Overpressure Protection of Pressure Vessels

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THE NATIONAL BOARD
OF BOILER AND PRESSURE VESSEL INSPECTORS
SINCE 1919

Overview of Session

- Compare/contrast Section I and IV provisions for Overpresssure Protection with Section VIII
- Overview of Section VIII pressure relief requirements
- Process for review of Section VIII pressure vessel overpressure protection installations

How do Jurisdictions become Involved?

- Formally through requirements for operating permits, installation inspection or periodic inspection (NBIC refers to Original Code of Construction)
- Informally: may be asked to comment on installations, or assist other agencies when issues arise
- “Accidentally” when there is a pressure equipment incident

Jurisdictional Coverage

Tabulation of ASME Boiler and Pressure Vessels Codes (from NB web page)

Requires Section VIII

States: 41

Provinces: 12

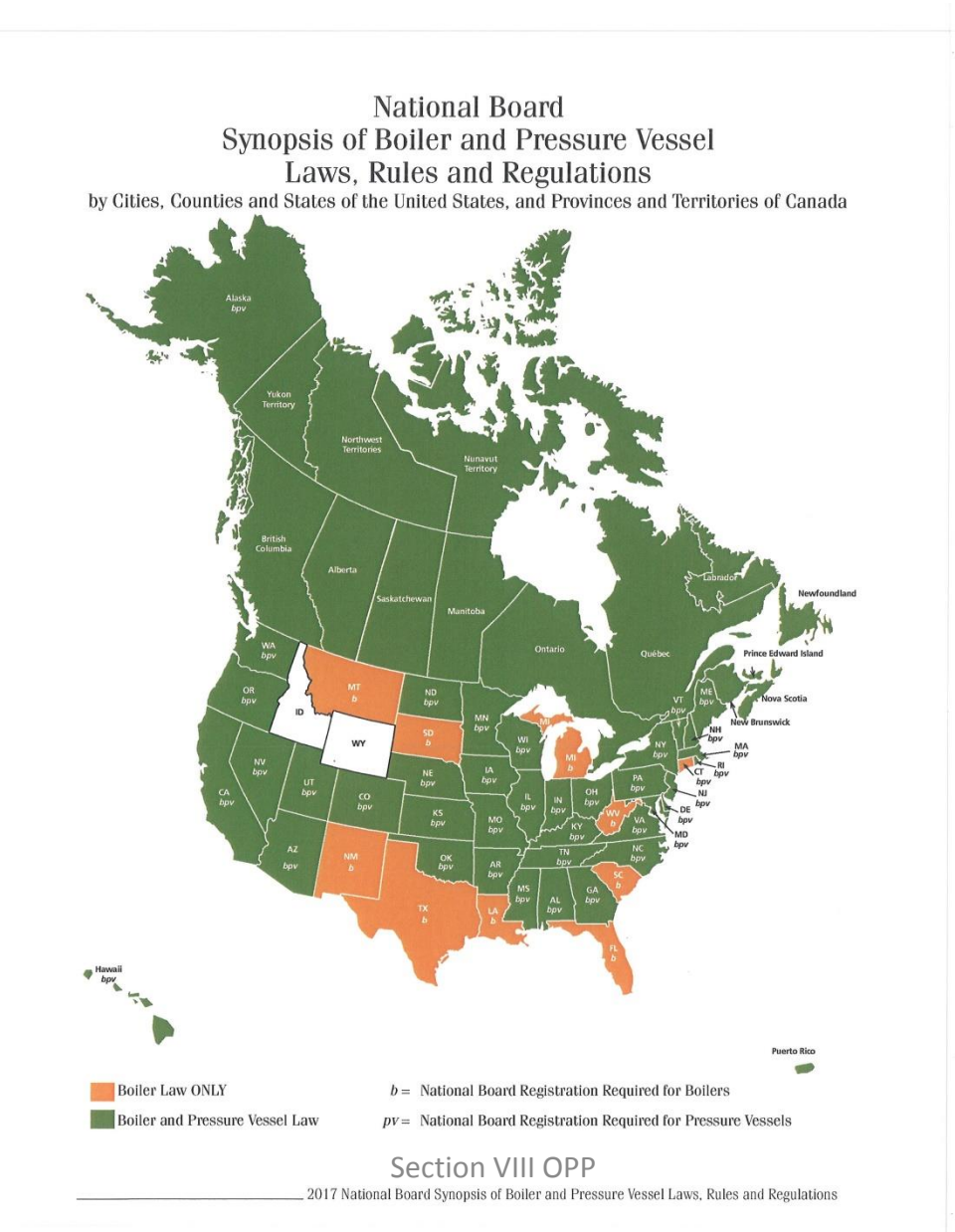
Cities: 15

Do not require Section VIII

States: 9, Provinces: 1, Cities: 1

(slightly different numbers when using *Stamping Requirements by Jurisdiction*)

Jurisdictional Coverage



Section VIII OPP

2017 National Board Synopsis of Boiler and Pressure Vessel Laws, Rules and Regulations

Example

State of Ohio

- All boilers and pressure vessels proposed for use in the state of Ohio shall be designed, constructed, installed, altered, repaired, maintained, and operated in accordance with the rules adopted by the board as prescribed in Chapters 4101:4-1 to 4101:4-10 of the Administrative Code, except as follows:
- (A) Unless exempt by paragraph (B) of rule 4101:4-2-01 of the Administrative Code, upon completion of an installation and in accordance with rules 1301:3-5-01 to 1301:3-5-09 of the Administrative Code, all boilers shall be inspected by a general or special inspector who holds an Ohio commission issued by the superintendent.
- (A) All existing boilers and pressure vessels and the associated equipment, controls, devices, and safeguards shall be maintained in a safe and sanitary condition, in good working order, and free of leaks and defects. The owner or the owner's designated agent shall be responsible for the maintenance of such boilers and pressure vessels and associated equipment, controls, devices, and safeguards.

Sections I and IV

Section I: Overpressure protection is provided by the boiler manufacturer.

