

## DEP SPECIFICATION

# OVERPRESSURE AND UNDERPRESSURE - PREVENTION AND PROTECTION

DEP 80.45.10.11-Gen.

February 2012

ECCN EAR99

## DESIGN AND ENGINEERING PRACTICE

### DEM1



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## 1. INTRODUCTION

### 1.1 SCOPE

This DEP specifies requirements and gives recommendations for the protection of equipment against overpressure and underpressure. This DEP is a supplement to ISO 23251 and ISO 28300.

NOTES: 1. API Std 521 is identical to ISO 23251.  
2. API Std 2000 is identical to ISO 28300.

For pressure relief facilities of liquefied petroleum gas in bulk storage installations, DEP 30.06.10.12-Gen. shall also apply.

For LPG supply/distribution facilities (for retail and commercial distribution), the relieving facilities for vessels with capacities not greater than 135 m<sup>3</sup> shall be in accordance with NFPA 58.

Design of pressure relief, flare and vent systems shall be in accordance with DEP 80.45.10.10-Gen.

Emergency depressuring and sectionalizing shall be in accordance with DEP 80.45.10.12-Gen.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual DEM 1 – Application of Technical Standards.

This is a revision of the DEP of the same number dated February 2011; see (1.5) regarding the changes.

### 1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

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This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

### 1.3 DEFINITIONS

#### 1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorized to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The capitalized term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

### 1.3.2 Specific definitions

| Term                                                              | Definition                                                                                                                                                                                                                                                                               |
|-------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Administrative Controls</b>                                    | Operational and maintenance procedures that, along with proper training and/or supportive measures, seek to ensure that personnel actions do not compromise overpressure protection. Refer to (2.15).                                                                                    |
| <b>Car Seal</b>                                                   | Band or wire that has to be broken in order to change the valve position. Car seals installed on a valve inhibit unauthorized valve operation. Refer to (2.15).                                                                                                                          |
| <b>Corrected Hydrotest Pressure</b>                               | Applied hydrotest pressure multiplied by the ratio of design stress value at upset temperature over the design stress value at test temperature. For new ASME Section VIII equipment the corrected hydrotest pressure would be $1.3 \times \text{MAWP}$ .                                |
| <b>Class 1 Check Valves (also known as Critical check valves)</b> | Check valves that are inspected (or tested) to assure reliable operation. These check valves are used to prevent backflow to suction vessels and tanks, prevent reverse overspeed on turbomachinery, and minimize damage from furnace tube ruptures.                                     |
| <b>Double Jeopardy Scenario</b>                                   | Scenario caused by two unrelated events.                                                                                                                                                                                                                                                 |
| <b>Equipment</b>                                                  | Pressure vessels, piping, heat exchangers, rotating equipment, tanks, and fired heaters.                                                                                                                                                                                                 |
| <b>HEMP</b>                                                       | Hazard and Effects Management Process – overall work process for identifying, assessing, and managing hazards.                                                                                                                                                                           |
| <b>LNG / LPG</b>                                                  | Liquefied Natural Gas / Liquefied Petroleum Gas                                                                                                                                                                                                                                          |
| <b>LOPA</b>                                                       | Layers of Protection Analysis – a quantitative method to determine the frequency of a scenario outcome.                                                                                                                                                                                  |
| <b>Maximum Allowable Accumulated Pressure (MAAP)</b>              | Maximum internal pressure allowed by this DEP during a pressure relieving event. This is equal to the Design pressure (or Maximum Allowable Working Pressure) plus the maximum allowable accumulation by the relevant pressure vessel code. Refer to (2.13) for allowable accumulations. |
| <b>Overpressure</b>                                               | Pressure increase over the set pressure of a pressure relief device during discharge and is usually expressed as a percentage of the set pressure.                                                                                                                                       |
| <b>Pressure System Safety Study (PSSS)</b>                        | Structured examination of each pressure system for all potential overpressure and underpressure scenarios.<br><br>This is also known as the “Relief, Flare, and Vent Study” within the Discipline Controls and Assurance Framework (DCAF) project work process.                          |
| <b>PFD</b>                                                        | Probability of failure upon demand                                                                                                                                                                                                                                                       |

| Term                                           | Definition                                                                                                                                                                                                                                                                                                                       |
|------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Process Engineering Flow Schemes (PEFS)</b> | Pictorial representation of a process or utility unit which shows all the equipment, including installed spares and the associated piping and piping components, instrumentation, heat tracing and insulation.<br><br>NOTE: These are also known as Piping and Instrument Diagrams (P&IDs) and Engineering Flow Diagrams (EFDs). |
| <b>Process Safeguarding Flow Scheme (PSFS)</b> | Simplified flow diagram that highlights all pressure systems and their elements and those elements that protect the system against overpressures. This diagram is included as part of the Safeguarding Memorandum.<br><br>NOTE: The requirements for the PSFS are specified in DEP 01.00.02.12-Gen.                              |
| <b>Relief Pressure</b>                         | Set pressure plus the overpressure. Also known as the relieving pressure.                                                                                                                                                                                                                                                        |
| <b>Safeguarding Memorandum</b>                 | Document that summarizes the PSSS and other related issues.<br><br>NOTE: These may also be referred to as Process Safeguarding Memorandum (PSM) or Safeguarding Memorandum (SGM). The requirements for the Safeguarding Memorandum requirements are specified in DEP 01.00.02.12-Gen.                                            |
| <b>Pressure System</b>                         | Single equipment item or group of equipment items including associated piping that is protected by a common pressure protection device or set of devices.                                                                                                                                                                        |
| <b>PRV</b>                                     | Pressure relief valve                                                                                                                                                                                                                                                                                                            |
| <b>Thermal Relief</b>                          | Pressure relief for systems that are liquid full and, when blocked in, can generate overpressures due to heat ingress either from a source or from the environment. Thermal relief can often be provided via a small PRV (often called a Thermal Expansion Relief Valve or TERV).                                                |
| <b>Very toxic (substances)</b>                 | Substances that are very hazardous for the environment or human health, as specified in DEP 01.00.01.30-Gen. (which also identifies "toxic" substances by reference to chemical substances databases).                                                                                                                           |

#### 1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets ( ). Other documents referenced by this DEP are listed in (8).

