Pressure Relief Streams

Part One General Overview

What is a Protection Device or System

It is usually described as devices available to protect plant from overpressure conditions.

What is a Relief Stream System?

- A relief device, and
- Associated lines and process equipment to safely handle the material ejected

Safety Relief System

- Entirely self-contained, no external power required
- The action is automatic - does not require a person
- Usually, goal is to achieve reasonable pressure

  - Prevent high (over-) pressure
  - Prevent low (under-) pressure

- The capacity should be for the “worst case” scenario

What is the Hazard?

- Despite safety precautions …
  - Equipment failures
  - Human error, and
  - External events, can sometimes lead to …
- Increases in process pressures beyond safe levels, potentially resulting in …
- *OVERPRESSURE due to a RELIEF EVENT*

RELIEF SYSTEMS IN PROCESS PLANTS

- Increase in pressure can lead to rupture of vessel or pipe and release of toxic or flammable material
- Also, we must protect against unexpected vacuum!
- Naturally, best to prevent the pressure increase large disturbances, equipment failure, human error, power failure, ...
- Relief systems provide an exit path for fluid
- Benefits: safety, environmental protection, equipment protection, reduced insurance, compliance with governmental code

Most Common Causes of Relief Events?

- External fire
- Flow from high pressure source
- Heat input from associated equipment
- Pumps and compressors
- Ambient heat transfer
- Liquid expansion in pipes and surge

Potential Lines of Defense

- Inherently Safe Design
  - Low pressure processes
- Passive Control
  - Overdesign of process equipment
- Active Control
  - Install Relief Systems design

Why Use a Relief System?

- Inherently Safe Design simply can’t eliminate every pressure hazard
- Passive designs can be exceedingly expensive and cumbersome
- Relief systems work!

Safety Valve or Relief Valve?

Pressure Safety Valve' and 'Pressure Relief Valve' are commonly used terms to identify pressure relief devices on a vessel. Frequently these terms are used interchangeably and it may entirely depend on a particular project or company standards to identify all the pressure relief devices either as 'safety valves' or as 'relief valves' or sometimes even as 'safety relief valves. In general a safety valve handles gases and a relief valve handles liquids.

Pressure Safety Valve

Pressure Safety Valve – is the term used to describe relief device on a compressible fluid or gas filled vessel.

For such a valve the opening is sudden.

When the set pressure of the valve is reached, the valve opens almost fully.

Pressure Relief Valve

Pressure Relief Valve – is the term used to describe relief device on a liquid filled vessel.

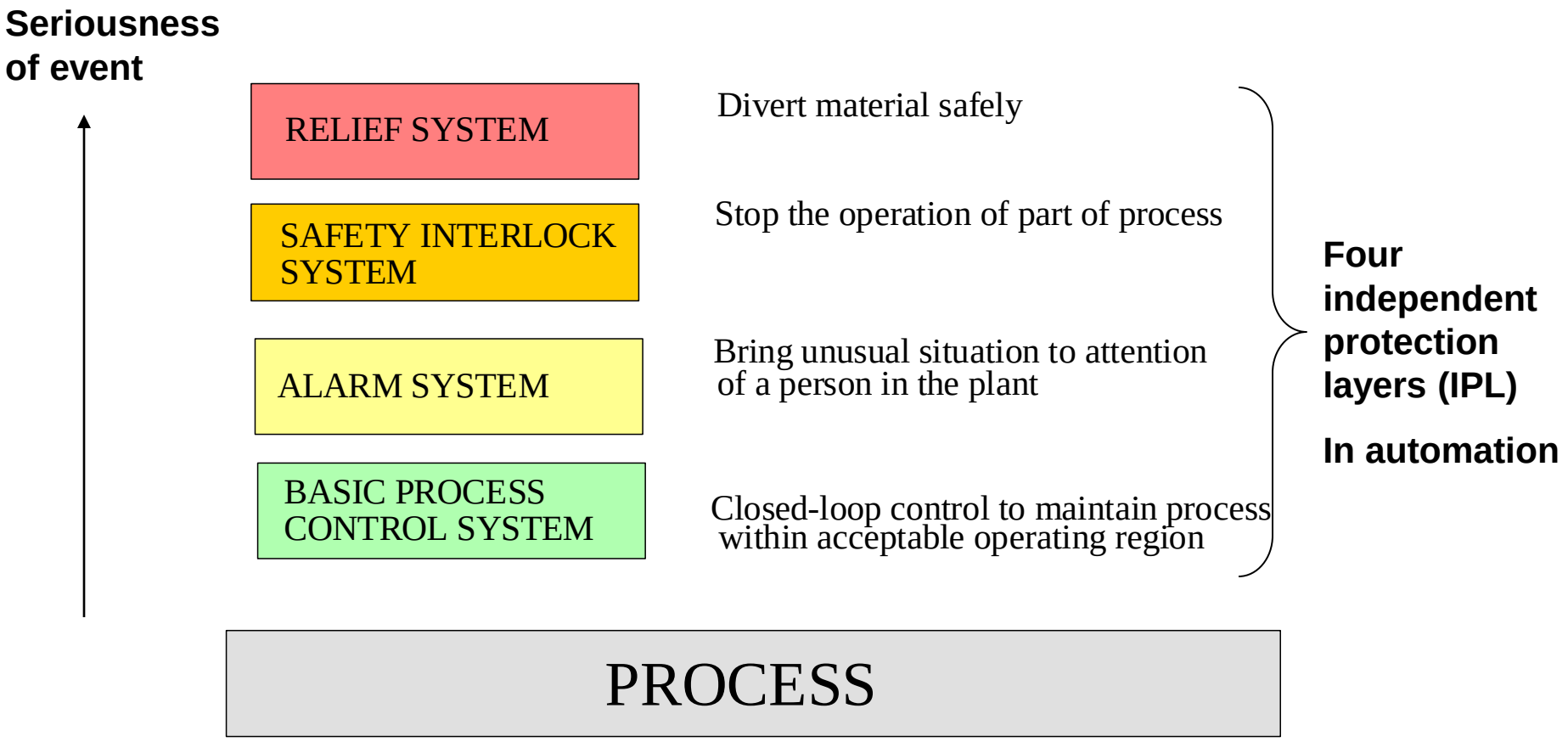
For such a valve the opening is proportional to increase in the vessel pressure.

Hence the opening of valve is not sudden, but gradual if the pressure is increased gradually.

They are sometimes referred to as thermal relief valves.

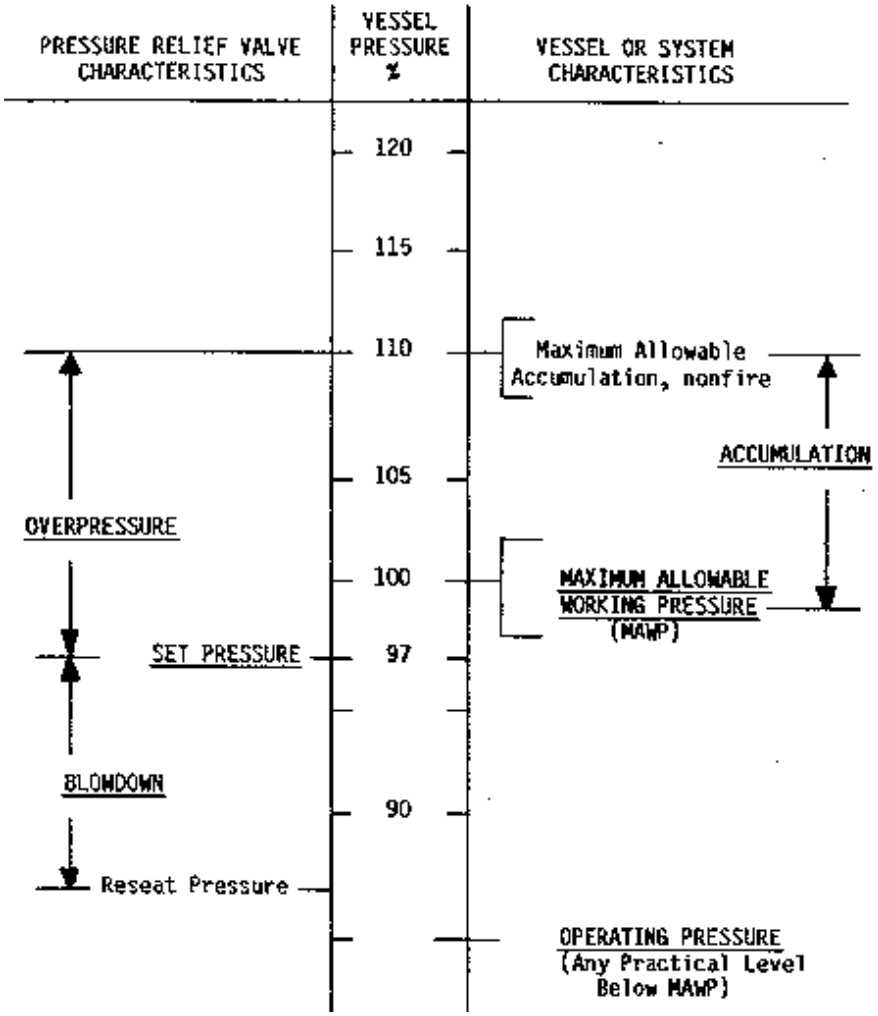
Key Concept in process Safety: REDUNDANCY

SAFETY STRENGTH IN DEPTH !



Pressure Terminology

  - MAWP
- Design pressure
- Operating pressure
- Set pressure
- Overpressure
- Accumulation
- Blowdown



Relief Device Requirements

Relieving pressure shall not exceed MAWP (accumulation) by more than:

- 3% for fired and unfired steam boilers
- 10% for vessels equipped with a single pressure relief device
- 16% for vessels equipped with multiple pressure relief devices
- 21% for fire contingency

Relief Design Methodology

LOCATE RELIEFS

CHOOSE TYPE

DEVELOP SCENARIOS

SIZE RELIEFS

CHOOSE WORST CASE

DESIGN RELIEF SYSTEM

Location of Relief System

Identify potential for damage due to high (or low) pressure (HAZOP Study)

In general, closed volume with ANY potential for pressure increase

may have exit path that should not be closed but could be either hand valve, control valve (even fail open), or blockage of line

Remember, this is the last resort, when all other safety systems have not been adequate and a fast response is required!

