PDHonline Course K139 (2 PDH)

Relief Device Basics for the Engineer

Instructor: John C. Huang, Ph.D, PE

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5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

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Relief Device Basics for the Engineer

W.N. Weaver, PE and John C. Huang, PhD, PE

Course Content

INTRODUCTION

Relief devices exist for equipment protection; aside from the practical reasons to install them certain legal and insurance requirements exist as well. Sizing relief devices appears to be relatively simple and straight forward and many engineers do it themselves or have one of the relief valve manufacturers provide the sizing. The intent of this course material is to develop some understanding of the concept, it is not the intent to teach relief device sizing. However, from this understanding most competent engineers can complete the task successfully utilizing vendor catalogs and the formulas contained in them.

Understanding the various codes involved appears to be the most complicated portion of the effort. In addition it is absolutely essential that a correct analysis be made of the potential causes of system over pressure.

In this course we will look at a variety of items which must be understood in order to do this activity correctly. We'll also look at some common traps that the calculations can present to the unwary engineer.

TYPES OF DEVICES
ASME provides the following definitions to help us: [ASME UG-126 and UG-127]

Safety Valve: is a pressure relief valve actuated by inlet static pressure and characterized by rapid opening or "pop" action.

Relief Valve: is a pressure relief valve actuated by inlet static pressure which opens in proportion to the increase in pressure over the opening pressure.

Pilot Operated Relief Valve: is a pressure relief valve in which the major relieving device is combined with and is controlled by a self-actuated auxiliary pressure relief valve.

Rupture Disk Device: is a non-reclosing pressure relief device actuated by inlet static pressure and designed to function by the bursting of a pressure containing disk.

Not under consideration in this material are combination temperature/pressure devices such as found on hot water heaters, inline devices used in hydraulic systems and devices listed as HRV's (Hydraulic Relief Vales) which are very simple spring loaded inline vent devices. All of these devices have their place in safety but are generally not part of relief valve sizing calculations.

WHAT GETS PROTECTED

Determination of what requires a relief device is dependent on which code is applicable to your particular system. For example under ASME Section 8 relief devices are not required on piping only systems. However, ASME B31.3 may very well require them for your system. From a practical standpoint outdoor piping containing very low boilers for example can generate considerable pressure in the sunlight and should be protected.

Basically any pressure containing vessel requires a relief device; certain types are exempted by ASME. For example under ASME Section 8 the following are exempted:

Fired process heaters
Components of systems such as internal parts of compressors (not the tank), pumps, turbines, engines (internal combustion), hydraulic and pneumatic cylinders
Piping system components like flanges, valves, expansion joints, etc.
Water tanks
Vessels with a rating of less than 15 psig
Vessels with an internal diameter of 6 inches or less
Vessels for human occupancy

Some confusion exists in industry about vessels of less than 5 cubic feet and 250 psig design. Many engineers interpret ASME Section 8 U-1(j)(1) as meaning these vessels do not require pressure relief. Actually the language only eliminates "inspection by Inspectors", not the necessity of relief device protection.

As you can see a thorough understanding of which of the many codes you will be operating under has an effect on what you need to do for your particular situation.

NECESSARY DATA BEFORE YOU BEGIN

Before Relief Valve sizing can be accomplished considerable information is required:
1. *P&ID* This document gives you the basic information needed and provides equipment identification and pipe codes involved. It also tells you how the system being protected is configured, and allows you to answer several questions relative to how the system may arrive to an overpressure situation.
2. *Process Flow Diagram* This document provides basic information on what is being relieved (chemical), operating flows and temperatures for relief calculations.
3. *Physical Data* This is critical information on the relieving chemical(s) and includes a vapor pressure curve, density curve, viscosity curve for liquids and in the case of flashing flow through the relief device the same data for the vapor. For vapor venting you will also need specific heats, thermal conductivities and specific heat ratios (Cp/Cv or *k*). Information which will indicate the possibility of foaming flow or two phase flow is difficult to obtain but failure to consider this is a serious fault. Liquids near their

boiling point and being relieved to a lower pressure generally will produce two phase flow.

