

**DIN EN ISO 23251**

ICS 75.180.20

**Entwurf**

Einsprüche bis 2011-07-30  
Vorgesehen als Ersatz für  
DIN EN ISO 23251:2007-12,  
DIN EN ISO 23251  
Berichtigung 1:2008-12 und  
DIN EN ISO 23251/A1:2008-11

**Erdöl-, petrochemische und Erdgasindustrie –  
Druckentlastungs- und Druckausgleichssysteme (ISO/DIS 23251:2011);  
Englische Fassung prEN ISO 23251:2011, nur auf CD-ROM**

Petroleum, petrochemical and natural gas industries –  
Pressure-relieving and depressuring systems (ISO/DIS 23251:2011);  
English version prEN ISO 23251:2011, only on CD-ROM

Industries du pétrole, de la pétrochimie et du gaz naturel –  
Systèmes de dépressuration et de protection contre les surpressions  
(ISO/DIS 23251:2011);  
Version anglaise prEN ISO 23251:2011, seulement en CD-ROM

**Anwendungswarnvermerk**

Dieser Norm-Entwurf mit Erscheinungsdatum 2011-05-30 wird der Öffentlichkeit zur Prüfung und  
Stellungnahme vorgelegt.

Weil die beabsichtigte Norm von der vorliegenden Fassung abweichen kann, ist die Anwendung dieses  
Entwurfes besonders zu vereinbaren.

Stellungnahmen werden erbeten

- vorzugsweise als Datei per E-Mail an [noeg@din.de](mailto:noeg@din.de) in Form einer Tabelle. Die Vorlage dieser Tabelle  
kann im Internet unter [www.din.de/stellungnahme](http://www.din.de/stellungnahme) oder für Stellungnahmen zu Norm-Entwürfen der DKE  
unter [www.dke.de/stellungnahme](http://www.dke.de/stellungnahme) abgerufen werden;
- oder online im Norm-Entwurfs-Portal des DIN unter [www.entwuerfe.din.de](http://www.entwuerfe.din.de), sofern dort wiedergegeben;
- oder in Papierform an den Normenausschuss Erdöl- und Erdgasgewinnung (NÖG) im DIN, 10772 Berlin  
(Hausanschrift: Burggrafenstr. 6, 10787 Berlin).

Die Empfänger dieses Norm-Entwurfs werden gebeten, mit ihren Kommentaren jegliche relevanten  
Patentrechte, die sie kennen, mitzuteilen und unterstützende Dokumentationen zur Verfügung zu stellen.

Gesamtumfang 268 Seiten

Normenausschuss Erdöl- und Erdgasgewinnung (NÖG) im DIN  
Normenausschuss Maschinenbau (NAM) im DIN

## Nationales Vorwort

Dieses Dokument (prEN ISO 23251:2011) wurde vom Technischen Komitee ISO/TC 67/SC 6/WG 12: „Pressure-relieving and depressuring systems“ in Zusammenarbeit mit dem Technischen Komitee CEN/TC 12 „Materialien, Ausrüstungen und Offshore-Bauwerke für die Erdöl-, petrochemische und Erdgasindustrie“ (Sekretariat: AFNOR, Frankreich) erarbeitet.

Für Deutschland hat hieran der Arbeitsausschuss NA 109-00-01 AA „Materialien, Ausrüstungen und Offshore-Bauwerke für die Erdöl-, petrochemische und Erdgasindustrie — Spiegelausschuss zu CEN/TC 12 und ISO/TC 67“ im Normenausschuss Erdöl- und Erdgasgewinnung (NÖG) des DIN Deutsches Institut für Normung e. V. mitgearbeitet.

Diese Europäische Norm enthält unter Berücksichtigung des DIN-Präsidialbeschlusses 1/2004 nur die englische Originalfassung der ISO-Norm.

Das Ausgabedatum des Europäischen Norm-Entwurfs stand zum Zeitpunkt der Veröffentlichung dieses DIN-EN-ISO-Entwurfs noch nicht fest; der prEN ISO wird jedoch vom CMC unter der angegebenen prEN-Nummer demnächst zur CEN-Umfrage verteilt. Um der deutschen Öffentlichkeit eine möglichst lange Einspruchsfrist einzuräumen, wurde dieser Norm-Entwurf bereits vorab veröffentlicht.

Diese Norm enthält neben den gesetzlichen Einheiten auch die Einheiten „°F“, „°R“, „bbl“, „BTU/h“, „ft“, „gal (galone)“, „in (inch)“, „lb (pound)“, „lbf“, „mph“, „NPS“ und „psi (psig)“, die in Deutschland nicht zugelassen sind. Es wird ausdrücklich darauf hingewiesen, dass die Anwendung dieser Einheiten im nationalen amtlichen und geschäftlichen Verkehr aufgrund des Gesetzes über Einheiten im Messwesen nicht zulässig ist.

### Umrechnung:

| Nicht-SI-Einheit | SI-Einheit      | Umrechnung |                           |
|------------------|-----------------|------------|---------------------------|
| °F               | °C              | °C         | = (5/9) (°F – 32)         |
| °R               | °C              | 1 °R       | = 1,25 °C                 |
| bbl              | dm <sup>3</sup> | 1 bbl      | = 158,987 dm <sup>3</sup> |
| BTU/h            | kJ/h            | 1 BTU/h    | = 1,055 kJ/h              |
| ft               | m               | 1 ft       | = 0,304 8 m               |
| gal (galone)     | l               | 1 gal      | = 3,785 l                 |
| in (inch)        | mm              | 1 inch     | = 25,4 mm                 |
| lb (pound)       | kg              | 1 lb       | = 0,453 592 37 kg         |
| lbf              | N               | 1 lbf      | = 4,448 222 N             |
| mph              | km/h            | 1 mph      | = 1,6 km/h                |
| NPS              | DN              | 1 NPS      | = DN 25                   |
| psi (psig)       | kPa             | 1 psi      | = 6,894 757 kPa           |

Für die in diesem Dokument zitierten Internationalen Normen wird im Folgenden auf die entsprechenden Deutschen Normen hingewiesen:

|            |       |                   |
|------------|-------|-------------------|
| ISO 4126-1 | siehe | DIN EN ISO 4126-1 |
| ISO 4126-2 | siehe | DIN EN ISO 4126-2 |
| ISO 4126-3 | siehe | DIN EN ISO 4126-3 |
| ISO 4126-4 | siehe | DIN EN ISO 4126-4 |
| ISO 4126-5 | siehe | DIN EN ISO 4126-5 |
| ISO 4126-6 | siehe | DIN EN ISO 4126-6 |
| ISO 4126-7 | siehe | DIN EN ISO 4126-7 |

## Änderungen

Gegenüber DIN EN ISO 23251:2007-12, DIN EN ISO 23251 Berichtigung 1:2008-12 und DIN EN ISO 23251/A1:2008-11 wurden folgende Änderungen vorgenommen:

- a) Aktualisierungen der normativen Verweisungen;
- b) Umorganisation der alten Abschnitte 4 bis 7 in Abschnitt 4 „Causes of overpressure and their relieving rates“ und in Abschnitt 5 „Disposal systems“;
- c) Aktualisierung der Literaturhinweise.

## Nationaler Anhang NA (informativ)

### Begriffe

Die Benennung der folgenden Begriffe ist identisch mit der Benennung in der englischen Fassung.

### 3 Begriffe

Für die Anwendung dieses Dokuments gelten die folgenden Begriffe.

#### 3.1

##### **Drucküberschreitung**

Druckanstieg über den maximal zulässigen Betriebsdruck des Behälters, der während der Ableitung durch die Druckentlastungseinrichtung zulässig ist

ANMERKUNG Die Drucküberschreitung wird in Druckeinheiten angegeben oder als prozentualer Anteil am maximal zulässigen Betriebsdruck (MAWP) oder als Bemessungsdruck. Die maximal zulässigen Drucküberschreitungen werden durch Druck-Bemessungsvorschriften für Notfall-Betrieb und Brandschutz-Notfallpläne festgelegt.

#### 3.2

##### **administrative Überwachung**

Maßnahmen zur Sicherstellung, dass Handlungen des Personals nicht den Überdruckschutz der Ausrüstung gefährden

#### 3.3

##### **Hilfsgas**

Brenngas, das dem Abblasegas vor dem Fackel-Brenner oder an der Verbrennungsstelle beigegeben wird, um den Brennwert zu erhöhen

ANMERKUNG Bei einigen Konstruktionen kann sich durch das Hilfsgas die Verwirbelung erhöhen, wodurch eine bessere Verbrennung erreicht wird.

#### 3.4

##### **Ableitung in die Atmosphäre**

Freisetzung von Dämpfen und Gasen aus Druckentlastungs- und Druckausgleichseinrichtungen in die Atmosphäre

#### 3.5

##### **Betriebsbereitschaft**

Zeitabschnitt, innerhalb dessen ein System (z. B. Sicherheitssystem, Abblaseeinrichtung oder Gasfackel-Entlastungssystem) in der Lage ist, falls für die Anwendung gefordert, die vorgesehenen Leistungen zu erbringen

#### 3.6

##### **Gegendruck**

Druck, der am Ausgang einer Druckentlastungseinrichtung infolge des Drucks im Abblasesystem vorhanden ist

ANMERKUNG Der Gegendruck ist die Summe aus dem Fremdegendruck und dem Eigengegendruck.

#### 3.7

##### **ausgeglichenes Druckentlastungsventil**

federbelastetes Druckentlastungsventil, das über einen Balg oder ein anderes Mittel zur Geringhaltung der Auswirkung des Gegendrucks auf die Betriebseigenschaften des Ventils verfügt

**3.8****Rückhaltebehälter**

Abscheidebehälter, der über ein zur Atmosphäre hin offenes Abzugsrohr verfügt oder an ein solches angeschlossen ist

ANMERKUNG 1 Der Begriff Rückhaltebehälter wird mitunter auch für Abscheidebehälter verwendet, die an eine Gasfackel oder andere Abblasesysteme angeschlossen sind, in dieser Internationalen Norm wird er jedoch nicht in diesem Zusammenhang verwendet.

ANMERKUNG 2 Der Begriff Rückhaltebehälter wird mitunter im Zusammenhang mit einer Notfall-Druckentlastung einer Anlage oder eines Anlagenteils verwendet, jedoch nicht in dieser Internationalen Norm.

**3.9****Abblasen**

Verlust einer stabilen Flamme, wenn die Flamme über den Brenner angehoben wird, was vorkommt, wenn die Geschwindigkeit des Brenngases höher ist als die Flammengeschwindigkeit

**3.10****Bruchbolzensicherung**

Druckentlastungseinrichtung, die auf den statischen Differenzdruck oder den statischen Eingangsdruck anspricht und so ausgeführt ist, dass sie durch den Bruch eines lasttragenden Abschnitts eines Bolzens, der ein drucktragendes Bauteil stützt, funktioniert

**3.11****Knickstab-Berstsicherung**

Druckentlastungseinrichtung, die auf den statischen Differenzdruck oder den statischen Eingangsdruck anspricht und so ausgeführt ist, dass sie durch das Abknicken eines axial belasteten Druckstabs, der ein drucktragendes Bauteil stützt, funktioniert

**3.12****Eigengegendruck**

Druckanstieg am Ausgang einer Druckentlastungseinrichtung, der infolge der Strömung nach Öffnen der Druckentlastungseinrichtung auftritt

**3.13****Auftriebssperre**

(en: buoyancy seal)

Trockendampf-Sperre, durch die die Menge des zum Schutz gegen das Eindringen von Luft benötigten Spülgases gering gehalten wird

ANMERKUNG Die Auftriebssperre funktioniert durch Einschluss eines Volumens von leichtem Gas in einer umgedrehten Innenkammer; dadurch wird verhindert, dass die Luft das leichte Traggas in der Fackel verdrängt.

**3.14****Rückbrand**

innerer Brand innerhalb des Fackelkopfes

ANMERKUNG Ein Rückbrand kann durch beim Spülen zum Fackelbrenner zurückströmende Luft oder niedrige Fackelraten entstehen.

**3.15****Abbrandgeschwindigkeit****Flammgeschwindigkeit**

Geschwindigkeit, mit der sich eine Flammenfront in ein unverbranntes brennbares Gemisch bewegt

**3.16****Brenngruben-Fackel**

(en: burn-pit flare)

offener Aushub, der gewöhnlich über einen horizontalen Fackelbrenner verfügt, der sowohl für flüssige Kohlenwasserstoffe als auch Kohlenwasserstoffdämpfe geeignet ist

**3.17****Berstdruck**

Wert des statischen Vordrucks abzüglich des Wertes des statischen Nachdrucks unmittelbar vor dem Bersten der Berstscheibe

ANMERKUNG Wenn der Nachdruck dem atmosphärischen Druck entspricht, ist der Berstdruck der statische Manometer-Vordruck.

**3.18****geschlossenes Entsorgungssystem**

Entsorgungssystem, das in der Lage ist, Drücke aufzunehmen, die sich vom atmosphärischen Druck unterscheiden

**3.19****Kalt-Einstelldruck****CDTP**

Druck, bei dem ein Druckentlastungsventil auf dem Prüfstand zur Öffnung eingestellt ist

ANMERKUNG Der Kalt-Einstelldruck schließt Korrekturen für die Betriebsbedingungen des Gegendrucks oder der Temperatur oder von beiden ein.

**3.20****Verbrennungsluft**

Luft, die zur Verbrennung der Fackelgase erforderlich ist

**3.21****begrenzter Brand**

Brand innerhalb eines Gebäudes oder eines geschlossenen Prozessmoduls, bei dem die Wände und/oder die umliegende Ausrüstung zurückstrahlen und die Verbrennungsluft vorwärmen können, wodurch höhere Wärmestromdichten verursacht werden als bei einem nicht begrenzten (d. h. offenen) Brand

**3.22****konventionelles Druckentlastungsventil**

federbelastetes Druckentlastungsventil, dessen Betriebseigenschaften direkt von Änderungen des Gegendrucks beeinflusst werden

**3.23****korrigierter hydrostatischer Prüfdruck**

hydrostatischer Prüfdruck, multipliziert mit dem Verhältnis aus dem Spannungswert bei der Temperatur unter Störbedingungen zum Spannungswert bei der Prüftemperatur

ANMERKUNG 1 Siehe 4.2.2.

ANMERKUNG 2 In dieser Definition wird unter dem hydrostatischen Prüfdruck der in der Druckbemessungsrichtlinie festgelegte hydrostatische Prüfdruck verstanden, unabhängig davon, ob die Ausrüstung tatsächlich einer hydrostatischen Druckprüfung unterzogen wurde oder nicht.