Locating Reliefs – Where?

- All vessels
- Blocked in sections of cool liquid lines that are exposed to heat
- Discharge sides of positive displacement pumps, compressors, and turbines
- Vessel steam jackets
- Where PHA (*Process Hazards Analysis*) indicates the need

Some Information about Relief Valves

ADVANTAGES

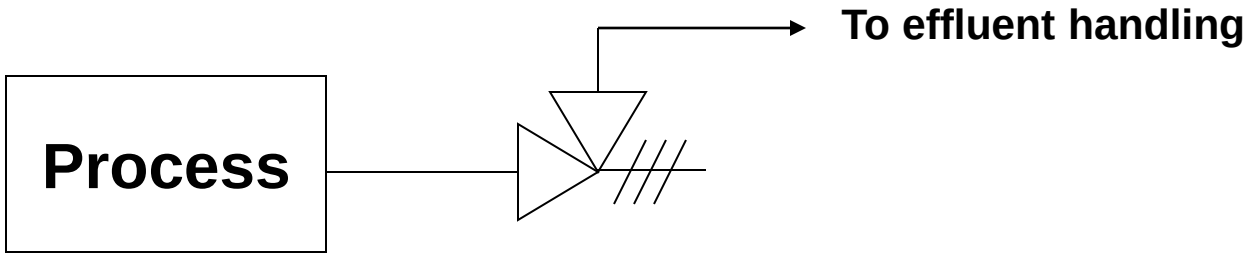
- simple, low cost and many commercial designs available
- regain normal process operation rapidly because the valve closes when pressure decreases below set value

DISADVANTAGES

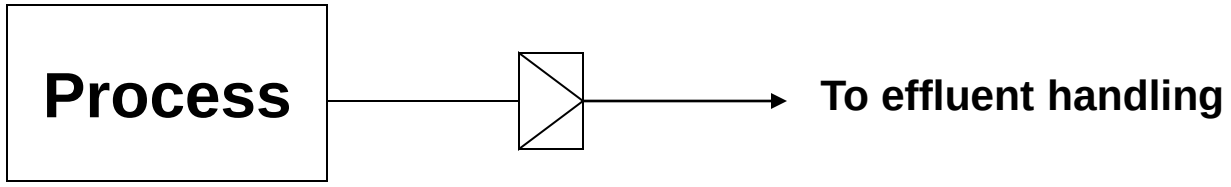
- can leak after once being open
- not for very high pressures (20,000 psi)
- if oversized, can lead to damage and failure (do not be too conservative; the very large valve is not the safest!)

Symbols used in P&I D

- **Spring-loaded safety relief valve**



- **Rupture disc**



Choosing Relief Types

- Spring or Pilot Operated Valves
- Rupture Devices

General Types of Safety Relief Valve Design

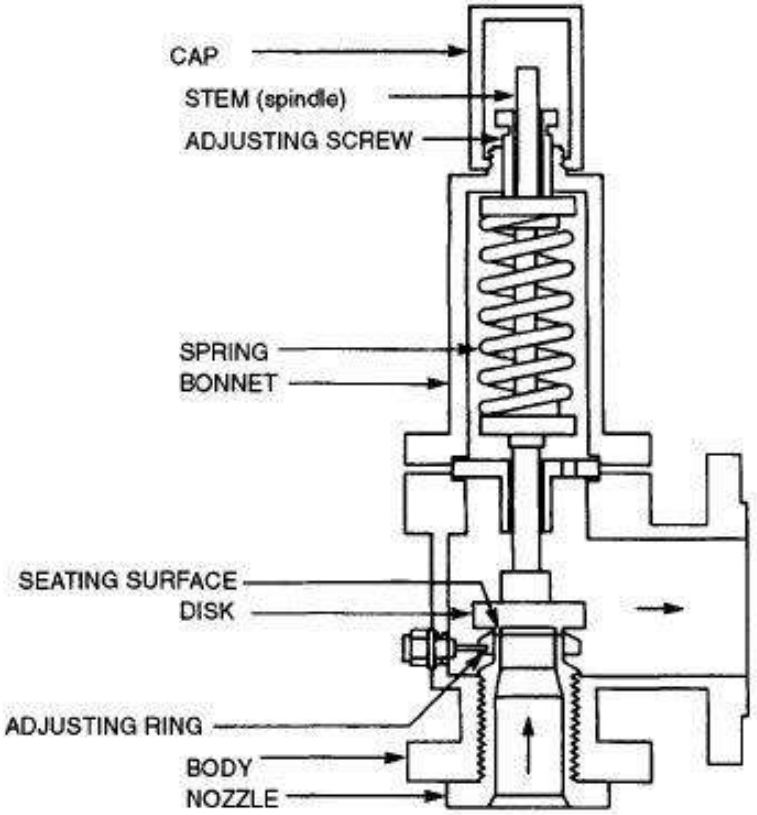
- Direct acting type
  - Oldest and most common
  - Kept closed by a spring or weight to oppose lifting force of process pressure
- Pilot operated type
  - Kept closed by process pressure

Consider Materials of Construction

Valve body material obviously needs to be the same as or a higher quality than the system the valve is protecting.

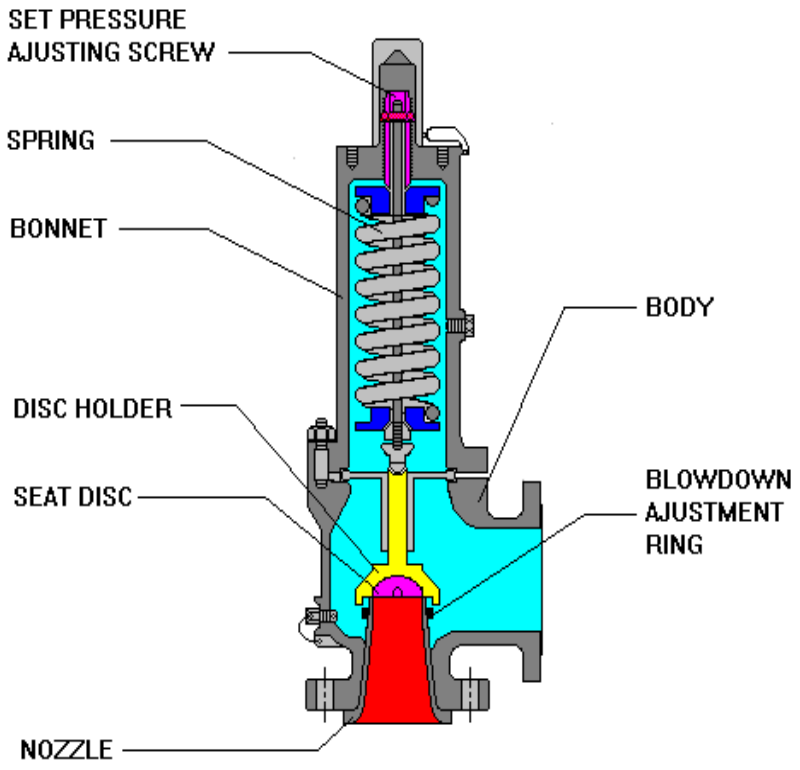
In general these will be bronze, aluminum, cast iron, cast steel, or stainless steel.

In some instances composites are used but these will almost certainly be very exceptional.



Conventional relief valve set-up

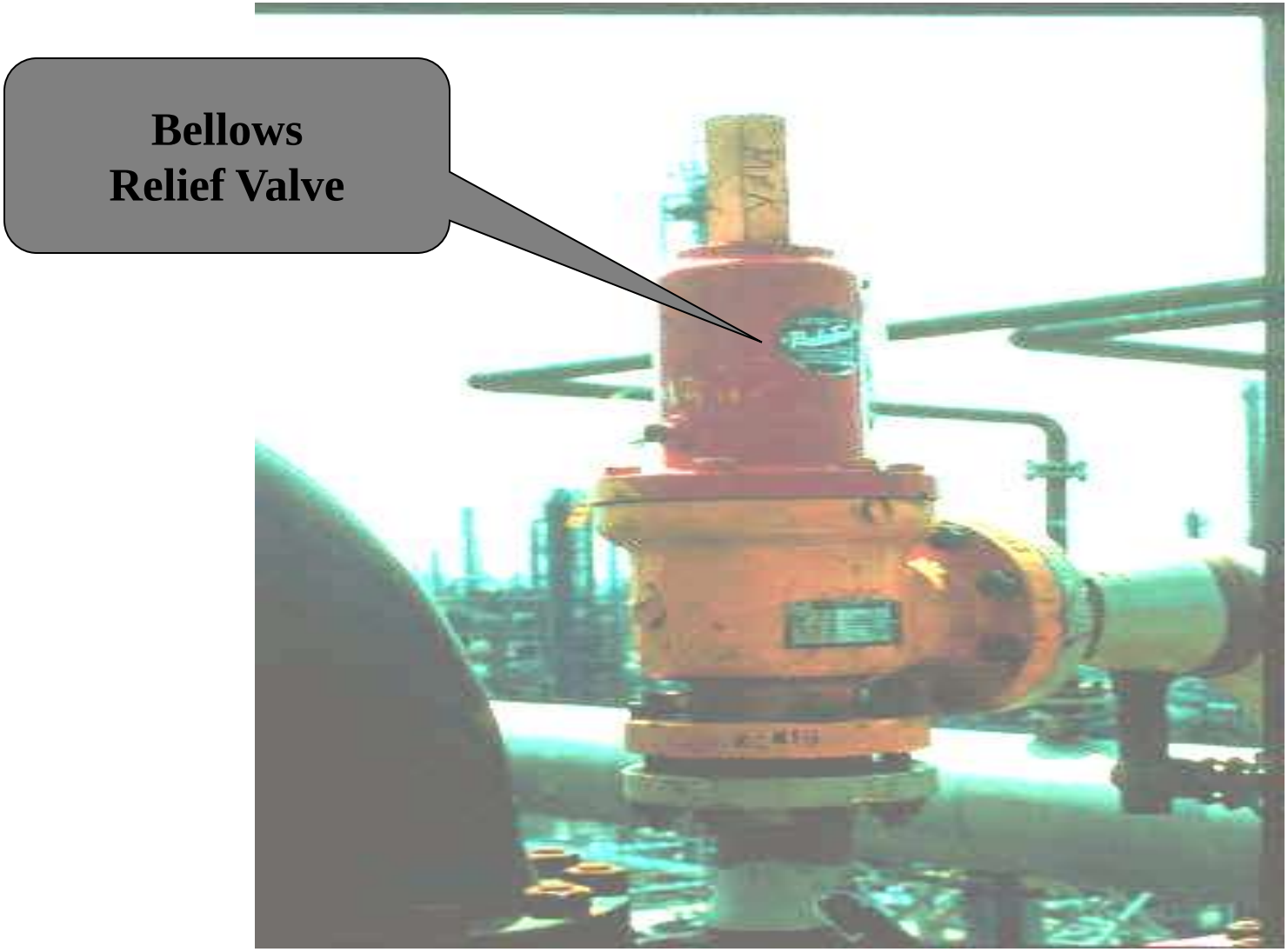
Conventional Spring Loaded Safety Relief Valve