4. *Piping Arrangement Drawing* This is essential for the calculations since pipe size and schedule, inlet pipe length and discharge pipe length as well as elevation changes affect the calculations.

5. *Equipment Data Sheets* These documents provide vessel dimensions and MAWP (Maximum Allowable Working Pressure), pump curves, heat exchangers involved, etc. This list cannot be completed until the potential sources of over pressure have been evaluated. See Table 1 "Causes of Overpressure" below.

CAUSES OF OVERPRESSURE

An analysis by the engineer of the causes of overpressure is the first "Trap" encountered. Most engineers consider the simplest of scenarios when new to this work. The following table lists some but not all causes of overpressure. The engineer may need to call in the research chemist or mechanical engineer to make some of these determinations.

Table 1: Causes of Overpressure

ITEM	OVERPRESSURE CAUSE	HOW IT CAUSES OVERPRESSURE
1	Vessel closed outlets -Feed continues	Incoming liquids or gases may exceed MAWP depending on the motive source
2	Pumps - Isolated	Pump discharge capability may exceed MAWP of downstream equipment
3	Compressors – Isolated	Compressor discharge capability may exceed MAWP of downstream equipment
4	Closed vessel outlets – heat input continues	Liquid contents continuously heated with no space for thermal expansion or the venting of vapors
5	Cooling or reflux failure	Failure of a cooling system allows heats of reaction to build expansion or vapor pressure above MAWP
6	Thermal expansion of liquids	Similar to 4 above but may be caused by other than expected heat inputs. Solar radiation or heat radiation from nearby equipment can cause this.
7	Power failure	This may be electrical or hydraulic in an agitated vessel for example with resulting loss of heat transfer capacity and result in vapor pressures above MAWP
8	Instrument failure	Failure of various control instrumentation may cause steam to continue to a vessel jacket and take the contents above the boiling point and vapor pressure above MAWP
9	Control valve failure	Same as 8 above

10	Heat from external fire	An external fire from spilled liquids can rapidly introduce enough heat to take contents vapor pressures above MAWP
11	Introduction of highly volatile liquid	Accidental introduction of a low boiling liquid into a hot system can rapidly produce high pressures
12	Chemical reaction or decomposition	Frequently reactions produce large volumes of gases as by products; in a closed system these large volumes may mean high pressures
13	Backflow from downstream systems	A failure in downstream equipment may cause those materials to flow backwards in the system into a lower pressure rated vessel
14	Failure of internal pressure boundary	This can be the failure of a vessel jacket, heating coil or failure of a tube seal in a heat exchanger. This can introduce high pressure steam into a vessel interior insufficiently rated for jacket pressure
15	Start-up or shut-down conditions	Transient conditions caused by unexpected reactions etc during these phases may produce unplanned for gas evolution etc.
16	OTHER	

Some of these causes are obvious and known to most engineers; some require imagination to envision. A thorough analysis of your specific system is required to generate all of the potential causes. Each potential cause requires evaluation.

CONFIGRING THE RELIEF SYSTEM

Depending on the material to be vented by the relief device the system configuration may be different.

General Guidelines

1. Non toxic, non flammable, non environmentally damaging, inexpensive materials may be vented directly to the atmosphere. Examples would be steam or water. See Figure 1.
2. Toxic, flammable, expensive and environmentally destructive materials need a method to stop flow once the overpressure situation has been corrected. In this case a self closing device is essential, capture of vented materials until the relief valve closes is prudent. Examples would be most organics, metallic salt solutions, and most oils. See Figure 2.
3. Highly viscous materials (polymers) and materials which on sitting in the relief device inlet may solidify need a special configuration. Here we would normally install a rupture assembly flush to the interior of the vessel to prevent buildup, the relief valve is then installed on top of the disc holder. General practice places a pressure sensor between the rupture disc and the relief device to indicate disc failure from fatigue or corrosion. Examples

would be polyester resins, hot melt adhesives and solutions of salts which will precipitate out. See Figure 3.