Documented on boiler data report: (for example P2 form) and P7 form when necessary.

Section IV: Overpressure protection requirements are defined by boiler manufacturer who applies *safety or safety relief valve capacity (minimum)* to nameplate (HG-530.1) or *Maximum allowable input* in Btu/hr (HLW-602.1)

Section VIII

UG-125(a)

…all pressure vessels … irrespective of size or pressure, shall be provided with overpressure protection in accordance with the requirements of UG-125 through UG-138 (pressure relief devices) or with overpressure protection by system design in accordance with UG-140, or a combination of the two.

Section VIII

UG-125(a)(1)

(1) It is the **user's** or his/her designated agent's responsibility to identify all potential overpressure scenarios and the method of overpressure protection used to mitigate each scenario.

(2) It is the responsibility of the **user** to ensure that the required overpressure protection system is properly installed prior to initial operation.

Section VIII

UG-125 (a)(4) The overpressure protection system need not be supplied by the vessel Manufacturer.

What is a User?

Section VIII, Appendix NN

"Guidance to the Responsibilities of the User and Designated Agent"

(1) " … a "user" as defined in this Division is an entity that defines the design conditions and parameters of the pressure vessel under consideration and communicates these conditions and parameters to the Manufacturer."

What is a User?

The user could have a *designated agent*:

(a) The designated agent may be:

(1) a design agency specifically engaged by the user

(2) the Manufacturer of a system for a specific service that includes a pressure vessel as a part that is purchased by the user, or

(3) an organization that offers pressure vessels for sale or lease for specific services

Section VIII overview

UG-125(a)(3)

If a pressure relief device(s) is to be installed, it is the responsibility of the **user** or his/her designated agent to size and select the pressure relief device(s) based on its intended service. Intended service considerations shall include, but not necessarily be limited to, the following:

(-a) normal operating and upset conditions

(-b) fluids

(-c) fluid phases

Section VIII overview

UG-125(b) Unfired steam boilers equipped with pressure relief devices as required by Section I…

Capacity related requirements

UG-125(c) lists overpressure limits.