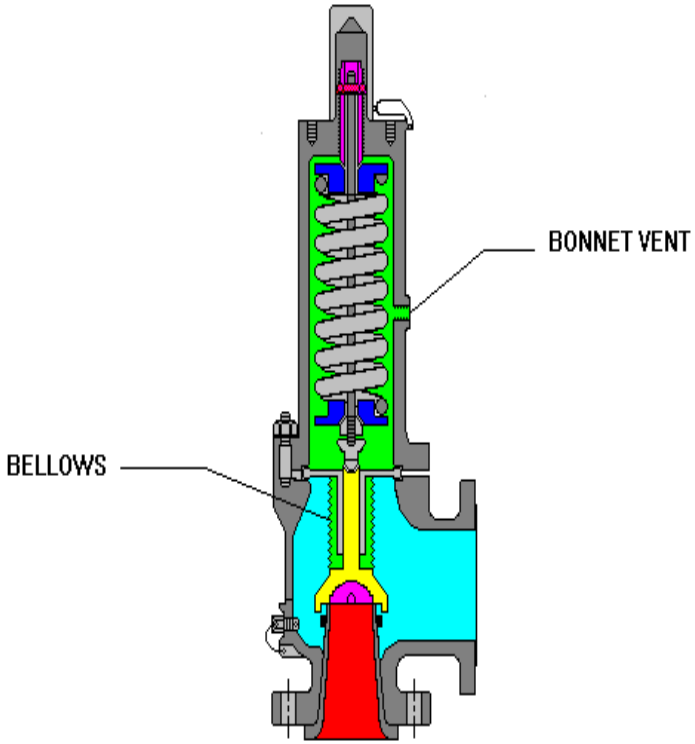
Pros & Cons: Conventional Valve

- Advantages
  - + Most reliable type if properly sized and operated
  - + Versatile -- can be used in many services

- Disadvantages
  - – Relieving pressure affected by back pressure
  - – Susceptible to chatter if built-up back pressure is too high


Bellows
Relief Valve

Spring-Operated Valves Balanced Bellows Type



Pros & Cons: Balanced Bellows Valve

- Advantages
  - + Relieving pressure not affected by back pressure
  - + Can handle higher built-up back pressure
  - + Protects spring from corrosion

- Disadvantages
  - – Bellows susceptible to fatigue/rupture
  - – May release flammables/toxics to atmosphere
  - – Requires separate venting system

A Special Issue: Chatter

- Spring relief devices require 25-30% of maximum flow capacity to maintain the valve seat in the open position
- Lower flows result in *chattering*, caused by rapid opening and closing of the valve disc
- This can lead to destruction of the device and a dangerous situation

Chatter

- Chattering is the rapid, alternating opening and closing of a PR Valve.
- Resulting vibration may cause misalignment, valve seat damage and, if prolonged, can cause mechanical failure of valve internals and associated piping.
- Chatter may occur in either liquid or vapor services

Chatter - Principal Causes

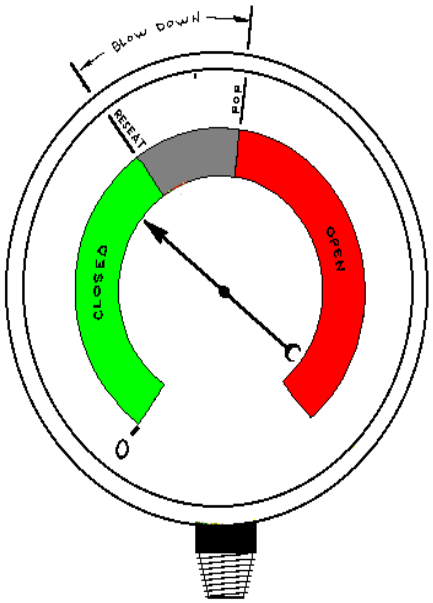
- Valve Issues
  - Oversized valve
  - Valve handling widely differing rates
- Relief System Issues
  - Excessive inlet pressure drop
  - Excessive built-up back pressure

Valve Considerations

- Oversized valve
  - Must flow at least 25% of capacity to keep valve open
  - Especially bad in larger sizes
- Valve handling widely differing rates
  - Leads to oversized valve case

Excessive Inlet Pressure Drop

- Normal PRV has definite pop and reseat pressures
- These two pressures can be noted on a gauge as shown.



Non-Piping Solutions

If you can’t change the piping

- Increase blowdown
- Install smaller PRV
- Install different type of PRV

Inlet Line Considerations

- Inlet line size must be at least equal to PRV inlet flange size
- Inlet piping should slope continuously upward from vessel to avoid traps
- Inlet piping should be heat traced if freezing or congealing of viscous liquids could occur
- A continual clean purge should be provided if coke/polymer formation or solids deposition could occur
- CSO valves should have the stem horizontal or vertically downward (CSO Care Seal-open)

Excessive Built-up Back Pressure

Excessive outlet pressure will also cause chatter.

- Avoid
  - Long outlet piping runs
  - Elbows and turns
  - Sharp edge reductions

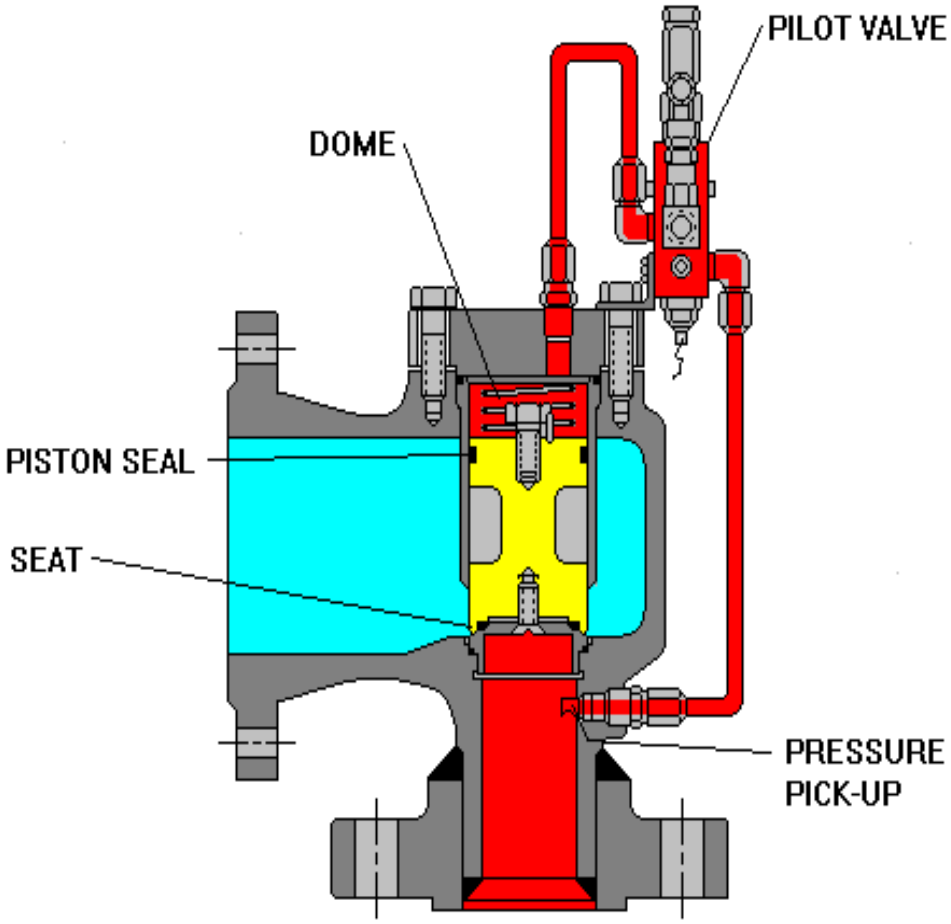
- But if you must
  - Make outlet piping large!

