overheating, less the normal condensation or vapor outflow rate. In every case, the designer should consider the potential behavior of a system and each of its components. For example, the fuel or heating medium control valve or the tube heat transfer may be the limiting consideration. Consistent with the practice in other causes of overpressure, design values should be used for an item such as valve size (except maximum trim is used for control valves). However, built-in overcapacity, such as the common practice of specifying burners capable of 125 percent of heater design heat input, must be considered.

Where limit stops are installed on valves, the wide-open capacity should be used rather than the capacity at the stop setting. In shell and tube heat exchange equipment, heat input should be calculated on the basis of clean, rather than fouled, conditions.

#### 6.8.10 Emergency Conditions in Integrated Plants

In integrated plants, a process upset in one unit may have an effect on other units (e.g., loss of flow of a pumparound which is used as a source of heat for reboiling other towers). All possibilities such as these must be carefully considered and the potential for resulting overpressure evaluated.

#### 6.8.11 Accumulation of Noncondensibles

Noncondensibles do not accumulate under normal conditions since they are released with the process vapor streams. However, with certain piping configurations, it is possible for noncondensibles to accumulate to the point that a condenser is "blanketed." Such a condition could occur if an automatic vent control valve failed closed for a period of time. This effect is equal to a total loss of coolant, and thus need not be considered separately.

#### 6.8.12 Water or Light Hydrocarbon Into Hot Oil

Although this situation remains a source of potential overpressure, no generally recognized methods for calculating the relieving rate requirements are available. In some situations, the quantity of water present and the heat available in the process stream are known, or can be estimated hence, the PR valve size can be calculated. For example, in the case of a hot feed accumulator, it may be possible to estimate the pressure that would be developed if water were pumped into the vessel at various rates. Other examples where it may be possible to estimate the potential quantity of water that may enter the equipment include towers where loss of level in the overhead separator may send an oil-water mixture or even water as reflux to the tower, and in heat exchangers where a tube failure can introduce low boiling liquid or water (heat exchanger tube rupture is discussed in [OVERPRESSURE IN SPECIFIC EQUIPMENT ITEMS](#)).

Since the expansion in volume from liquid to vapor is so great (approximately 1,400-fold at atmospheric pressure in the case of water) and the speed of vapor generation is very great, it is questionable whether the PR valve could open fast enough to be of value. However, a rupture disc could provide relief for these explosion-like events and therefore, may be the most appropriate pressure relief device for this contingency.

Proper process system design and operation, including startup conditions, are very important requirements to eliminate the possibility of introducing water or light hydrocarbon into hot oil. Avoidance of water-collecting pockets, proper steam condensate traps, and double blocks and bleeds on water connections to hot process lines are some precautions that can be taken. Likewise, vessel bottom withdrawal connections should not be installed with internal extensions, which could result in water being trapped in the bottom of the vessel. Refer also to the discussion under *Asphalt Operations and Atmospheric Tankage* in [DP XV-B](#).

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#### 6.8.13 Internal Equipment Blockage

Contingencies such as collapsed reactor bed vessel internals (e.g., fixed-bed reactor grids, reactor outlet collector collapse/plug, coked catalyst beds, accumulation of catalyst fines, plugging of screens and strainers, lines blocked with coke, etc.), should be considered, to identify any overpressure situations that could result. The use of the "1.5 Times Design Pressure Rule" (see [DESIGN PROCEDURE, PART I, INTRODUCTION](#)) is generally applicable in such cases, if this is a remote contingency. Overpressure due to collapse of fractionator tower tray internals is so rare that it is generally not a design consideration.

#### 6.8.14 Manual Valve Maloperation

Inadvertent operation of a block valve while the plant is onstream may expose equipment to a pressure that exceeds the maximum allowable working pressure. For the purpose of design, it is considered that only one manual valve is opened or closed (except as noted below) and control devices are in their normal operation position, as described earlier. A PR valve is required if the block valve is not locked or car sealed in its "safe" position (either open or closed) and if closure or opening of such valve can result in overpressure. For limitations on the use of car-sealed valves, see the discussion under [EVALUATION OF ESCAPE PATH IN PRESSURE RELIEF DESIGN](#).