Single device: Shall prevent the pressure from rising more than 10% or 3 psi above MAWP whichever is greater

Multiple devices: Pressure can not rise more than 16% or 4 psi above MAWP, whichever is greater

(Need **system capacity** to evaluate these requirements)

Capacity related requirements

UG-125(c)(2) When a vessel can be exposed to fire or other unexpected source of external heat, pressure cannot rise more than 21% above MAWP

Can be same the overpressure protection device as previous or a supplemental device.

(Again, **system capacity** is needed)

Capacity related requirements

UG-125(c)(3)

- Non-refrigerated liquefied compressed gases at ambient temperate, with no permanent supply connection
- Intended primarily for protection against fire or unexpected external heat
- Vessel has sufficient ullage to protect against being liquid filled

Valves for this service are rated at 20% overpressure (**need system capacity**) and have a positive set pressure tolerance

Capacity related requirements

UG-133(d)

(d) Heat exchangers and similar vessels shall be protected with a pressure relief device of sufficient capacity to avoid overpressure in case of an internal failure. (How much is sufficient?)

Other capacity related requirements

UG-135 (b)(1)

The opening through all pipe, fittings, and nonreclosing pressure relief devices (if installed) between a pressure vessel and its pressure relief valve shall have at least the area of the pressure relief valve inlet. The characteristics of this upstream system shall be such that the pressure drop will not reduce the relieving capacity below that required or adversely affect the proper operation of the pressure relief valve.

Other capacity related requirements

UG-135(f)

The size of the discharge lines shall be such that any pressure that may exist or develop will not reduce the relieving capacity of the pressure relief devices below that required to properly protect the vessel, or adversely affect the proper operation of the pressure relief devices.

Jurisdictional Actions

Field Inspector Level

Basic evaluation of installed pressure relief devices including:

1) Relationship of device set pressure to MAWP

2) Correct type of device for the application:

Steam, gas, liquid etc.

3) Certification status of device

Jurisdictional Actions (in the field)

4) Installation condition (includes pipe sizes and length, drainage, safe discharge, combined areas, device condition etc.)

Also UG-125(d):

Pressure relief devices shall be located and installed so they are accessible for testing, inspection, replacement and repair…

Jurisdictional Actions (in the field)

5) Evaluation of “relief path”

From Appendix M:

pressure relief path: consists of all equipment, pipe, fittings, and valves in the flow path between any protected equipment and its pressure-relieving device, and between the pressure-relieving device and the discharge point of the relieving stream.

May include isolation valves for pressure relief valves

Jurisdictional Actions (in the field)

6) Evaluation of changes

- Has the process been changed?
- Has the protected equipment been changed?
- Has the pressure relief device been replaced?

Jurisdictional Actions (in the field)

7) Recognition of unique circumstances

- Overpressure Protection by System Design (UG-140)
- Use of isolation valves
- Large changes in the process or protected equipment

Avoid system capacity evaluations by the Inspector

Jurisdictional Actions

Accepting new or revised installations, and supporting the field inspector

- “Code” responsibility remains with the User
- When needed, calculations should come from them
- Be able to do reviews of the design process employed by the user
- Be aware of unique circumstances

Jurisdictional Actions

Process for Jurisdictional design review:

1. Understand protected equipment

   Data reports, description of the installation

2. Understand the system where the protected equipment is installed (P&ID drawings are helpful)
3. Understand the basic process in the protected equipment.
4. Audit that the User has done a thorough review, including complete installation and *device sizing*.

Jurisdictional Actions

Code gives guidance for sizing by reference only.

Appendix M-13: **Sizing of Pressure Relief Devices for Fire Conditions** lists a number of guidance documents including API-520 and 521