#### 1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated February 2011. The following are the main non-editorial changes:

| Section | Change                                                                                                                                                 |
|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.3.2   | Added definition of "corrected hydrotest pressure"                                                                                                     |
| 2.3     | Added more guidance on designing for containment                                                                                                       |
| 2.10.2  | Clarified that favourable response of ESDs and IPFs should not be taken into account for relief device sizing                                          |
| 2.10.3  | Clarified that design requirements of the section are not applicable if system is protected via equipment design pressure rating or by pressure relief |

| Section    | Change                                                                                                                                                                                               |
|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2.10.3.3   | Changed criteria from 150% of design to the corrected hydrotest pressure                                                                                                                             |
| 2.11.1.5.c | Relocated the PRV backflow sizing criteria for existing facilities to DEP 80.45.10.13-Gen.                                                                                                           |
| 2.11.2     | Added option to do check valve backflow performance testing in lieu of internal inspection (see Informative for considerations)                                                                      |
| 2.11.3.3   | Changed criteria from 150% of design to the corrected hydrotest pressure                                                                                                                             |
| 2.11.3.4   | Changed criteria from 150% of design to the corrected hydrotest pressure                                                                                                                             |
| 2.11.3.5   | Revised language to be consistent with the figure. Clarified that the 1E-3 design is the PFD for the barriers and not residual risk                                                                  |
| 2.11.3.7   | Typo. Changed reference from (5.5.4) to (5.2.2)                                                                                                                                                      |
| 2.11.3.8   | Referenced (5.4) (new guidance for backflow through other rotating equipment)                                                                                                                        |
| 2.11.3.9   | In the table under paragraph 9, deleted comment about regular check valves (see informative for comments). Also moved the 1% of check valve flow area (for existing systems) to DEP 80.45.10.13-Gen. |
| 2.11.3.10  | Added criteria that any IPFs need to follow the IPF DEP                                                                                                                                              |
| Figure 1   | Changed criteria from 150% of design to the corrected hydrotest pressure. Changed Note 3 also.                                                                                                       |
| Figure 2   | Clarification. Changed "delta pressure ratio" to "pressure ratio. Changed the 1E-3 criteria from residual risk to barrier PFD.                                                                       |
| 2.13.1     | For completeness, added references to PD 5500 and GB150 design codes in the 2 <sup>nd</sup> and 3 <sup>rd</sup> items.                                                                               |
| 2.13.2     | Changed the allowable accumulation for remote contingencies from 50% to the corrected hydrotest pressure.                                                                                            |
| 2.14.1.4   | Added requirement that vessels and their foundation to be designed to withstand the overfill case.                                                                                                   |
| 2.15.3.1   | Clarified that mis-operation of valve locks applies to locked closed as well as locked open valves. Added corrected hydrotest pressure (previously, it could be read as any overpressure)            |
| 3.6        | Included remote operated valves and choke valves within the scenario of control valves –open and closed                                                                                              |
| 3.6.1      | Highlighted case where two liquid phases exist and there is an analogous scenario to the vapour break through, but with liquid.                                                                      |
| 3.7.2.2.1  | Changed "maximum" to "normal" operating pressure to be consistent with (3.7.2.3)                                                                                                                     |
| 3.7.2.4    | Removed the option to install close coupled relief for the basis for design scenario since large liquid reliefs should be avoided with new designs                                                   |