As an example, consider a control valve station equipped with a manual bypass valve. If opening of the manual valve can overpressure equipment or piping downstream of the control valve, a pressure relief device is required to protect the downstream equipment unless the bypass valve is car-sealed closed and the system meets the limitations on the use of car-sealed valves discussed under [EVALUATION OF ESCAPE PATH IN PRESSURE RELIEF DESIGN](#). For the purposes of calculating the required relief rate, the control valve is assumed to remain in its normal operating position.

When normally closed double block valves are installed in accordance with **GP-03-12-01**, it shall be assumed that both block valves can be inadvertently opened (as if only a single block valve were present), unless at least one of them is car-sealed closed. The limitations on the use of car-sealed valves discussed under [EVALUATION OF ESCAPE PATH IN PRESSURE RELIEF DESIGN](#) also apply to this case.

For all cases that rely on a pressure relief device to prevent overpressure, the quantity of material to be relieved should be determined at conditions corresponding to the PR valve set pressure plus overpressure, not at normal operating conditions. Frequently, there is an appreciable reduction in required PR valve capacity when this difference in conditions is considerable. The effect of friction pressure drop in the connecting line between the source of pressure and the system being protected should also be considered in determining the capacity requirement. If the valve passes a liquid which flashes or the heat content causes vaporization of liquid, this must be considered in determining PR valve size.

#### 6.8.15 Hydraulic Surge

Pressure surge occurs in liquid filled piping systems when the velocity of the liquid changes rapidly due to sudden valve closure, sudden pressure letdown, pump startup, pump shutdown or similar events. When pressure surge occurs, forces produced in the piping system may exceed the design capability. Various mechanical relief devices can be used to limit the magnitude of this pressure surge: rupture discs, accumulators, and proprietary devices such as the Grove Flexflo valve. Methods for evaluating surge pressures and selecting the best surge relief device can be found in Report Nos. EE.74E.83, EE.62E.86, EE.86E.95 and EE.35E.98.

#### 6.8.16 Startup, Shutdown and Alternate Operations

Not only design steady-state conditions, but also startup, shutdown, washout, regeneration, alternate feed stocks, blocked operations and other possible different conditions must be evaluated for overpressure protection.

#### 6.8.17 Increased Plant Capacity

When an existing plant capacity is increased, the entire pressure relieving system should be reevaluated, even though no new equipment has been added.

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## 6.9 OVERPRESSURE IN SPECIFIC EQUIPMENT ITEMS

In addition to equipment malfunctions which can cause process overpressure in associated equipment (e.g., overpressure in a fractionator due to failure of cooling water or reflux pump), certain items of equipment are themselves subject to overpressure due to mechanical reasons. Such items include heat exchangers, pumps, compressors, turbines and fired heaters. The design of appropriate protection for them is covered in the following paragraphs.

### 6.9.1 Heat Exchanger Split Tube and Tube Leakage

In a shell and tube exchanger, the tubes are subject to failure from a number of causes, such as thermal shock, vibration or corrosion. Whatever the cause, the possibility of the high-pressure stream overpressuring equipment on the low-pressure side of the exchanger is the result. Hence, in heat exchangers, tube failure must be considered as a potential contingency for overpressure of the low-pressure side. Note that normally the higher-pressure stream flows through the tubes and that tubes and tubesheets are designed for differential pressure, potentially creating unusual problems.

♦ A tube split contingency need not be considered for the following types of exchangers:

- Tubular reactors and waste heat boilers with tubes 1.5 in. (38 mm) and larger in diameter, in which the tubes have wall thickness equivalent to process piping, and in which the tubes are welded to the tube sheet.
- Double-pipe exchangers except those with multiple tubes.
- Shell and tube exchangers that meet ALL of the following criteria:
  - Tube vibration is not likely based on a rigorous tube vibration analysis.
  - Tube wall thickness is at least one standard gauge thicker than the minimum required for the specified material or a detailed equipment strategy has been developed, documented and reviewed by experienced equipment specialists (both mechanical and metallurgical). The equipment strategy must specifically recognize the application of the 6mm hole concept and, consider all potential Equipment Degradation Modes, see TME 062 Section 7 EDD's and Section 8 PDD's. In addition, inspection data with similar designs, process conditions and metallurgy should confirm that no degradation has been found.
  - The tubes are not subject to erosion.
  - The tubes will operate at temperatures warmer than -150°F (-101°C). Research has shown that carbon steel tubes are not susceptible to brittle fracture above this temperature (see **EE.10E.78**). Nickel steel, stainless steel, nickel alloy and aluminum tubes may operate at even lower temperatures without risk of brittle fracture.
  - The tubes are not subject to fatigue or creep.
  - The process fluid will not cause aggressive corrosion or degradation of tubes and tubesheets (for example pitting from salt deposits, corrosion from acidic condensates or stress corrosion cracking). Consult with EMRE's Materials Engineering specialists to determine the appropriate material for the service conditions.
  - An appropriate tube inspection program will be developed for the exchanger bundle, after consulting with EMRE's Materials Engineering specialists.