**3.24****Verpuffung**

Explosion, bei der die Flammenfront eines brennbaren Mediums sich mit einer Geschwindigkeit ausbreitet, die unterhalb der Schallgeschwindigkeit liegt

vgl. **Detonation** (3.27)

**3.25****Bemessungsdruck**

Druck, der zusammen mit der Bemessungstemperatur zur Ermittlung der kleinsten zulässigen Dicke oder der physikalischen Eigenschaft jedes Bauteils, wie in den Konstruktionsvorschriften der Druckbemessungsrichtlinie festgelegt, verwendet wird

**ANMERKUNG** Der Bemessungsdruck wird vom Anwender ausgewählt, um eine geeignete Spanne oberhalb des stärksten Drucks bereitzustellen, der bei gewöhnlichem Betrieb bei der zugehörigen Temperatur zu erwarten ist, und es handelt sich dabei um den Druck, der in der Bestellung festgelegt ist. Der Bemessungsdruck ist kleiner oder gleich dem höchsten zulässigen Betriebsdruck (MAWP), (wobei der Bemessungsdruck als MAWP verwendet werden kann, wenn der MAWP nicht eigens festgelegt wurde).

### 3.26

#### **Zerstörungsgrad**

prozentualer Massenanteil des brennbaren Dampfes, der mindestens teilweise oxidiert ist

**ANMERKUNG** Bei einem Kohlenwasserstoff ist der Zerstörungsgrad der prozentuale Massenanteil an Kohlenstoff in dem Fluidampf, der zu CO oder CO<sub>2</sub> oxidiert.

### 3.27

#### **Detonation**

Explosion, bei der die Flammenfront eines brennbaren Mediums sich mit Schallgeschwindigkeit oder einer höheren Geschwindigkeit ausbreitet

vgl. **Verpuffung** (3.24)

### 3.28

#### **Dispersion**

Verdünnung eines Abzugsstroms oder von Verbrennungsprodukten bei Bewegung der Fluide durch die Atmosphäre

### 3.29

#### **Hochfackel**

Gasfackel, bei der der Brenner hoch über dem Bodenniveau angeordnet ist, um die Strahlungsintensität zu verringern und zur Dispersion beizutragen

### 3.30

#### **umschlossene Fackel**

Gehäuse mit einem oder mehreren Brenner(n), der/die so angeordnet ist/sind, dass die Flamme nicht direkt sichtbar ist

### 3.31

#### **Anreicherung**

Vorgang des Beigebens eines Hilfsgases zum Abblasegas

### 3.32

#### **Flammenrückhalteeinrichtung**

Vorrichtung zur Verhinderung des Abblasens der Flamme von einem Fackelbrenner

### 3.33

#### **Fackel**

Vorrichtung oder System zum sicheren umweltgerechten Beseitigen von Abblasegasen mittels Verbrennung

### 3.34

#### **Fackelbrenner**

##### **Fackelkopf**

Teil der Fackel, in dem Brenngas und Luft mit der zur Erreichung und Aufrechterhaltung einer angemessenen Zündung und stabilen Verbrennung erforderlichen Geschwindigkeit, Verwirbelung und Konzentration gemischt werden

### 3.35

#### **Sammelleitung der Fackel**

Rohrleitungssystem, das die Abblasegase sammelt und der Fackel zuführt

**3.36****brennstoffgesteuerter Brand**

Brand, bei dem immer mindestens genügend Luft für die Verbrennung vorhanden ist, so dass die Wärmeabgaberate von der Brennstoffmenge (d. h. der Größe des Brennstofftanks oder der Brennstoff-Leckrate) gesteuert wird

**3.37****Flammenrückschlag**

Erscheinung, die in einem brennbaren Luft-Gas-Gemisch auftritt, wenn die Strömungsgeschwindigkeit des brennbaren Gemischs örtlich geringer ist als die Flammengeschwindigkeit, wodurch die Flamme zum Mischpunkt zurückschlägt

**3.38****Bodenfackel**

nicht erhöht angeordnete Fackel

ANMERKUNG Eine Bodenfackel ist gewöhnlich eine umschlossene Fackel, kann aber auch eine offene Bodenfackel mit mehreren Brennern oder eine Brenngruben-Fackel sein.

**3.39****Wärmeabgabe**

Gesamtwärme, die durch die Verbrennung der Abblasegase aufgrund des niedrigeren Brennerts freigesetzt wird

ANMERKUNG Die Wärmeabgabe wird in kW (Btu/h) angegeben.

**3.40****Hydrat**

fester, kristalliner Verbund aus Wasser und einem Gas mit niedrigem Siedepunkt (z. B. Methan und Propan), bei dem sich das Wasser mit den Gasmolekülen zu einem Feststoff verbindet

**3.41****gezündeter Freistrah**

Brand, der entsteht, wenn eine Leckage aus einem druckbeaufschlagten System gezündet wird und einen brennenden Strahl bildet

ANMERKUNG Ein gezündeter Freistrah kann sich auf andere Ausrüstungen auswirken und zu Schäden führen.

**3.42****Abscheidebehälter**

Behälter im Abflussbehandlungssystem zur Beseitigung und Lagerung von Flüssigkeiten

**3.43****Abzweigstück**

Rohrabschnitt vom/von (den) Ausgangsflansch(en) von (einer) Entlastungseinrichtung(en) mit einer einzigen Quelle stromabwärts einer Sammelrohrverbindung, an die Entlastungseinrichtungen von anderen Quellen angeschlossen sind

ANMERKUNG Die Abblasegase in einem Abzweigstück stammen immer aus einer einzigen Quelle, während die Abblasegase in einer Sammelleitung entweder aus einer oder gleichzeitig aus mehreren Quellen stammen können.

**3.44****Hub**

tatsächliche Bewegung der Scheibe aus der geschlossenen Stellung beim Entlasten eines Ventils

**3.45****Flüssigkeitsvorlage****Tauchung**

Vorrichtung, die den Fluss von Abblasegasen auf dem Weg zum Fackelbrenner durch eine Flüssigkeit (üblicherweise Wasser) leitet und dazu dient, die Fackel-Sammelleitung vor dem Eindringen von Luft oder

einem Flammenrückschlag zu schützen, den Durchfluss umzulenken oder Gegendruck für die Fackel-Sammelleitung zu erzeugen

### 3.46

#### **Mach-Zahl**

Verhältnis der Geschwindigkeit eines Fluids, die in Bezug auf ein Hindernis oder eine geometrische Figur gemessen wird, zur Geschwindigkeit, bei der sich Schallwellen durch das Fluid fortpflanzen

### 3.47

#### **Manifold**

Rohrleitungssystem zum Sammeln und/oder Verteilen eines Fluids in oder aus mehrere(n) Durchflusswege(n)

### 3.48

#### **gekennzeichneter Berstdruck**

##### **Nennberstdruck**

⟨einer Berstscheibe⟩ Berstdruck, der durch Prüfungen für die festgelegte Temperatur ermittelt wurde und vom Hersteller auf der Berstscheibenfahne gekennzeichnet ist

ANMERKUNG Der gekennzeichnete Berstdruck kann jeder Druck innerhalb des Auslegungsbereichs sein, wenn nicht anders vom Kunden gefordert. Der gekennzeichnete Berstdruck wird auf alle Berstscheiben aus demselben Los angewendet.

### 3.49

#### **höchster zulässiger Betriebsdruck**

##### **MAWP**

höchster Manometerdruck, der an der Oberseite eines vollständigen Behälters in seiner üblichen Betriebsstellung bei der vorgesehenen zugehörigen für diesen Druck festgelegten Temperatur zulässig ist

vgl. **Bemessungsdruck** (3.25)

ANMERKUNG Der MAWP ist der kleinste der Werte für den in den Konstruktionsvorschriften des Behälters bestimmten Innen- oder Außendruck für jedes Element des Behälters auf der Grundlage der tatsächlichen Nenndicke, wobei die Dicke von zusätzlichem Metall zur Berücksichtigung von Korrosion und anderen Belastungen als Druck nicht eingerechnet ist. Der MAWP ist die Grundlage für die Druckeinstellung der Druckentlastungsventile, die den Behälter schützen.

### 3.50

#### **nicht kondensierbares Gas**

Gas oder Dampf, das/der bei der erwarteten Temperatur und dem erwarteten Druck im gasförmigen Zustand verbleibt

### 3.51

#### **offener Brand**

Brand, bei dem die Umgebung nicht zum Vorwärmen der Belüftungsluft oder zu einer Rückstrahlung beiträgt. Daher wird im Vergleich zu begrenzten Bränden mehr Wärme an die Umgebung freigesetzt

### 3.52

#### **Betriebsdruck**

Druck, dem das Prozesssystem bei üblichem Betrieb ausgesetzt ist, einschließlich der üblichen Schwankungen

### 3.53

#### **Überdruck**

⟨allgemein⟩ Zustand, in dem der MAWP oder ein anderer festgelegter Druck überschritten wird

⟨Entlastungseinrichtung⟩ Druckanstieg über den Einstelldruck einer Entlastungseinrichtung

ANMERKUNG Im letztgenannten Zusammenhang ist Überdruck dasselbe wie **Drucküberschreitung** (3.1), sofern die Entlastungseinrichtung so eingestellt ist, dass sie beim MAWP des Behälters öffnet.

**3.54****pilotgesteuertes Druckentlastungsventil**

Druckentlastungsventil, bei dem die Hauptentlastungseinrichtung oder das Hauptventil mit einem selbsttätigen Hilfs-Druckentlastungsventil (Pilotventil) kombiniert ist und von diesem gesteuert wird

**3.55****Bolzensicherung**

nicht wieder schließende Druckentlastungseinrichtung, die auf den statischen Druck anspricht und so ausgeführt ist, dass sie durch Knicken oder Brechen eines Bolzens funktioniert, der einen Kolben oder Zapfen fixiert; beim Knicken oder Brechen des Bolzens bewegt sich der Kolben oder Zapfen sofort in die vollständig geöffnete Stellung

**3.56****Lachenbrand**

brennende Flüssigkeitslache

**3.57****Druckbemessungs-Richtlinie**

Norm, nach der die Druckgeräte konstruiert und gebaut werden

BEISPIEL ASME Section VIII, Division 1 [20].

**3.58****Druckentlastungsventil**

Ventil, das so konstruiert ist, dass es öffnet und Überdruck abbaut und wieder schließt, um zu verhindern, dass nach Wiedereinstellung der üblichen Bedingungen weiterhin Fluid ausströmt

ANMERKUNG In ISO 4126-1 wird hierfür der Begriff Sicherheitsventil verwendet.

**3.59****Prozesstank****Prozessbehälter**

Tank oder Behälter für einen integrierten Prozessablauf in petrochemischen Anlagen, Raffinerien, Gaswerken, Öl- und Gasförderanlagen und weiteren Anlagen

vgl. **Lagertank** (3.76)

ANMERKUNG Ein für einen integrierten Prozessablauf verwendeter Prozesstank oder -behälter kann die Vorbereitung, Trennung, Reaktion, Überdruck-Überwachung, Mischung, Reinigung, Zustandsänderung, Änderung des Energiegehaltes oder der Zusammensetzung eines Werkstoffs umfassen, ist jedoch nicht allein darauf beschränkt.

**3.60****Spülgas**

Brenngas oder nicht kondensierbares Inertgas, das der Fackel-Sammelleitung beigegeben wird, um den Lufteintritt und Rückbrand abzuschwächen

**3.61****Abschrecken**

Kühlen eines Fluids, indem es mit einem anderen Fluid mit einer niedrigeren Temperatur gemischt wird

**3.62****Strahlungsintensität**

örtliche Wärmeübergangszahl durch Strahlung von der Fackelflamme, die gewöhnlich in Gradstufen betrachtet wird

**3.63****Nennabblaseleistung**

Abblaseleistung, die als Grundlage für die Anwendung einer Druckentlastungseinrichtung verwendet, nach der Druckbemessungsrichtlinie oder einer Rechtsvorschrift bestimmt und vom Hersteller angegeben wird

ANMERKUNG Die auf dem Gerät gekennzeichnete Leistung ist die Nennleistung für Dampf, Luft, Gas oder Wasser, wie jeweils in der zutreffenden Richtlinie gefordert.

### 3.64

#### **Abblasegas abgefackeltes Abgas Abblasdampf**

alle Gase und Dämpfe, die unmittelbar nach dem Austritt aus dem Fackelkopf vorhanden sind, ausgenommen Lufteträge, und die die Gesamtheit aller organischen Stoffe, Stickstoff und aller weiteren Gase umfassen, die dem Abgassammelsystem beigegeben wurden sowie das als zusätzliches Brenngas beigegebene Erdgas, der als Spülgas beigegebene Stickstoff, das zu den Fackel-Pilotventilen strömende Erdgas sowie der am Fackelkopf zugegebene Dampf

### 3.65

#### **Überströmventil**

federbelastetes Überdruckventil, das auf den statischen Druck stromaufwärts des Ventils anspricht, durch den das Ventil gewöhnlich proportional zum Druckanstieg über den Öffnungsdruck öffnet

ANMERKUNG Ein Überströmventil wird gewöhnlich mit nicht komprimierbaren Fluiden verwendet.

### 3.66

#### **Entlastungsbedingungen**

Eingangsdruck und Temperatur an einer Druckentlastungseinrichtung während eines Überdruckzustands

ANMERKUNG Der Abblasedruck ist gleich dem Einstelldruck des Ventils (oder Berstscheiben-Berstdruck) zuzüglich des Überdrucks. Die Temperatur des strömenden Fluids bei Entlastungsbedingungen kann höher oder niedriger als die Betriebstemperatur sein.

### 3.67

#### **Berstscheibensicherung**

eine sich nicht wieder schließende Einrichtung gegen Überdruck, die auf statischen Differenzdruck zwischen Eingang und Ausgang der Einrichtung anspricht und so ausgeführt ist, dass sie durch das Bersten einer Berstscheibe funktioniert

ANMERKUNG 1 Eine Berstscheibensicherung besteht aus einer Berstscheibe und einer Haltevorrichtung für die Berstscheibe.

ANMERKUNG 2 In ISO 4126-2 wird für diese Einrichtung der Begriff Berstscheibeneinrichtung verwendet.

### 3.68

#### **Sicherheitssystem**

##### **SIS**

##### **Notabschalteinrichtung**

##### **ESD, ESS**

##### **Hochleistungs-Schutzsystem**

##### **HIPS**

##### **Hochleistungs-Überdruckschutzsystem**

##### **HIPPS**

##### **Sicherheitsabschaltsystem**

##### **SSD**

##### **Sicherheitsverriegelungssystem**

System, das aus Sensoren, Logiksystemen und Stellgliedern besteht und dazu bestimmt ist, den Prozess bei Verletzung vorherbestimmter Bedingungen in einen sicheren Zustand zu überführen

### 3.69

#### **Stufe der Sicherheitsintegrität**

##### **SIL**

diskrete Integritätsstufe einer sicherheitsbezogenen Funktion in einem Sicherheitssystem

ANMERKUNG Die Einstufung in SIL erfolgt auf der Grundlage der Versagenswahrscheinlichkeit, siehe Anhang E.

**3.70****Sicherheitsüberströmventil**

federbelastetes Überdruckventil, das in Abhängigkeit von der Anwendung entweder als Sicherheitsventil oder als Überströmventil verwendet werden kann

**3.71****Sicherheitsventil**

federbelastetes Überdruckventil, das auf den statischen Druck stromaufwärts des Ventils anspricht und durch schnelles bzw. schlagartiges Öffnen gekennzeichnet ist

ANMERKUNG 1 Ein Sicherheitsventil wird gewöhnlich mit komprimierbaren Fluiden verwendet.

