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IChemE Safety Centre Guidance

Lead Process Safety Metrics

Supplementary guide – Pressure Relief Device (PRD) – design and operational performance requirements

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IChemE Safety Centre

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Disclaimer

This document is a supplement to the ISC Guidance Document 'Lead Process Safety Metrics – selecting tracking and learning 2015'. This guidance note is used to provide context for barrier failures and in particular the lead metric 'barrier fail on test' and 'barrier failing on demand'. This guidance should be used to help understand the difference between design and operational acceptance criteria. This is the first in a series of guidance documents that will focus on providing more clarity on the type of failures/events to be included in your metrics and will also aid in the goal of capturing similar data across companies and across industries. This will allow for benchmarking and identification of good practice for us to learn from. As acknowledged by the US Chemical Safety and Hazard Investigation Board, it is important that we focus on lead metrics since the focus on lagging metrics is not a good measure or statistically significant for most companies.

Purpose

Pressure relief devices shall protect the system from overpressure/under pressure hazards that could cause loss of containment. The guidance is applicable to protective devices operating across all services.

Scope

PRD includes devices used to protect pressure vessels, piping, pipelines and tanks from over and under pressure. API RP 520 and 578 is the accepted harmonised standard for PRD sizing, installation and maintenance. These standards form the backbone of refrigeration standards. However, refrigeration systems should be designed to either ANSI/IIAR or EN 13136 standards as required by local legislation.

Definitions

PRDs – generic term which includes the following:

- **pressure relief valves (PRVs)**
- **pressure safety valves (PSVs)**
- **pressure vacuum safety valves (PVSVs)**
- **hydrostatic (thermal) relief valves**
- **bursting disks (BDs)**
- **rupture pin valves (RPVs)**

and excludes hydrostatic legs, fusible plugs and burst/lift hatches.

Pass

The device fulfils all the operational acceptance criteria and operational performance testing requirements.

Failed safe

The device does not fulfil all the operational acceptance criteria and operational performance testing requirements, does not fulfil any of the failed to danger criteria (eg failed safe: the PSV tag is missing from the devices; however, all the other requirements are met).

Failed to danger

The device does not fulfil any of the operational acceptance criteria or operational performance testing requirements, fulfils any 'failed to danger' criteria.

Design acceptance criteria

These items are criteria that will need to be addressed in the initial design phase and may need to be revisited as part of the management of change process:

- PRDs shall have their set points no higher than the maximum allowable working pressure (MAWP) of the system they are protecting
- operating pressure should not be within 10% of the PRDs set point unless device has proven ability to tighter window
- selection of the device should match the intended operational fluid, eg clean, dirty, sticky or corrosive
- the PRD should be sized for whichever is the largest case, eg fire, tube rupture, blow-by case, blocked discharge, etc
- this sizing case and relevant input data shall be documented on an engineering data sheet or equivalent and consideration should be given to conducting design verification
- PRD sizing in ammonia refrigeration service should consider excess internal pressure caused by liquid expansion, internal and external heat source across pumps, vessels and compressors
- the PRD system should be designed so that inlet pressure losses and outlet back pressures are allowed for in the design
- where PRDs relieve to common headers, PSV load calculation shall be performed using reliable two phase flow software to ensure back pressure/choke flow is not created during a relieving scenario
- in ammonia service, all PRDs are fitted with dual relief with 3-way valve to allow testing and repair flexibility. Each relief valve must be sufficient to relieve the required rate. 3-way valve stem must be positioned so that only one pressure relief is activated
- relief devices that are discharging to atmosphere shall have tail pipe routed to 'Safe Location' and discharge piping shall be designed to prevent accumulation of liquid, fouling, blockage from vermin and free from restriction
- in case of toxic material release discharge to safe location should consider use of additional mitigation steps such as vent stacks and diffusion systems adequately sized so reduce risk to offsite community
- valve must remain reseated within 10% of the lift pressure. To achieve this condition, the valve lift pressure may be reduced to 75% or until the valve re-seats. Reseat tightness checked and the pressure increased to 90% of the lift pressure
- bursting disks may be installed to provide a hygiene seal upstream of PSV
- handling and transport of PRD:
  - all valves shall be transported in an upright position in purpose built transport frames
  - valves shall be secured to resist shock, impact and movement while in transit
  - valves should be protected from the weather during transport and storage