However, all these exchanger types should be evaluated considering leakage through a 0.25 in. (6 mm) hole due to corrosion.

The pressure relationships in the heat exchanger must be known to permit proper evaluation of the results of a tube split. The ability of the complete low-pressure system to absorb the release through the split tube must be determined. The possible pressure rise must be ascertained, to determine whether additional pressure relief will be required if flow from the split tube were to discharge into the lower pressure stream.

The low pressure side of an exchanger must be protected by pressure relief devices if the design pressure on the high pressure side is more than "C" times the design pressure of the low pressure side and the low pressure side cannot handle the discharge from a split tube without exceeding "C" times the low pressure side design pressure, where "C" is the multiplier applied to the low-pressure side design pressure to determine the hydrostatic test pressure per **GP 05-03-01**. In determining whether the piping and equipment on the low-pressure side can handle a discharge from a split tube, any control valve present shall be assumed to be positioned for the minimum (turndown) normal design flow rate. If the control valve is normally closed or if the tube failure may cause the control valve to close, then

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no pressure relief can be assumed to occur through the piping. **The entire low-pressure system must be examined for potential overpressure by a split tube.** If the decision is to uprate the design pressure of the low pressure system in order to eliminate a split tube contingency, the complete low pressure system must be uprated or the entire low pressure side must be checked to ascertain that the "1.5 Times Design Pressure Rule" is met.

If a PR valve is required to protect the low-pressure side, the relief rate is defined by the maximum flow through the two open ends resulting from a guillotine cut of a single tube. Refer to a sample procedure for calculating the maximum flow in [APPENDIX 3](#). In calculating this maximum flow rate, the normal process flow into the low-pressure side is typically assumed to stop and the pressure difference across the tube opening is the difference between the maximum operating pressure of the high-pressure side and 1.5 times the design pressure (or the proof test pressure, if lower) of the low-pressure side. The effect of flashing as liquid flows from the high pressure side to the low pressure side, vaporization of any liquid in the low pressure side due to resultant high temperature fluid, and loss of normal process flow in the low pressure side must be taken into consideration in determining the relieving rate for the PR valve.

- ◆ In the event of a tube failure, transient pressures on the low-pressure side of the heat exchanger should be evaluated when the differential pressure between the high pressure side and the low pressure side equals or exceeds 500 psi (3,500 kPa). If the high pressure is on the tube side of the heat exchanger, the shell side transient pressure can be evaluated using "BREAK-X," a computer program for predicting peak pressures in heat exchangers due to tube rupture (refer to Report No. EE.18E.81), or equivalent computer program if approved and validated by EMRE. If the high pressure is on the shell side of the heat exchanger, "BREAK X" is not applicable. Therefore, to evaluate transient pressures in this situation, the Mechanical Engineering Section of ExxonMobil Engineering should be consulted.
- ◆ When the design pressure of the high pressure side exceeds the design pressure of the low pressure side by 1000 psi (6,900 kPa) or more and where an active corrosion mechanism is present, the probability and potential consequence of a multiple tube rupture shall be assessed qualitatively. Experience shows that in such exchangers the rupture of one tube has resulted in the rupture of several adjacent tubes due to a sudden pressure surge and deteriorated conditions of tubes in the exchanger. This assessment shall consider both the Safety, Health and Environmental (SHE) risks and the operational risk due to the likelihood that the event may render the affected equipment unfit for service, which will require replacement before normal operations are resumed. In addition, the upstream and downstream piping and equipment shall be designed to accommodate the surge forces due to the pressure surge predicted by "BREAK X" for a single tube rupture. Also the low-pressure side shall be examined for potential overpressure from ten split tubes, assuming the maximum flow through two open ends of each tube. If the resulting pressure could exceed C times the design pressure of the low-pressure system, then overpressure protection shall be provided.