ANMERKUNG 2 Diese Definition unterscheidet sich von der Definition in ISO 4126-1; siehe 3.58.

**3.72****Einstelldruck**

Eingangs-Manometerdruck, bei dem eine Druckentlastungseinrichtung unter Betriebsbedingungen beginnt zu öffnen

**3.73****Scherstiftsicherung**

sich nicht wieder schließende Druckentlastungseinrichtung, die auf statischen Differenz- oder statischen Eingangsdruck anspricht und so ausgeführt ist, dass sie durch Abscheren eines lasttragenden Bauteils, das ein drucktragendes Bauteil stützt, funktioniert

**3.74****gestufte Fackelanlage**

Gruppe von zwei oder mehr Fackeln oder Brennern, die so gesteuert werden, dass die Anzahl der Fackeln oder Brenner, die in Betrieb sind, proportional zum Abblasegasstrom ist

**3.75****stöchiometrisches Luft-Brennstoff-Gemisch**

chemisch einwandfreies Verhältnis von Brennstoff zur Luft, wodurch eine vollkommene Verbrennung ermöglicht wird, bei der weder Brennstoff noch Luft unverbrannt zurückbleiben

**3.76****Lagertank****Lagerbehälter**

ortsfester Tank oder Behälter, der nicht Teil der Prozesseinheit in petrochemischen Anlagen, Raffinerien, Gaswerken, Öl- und Gasförderanlagen und weiteren Anlagen ist

vgl. **Prozesstank** (3.59)

ANMERKUNG Diese Tanks oder Behälter befinden sich oftmals in Tanklagern.

**3.77****Fremdegendruck**

statischer Druck, der am Ausgang der Druckentlastungseinrichtung zu dem Zeitpunkt vorhanden ist, an dem die Einrichtung zu arbeiten beginnen soll

ANMERKUNG Er ist das Ergebnis des Drucks im Ausblasesystem, der aus anderen Quellen stammt und kann konstant oder veränderlich sein.

**3.78****Dampfdruckausgleichssystem**

Schutzanordnung von Ventilen und Rohrleitungen, um eine schnelle Druckminderung in Ausrüstungen zu erreichen, indem Dämpfe freigesetzt werden

ANMERKUNG Das System kann automatisch oder von Hand betätigt werden.

**3.79**

**Geschwindigkeitssperre**

**Drosselsperre**

Trockendampf-Sperre, durch die die Menge des zum Schutz gegen das Eindringen von Luft in den Fackelbrennerausgang benötigten Spülgases gering gehalten wird

**3.80**

**Abzugsgas**

organische Stoffe, Stickstoff und weitere Gase, die aus den Prozesseinheiten strömen, der als Spülgas beigegebene Stickstoff sowie alle weiteren Gase oder Dämpfe, die der Fackelanlage vor dem Fackelkopf beigegeben werden

**3.81**

**Abzugs-Sammelleitung**

Rohrleitungssystem, in dem die Abblasegase gesammelt und zum Abluftkamin geleitet werden

**3.82**

**Abluftkamin**

erhöht angeordneter senkrechter Abschluss eines Entsorgungssystems, der Dämpfe ohne Verbrennung oder Umwandlung des entspannten Fluids in die Atmosphäre abbläst

**3.83**

**zuluftgesteuerter Brand**

Brand, bei dem es an Luft mangelt, so dass folglich die verfügbare Luft – die Zuluft – die Wärmeabgaberate steuert

**3.84**

**Behälter**

Behältnis oder Strukturhülle, in dem/der Werkstoffe verarbeitet, behandelt oder gelagert werden

BEISPIELE      Druckbehälter, Reaktorbehälter und Lagerbehälter (Tanks).

**3.85**

**Windschutz**

Vorrichtung zum Schutz der windabgewandten Seite eines Hochfackel-Brenners vor direkter Flammenbeaufschlagung

ANMERKUNG    Ein Windschutz ist außerdem auch fester Bestandteil der Konstruktion von Pilotbrennern, um das Erlöschen der Flamme bei schlechtem/stürmischem Wetter zu verhindern.

## Nationaler Anhang NB (informativ)

### Literaturhinweise

DIN EN ISO 4126-1, *Sicherheitseinrichtungen gegen unzulässigen Überdruck — Teil 1: Sicherheitsventile*

DIN EN ISO 4126-2, *Sicherheitseinrichtungen gegen unzulässigen Überdruck — Teil 2: Berstscheibeneinrichtungen*

DIN EN ISO 4126-3, *Sicherheitseinrichtungen gegen unzulässigen Überdruck — Teil 3: Sicherheitsventile und Berstscheibeneinrichtungen in Kombination*

DIN EN ISO 4126-4, *Sicherheitseinrichtungen gegen unzulässigen Überdruck — Teil 4: Pilotgesteuerte Sicherheitsventile*

DIN EN ISO 4126-5, *Sicherheitseinrichtungen gegen unzulässigen Überdruck — Teil 5: Gesteuerte Sicherheitsventile (CSPRS)*

DIN EN ISO 4126-6, *Sicherheitseinrichtungen gegen unzulässigen Überdruck — Teil 6: Berstscheibeneinrichtungen; Anwendung, Auswahl und Einbau*

DIN EN ISO 4126-7, *Sicherheitseinrichtungen gegen unzulässigen Überdruck — Teil 7: Allgemeine Daten*

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**Petroleum, petrochemical and natural gas industries —  
Pressure-relieving and depressuring systems  
(ISO/DIS 23251:2011)**

Industries du pétrole, de la pétrochimie et du gaz naturel —  
Systèmes de dépressurisation et de protection contre les  
surpressions  
(ISO/DIS 23251:2011)

Erdöl-, petrochemische und Erdgasindustrie —  
Druckentlastungs- und Druckausgleichssysteme  
(ISO/DIS 23251:2011)

This draft European Standard is submitted to CEN members for parallel enquiry. It has been drawn up by the Technical Committee CEN/TC 12.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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## Foreword

This document (prEN ISO 23251:2011) has been prepared by Technical Committee CEN/TC 12 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries” the secretariat of which is held by AFNOR.

This document is currently submitted to the parallel Enquiry.

This document will supersede EN ISO 23251:2007.

### Endorsement notice

The text of ISO/DIS 23251:2011 has been approved by CEN as a prEN ISO 23251:2011 without any modification.

## Introduction

The portions of this International Standard dealing with flares and flare systems are an adjunct to ISO 25457)<sup>[10]</sup>, which addresses mechanical design, operation and maintenance of flare equipment. It is important for all parties involved in the design and use of a flare system to have an effective means of communicating and preserving design information about the flare system. To this end, ISO and API has developed a set of flare data sheets, which can be found in ISO 25457 Annex E. The use of these data sheets is both recommended and encouraged as a concise, uniform means of recording and communicating design information.

The Bibliography lists the documents that are referenced informatively in this International Standard, as well as other documents that are not cited in this International Standard but that contain additional useful information. Some of the content of the documents listed might not be suitable for all applications and therefore needs to be assessed for each application before use.

## 1 Scope

This International Standard is applicable to pressure-relieving and vapour-depressuring systems. Although intended for use primarily in oil refineries, it is also applicable to petrochemical facilities, gas plants, liquefied natural gas (LNG) facilities and oil and gas production facilities. The information provided is designed to aid in the selection of the system that is most appropriate for the risks and circumstances involved in various installations.

This International Standard is intended to supplement the practices set forth in ISO 4126 or API RP 520-1 for establishing a basis of design.

This International Standard specifies requirements and gives guidelines for examining the principal causes of overpressure; and determining individual relieving rates; and selecting and designing disposal systems, including such component parts as piping, vessels, flares, and vent stacks. This International Standard does not apply to direct-fired steam boilers.

Piping information pertinent to pressure-relieving systems is presented in 5.5.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4126 (all parts), *Safety devices for protection against excessive pressure*

API STD 520-I:2008, *Sizing, Selection and Installation of Pressure-Relieving Devices in Refineries — Part I: Sizing and Selection*<sup>1)</sup>

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

### 3.1

#### **accumulation**

pressure increase over the maximum allowable working pressure of the vessel allowed during discharge through the pressure-relief device

NOTE Accumulation is expressed in units of pressure or as a percentage of MAWP or design pressure. Maximum allowable accumulations are established by pressure-design codes for emergency operating and fire contingencies.

### 3.2

#### **administrative controls**

procedures intended to ensure that personnel actions do not compromise the overpressure protection of the equipment

### 3.3

#### **assist gas**

fuel gas that is added to relief gas prior to the flare burner or at the point of combustion in order to raise the heating value

NOTE In some designs, the assist gas can increase turbulence for improved combustion.

---

<sup>1)</sup> American Petroleum Institute, 1220 L Street, N.W., Washington, D.C., 20005-4070, USA.

### 3.4

#### **atmospheric discharge**

release of vapours and gases from pressure-relieving and depressuring devices to the atmosphere

### 3.5

#### **availability**

fraction of time that a system (e.g. safety instrumented system, atmospheric relief system or flare relief system) is able to perform the designated service if required for use

### 3.6

#### **back pressure**

pressure that exists at the outlet of a pressure-relief device as a result of the pressure in the discharge system

NOTE The back pressure is the sum of the superimposed and built-up back pressures.

### 3.7

#### **balanced pressure-relief valve**

spring-loaded pressure-relief valve that incorporates a bellows or other means for minimizing the effect of back pressure on the operational characteristics of the valve

### 3.8

#### **blowdown drum**

knockout drum with or connected to a stack open to atmosphere

NOTE 1 The term blowdown drum is sometimes also used for knockout drums connected to flare or other disposal systems, but it is not used in this context in this International Standard.

NOTE 2 The term blowdown is sometimes used in the context of emergency depressuring of a plant or part of a plant, but it is not used in this context in this International Standard.

### 3.9

#### **blow-off**

loss of a stable flame where the flame is lifted above the burner, occurring if the fuel velocity exceeds the flame velocity

### 3.10

#### **breaking-pin device**

pressure-relief device actuated by static differential or static inlet pressure and designed to function by the breakage of a load-carrying section of a pin that supports a pressure-containing member

### 3.11

#### **buckling pin device**

pressure-relief device actuated by static differential or static inlet pressure and designed to function by the buckling of an axially-loaded compressive pin that supports a pressure-containing member

### 3.12

#### **built-up back pressure**

increase in pressure at the outlet of a pressure-relief device that develops as a result of flow after the pressure-relief device opens

### 3.13

#### **buoyancy seal**

dry vapour seal that minimizes the amount of purge gas needed to protect against air infiltration

NOTE The buoyancy seal functions by trapping a volume of light gas in an internal inverted compartment; this prevents air from displacing buoyant light gas in the flare.

### 3.14

#### **burnback**

internal burning within the flare tip

NOTE Burnback can result from air backing down the flare burner at purge or low flaring rates.

### 3.15

#### **burning velocity**

#### **flame velocity**

speed at which a flame front travels into an unburned combustible mixture

### 3.16

#### **burn-pit flare**

open excavation, normally equipped with a horizontal flare burner that can handle liquid as well as vapour hydrocarbons

### 3.17

#### **burst pressure**

value of the upstream static pressure minus the value of the downstream static pressure just before a rupture disk bursts

NOTE If the downstream pressure is atmospheric, the burst pressure is the upstream static gauge pressure.

### 3.18

#### **closed disposal system**

disposal system capable of containing pressures that are different from atmospheric pressure

### 3.19

#### **cold differential test pressure**

#### **CDTP**

pressure at which a pressure-relief valve is adjusted to open on the test stand

NOTE The cold differential test pressure includes corrections for the service conditions of back pressure or temperature or both.

### 3.20

#### **combustion air**

air required to combust the flare gases

### 3.21

#### **confined fire**

fire inside a building or a compact process module where the walls and/or surrounding equipment can re-radiate and preheat the combustion air causing higher heat fluxes than an unconfined (i.e., open) fire

### 3.22

#### **conventional pressure-relief valve**

spring-loaded pressure-relief valve whose operational characteristics are directly affected by changes in the back pressure

### 3.23

#### **corrected hydrotest pressure**

hydrostatic test pressure multiplied by the ratio of stress value at upset temperature to the stress value at test temperature

NOTE 1 See 4.2.2.

NOTE 2 In this definition, the hydrostatic test pressure is that specified by the pressure design code, whether or not the equipment has actually been hydrostatically tested.

### 3.24

#### **deflagration**

explosion in which the flame-front of a combustible medium is advancing at less than the speed of sound

cf. **detonation** (3.27)

### 3.25

#### **design pressure**

pressure, together with the design temperature, used to determine the minimum permissible thickness or physical characteristic of each component, as determined by the design rules of the pressure-design code

NOTE The design pressure is selected by the user to provide a suitable margin above the most severe pressure expected during normal operation at a coincident temperature, and it is the pressure specified on the purchase order. The design pressure is equal to or less than the MAWP (the design pressure can be used as the MAWP in cases where the MAWP has not been established).

### 3.26

#### **destruction efficiency**

mass percent of the combustible vapour that is at least partially oxidized

NOTE In the case of a hydrocarbon, destruction efficiency is the mass percentage of carbon in the fluid vapour that oxidizes to CO or CO<sub>2</sub>.

### 3.27

#### **detonation**

explosion in which the flame-front of a combustible medium is advancing at or above the speed of sound

cf. **deflagration** (3.24)

### 3.28

#### **dispersion**

dilution of a vent stream or products of combustion as the fluids move through the atmosphere

### 3.29

#### **elevated flare**

flare where the burner is raised high above ground level to reduce radiation intensity and to aid in dispersion

### 3.30

#### **enclosed flare**

enclosure with one or more burners arranged in such a manner that the flame is not directly visible

### 3.31

#### **enrichment**

process of adding assist gas to the relief gas

### 3.32

#### **flame-retention device**

device used to prevent flame blow off from a flare burner

### 3.33

#### **flare**

device or system used to safely dispose of relief gases in an environmentally compliant manner through the use of combustion

### 3.34

#### **flare burner**

##### **flare tip**

part of the flare where fuel and air are mixed at the velocities, turbulence and concentration required to establish and maintain proper ignition and stable combustion

### 3.35

#### **flare header**

piping system that collects and delivers the relief gases to the flare

**3.36**

**fuel-controlled fire**

fire that always has at least enough air for combustion so the amount of fuel (i.e., the size of the pool or the fuel leak rate) controls the heat release rate

**flashback**

phenomenon occurring in a flammable mixture of air and gas when the local velocity of the combustible mixture becomes less than the flame velocity, causing the flame to travel back to the point of mixture

**3.38**

**ground flare**

non-elevated flare

NOTE A ground flare is normally an enclosed flare but can also be a ground multi-burner flare or a burnpit.

**3.39**

**heat release**

total heat liberated by combustion of the relief gases based on the lower heating value

NOTE The heat release is expressed in kW (Btu/h).