UG-140 (a)(2) also references API-521

Basic API-520 requirement

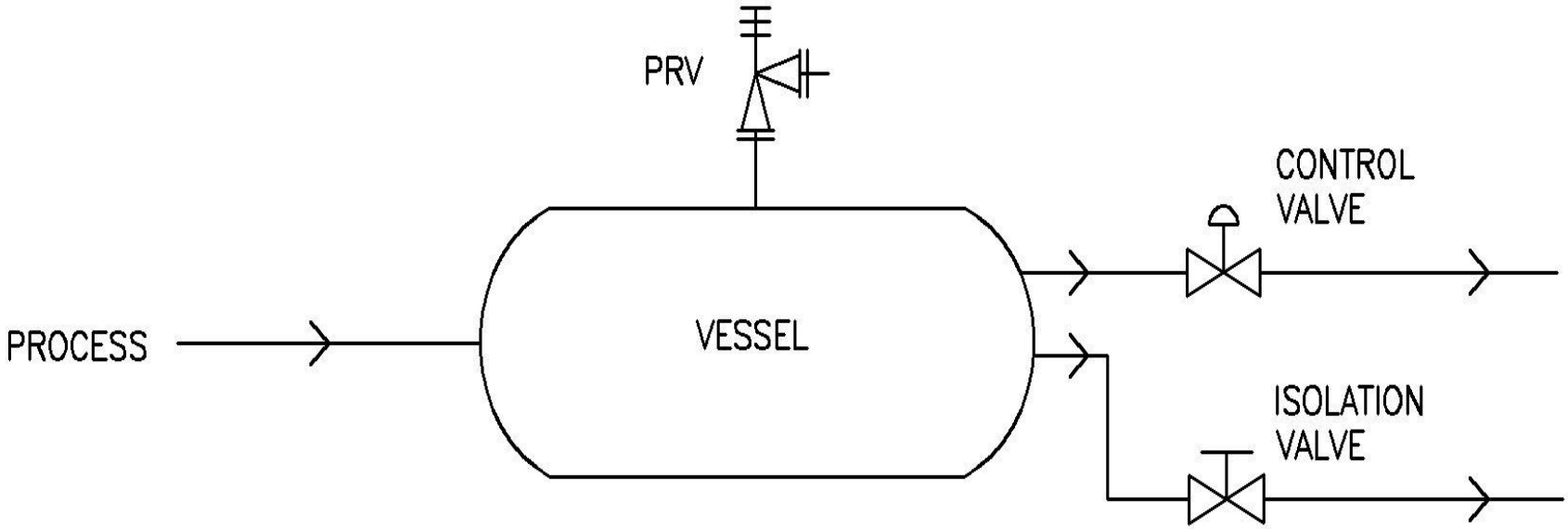
"To establish the size and design of a pressure relied device for any application, the designer shall first determine the conditions for which overpressure protection may be required. Care should be exercised on establishing the various contingencies that could result in overpressure." (par. 5.1.1)

Basic API-520 requirement

"The contingencies that can cause overpressure shall be evaluated in terms of the pressures generated and the rate at which fluids are required to be relieved." (par. 5.1.2)