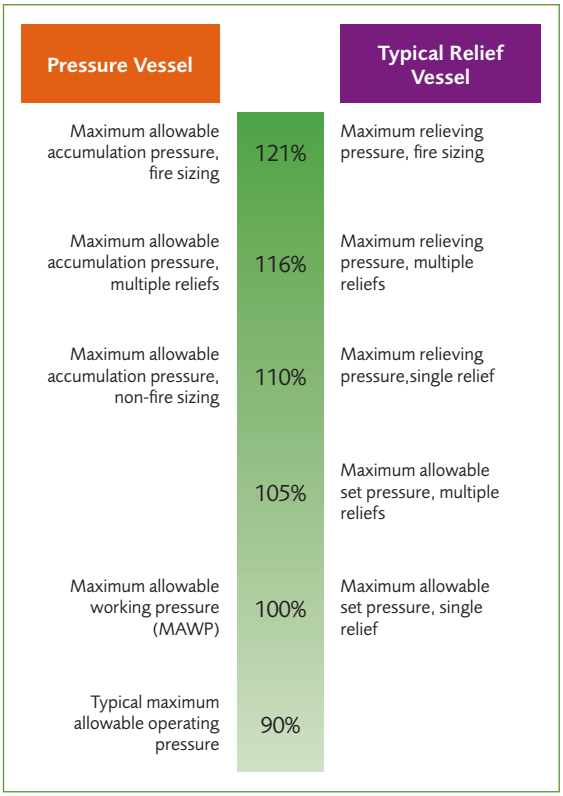


Figure 1: Adapted from ASME Boiler and Pressure Vessel Code VIII outlines vessel (left) and PRD (right) requirements

Operational acceptance criteria

These items are criteria that will need to be addressed whilst the equipment is in operation and following the operational performance testing activities:

- PRD shall be in a free flow path, without blockages, any intervening valves upstream or downstream of any online PRV shall be locked open
- PRDs shall be maintained in 'fit for purpose' conditions and have a valid test certificate
- PRDs 'system' service conditions shall continue to meet the design input/assumptions and manufacturer's specifications. If this is not met, then action should be taken to:
  - eliminate the root cause
  - modify the design and/or operating envelope
  - reduce the inspection/test interval
  - install a device of more appropriate specification

Section 1 – PSVs and PVSVs

Operational performance testing requirements for PSVs and PVSVs. These activities are required to be conducted by a competent person who is familiar with failure mechanisms and installation requirements:

Two activities typically required for testing PSVs, PVSV or thermal relief valves:

- online external visual inspection – nominally 12 months
- scheduled testing and recertification – typically 12–60 months for pressure vessels, and 10–12 years for storage tanks, depending on service and prior inspection history:
  - the interval shall not exceed the internal inspection of the item of pressure equipment it protects
  - where an 'as received' test cannot be conducted due to cleanliness or fouling, the device will be considered as failed to danger

Online external visual inspection for PSVs – pass/fail criteria:

A PSV test result can be classified as passed, failed safe, or failed to danger, as described below:

Pass

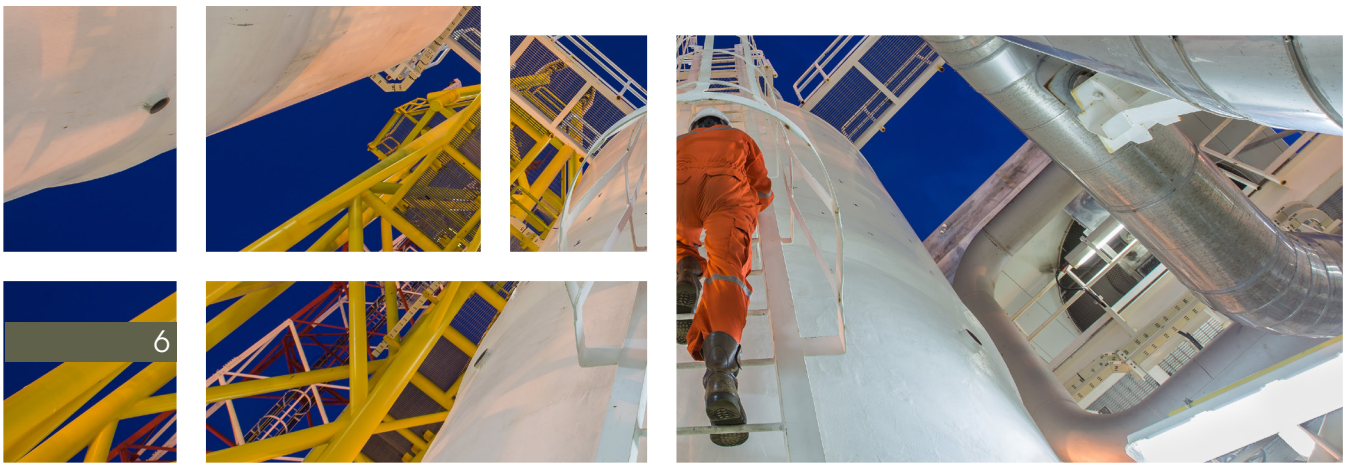
A PSV test result will be deemed as a pass when all have been satisfied:

- the correct PSV installed has the correct identification tag number and relieving pressure as per the P & ID or data sheet
- <30% surface corrosion on the pipework or body (as this shows potential for pitting due to coating damage)
- there is no blockage/damage or leakage of impulse, sensing, inlet and discharge lines

Failed safe

A PSV will be deemed to have failed safe if it does not meet the requirements of Section 1 and does not meet the requirements of failed to danger.

- the valve has lost its identification or last recertification tag, but is confirmed as being the correct valve installed
- the PSV has >30% corrosion and a passed 'fitness for service' assessment
- there is minor restriction/damage of impulse and sensing lines



Failed to danger

A PSV test result will be classified as failed to danger when any of the following have occurred:

- the valve has had the tamper proof seals broken or physical damage
- the PSV last inspection is not within the certification date
- the PSV has failed 'fitness for service' assessment
- the PSV has a closed valve or blind installed upstream or downstream of online PRD (typically locked open/car seal/fortress/castell key)
- the PSV has blocked/leaking or damaged impulse/sensing lines
- the bellows (where fitted) is found to be leaking or damaged, or the vent path is blocked/obstructed
- the pilot diaphragm (where fitted) is not found to be leaking or significantly damaged, or the vent path is blocked/obstructed
- vent stacks, discharge piping and downstream receiving vessels are not properly supported

PSV testing and recertification – pass/fail criteria:

Conduct periodic inspection and function testing, including 'pop test' on the valve in as found condition and visual inspection of valve components. Frequency will be set by API 520 or API 581 if a risk-based approach is taken to recertify PSVs. Depending on your location, there may be other standards, for example, in Australia/New Zealand AS/NZA 3788 is applicable.

Reseating of the valve must be tested during recertification.

The valve must remain reseated within 10% of the lift pressure. To achieve this condition, the valve lift pressure may be reduced to 75% or until the valve reseats. Reseat tightness checked and the pressure increased to 90% of the lift pressure.

A PSV test result can be classified as passed, failed safe, or failed to danger.

<97%	97–103%	103–110%	>110%
FAILED SAFE	**PASS**	**FAILED SAFE**	**FAILED TO DANGER**

Pass

A PSV test result will be deemed as a pass when all have been satisfied:

- its initial 'POP' test lifts cleanly within +/-3% of its cold differential set pressure (CDSP)
- the valve reseats within its acceptable range of +2.5% to -7% of the CDSP, for valves with an adjustable blow down ring, and -2.5% to -15% for all other valves
- the bubble rate is within the limits set out in API 527. May be dangerous failure if this does not go to flare or if the material is toxic and does not go to scrubber
- there are no leaks evident during the back-pressure test

Failed safe

A PSV will be deemed to have failed safe if it does not meet the requirements of Section 1 pass and has not failed to danger:

- its initial 'POP' test lifts cleanly within 110% to 103% or <97% of its CDSP
- the seat tightness test or bubble rate is greater than the limits set out in API 527. May be dangerous failure if this does not go to flare or if the material is toxic and does not go to scrubber
- there is minor restriction/damage of impulse and sensing lines

Failed to danger

A PSV test result will be classified as failed to danger when any of the following have occurred:

- the relief pressure is >110% of the CDSP or live lift (if conducted on steam system as per relevant standard)