**3.40**

**hydrate**

solid, crystalline compound of water and a low-boiling-point gas (e.g. methane and propane), in which the water combines with the gas molecule to form a solid

**3.41**

**jet fire**

fire created when a leak from a pressurized system ignites and forms a burning jet

NOTE A jet fire can impinge on other equipment, causing damage.

**3.42**

**knockout drum**

vessel in the effluent handling system designed to remove and store liquids

**3.43**

**lateral**

section of pipe from outlet flange(s) of single-source relief device(s) downstream of a header connection where relief devices from other sources are tied in

NOTE The relief flow in a lateral is always from a single source, whereas the relief flow in a header can be from either single or multiple sources simultaneously.

**3.44**

**lift**

actual travel of the disc from the closed position when a valve is relieving

**3.45**

**liquid seal**

**water seal**

device that directs the flow of relief gases through a liquid (normally water) on the path to the flare burner, used to protect the flare header from air infiltration or flashback, to divert flow, or to create back pressure for the flare header

**3.46**

**Mach number**

ratio of a fluid's velocity, measured relative to some obstacle or geometric figure, divided by the speed at which sound waves propagate through the fluid

### 3.47

#### **manifold**

piping system for the collection and/or distribution of a fluid to or from multiple flow paths

### 3.48

#### **marked burst pressure**

#### **rated burst pressure**

⟨rupture disk⟩ burst pressure, established by tests for the specified temperature and marked on the disk tag by the manufacturer

NOTE The marked burst pressure can be any pressure within the manufacturing design range unless otherwise specified by the customer. The marked burst pressure is applied to all of the rupture disks of the same lot.

### 3.49

#### **maximum allowable working pressure**

#### **MAWP**

maximum gauge pressure permissible at the top of a completed vessel in its normal operating position at the designated coincident temperature specified for that pressure

cf. **design pressure** (3.25)

NOTE The MAWP is the least of the values for the internal or external pressure as determined by the vessel design rules for each element of the vessel using actual nominal thickness, exclusive of additional metal thickness allowed for corrosion and loadings other than pressure. The MAWP is the basis for the pressure setting of the pressure-relief devices that protect the vessel.

### 3.50

#### **non-condensable gas**

gas or vapour that remains in the gaseous state at the temperature and pressure expected

### 3.51

#### **open fire**

fire for which the surroundings do not contribute to preheating the ventilation air or reradiation. More heat will be lost to the surroundings as compared with confined fires

### 3.52

#### **operating pressure**

pressure the process system experiences during normal operation, including normal variations

### 3.53

#### **overpressure**

⟨general⟩ condition where the MAWP, or other specified pressure, is exceeded

⟨relieving device⟩ pressure increase over the set pressure of a relieving device

NOTE In the latter context, overpressure is the same as **accumulation** (3.1) only when the relieving device is set to open at the MAWP of the vessel.

### 3.54

#### **pilot-operated pressure-relief valve**

pressure-relief valve in which the major relieving device or main valve is combined with and controlled by a self-actuated auxiliary pressure-relief valve (pilot)

### 3.55

#### **pin device**

non-reclosing pressure-relief device actuated by static pressure and designed to function by buckling or breaking a pin that holds a piston or a plug in place; upon buckling or breaking of the pin, the piston or plug instantly moves to the fully open position

**3.56**

**pool fire**

burning pool of liquid

**3.57**

**pressure-design code**

standard to which the equipment is designed and constructed

EXAMPLE ASME Section VIII, Division 1 [20].

**3.58**

**pressure-relief valve**

valve designed to open and relieve excess pressure and to reclose and prevent the further flow of fluid after normal conditions have been restored

NOTE In ISO 4126-1, this is termed a safety valve.

**3.59**

**process tank**

**process vessel**

tank or vessel used for an integrated operation in petrochemical facilities, refineries, gas plants, oil and gas production facilities, and other facilities

cf. **storage tank** (3.76)

NOTE A process tank or vessel used for an integrated operation can involve, but is not limited to, preparation, separation, reaction, surge control, blending, purification, change in state, energy content, or composition of a material.

**3.60**

**purge gas**

fuel gas or non-condensable inert gas added to the flare header to mitigate air ingress and burnback

**3.61**

**quenching**

cooling of a fluid by mixing it with another fluid of a lower temperature

**3.62**

**radiation intensity**

local radiant heat transfer rate from the flare flame, usually considered at grade level

**3.63**

**rated relieving capacity**

relieving capacity used as the basis for the application of a pressure-relief device, determined in accordance with the pressure-design code or regulation and supplied by the manufacturer

NOTE The capacity marked on the device is the rated capacity on steam, air, gas or water as required by the applicable code.

**3.64**

**relief gas**

**flared gaswaste gas**

**waste vapour**

all gases and vapors present just after the exit from the flare tip, not including entrained air, and consisting of the sum of organic material, nitrogen and any other gases added to the vent gas collection system, natural gas added as supplemental fuel, nitrogen added as purge gas, natural gas flowing to the flare pilots, and steam added at the flare tip

**3.65**

**relief valve**

spring-loaded pressure-relief valve actuated by the static pressure upstream of the valve, due to which the valve normally opens in proportion to the pressure increase over the opening pressure

NOTE A relief valve is normally used with incompressible fluids.

### 3.66

#### **relieving conditions**

inlet pressure and temperature on a pressure-relief device during an overpressure condition

NOTE The relieving pressure is equal to the valve set pressure (or rupture disk burst pressure) plus the overpressure. The temperature of the flowing fluid at relieving conditions can be higher or lower than the operating temperature.

### 3.67

#### **rupture-disk device**

non-reclosing pressure-relief device actuated by static differential pressure between the inlet and outlet of the device and designed to function by the bursting of a rupture disk

NOTE 1 A rupture disk device includes a rupture disk and a rupture disk holder.

NOTE 2 In ISO 4126-2, this is termed a bursting-disc safety device.

### 3.68

#### **safety instrumented system**

##### **SIS**

##### **emergency shutdown system**

##### **ESD, ESS**

##### **high-integrity protection system**

##### **HIPS**

##### **high-integrity pressure-protection system**

##### **HIPPS**

##### **safety-shutdown system**

##### **SSD**

##### **safety-interlock system**

system composed of sensors, logic solvers and final control elements for the purpose of taking the process to a safe state when predetermined conditions are violated

### 3.69

#### **safety-integrity level**

##### **SIL**

discrete integrity level of a safety instrumented function in a safety instrumented system

NOTE SILs are categorized in terms of probability of failure; see Annex E.

### 3.70

#### **safety relief valve**

spring-loaded pressure-relief valve that can be used as either a safety valve or a relief valve depending on the application

### 3.71

#### **safety valve**

spring-loaded pressure-relief valve actuated by the static pressure upstream of the valve and characterized by rapid opening or pop action

NOTE 1 A safety valve is normally used with compressible fluids.

NOTE 2 This definition is different than that in ISO 4126-1; see 3.58.

### 3.72

#### **set pressure**

inlet gauge pressure at which a pressure-relief device is set to open under service conditions

**3.73**

**shear pin device**

non-reclosing pressure-relief device actuated by static differential or static inlet pressure and designed to function by the shearing of a load-carrying member that supports a pressure-containing member

**3.74**

**staged flare**

group of two or more flares or burners that are controlled so that the number of flares or burners in operation is proportional to the relief gas flow

**3.75**

**stoichiometric air**

chemically correct ratio of fuel to air capable of perfect combustion with no unused fuel or air

**3.76**

**storage tank**

**storage vessel**

fixed tank or vessel that is not part of the processing unit in petrochemical facilities, refineries, gas plants, oil and gas production facilities, and other facilities

cf. **process tank** (3.59)

NOTE These tanks or vessels are often located in tank farms.

**3.77**

**superimposed back pressure**

static pressure that exists at the outlet of a pressure-relief device at the time the device is required to operate

NOTE It is the result of pressure in the discharge system coming from other sources and can be constant or variable.

**3.78**

**vapour depressuring system**

protective arrangement of valves and piping intended to provide for rapid reduction of pressure in equipment by releasing vapours

NOTE The actuation of the system can be automatic or manual.

**3.79**

**velocity seal**

orifice seal dry vapour seal that minimizes the required purge gas needed to protect against air infiltration into the flare burner exit

**3.80**

**vent gas**

organic materials, nitrogen and any other gases that flow from process units, nitrogen added as purge gas, and any other gases or vapors added to the flare system prior to the flare tip

**3.81**

**vent header**

piping system that collects and delivers the relief gases to the vent stack

**3.82**

**vent stack**

elevated vertical termination of a disposal system that discharges vapours into the atmosphere without combustion or conversion of the relieved fluid

**3.83**

**ventilation-controlled fire**

fire that is in shortage of air; hence the available air - the ventilation - controls the heat release rate

**3.84**  
**vessel**

container or structural envelope in which materials are processed, treated or stored

EXAMPLES      Pressure vessels, reactor vessels and storage vessels (tanks).

**3.85**  
**windshield**

device used to protect the down-wind side of an elevated flare burner from direct flame impingement

NOTE      Windshields are also integral to the design of pilots to avoid flame-outs during bad/stormy weather.

## **4 Causes of overpressure and their relieving rates**

### **4.1 General**

Pressure vessels, heat exchangers, operating equipment and piping are designed to contain the system pressure. The design is based on

- a) the normal operating pressure at operating temperatures;
- b) the effect of any combination of process upsets that are likely to occur;
- c) the differential between the operating, and set pressures of the pressure-relieving device;
- d) the effect of any combination of supplemental loadings such as earthquake and wind.

Clause 4 discusses the principal causes of overpressure where the MAWP, design pressure, or other specified pressure can be exceeded. Guidance in plant design to minimize the effects of these overpressure causes and guidance on estimating relieving rates is provided. Overpressure is the result of an unbalance or disruption of the normal flows of material and energy that causes the 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.

The principal causes of overpressure listed in 4.4.2 through 4.4.16 are guides to generally accepted practices. The process-systems designer shall define the minimum pressure-relief capacity required to prevent the pressure in any piece of equipment from exceeding the maximum allowable accumulated pressure. Annex B provides guidance on the use of a common relief device to protect multiple pieces of equipment from overpressure.

The application of the principles outlined in Clause 4 is unique for each processing system. Although efforts have been made to cover all major circumstances, the user is cautioned not to consider the conditions described as the only causes of overpressure. The treatment of overpressure in this International Standard can be only suggestive. Any circumstance that reasonably constitutes a hazard under the prevailing conditions for a system should be considered in the design. Pressure-relieving devices are installed to ensure that a process system or any of its components is not subjected to pressures that exceed the maximum allowable accumulated pressure. The practices evaluated in Clause 4 should be used in conjunction with sound engineering judgment and with full consideration of federal, state and local rules and regulations.

### **4.2 Overpressure protection philosophy**

#### **4.2.1 Hierarchy of protective measures**

A hierarchy of measures should be used to ensure that equipment is not subject to excess pressure. Such a hierarchy involves firstly avoiding or reducing risks, then providing engineering controls and lastly providing administrative controls. Avoiding risks includes, for example, setting the maximum allowable working pressure of the equipment above the maximum pressure of all possible sources. Engineering controls include providing pressure relief on the vessel. Administrative controls include provision of block valves of the locked-open

design. The user is cautioned that some systems may have unacceptable risk due to failure of administrative controls and resulting consequences due to loss of containment.

#### 4.2.2 Test pressure

Certain pressure design codes allow the use of administrative controls if the potential overpressure does not exceed the corrected hydrotest pressure, whereas other pressure design codes do not address this subject. Therefore, applying this for equipment built to pressure design codes that do not address the issue could cause the equipment to be overstressed. In these cases, the user should perform mechanical analyses and/or risk analyses. This philosophy is applied to the following scenarios:

- a) Closed outlets on vessels – see 4.4.2
- b) Check-valve leakage or failure – see 4.4.9.3
- c) Inadvertent valve opening – see 4.4.9.2
- d) Heat-transfer equipment failure – see 4.4.14

The user is cautioned that some systems can have unacceptable risk due to failure of administrative controls and resulting consequences due to loss of containment. In these cases, limiting the overpressure to the normally allowable overpressure can be more appropriate. Note that the entire system, including all of the auxiliary devices (e.g. gasketed joints, instrumentation), should be considered for the overpressure during the failure of administrative controls.

The corrected test pressure is explained as follows. For example, an ASTM A 515 [22] Grade 70 carbon steel vessel with a design gauge pressure of 517 kPa (75 psi) and design temperature of 343 °C (650 °F) has an allowable stress of 130 MPa (18 800 psi) at these design conditions. Because the hydrostatic test is often performed at a temperature less than design temperature, the hydrostatic test pressure should be specified to account for the allowable stress differences at the two temperatures by multiplying the design pressure by the ratio of stress at test temperature to the stress at design temperature. At ambient temperature, the allowable stress of ASTM A 515 Grade 70 carbon steel is 138 MPa (20 000 psi). If the pressure-design code requires the hydrostatic test be performed at 130 % of the design pressure, then the hydrostatic test pressure is as follows:

In SI units:

$$517 \times (138/130) \times 1,3 = 713 \text{ kPa (gauge)}$$

In USC units:

$$75 \times (20/18,8) \times 1,3 = 103,7 \text{ psig}$$

The uncorrected hydrotest gauge pressure is  $517 \times 1,3 \times 672 \text{ kPa}$  ( $75 \times 1,3 \times 97,5 \text{ psi}$ ). In this example, reliance on administrative controls as the sole means of overpressure protection might not be appropriate if the gauge pressure caused by closure of the outlet valve exceeds 672 kPa (97,5 psi). This assumes the overpressure occurs while the vessel is at design temperature. Within stage 1 and stage 2 creep, short-duration pressure exceedances up to 1,5 times the design pressure at design temperature should not result in damage, provided that there is no significant coincident temperature increase. This is based on allowable values in the creep regime being based on 100 000 h design.

#### 4.2.3 Double jeopardy

The causes of overpressure are considered to be unrelated if no process or mechanical or electrical linkages exist among them, or if the length of time that elapses between possible successive occurrences of these causes is sufficient to make their classification unrelated. The simultaneous occurrence of two or more unrelated causes of overpressure (also known as double or multiple jeopardy) is not a basis for design. Examples of double-jeopardy scenarios are fire exposure simultaneous with exchanger internal tube failure, fire exposure simultaneous with failure of administrative controls to drain and depressure isolated equipment, or operator error that leads to a blocked outlet coincident with a power failure. On the other hand, instrument

air failure during fire exposure may be considered single jeopardy if the fire exposure causes local air line failures.

This International Standard describes single-jeopardy scenarios that should be considered as a basis for design. The user may choose to go beyond these practices and assess multiple jeopardy scenarios. Since such assessments are outside the basis for design, the user is not required to meet accumulations allowed by the pressure-design code for these scenarios. Acceptance criteria are the sole responsibility of the user.

#### 4.2.4 Latent failures

Latent failures should normally be considered as an existing condition and not as a cause of overpressure when assessing whether a scenario is single or double jeopardy. For example, latent failures can exist in instrumentation that prevents it from functioning favourably during an overpressure condition. It is not double jeopardy to assume the absence of beneficial instrumentation response in combination with an unrelated overpressure cause. Likewise, it is not double jeopardy to assume a latent failure of a check valve allowing reverse flow during a pump failure.