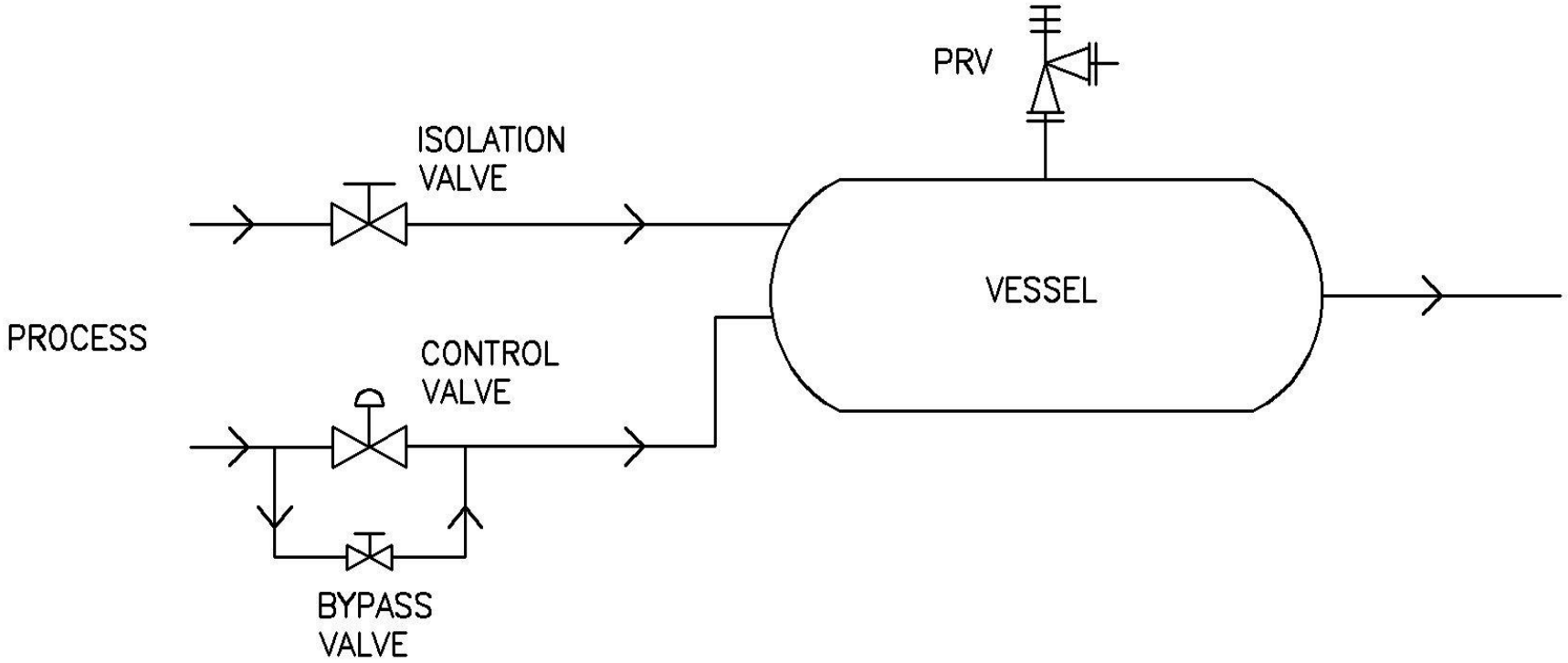
Potential for Overpressure

Closed outlets on vessels (API-521, par. 4.3.2)



Potential for Overpressure

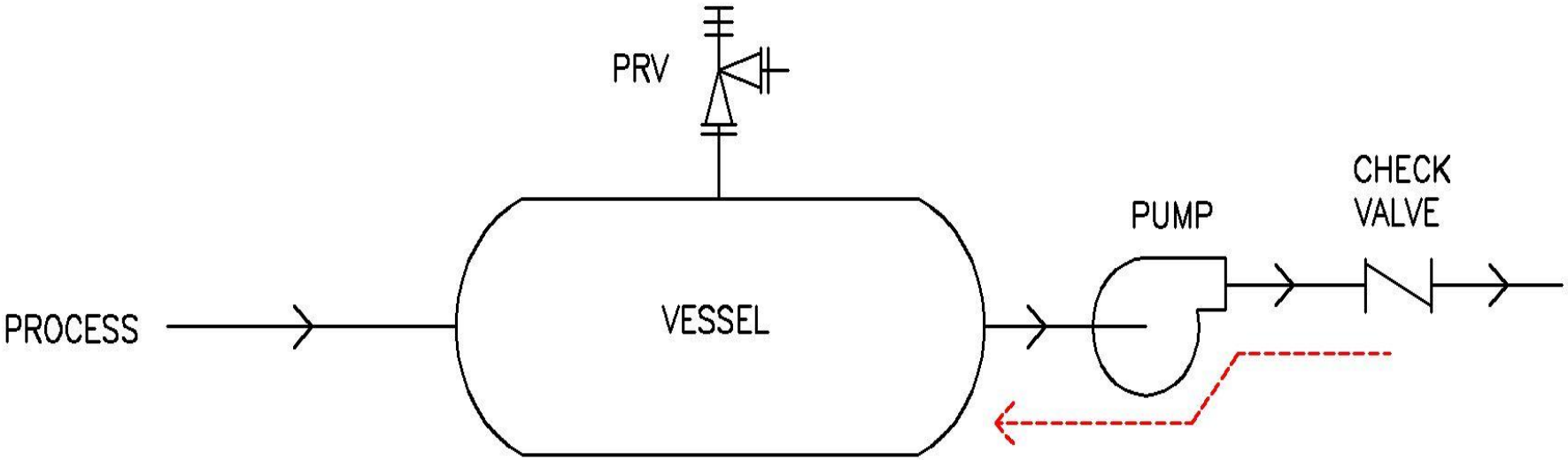
Inadvertent valve opening (API-521, par. 4.3.3)