| Section   | Change                                                                                                                                                                                                                                                                  |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3.7.5.3   | For the excess system inventory (using abnormal liquid levels), extended the use of 50 % accumulation from only rupture disks to also PRVs                                                                                                                              |
| 3.8.2     | Clarified last sentence to eliminate a misunderstanding of the remote contingency scenario which is described in (4.4).                                                                                                                                                 |
| 3.9.1     | Added need to still consider pool fire scenario for PRV sizing, if the only fire exposure involves flammable streams that do not pool. Noted that some facilities may be required to evaluate fire scenarios that have high intensity than typical refinery pool fires. |
| 3.9.1     | Clarified fire case exclusion and included an exception (reactive hazard) to the exclusion.                                                                                                                                                                             |
| 3.9.2.3   | Expanded the vapour filled vessel exclusion to cover all vapour filled vessels, not just small ones.                                                                                                                                                                    |
| 3.9.2.7   | Expanded the fire case exclusion for piping to cover equipment designed to piping codes                                                                                                                                                                                 |
| 3.9.5.1   | Clarified the point that wetted areas for some pressure equipment can extend above the standard 8 m (25 ft) or 9.1 m (30 ft) that is typically used.                                                                                                                    |
| 3.9.5.1.f | Softened requirement in how piping wetted area is accounted for                                                                                                                                                                                                         |
| 3.9.7     | Added “at relieving conditions” in the 1 <sup>st</sup> paragraph                                                                                                                                                                                                        |
| 3.10      | Eliminated the term “hydrostatic overpressure” and used “liquid thermal expansion” instead                                                                                                                                                                              |
| 3.10.1.1  | Deleted “or process” from Thermal Relief, since any vapour relief from process heat would be considered a process relief, not a thermal relief.                                                                                                                         |
| 3.10.4.3  | Replaced “probable” with “intended” to reduce ambiguity                                                                                                                                                                                                                 |
| 3.10.4.3  | Added minimum pipe volume criteria in e).                                                                                                                                                                                                                               |
| 3.10.6.   | Relocated since the overpressure scenario is liquid thermal expansion. Originally valve body overpressures were located in (5.8).                                                                                                                                       |
| 3.10.6.1  | Removed some of the details with double seated gate valves, since this might conflict with the referenced DEP.                                                                                                                                                          |
| 3.10.6.2  | Changed SHALL [PS] to shall since the referenced DEP is a DEM-1. This was done elsewhere for identical reasons.                                                                                                                                                         |
| 3.10.6.2  | Added requirement to notate on the PEFs where thermal relief is provided to protect a block valve bonnet.                                                                                                                                                               |
| 3.10.7    | Added paragraph to cover other systems that are routinely isolated (e.g., truck loading facilities)                                                                                                                                                                     |
| 4.2.1     | Used the general term “internal failure” instead of “tube rupture.” Clarified that consequences of a tube leak while exchanger is isolated should also be evaluated                                                                                                     |
| 4.2.1.    | Changed tube rupture allowable accumulation from “50%” to “the the corrected hydrotest pressure”. Eliminated the 2/3rds rule language.                                                                                                                                  |

| Section | Change                                                                                                                                            |
|---------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| 4.2.1.6 | Clarified guidance on plate and frame exchanger internal failure. Added drawing to illustrate the points.                                         |
| 4.2.1.7 | Clarified guidance on printed circuit exchanger internal failure. Added drawing to illustrate the points.                                         |
| 4.2.1.8 | Added guidance on brazed aluminium heat exchanger internal failure. Added drawing to illustrate the points.                                       |
| 4.2.2   | Changed 50% accumulation to corrected hydrotest pressure                                                                                          |
| 4.2.3   | Changed 50% accumulation to the lowest corrected hydrotest pressure of any component in the downstream system                                     |
| 4.2.4   | Changed accumulation for PRV sizing to corrected hydrotest pressure                                                                               |
| 4.3.1   | Clarified use of remote contingency specified accumulation                                                                                        |
| 4.4     | Clarified use of remote contingency specified accumulation                                                                                        |
| 4.6.3   | Clarified use of remote contingency specified accumulation                                                                                        |
| 4.7.2   | Clarified use of remote contingency specified accumulation                                                                                        |
| 5.4.1   | Added guidance on determining maximum discharge pressure                                                                                          |
| 5.4.4   | Added guidance that addresses backflow through positive displacement pumps                                                                        |
| 5.4.5   | Added guidance that addresses backflow through positive displacement compressors                                                                  |
| 5.4.6   | Added guidance that addresses backflow through reciprocating compressors                                                                          |
| 5.7.1   | Removed details on pipeline pressure relief and referred to the DEP instead. Clarified relief device sizing using remote contingency accumulation |
| 5.8     | Clarified practice to vent Coriolis meter RDs directly to atmosphere                                                                              |
| 6.3.4   | Removed details and referred to the DEP instead                                                                                                   |

## 1.6 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at [standards@shell.com](mailto:standards@shell.com), using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://swwww.shell.com/standards> and on the main page of the DEPs DVD-ROM.

## 1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

**2. DESIGN PHILOSOPHY****2.1 PRESSURE SYSTEM SAFETY STUDY**

- 2.1.1 A structured examination of all potential overpressure and underpressure scenarios SHALL [PS] be performed during design. This examination is called a Pressure System Safety Study (PSSS). Management of Change procedures SHALL [PS] assure that process modifications are assessed and the PSSS updated as required.
- 2.1.2 The PSSS shall verify that all equipment is adequately protected against overpressure and underpressure
- 2.1.3 Protection against overpressure/underpressure shall be implemented by the use of any or all of the following:

|                         |                                                                            |
|-------------------------|----------------------------------------------------------------------------|
| Mechanical Design       | Selection of design pressures. See (2.2).                                  |
| Mechanical Safeguards   | Pressure relief devices.                                                   |
| Instrumented Safeguards | See (2.10) for restrictions.                                               |
| Emergency Procedures    | Emergency depressuring and emergency isolation (see DEP 80.45.10.12-Gen.). |
| Administrative Controls | See (2.15).                                                                |

- 2.1.4 The PSSS shall reference the design premise. This premise shall include, as a minimum, the design flow rate used for the analysis and the composition and temperature of each feed stream.
- 2.1.5 Design of the relief system shall be based on a heat and material balance that reflects the intended range of unit operation. This shall include unit start-up and shut-down conditions since they can be more severe than at design operating conditions.
- 2.1.6 A summary of the PSSS shall be documented in the Safeguarding Memorandum conforming to DEP 01.00.02.12-Gen.

**2.2 DESIGN PRESSURE**

- 2.2.1 A structured method for determining the upper and lower design pressure of pressure equipment shall be used. For Shell installations, DEP 01.00.01.30-Gen. provides requirements on establishing the upper and lower (vacuum) design pressure for equipment.
- 2.2.2 If the MAWP is used in the PSSS in lieu of the equipment design pressure, the MAWP shall be added to the PEFS and PSFS where applicable.