#### 4.2.5 Operator error / Effect of operator response

Operator error is considered a potential source of overpressure.

The decision to take credit for operator response in determining maximum relieving conditions requires consideration of those who are responsible for operation and an understanding of the consequences of an incorrect action. A commonly accepted time range for the response is between 10 min and 30 min, depending on the complexity of the plant. The effectiveness of this response depends on the process dynamics.

#### 4.2.6 Role of instrumentation in overpressure protection

Fail-safe devices, automatic start-up equipment and other conventional instrumentation should not be a substitute for properly sized pressure-relieving devices as protection against single-jeopardy overpressure scenarios. There can be circumstances, however, where the use of pressure-relief devices is impractical and reliance on instrumented safeguards is needed. Where this is the case, if permitted by local regulations, a pressure-relieving device might not be required.

NOTE See ASME Code Case 2211 <sup>[129]</sup>.

The design shall comply with the local regulations and the owner's risk tolerance criteria, whichever is more restrictive. If these risk tolerance criteria are not available, then, as a minimum, the overall system performance including instrumented safeguards should provide safety-integrity-level 3 (SIL-3) performance. Guidance on the application of safety instrumented systems is given in Annex E.

Although favourable response of conventional instrumentation should not be assumed when sizing individual process-equipment pressure relief, in the design of some components of a relieving system, such as the collection header, flare, and flare tip, favourable response of some instrument systems can be assumed. The decision to base the design of such systems on excluded or reduced specific loads due to the favourable response of instrument systems should consider the number and reliability of applicable instrument systems. See Clause 5 for more details on sizing disposal systems.

Some pipeline design codes (i.e., Gas Transmission and Distribution Systems, ASME B31.8) permit the use of a pressure limiting station to protect gas transmission lines, in lieu of, or in addition to, a pressure relief device. A pressure limiting station is defined as "equipment that under abnormal conditions acts to reduce, restrict, or shutoff the supply of gas flowing into a system to prevent the gas pressure from exceeding a predetermined value". The design options for these pressure limiting stations are prescribed by ASME B31.8 and typically include a combination of multiple pressure regulators in addition to a shutdown valve.

### 4.3 Determination of individual relieving rates

#### 4.3.1 General philosophy

The basis for determining individual relieving rates that result from various causes of overpressure is presented in the form of general considerations and specific guidelines. Good engineering judgment, rather than blind adherence to these guidelines, should be followed in each case. The results achieved should be economically, operationally and mechanically feasible, but in no instance should the safety of a plant or its personnel be compromised.

The liquid or vapour rates used to establish relief requirements are developed by the net energy input. The two most common forms of energy are (a) heat input, which increases pressure through vaporization or thermal expansion, and (b) direct pressure input from higher pressure sources. Overpressure can result from one or both of these sources.

The peak individual relieving rate is the maximum rate at which the pressure shall be reduced to protect equipment against overpressure due to any single cause. The probability of two unrelated failures occurring simultaneously is remote and normally does not need to be considered.

#### 4.3.2 Effects of pressure, temperature, and composition

Pressure and temperature should be considered to determine individual relieving rates, since they affect the volumetric and compositional behaviour of liquids and vapours. Vapour is generated when heat is added to a liquid. The rate at which vapour is generated changes with equilibrium conditions because of the increased pressure in a confined space and the heat content of streams that continue to flow into and out of the equipment. In many instances, a volume of liquid can be a mixture of components with different boiling points. Heat introduced into fluids that do not reach their critical temperature under pressure-relieving conditions produces a vapour that is rich in low-boiling components. As heat input is continued, successively heavier components are generated in the vapour. Finally, if the heat input is sufficient, the heaviest components are vaporized.

During pressure-relieving, the changes in vapour rates and relative molecular masses at various time intervals should be investigated to determine the peak relieving rate and the composition of the vapour. The composition of inflowing streams can also be affected by variations in time intervals and, therefore, requires study.

Relieving pressure can sometimes exceed the critical pressure (or pseudo-critical pressure) of the components in the system. In such cases, reference shall be made to compressibility correlations to compute the density — temperature — enthalpy relationships for the system fluid. If the overpressure is the result of an inflow of excess material, then the excess mass quantity shall be relieved at a temperature determined by equating the incoming enthalpy with the outgoing enthalpy.

In a system that has no other inflow or outflow, if the overpressure is the result of an extraneous excess heat input, the quantity to be relieved is the difference between the initial contents and the calculated remaining contents at any later time. The cumulative extraneous enthalpy input is equal to the total gain in enthalpy by the original contents, whether they remain in the container or are vented. By calculating or plotting the cumulative vent quantity versus time, the maximum instantaneous relieving rate can be determined. This maximum usually occurs near the critical temperature. In such cases, the assumption of an ideal gas can be too conservative, and Equation (8) (see 4.4.13.2.3) oversizes the pressure-relief valve. This equation should be used only when physical properties for the fluid are not available.

### 4.3.3 Dynamic simulation

Dynamic simulation can be used in pressure-relief system design to calculate transient pressure increases as indicated in 4.4.14 or to calculate required relief rates from individual pressure-relief devices. Conventional methods for calculating relief loads are generally conservative and can lead to overly sized relief- and flare-system designs. Dynamic simulation provides an alternative method to better define the relief load and improves the understanding of what happens during relief.

Dynamic simulation is particularly useful in analysing existing flare systems (see 5.3.4.2). A dynamic simulation of a single system is discussed below.

Dynamic simulation is an alternative calculation method for determining the relief requirements for an individual column. Dynamic simulation can be applied wherever conventional methods can be applied. Column-relief-load calculations using dynamic simulation shall follow the same rules set elsewhere in this International Standard for performing relief-load calculations using conventional calculation methods. It can be necessary to perform sensitivity analyses with respect to control response in order to identify appropriate control response. In general, no credit is taken for automatic control action unless it tends to increase the relief load.

If dynamic simulation is used for column-relief-system design, it is necessary to ensure that the model is conservative with respect to calculating the maximum relief load. If the physical phenomena are not well understood, the dynamic simulation model shall include conservative assumptions. These assumptions shall be checked by sensitivity analyses to assess their impact on the column-relief load. For example, several simulation runs can be required to determine the affect of different froth correlations on the tray liquid hold-up and resulting relief load. Additionally, it can be advisable to have operating personnel review the appropriate aspects of the model. The user of the dynamic-simulation program should be aware of the underlying assumptions that are built into the dynamic simulation software code and how they affect the results. The user should not use a dynamic simulation developed for another purpose, i.e., operator training, and assume that this model gives accurate relief loads without a detailed review of the modelling assumptions.

At steady-state conditions, the dynamic model shall closely match the steady-state model. The model shall reflect current or expected operation. An adequate level of detail is required to assure accurate predictions of peak relief loads. The model shall incorporate physical features of the system (e.g. liquid inventories of vessels and piping). Sensitivity analyses should be performed for the full range of operating conditions (e.g. variable compositions and turndown rates). For example, the differences in tray-draining mechanisms between valve and sieve trays can have a significant impact on the calculated relief load for some columns. An accurate estimate of tray inventories can also be important where column light-ends inventory can impact the peak relief load.

If dynamic simulation is used, sensitivity analyses shall be performed to assess factors such as the effect of pressure-relief devices with excess capacity, the action of automatic controls, controller tuning, heat integration with other columns and operator intervention. These factors increase the number of run permutations that shall be performed.

## 4.4 Individual overpressure causes and their relieving rates

### 4.4.1 General

Table 1 lists some common occurrences that can require overpressure protection. This table is not intended to be all-inclusive or complete in suggesting maximum required relieving rates; it is merely recommended as a guide. A more descriptive analysis is provided in the remainder of 4.4.

### 4.4.2 Closed outlets

#### 4.4.2.1 Description of a closed outlet

If designing the vessel to the maximum source pressure is practicable then closure of an outlet block valve will not result in overpressure so a pressure relief device is not required for the closed outlet scenario. Every valve should be considered as being subject to inadvertent operation. In general, the elimination of block valves and the omission of block valves interposed in vessels in a series can simplify pressure relieving requirements. If the pressure resulting from the failure of administrative controls can exceed the corrected hydrotest pressure (see 3.23 and 4.2.2), reliance on administrative controls as the sole means to prevent overpressure for this scenario is not appropriate and risk avoidance/reduction should be considered. Note that the entire system including all of the auxiliary devices (e.g. gasketed joints, instrumentation) should be considered for the overpressure during the failure of administrative controls.

The inadvertent closure of a manual block valve on the outlet of a pressure vessel while the equipment is on stream can expose the vessel to a pressure that exceeds the maximum allowable working pressure. If closure of an outlet-block valve can result in accumulation in excess of that allowed by the design code, a pressure-relief device is required. Every valve should be considered as being subject to inadvertent operation. In general, the omission of block valves interposed in vessels in a series can simplify pressure-relieving requirements.

Similarly, the inadvertent closure of a remotely operated valve on the outlet of a pressure vessel while the equipment is on stream can expose the vessel to a pressure that exceeds the maximum allowable working pressure. If closure of a remotely operated outlet valve can result in overpressure, a pressure-relief device is required. Every control valve should be considered as being subject to inadvertent operation.

#### 4.4.2.2 Additional considerations involving pumps

The closed outlet scenario does not need to be considered in pressure relief design if the pump, piping and other equipment downstream of a centrifugal pump (which can be exposed to the shut-in pressure of the pump, e.g. closed block valve in the discharge system) are designed to withstand the maximum shut-in pressure of the pump.

For positive displacement pumps, pressure relief protection is usually required to protect the pump itself and downstream equipment against shut-in conditions.

#### 4.4.2.3 Additional considerations involving reciprocating compressors

Even where there are no block valves between stages, inter-stage pressure relief device(s) might be required to prevent overpressure in the event of loss of inter-stage cooling. A remote, but possible, contingency, however, would be internal failure of one of the downstream stages. Loss of downstream stage compression would essentially shift all of the gas compression work to the previous stage. A pressure relief device sized for the blocked outlet flow conditions at the inter-stage design pressure is required to prevent overpressure.

Table 1 — Guidance for required relieving rates under selected conditions

| Item No. | Condition                                                                                 | Clause   | Liquid-relief guidance <sup>a</sup>                                             | Vapour-relief guidance <sup>a</sup>                                                                                                                                                   |
|----------|-------------------------------------------------------------------------------------------|----------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1        | Closed outlets                                                                            | 4.4.2    | Maximum liquid pump-in rate                                                     | Total incoming steam and vapour plus that generated therein at relieving conditions                                                                                                   |
| 2        | Cooling-water failure to condenser                                                        | 4.4.3    | —                                                                               | Total vapour to condenser at relieving conditions                                                                                                                                     |
| 3        | Top-tower reflux failure                                                                  | 4.4.3    | —                                                                               | Total incoming steam and vapour plus that generated therein at relieving conditions less vapour condensed by sidestream reflux                                                        |
| 4        | Sidestream reflux failure                                                                 | 4.4.3    | —                                                                               | Difference between vapour entering and leaving equipment at relieving conditions                                                                                                      |
| 5        | Lean-oil failure to absorber                                                              | 4.4.4    | —                                                                               | None, normally                                                                                                                                                                        |
| 6        | Accumulation of non-condensables                                                          | 4.4.5    | —                                                                               | Same effect in towers as found for Item 2; in other vessels, same effect as found for Item 1                                                                                          |
| 7        | Entrance of highly volatile material                                                      | 4.4.6    | —                                                                               | —                                                                                                                                                                                     |
|          | a) Water into hot oil                                                                     | 4.4.6.1  | —                                                                               | For towers, usually not predictable                                                                                                                                                   |
|          | b) Light hydrocarbons into hot oil                                                        | 4.4.6.2  | —                                                                               | For heat exchangers, assume an area twice the internal cross-sectional area of one tube to provide for the vapour generated by the entrance of the volatile fluid due to tube rupture |
| 8        | Overfilling storage or surge vessel                                                       | 4.4.7    | Maximum liquid pump-in rate                                                     | —                                                                                                                                                                                     |
| 9        | Failure of automatic controls                                                             | 4.4.8    | —                                                                               | Analyse on a case-by-case basis                                                                                                                                                       |
|          | a) Inlet control devices and bypasses                                                     | 4.4.8.3  |                                                                                 |                                                                                                                                                                                       |
|          | b) Outlet control devices                                                                 | 4.4.8.4  |                                                                                 |                                                                                                                                                                                       |
|          | c) Fail-stationary valves                                                                 | 4.4.8.5  |                                                                                 |                                                                                                                                                                                       |
|          | d) Choke valves                                                                           | 4.4.8.6  |                                                                                 |                                                                                                                                                                                       |
| 10       | Abnormal process heat or vapour input                                                     | 4.4.9    | —                                                                               |                                                                                                                                                                                       |
|          | a) Abnormal process heat input                                                            | 4.4.9.1  |                                                                                 | Estimated maximum vapour generation including non-condensables from overheating                                                                                                       |
|          | b) Inadvertent valve opening                                                              | 4.4.9.2  |                                                                                 |                                                                                                                                                                                       |
|          | c) Check valve failure                                                                    | 4.4.9.3  |                                                                                 |                                                                                                                                                                                       |
| 11       | Internal explosions or transient pressure surges (e.g. water, steam or condensate hammer) | 4.4.10   | Not controlled by conventional relief devices but by avoidance of circumstances | Not controlled by conventional relief devices but by avoidance of circumstances                                                                                                       |
| 12       | Chemical reaction                                                                         | 4.4.11   | —                                                                               | Estimated vapour generation from both normal and uncontrolled conditions; consider two-phase effects                                                                                  |
| 13       | Hydraulic expansion:                                                                      | 4.4.12   |                                                                                 |                                                                                                                                                                                       |
|          | Cold-fluid shut in                                                                        |          | See 4.4.12                                                                      | —                                                                                                                                                                                     |
|          | Lines outside process area shut in                                                        |          | See 4.4.12                                                                      | —                                                                                                                                                                                     |
| 14       | Exterior fire <sup>b</sup>                                                                | 4.4.13   |                                                                                 |                                                                                                                                                                                       |
|          | Open pool fire                                                                            | 4.4.13.2 | See 4.4.13.2.4                                                                  | Estimated by the methods given in 4.4.13.2 or Annex A                                                                                                                                 |
|          | Confined pool fire                                                                        | 4.4.13.3 |                                                                                 |                                                                                                                                                                                       |
|          | Jet fire                                                                                  | 4.4.13.4 |                                                                                 |                                                                                                                                                                                       |
| 15       | Heat-transfer equipment failure                                                           | 4.4.14   |                                                                                 |                                                                                                                                                                                       |

| Item No.                                                                                                                                            | Condition                                 | Clause   | Liquid-relief guidance <sup>a</sup>                             | Vapour-relief guidance <sup>a</sup>                                                                                                  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|----------|-----------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                     | Split exchanger tube                      | 4.4.14.2 | Liquid entering from twice the cross-sectional area of one tube | Steam or vapour entering from twice the cross-sectional area of one tube; also same effects found in Item 7 for exchangers           |
|                                                                                                                                                     | Double-pipe                               | 4.4.14.3 |                                                                 |                                                                                                                                      |
|                                                                                                                                                     | Plate-and-frame                           | 4.4.14.4 |                                                                 |                                                                                                                                      |
| 16                                                                                                                                                  | Power failure (steam, electric, or other) | 4.4.15   | —                                                               | Study the installation to determine the effect of power failure; size the relief valve for the worst condition that can occur        |
|                                                                                                                                                     | Fractionators                             |          | —                                                               | Loss of all pumps, with the result that reflux and cooling water would fail                                                          |
|                                                                                                                                                     | Reactors                                  |          | —                                                               | Consider failure of agitation or stirring, quench or retarding stream; size the valves for vapour generation from a runaway reaction |
|                                                                                                                                                     | Air-cooled exchangers                     |          | —                                                               | Fan failure; size valves for the difference between normal and emergency duty                                                        |
|                                                                                                                                                     | Surge vessels                             |          | —                                                               | Maximum liquid inlet rate                                                                                                            |
| 17                                                                                                                                                  | Maintenance                               | 4.4.16   | —                                                               | —                                                                                                                                    |
| <sup>a</sup> Consideration can be given to the reduction of the relief rate as the result of the relieving pressure being above operating pressure. |                                           |          |                                                                 |                                                                                                                                      |
| <sup>b</sup> Additional guidance on fire relief is given in Annex A.                                                                                |                                           |          |                                                                 |                                                                                                                                      |

#### 4.4.2.4 Relieving rate estimation for a closed outlet

For determining relief loads, it may be assumed that manual or remotely operated valves that are normally open and functioning at the time of failure and that are not affected by the primary cause of failure remain in operation at their normal operating positions.