  (*Discharge line diameter must be at least equal to PRV outlet flange size*)

Outlet Line Considerations

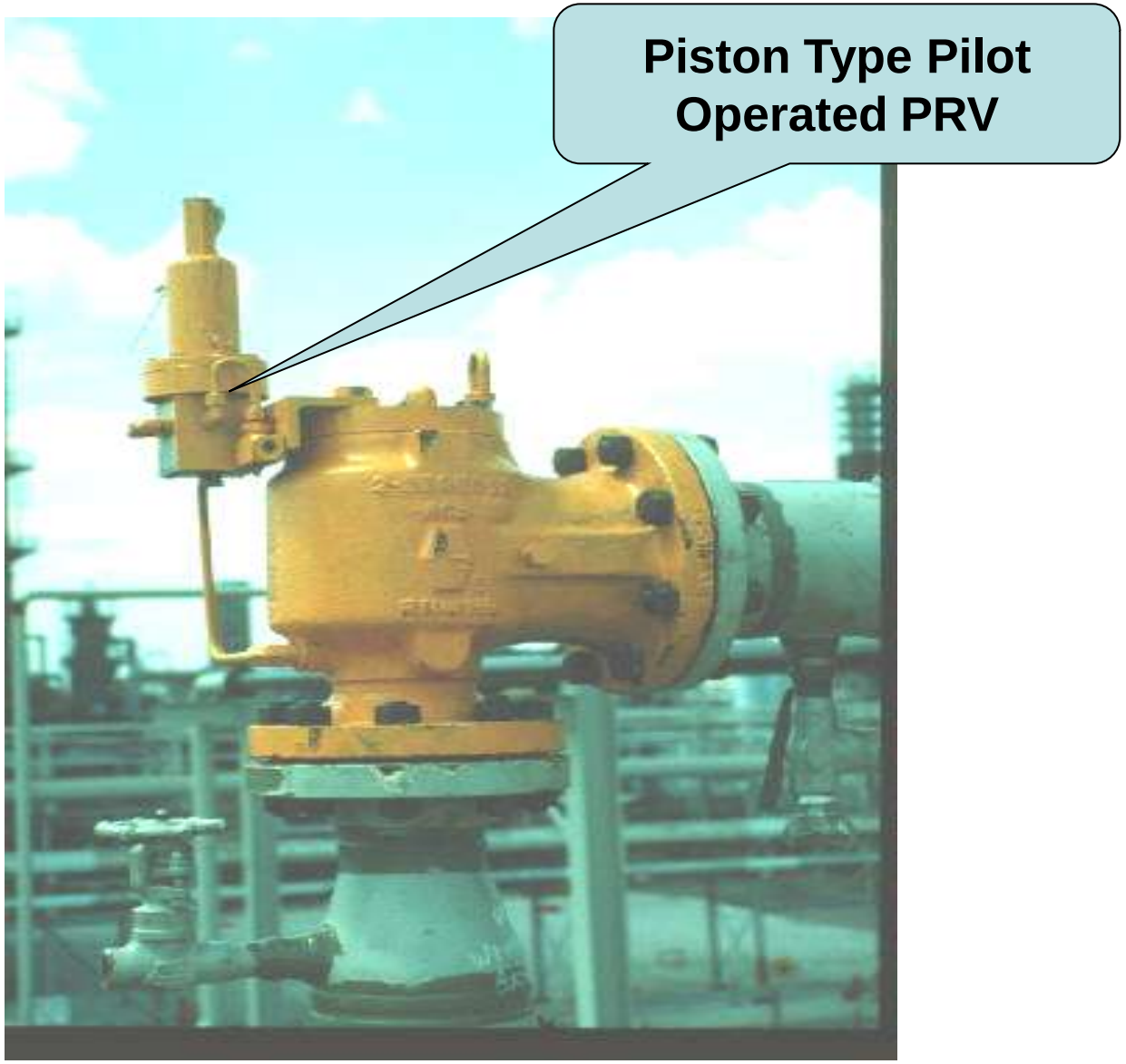
- No check valves, orifice plates or other restrictions permitted
- Atmospheric discharge risers should have drain hole
- CSO valves should have the stem oriented horizontally or vertically
- Piping design must consider thermal expansion due to hot/cold release
- Autorefrigeration and need for brittle fracture resistant materials
- Closed discharge piping should slope continuously downward to header to avoid liquid traps

Piston Type Pilot Operated Safety Relief Valve



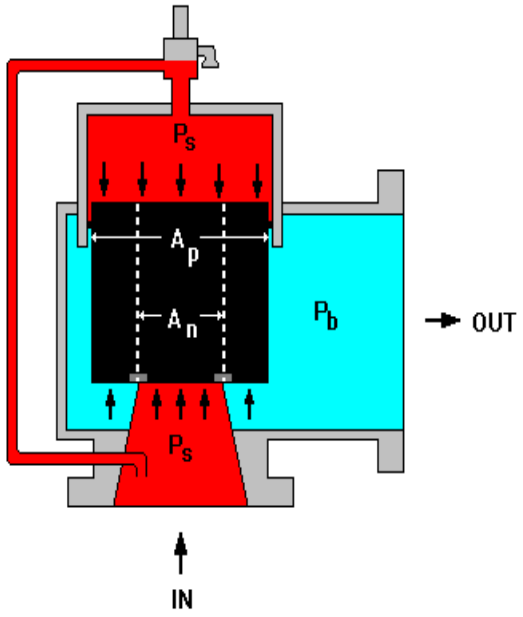
Advantages / Disadvantages Pilot Operated Valve

- Advantages
  - + Relieving pressure not affected by backpressure
  - + Can operate at up to 98% of set pressure
  - + Less susceptible to chatter (some models)
- Disadvantages
  - – Pilot is susceptible to plugging
  - – Limited chemical and high temperature use by “O-ring” seals
  - – Vapor condensation and liquid accumulation above the piston may cause problems
  - – Potential for back flow


Piston Type Pilot Operated PRV

Back Pressure Effects on Pilot Operated Valve (No Backflow Prevention)

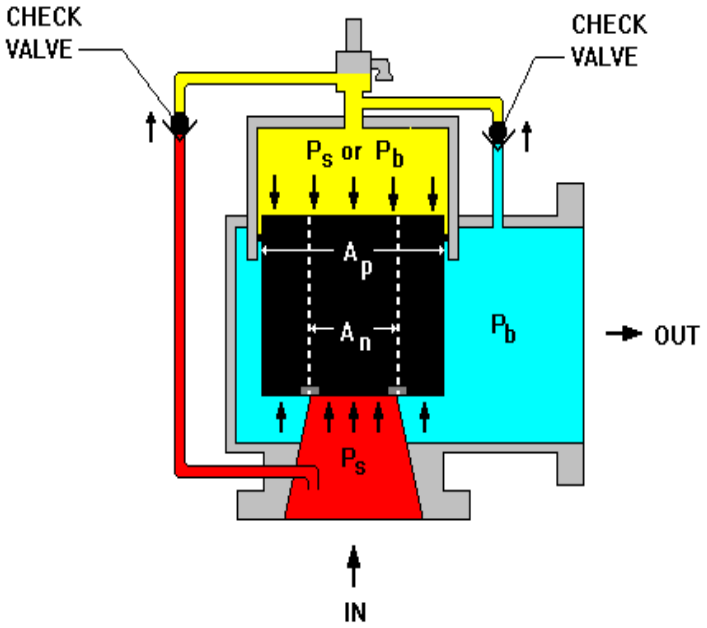
WHEN BACKPRESSURE (Pb) IS GREATER THAN THE PROCESS PRESSURE (Ps), THE NET FORCE IS IN THE LIFT DIRECTION CAUSING THE VALVE TO OPEN AND FLOW BACKWARDS.



Back Pressure Effects on Pilot Operated Valve (With Backflow Prevention)

WHEN BACKPRESSURE (Pb) IS GREATER THAN THE PROCESS PRESSURE (Ps), THE NET FORCE ACTING ON THE PISTON IS IN THE CLOSED DIRECTION AND VALVE WILL NOT BACKFLOW.

PRESSURE ABOVE PISTON IS ALWAYS GREATER OF P_s OR P_b .



Multiple pressure relief devices

Some vessels are equipped with multiple pressure relief devices

Duel System Relief Valves

Developed to provide a safe and efficient method of switching from an active PRV to a standby PRV.

Point to consider when removing PRV's from a system.

- On a Duel System PRV's both open ends must be blacked off.
- Consider decontamination if it's appropriate
- Check the lift settings of the PRV before it is dismantled
- Ensure the valves are returned to there locations carefully protected from bumps and shocks and the inlet & outlet nozzles are sealed.

Sizing Reliefs

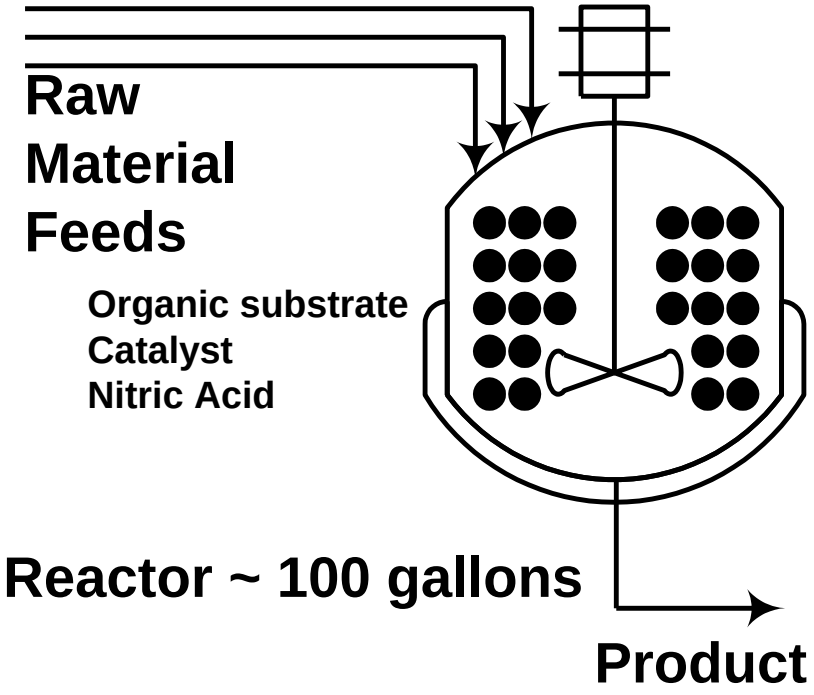
- Determining relief rates
- Determine relief vent area

Relief Event Scenarios

- A description of one specific relief event
- Usually each relief has more than one relief event, more than one scenario
- Examples include:
  - Overfilling/overpressuring
  - Fire
  - Runaway reaction
  - Blocked lines with subsequent expansion
- Developed through Process Hazard Analysis (PHA)

As an Example: Batch Reactor

- Control valve on nitric acid feed line stuck open, vessel overfills
- Steam regulator to jacket fails, vessel overpressures
- Coolant system fails, runaway reaction



Scenarios Drive Relief Rates

- Overfill (e.g., control valve failure)
- Maximum flow rate thru valve into vessel