**2.3 DESIGN FOR CONTAINMENT****2.3.1 Design for internal pressure**

It may be possible to design for pressure containment in order to avoid relief. The criteria in this DEP may be used to determine the maximum pressures that a pressure system could be subjected to in order to achieve this.

It is preferable to design for containment in order to avoid large liquid reliefs. See (5.4.1). for guidance on determining pump deadhead pressures.

**2.3.2 Design for vacuum**

Equipment in steam service shall be designed for full vacuum.

**2.3.3 Design for external pressure**

Piping and equipment subjected to external pressures (e.g., subsea) shall be designed for the full hydrostatic pressures at installation depth. No credit for internal pressures may be taken without approval of the Principal.

## 2.4 PRESSURE SYSTEM

See DEP 01.00.01.30-Gen. for definition of pressure system and pressure relief considerations in specifying pressure system equipment design pressures.

2.4.1 A pressure system is an individual equipment item or groups of equipment including associated piping that, within its boundaries, remains open under all conditions, and it can be demonstrated that blockage due to freezing, solidification, fouling, sublimation, damage of internals, scale, debris, foreign objects, etc. cannot occur within that system.

2.4.2 The design pressure (or MAWP) for the pressure system SHALL [PS] be based on the lowest design pressure (or MAWP) of any system component. The effects of static head shall be taken into account.

2.4.3 If multiple equipment items in a pressure system are protected by a relief device(s) located in one part of the pressure system, the hydraulics shall be evaluated to assure that no equipment exceeds its design pressure before a pressure relief device activates and during relieving conditions no equipment exceeds its Code-allowable accumulation (2.13).

Pressure drop in a system shall be considered when determining the proper relief valve set pressure. For example, if all equipment items in a system have equal design pressures with the PRV located on the last piece of equipment, then due to the pressure drop the set pressure of the PRV shall be below the design pressure to ensure that the upstream equipment is not overpressured before the PRV opens.

2.4.4 If a systems approach is taken and the interconnecting piping's normal flow is very low relative to the relieving flow (creating a possibility of undetected line fouling), then the relief device should be located upstream of this potential restriction.

2.4.5 If parallel vessels or exchangers are valved in order to permit on-stream isolation for maintenance, and both are normally on-line, the increased pressure drop shall be aligned with the design operating window.

## 2.5 UNIT TURNDOWN CONSIDERATIONS

Taking credit for the normal flow leaving a system is allowed in accordance with ISO 23251 and this DEP. Such credits, however, shall be based on the minimum turndown operating limit for the equipment/process unit and such credits shall be clearly documented in the PSSS and the Safeguarding Memorandum, if applicable.

NOTE: In new designs, such credits should not normally be taken, in order to keep the analysis simple.

## 2.6 IMPACT OF UPSTREAM CONDITIONS ON DOWNSTREAM SYSTEMS

2.6.1 The impact of upstream systems at abnormally high (upset) or relieving pressure on downstream systems shall be considered when evaluating downstream system overpressure scenarios. Criteria for evaluation are:

a) The upstream system's pressure compared with the downstream equipment's design pressure.

NOTES: Flows to downstream systems can be higher than normal when the upstream system is at relieving pressure because:

(i) Open piping and chokes can pass more flow if the upstream pressure is higher.

(ii) Control valves (e.g., flow control valves) between the upstream and downstream systems, which would normally react to maintain a normal condition in the downstream system, are assumed to not respond, see (2.10.1). Thus with a higher differential pressure and the control valve in its "normal" position, more flow will enter the downstream system.

(iii) Control valves (e.g., pressure control valves) between the upstream and downstream systems, which would normally open to maintain the upstream conditions, are assumed to function as designed, see (2.10.1). Thus with both a higher differential pressure and a potentially wide-open control valve, more flow will enter the downstream system.

b) Common-mode failure scenarios shall be taken into account to evaluate their impact on the supply to the downstream common system and their effect on the consumers

from the system, in order to determine any resulting overpressure condition and pressure relief capacity of the common downstream system.

- c) The potential reduction (but not the potential increase) of flows leaving the downstream system due to instrumentation/operator response shall be taken into consideration. See (2.6.2) for example.

- 2.6.2 Common-mode relief scenarios shall be considered when the flows into and out of the downstream system are evaluated. This can be a significant relieving scenario for downstream systems tied to multiple upstream flow sources.

For example, this applies to gas collection systems which collect gas streams from tanks or vessels that are routed to a common facility for compression, treatment, incineration, flaring, etc. These may have one or more sources of gas going into the downstream system and typically one avenue out. Any scenario that increases the pressure in upstream systems will likely result in their vent valves (typically on pressure control) to open as designed. This flow can be substantially higher than normal and higher than the flow through one wide-open control valve with normal upstream pressure. The amount of flow leaving the downstream system should be evaluated, as it can vary from normal depending on the system design and the common-mode failure under study.

Moreover, fuel gas collection systems can have very high relief loads since during power failure the vent valves feeding the fuel gas collection vessel can be wide open (as described above) and many, if not all avenues, out of the downstream vent gas collection vessel will automatically shut because the furnace fuel gas system trips are assumed to function as designed.

## 2.7 MIXING OF HOT MATERIALS WITH VOLATILE MATERIALS

- 2.7.1 Mixing of hot materials with volatile materials, such as water and hot oil, can result in transient vaporisation rates that are difficult to quantify. Guidelines for preventing these scenarios, as described in ISO 23251, should be implemented where possible.

- 2.7.2 Overpressure protection shall be provided for the steady state mixing of hot materials with volatile materials (for any valid single jeopardy scenarios).