- upon inspection after disassembly, there is evidence of:
  - spring damage (incorrect rated spring, reduced spring length, corrosion, scoring or cracking) to the extent that it may reasonably be expected to cause the valve to fail to open within 110% of its CDSP
  - fouling, galling or sticking of any components to the extent that it may reasonably be expected to cause the valve to fail to open within 110% of its CDSP, while in service. For fouling, galling or sticking that could not prevent the PSV from lifting within 110%, the test should be considered to have failed safe
  - the bellows (where fitted) is found to be leaking or significantly damaged, or the vent path is blocked/obstructed
  - the pilot diaphragm (where fitted) is found to be leaking or significantly damaged, or the vent path is blocked/obstructed
  - if PSV is POP type, the valve must not simmer and fully open
  - blockage or leakage of impulse and sensing lines

API RP 581 allows operators to adopt a risk-based approach to PRD testing which takes into consideration prior inspection results (eg pass, failed to danger, etc), probability of failure (POF) and consequence of failure (COF) to set the next inspection frequency for each PRD. A risk-based approach allows for a more quantified approach to risk and guides operators to either reduce testing frequency, allow flexibility to extend inspection timelines and verify whether replacement or continued inspection is suited.

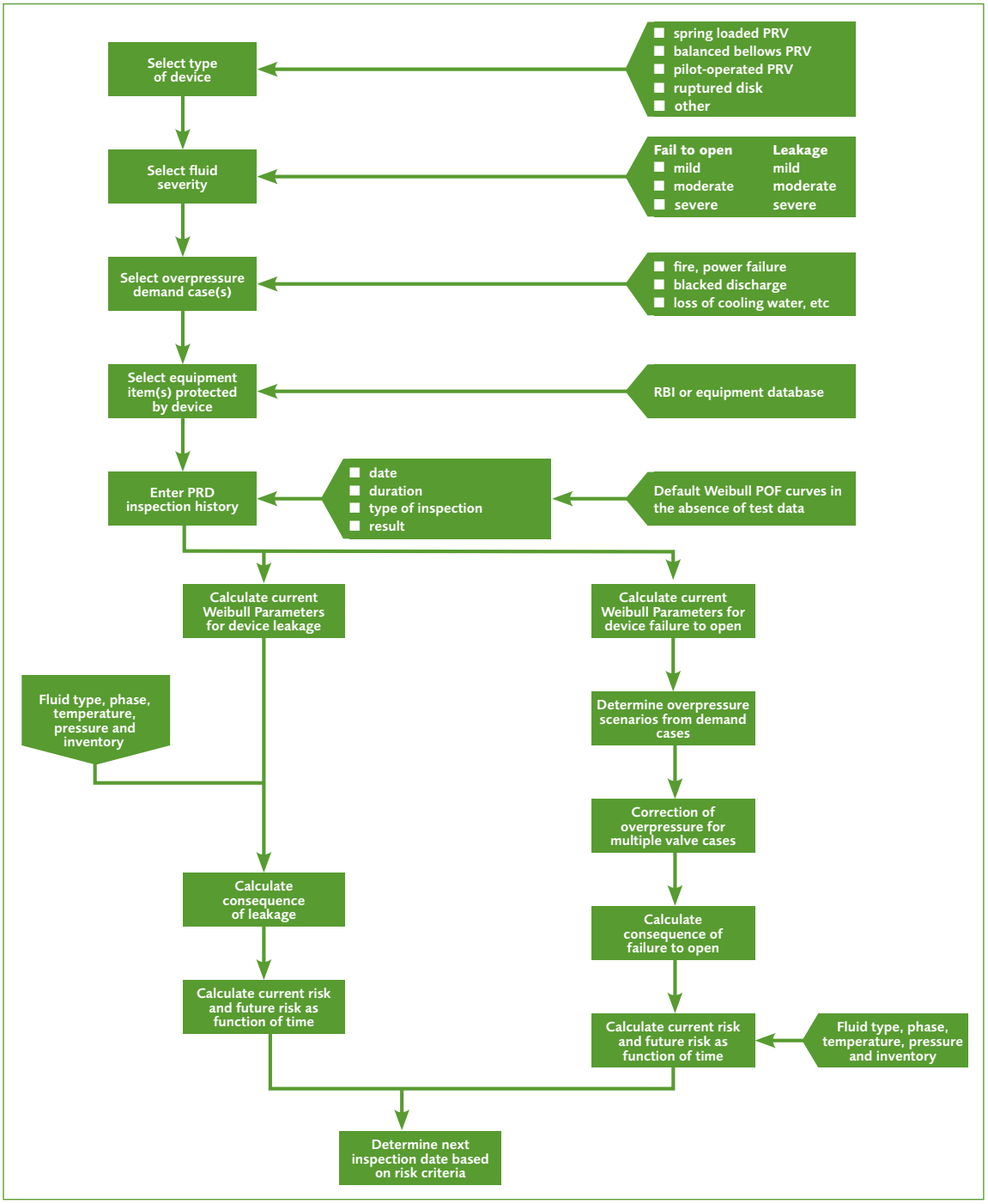


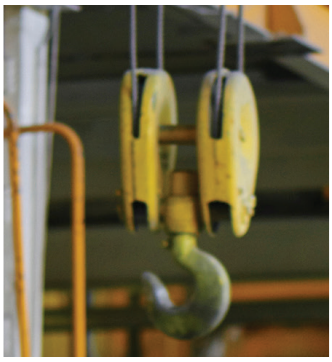
Figure 2: Adapted from Extract API 581–2008 – Risk Based Inspection approach to PRD maintenance

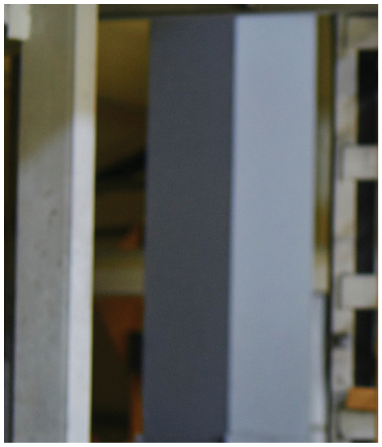
Section 2 – bursting disk (BDs) and rupture pin valves (RPVs)

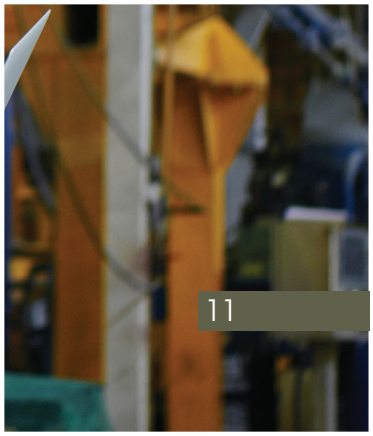
Performance testing requirements for BDs and RPVs these activities are required to be conducted by a competent person who is familiar with failure mechanisms and installation requirements:

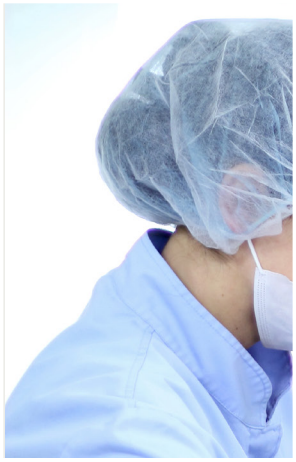
Three activities typically required for testing BDs and RPVs:

- **continuous or daily online testing to ensure integrity of BDs for those that provide integrity seal to PSV or alternate path for flame arrestors:**
  - BDs will be on a daily external visual inspection/testing routine or operational surveillance task to determine integrity of the disk