- Fire
- Vaporization rate due to heat-up

- Blocked discharge
- Design pump flow rate

Worst Case Event Scenario

- Worst case for each relief is the event requiring the largest relief vent area
- Worst cases are a subset of the overall set of scenarios for each relief
- The identification of the worst-case scenario frequently affects relief size more than the accuracy of sizing calcs

Design Relief System

- Relief System is more than a safety relief valve or rupture disc, it includes:
  - Backup relief device(s)
  - Line leading to relief device(s)
  - Environmental conditioning of relief device
  - Discharge piping/headers
  - Blowdown drum
  - Condenser, flare stack, or scrubber

Installation, Inspection, and Maintenance

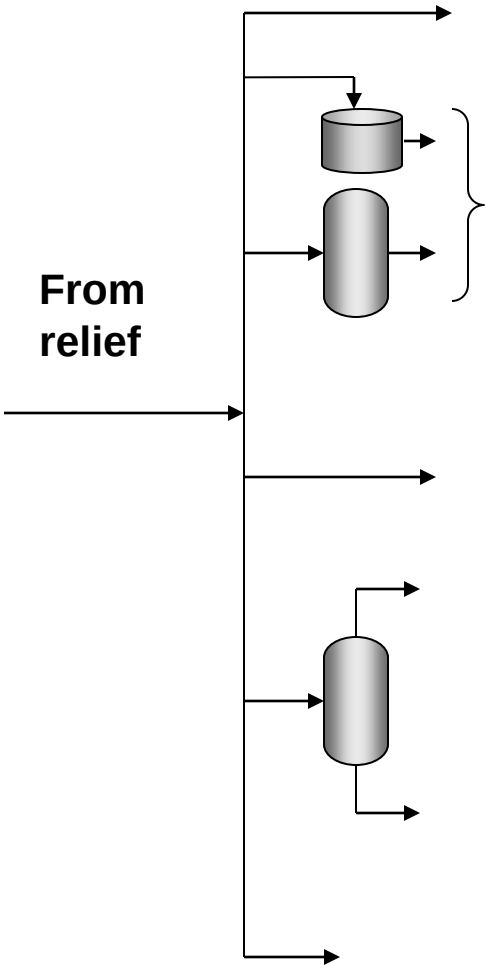
- To undermine all the good efforts of a design crew, simply …

1. Improperly install relief devices
2. Fail to regularly inspect relief devices, or
3. Fail to perform needed/required maintenance on relief devices

Summary

- Pressure Relief
  - Very Important ACTIVE safety element
  - Connected intimately with Process Hazard Analysis
  - Requires diligence in design, equipment selection, installation, inspection and maintenance.

Materials from relief must be process or dispose safely



To environment Vent steam, air

Holding for later processing Waste water treating

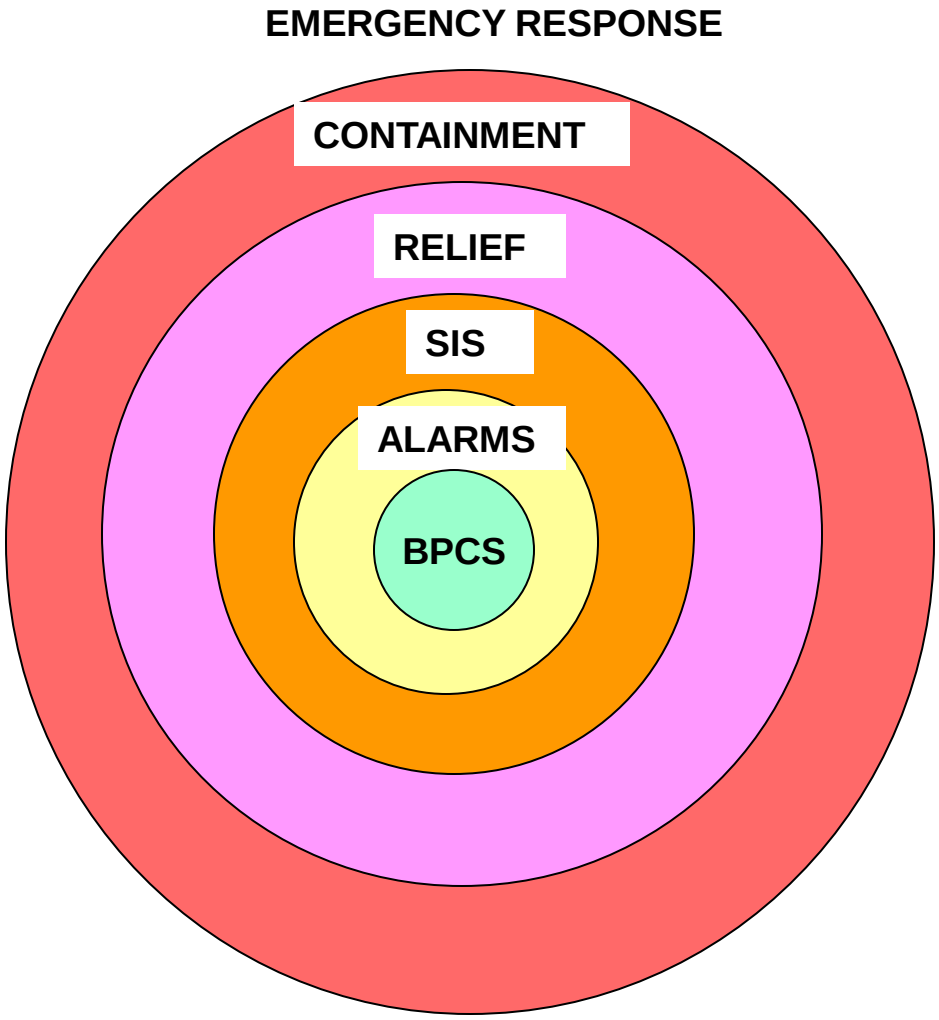
Recycle to process

Fuel gas, fuel oil, solvent

Recover part to process

Immediate neutralization
Flare, toxic materials

Layers of Protection for High Reliability

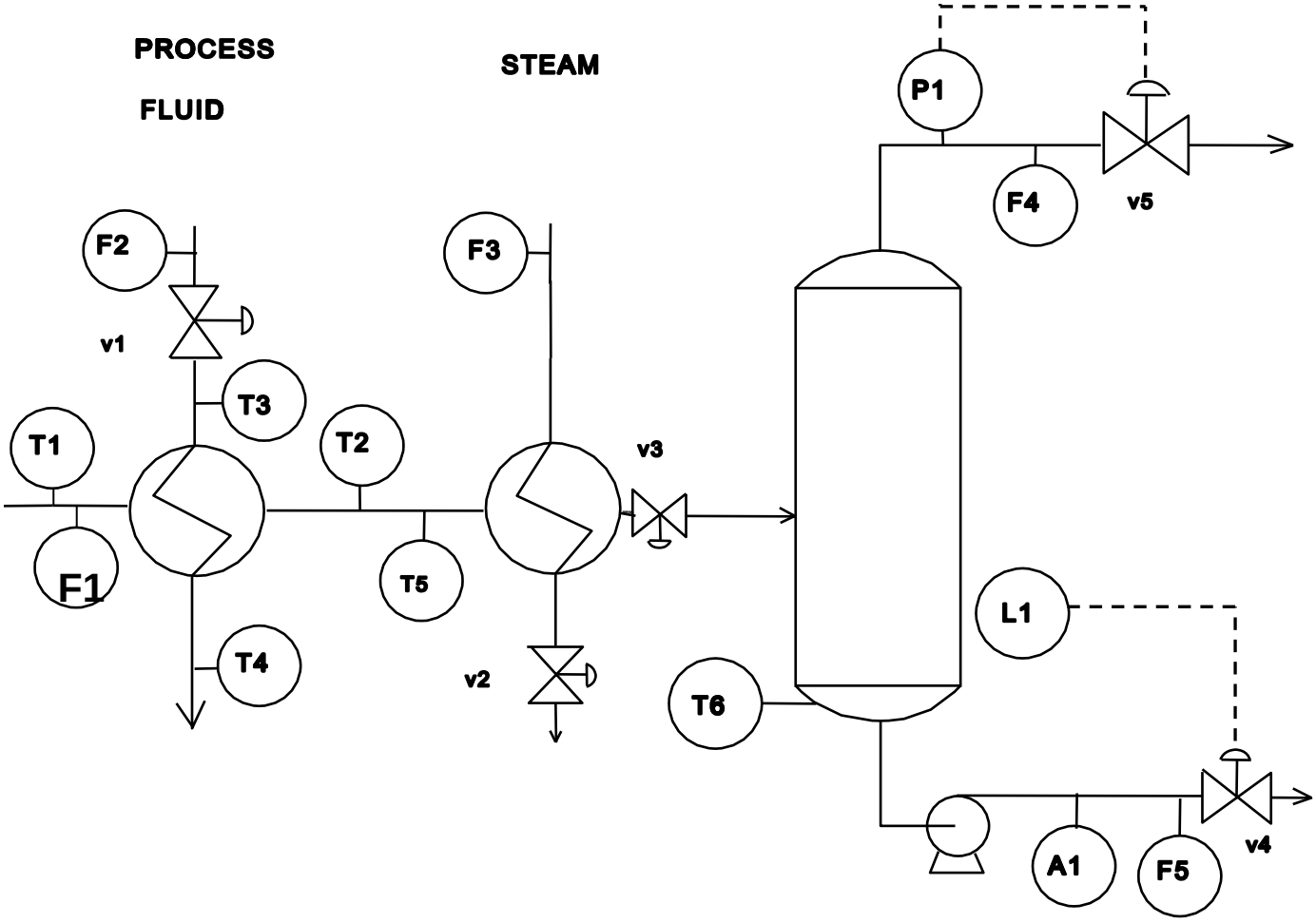


AUTOMATION

Strength in Reserve

- BPCS - Basic process control
- Alarms - draw attention
- SIS - Safety interlock system to stop/start equipment
- Relief - Prevent excessive pressure
- Containment - Prevent materials from reaching, workers, community or environment
- Emergency Response - evacuation, fire fighting, health care, etc.