To protect a vessel or system from overpressure when all outlets on the vessel or system are blocked, the capacity of the relief device shall be at least as great as the capacity of the sources of pressure. If all outlets are not blocked, the capacity of the unblocked outlets may properly be considered. The sources of overpressure include pumps, compressors, high-pressure supply headers, stripped gases from rich absorbent and process heat. In the case of heat exchangers, a closed outlet can cause overpressure due to either thermal expansion (see 4.4.12) or vapour generation.

The quantity of material to be relieved should be determined at conditions that correspond to relieving conditions instead of at normal operating conditions. The required relieving rate is often reduced appreciably when this difference in conditions is considered. The effect of frictional-pressure drop in the connecting line between the source of overpressure and the system being protected should also be considered in determining the required relieving rate.

#### 4.4.3 Cooling or reflux failure

##### 4.4.3.1 Description of the cooling or reflux failure

The failure of electrical or mechanical equipment that provides cooling or condensation in process streams can cause overpressure in process vessels. The loss of reflux as a result of pump or instrument failure can cause overpressure in a column because of condenser flooding or loss of coolant in the fractionating process. Fans on air-cooled heat exchangers or cooling towers occasionally become inoperative because of a loss of power or a mechanical breakdown. On cooling towers and air-cooled exchangers where independent operation of the louvers can be maintained, credit for the cooling effect may be obtained by convection and radiation.

#### **4.4.3.2 Relieving rate estimation for loss of cooling or reflux**

##### **4.4.3.2.1 General**

The required relieving rate is determined by a heat and material balance on the system at the relieving pressure. In a distillation system, the rate can require calculation with or without reflux. Credit is normally not taken for the effect of residual coolant after the cooling stream fails because this effect is time-limited and depends on the physical configuration of the piping. However, if the process piping system is unusually large and bare, the effect of heat loss to the surroundings may be considered.

Because of the difficulty in calculating detailed heat and material balances, the simplified bases described in 4.4.3.2.2 through 4.4.3.2.9 have generally been accepted for determining relieving rates.

##### **4.4.3.2.2 Total condensing**

The required relieving rate is the total incoming vapour rate to the condenser, recalculated at a temperature that corresponds to the new vapour composition at relieving conditions, and the heat input prevailing at the time of relief. The surge capacity of the overhead accumulator at the normal liquid level is generally limited to less than 10 min. If cooling failure exceeds this time, reflux is lost, and the overhead composition, temperature and vapour rate can change significantly.

##### **4.4.3.2.3 Partial condensing**

The required relieving rate is the difference between the incoming and outgoing vapour rate at relieving conditions. The incoming vapour rate should be calculated on the same basis used in 4.4.3.2.2. If the composition or rate of the reflux is changed, the incoming vapour rate to the condenser should be determined for the new conditions.

##### **4.4.3.2.4 Air-cooler fan failure**

Because of natural convection effects, credit for a partial condensing capacity of 20 % to 30 % of normal air-cooler duty is often used, unless the effects at relieving conditions are determined to be significantly different. The required relieving rate is then based on the remaining 70 % to 80 %, depending on the service (see 4.4.3.2.2 and 4.4.3.2.3). However, the actual duty available by natural convection is usually a function of the air-cooled heat-exchanger design. Some designs can allow significantly more credits if a supporting engineering analysis is performed. In addition, reduction in cooling capabilities can also occur if variable-pitch fans are used and a failure of the pitch mechanism occurs.

##### **4.4.3.2.5 Louver closure**

Louver closure on air-coolers is considered to result in total loss of cooling. Louver closure can result from automatic-control failure, mechanical-linkage failure or destructive vibration on a manually positioned louver.

##### **4.4.3.2.6 Overhead circuit**

In many cases, failure of the reflux that results, for example, from pump shutdown or valve closure, causes flooding of the overhead condenser, which is equivalent to total loss of cooling. Compositional changes caused by loss of reflux can produce different vapour properties that affect the required relieving rate. A pressure-relief device sized for total failure of the coolant is usually adequate for this condition, but each case shall be examined in relation to the particular components and system involved.

##### **4.4.3.2.7 Pump-around circuit**

The required relieving rate is the vaporization rate caused by an amount of heat equal to that removed in the pump-around circuit. The latent heat of vaporization corresponds to the latent heat under the relieving conditions of temperature and pressure at the point of relief.

#### 4.4.3.2.8 Overhead circuit plus pump-around

An overhead circuit plus pump-around is usually arranged so that simultaneous failure of the pump-around and the overhead condenser do not occur; however, partial failure of one with complete failure of the other is quite possible. The required relieving rate is discussed in 4.4.3.2.6 and 4.4.3.2.7.

#### 4.4.3.2.9 Sidestream reflux failure

Principles similar to those described in 4.4.3.2.6 and 4.4.3.2.7 apply in overhead-condenser flooding (if a condenser is in the system) or changes in vapour properties resulting from changes in composition. The required relieving rate should be large enough to relieve the vaporization rate caused by the amount of heat normally removed from the system.

#### 4.4.4 Absorbent flow failure

For lean-oil absorption of hydrocarbons, generally no relief requirement results from lean-oil failure. However, in an acid-gas removal unit in which large quantities (25 % or more) of the inlet vapour can be removed in the absorber, loss of absorbent can cause a pressure rise to relief pressure, since the downstream system might not be adequate to handle the increased vapour flow. The case of a synthesis-gas carbon-dioxide removal unit in which the downstream gas goes to a methanator is more complicated to analyse. Any quantity of carbon dioxide above design capability that enters the methanator, as occurs on even partial absorbent failure, produces a rapid temperature rise that usually closes a methanator feed shutoff valve and opens a vent to the atmosphere. If the vent to the atmosphere fails to open, the possibility of overpressure arises.

Each individual case shall be studied for its process and instrumentation characteristics. The study should include the effect on downstream process units in addition to the reaction in piping and instrumentation immediately downstream of the absorber.

#### 4.4.5 Accumulation of non-condensables

Non-condensables do not accumulate under normal conditions, because they are released with the process streams. However, with certain piping configurations, non-condensables can accumulate to the point that the overhead condenser is blocked. This effect is equal to a total loss of cooling.

#### 4.4.6 Entrance of volatile material into the system

##### 4.4.6.1 Water into hot oil

Although the entrance of water into hot oil remains a source of potential overpressure, no generally recognized method for calculating the relieving requirements is available. In a limited sense, if the quantity of water present and the heat available in the process stream are known, the size of the pressure-relief device can be calculated like that of a steam valve. Unfortunately, the quantity of water is almost never known, even within broad limits. Also, since the expansion in volume from liquid to vapour is so great (approximately 1:1 400 at atmospheric pressure) and the speed of vapour generation is essentially instantaneous, it is questionable whether the pressure-relief device could open fast enough to be of value. Normally, a pressure-relieving device is not provided for this contingency. Proper design and operation of the process system are essential in attempts to eliminate this possibility. The following are some precautions that can be taken:

- a) designing the water side to be at a lower operating pressure than the hot oil side;
- b) maintaining minimum circulation of hot oil through equipment on stand-by in order to minimize collection of water;
- c) avoiding water-collecting pockets;
- d) installing proper steam condensate traps;
- e) installing heat tracing to eliminate condensation;

- f) installing double-block and bleed valves on water connections to hot process lines;
- g) installing interlocks to trip sources of heat in the event of water-contaminated feedstock.

#### 4.4.6.2 Light hydrocarbons into hot oil

The information in 4.4.6.1 applies to the entrance of light hydrocarbons into hot oil even though the ratio of liquid volume to vapour volume can be considerably less than 1:1 400.

#### 4.4.7 Overfilling process or surge vessel

##### 4.4.7.1 General

Many process or surge vessels, including columns and towers, have a liquid level present during normal, start-up, or shutdown conditions. Experience has shown that this equipment can be overfilled under certain conditions. If the source pressure of a liquid feed or supply line can exceed the relief device set pressure and/or the design pressure of the equipment, then overfilling shall be included in the system design. System design options to deal with liquid overfill include but are not limited to

- a) increasing the system design pressure and/or pressure relief device set pressure within pressure design code allowances,
- b) designing a pressure relief system that can safely accommodate the overfill (including the effects of operator intervention response as discussed in 4.2.5),
- c) installing a safety instrumented system (SIS) to prevent the liquid overfill (see Annex E for additional information on safety instrumented systems (SIS)).

For all design options, all phases of operation shall be evaluated. Particular attention shall be given to start-up and other non-routine operations where process conditions (e.g. flow rates, temperature and density) can be different from normal and where conditions that lead to overfilling can be more likely to occur when compared with normal operations.

If option a) is chosen, the user shall validate the design (foundation, piping, etc.) consistent with the liquid overfill scenario.

If option b) is chosen, the user shall select the pressure-relief devices, design their inlet and outlet piping, validate the foundation design, etc. consistent with the liquid overfill scenario. If operator intervention is used as part of the system design, then the risk of failure of the operator to properly intervene shall be addressed. The pressure-relief device may discharge back into a disposal system such as a lower-pressure section of the process, a flare or to other disposal system. If it is a basis for the disposal-system design, then the user shall consider liquid overfill when designing the knockout drum, collection headers, etc. The design of the disposal system shall prevent the discharge of liquids above their flash point directly to atmosphere (into the air or on the ground) if there is an unacceptable risk as a result of a vapour-cloud explosion or other hazardous condition. See 5.8.2.4 for cautions regarding the atmospheric discharge of liquids. See 5.2 regarding options for the disposal of liquids.

##### 4.4.7.2 Mitigation measures

When designing the system to mitigate liquid overfill, the following can affect the design and shall be evaluated:

- a) risk of failure of the operator to respond properly;
- b) operator training and operating procedures that include instrumentation behaviour;
- a) **EXAMPLE** If a differential-pressure or displacer-level measurement reads low compared to actual level if the fluid specific gravity is less than the design gravity. This can mean that the indicated level cannot reach 100 % even if the actual level is well above the measured range.

- c) availability of instrumentation that is required for adequate operator intervention;
- d) availability of instrumentation that is required for safety instrumented system (SIS) response;
- e) potential consequence associated with relief-stream disposition (e.g. discharge back into the process, discharge to atmosphere, discharge to a treatment system such as flare, etc.);
- f) The pressure design code requirements.

If operator intervention and/or SIS options are selected, then a risk analysis method shall determine the adequacy of the protection.

#### 4.4.7.3 Level instruments

Some criteria to consider when evaluating level instrumentation and alarms to demonstrate availability and independence from the basic process control system include the following:

- a) whether the level instruments used for safeguards against overfilling are on separate process taps from the process control system;
- b) whether level instruments used for safeguards against overfilling are susceptible to the same common mode device failures as those used for the basic process control system. Diverse instrumentation can minimize the potential for common-mode device failures (e.g. differential pressure and radar, displacer and float, etc.);
- c) whether the instruments are proven in use for the specific process applications;
- d) whether the range of at least one of the level measurement(s) can indicate a valid level reading over the full range between the high critical alarm point and any shutdown or interlock point;
- e) whether operating characteristics of the level measurement during off-design, start-up, and shutdown operations are considered in display of level, setting alarms, trip points, operator training, and operating procedures.
- f) maintenance and testing frequency required for the instrumentation.

#### 4.4.8 Failure of process stream automatic controls

##### 4.4.8.1 General

Automatic control devices, directly actuated from the process or indirectly actuated from a process variable (e.g. pressure, flow, liquid level, or temperature) are used at inlets and outlets of vessels or systems. When the transmission signal or operating medium to a final control element (such as a valve operator) fails, the control devices should assume either a fully open or fully closed position according to their basic design. Final control elements that fail in a stationary position should be assumed to fail fully open or fully closed (see 4.4.8.5). 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 be reviewed to determine the effect on the final controlled element. Operation of the manual bypass valve is discussed in 4.4.8.3. Possible failure of the control device while the manual bypass valve is fully or partially open deserves to be considered; however, this factor is not intended to cover the condition of an undersized control valve.

In evaluating relief considerations, the designer should assume proper sizing of the control valve and unit operation at or near design unless he knows a specific condition that exists to the contrary. The designer should be alert to temporary start-up or upset conditions when unit operators are using the control valve's bypass valve. Since these are upset and off-control conditions, the probability that relieving requirements will arise is usually greater than when the unit is running normally under control with all bypasses closed.

#### 4.4.8.2 Capacity credit

In evaluating relieving requirements due to any cause, any automatic control valves that are not under consideration as causing a relieving requirement and that would tend to relieve the system should be assumed to remain in the position required for minimum normal processing flow. In other words, no credit should be taken for any favourable instrument response. Minimum normal valve position is the expected position of the valve prior to the upset incident, that is, the position of the valve when at minimum design flow rates (unit turndown conditions). Therefore, unless the condition of flow through the control valves changes (see 4.4.8.7), credit can be taken for the normal minimum flow of these valves, corrected to relieving conditions, provided that the downstream system is capable of handling any increased flow. Although controllers actuated by variables other than the system pressure can try to open their valves fully, credit can be taken for such control valves only to the extent permitted by their operating position at normal minimum flow regardless of the valve's initial condition.