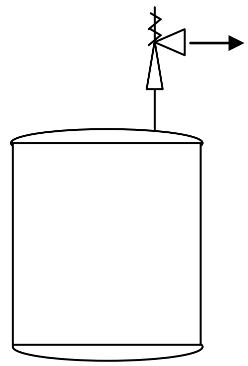

Figure 1
Direct Atmospheric Venting

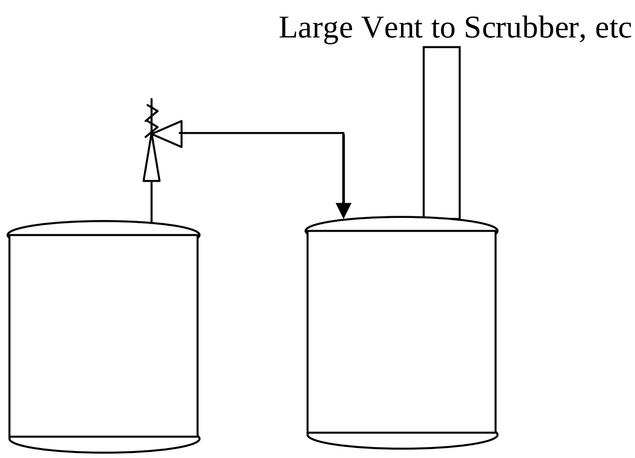

Figure 2
Venting to Capture Vented Materials

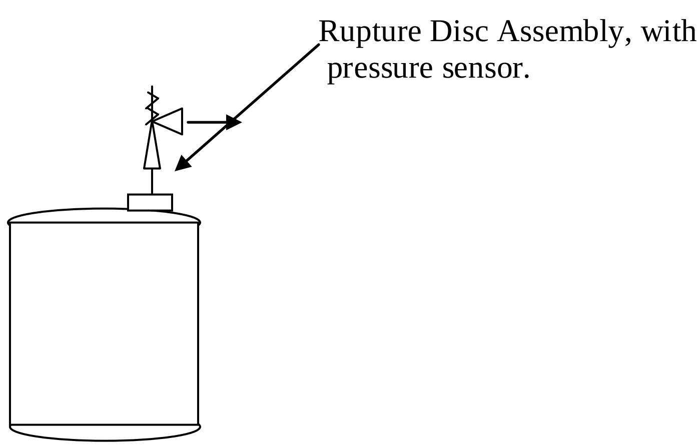

Figure 3

Valve with Rupture Assembly

In the event that the material is stringy and prevents tight closure of the relief valve when pressure has fallen below the set point of the valve we need a closable configuration. Two relief valves may be installed with either lockable manual valves or a linked set of valves which prevents both relief devices from being closed off at the same time. This allows the mechanics to close off the leaking relief valve and bring a properly operating unit on line once the over pressure situation is corrected. Anderson Greenwood and others offer a valve set specifically designed to make this a safe arrangement.

What must not be done in any configuration:

1. Valve on the inlet side of the relief device. An exception can be made by using a lockable valve with absolute control by a responsible person.
2. Valve on the outlet side of the relief device. An exception can be made by using a lockable valve with absolute control by a responsible person.

PLACING THE DEVICES

The second serious trap comes with placement of the relief device.

There is a restriction on allowable pressure drop of the venting fluid in the inlet piping. This pressure drop is limited to 3 percent of the device set pressure. For example for a device set at 100 psig, pressure drop at *rated* flow into the device from the connection point on the protected equipment to the inlet of the pressure relief device cannot exceed 3 psi.

Likewise, there is a limitation on pressure drop on the discharge of the pressure relief device. This pressure drop is limited to 10 percent of the device set pressure. For example for a device set at 100 psig, pressure drop at *rated* flow from the device to the vent point cannot exceed 10 psi. Vent point of the pressure relief device is generally taken as the atmosphere; when there is a scrubber or receiver tank on the pressure relieving device discharge the pressure drop through that equipment to the atmosphere must be taken into account as part of the 10 percent. This restriction is sometimes difficult to meet and is generally overcome by use of a pilot operated relief valve or a balanced bellows valve.