Consider bypass valve in open position

Potential for Overpressure

Check valve leakage or failure (API-521, par. 4.3.4)



One step to limit capacity: Install 2 devices in series

Potential for Overpressure

Utility failure, both complete and partial (API-521, par. 4.3.5)

Examples

- Electricity: pumps, fans compressors, instrumentation, motor operated valves
- Cooling fluid (water or other): Condensers coolers, jackets on rotating equipment
- Instrument air: Transmitters, controllers, control valves, alarm and shutdown systems
- Process steam: Turbines for pumps, compressors, blowers, combustion fans
- Steam or other heating fluid: heat exchangers
- Fuel: boilers, reheaters, compressors, gas turbines
- Inert gas: seals, catalytic reactors, purges for instrumentation

Potential for Overpressure

Process changes/ chemical reactions (API-521, par. 4.3.15)

- Failure of Controls
- Failure of outlet control devices (no credit for “fail- stationary” valves)
- Runaway chemical reactions: DIERS methodology may be used
  - Bench tests used to simulate upset conditions
  - Two phase flow needs to be accounted for

Potential for Overpressure

Hydraulic Expansion (API-521, par. 5.14)

Overpressure caused by increase in liquid volume caused by an increase in temperature ("thermal relief") – a ¾ x 1 valve is often used

Should also be considered for gas storage vessels.

Potential for Overpressure

Heat-Transfer Equipment Failure (API-521, par. 5.19)

Internal failure of high to low pressure side in a heat exchanger. Usually modeled as complete break of a single tube (flow area is the internal area of two tubes)

Potential for Overpressure

Fire case (API-521, par. 5.15)

- Used for “external pool fires”
- Primarily for liquid /gas systems
- Vessel wetted area used (limited to 25 ft. above ground or less)
- Credit may be taken for insulation
- Very high temperatures may cause vessel rupture, and additional protective methods may be required
  - -Water cooling of vessel
  - -Depressurizing systems
  - -Vessel siting

Arrangement of Systems

UG-125 (g)

(g) The pressure relief devices required in (a) above need not be installed directly on a pressure vessel when either of the following conditions apply:

(1) the source of pressure is external to the vessel and is under such positive control that the pressure in the vessel cannot exceed the maximum allowable working pressure at the operating temperature except as permitted in (c) above (see UG-98), or under the conditions set forth in Nonmandatory Appendix M.

Arrangement of Systems

Appendix M-1

(a) The rules in this Appendix are for general information only, because they pertain to the installation and operation of pressure vessels, **which are the prerogative and responsibility of the law enforcement authorities** in those states and municipalities which have made provision for the enforcement of Section VIII.

(b) It is permissible to use any departures suggested herein from provisions in the mandatory parts of this Division **when granted by the authority having legal jurisdiction** over the installation of pressure vessels.