Add Relief to the Following System



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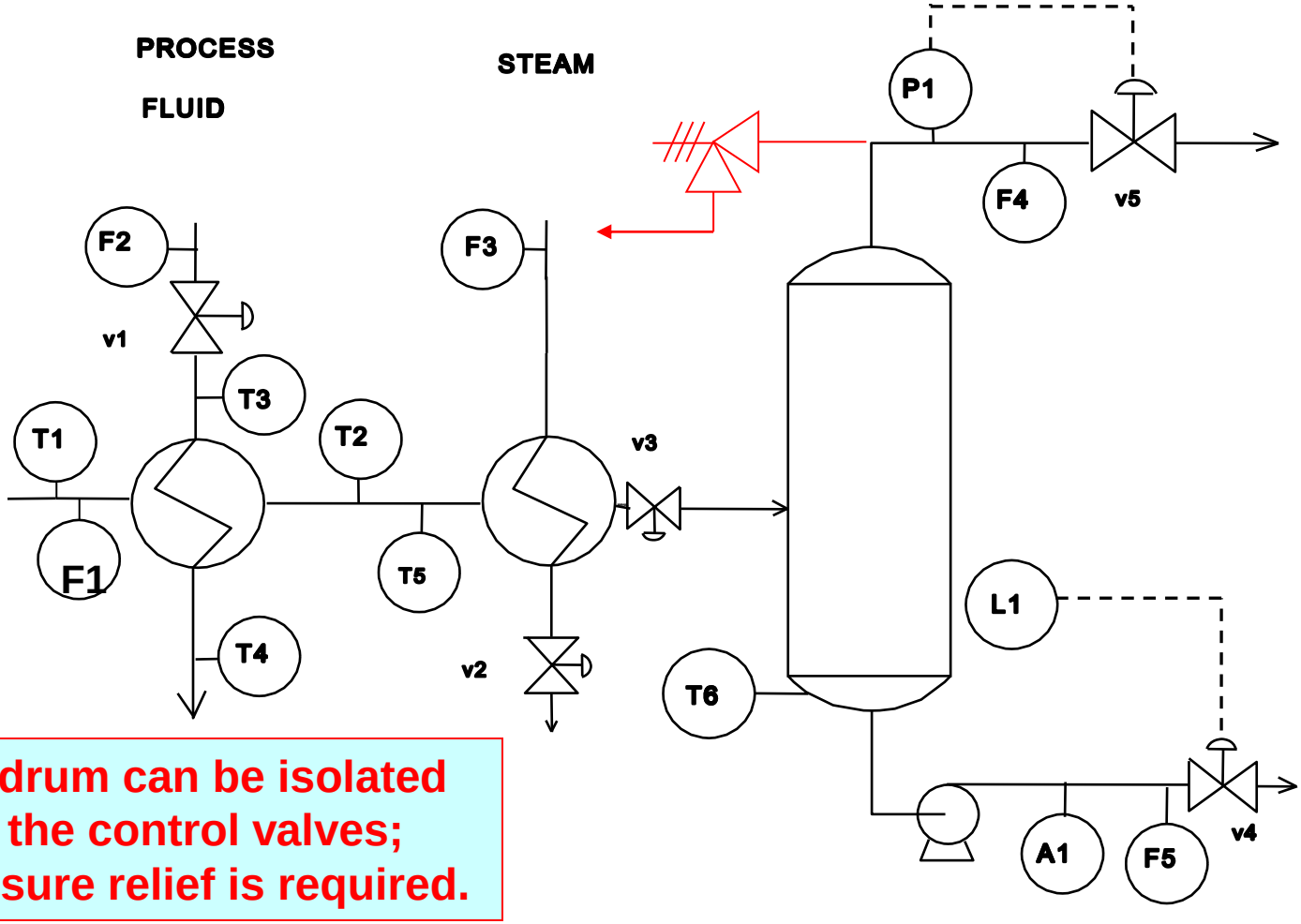
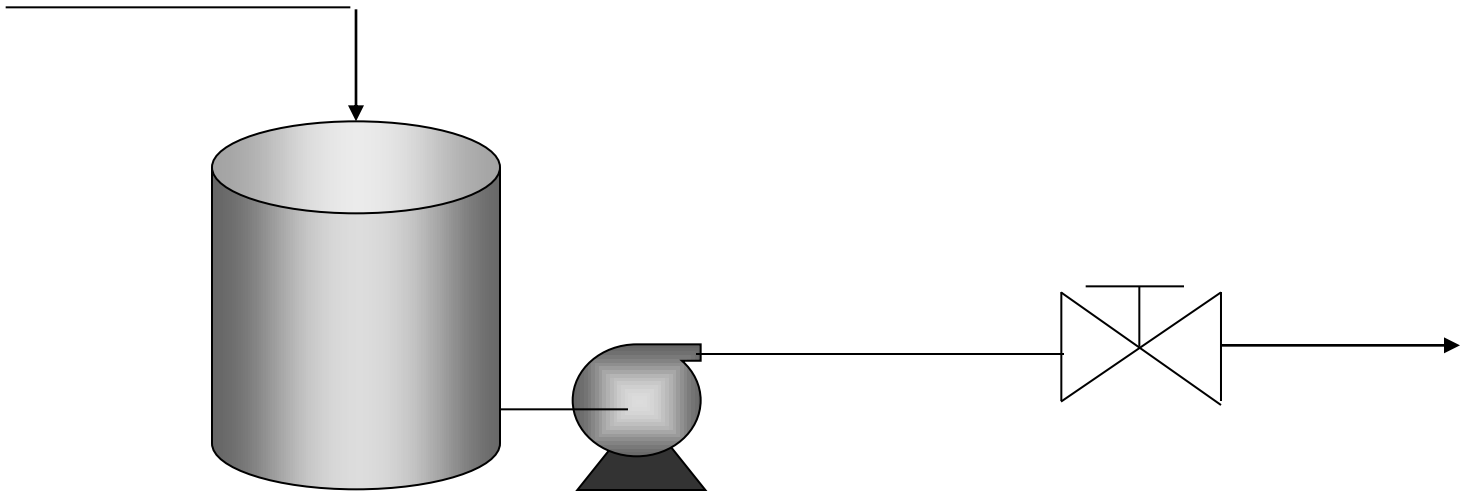


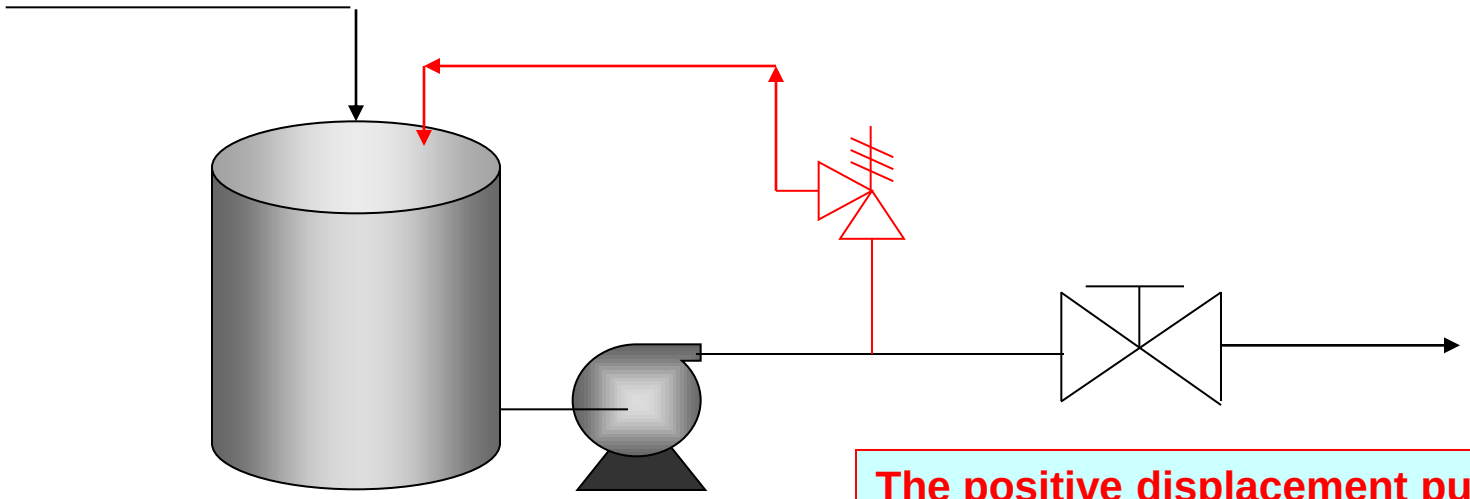
The drum can be isolated with the control valves; pressure relief is required.