In addition to evaluating the effect of a split tube, it should be recognized that internal tube sheet or tube leakage can occur, often unknowingly, under normal operation. Where the single action of deliberately blocking the low pressure side of the exchanger would result in the low pressure side of the exchanger exceeding 1.5 times its design pressure or its proof test pressure, whichever is lower, as a result of an internal leak, the low pressure side of the exchanger should be uprated; or a PR valve sized for the leakage through a 0.25 in. (6 mm) hole or a minimum size PR valve [1 in. x 2 in. (25 mm x 50 mm)] should be installed. Alternatively, permanent signs warning against closing the block valves on the low pressure side unless a bleeder has been opened or the high pressure side has been isolated and blinded should be attached to the block valves on the low pressure side. If blockage of the low-pressure side can occur as a result of an **operating event** such as total closure of a control valve, the contingency is no longer considered remote and must be treated as a **design contingency** for the purposes of overpressure protection.

The effect of a temperature change on the low-pressure side as a result of tube leakage is generally neglected when the design temperature of the low-pressure side is specified, since an increase in temperature is usually considered as a case of short-term allowable stress. The impact of low temperature caused by depressuring through the split tube must also be analyzed. Where brittle fracture conditions might occur in the low pressure side, various procedures to minimize the chance of tube failure (such as welding the tubes into the tube sheet and upgrading the tube materials to obtain better corrosion resistance) are acceptable alternatives to specifying brittle fracture resistant materials throughout the low pressure side.

#### 6.9.2 Pumps and Downstream Equipment

See [DP II](#) to calculate pump casing and downstream equipment design pressures. A PR valve is required for a pump when the shutoff pressure of the pump is greater than the design pressure of the pump casing, the discharge piping,

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or any downstream equipment that may be blocked-in against the pump. Positive displacement pumps normally require a PR valve for overpressure protection since the pump shutoff pressure can not generally be defined. In most cases centrifugal pumps do not require a PR valve for overpressure protection since the pump shutoff pressure can be defined and the pump and downstream equipment is generally designed for this pressure.

When a PR valve is required, the PR valve set pressure is normally equal to the design pressure of the equipment being protected. When the equipment being protected has different design pressures, the set pressure of the PR valve must take into consideration the lowest design pressure in the system (which may be in the pump auxiliary equipment such as flushing/seal systems). The PR valve is sized such that the accumulation during relief will not exceed allowable overpressure (1.1 or 1.16 times the lowest design pressure, depending upon the number of relief devices used). However, where only piping is involved, a short-term pressure allowance may apply.

If the pump casing design pressure or the mechanical seal design pressure is lower than the maximum pressure at shutoff of the pump, the maximum pressure at shutoff of an associated operating pump, or the design pressure of the pump auxiliary equipment (such as external flushing or seal systems), a PR valve must be installed to protect the pump. The set pressure for a pump PR valve is the lower of the pressure rating of the mechanical seal, the pump casing pressure or the design pressure of any other limiting component. The PR valve is sized for the potential source of excessive pressure, as follows:

1. If external flushing or seal systems are the only source of excessive pressure, a pump suction PR valve is sized for the maximum flow from these systems.
2. If the only source of excessive pressure is an associated pump, a pump suction PR valve is sized for reverse flow through the downstream check valve. Refer to ["EVALUATION OF PRESSURIZATION PATH IN PRESSURE RELIEF DESIGN"](#) for a discussion on the use of check valves to limit overpressure. When drilled check valves or check valve bypasses are specified for pump warm-up purposes per **GP 03-03-02**, the pump suction PR valve shall include capacity for the normal flow associated with these facilities.
3. If the source of excessive pressure can be both the external flushing/seal system and an associated pump, a pump suction PR valve is sized for the greater of 1 or 2.
4. If the source of excessive pressure is the discharge of the pump, a pump discharge PR valve is sized for the maximum actual rate that the pump can deliver at the accumulated pressure of the PR valve.