Note the emphasis on *rated* in the above paragraphs. This is the third trap and the one most often missed by inexperienced engineers.

When sizing a relief device the calculations all lead to an orifice size for the valve; it is rare where the available orifice size exactly matches the calculated required orifice size. The result is that the engineer must use an orifice size which is larger than the calculated orifice, this results in more flow than the original calculations indicated. The pressure drops for the flow of venting fluid must now be recalculated using the flow through the actual orifice, this calculation determines the required inlet and outlet pipe sizes to remain below the pressure drop restrictions.

Frequently engineers assume that putting in a larger pressure relief valve is better, however, when the actual capacity of the valve is used to determine pipe sizes it becomes very expensive. Occasionally this practice even results in requiring a larger nozzle on the vessel. This is the point most often missed and least understood by engineers and engineering companies.

Relief valves may be placed directly on a vessel nozzle or on the pipe coming from that nozzle. For a jacket the relief device can be on the inlet pipe to the jacket, outlet pipe of the jacket or a separate nozzle on the jacket, as long as there is no valve between the jacket and the relief device.

SIZING THE DEVICES – BEGINNING THE CALCULATIONS

Now that we have accumulated all the necessary data, determined the potential causes of overpressure, and worked out the valve and piping configurations we can determine the flow of fluid to be vented..

If one of your overpressure causes is an external fire you use ASME or API equations for heat input to the vessel to determine vapor flows; on vessels with no vapor space you will need to determine flow caused by thermal expansion of the liquid.

If a pump can be the cause or overpressure the pump curve will tell you how much fluid to vent, similar data would be used for compressors, positive displacement blowers and turbines.

Over pressure from reactions and decomposition require extensive knowledge of the reactions and products of the reaction. Gas liberated from the reaction must be vented; heats of reaction may cause boiling in the vessel with subsequent vapor pressures to be relieved.

Each possible cause of over pressure must be analyzed to determine the rate at which fluid must be vented by the relief device. Once this rate is determined then the valve can be selected and the orifice size chosen.

Further effort to select a pressure relief device depends on the manufacturer selected. Each vendor varies slightly in his approach and how many steps there are to the calculations. Some of these steps relate to compressibility, valve type, etc. generating as many as eight correction factors to be applied. As stated above these calculations all lead to an orifice size which then allows for valve size selection in the vendor catalog.

The actual vendor formula used depends to some extent on the vendor and significantly on the fluid under consideration. There are different equations for Vapors or Gases, Steam, Air, Liquids, Foaming Liquids and Two Phase Flow.

The vendor catalogs provide equations for each of the above along with methods to determine correction factors.

WHO REQUIRES RELIEF DEVICES

OSHA requires them on certain systems
ASME requires them on boilers and vessels
API requires them on certain storage vessels
UL requires them on storage vessels
NFPA requires them on storage vessels
Insurance companies require them on a wide range of items
ANSI requires them on certain systems

SOME REFERENCES

ASME Boiler and Pressure Vessel Code, B31.3 and B31.6
API (American Petroleum Institute) API 520 and 521
NFPA
OSHA
UL

A FEW SUPPLIERS

Consolidated Safety Relief Valve Catalog SRV-1
Farris Engineering Series 2600 Pressure Relief Valves Catalog
BS&B Pressure Relief Devices
Anderson Greenwood Co.
Crosby Valve Division
Kunkle Valve Division
Fike Rupture Discs

CONCLUSION

Most manufacturers will provide the necessary calculations, however, they must know the system thoroughly and take into account entrance and discharge piping arrangements in order to provide the proper valve. Experience indicates these people are very helpful but the engineer assuming the responsibility needs to review the work to ensure that it adequately represents his system.
Most insurance companies will require documentation of sizing in the event of an incident, OSHA will require that same documentation if there is an injury related to an incident. These calculations are critical and should be done carefully and kept on file.

Competent engineers will have no problems with the math or theory.