#### 4.4.8.3 Inlet control devices and bypass valves

There can be single or multiple inlet lines fitted with control devices. The scenario to consider is that one inlet valve is in a fully opened position regardless of the control-valve failure position. Opening of this control valve can be caused by instrument failure or misoperation. If the system has multiple inlets, the position of any control device in those remaining lines shall be assumed to remain in its normal operating position. Therefore, the required relieving rate is the difference between the maximum expected inlet flow and the normal outlet flow, adjusted for relieving conditions and considering unit turndown, assuming that the other valves in the system are still in operating position at normal flow (that is, normally open, normally closed, or throttling). If one or more of the outlet valves are closed, or more inlet valves are opened by the same failure that caused the first inlet valve to open, the required relieving rate is the difference between the maximum expected inlet flow and the normal flow from the outlet valves that remain open. All flows should be calculated at relieving conditions. An important consideration is the effect of having a manual bypass on the inlet control valve(s) at least partially open. If, during operation, the bypass valve is opened to provide additional flow, then this total flow (control valve wide open and bypass valve normal position) shall be considered in the relieving scenario. If the bypass is used only during maintenance to permit the control valve to be blocked in and removed from service, then the maximum flow of either the control valve or bypass valve needs to be considered.

The potential for the bypass valve to be inadvertently opened while the control valve is operating should also be considered unless administrative controls are in place. If the pressure resulting from the opening of the bypass valve can exceed the corrected hydrotest pressure (see 3.23 and 4.2.2), reliance on administrative controls as the sole means to prevent overpressure might not be appropriate. The user is cautioned that some systems can have unacceptable risk due to failure of administrative controls and resulting consequences due to loss of containment. In these cases, limiting the overpressure to the normally allowable overpressure can be more appropriate. Note that the entire system, including all of the auxiliary devices (e.g. gasketed joints, instrumentation), should be considered for the overpressure during the failure of administrative controls.

Other situations can arise where problems involved in evaluating relief requirements after the failure of an inlet control device are more complex and of special concern (e.g. a pressure vessel operating at a high pressure where liquid bottoms are on level control and discharge into a lower-pressure system). Usually, when the liquid is let down from the high-pressure vessel into the low-pressure system, only the flashing effect is of concern in the event that the low-pressure system has a closed outlet. However, the designer should also consider that vapours flow into the low-pressure system if loss of liquid level occurs in the vessel at higher pressure. In this case, if the volume of the source of incoming vapours is large compared with the volume of the low-pressure system or if the source of vapour is unlimited, serious overpressure can rapidly develop. When this occurs, it can be necessary to size relief devices on the low-pressure system to handle the full vapour flow through the liquid control valve.

In circumstances where process systems involve significant differences in pressure level and the volume of vapour contained by the high-pressure equipment is less than the volume of the low-pressure system, the additional pressure can, in some cases, be absorbed without overpressure.

In the event of loss of liquid level, the vapour flow into the low-pressure system depends on what the interconnecting system, which usually consists of wide-open valves and piping, passes with a differential pressure based on the normal operating pressure upstream and the relieving pressure on equipment downstream. This pressure drop at initial conditions frequently results in critical flow (choking across a control valve) and can cause the rate to be several times higher than the normal rate of vapour inflow to the high-pressure system. Unless makeup equals outflow, this condition is of short duration as the upstream reservoir is depleted. Nonetheless, the relief facilities that protect the low-pressure system shall be sized to handle the peak flow. If the low-pressure side has a large vapour volume, it can prove worthwhile to take credit for the following: The transfer of vapours from the high-pressure system needed to raise the pressure on the downstream side from operating pressure to relieving pressure (normally 110 % of design pressure or MAWP) lowers the upstream pressure. This decrease produces a corresponding reduction in the flow that establishes the relieving requirement. Where such credit is taken, an allowance shall be made for the normal makeup of vapour to the high-pressure system that tends to maintain upstream pressure.

#### 4.4.8.4 Outlet control devices

Each outlet control valve should be considered in both the fully opened and the fully closed positions for the purposes of relief-load determination. This is regardless of the control-valve failure position because failure can be caused by instrument-system failure or misoperation. If one or more of the inlet valves are opened by the same failure that caused the outlet valve to close, pressure-relieving devices can be required to prevent overpressure. The required relieving rate is the difference between the maximum inlet and maximum outlet flows. All flows should be calculated at relieving conditions. Also, one should consider the effects of inadvertent closure of control devices by operator action.

For applications involving single outlets with control devices that fail in the closed position, pressure-relieving devices can be required to prevent overpressure. The required relieving rate is equal to the maximum expected inlet flow at relieving conditions and should be determined as outlined in 4.4.2.2.

For applications involving more than one outlet and a control device that fails in the closed position on an individual outlet, the required relieving rate is the difference between the maximum expected inlet flow and the design flow (adjusted for relieving conditions and considering unit turndown) through the remaining outlets, assuming that the other valves in the system remain in their normal operating position.

For applications involving more than one outlet, each with control devices that fail in the closed position because of the same failure, the required relieving rate is equal to the maximum expected inlet flow at relieving conditions.

#### 4.4.8.5 Fail-stationary valves

Even though some control devices are designed to remain stationary in the last controlled position, one cannot predict the position of the valve at time of failure. Therefore, the designer should always consider that such devices could be either open or closed: no reduction in required relieving rate should be considered when such devices are used.

#### 4.4.8.6 Choke valve failure

Experience has shown that, under certain conditions and in certain services, choke valves may be subject to a sudden and complete failure of the valve trim, leading to a dramatic increase in the valve's flow capacity. Such a failure may lead to a sustained flow that is substantially larger than normal flow. A dynamic analysis may be required to determine these effects (see 4.3.3). The user should determine whether choke valve collapse is a basis for design, a remote contingency or not credible. The user should also determine whether a choke valve collapse in combination with inadvertent valve opening (see 4.4.9.2) is a possible contingency.

Production chokes (e.g. subsea choke, topside (riser) choke, wellhead choke) may be subject to a collapse and subsequent sudden increase in flow capacity. Among the possible causes are:

- a) Impact by solids from the formation (e.g. during a well cleanup or well startup)
- b) Impact by fragments of tools/devices from the well
- c) Erosion/corrosion
- d) Mechanical fatigue
- e) Brittle fracture

Measures to consider for mitigating the consequences of a choke failure include:

- a) Pressure relief device;
- b) Replacing a large valve with multiple smaller valves, as it is necessary to consider only one choke valve failure at a time;
- c) The user may define choke failure as not credible based on selection of high integrity choke designs. Such a conclusion should be substantiated by a careful analysis of the nature and characteristics of mechanical loads and/or a program for testing and qualification.;
- d) Use of dedicated choke valves or change of choke trim for special operations in which solids are expected, such as well cleanup;
- e) Restrictions (e.g. perforated plate) in the flow path which will serve to limit the maximum mechanical load caused by impacts.

The user should avoid rapid opening of the choke valve and carefully evaluate the need for regular inspection and maintenance programs for the choke valves.

#### 4.4.8.7 Special capacity considerations

Although control devices, such as diaphragm-operated control valves, are specified and sized for normal design 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 should be selected to position the valve plug properly in accordance with control signals during abnormal conditions. Because the control-valve capacities at pressure-relieving conditions are not the same as those at normal conditions, the control-valve capacities should be calculated for the relieving conditions of temperature and pressure in determining the required relieving rates. In extreme cases, the state of the controlled fluid can change (e.g. from liquid to gas or from gas to liquid). The wide-open capacity of a control valve selected to handle a liquid can, for example, differ greatly when it handles a gas. This becomes a matter of particular concern where loss of liquid level can occur, causing the valve to pass high-pressure gas to a system sized to handle only the vapour flashed from the normal liquid entry.

#### 4.4.8.8 Piping design considerations for gas breakthrough

Gas breakthrough across a control valve can result in slug-flow high liquid velocities. The resultant transient loads on the piping shall be taken into account, including the mechanical design and pipe supports.

**NOTE** Locating the relief device closer to the upstream control valve can reduce the amount of pipe support required and can also reduce the size of the relief device.

#### 4.4.9 Abnormal process heat or vapour input

##### 4.4.9.1 Abnormal process heat input

Reboilers and other process heating equipment are designed with a specified heat input. When they are new or recently cleaned, additional heat input above the normal design can occur. In the event of a failure of temperature control, vapour generation can exceed the process system's ability to condense or otherwise absorb the build-up of pressure, which may include non-condensables caused by overheating.

The required relieving rate is the maximum rate of vapour generation at relieving conditions (including any non-condensables produced from overheating) less the rate of normal condensation or vapour outflow. In every case, the designer should consider the potential behaviour of the system and each of its components. For example, the fuel or heat-medium control valve or the tube heat flux can be the limiting consideration. To be consistent with the practice used for other causes of overpressure, design values should be used for an item such as control-valve size. However, built-in overcapacity, which is applicable to the common practice of specifying burners capable of 125 % of heater design heat input, shall be considered.

If limit stops are installed on control valves, the wide-open capacity, rather than the capacity at the stop setting, should normally be used. However, if a mechanical stop is installed and is adequately documented, use of the limited capacity can be appropriate. In shell-and-tube heat exchange equipment, heat input should be calculated on the basis of clean, rather than fouled, conditions.

#### **4.4.9.2 Inadvertent valve opening**

The inadvertent opening of any valve from a source of higher pressure, such as high-pressure steam or process fluids, should be considered. This action can require pressure-relieving capacity unless administrative controls, as defined in 3.2, are in place to prevent inadvertent valve opening. Where the upstream shut-in pressure may be substantially higher than the normal operating system pressure, the user should determine whether inadvertent valve opening combined with maximum shut-in pressure in upstream system is a credible relief case. This may for instance be the case if the pressure source is a pipeline or a production well where the pressure upstream of a closed valve may reach the maximum shut-in pressure of the source after a shutdown, and opening of the isolating block valve will result in an extremely large flow rate to be relieved.

The following applies when a manual or actuated valve is inadvertently opened, causing pressure build-up in a vessel. The vessel should have a pressure-relief device large enough to pass a rate equal to the flow through the open valve; credit may be taken for the flow capacity of vessel outlets that can reasonably be expected to remain open. The manual or actuated valve should be considered as passing its capacity at a full-open position with the pressure in the vessel at relieving conditions. Volumetric or heat-content equivalents may be used if the manual or actuated valve admits a liquid that flashes or a fluid that causes vaporizing of the vessel contents. It is typical to consider only one inadvertently opened manual or actuated valve at a time, although simultaneous inadvertent opening of multiple valves needs to be considered if a common cause is identified (e.g. sequential valve operations). Automatic control failures are discussed separately in 4.4.8.

#### **4.4.9.3 Check-valve leakage or failure**

##### **4.4.9.3.1 Causes of overpressure due to check-valve leakage or failure**

A single check valve is not always an effective means for preventing overpressure by reverse flow from a high-pressure source. For example, if a fluid is pumped into a system that contains vapour at significantly higher pressure than the design rating of the equipment upstream of the pump, loss of pumped flow with leakage or latent failure of a check valve in the discharge line results in a reversal of the liquid's flow. When high-pressure fluid enters the low-pressure system, overpressure can result.

In most cases, focus should be on prevention of reverse flow. It is important to note that, in addition to overpressure of the upstream system, reverse flow through machinery can destroy mechanical equipment, causing loss of containment. If this hazard is of concern, additional means of backflow prevention should be provided.

##### **4.4.9.3.2 Pressure consideration for single check-valve latent failure**

Overpressure protection shall be provided for single check-valve latent failure (e.g. stuck open or broken flapper) where the maximum normal operating pressure of the high-pressure system is greater than the design pressure or MAWP of vessels, equipment and piping in the upstream low-pressure system and there is enough stored energy in the high-pressure system to cause an overpressure in the low-pressure system (e.g. large vapour cap in the high-pressure system).

When sizing a pressure-relief device to prevent exceeding the allowable accumulation of the protected equipment for the latent check-valve failure, the reverse flow rate through a single check valve may be

determined using the normal flow characteristics (i.e., forward-flow  $C_v$ ) of the check valve. If the check valve  $C_v$  is unavailable, one may conservatively assume that the check valve is not there by taking no credit for its flow resistance.

If the single check valve is inspected and maintained to ensure its reliability and capability to limit reverse flow, the user may determine that the check-valve latent failure is unlikely. In this case, overpressure protection should be provided where the maximum normal operating pressure of the high-pressure system is greater than the upstream equipment's corrected hydrotest pressure (see 3.23 and 4.2.2). The user is cautioned that some systems can have unacceptable risk due to latent failure of the check valve and resulting consequences due to loss of containment. In these cases, limiting the overpressure to the normally allowable overpressure can be more appropriate. Note that the entire system, including all of the auxiliary devices (e.g. gasketed joints, instrumentation), should be considered for the overpressure during the latent failure of the check valve.

#### **4.4.9.3.3 Pressure consideration for single check-valve leakage**

Even properly inspected and maintained check valves might not completely eliminate check-valve seat leakage. Consequently, the user should be aware that isolation of the low-pressure system upstream of the check valves can still result in overpressure. If operator action (e.g. manual isolation from the high-pressure system) is being considered to prevent overpressure due to check-valve leakage, then a layers-of-protection analysis (LOPA) or other process hazard analysis can be useful to understand possible risk and sensitivities of key assumptions. A detailed analysis can then show that automatic isolation, a pressure-relief device sized for leakage, or an alternative means of protection can be preferred. It is necessary for the user to define the appropriate leakage rate for his/her specific system.

#### **4.4.9.3.4 Pressure consideration for series back-flow prevention**

Experience has shown that when inspected and maintained to ensure reliability and capability to limit reverse flow, two back-flow-prevention devices in series are sufficient to eliminate significant reverse flow. As the differential pressure increases, the use of additional safeguards should be considered to reduce the risk of check-valve latent failures resulting in mechanical equipment damage causing loss of containment. The user might want to consider diverse back-flow prevention devices.

If reliability of the series back-flow prevention cannot be assured, then it can be necessary to estimate the reverse flow. The quantity of back-flow leakage through check valves in series depends on the types of check valves, the fouling nature of the fluid and other system considerations. Therefore, it is the responsibility of the user to determine an appropriate technique for estimating the reverse flow through check valves in series. The maximum expected differential pressure across the check valve at the time of demand should be used as the basis for relief rate calculations.

Where no specific experience or company guidelines exist, one may estimate the reverse flow through series check valves as the flow through a single orifice with a diameter equal to one-tenth of the largest check valve's nominal flow diameter. A lower value may be used if a condition-monitoring system for the check valves (e.g. pressure indicators with appropriate volumes between the check valves) is installed to monitor the condition to ensure that the leakage rate is below the capacity of the low-pressure side relief device.

#### **4.4.9.4 Reciprocating compressor rod packing failure**

Reciprocating compressors should be protected from rod packing failures in the distance piece by an adequately sized vent line or pressure relief device. Options to size the pressure relief device or vent line can include 1) determine the annular gap between the compressor rod and packing gland and calculate flow using an equivalent square edge orifice area or 2) provide a pressure relief device with inlet size equal to the nominal pipe size of the vent piping.

An alarm may be provided to indicate to operators that there is abnormally high packing leak off rate (e.g. a high temperature alarm or a high pressure alarm).