- 2.7.3 Overpressure risks associated with transient vapourization shall be mitigated by one or more of the following:

- a) System design (increased design pressure)
- b) Inlet nozzle locations
- c) Minimization of pockets in hot process piping
- d) Low point drains to remove all water prior to starting up
- e) Swing elbows, double block and blind, and other safeguards for utility connections
- f) Equipment start-up and operating procedures
- g) Bursting disk

## 2.8 INTERFACES WITH THIRD PARTIES

Managing source pressures from third parties shall be covered by contractual agreements. When applicable, the Principal shall verify that maximum source pressures comply with the contractual limits. For example, there should be an understanding of how the third party is limiting the source pressure (e.g. whether it is limited by pump deadhead or by the use of relief devices). Relief valves owned and operated by third parties shall be assumed to be sized appropriately under the applicable design codes, and the reliability of these relief devices shall be assumed equal to those of the Principal. If the Principal's facilities provide the source of pressure for third parties, then the Principal shall take measures as described in this DEP to prevent overpressure to the third party.

**2.9 FAILURE POSITION OF CONTROL VALVES**

The failure position of control valves shall allow each system to reach an inherently safe condition (e.g. stop flows and process heat) during a total instrument air failure scenario.

**2.10 ROLE OF INSTRUMENTATION IN OVERPRESSURE PROTECTION****2.10.1 General**

In some cases, the Principal may choose to specify Instrumented Protective Functions to eliminate a relief scenario or, in rare cases, eliminate the relief device. See (2.10.3) for details.

1. Pressure relief due to instrumentation malfunction (either single- or common-mode) is covered in (3.5) and (3.6). When these or any other relief scenarios are evaluated, the assumptions described below shall be made as to how the other instrumentation in the system might respond.
2. Unless otherwise specified in this DEP, when determining relief loads for a single pressure system, credit SHALL [PS] not be taken for favourable instrumentation response. Favourable instrumentation response is any expected normal response (the instrument's intended function) that would reduce the relief loads on the pressure system under study. Any instrumentation that could provide favourable response SHALL [PS] be assumed to be frozen (or on "manual" mode). Examples of favourable instrumentation response that shall not be used to eliminate or reduce relief loads include:
  - a) Pressure control valve opens to relieve vessel pressure.
  - b) Level control valve closes to prevent vapour break-through.
  - c) High level trip opens dump valve.
3. Instrumentation response that increases relief loads within the pressure system under study SHALL [PS] be assumed to function properly.

**2.10.2 Reduction of calculated relief loads**

The following table summarizes methods that may be used to further analyze the calculated flare and relief loads and that could result in a reduction of the calculated loads.

| Method                                                   | PRV sizing     |             | Flare system sizing |                  |
|----------------------------------------------------------|----------------|-------------|---------------------|------------------|
|                                                          | ISO 23251      | DEP Section | ISO 23251           | DEP              |
| Assessment of System Dynamics                            | Yes            | -           | Yes                 | 80.45.10.10-Gen. |
| Beneficial Response from Basic Process Control           | No             | -           | Yes                 | 80.45.10.10-Gen. |
| Emergency Shutdowns or Instrumented Protective Functions | No<br>(Note 1) | 2.10.3      | Yes                 | 80.45.10.10-Gen. |
| Operator Intervention                                    | Yes            | 2.14        | Yes                 | 80.45.10.10-Gen. |

- NOTES:
1. IPFs may be used if it is impossible or impractical to size the relief device for the scenario.
  2. There are different methods allowed for PRV sizing and flare system sizing.
  3. ISO 23251 describes various analytical methods and assumptions that may be used in some cases to reduce calculated relief loads.

### 2.10.3 Instrumented Protective Functions (and other measures) to eliminate the relief device

1. When protection against overpressure only cannot be achieved by equipment pressure rating or pressure relief, alternative design criteria may be considered.

NOTE: For guidance on mitigating flare loads see DEP 80.45.10.10-Gen.

2. A core principle in relief system design is to not take instrumentation credits. To deviate from this principle it shall be demonstrated that designing or re-designing the equipment, the relief devices, or relief stream disposal system is not possible or practicable. Criteria for such designs are given below.

#### Equipment design capability issues:

- a) The equipment cannot practicably be designed for the overpressure scenario conditions.

#### Relief design capability issues:

- a) There is no relief device that can reliably cope with the conditions of the scenario.
- b) The required relief capacity cannot practicably be achieved with relief devices.
- c) The relief load for reactive systems cannot be determined with confidence due to lack of reactive chemistry knowledge or physical property data.

#### Relief stream disposal capability issues:

- a) The capability of the flare/disposal system could be exceeded (this includes liquid knock out capability, or temperature limits). Refer to DEP 80.45.10.10-Gen. if the hydraulic capacity of the disposal/flare system could be exceeded.
  - b) The relief stream composition from this system creates a hazard for the flare/disposal system (this includes introduction of incompatible materials that result in violent chemical reactions, introduction of oxidizers, and materials that can plug the relief system.)
  - c) The discharge to atmosphere would be a significant safety, environmental, or reputation issue
3. When the overpressure scenario cannot be covered by traditional relief system design, mitigation measures SHALL [PS] meet all of the criteria below. The use of Instrumented Protective Functions is the most commonly used mitigating measure but other measures (e.g., mechanical interlocks, basic process controls) may be used as well.
    - a) Mitigation measures shall be valid as defined by HEMP/LOPA design criteria (i.e., independent, effective, and auditable). If the credit for Instrumented Protective Functions is taken, the IPF design shall meet DEP 32.80.10.10-Gen. requirements.
    - b) Except for the fire scenario, the combined probability of failure upon demand (PFD) of valid measures used to prevent the scenario (e.g., prevent the relief, prevent exceeding allowable accumulations, prevent exceeding design temperatures, etc.) shall be at least equivalent to the PFD achieved by a relief valve in clean service.
    - c) If the scenario, without taking credit for mitigation measures as described above will result in pressures exceeding the corrected hydrotest pressure, then in addition, the risks shall be demonstrated to be ALARP using applicable HEMP methodology (e.g., perform LOPA if required).
    - d) For fire scenario, the risk shall be demonstrated to be ALARP using applicable HEMP methodology.
    - e) Operating above the certified pressure range (e.g., above the MAWP) is not permitted. Conditions that result in pressures exceeding the MAWP shall be corrected in a timely manner.