  - or have the cavity space monitoring/alarmed to ensure integrity of the seal
- **interval based online external visual inspection – nominally 6–12 months:**
  - BDs will be on an external visual inspection routine or operational surveillance task to determine integrity of the disk
- **scheduled testing and recertification – typically 12– 84 months for BDs and RPVs, depending on service and prior inspection history:**
  - the interval shall not exceed the internal inspection of the item of pressure equipment it protects











Online external visual inspection bursting disk and rupture pin valve (RPV) – pass/fail criteria:

A BD and RPV test result can be classified as passed, failed safe, or failed to danger, as described below:

Pass

A BD/RPV test result will be deemed as a pass when all have been satisfied:

- the correct valve is installed in the correct direction, has the correct identification tag number and relieving pressure as per the P & ID or data sheet
- <30% surface corrosion on the pipework or body (as this shows potential for pitting due to coating damage)
- there is no blockage/damage or leakage of inlet and discharge lines

Failed safe

A BD/RPV will be deemed to have failed safe if it does not meet the requirements of Section 1 and does not meet the requirements of failed to danger:

- the valve has lost its identification or last recertification tag, but is confirmed as being the correct valve installed
- RP has signs of damage or corrosion (since these modes will cause early relieving pressure)

Failed to danger

A BD/RPV test result will be classified as failed to danger when any of the following have occurred:

- the valve has had the incorrect bolt torquing applied (if specified for BD), incorrect rupture pin installed or physical distortion/damage
- the valve last inspection is not within the certification date
- the valve has failed 'fitness for service' assessment
- the PSV has a closed valve or blind installed upstream or downstream of online PRD (typically locked open/car seal/fortress/castell key)
- vent stacks, discharge piping and downstream receiving vessels are not properly supported

BD/RPV test certification:

A BD test result can be classified as passed, failed safe or failed to danger.

