# SAFETY VALVES IN PROCESS PLANTS

(Design, Operation, Maintenance and the ASME Code)

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## Design, Operation, Maintenance & the ASME Code

On October 7, 1986 The State of Georgia passed legislation that adopted the ASME (American Society of Mechanical Engineers) Code for design and repair of steam and hot water boilers located in public gathering places such as hospitals, schools, health clubs, amusement parks etc. On October 7, 1987 The State if Florida passed the same type legislation. Florida and Georgia were two of the last of only a hand full of states that had not already adopted some sort of state enforced boiler and pressure vessel code.

In 1989 the State of Georgia altered the law to include coverage of most process and power boilers. Certainly, the State of Florida will follow suit shortly. Safety devices, including all types of safety valves, are an important part of the ASME code. Boiler inspectors from your insurance companies as well as state boiler inspectors will become increasingly interested in the safety devices in your plants.

This presentation will deal only with the design, specification, operation and maintenance of safety valves in steam, air and ammonia services on process and power boilers and vessels in Industrial installations.

## I. Types of Safety Valves

A.) ASME Section I - Safety valves for fired pressure vessels.

Safety valves for use on fired pressure vessels are designed in accordance with Section I of the ASME code. These design criteria are the most stringent of all and in fact are so stringent that many safety valve manufacturers have gone out of business because their valve designs could not pass the requirements of Section I.

At first glance this may seem strange since we are all familiar with and have seen safety relief valves that appear to be nothing more than a heavy pipe cap on top of a vertical piece of pipe or a check valve with an oversize spring. So why all the specifications and why do these simple devices seem to need so much attention and maintenance.

The answer lies within your process requirements and the laws of physics.

Fired pressure vessels, or boilers, are normally operated at very near the design limits of the vessels and piping that make up the systems.

Section I of the ASME code provides that there must be at least one safety valve on small boilers and at least two on boilers with more than 500 sq. ft. of tube surface, or over 1100 KW of electrical input or 4000#/hr. of steam capacity. Also the safety valves must be able to relieve all the steam that can be generated by the boiler without exceeding 106% of maximum allowable working pressure. At least one safety valve on the boiler must be set below the maximum allowable working pressure and no valve may be set at more than 3% over the maximum allowable working pressure.

For operating reasons, one of your process requirements is that the safety valve close soon after the pressure in the system drops below the dangerous level. The pressure difference between the "pop off" pressure and the closing pressure is called the "blowdown" and for Section I valves this valve cannot exceed 6% of set pressure. This is one of the most difficult design criteria for safety valves to reach consistently.

The popping point tolerances for section I valves cannot exceed:
2 PSI for pressures from 0-70 PSI
3% for pressures from 71-300 PSI
10 PSI for pressures from 301-1000 PSI
1% for pressures from 1001-

Section I valves are often used on unfired pressure vessels to protect the vessels while allowing operation at very near design pressure.

B.) ASME Section VIII - Safety valves for unfired pressure vessels.
Section VIII valves are most often called pressure relief valves because they are not designed strictly for protecting a very well defined pressure limit to prevent explosion.

Section VIII valves operate less vigorously to open gradually as over-pressure occurs to a fully open position at 110% of "set" pressure and to close gradually as pressure is relieved to a fully closed position at 90% of set pressure.

Section VIII relief valves are often used on steam, air or gas lines or vessels within processes where the valve discharges into another process line or vessel rather than venting to the atmosphere. Closed bonnet valves are therefore the most common section VIII relief valve.

If the valve is to discharge into a line or header under pressure, a bellows may be installed in the valve to prevent the backpressure on the valve from affecting the "pop off" pressure of the valve.

Mechanical Requirements

Section I and Section VIII steam valves must be equipped with a lifting lever.

## II. Safety Valve Operation

Consider for a moment all of the requirements that we place on a Section I Safety Valve -

1.) Operate at very near "pop off" pressure without leaking.

2.) "Pop off" consistently at set pressure.

3.) Pop open to fully open within 103% of set pressure.

4.) Close completely before inlet pressure drops below 94% of set pressure.

5.) Seal off to a no leak condition at 94% of set pressure.

Lets study these one at a time:

1.) Operate at very near "pop off" pressure without leaking - Normally a valve is closed and kept from leaking by exerting tremendous pressure on the seating surfaces. The pressure in the line itself often aids in exerting additional force to increase the pressure between the seats. When the adjusting nut on a safety valve is tightened, the spring exerts force on the disk through the spindle and the disk seat is forced against the seat on the nozzle.

When the inlet pressure on the valve is increased however, force is exerted on the bottom of the disc and the pressure between the seats is reduced. Just before reaching set pressure, the pressure between the seats is near zero. The seats on a safety valve must therefore be in perfect condition. Also because a seal must be maintained with very little force between the disc and nozzle seats when operating, the seat surfaces must be as narrow as possible to increase contact pressure. This is an important and often overlooked detail for proper maintenance.