- f) For applications involving ASME Section VIII equipment, the technical and documentation requirements in UG-140 of Division 1 shall also be followed and mitigated accumulations shall be limited to 16 %. For applications involving other vessel design codes, mitigated accumulations shall be limited to Code Allowables (generally 10 %).
- g) For individual pressure systems that have design challenges with a particular relief scenario, as described in (2.10.3.2), and are mitigated as described above, the calculated relief load that would result if the mitigation measures failed does not need to be included for relief disposal system design for that particular relief scenario.

## NOTES:

- 1. When mitigation measures are used to eliminate the scenario (no relief at all) then assume no load from this system during that specific scenario.
- 2. When mitigation measures are used to reduce the system's relief load (the PRV relieves but does not have sufficient capacity if mitigation measures fail), then for relief disposal system design use the calculated relief load assuming the mitigation measures function properly.

4. Scenarios and mitigating measures are subject to approval of the Principal.

#### 2.10.4 Instrumentation for flare load management

Flare loads may be reduced using IPFs. See DEP 80.45.10.10-Gen. for details.

### 2.11 ROLE OF CHECK VALVES (NON RETURN VALVES) IN OVERPRESSURE PROTECTION

#### 2.11.1 General

In considering backflow from a high pressure source, it is evident that a check valve will not protect against overpressure due to its inherent mechanical design. A check valve will always have some fluid passing, the quantity of which is not possible to determine precisely and verifiably. The restriction of the backflow and the measures coping with the resultant quantities can vary and are based on engineering assumptions.

- 1. The consequences of backflow (reverse flow) include but are not limited to overpressure of upstream equipment, reverse overspeed of mechanical equipment and their drivers, system contamination, and relief or atmospheric release of undesirable process streams. For example, loss of power to the pump could cause backflow which could result in overpressure of the equipment on the suction side of the pump and damage to the pump or motor.
- 2. Since check valves in practice reduce the likelihood of gross backflow, the presence of check valves can be taken into account in the design of any instrumented safeguards (see DEP 32.80.10.10-Gen. for IPF design requirements). Specifically, check valves may reduce the demand rate on an IPF. Credit for check valves may only be taken into account once (for example, if factored in the initiating event frequency, it cannot be used again to reduce the demand rate for the IPF).
- 3. Alternatively, where sites have established HSE Management Systems to manage check valve reliability, credit for these check valves (Class 1 check valves) in overpressure design may be considered. See (2.11.2) for requirements and guidelines.
- 4. For the purposes of overpressure design due to backflow, check valves, regardless of design or class, shall not be considered tight shut-off. If the piping upstream of the check valve is blocked in, it is assumed that this will eventually be pressurised to the discharge side pressure.
- 5. Where relief devices will be sized for reverse flow, the following assumptions shall be made:
  - a) Where there is no check valve, base reverse flow on hydraulics.
  - b) Where there is a single Class 1 check valve or regular check valve(s), do not take

any flow restriction credits for the check valves (either ignore the flow resistance of the valves or assume the check valves are wide open).

- c) Where there are dual Class 1 check valves, calculate the backflow assuming a check valve flow area of 10 % for new facilities.
  - d) Where a vapour cap is driving the backflow, the vapour flow may control the relief device sizing after vapour breakthrough.
6. Selection of an adequate check valve type shall be part of the design. Certain process or operating conditions may lead to malfunctioning of the check valve (due to fouling, corrosion, construction, location and flow path of the backflow, etc.).

### 2.11.2 Class 1 check valves

1. Class 1 check valve design concept requires the site's HSE Management Systems to manage check valve reliability as follows:
  - a) Class 1 check valves shall be included in an inspection programme, as follows:
    - i. Class 1 check valves should be subjected to internal inspection (or performance tested) to detect gross deficiencies such as a stuck flapper, corroded seats, damaged hinge, or galling.  
  
NOTE: Failure to close due to fouling might not be detected.
    - ii. Inspection (or performance test) interval philosophy for Class 1 check valves should be consistent with that for PRVs. Unless otherwise specified by applicable regulations, the inspection intervals should be condition-based. These should, but might not necessarily, correspond to the planned shutdown (turnaround) intervals.
    - iii. Class 1 check valves should have a unique number assigned for tracking purposes, and each valve should be labelled or tagged in the field with this identifying number.
    - iv. Inspection (or performance test) records for each Class 1 check valve shall be maintained.
  - b) Class 1 check valves shall be shown in the PEFS, PSFS, Safeguarding Memorandum, and SHALL [PS] be included in the site's HSE-MS documentation for critical barriers/tasks.
  - c) Class 1 check valves may be single or dual (two in series). In many applications two Class 1 check valves are used but, as described in this DEP, there are applications where only one Class 1 check valve is warranted.
  - d) Class 1 designation does not dictate a specific valve design, but the Principal may do so. Class 1 check valves shall be sized and specified so that under the range of design forward flow conditions the valve will have stable performance (i.e., not flutter) as specified by the check valve Manufacturer.