Pass

A BD/RPV test result will be deemed as a pass when all have been satisfied:

- **BD is in good condition and shows no signs of damage/deformation or corrosion**
- **RPV is in good condition and shows no signs of damage/deformation or corrosion**

Failed safe

A BD/RPV will be deemed to have failed safe if it does not meet the requirements of Section 1 pass and has not failed to danger:

A valve will be deemed to have failed safe if:

- **it has signs of damage or corrosion (since these modes will cause early relieving pressure)**
- **or if there is minor restriction/blockage on the inlet line**

Failed to danger

A BD/RPV will be classified as failed to danger when any of the following have occurred:

- **if the BD is used for a hygiene seal and has lost integrity of seal (that is discovered via certification process and not daily or online monitoring. It may also be used for pressure relief of flame arrestors or the like and loss of the seal will allow air/contamination of system**
- **if the device is inspected and found to be impaired or blocked to limit its ability to relieve flow eg build up on RPVs piston seal, or BD found installed in reverse position, is coated (eg may relieve at higher than design pressure)**

Applicable codes

American National Standards Institute/American Society of Heating, Refrigerating, and Air-Conditioning Engineers 15–2016, Safety Standard for Refrigeration Systems.

American National Standards Institute/International Institute of Ammonia Refrigeration 2–2014 American National Standard the Safe Design of Closed-Circuit Ammonia Refrigeration Systems standard.

AS 1210–2010 Pressure Vessels, Standards Australia, ISBN 978-0-7337-9687-6. Sydney, Australia.

AS 1271–2003 Safety valves/other valves/liquid level gauges and other fittings for boilers and unfired pressure vessels, Standards Australia, ISBN 0-7337-5453-8. Reconfirmed 27/05/2016. Sydney, Australia.

AS 1358–2004 Bursting Discs and Bursting Disc Devices – Guide to Application, Selection, and Installation (ISO 6718), Standards Australia, ISBN 0-7337-6345-6. Sydney, Australia.

AS/NZS 3788–2006 Pressure Equipment – In service inspection, Standards Australia, ISBN 0-7337-7657-4. Reconfirmed 20/01/2017.

ASME Boiler and Pressure Vessel Code, Section VIII (Pressure Vessels Division l), 2001 ed., 2002 addenda, American Society of Mechanical Engineers, New York.

API Recommended Practice 520, Parts I and II, Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries, 7th ed., American Petroleum Institute, Washington, D.C., January 2000.

API Recommended Practice 521, Guide for Pressure-Relieving and Depressuring Systems, 4th ed., American Petroleum Institute, Washington, D.C. 1997.

API Standard 527, Seat tightness of pressure relief valves, American Petroleum Institute, Washington, D.C. 2014.

API Recommended Practice 580 Risk Based Inspection, American Petroleum Institute, Washington, D.C. 2002.

API Recommended Practice 581 Risk Based Inspection Technology, American Petroleum Institute, Washington, D.C. 2000.

API Standard 2000 – Venting Atmospheric & Low Pressure Storage Tanks, American Petroleum Institute, Washington, D.C. 1998.

API Recommended Practice 576 Inspection of Pressure-Relieving Devices, American Petroleum Institute, Washington, D.C. 1992.

API Standard 650 Oil Storage Tanks, American Petroleum Institute, Washington, D.C. 2007.

BS 2915 – Specification for bursting discs and bursting disc devices.

European Committee for Standards. (2016) EN 13136 Refrigerating Systems and Heat Pumps – Pressure Relief Devices and Their Associated Piping – Methods for Calculation standard.

European Committee for Standards. (2016). BS EN 378 Refrigerating Systems and Heat Pumps – Safety and Environmental Requirements standard.

NFPA58 Liquefied Petroleum Gas Code. National Fire Protection Association, 2014.

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