Add Relief to the Following System



Positive displacement pump

Add Relief to the Following System

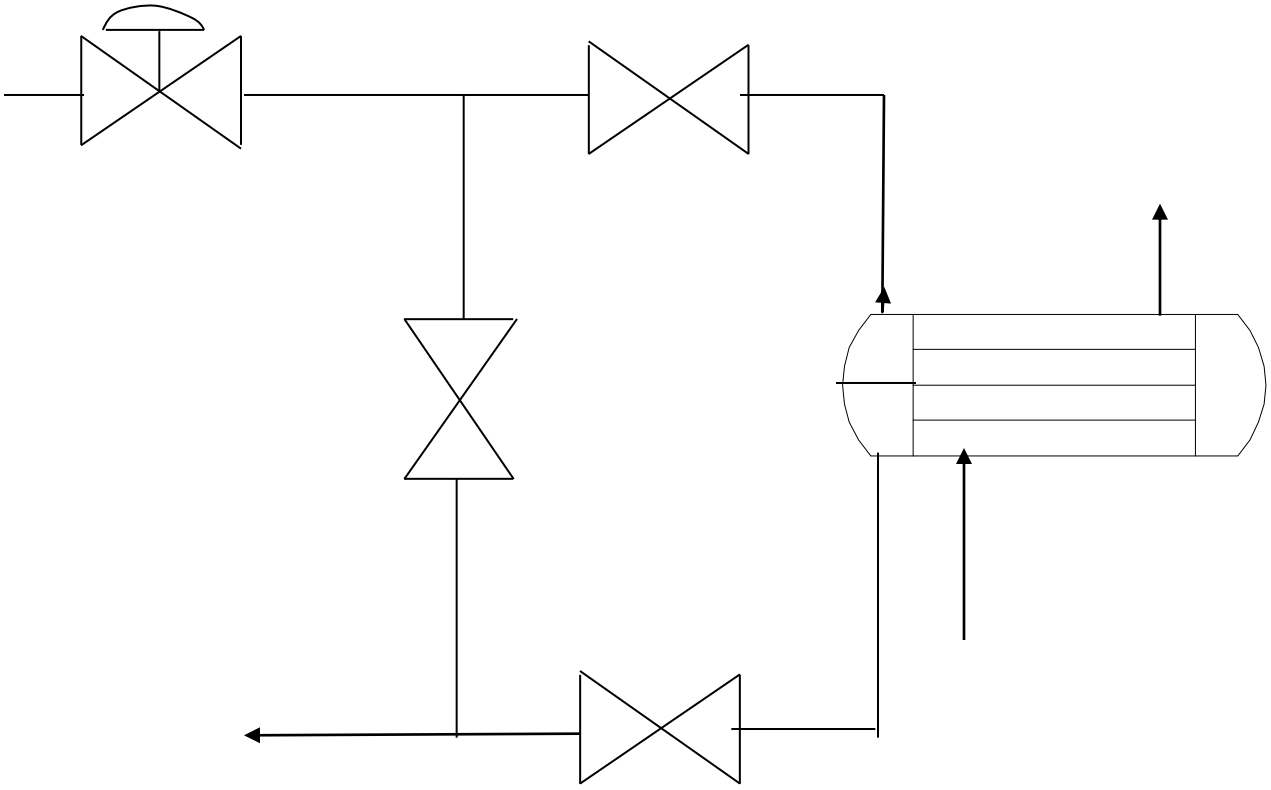


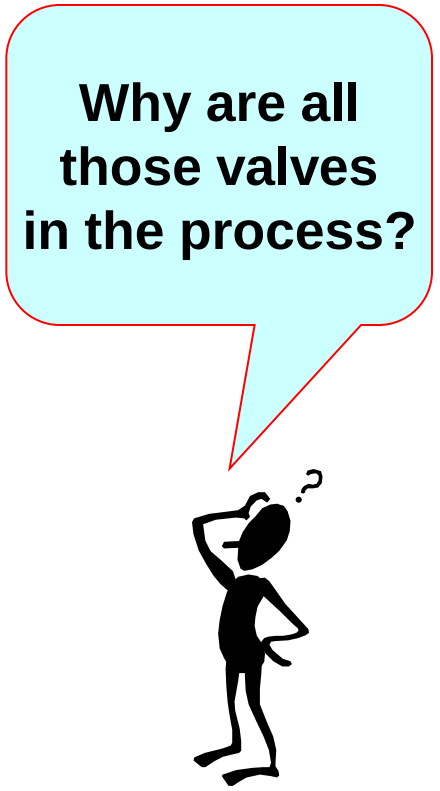
Positive displacement pump

The positive displacement pump will be damaged if the flow is stopped; we need to provide relief.

We would like to recover without shutdown; we select a relief valve.

Add Relief to the Following System





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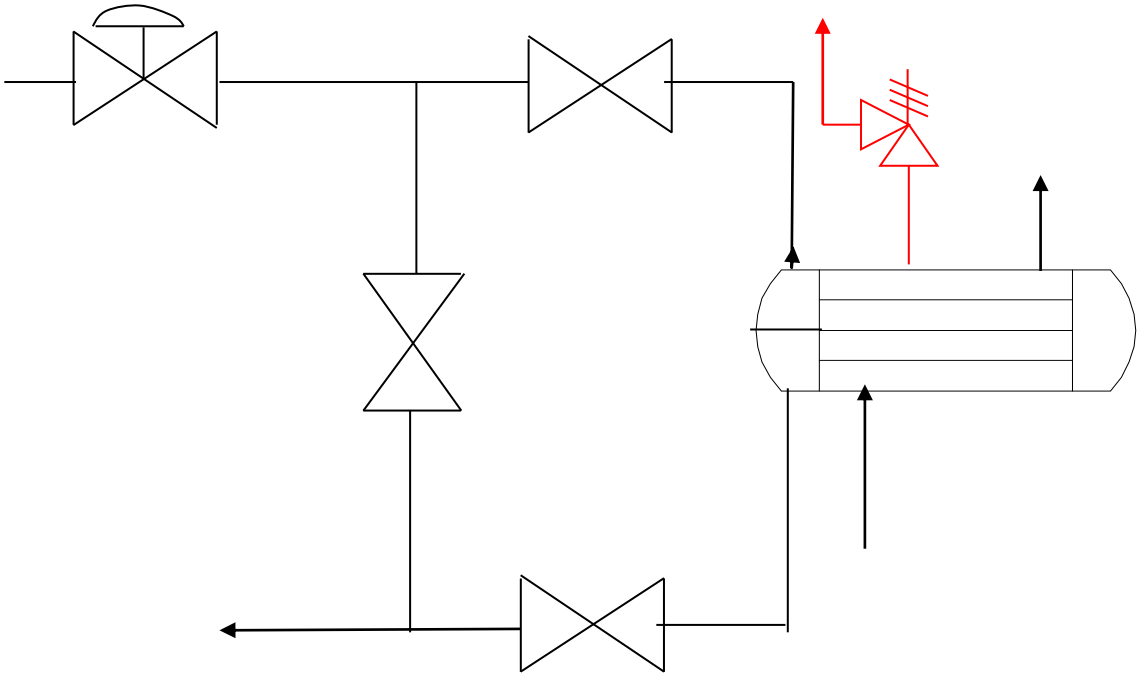


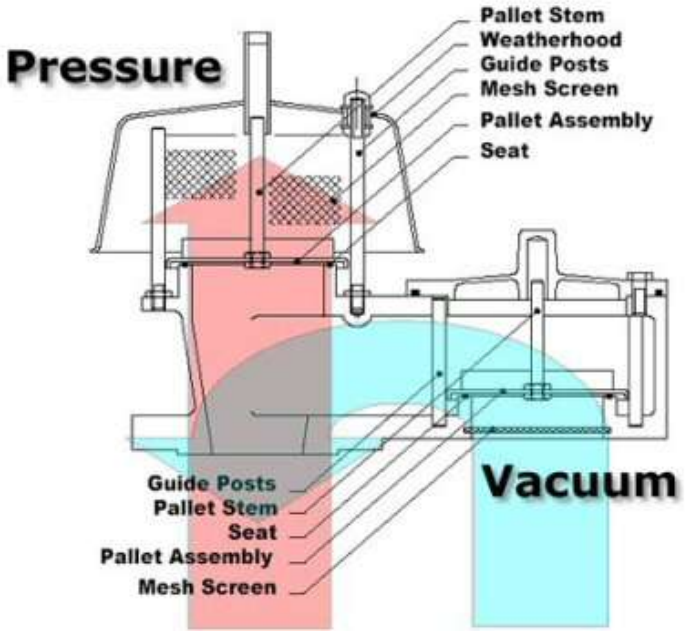
The extra “hand”`valves enable us to isolate and remove the heat exchanger without stopping the process.

The shell side of the heat exchanger can be isolated; we need to provide relief.

Containment

- Use to moderate the impact of spill or an escape
- Example
  - Bund containment for storage tanks
  - Location of relief valves and vents
  - diversion to temporary storage /drain system (following breakage of rupture disk)
  - Safety management in containment areas.
  - Containment building (if applicable)

Vacuum Relief Devices



Vacuum Relief Devices

The vacuum relief system must limit the vacuum to less than 80% of the design vacuum capability of a vessel.

If pressure loading or unloading devices are provided , the pressure relief system must have adequate vapor and liquid capacity to limit tank pressure to the cargo tank test pressure at the maximum loading or unloading rate.

The maximum loading and unloading rates must be included on the metal specification plate .

Do we really need them??

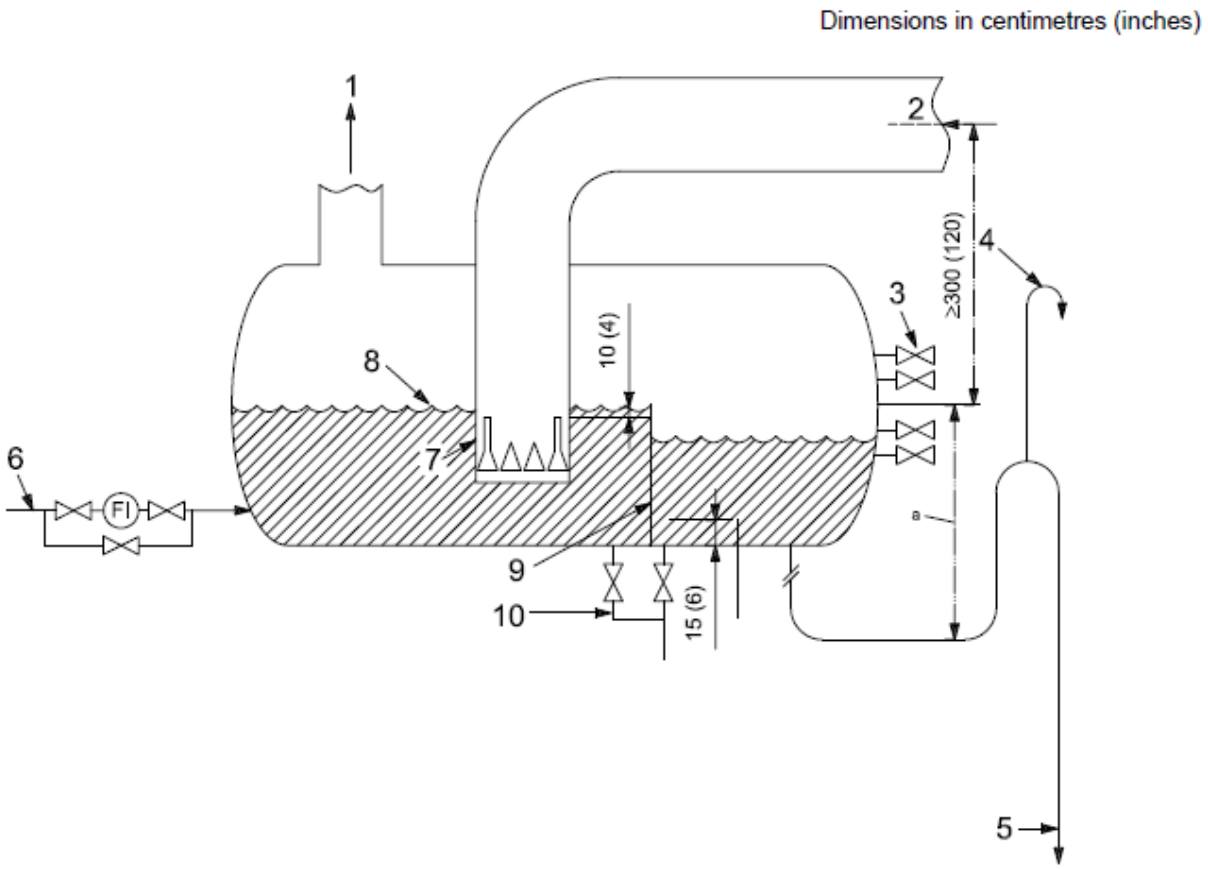
This is what can happen?