### 2.11.3 Backflow overpressure protection of equipment excluding low pressure and atmospheric storage tanks

1. The steps (2-10) below SHALL [PS] be followed to provide overpressure protection against backflow. See Figure 1 for the overall logic. Other risks caused by the backflow (e.g. environmental releases, contamination, etc.) shall be considered and evaluated on a case-by-case basis. Sizing the upstream relief device for the backflow is only required where specifically stated in the steps below.

NOTE: If backflow is mitigated by sizing the relief devices for the reverse flow, the consequences of potential reverse overspeed damage to mechanical equipment shall be considered.

2. If there is no check valve to stop the reverse flow, size the relief device for the backflow and stop.
3. If there is a check valve to stop the reverse flow, an assessment of the backflow scenarios shall be carried out. If the analysis demonstrates that the upstream system

will not exceed corrected hydrotest pressure during the backflow, then a single check valve is adequate as a minimum. Typically, backflow from a higher pressure system requires vapour or a large liquid volume to sustain a backflow. The analysis may consider settle out pressures, calculated backflow, see (2.11.1.5) and PRV capacity, etc. If the backflow introduces a reactive hazard that can generate a pressure greater than the backflow source pressure, this will be evaluated separately as part of a reactive hazard scenario.

4. If the backflow scenario assessment is not able to demonstrate that the upstream system pressure will not exceed corrected hydrotest pressure the backflow, then calculate the pressure ratio (the backflow source gauge pressure divided by the equipment design pressure).

NOTE: This process takes the pressure ratio as an indicator of how severe a "sustained" backflow into the upstream equipment could be. In order for a sustained backflow to occur, the high pressure system needs stored energy (e.g., a vapour cap or a large volume of compressible liquid). Typically, liquid full systems rapidly lose pressure and backflow potential once the source of forward flow is stopped.

5. If the pressure generating equipment is a centrifugal pump or compressor and the pressure ratio is less than 5, then assume consequence is asset damage only. Provide barriers to prevent the backflow equivalent to a PFD of 1E-3 or design to risk tolerability and ALARP. Consider single Class 1 check valve, dual Class 1 check valves, PRV sized in combination with dual Class 1 check valves, and/or an instrument safeguard that stops the backflow. This instrument safeguard can be an IPF or a basic process control trip.

NOTE: Experience has shown that pressure ratios less than 5 can lead to pump or motor damage.

6. If the pressure generating equipment is a centrifugal pump or compressor and the pressure ratio is greater than 5, then provide dual Class 1 check valves and an IPF. Assume potential vessel rupture when evaluating the IPF SIL requirements. Use 1E-2 as the probability of failure upon demand for the pair of Class 1 check valves.
7. If the backflow is caused by a tube rupture in a fired heater see (5.2.4).
8. See (5.4) for specific guidance on backflow through other rotating equipment. Backflow involving other systems (utility connections, etc.) should be evaluated on a case by case basis if no other guidance is provided in the applicable DEP.
9. When quantifying the likelihood of backflow through check valves, use the probability of failure on demand data shown below when using LOPA.

| Independent Protection Layer                                                                                                                                                     | Probability of failure on demand |                            |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|----------------------------|
|                                                                                                                                                                                  | Clean service                    | Dirty or corrosive service |
| Single Class 1 check valve for back flow                                                                                                                                         | $1 \times 10^{-1}$               | 1                          |
| Class 1 dual check valves for overpressure due to backflow per the flow chart.                                                                                                   | $1 \times 10^{-2}$               | $1 \times 10^{-1}$         |
| Class 1 dual check valves including pressure relief device sized to pass the backflow. For new equipment, assume check valve opening equivalent to 10 % of the check valve area. | $1 \times 10^{-3}$               | $1 \times 10^{-2}$         |

- NOTES: 1. Clean service can be regarded as gas or liquid streams that contain no components with a tendency to foul. Process streams like LNG, H<sub>2</sub>, NG, treated LPG, pure products as isopentane, butane, hexane, benzene, toluene, and the like, would be considered clean. Fouling tendency substances can be hydrocarbons with high pour points above lowest ambient temperature, coking services, polymerizing services, etc.
2. Credit for more than two (2) check valves should not be taken, since common cause failures may result in diminishing effectiveness.

10. If IPFs are required, an analysis shall be performed to confirm that the IPF will be fast enough to mitigate the risks. IPFs shall meet DEP 32.80.10.10-Gen. requirements.

#### **2.11.4 Backflow overpressure protection of low pressure and atmospheric storage tanks**

1. The steps below shall be followed to provide overpressure protection against backflow. See Figure 1 and 2 for the overall logic.

NOTE: If backflow is mitigated by sizing the relief devices for the reverse flow, the consequences of potential reverse overspeed damage to mechanical equipment shall be considered.

2. Where backflow results in a vapour relief coming from the downstream equipment, the relieved vapour is flammable and has the potential to develop a vapour cloud that could accumulate at grade, size the tank relief devices for the full backflow (per 2.11.1.5) and install at least a single Class 1 check valve.