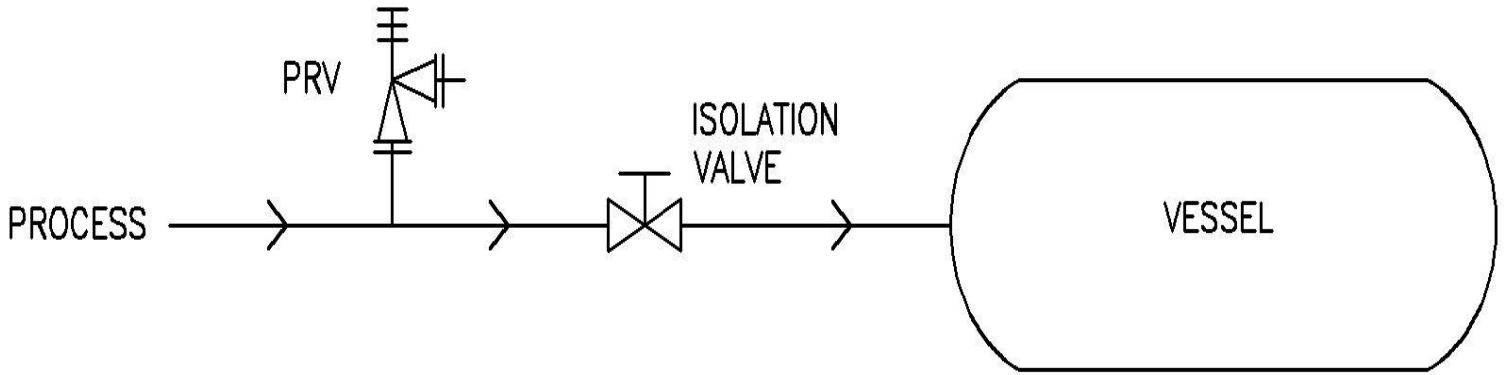
Arrangement of Systems

M-5.5 STOP VALVES PROVIDED IN SYSTEMS FOR WHICH THE PRESSURE ORIGINATES EXCLUSIVELY FROM AN OUTSIDE SOURCE

A vessel or system [see UG-133(c)] for which the pressure originates from an outside source exclusively may have individual pressure-relieving devices on each vessel, or connected to any point on the connecting piping, or on any one of the vessels to be protected. Under such an arrangement, there may be stop valve(s) between any vessel and the pressure-relieving devices, and these stop valve(s) need not have any administrative controls, valve operation controls, or valve failure controls, provided that the stop valves also isolate the vessel from the source of pressure.

Arrangement of Systems

Have remaining causes of overpressure been considered?



Special Conditions

UG-140 OVERPRESSURE PROTECTION BY SYSTEM DESIGN

(a) A pressure vessel does not require a pressure relief device if the pressure is self-limiting (e.g., the maximum discharge pressure of a pump or compressor), and this pressure is less than or equal to the MAWP of the vessel at the coincident temperature and the following conditions are met:

(1) The decision to limit the pressure by system design is the responsibility of the user.

Special Conditions

UG-140 cont.

(2) The user shall conduct a detailed analysis to identify and examine all potential overpressure scenarios. (Pressure cannot exceed MAWP)

(3) The results of the analysis shall be documented and signed by the individual in responsible charge of the management of the operation of the vessel.

Special Conditions

UG-140 cont.

(b) If the pressure is not self-limiting, a pressure vessel may be protected from overpressure by system design or by a combination of overpressure by system design and pressure relief devices, if the following conditions are met.

Requires detailed design review and signed report.

Code acknowledges: “If no pressure relief device is to be installed, acceptance of the jurisdiction may be required.”

Special Conditions

Internal Explosion (Deflagration)

Rupture disks or explosion panels should be used instead of pressure relief valves

Control explosive mixtures (purge with inert gas, suitable startup or shutdown procedures)

Active systems for explosion prevention

(Ref.: NFPA 68, Guide for Venting of Deflagrations, NFPA 69, Deflagration Pressure Containment)

Excluded Conditions

Transient Pressure Surges (API-521, par. 4.3.13)

Water and steam hammer: Often caused by quick closing valves: limit valve closing speed, install pulsation dampeners

Condensate-induced hammer: Isolation of steam bubble by cold condensate with rapid collapse of steam bubble: eliminate cold condensate by traps, steam pipe slope, control of startup processes

Excluded Conditions

Jet Fires (API-521, par. 5.16)

Jet fire causes intense, localized overheating of the metal wall where the fire impinges. Failure can occur without increasing the pressure in the vessel.

Consider programs for prevention of leaks, fireproofing, depressurizing systems, and isolation of the leak. Equipment and flange orientation and emergency response are also considered.

Specification of Overpressure Protection

All sizing scenarios are considered, and pressure relief devices to cover the most severe case is supplied.

“The simultaneous occurrence of two or more unrelated causes of overpressure (known as double or multiple jeopardy) is not a basis for design.” (API-521, par. 4.2.1)

Note: Not all multiple failures are double jeopardy.

Example: Leaking check valve during pump failure

Conclusion

Comprehensive design of a complete overpressure protection system should be a detailed exhaustive process.

Jurisdictions need to rely on the work done by the user, but should have enough knowledge about the process to know what to look at.

Assistance can be obtained from other agencies and multiple standards. The National Board will be willing to assist where necessary.

Thanks!