The design pressure of a steam-driven reciprocating pump and downstream equipment may be set by the maximum process pressure which the steam cylinder is able to produce at maximum steam pressure, in which case no pressure relief facilities are required. However, in most cases it is not economical to set the design pressure of downstream equipment as high as this maximum stalling pressure. In these cases, a PR valve would be required to protect the downstream equipment against overpressure.

For reciprocating pumps driven by electric motors, PR valves serve the dual purposes of protecting the pump and downstream piping from overpressure, and protecting the driver from overload. [DP X-F](#) describes this application.

Other positive displacement pumps, such as rotary, gear, and diaphragm pumps, normally require PR valve protection for both the pump and downstream equipment.

For any pump requiring a PR valve for its protection or for protection of downstream equipment, the PR valve set pressure should be higher than the normal pump discharge pressure as defined in [DP II](#). Note, however, that in some cases a higher PR valve set pressure may be desirable to assure a sufficient differential when the pump is to be operated under lower than normal design pumping rate. This will recognize the higher pump discharge pressure under low flow conditions. In the case of reciprocating pumps protected by spring loaded PR valves, the PR valve should be set above the maximum pulsation pressure or 15 percent above the operating pressure, whichever is greater. When this is not possible because of equipment design pressure or specified operating pressure level, pilot-operated valves should be considered.

The capacity of a pump discharge PR valve should equal the capacity of the pump at the pressure conditions existing while the PR valve is relieving. To reduce the size of a PR valve installed at the discharge of a centrifugal pump with a known pump curve, advantage can be taken for the reduction in pump capacity as it backs up on its performance curve.

Pump PR valves should discharge to a closed system. In many cases discharge paths may be routed to the suction line or suction vessel.

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### 6.9.3 Compressor and Downstream Equipment

PR valves are required for any compressor where the maximum pressure which can be generated during surge or restricted discharge conditions exceeds the design pressure of the discharge piping, downstream equipment compressor seals, or compressor casing.

For centrifugal compressors, it is usually economical to set the design pressure lower than the maximum possible pressure that the compressor can develop, and to provide appropriate PR valve protection on the discharge. In some cases (e.g., where the flow through a PR valve would be the release which establishes the size of a closed disposal system), it may be advantageous to set the design pressure of the compressor casing and downstream equipment equal to the maximum pressure that can be generated at the surge point, assuming the most severe combination of speed, molecular weight, suction pressure and temperature conditions that can occur as the result of a design contingency.

For positive displacement compressors, discharge PR valves are nearly always required. Reliance on stalling of a reciprocating compressor is generally not economically attractive, since driver stalling pressures are usually quite high in comparison to operating pressure.

Pressure relief valves for centrifugal compressors should be set higher than the normal operating pressure by 25 psi (170 kPa) or 10% of operating pressure, whichever is greater.. Interstage PR valves should be set at least as high as the compressor settling-out pressure, to avoid valve lifting during compressor shutdowns. In the case of reciprocating compressors protected by spring loaded PR valves, the PR valve should be set above the maximum pulsation pressure or 15 percent above the operating pressure, whichever is greater. When this is not possible because of equipment design pressure or specified operating pressure level, pilot-operated valves should be considered.

Short-term pressure allowances for piping may be considered.

Low-pressure stage casings and interstage circuits on both centrifugal and positive displacement multi-stage compressors are not normally designed for full discharge pressure and must also be provided with overpressure protection.

Where interstage PR valves are required, PR valve capacity should be equal to the compressor capacity at the emergency conditions. If recycle and/or anti-surge lines are provided, interstage PR valves should be sized for the greater of the compressor capacity or the flow through the recycle lines with fully opened recycle valves, assuming check valve leakage (see check valve reverse flow under ["EVALUATION OF PRESSURIZATION PATH IN PRESSURE RELIEF DESIGN"](#) in this Design Practice). Where a reciprocating compressor is used, the compressor internals may be considered the same as a single check valve.

For reciprocating compressors, if an operating compressor stops running, vapor may backflow through the compressor and overpressure equipment upstream of the compressor. To calculate the amount of vapor which may backflow through a reciprocating compressor consider each compressor stage as a single check valve. If there is a check valve in the discharge of the stage, consider it as an additional check valve. Refer to ["EVALUATION OF PRESSURIZATION PATH IN PRESSURE RELIEF DESIGN"](#) for a discussion on reverse flow through check valves

Note some multi-stage machines have recycle lines around individual cylinders, with control valves, for startup or capacity control. These must be assessed separately, similar to the standard low flow recycle loops.