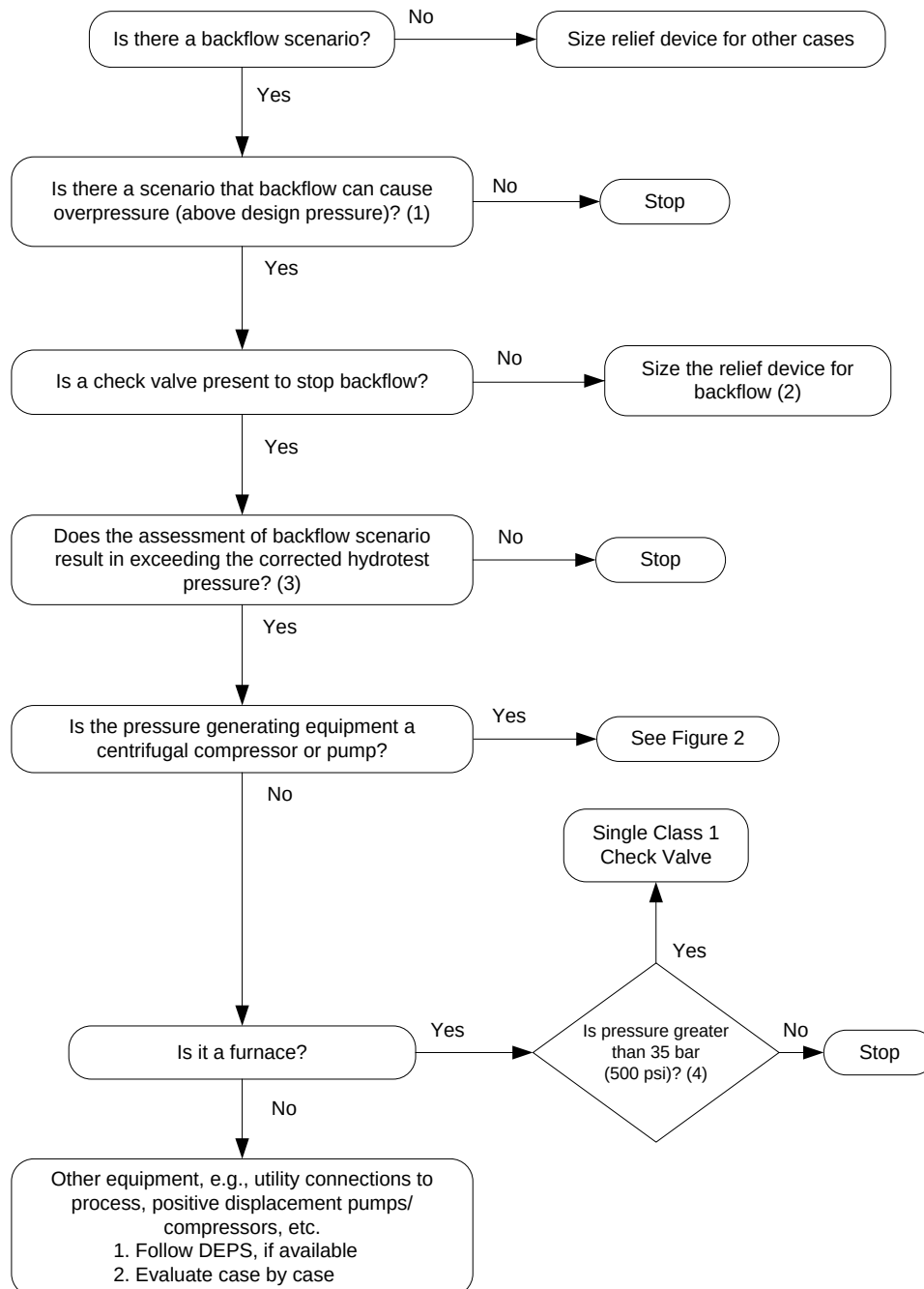
If the vapour released from the tank will not likely accumulate at grade, size the tank relief devices for the full backflow (per 2.11.1.5) and install a single check valve (a Class 1 check valve is not required).

If the sizing of the relief device for the full backflow is impractical, then install dual Class 1 check valves and an IPF. Assume potential tank rupture when evaluating the IPF SIL requirements.

3. If the tank relief device is sized for the full backflow, the relief device discharges to atmosphere, and the relief stream is "very toxic", then assess the consequences and mitigate as needed.

NOTE: Very toxic releases may require additional safeguards (IPF) to meet risk criteria.

4. If the tank relief device is sized for the full backflow, the relief device discharges to atmosphere, and the tank is located close to occupied buildings or process units, then assess the environmental and safety consequences and mitigate as needed.



- NOTES:
- (1) This should include overpressure caused by reactive hazards scenarios, contamination reactions that cause "very toxic" releases, etc. Subject matter experts should be consulted to determine the appropriate evaluation technique required.
  - (2) When assessing, consider the potential for the phase of the backflow stream to change from liquid to vapour if vapour is driving the backflow. The installed relief device is assumed to be routed to a closed system (i.e. flare). If to atmosphere, further assessment is required.
  - (3) An assessment of the backflow scenarios shall be carried out. If the analysis demonstrates that the upstream system will not exceed the corrected hydrotest pressure during the backflow, then a single check valve is adequate. Typically, backflow from a higher pressure system requires vapour or a large liquid volume to sustain a backflow. The analysis may consider settle out pressures, calculated backflow, see (2.11.1.5) and PRV capacity, etc. Resulting pressures may not be limited by the source. Examples of this include reactive hazards and hot oil/water contact.
  - (4) Scenario for a furnace is a ruptured tube where back flow would also result in back pressure to the furnace tubes.

**Figure 1** Flow chart – Design/system review for relief valve sizing and backflow prevention