LUTE POTS AND VENTS

Lute pots from part of the relief stream system to safely transfer dangerous possibly flammable substances to safe locations such as flare stacks.

They do rely on maintaining an internal water level and should be inspected for integrity such as internal corrosion along with all relief stream system lines and associated plant equipment.

Typical horizontal flare seal drum

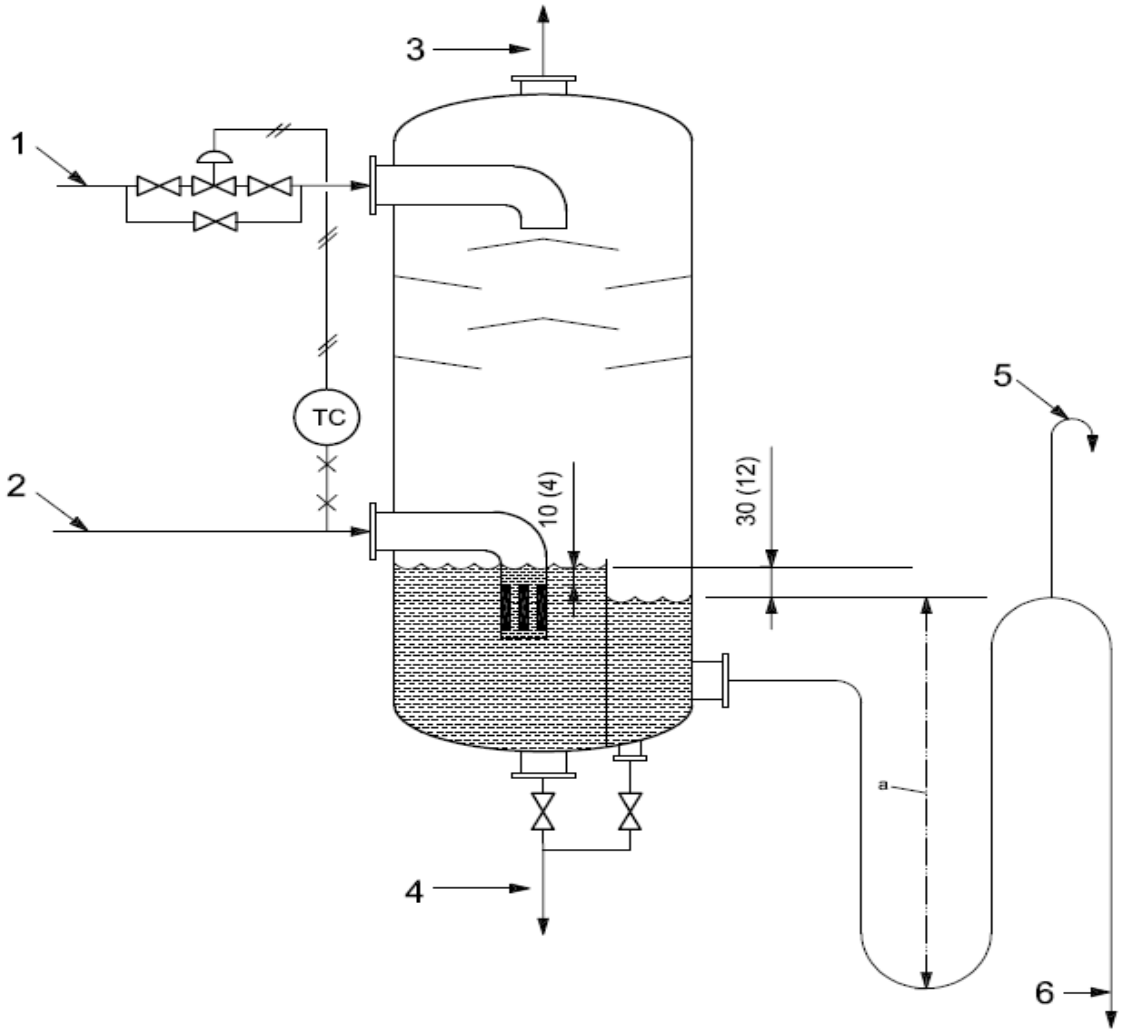


Key

1 to flare
2 flare header
3 Try cocks for checking for hydrocarbons
4 vent
5 to sewer
6 water supply
7 submerged weir welded on end of flare line
8 water level
9 baffle
10 drain

The sewer seal should be designed for a minimum of 175 % of the drum's maximum operating pressure.

Quench drum

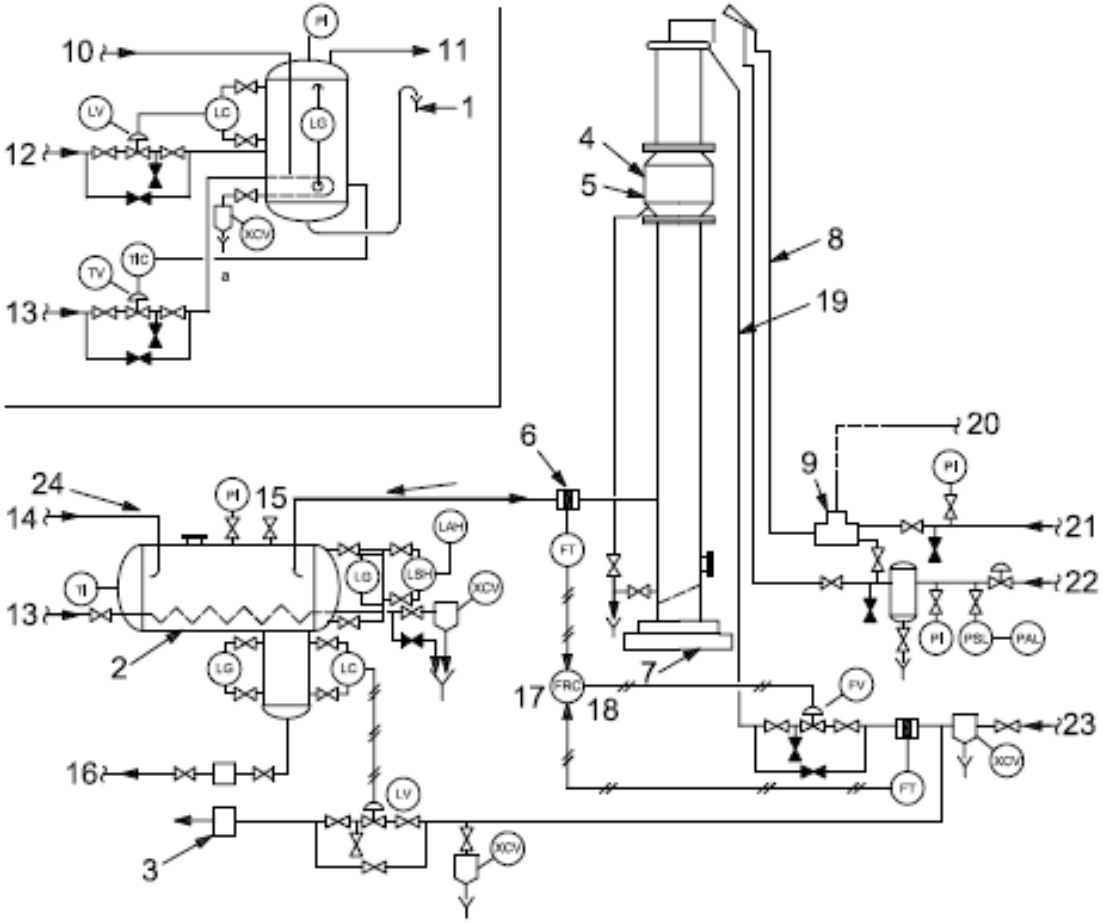


Key

1 cooling water
2 hydrocarbon
3 vent to atmosphere or flare header
4 drain
5 vent
6 water and condensed hydrocarbon out to sewer

The sewer seal should be designed for a minimum of 175 % of the drum's maximum operating pressure.

Typical flare installation



Key

1 oily water sewer (to sour water system if large quantities of H2S are flared continuously)
2 knockout drum
3 steam-driven pump and electrically-driven spare
4 molecular seal
5 purge gas
6 flow-measuring element
7 flare stack
8 igniter line
9 flame-front generator
10 from knockout drum
11 to flame stack
12 water
13 steam

14 from relief or vent header system
15 vent
16 to oil recovery facilities or slop
17 panel-mounted
18 ratio
19 steam to nozzle manifold for smokeless burning
20 power supply for spark ignition
21 air supply
22 fuel gas to pilots and ignition
23 steam for smokeless burning
24 slope towards drum

Insert shows alternative sealing method (water seal).

END OF PRESENTATION
ANY QUESTIONS