For centrifugal compressors, the combination of PR valve set point and relieving capacity should be such as to avoid surge conditions over the anticipated combinations of emergency conditions and operating variables. Compressor PR valves should discharge to an appropriate atmospheric or closed system, and not directly to the suction of the machine.

Since many variables are involved, it may be advisable to consult the Machinery Engineering Section on specific problems.

### 6.9.4 Steam Turbine

A PR valve is required on the steam inlet to any steam turbine if the maximum steam supply pressure is greater than the design pressure of the casing inlet. The PR valve should be set at the casing inlet design pressure and sized such that overpressure of the casing is prevented under conditions of wide open steam supply and no exhaust flow.

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Protection of the exhaust end of steam turbines is dependent on whether they are in condensing or noncondensing service, as follows:

1. **Condensing Turbine** - The condenser and the exhaust end of a condensing turbine casing are not normally designed for full steam supply pressure. Therefore, in such cases, protection must be provided against overpressure which could result from loss of cooling water or other operating failure. The special type of pressure relief valve which is normally installed on the turbine exhaust for this purpose is illustrated in [Figure I-1](#). It has no spring end and is normally held closed by the vacuum conditions in the condenser; but a supply of fresh water (not salt or brackish water) is required for the sealing system. The condenser vendor usually specifies and provides the PR valve in accordance with the specification of the Standards of the Heat Exchanger Institute.

The required relieving rates for these PR valves are based upon the steam rate to the turbine under ordinary condensing operation only, and the appropriate size can be checked against the following table, which is taken from Standards of the Heat Exchanger Institute, Surface Condenser Section.

| MAXIMUM STEAM RATE TO TURBINE, lb/h | REQUIRED PR VALVE SIZE (INLET FLANGE DIAMETER, in.) | MAXIMUM STEAM RATE TO TURBINE, kg/s | REQUIRED PR VALVE SIZE (INLET FLANGE DIAMETER, mm) |
|-------------------------------------|-----------------------------------------------------|-------------------------------------|----------------------------------------------------|
| Up to 7,500                         | 6                                                   | < 0.95                              | 150                                                |
| 7,501 to 11,800                     | 8                                                   | 0.95 to 1.49                        | 200                                                |
| 11,801 to 17,000                    | 8                                                   | 1.50 to 2.14                        | 200                                                |
| 17,001 to 20,000                    | 10                                                  | 2.15 to 2.52                        | 250                                                |
| 20,001 to 23,100                    |                                                     | 2.53 to 2.91                        |                                                    |
| 23,101 to 30,200                    | 10                                                  | 2.92 to 3.80                        | 250                                                |
| 30,201 to 38,200                    | 12                                                  | 3.81 to 4.81                        | 300                                                |
| 38,201 to 45,000                    | 12                                                  | 4.82 to 5.67                        | 300                                                |
| 45,001 to 47,200                    | 14                                                  | 5.68 to 5.94                        | 350                                                |
| 47,201 to 62,000                    | 14                                                  | 5.95 to 7.80                        | 350                                                |
| 62,001 to 68,000                    | 16                                                  | 7.81 to 8.56                        | 400                                                |
| 68,001 to 82,000                    | 16                                                  | 8.57 to 10.33                       | 400                                                |
| 82,001 to 106,000                   | 18                                                  | 10.34 to 13.38                      | 450                                                |
| 106,001 to 120,000                  | 18                                                  | 13.39 to 15.15                      | 450                                                |
| 120,001 to 170,000                  | 20                                                  | 15.16 to 21.46                      | 500                                                |
| 170,001 to 250,000                  | 24                                                  | 21.47 to 31.56                      | 600                                                |
| 250,001 to 380,000                  | 30                                                  | 31.57 to 47.98                      | 750                                                |
| 380,001 to 550,000                  | 36                                                  | 47.99 to 69.44                      | 900                                                |

When a condensing turbine has one or more intermediate extraction stages, each extraction line should be protected against overpressure due to blockage of the extraction line. If a PR valve is used to provide this protection, it should be sized for the full steam flow rate to the turbine without taking credit for the steam extraction at other stages (if any) or for steam flow to the condenser. Condensing turbines with intermediate extraction typically rely on internal re-admission valves to route the steam flow that exceeds the extraction rate to the condenser (or to lower pressure extraction stages, if any). This approach is consistent with the

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concept that no credit may be taken for favorable response of instruments or control valves in reducing the required relief load.