At set pressure the gas in the nozzle begins to flow outward between the seating surfaces. At this point the high pressure gases begin to "see" more area of the disk than previously and therefore the force on the disk increases drastically and causes the valve to go into "lift". For this reason, a leaking (simmering) safety valve will normally pop off at below original set pressure. A safety valve cannot therefore be reset correctly if it is leaking.

2.) "Pop Off" Consistently at set pressure - As pointed out previously, the "pop off" occurs when the downward force of the spring on the valve is overcome by the force of the pressure in the nozzle over the area of the bottom of the disc seen by the gas in the nozzle. If the seat surfaces on either the nozzle or disc are not perfectly flat, the gas pressure in the nozzle will be exposed to a different amount of disc surface area and therefore the overall force on the disc and "pop off" pressure will vary. This condition can be caused by improper lapping of the surface or distortion of the disc, or the nozzle, or both, due to heat.

If the seat surfaces are not matched each time the valve is assembled or after the valve operates, there will be more force on one side of the disc than on the other and one side will begin to lift first. This will often cause "simmering" or "fluttering" of the disc. The seats will become damaged and also the valve will relieve inconsistantly. This condition can be caused by too much mechanical clearance between the disc holder and guide causing the disc to seat off - center from the nozzle.

Also, if the contact between the bottom of the spindle and the top of the disc are not at the geometric center of the disc, a similar imbalance of forces will exist. This condition could result from a bent spindle or improperly manufactured or maintained parts.

3.) & 4.) Pop open to fully open within 103% of set pressure and close completely before inlet pressure drops below 94% of set pressure. Quick opening could be accomplished easily by increasing the area of the disc outside of the seat to expose more area of the bottom of the disc to the exiting high pressure, high velocity gases. This design procedure would however make it more difficult to meet the 6% blowdown requirement. Valve lift and blowdown requirements are met by introducing blowdown rings into the valve design. Most modern designs utilize two blowdown rings - an upper and a lower. Proper setting of these rings is the most difficult task accomplished by safety valve technicians. Ring pins are installed thru the body of the valve to prevent the blowdown rings from turning due to the vibration. Wire seals are installed on ring pins to detect tampering with ring settings.

5.) Seal off to a no leak condition at 94% of set pressure - This condition is difficult to accomplish because there is very little driving force to effect the seal between the seats and temperature changes during the lift may distort the seats. Also heating of the spring during lift may temporarily weaken the spring. Practically speaking however, the most frequently occurring condition that prevents reseating after lift is the capture of particles between the seats as they come together just before closing. At this point, all discharging gases are passing between two highly polished, flat, parallel surfaces that can filter sub micron particles of rust from the discharging gases.

Now that we have covered some of the basic design and operating criteria, let us focus our attention on some important aspects of safety valve maintenance.

The ASME has established basic guidelines for repair and maintenance of safety valves. This is called the "VR" program. It is administered by the National Board of Boiler and Pressure Vessel Inspectors. The basic elements of the program include the following outlined concepts.

1.) Safety Valves must be brought back to operate in accordance with new valve design and performance standards. The valve performance standards can best be tested on an ASME certified test stand.

2.) All parts utilized in repair of safety valves must meet all standards of the original manufacturer. This requirement creates the most problems to the maintenance organization for the following reasons:

a.) Only the valve manufacturer knows all of the standards that they utilize including dimensions, materials of construction, surface finishes, heat treating requirements, etc. and often parts are not readily available.

b.) There are so many variations in design from valve to valve including materials of construction of valve body parts and spring, temperature range, design changes, etc. that the exact serial number of the valve is required for "VR Repair" and is often not legible.

3.) Repair organizations must be certified. This is not a "paper certification"! In addition to written procedures, the certification requires that all types of valves be repaired and set in the presence of an examiner from the "National Board" and later tested at another certified facility.

4.) The valves are sealed after repair to prevent tapering. Wire seals on the cap and lever assembly and ring pins are installed to prevent undetected adjustment of the adjusting screw and the blowdown rings.

The ASME Codes do not address the subject of frequency of preventative maintenance. From a practical point of view, the atmospheric environment, process conditions and frequency of operation affect the deterioration of the valve parts most dramatically. Explosions caused by complete failure to operate are caused most often by operating environment problems because in most applications the moving parts are subjected to the atmosphere thru the discharge opening. Rust and dust particles from the discharge piping and atmosphere can accumulate in the valve body and pack by rain water to the extent that the parts are bound by foreign matter. Drains are installed on most valves but often the drain or drain piping becomes plugged.

Electronic valve testers have become popular in recent years for checking or resetting set pressures of valves while in operation. These devices however verify only set pressure and should be used only on valves known to be in good serviceable condition with the proper parts in good condition. These devices normally cannot detect worn parts or buildup of foreign matter in the valve. Periodic inspection is therefore required.