#### 4.4.10 Internal explosions or transient pressure surges

##### 4.4.10.1 Internal explosion (excluding detonation)

If overpressure protection against internal explosions caused by ignition of vapour-air mixtures is to be provided, rupture disks or explosion-vent panels, not relief valves, should be used. Relief valves react too slowly to protect the vessel against the extremely rapid pressure build-up caused by internal flame propagation. The vent area required is a function of a number of factors including the following:

- a) initial conditions (pressure, temperature, composition);
- b) flame propagation properties of the specific vapours or gases;
- c) volume of the vessel;
- d) pressure at which the vent device activates;
- e) maximum pressure that can be tolerated during a vented explosion incident.

It should also be noted that the peak pressure reached during a vented explosion is usually higher, sometimes much higher, than the pressure at which the vent device activates.

Design of explosion-relief systems should follow recognized guidelines such as those contained in NFPA 68 [34]. Simplified rules-of-thumb should not be used as these can lead to inadequate designs. If the operating conditions of the vessel to be protected are outside the range over which the design procedure applies, explosion-vent designs should be based on specific test data, or an alternate means of explosion protection should be used.

Some alternate means of explosion protection are described in NFPA 69 [35], including explosion containment, explosion suppression, oxidant-concentration reduction, and so forth.

Explosion-relief systems, explosion containment and explosion suppression should not be used for cases where detonation is considered a credible risk. In such cases, the explosion hazard should be mitigated by preventing the formation of mixtures that could detonate.

Explosion-prevention measures, such as inert gas purging, in conjunction with suitable administrative controls can be considered in lieu of explosion-relief systems for equipment in which internal explosions are possible only as a result of air contamination during start-up or shutdown activities.

##### 4.4.10.2 Transient pressure surges

###### 4.4.10.2.1 Water hammer

The probability of hydraulic shock waves, known as water hammer, occurring in any liquid-filled system should be carefully evaluated. Water hammer is a type of overpressure that cannot be controlled by typical pressure-relief valves, since the response time of the valves can be too slow. The oscillating peak pressures, measured in milliseconds, can raise the normal operating pressure by many times. These pressure waves damage the pressure vessels and piping where proper safeguards have not been incorporated. Water hammer is frequently avoided by limiting the speed at which valves can be closed in long pipelines. Where water hammer can occur, the use of pulsation dampeners or special bladder-type surge valves should be considered, contingent on proper analysis.

#### 4.4.10.2.2 Steam hammer

An oscillating peak-pressure surge, called steam hammer, can occur in piping that contains compressible fluids. The most common occurrence is generally initiated by rapid valve closure. This oscillating pressure surge occurs in milliseconds, with a possible pressure rise in the normal operating pressure by many times, resulting in vibration and violent movement of piping and possible rupture of equipment. Pressure-relief valves cannot effectively be used as a protective device because of their slow response time. Avoiding the use of quick-closing valves can prevent steam hammer.

#### 4.4.10.2.3 Condensate-induced hammer

Isolation of a steam bubble by cold condensate can lead to the eventual rapid collapse of the bubble and catastrophic damage to steam pipework. Proper design and operation of the process system are essential in attempts to eliminate this possibility (e.g. by the use of drains, steam traps, appropriate pipe slope, training and careful management of change).

The hazard is particularly acute during turnaround and maintenance activities where dead-legs that trap a steam bubble can be inadvertently created. Pressure-relief devices cannot effectively be used as a protective device.

### 4.4.11 Chemical reaction

#### 4.4.11.1 General

In some reactions and processes, loss of process control can result in a significant change in temperature and/or pressure. The result can exceed the intended limits of the materials selected. Thus, where cryogenic fluids are being processed, a reduction in pressure could lower the temperature of the fluids to a level below the minimum allowable design temperature of the equipment, with the attendant risk of a low-temperature brittle failure. For exothermic reactions (e.g. decompositions, acid dilutions, polymerizations), excessive temperatures and/or pressures associated with runaway reactions can reduce the allowable stress levels below the design point, or increase the pressure above the maximum allowable working pressure (MAWP). Where normal pressure-relieving devices cannot protect against these situations, controls are necessary to warn of changes outside the intended temperature/pressure limits to provide corrective action (see 4.4.8 and 4.4.9). The potential for a chemical reaction in conjunction with the other overpressure scenarios in 4.4 should be considered when appropriate.

The methodology for determining the appropriate size of an emergency vent system for chemical reactions has been established by DIERS (Design Institute for Emergency Relief Systems) [38], [39], [40], [41], [42].

The DIERS methodology is based on the following:

- a) defining the design-basis upset conditions for the reaction system;
- b) characterizing the systems through bench-scale tests simulating the design-basis upset conditions;
- c) using vent-sizing formula that account for two-phase gas/liquid vent flow.

#### 4.4.11.2 Scenarios

The design basis upset conditions are process-specific, but generally include one or more of the following:

- a) external fire;
- b) loss of mixing;
- c) loss of cooling;
- d) mischarge of reagents.

#### 4.4.11.3 Reaction rates / sizing

Reaction rates are rarely known; therefore, bench scale tests simulating the design basis upset condition are usually required. There are a number of test apparatus available for this purpose. With the information obtained from the bench scale tests, the system can be characterized by one of the following terms:

- tempered: Tempered systems are those in which the unwanted reaction produces condensable products and the rate of temperature rise is tempered by liquid boiling at system pressure. Typically, tempered systems are liquid-phase reactions in which a reactant (or solvent) is a major portion of the reactor contents.
- gassy: Gassy systems are those in which the unwanted reaction produces non-condensable products and the rate of temperature rise is not tempered by boiling liquid. Gassy systems can be either liquid-phase decompositions or vapour-phase reactions.
- hybrid: Hybrid systems are those in which the rate of temperature rise due to an unwanted reaction can be tempered by liquid boiling at system pressure, but can also give rise to the generation of non-condensable gas.

Following characterization of the system, the appropriate vent-sizing formula can be selected. An excellent discussion of these procedures is contained in Grolmes *et al* [38]. However, the reader should be cautioned that this is an area with rapidly changing technology and the most current technology should be used, if available.

If the bench-scale simulations indicate the potential for an explosion, the considerations in 4.4.10 should be applied. It can also be prudent to consider housing the reactor in a specially constructed bay to handle potentially explosive reactions or to increase the equipment-design conditions to contain maximum expected temperature and pressure.

Where feasible, a pressure-relief device should be used to control overpressure. Where this is infeasible, other design strategies can be employed to control equipment over-stressing. These strategies can include using safety systems such as automatic shutdown systems, inhibitor injection, quench, de-inventorying, alternative power supplies and depressuring. When this approach is taken, the reliability of the protective system(s) should be addressed in a formal risk analysis. This analysis is outside the scope of this International Standard.

Other forms of reactions that generate heat (dilution of strong acids) should also be evaluated.

#### 4.4.12 Hydraulic expansion

##### 4.4.12.1 Causes

Hydraulic expansion is the increase in liquid volume caused by an increase in temperature (see Table 2). It can result from several causes, the most common of which are the following.

- a) Piping or vessels are blocked in while they are filled with cold liquid and are subsequently heated by heat tracing, coils, ambient heat gain or fire.
- b) An exchanger is blocked in on the cold side with flow in the hot side.
- c) Piping or vessels are blocked in while they are filled with liquid at near-ambient temperatures and are heated by direct solar radiation.

In certain installations, such as cooling circuits, the processing scheme, equipment arrangements and methods, and operation procedures make feasible the elimination of the hydraulic-expansion relieving device, which is normally required on the cooler, fluid side of a shell-and-tube exchanger. Typical of such conditions are multiple-shell units with at least one cold-fluid block valve of the locked-open design on each shell and a single-shell unit in a given service where the shell can reasonably be expected to remain in service, except on shutdown. In this instance, closing the cold-fluid block valves on the exchanger unit should be controlled by administrative procedures and possibly the addition of signs stipulating the proper venting and draining procedures when shutting down and blocking in. Such cases are acceptable and do not compromise the safety of personnel or equipment, but the designer is cautioned to review each case carefully before deciding that a relieving device based on hydraulic expansion is not warranted.

**Table 2 — Typical values of cubic expansion coefficient for hydrocarbon liquids and water**

| Gravity of liquid<br>°API        | Cubic expansion coefficient <sup>a</sup><br>1/°C (1/°F) |
|----------------------------------|---------------------------------------------------------|
| 3 to 34,9                        | 0,000 72 (0,000 4)                                      |
| 35 to 50,9                       | 0,000 9 (0,000 5)                                       |
| 51 to 63,9                       | 0,001 08 (0,000 6)                                      |
| 64 to 78,9                       | 0,001 26 (0,000 7)                                      |
| 79 to 88,9                       | 0,001 44 (0,000 8)                                      |
| 89 to 93,9                       | 0,001 53 (0,000 85)                                     |
| 94 and lighter                   | 0,001 62 (0,000 9)                                      |
| water                            | 0,000 18 (0,000 1)                                      |
| <sup>a</sup> At 15,6 °C (60 °F). |                                                         |

#### 4.4.12.2 Sizing and set pressure

The required relieving rate is not easy to determine. Since every application is for a relieving liquid, the required relieving rate is small; specifying an oversized device is, therefore, reasonable. A DN 20 × DN 25 (NPS ¾ × NPS 1) relief valve is commonly used. If there is reason to believe that this size is not adequate, the procedure in 4.4.12.3 can be applied. If the liquid being relieved is expected to flash or form solids while it passes through the relieving device, the procedure in 4.9.2 is recommended.

Proper selection of the set pressure for these relieving devices should include a study of the design rating of all items included in the blocked-in system. The thermal-relief pressure setting should never be above the maximum pressure permitted by the weakest component in the system being protected. However, the pressure-relieving device should be set high enough to open only under hydraulic expansion conditions. If thermal-relief valves discharge into a closed system, the effects of back pressure should be considered.

#### 4.4.12.3 Special cases

Two general applications for which thermal relieving devices larger than a DN 20 × DN 25 (NPS ¾ × NPS 1) valve can be required are long pipelines of large diameter in uninsulated, aboveground installations and large vessels or exchangers operating liquid-full. Long pipelines can be blocked in at or below ambient temperature; the effect of solar radiation raises the temperature at a calculable rate. If the total heat-transfer rate and thermal-expansion coefficient for the fluid are known, a required relieving rate can be calculated. See Parry<sup>[43]</sup> for additional information on thermal relief.

If the fluid properties vary significantly with temperature, the worst-case temperature should be used. Alternatively, more sophisticated calculation methods that include temperature-dependent fluid properties can be used to optimize the size of the relief device.

For liquid-full systems, expansion rates for the sizing of relief devices that protect against thermal expansion of the trapped liquids can be approximated using Equation (1), in SI units, or Equation (2) in USC units:

$$q = \frac{\alpha_v \cdot \phi}{1\,000 d \cdot c} \quad (1)$$

where

$q$  is the volume flow rate at the flowing temperature, expressed in m<sup>3</sup>/s;

$\alpha_v$  is the cubic expansion coefficient for the liquid at the expected temperature, expressed in 1/°C;

NOTE This information is best obtained from the process-design data; however, Table 2 shows typical values for hydrocarbon liquids and water at 15,6 °C.

$\phi$  is the total heat transfer rate, expressed in watts;

NOTE For heat exchangers, this can be taken as the maximum exchanger duty during operation.

$d$  is the relative density referred to water ( $d = 1,00$  at 15,6 °C), dimensionless;

NOTE Compressibility of the liquid is usually ignored.

$c$  is the specific heat capacity of the trapped fluid, expressed in J/kg·K.

$$q = \frac{\alpha_v \cdot \phi}{500 d \cdot c} \quad (2)$$

where

$q$  is the volume flow rate at the flowing temperature, expressed in U.S. gallons per minute;

$\alpha_v$  is the cubic expansion coefficient for the liquid at the expected temperature, expressed in 1/°F;

NOTE This information is best obtained from the process design data; however, Table 2 shows typical values for hydrocarbon liquids and water at 60 °F.

$\phi$  is the total heat transfer rate, expressed in Btu/h;

NOTE For heat exchangers, this can be taken as the maximum exchanger duty during operation.

$d$  is the relative density referred to water ( $d = 1,00$  at 60 °F), dimensionless;

NOTE Compressibility of the liquid is usually ignored.

$c$  is the specific heat capacity of the trapped fluid, expressed in Btu/lb·°F.

This calculation method provides only short-term protection in some cases. If the blocked-in liquid has a vapour pressure higher than the relief-design pressure, then the pressure-relief device should be capable of handling the vapour-generation rate. If discovery and correction before liquid boiling is expected, then it is not necessary to account for vaporization in sizing the pressure-relief device.

#### 4.4.12.4 Piping

##### 4.4.12.4.1 Theoretical background for rigorous calculations

Where the system under consideration for thermal relief consists of piping only (does not contain pressure vessels or heat exchangers), a pressure-relief device might not be required to protect piping from thermal expansion if

- a) the piping always contains a pocket of non-condensing vapour, such that it can never become liquid-full;

**CAUTION — Small vapour or gas pockets can disappear upon heating due to compression and/or solubilization. In contrast, multi-component mixtures with a wide boiling range can always have sufficient vapour present to preclude becoming completely liquid-full. The liquid-volume change upon solar heating, heat tracing, heating to ambient temperature or heat from another source should be estimated to determine if the volume of the vapour pocket is sufficient for liquid expansion.**

or

- b) the piping is in continuous use (i.e., not batch or semi-continuous use) and drained after being blocked-in using well supervised procedures or permits;

or

- c) the fluid temperature is greater than the maximum temperature expected from solar heating [usually approximately 60 °C to 70 °C (approximately 140 °F to 160 °F)] and there are no other heat sources such as heat tracing (note that fire is generally not considered when evaluating pressure-relief requirements for piping);

or

- d) the estimated pressure rise from thermal expansion is within the design limits of the equipment or piping.

The pressure rise due to simultaneous heating of the pipe and blocked-in liquid can be calculated from Equation (3) (Karcher [44] and CCPS [45]):

$$p_2 = p_1 + \frac{(T_2 - T_1)(\alpha_v - 3\alpha_l) - \left(\frac{q_{ll} \cdot t}{V}\right)}{\chi + \left(\frac{d}{2E \cdot \delta_w}\right)(2,5 - 2\mu)} \quad (3)$$

where

$p_2$  is the final gauge pressure of blocked-in, liquid-full equipment, expressed in kPa (psi);

$p_1$  is the initial gauge pressure of blocked-in, liquid-full equipment, expressed in kPa (psi);

$T_2$  is the final temperature of blocked-in, liquid full equipment, expressed in °C (°F);

$T_1$  is the initial temperature of blocked-in, liquid full equipment, expressed in °C (°F);

$\alpha_v$  is the cubic expansion coefficient of the liquid, expressed in 1/°C (1/°F);

$\alpha_l$  is the linear expansion coefficient of metal wall, expressed in 1/°C (1/°F);

$\chi$  is the isothermal compressibility coefficient of the liquid, expressed in 1/kPa (1/psi);

$d$  is the internal pipe diameter, expressed in metres (inches);