2. **Noncondensing Turbine** - The casing of a noncondensing turbine is usually not designed for full steam supply pressure at the exhaust end. A pressure relief valve is therefore required at the turbine exhaust if the pressure in any part of the casing can exceed its design pressure as a result of exhaust valve closure, back pressure fluctuations or similar contingency. The PR valve should exhaust to the atmosphere, and its set pressure should be higher than the normal exhaust pressure by 25 psi (170 kPa) or 10% of operating pressure, whichever is greater. In addition, the lowest design pressure of any section of the casing must be specified to be no lower than the PR valve set pressure plus the pressure drop to the PR valve during relief.

The PR valve should be sized to pass the maximum steam flow assuming sonic velocity through the smallest restriction in the flow and at the maximum inlet pressure. Credit may be taken for steam flow which is withdrawn from an intermediate turbine stage if it would not be blocked by the same contingency as closure of the exhaust.

Exceptions to the foregoing requirements apply in the following cases:

- a. Turbines exhausting to the atmosphere through open piping without valves do not require exhaust overpressure protection.
- b. Turbines exhausting into an exhaust steam main through a top or side connection do not require exhaust overpressure protection, provided that the maximum inlet steam pressure does not exceed 150 psig (1,000 kPa gage), but a warning notice must be provided at the exhaust valve and the valve must be CSO, in accordance with **GP 03-03-07**.

#### 6.9.5 Fired Heaters and Boilers

Two potential forms of overpressure may apply to fired heaters and boilers: overpressure of the firebox by forced-draft fans or tube rupture; and overpressure of tubes due to outlet blockage or from overheating due to loss of process flow.

1. **Firebox Overpressure** - The firebox of a forced-draft fired heater or boiler is designed to withstand the overpressure that can be generated by the fans with dampers in their closed position, in accordance with [BP VIII-K](#), *Air-Preheaters*, and **GP 07-01-01** and **GP 07-02-01**. This needs to be specially checked when both forced and induced-draft fans are provided to discharge combustion products through heat recovery facilities, since higher than normal fan pressures may be used to overcome pressure drop. When excessive pressure can be developed, protection can be provided by use of a high pressure cut-out or pressure relief doors.

In the case of high pressure process fired heaters, a tube rupture could also be the cause of firebox overpressure. In this case, "explosion" doors can be used to provide protection. When the tube pressure exceeds 1,000 psig (6900 kPa gage), the analysis is complex and COMBUSTION ENGINEERING SPECIALISTS should be consulted.

2. **Boiler Steam Side Overpressure** - All fired boilers are provided with PR valves sized to relieve the full steam rate in the event of closure of the normal outlet, in accordance with the ASME Code, Section I (*Power Boilers*), or other applicable regulations.

Overpressure protection for waste heat boilers is designed in accordance with the ASME Code requirements for "pressure vessels," provided that they comply with the definitions in **Paragraph U-1 (e) of Section VIII, Division 1**, of the Code.

3. **Process Fired Heater Coil Overpressure** - The coil of any fired heater where the process flow can be stopped by inadvertent closure of a valve in the fired heater outlet (operator error) or as a result of planned emergency action, is subject to potential overpressure and tube failure due to overheating and consequent reduction in allowable stress. Unless such mechanisms of flow interruption (arising from a design contingency) can be effectively eliminated, the fired heater must be protected against loss of process flow, which can lead to overheating and tube failure, and against overpressure from upstream equipment such as pumps or compressors. Protection against loss of process flow is required by **GP 15-01-01** for all fired heaters, whether or not they are equipped with a block valve and/or a PR valve at the coil outlet. According to **GP 15-01-01**, all fired heaters shall have a **safety critical** low-flow cut-out [FL(CO)] with pre-alarm which shuts off the main fuel(s) on low total process feed flow. The provision of a PR valve on the outlet of a fired heater to ensure continuity of process flow if the coil outlet is blocked is not recommended because of the potential for coking at the PR valve inlet and for thermally shocking the discharge piping when the PR valve blows.